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A LAND USE CLASSIFICATION SCHEME FOR USE WITH REMOTE SENSOR DATA

Including

A. Proceedings of the Conference on Land Use Information and Classification, June 28-30, 1971

B. Land Use Classification Scheme, Levels I and II, with Definitions of Categories (preliminary version)

Inter-Agency Steering Committee on Land Use Information and Classification

United States Department of the Interior
Geological Survey
Washington, D. C.

1972

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FOREWORD

The needs of Federal agencies for a broad overview of national land use patterns, trends, and environmental impacts, with data inputs from both conventional sources and some of the more exotic sensors in high altitude aircraft and satellite platforms led to the formation in early 1971 of an Inter-Agency Steering Committee on Land Use Information and Classification. The work of this Committee, composed of representatives from the Geological Survey of the U.S. Department of the Interior, the Earth Observations Program of the National Aeronautics and Space Administration, the Soil Conservation Service of the U.S. Department of Agriculture, as well as the Association of American Geographers and the International Geographical Union, has been supported by NASA and the EROS Program of the Interior Department and coordinated by the USGS Geographic Applications Program. The Chairman of the Inter-Agency Committee was Dr. Arch C. Gerlach, Chief Geographer of the Geological Survey until his death in May 1972. Shortly before Dr. Gerlach's death, Dr. James R. Anderson was appointed Acting Chairman of the Committee.

One of the two objectives of the Inter-Agency Committee was to sponsor a national Conference on Land Use Information and Classification in order to bring together Federal, state, regional and local land use planners and officials to discuss their mutual land use data and classification needs. Part A of this volume includes the Proceedings of that Conference which was held June 28-30, 1971 in Washington, D.C.

The second objective of the Committee was to review and analyze already existing land use classification schemes and develop a classification scheme which at the first two levels could be used with ultra high altitude aircraft and satellite data in order to prepare and rapidly update national and large regional overviews of land uses, land use changes and trends, and environmental impact of potential policy decisions. The third and higher levels of the scheme are to be developed by state, regional and local agencies for use with statistics, field surveys, etc., and in such a way that these levels might be aggregated upward to Levels I and II of the classification scheme. There is also great need for more compatibility than now exists in dates, scales, and categories of land use information at Federal, state, regional and local levels. Such compatibility is particularly critical to those state, regional and local organizations who must attempt to comply with requirements of Federal land use and environmental policy legislation.

In July 1971, the Inter-Agency Committee met, and after consideration and discussion of the results of the Conference, appointed a Sub-Committee headed by Dr. Anderson to prepare a land use classification scheme for Levels I and II with definitions for those categories. Part B of this publication includes the preliminary version of this work. Since this scheme is meant to be a preliminary version, suggestions for alterations will be welcomed, carefully reviewed and tested.

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PROCEEDINGS

of the

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June 28-30, 1971

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CONFERENCE ON LAND USE INFORMATION AND CLASSIFICATION

June 28-30, 1971

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Bureau of Outdoor Recreation	25, 36, 66, 70, 80, 84, 104, 105, and 121
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METROPOLITAN AREAS

CITIES AND COUNTIES

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LAND USE INFORMATION AND CLASSIFICATION CONFERENCE

Introduction

by

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As Chairman of the Steering Committee which planned this Conference, it is my privelege to welcome you, to thank you for attending, and to express our hope that you will find the Conference stimulating and beneficial. If you take an active part in the two and half days of workshop sessions which follow this opening plenary meeting, you will surely have played a significant role in creating a system for an up-to-date, national overview of land uses and trends in the United States.

While making a land use map for the recently published National Atlas of the United States, we became painfully aware that putting together bits and pieces of land use information gathered by regional, state, and local agencies, at different dates, scales, and incompatible categories did not provide national patterns of very high validity, even at the Atlas scale of 1:7,500,000. To remedy that situation, it seems highly desirable for Federal agencies to have a land use classification system that will be receptive to data inputs from remote sensors on high altitude aircraft and satellite platforms to obtain frequent, synoptic overviews of the entire country. It is equally important that the national system constitute a framework into which the broad categories of more detailed land use studies by regional, state, and local agencies can be aggregated upward for more generalized, smaller scale use at the national level.

Members of this Conference Steering Committee are well aware that its objective is not a new one, and that many commendable schemes for land use classification have been developed in the United States and in many foreign lands. We have become even more acutely aware of that situation through correspondence and telephone calls from invitees to this Conference who called to our attention certain important classification systems that were not included among the four selected as examples in the background documents for this Conference. The selection of land use classification schemes in that documentation was intended to provide examples for discussion, rather than models to be followed.

Publication authorized by the Director, U.S. Geological Survey.

This Conference took root about six months ago at a meeting of officials, from the Department of the Interior's EROS Program and NASA's Earth Resources Survey, who were jointly supporting a Geographic Applications Program in the U.S. Geological Survey. They had noted that the Geographic Program was focussed largely around land use and its impact on the surrounding environmental complex, including both natural and socio-economic elements in that complex. Questions were raised as to whether the land use information systems and forecasting models being developed, truly meet user needs, and might be suitable for adoption on a national basis by all Federal agencies concerned with nation-wide patterns, trends, and impacts of land use.

The Geographic Applications Program has involved three years of contractual research by universities and working groups of the Association of American Geographers, an extensive literature search, many multidisciplinary contacts, and intensive studies of more than a dozen land use policy Acts and Bills that have been introduced in Congress during that period. It was decided, therefore, to hold a conference of land use data users, and a Steering Committee under my chairmanship was named to plan and organize such a conference. The members of the Steering Committee are listed at the top of the agenda sheets. They will take active roles in this Conference as speakers, section chairmen, reporters, and resources staff in discussion panels. They will not dominate the meetings, or impose their views upon you, but will provide information and gather facts about your experience and needs.

The primary focus of this Conference, after the opening plenary session, will be on your views, your experience, and your needs. Clearly the needs of Federal agencies include a synoptic overview of national land use patterns, trends, and environmental impacts, with inputs from both conventional data sources and some of the more exotic sensors in high altitude aircraft and satellites. We are deeply concerned about the need also for greater compatibility than now exists in dates, scales, and categories of land use information at regional, state, and local levels.

Such compatibility becomes increasingly critical when we contemplate attempts by state and local organizations to comply with requirements of the Water Resources Planning Act of 1965; the National Environmental Policy Act of 1969; and Senate Bills 632 and 992, plus related House of Representatives Bills currently before the 92nd Congress. We feel that the provisions of these and related Bills and Acts of Congress pertaining to national land use policies should be given full consideration, along with your own experience and that of foreign governments which have been successful in making land use analyses at both large scales (around 1:50,000) and smaller scales (ranging from 1:200,000 in Japan to 1:1,000,000 in Australia).

Instead of providing additional background information about this Conference, I shall now turn to the substantive portion of this plenary session, but before introducing the first speaker, I want to present to you the Conference Manager, Dr. John Place, who is also a member of the Steering Committee, and of the Geographic Applications Program staff. He has been assisted by Mrs. Betty Graziani in preparing documents, obtaining rooms, projection equipment and operators, tape recorders, sound systems, equipment for registration, coffee service during the morning break, and the many other details so essential to operating a conference. If either of them can be helpful to you during the Conference, do not hesitate to call upon them.

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LAND USE CLASSIFICATION SCHEMES AND THE NEED FOR STANDARDIZATION

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INTRODUCTION

Although it is very unlikely that the one ideal classification of land use will ever be developed, there is a growing appreciation of the need for more standardized approaches to land use classification. It must also be recognized that the process of making a classification of land use is a subjective matter even though an objective numerical approach is used. Therefore, it is quite necessary to be prepared to accommodate different perspectives in the classification of land use.

It is indeed encouraging to note several significant efforts at local, state, and Federal levels to resolve differences among classification schemes that hamper effective use of land use statistics for planning, management, and other purposes. An excellent example of coordinated effort to attain land use data compatibility within a metropolitan planning area may be found right here in Washington. Under the sponsorship of the Metropolitan Washington Council of Governments, the District of Columbia Government, and the U.S. Department of Housing and Urban Development a demonstration project was recently completed. The purpose of the project was to demonstrate (1) that land data "can be made available in compatible form from local government sources within a complex metropolitan area, and (2) that an actual operating metropolitan data system based on efforts of this kind will help greatly in attaining more effective standardization in the classification of land use."[1/] A similar effort among state governments would likewise contribute much toward getting more uniformity in classification for the nation as a whole.

One of the truly great landmarks in developing a uniform classification scheme for an entire country took place in Britain in the 1930's when L. Dudley Stamp was able to organize and execute with much help from many persons, a splendid land use survey for the whole of that country. This first British Land Use Survey was a truly remarkable effort from the standpoint of the effective involvement of school children throughout the nation in the data collection process. The great worth of this nationwide land use survey was clearly demonstrated when Britain entered the war and soon faced the extremely difficult task of increasing food production within the country. After the war was over, the land use information and maps available from that survey formed a firm foundation for effective national planning and the reconstruction of the economy. A second land utilization survey of Britain was completed in the 1960's. In this survey an expanded categorization was used but the

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1/ Metropolitan Planning Data from Local Governments: A Demonstration of Land Use Compatibility, 1970, Metropolitan Washington Council of Governments, p. i.

basic framework of the original classification scheme was maintained. The completion of these two surveys about 30 years apart with compatible classification schemes will offer an excellent opportunity for the study of land use changes.

Professor Stamp went on to play a major role in the organization and work of the World Land Use Survey Commission of the International Geographical Union. The report of that Commission published in 1949 presented a land use classification scheme for use on a worldwide basis. Although the ambitious idea of mapping the whole world at a scale of 1:1,000,000 was never realized, the efforts of this original and of continuing commissions has contributed much toward developing an awareness of the need for a standardized approach to gathering land use data on a global basis. As a matter of fact, the Food and Agriculture Organization of the United Nations adopted a very similar basic set of land use categories for the annual reporting of land use data by member nations. A table of land use data is published annually in the Production Yearbook of that organization, which is based on this classification scheme.

CONFERENCE OBJECTIVES

The main purpose of this Conference is to provide an opportunity for interested persons to discuss the feasibility and utility of a more standardized classification of land use and to take initial steps to devise a classification scheme or framework that will effectively serve a wide array of needs. Remote sensing techniques, including the use of conventional aerial photography, now have the capability of effectively completing surveys based on ground observation and enumeration. The development and adoption of a compatible scheme for classifying land use information obtained in different ways is urgently needed. A conference bringing together a representative cross section of the users of land use information seemed an appropriate first step in devising a national framework for land use classification which will:

1. Satisfy the needs of Federal agencies for an up-to-date overview of land use throughout the country on a basis which is uniform in date, scale, and categorization at the first and second digit levels;

2. Utilize the best features of existing, widely used classification schemes;

3. Provide an open-ended classification system that will enable regional, state, and local agencies to develop more detailed land use classification schemes at the third and fourth digit levels to meet their particular needs, and still be compatible with each other and with a national system; and

4. Be receptive to data from instrumented satellite and high altitude aircraft platforms.

Therefore the following groups of agencies and organizations have been invited to send representatives to this conference:

1. Federal, state, regional, and local planning agencies and organizations.

2. Metropolitan and transportation planning agencies and organizations.

3. Agencies administering public works programs.

4. Agricultural and resource management agencies.

5. Agencies and organizations concerned with property evaluation and tax assessment.

6. Agencies involved with the collection and dissemination of land use data.

NEED FOR STANDARDIZATION

During the decade of the 1960's a growing sense of need for more attention to the standardization in land use classification has been much in evidence. I would like to cite just a few of the many events, reports, and groups contributing to the movement toward a partially satisfactory solution to a difficult and longstanding problem.

In 1965, Resources for the Future published a book entitled Land Use Information: A Critical Survey of U.S. Statistics Including Possibilities for Greater Uniformity. This book was written by Marion Clawson and Charles L. Stewart following a series of meetings of a Committee on Land Use Statistics which had been held from the summer of 1962 to the winter of 1965 under the auspices of Resources for the Future. Dr. Clawson, who spent many years in public service, was eminently well qualified to serve as chairman of that committee and to take the leadership in preparing a report based in part on the activities of the committee.

The main thrust of that report is identical with the central purpose of the conference that is being held here now under the joint sponsorship of the U.S. Department of the Interior's Earth Resources Observation Systems (EROS) Program and the National Aeronautics and Space Administration's Earth Resources Survey (ERS) Program. A major contribution of the book on Land Use Information is the careful and enlightening discussion of concepts about land and the need for giving careful attention to land location and parcel identification. An activity approach to the classification of land use is strongly recommended and defended as a basic condition for attainment of greater uniformity in classification. The elements of an improved system of land use statistics for the United States is presented in the last chapter. Several informative appendices present information about the interests of several of the Federal agencies in land use data.

Also published in 1965, the Standard Land Use Coding Manual is another landmark of the 1960's contributing toward the attainment of greater uniformity in classifying land use. The coding manual was released jointly by the Urban Renewal Administration and the Bureau of Public Roads. The classification scheme is also reproduced in its entirety as Appendix I in Land Use Information. In so far as was feasible the Standard Land Use Coding Manual incorporated the category titles and detailed identification of activities from the Standard Industrial Classification (SIC) prepared by the Bureau of the Budget and published in 1957. "The standard system for coding land use activity published in 1965 is comprised of nine one-digit categories (two of which have been assigned to manufacturing), 67 two-digit categories, 294 three-digit categories, and 772 four-digit categories."2/

In part as a result of publication of the URA-BPR report and in recognition of the need for cooperation among local governments of metropolitan areas, many significant steps toward greater standardization of land use statistics have been taken in recent years. I have already mentioned the work of the Metropolitan Washington Council of Governments. Several other examples of cooperation for standardization can be cited, including that of the Tri State Transportation Commission, the Association of Bay Area Governments, the Delaware Valley Regional Planning Commission, the Association of Central Oklahoma Governments, and the Southern California Regional Information Study. The URA-BPR report has helped to establish a guideline for standardization in land use classification schemes being used by metropolitan governments.

States have also in various ways had occasion to work together in the study of land use conditions. All of us are familiar with the Tennessee Valley Authority and the land use studies carried out under its direction in the 1930's. In the 1950's and 1960's numerous river basin commissions have established some common guidelines for the study of land and water resources within their respective basins. Quite recently a number of state governments are authorizing statewide planning activities that necessitate a uniform approach to the collection and handling of land use data. However, there is as yet to my knowledge, no mechanism for bringing about a uniform approach to land use classification among states. Two very fine state-wide studies of land use have recently been undertaken in Minnesota and New York. In New York the study was carried out by the New York State Office of Planning Coordination with prime responsibility for the Land Use and Natural Resource Inventory (LUNR) assigned to the Center for Aerial Photographic Studies at Cornell University. The Minnesota State Planning Agency contracted with the Minnesota Land Management Information System Study at the University of Minnesota. Both states are preparing quality land use inventories, but the approach to land use classification is strikingly different. Minnesota is using a nine-category classification for current land use while New York has a more complex scheme, which distinguishes between area and point data. To achieve greater compatibility between these two schemes in order to provide an effective overview of land use throughout the United States will require considerable additional effort. What is needed is a national framework for land use classification, which

2/ Standard Land Use Coding Manual, Urban Renewal Admin. and Bureau of Public Roads, 1965, Washington, D.C., p. 9.

will provide for this effective overview and at the same time will enable regional, state, and local agencies to develop more detailed land use classification schemes to meet their particular needs and still be compatible with each other and with a national system.

I would like to take just a moment to mention a significant international symposium held in London in April 1970. The papers presented at that symposium have subsequently been published as Occasional Papers No. 9 of the World Land Use Survey of the International Geographical Union. The main focus of the symposium was to examine New Possibilities and Techniques for Land Use and Related Surveys with Special Reference to the Developing Countries. A clearly implied justification for holding such a meeting is the need for more international cooperation in carrying out land use inventory and mapping activities. Certainly as NASA plans for the launching of satellites that will be undertaking an earth resources survey, such a need should be ever more obvious.

In this review of recent attempts to bring about more coordinated efforts for standardizing land use classification, I would be remiss if I did not mention the longstanding and continuing efforts of several Federal agencies to achieve and maintain compatibility and continuity in the collection and handling of land use data. In addition to some agencies already cited, we should note the work of the Bureau of the Census, several agencies in the U.S. Department of Agriculture including the Economic Research Service, the Forest Service, Soil Conservation Service, and the Statistical Reporting Service, and agencies of the U.S. Department of the Interior assigned the responsibility for the management of millions of acres of Federally owned lands.

There has long been a concern about duplication and coordination among Federal, state, and local governments in the collection and handling of many different types of data. In some instances we have achieved reasonably effective, though not perfect, solutions as evidenced by present programs in soil survey, topographic mapping, collection of weather information, and the inventory of forest resources. The current need for effective approaches to cooperation with respect to land use data is becoming more and more evident and crucial. I mention just a few reasons as to why there should be a sense of urgency in developing more effective programs related to the collection and handling of land use data.

1. Studies focusing on the dynamics of land use changes in order to gain a better understanding of the forces contributing to such changes must be based on more sophisticated data if they are to be more meaningful.

2. There is a need to relate the current use of land resources to many other economic, social, and physical characteristics of land in a more detailed and precise manner.

3. Land use can serve as an effective surrogate in the analysis of environmental processes and problems that need to be better understood if the enhancement of living conditions for Americans is to be achieved.

4. Timeliness and currency are always key constraints in making studies just cited.

5. The problem of the cost of obtaining data is always present.

6. The widespread use of computer technology and the rapidly growing number of data banks focus attention to problems of compatibility in data handling, especially those related to collection and retrieval.

WHAT IS LAND USE?

Land has many attributes or characteristics. Present or current use, which is the main theme of this conference is only one of these attributes about which information is needed for planning, management, and other programs and uses. In a widely used book on Land Resource Economics by Raleigh Barlowe of Michigan State University, the author emphasizes that the "term 'land'suggests different things to different people." He goes on to point out that widespread acceptance of the term "refers to the solid portion of the Earth's surface." Then, Professor Barlowe emphasizes that we must be quite careful not to confuse the more commonly used definition with the concepts about land used by lawyers and economists. Seven economic concepts about land are discussed: 1) space; 2) nature; 3) a factor of production; 4) a consumption good; 5) situation; 6) property, and 7) capital."3/

In part because of these several different concepts that are held about land, there exists a similar range in ideas about what "land use" is. An attempt to arrive at a common precise definition of "land use" that will satisfy the diverse users of the term is not likely to meet with great success. However, there is a real need to reach a general area of agreement as to what the term means if we are to wrestle effectively with the problem of standardization in the classification of land uses. The Committee on Land Use Statistics, which has been mentioned earlier, grappled at length with this matter. As reported by Clawson, the Committee came to the conclusion that the term "land use" should refer "to man's activities on land which are directly related to the land." It was further recognized that phrases such as "human uses of land" or "human activities on land" might help in clarifying the concept of land use. Certainly such dimensions as "the natural qualities of land, improvements, tenure, and intensity of use," are closely related but it is the activity dimension that constitutes the central focus in defining land use. 4/

3/ Barlowe, Raleigh, Land Resource Econimics, 1958, Prentice-Hall Inc., Englewood Cliffs, N.J., pp. 7-10.

4/ Clawson, Marion and Charles L. Stewart, Land Use Information: A Critical Survey of U.S. Statistics Including Possibilites for Greater Uniformity, Resources for the Future, Inc. Distributed by the Johns Hopkins Press, Baltimore, 1965, p. 29.

More recently the study of Metropolitan Planning Data from Local Governments, which I have previously referred to, has recognized the complexity of the concept of land use. Those undertaking that study concluded that too often several concepts have "been wrapped up into a single classification scheme which hides many of the most important types of information which need to be analyzed."5/ Thus, the conclusion reached by this group was in a way similar to that arrived at five years earlier by the Committee on Land Use Statistics, but their recommendation for a clarification of the term "land use" was quite different. For purposes of their analysis "land use" was defined to include the following dimensions:

1. Activity
2. Ownership
3. Intensity of use
4. Quality of development
5. Restrictions on use
6. Public services
7. Financial value
8. Location
9. Type of structure
10. Other

Interesting to note is the fact that the natural quality of land, which is such an important concept about land in a rural setting, is not included as a specific dimension in the urban context. (After seeing two feet of water in apartments in Gainesville, Florida last year and after observing spetic fields that won't work, I wonder if urban planning should not recognize that dimension more explicitedly.)

Returning to the quotation, it is very important to recognize the following statements from the same section of that report:

> Several thousand terms were analyzed. They came from a number of different classification schemes and presented a great diversity of terminology, even for essentially the same concepts. Therefore, it was necessary to adopt some standard coding system to facilitate comparisons. The Standard Land Use Coding Manual prepared by the Urban Renewal Administration and the Bureau of Public Roads (URA-BPR) was chosen, although it

5/ Metropolitan Planning Data from Local Governments, ibid., pp.20-22.

provides a classification and coding system for only the activity dimension. It does not provide coding systems for location, ownership, governmental and contractual restrictions on use, building type, intensity of use, or the additional characteristics needed to get a full description of land use.

Activity alone, of course, does not contain all the information normally found among land use classifications presently being used by local governments. Thus, additional codes must be devised for supplementing the activity code in order to preserve and make available the data that local governments are used to having.6/

I agree wholeheartedly with that latter conclusion. At this time, however, I remind you that at this Conference we are concerned only with classification standardization for the activity dimension, much though the need exists for further work on other areas. This more restricted focus for this Conference relates directly and immediately to the problem of trying to obtain and maintain an effective degree of compatibility for the main categories of a land use (activity dimension) classification for the analysis of data to be obtained on the ERTS and Skylab satellite missions.

DATA COLLECTION AND COSTS

Several alternatives are available in the collection of land use information. Five basic approaches have generally been used: 1) ground observation; 2) enumeration; 3) air photo-interpretation; 4) remote sensing; and 5) a combination of the first four approaches mentioned. Of these, probably remote sensing is the least understood, since it is the most recent approach to be used. Actually, of course, remote sensing is an extension of air photo-interpretation and in reality the use of aerial photographs in gathering land use information can now appropriately be considered under the more general term of "remote sensing" which has only recently come into widespread use.

In certain situations each of these approaches to land use data collection may be used as the primary or even the sole method of collecting information about land resources and their use. In remote areas with sparse populations the advantages of getting some kinds of information by use of remote sensing techniques should be fairly obvious. On the other hand in densely settled parts of the world the complexity of land use patterns may make ground observation and enumeration essential. In many instances, however, more and more land use surveys are being carried out by using varying combinations of the basic approaches listed above.

Generally the critical question is posed. What single approach or combination of data collection approaches will yield the most data of the kind needed at the least cost under the time constraints which are present? In 1963 the Tri State Transportation Commission operating in a highly urbanized situation employed 900 persons in its extensive land use

6/ Op. cit., pp. 20-22.

inventory. Recently the Economic Research Service made a survey of land use changes in the lower Mississippi Alluvial Valley on a sampling basis, which required only about one and one-half man-days to determine the change occurring at 640 selected points, which yielded reliable data for a county of average size and complexity in land use patterns. Both of these approaches were valid for the data requirements needed by these agencies. Often it is difficult to determine just what single or combined approach to data collection will yield the most information of the kind and accuracy needed at least cost.

When the question of data costs is examined from another perspective, it becomes fairly evident that in most instances existing sources of land use information collected for specific purposes by agencies responsible for administering a particular program must be utilized. The major and most obvious exception to this statement is the data collection program of the Bureau of the Census. Even then the need to reapportion the Congress every ten years was, I believe, the initial basis for having a census of population. Thus, data collection has generally been authorized at Federal, state, and local levels of government as needed for implementing specific programs in such diverse areas as property tax assessment, urban and regional planning, management of public land, and the establishment of restrictions on use of public lands.

This is a fundamental issue in the context of this Conference. To what extent can more cooperation and coordination among agencies operating at all levels of government result in greater efficiencies in the collection of land use data? Can a more coordinated approach be realized without seriously hampering the many agencies and other users who have specific data needs? Certainly, I think there will be some kinds of data that will always have to be collected and maintained by user agencies. However, I am convinced that some kinds of land use data can be collected, stored, and retrieved from data banks available to all users, under some kind of cost-sharing arrangements.

LAND USE CLASSIFICATION SCHEMES EXAMINED

Earlier systematic attempts to devise schemes for classifying land in this country and elsewhere stemmed mainly from the desire to understand the distribution of agricultural activities and the conditions affecting the production of agricultural commodities. Aerial photographs were first used for mapping soils in Indiana in 1929. Extensive use was made of aerial photography in the TVA area in the 1930's. A land capability classification, which is now widely used, was developed by the Soil

Conservation Service during that period. A Land Committee of the National Resources Planning Board prepared a special report on Land Classification in the United States, which was published in 1941. The land classification activities of the U.S. Department of Agriculture and of the U.S. Department of the Interior were represented in the Committee membership of four in the persons of Carleton P. Barnes of the U.S. Department of Agriculture and John F. Deeds of the U.S. Geological Survey. Thus, the 1930's was a decade of great interest in improving the methodology of land classification.

However, the interest in land use in the 1930's was predominantly focused on rural areas. Some attention was being given to urban land use during this period, but in an entirely different perspective. The rural-urban fringe was not the dynamic meeting place of rural- and urban-oriented land uses that became such an important issue in the 1950's and 1960's. The pressure of finding more land for recreational activities in both rural and urban settings had not yet developed. The interstate highway system and other transportation improvements did not have a major impact until after the mid-1950's. Environmental quality and pollution were only infrequently discussed in the 1930's among those having interests and responsibilities for planning and managing the use of land resources. Some of the problems confronting this Conference today are historically related to the relative lack of need in pre-World War II years to coordinate studies of land use in rural and urban situations.

In order to provide a framework for group discussion at this Conference, you have been given in outline format four land use classification schemes that have been used recently in land use inventories and surveys. (See Appendix I) Three of these classification schemes were developed for use on a country-wide or national basis, while the other scheme was devised for use in the State of New York. However, the three national schemes differ significantly in the level of inventory detail which was contemplated in their use.

The Standard Land Use Coding Manual provides a four-digit categorization of land use developed mainly for use in urban and adjacent situations in the United States. This classification scheme was not designed specifically for use with air photo-interpretation or other remote sensing techniques. Ground observation and enumeration obviously must provide much of the information necessary to classify land use with this scheme when used in urban areas.

The Canada Land Inventory employed essentially a two-digit or two-level land use classification scheme for use throughout the settled part of Canada. Maps of present land use are being compiled at a scale of 1:50,000 using this scheme, which has six major or first-order categories, 12 second-order categories, and two third-order categories. Obviously the scope and objectives of the Canadian inventory necessitated a much more generalized scheme for classifying land use than for the situations for which the Standard Land Use Coding Manual was primarily prepared.

Still another scheme specifically presented to you here is the tentative land use classification scheme for use with orbital and other imagery to be complimented by some use of ground observation and enumeration. This classification scheme was the product of a study carried out by the Commission on Geographic Applications of Remote Sensing of the Association of American Geographers. The scale of 1:250,000 was used for a pilot study in the Phoenix, Arizona area to test the capabilities of the scheme for use mainly with conventional color and color infrared imagery taken from Apollo 9 and from high altitude aircraft (50,000 to 60,000 feet). This imagery was supplemented by some use of mosaics of black and white photography having a scale of 1:62,500 in the pilot project. The scheme has seven first-order categories, 27 second-order categories, and 30 third-order categories. Fourth- or even fifth-order categories can be added and would be appropriate for use with larger scale imagery or for more extensive use of ground observation and enumeration.

The New York State Land Use and Natural Resources Inventory classification scheme was developed mainly at the Center for Aerial Photographic Studies at Cornell University. The scheme was, of course, devised specifically for use in the State of New York, although it is quite adaptable for use elsewhere. Furthermore, it is important to recognize that this scheme was used with aerial photography having a scale of 1:24,000. Aerial photography contributed about 85 percent of the land use data obtained in that inventory. The categorization was developed to accommodate the recognition of areal and point data.

As these four and other land use classification schemes are reviewed and discussed at this Conference, we should remember the great need that exists in this country and around the world to obtain as much information about land use and related conditions as cheaply and as accurately as possible. A recently published study carried out at the Center for Aerial Photographic Studies at Cornell University for the Economic Research Service of the U.S. Department of Agriculture poses some significant questions and suggests some preliminary conclusions prior to the launching of the ERTS-A and Skylab satellites.

This study, which was published in April of this year, is entitled Land Use Classification with Simulated Satellite Photography. A number of significant questions were posed in the Preface for the study.[7]

1. Will the new (satellite) system eliminate the need for conventional land use data gathering systems?

2. Will the new systems merely supplement the old systems, and, if so, to what extent?

3. Will the data from the new remote sensing systems be compatible with data series of earlier years such as those used in the Economic Research Service?

7/ Belcher, Donald J., Hardy, Ernest E., and Phillips, Elmer S., 1971, Land Use Classification with Simulated Satellite Photography. Economic Research Service, U.S. Dept. of Agriculture, Washington, D.C., p. iii.

4. Will definitions of major land use categories have to be modified?

5. What are the limitations of expected satellite data in presenting a realistic picture of land use?

Conclusions reached were based on a simulation of satellite scale photography and on an estimate of the quality of such photography. These are the conclusions as quoted directly from the report:

1. The land use classification system currently in use by the U.S. Department of Agriculture will be compatible with satellite photography. Approximately 90 percent of the data now required for periodic land use reports can be obtained from satellite photography. An additional 5 to 8 percent of the required information can be inferentially derived from satellite photography and supplementary sources.

2. An estimated 2 to 5 percent of the data now included in the periodic reports cannot be obtained from satellite photography. Examples of agricultural information which satellite photography cannot provide include: land ownership; end-use for specific crops, e.g., for feed, seed, or human consumption; and transitional vegetation areas and some multiple-use areas, e.g., pastureland reverting to forest and cropland used as pasture.

3. Weather conditions are a serious inhibiting factor to the successful use of satellite photography of any type. This limitation would tend to be minimized if the Department continues to issue its periodic land use report at five-year intervals. The span of time would provide opportunity for coverage in favorable weather of areas which are generally subject to a high degree of cloud cover. The use of high altitude aircraft as a supplemental vehicle would assure adequate coverage of land use within any one year.

4. The fact that specific land use data can be tied to specific geographic locations will greatly increase the value of the periodic report as well as other land use reports. Development of base map information from initial satellite flights will greatly simplify subsequent land use inventories.8/

8/ Op. cit., p. vii.

SOME CRITERIA FOR DESIGNING AN EFFECTIVE LAND USE CLASSIFICATION SCHEME FOR USE WITH REMOTE SENSING TECHNIQUES

Although it is unlikely that complete reliance can be placed on remote sensing techniques for collecting land use data at first- and second-digit levels, many recent developments hold considerable promise for obtaining much information rapidly and at low unit cost. Clearly recognized, as previously pointed out, is the fact that such data will not meet all of the needs of the users of land use information. However, the time has come when a careful evaluation must be made of the possible contributions of remote sensing techniques to the total information needs pertinent to the study of land resources.

Some working criteria against which to evaluate land use classification schemes for use with orbital imagery are briefly presented here as a guideline for the deliberations at this Conference. Use of criteria such as these is suggested as one approach to gaining a better understanding of current problems related to developing an effective classification scheme for use with remote sensor imagery. These criteria apply mainly to a classification scheme developed for use at intermediate scales ranging from 1:62,500 to 1:250,000 for the United States. Furthermore, the potential users of land use information which might be available at the above indicated scales are assumed to be state, Federal, and other users needing information for regional and national level land resource planning, management, and related purposes.

Criteria which seem appropriate for evaluating such land use classification schemes are:

1. A minimum level of accuracy of about 90 percent or better should be approached in the interpretation of the imagery being used.

2. A well balanced reliability of interpretation for the several categories included in the classification scheme should be attained.

3. Repeatable or repetitive results should be obtainable from one interpreter to another and from one time of sensing to another.

4. The classification scheme should be useable or adaptable for use over an extensive area.

9/ Anderson, James R., April 1971, "Land-Use Classification Schemes Used in Recent Geographic Applications of Remote Sensing," Photogrammetric Engineering, pp. 379-387.

5. The categorization used in the classification scheme should permit vegetative and other cover types to be used as surrogates for activity-oriented categories whenever possible.

6. The classification scheme should be suitable for use with imagery taken at different times during the year.

7. The classification scheme should permit effective use of sub-categories that can be obtained from ground surveys or from the use of imagery available at a larger scale or with the use of such enhanced imagery as color infrared.

8. A need to collapse the categories must be recognized.

9. Comparison with land use information compiled at earlier points in time and data that will be collected in the future should definitely be possible.

10. The classification scheme should recognize the multiple-use aspects of land use whenever possible.

TOWARD A LAND USE INFORMATION SYSTEM

Later this morning Roger Tomlinson will be discussing "Geo-Information Systems and the Use of Computers in Handling Land Use Information." Therefore, I shall take only a moment to relate the need for standardization of land use classification to the need for a land data system. For many years, the land use map has so often been viewed as the dominant and only end product of many programs concerned with collecting and analyzing land use data. Today, we should consider the land use map as only one of several important products of land use data collection and analysis. Far more important is the idea of developing an effective land use information system that will permit the study of a wide range of information about land resources of which current or present land use is only one dimension.

Such a land information system should have the capability of collecting, storing, and retrieving information relevant to the analysis of land use as well as many other characteristics of land. To meet the needs of users effectively such an information system must have the capacity to relate the current land use situation to a wide variety of conditions related to that use such as soil, slope, and climatic conditions; assessed and sale values; size and type of ownership units; distances from centers of population of varying sizes; and access to differing types of transportation.

In the study of land use information needs carried out under the auspices of Resources for the Future, Inc., Clawson discusses several requirements that should be met in order to have a workable information system dealing with land resources. These are briefly summarized here, since it is so important that requirements such as these be kept clearly in mind as an effective guide to the deliberations at this Conference.10/

1. Information pertaining to the different concepts about land should not be indiscriminately assembled. Thus, the several characteristics of land should be treated separately in the system.

2. Data about land should be collected and handled in such a way that the data are carefully associated with a specific and easily identifiable location. Ease of parcel identification is a fundamental part of a good land information system.

3. A maximum of detail should be obtained in the collection stage. Grouping or summarization of the data should take place at a later stage. Such detail should remain separate and distinct when data are stored; otherwise some future user may be very disappointed and unable to make effective use of the data for his purposes.

4. Flexibility in regrouping and summarization of land information must be retained if a system is to supply essential data to potential users.

5. Ready, convenient, and inexpensive access to land information is always a prime requisite for a good system.

6. The land information system must be efficient and should provide data at the least possible cost.

In developing land information, attention will need to be given to the very important matter of scale. There is no easy single solution to this problem, but this important decision must be reached as the information system is being developed. In the statewide inventory for New York a one square kilometer cell or parcel (247 acres) was used with provision for using a quarter square kilometer or smaller cells when needed in urban and other areas. Thus, data summarization was made for 140,000 cells in New York. In the Minnesota Land Management Information System the basic reporting unit averaged 40 acres in size with about 1,300,000 units being summarized in the State. In a national land information system such differences in scale should be resolved in order to have information available on a comparable basis.

Lastly, the efficient quantitative analysis of land information with automated data processing techniques must almost be taken for granted in developing and using a land information system in the United States. The great quantity of spectral data to be obtained from the ERTS-A satellite offers a striking illustration of the compelling need to use

10/ Clawson, Ibid., pp. 161-64.

automated processing techniques. Each 9" x 9" frame will cover an area of 10,000 square miles and data will be obtained every 18 days over areas that have been designated as test sites. Several million resolution elements will be present in each image available in four different spectral bands.

* * *

APPENDIX I

A COMPARISON OF SELECTED LAND USE CLASSIFICATION SCHEMES

Scheme from Study by Association of American Geographers

I. Resource Production and Extraction

- A. Agricultural
  1. Crop production (cropland)
  2. Fruit (orchards, groves, & vineyards)
- B. Grazing
  1. Rangeland grazing (rangeland)
  2. Livestock pasturing (pasture)
- C. Forestry
  1. Commercial
  2. Non-commercial
- D. Mining
- E. Quarrying

II. Transportation, Communication, and Utilities

- A. Transportation
  1. Motoring (highways, parking, terminals, etc.)
  2. Railroading (rights-of-way, yards, terminals, etc.)
  3. Flying (airports)

Canada Land Inventory

I. Urban

1. Built-up area
2. Mines, quarries, sand & gravel pits
3. Outdoor recreation

II. Agricultural Lands

1. Horticultural, poultry, & fur operations
2. Orchards & vineyards
3. Cropland
4. Improved pasture & forage crops
5. Rough grazing & rangeland
   - a. Areas of natural grasslands, sedges, herbaceous plants, & abandoned farmland whether used for grazing or not
   - b. Woodland grazing

III. Woodland

1. Productive woodland
2. Non-productive woodland

Standard Land Use Coding Manual (One- and Two-Digit Levels Only)

1. Residential
   - 11. Household units
   - 12. Group quarters
   - 13. Residential hotels
   - 14. Mobile home parks or courts
   - 15. Transient lodgings
   - 19. Other residential, NEC[1]
2. Manufacturing
   - 21. Food & kindred products-manufacturing
   - 22. Textile mill products-manufacturing
   - 23. Apparel & other finished products made from fabrics, leather, & similar materials-manufacturing
   - 24. Lumber & wood products (except furniture)-manufacturing
   - 25. Furniture & fixtures-manufacturing
   - 26. Paper & allied products-manufacturing
   - 27. Printing, publishing, & allied industries
   - 28. Chemicals & allied products- manufacturing
   - 29. Petroleum refining & related industries

New York State Inventory

A. Agriculture

Areas:

- Ao Orchards
- Av Vineyards
- Ah Horticulture, floriculture
- Ay Specialty farms
- At High-intensity cropland
- Ac Cropland & cropland pasture
- Ap Permanent pasture
- Ai Inactive agricultural land
- Ui Other inactive lands
- Uc Lands under construction

Point data:

- Ay Specialty farms
  - y-1 Mink
  - y-2 Pheasant & game
  - y-5 Aquatic agriculture
  - y-6 Horse farms
  - d Dairy farms: number
  - e Poultry operation: number
  - f Active farmsteads: number

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4. Shipping (inland waterway & marine docks & related facilities)

B. Communications
   1. Telephone lines and facilities
   2. Telegraph lines and facilities
   3. Radio stations and facilities
   4. Television stations and facilities

C. Utilities
   1. Electric
   2. Gas
   3. Water (including irrigation)
   4. Sewage disposal
   5. Solid waste disposal

III. Urban Activities

A. Urbanized livelihood areas (urbanized areas defined by the Bureau of the Census)

   1. Industrial
   2. Commercial
   3. Services
   4. Residential
   5. Recreational

IV. Wetland (swamp, marsh or bog)

V. Unproductive Land (land which does not, and will not, support vegetation)

   1. Sand
   2. Rock & other unvegetated surfaces

VI. Water

3.
   31. Rubber & miscellaneous plastic products - manufacturing
   32. Stone, clay & glass products - manufacturing
   33. Primary metal industries
   34. Fabricated metal products - manufacturing
   35. Professional, scientific, & controlling instruments; photographic & optical goods; watches & clocks-manufacturing
   39. Miscellaneous manufacturing - NEC

4. Transportation, communication, and utilities
   41. Railroad, rapid rail transit, & street railway transportation
   42. Motor vehicle transportation
   43. Aircraft transportation
   44. Marine craft transportation
   45. Highway & street right-of-way
   46. Automobile parking
   47. Communication
   48. Utilities

F. Forest Land
Areas:
   Fc Forest brushland
   Fn Forest land
   Fp Plantations

W. Water Resources
<u>Areas</u>:
   Wn Natural ponds & lakes (1 acre +)
   Wc Artificial ponds & reservoirs (1 acre +)
   Ws Streams & rivers (100' ±)
   Wh Hudson River
   Wm Marine lakes, rivers & seas
   Wb Shrub wetlands, bogs, marshes
   Ww Wooded wetlands

<u>Point data</u>:
   n Natural ponds & lakes: number
   c Artificial ponds & reservoirs: number
   p Ponds less than 1 acre in size: number
   l Lake shoreline: miles
   s Streams & rivers: miles

N. Nonproductive land

   Ns Sand (unstabilized)

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B. Other urban livelihood (places of more than 2,500 population but not including urbanized areas)

1. Industrial
2. Commercial
3. Services
4. Residential
5. Recreational

IV. Towns and Other Built-Up Livelihood Areas

A. Industrial

B. Commercial

C. Services

D. Residential

E. Recreational

V. Recreational Activities (other than those in urban areas and towns)

A. Mountain oriented

B. Water Oriented

C. Desert Oriented

D. Forest Oriented

E. Other (including combinations of above)

49. Other transportation, communication, and Utilities, NEC

5. Trade
51. Wholesale trade
52. Retail trade - building materials, hardware, and farm equipment
53 Retail trade-general merchandise
54. Retail trade-food
55. Retail trade - automotice, marine craft, aircraft, & accessories
56. Retail trade-apparel & accessories
57. Retail trade-furniture, home furnishings, & equipment
58. Retail trade-eating & drinking
59. Other retail trade, NEC

6. Services
61. Finance, insurance, & real estate services
62. Personal services
63. Business services
64. Repair services
65. Professional services
66. Contract construction services
67. Governmental services

Nr Rock (exposed)

R. Residential Land Use

Areas:
- Rh High density (50' frontage)
- Rm Medium density (50-100' frontage)
- Rl Low density (100' + frontage)
- Re Residential estates (5 acres+)
- Rs Strip development
- Rr Rural hamlet
- Rc Farm labor camp
- Rk Shoreline cottage development

Point data:
- k Shoreline developed in cottages: miles
- z High-rise apartment buildings: number
- v Trailer parks: number
- x Rural non-farm residences never a farm residence: number
- o Rural non-farm residences once a farm residence: number

C. Commercial Areas

Areas:
- Cu Central business district
- Cc Shopping center
- Cs Strip development
- Cr Resorts

I. Industrial Areas

Areas:
- Ii Light manufacturing
- Ih Heavy manufacturing

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VI. Low-Activity Areas

A. Marshland oriented

B. Tundra oriented

C. Barren land oriented (including lava flows, dunes, salt flats, mountain peaks above timber line, etc.)

VII. Water-Using Activities

A. Lakes

B. Reservoirs

C. Streams

D. Ponds

68. Educational services
69. Miscellaneous services

7. Cultural, Entertainment, and Recreational
   71. Cultural activities
   72. Public assembly
   73. Amusements
   74. Recreational activities
   75. Resorts & group camps
   76. Parks
   79. Other cultural, entertainment, recreation, & NEC

8. Resource Production and Extraction
   81. Agriculture
   82. Agricultural related activities
   83. Forestry activities & related services
   84. Fishing activities & related services
   85. Mining activities & related services
   89. Other resource production & extraction, NEC

E. Extractive Industry

<u>Areas</u>:

Es Stone quarries
Eg Sand and gravel pits
Em Metalic mineral extraction
Eu Underground mining

<u>Point data</u>:

Eu Underground mining: types present
u-1 Oil and gas
u-2 Salt
u-3 Other
u-4 Abandoned

OR. Outdoor Recreation

<u>Areas</u>:

OR All outdoor recreation facilities

<u>Point data</u>:

OR Outdoor recreation facilities: types present
OR-1 Golf courses
OR-2 Ski areas, other winter sports
OR-3 Beaches and pools
OR-4 Marinas, boat launching sites
OR-5 Campgrounds
OR-6 Drive-in theaters, race tracks, amusement parks
OR-8 Fairgrounds
OR-9 Public parks
OR-13 Shooting, archery
OR-16 Private company facilities, community areas

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9. Undeveloped Land and Water Areas
   91. Undeveloped & unused land area (excluding non-commercial forest development)
   92. Noncommercial forest development
   93. Water areas
   94. Vacant floor area
   95. Under construction
   99. Other undeveloped land and water areas, NEC

1/ NEC - Not elsewhere classified

P. Public and Semi-Public Land Uses

<u>Areas</u>:

P All public & semi-public areas

<u>Point data:</u>

P Public & semi-public areas - types present
P-1 Educational institutions
P-2 Religious institutions
P-3 Health institutions
P-4 Military bases & armories
P-5 Solid waste disposal
P-6 Cemeteries
P-7 Water supply treatment
P-8 Sewage treatment plants
P-9 Flood control structures
P-11 Correctional institutions
P-12 Road equipment centers
P-16 Welfare centers, county farms

T. Transportation

<u>Areas:</u>

Th Highway interchanges, limited access right-of-way, etc.
Tr Railway facilities
Ta Airport facilities
Tp Marine port and dock facilities
Ts Shipyards
Tl Marine locks
Tt Communication and utility facilities

<u>Point data</u>:

h Highway category: highest present
h-o None
h-3 Unimproved, gravel, town roads

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h-4 Two-three land highway
h-5 Four-line highway
h-6 Divided highway
h-7 Limited access highway
h-8 Limited access interchange

Tr Railway facilities: type present
r-1 Abandoned right-of-way
r-2 Active track
r-3 Switching yards
r-4 Stations and structures
r-5 Spur

Ta Airport facilities: type present
a-1 Personal
a-2 Non-commercial
a-3 Commercial
a-4 Airline
a-5 Military
a-6 Heliport
a-7 Seaplane base

Tb Barge canal facilities: types present
b-1 Channel
b-2 Lock
b-3 Abandoned channel

Tt Communications & utilities: types present
t-1 TV-radio tower
t-2 Microwave station
t-3 Gas & oil-long distance transmission
t-4 Electric power-long distance transmission
t-5 Water - long-distance transmission
t-6 Telephone - long-distance transmission

THE USE OF REMOTE SENSORS IN OBTAINING LAND USE INFORMATION

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I will try to explain very briefly NASA's interest in co-sponsoring this meeting and the continuing interest we will have in the deliberations of groups such as this. In planning an information system, it is particularly appropriate and important for the remote sensing data collection agency, whether the data comes from aircraft or spacecraft platforms, to be a part of the deliberations of users. The reason for that is that we can deliberately plan collection formats that will fit into information systems easily. If we do it in a vacuum we can give you some rather dreadful times in trying to reformat the data collected into the format of the information system that you plan. Even though we are not a part of the user community, we need to be aware of the kinds of discussions and planning that are taking place in the user community.

What I'm going to show you are the unconventional sensors. Then, Dr. Hardy will talk about the conventional air photos and information systems that can be derived from air photos. I have tried, however, to stay in the same realm, that is the pictorial format, even though the information is from different parts of the electromagnetic spectrum than the air photo.

Figure 1 shows a conventional black and white air photo, and the only unconventional thing about this photo is that it was taken from nearly 70,000 feet with a 3-inch camera. The point being made is that these collection systems (films and lenses) are very far advanced. In this illustration, note the airport and to the lower part of the airport is a golf course, although you wouldn't recognize it as such. However, when you get the color infrared photograph, Figure 1-A, the links, greens and tees of the golf course show up exceedingly well.

We have some rather exotic mapping missions in our program. Most of you will not be concerned with the oceans, but coastal mapping is important, and offshore mapping is a very important application for the Department of the Interior, as well as other agencies of the Government. Figure 2 simply shows that if you select the right frequency, you can penetrate water exceedingly well, and bottom features start to be able to be mapped. The .55 and .58 micrometer region is best for this purpose near shore. If you are in deeper water where the ocean is bluer, then you have to switch from green to blue. The eye is a rather poor tool in judging the merits of a color photograph and the analog technique of density slicing is a very powerful method of demonstrating differential depth penetration. Indeed, it can sometimes be used to map surface features or bottom features such as grasses and different types of sands.

An interesting radar image is illustrated in Figure 3. The ciruclar feature rather strikingly apparent in this image was not previously known, much less apparent on the air photo shown next to it, and this information did in fact contribute to a geologic map of the area.

We have conducted some experiments using oblique photography and you do get somewhat the same kind of information as the radar acquires because it, too, is an oblique looking device. However, and strangely enough, the higher resolution of the photograph does interfere with the morphology of the terrain that you're looking at. You get confused with the detail that is in the photograph and when you integrate that detail with the somewhat lower resolution radar, then the surface features tend to stand out. There has been a lot of discussion about whether the radar does in fact penetrate foliage to give you a return simply from the surface and, perhaps in some wavelength bands, this may be true.

By using different polarizations of these instruments, additional information can be obtained. The bottom frequency is horizontally propogated and horizontally received. In Figure 4 you can see the kelp bed off the point quite vividly in H-H polarization. The upper image is horizontally propogated also but only the vertical component is recorded by the antenna. Although the kelp bed is there you would certainly miss it if you were in a hurry. The interpreter's eyes and brain are what aid the improvement in many of these devices. If you knew the kelp bed was there you could probably find it. But, in an unknown case, such an aid to the interpretation is very important indeed, especially when the interpretation team is working on large areas.

Switching from the radar to thermal infrared imagery, which has become fairly popular, different kinds of mapping now become important and feasible. Thermal infrared imagery, such as Figure 5, shows the discharge from an industrial plant. You can see the plant above the thermal plume if you follow it. Thermal plume mapping becomes important in a regulatory sense, particularly now that the Environmental Protection Agency has issued regulations with respect to such discharges. We fully expect that this kind of imagery will, if properly calibrated, be used as evidence in court proceedings with respect to the thermal effluent. Figure 6 shows a rather interesting thermal feature, again in the Pacific, which is not the plume but rather the inversion layer in the ocean itself. If you look closely you will see the plume is actually being prevented from spreading further into the ocean by another thermal anomaly, in this case, cold water.

The only non-imaging sensor, Figure 7, that I will refer to is rather important to mineral exploration and we are just starting to learn about this instrument. This is a spectrometer of the type that is going to be flown on Skylab. It is sensitive in the same frequency domain. This happens to be a spectra entirely in the thermal infrared region. We are taking spectra of different rock types with this instrument. As you can see, there is considerable difference in the pulse shape of the return of different rock types. This instrument is now airborne on our aircraft in Houston.

We have expanded the frequency domain several orders of magnitude simply because the radiation characteristics of the Earth's surface require that we look beyond the visible spectrum even though it is difficult to convert these data into images. The information we seek simply is not in the visible domain. The most information about vegetation is in non-visible frequencies. Of course, if you're going to make maps, the spatial information is best contained in the visible spectrum. But, the data that permit you to separate vegetation into classes, and sometimes into species, are certainly not in the visible domain. The "RBV" referred to on the bottom line of Figure 8 is the Return Beam Vidican camera that is on ERTS-A and B. The "MSS" is the multispectral scanner on ERTS-A and B and the "MSS ERTS-2" under 5 indicates that we're going to have a 5-channel device on the second spacecraft, acquiring high resolution thermal infrared data of the surface. Skylab has sensors in the centimeter wavelength region. We are looking in the frequency domain from the ultraviolet practically into the radio waves.

The sensor that I'm going to talk about the most is the multispectral scanner as shown in Figure 9. And the reason I'm going to spend so much time on it is that we have achieved something rather important in this particular instrument, and that is spatial registration between channels. If you are trying to describe a feature on the surface of the Earth by the amplitude of its response in the ultraviolet to the response in the visible, near, middle and thermal infrared channels, then you have one of two choices. You either collect the data in spatial registry, using a single instrument, or you decide to pay the penalty of creating a rubber map in the computer so that you can take the output product from a number of different sensors, reformat them and I mean by that literally to stretch them to achieve registry. It is necessary to overlay the data, resolution element by resolution element, before you can then describe a patch of terrain in all these different wavelength bands. This optical mechanical scanner does just that. It has single optics. The visible spectrum is split by prisms or spectrometers. This particular one shows a prism and fiber optics (people call them light pipes) into the photomultiplier tubes where the light energy is changed into electrical energy and then recorded on a tape recorder. Similarly, the non-visible, emissive part of the spectrum from about 3½ micrometers on up to 14 micrometers is split and focussed on a detector array where it is converted into electrical energy. You record these on multi-tract tape recorders.

Figure 10 shows what the multi-tract tape looks like in a schematic sense. I neglected to mention that one of the most important attributes of these kinds of devices is that they can be calibrated. In this case we show two calibration pulses. One could take the first one as a grey-scale calibration, and a black body reference for the second calibration pulse. The problem with the thermal channel is that if you really want to talk about temperature, then you have to know the emissivity of the object because these devices do not measure temperature directly they measure temperature multiplied by emissivity. The research program is to understand this relationship and actually create a data file of surface features that can be recognized by this particular phenomenon. I would point out one thing in this Figure, that is the big spike shown schematically represents the road that you see in the scene below. The rest is the relative response of the fields.

Because you have your data in electrical form you can digitize it, put it directly into computers, and what you see in Figure 11 is a grey-scale printout in each one of the bands of that scanner. You can see that if you take a particular field and follow it from frequency to frequency, you can easily see several changes in tone, and if you summarize these as the computer does, you can print out what is referred to as the spectral signature of the field. I would add that spectral signatures are actually the relative response as a function of wavelength.

Some of the research I consider to be done. Figure 12 illustrates a simple terrain map made with data from remote sensors. We have had such high success over almost kinds of terrain that we could say that we're very close to being operational with this feature classification algorithm. Green vegetation, bare soil and water--we just don't make many mistakes. And, this kind of map is going to be produced with data from the very first satellite. Of course, you can produce all three elements (vegetation, soil and water), or you can have the computer print out only one if you wish.

Much more of a research effort is the business of species identification as shown in Figure 13, but we will do extensive experimentation on the spacecraft with this kind of a recognition map where we've identified the different species. On the right side of the Figure you see only the wheat print out for this flight line.

More recently, the recognition map has been made up in a very different form, as illustrated in Figure 14, which shows species identification on a per data point recognition basis. Figure 13 shows the data on a per field basis, where the algorithm took not only the agricultural field in a literal sense but it also did it on a data field basis. Both kinds of algorithms, however, are available to us. This type of a printout is important if one is attempting to do something about the yield, because the errors in a field of corn, for example, can indeed be corn that is either suffering from some form of stress, or where the scanner has seen soil instead of corn because of drought conditions, or where weeds occur and the scanner has recognized that it is not corn. Now, when you want to know acreage measurements, you need to have the per field classifier working because then you want the boundaries of the field. When you're talking about yield recognition, then you need the per data classifier in the scheme because you want to know on an individual point basis how the computer classified each resolution element. One other thing I would like to say before I leave this is that if you want to know acreage, this is very easy to do. You have the altitude of the aircraft or spacecraft, its speed, the scan rate of the mirror, and scan angle. All of these things combined can give you the total field of view of the instrument. The resolution cell, therefore, has x and y dimensions to it and the computer merely has to count resolution elements. Once the classifier has said this is corn or wheat, beyond that you have a very easy task of how many acres of corn or wheat because you simply count resolution elements.

Purdue is also doing work in soils and soils mapping with remote sensing data. The Indiana State Soil Conservation Service and state conservationists in Indiana are involved in this research. Munsell color chips have been used for years to compare soil colors, however, this is an automatic system and can work at very high data rates. Figure 15 illustrates a soil color map and I ask you to compare the pattern you see in this figure with the organic matter map of that soil--it is quite highly correlated. A conventional map of Morgan County, Indiana and the same boundary conditions shown by the scanner are shown in Figure 16. The detail within the boundaries is real as it has been verified on the ground. This is the exciting part of the research--to compare data from remote sensors with modern soil surveys and, of course, the researchers are very encouraged.

Finally, our most difficult target of all, Yellowstone National Park, which has very complex, multi-faceted terrain is illustrated in Figure 17. The importance here and the reason that I'm so encouraged, is that this is an ERTS feasibility type of experiment. One can expect to have this kind of performance from the spacecraft. You can see that the ERTS bands were some 4 percent less correct than the best bands. The best bands being chosen by the computer. The computer has the capability of reviewing the classification processes internally and remembering the best bands for each classification task. The thermal band was tried as well and you can see there is very little confusion introduced by the thermal band, which is not surpising, but not completely understood by many people. Remember I said before that it is temperature multiplied by emissivity and not just temperature alone. You have to consider the emissivity if you're looking at the response of the scanner in the thermal bands. That is why you get complex information about the terrain.

Finally, we are doing some automatic data work in disease recognition. I've always had fun with the particular image shown in Figure 18 because the big clumps of trees that are affected by pine bark beatle are quite easy to see and this is a very large scale photograph--just a few hundred feet of altitude. And yet, if you locate the individual red dots on the computer printout and then try to find the trees, it is not easy. It's not that the scanner is all that exotic and, therefore, so much better than the photograph, it is just that the eye does not respond to the very subtle changes in color.

The most exhaustive disease work that we've done with remote sensing data has been on corn blight. Figure 19 illustrates some of last year's work in this research. Human photo-interpreters could sort out three classes of the infection. The subtly of the color shift in terms of the various severity classes of the disease were such that three were about the human interpreter's limit. However, all five classes of the disease were able to be sorted out by the computer. The optical mechanical scanner is one device at least, if we properly manage it, that can provide direct input to computer programs that are land use oriented. We are conducting our research so that we may go directly from the airborne equipment into environmental data systems with little or no supervision of the computer programs. We think it offers great promise in this area.

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NOTE: SEE MICROFICHE CARD IN POCKET AT BACK OF THIS PUBLICATION FOR ALL ILLUSTRATIONS MENTIONED IN THIS PAPER.

Interpretation of Aerial Photographs for Land Use Classification

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The purpose of my talk this morning is to provide a background of information concerning what kinds of land uses can be interpreted from conventional aerial photographs. Confusion often develops in understanding the difference between air photo-interpretation and photogrammetry. Air photo-interpretation is the field where we use the air photo as a source of information and the human mind is the interpreting device. By comparison, photogrammetry relies more heavily on methematics, triangulation, and uses quite sophisticated machinery.

Previously we have stated in print that only about 5 percent of the information that is useful to agriculture has ever been extracted from the ordinary black and white aerial photograph. Although this statement was made several years ago, we have not yet had anyone rebut it in any way. This means then that actually as time has progressed, although there is a tremendous amount of information available in ordinary black and white aerial photography, we have yet to find ways of exploiting it economically and to make use of it as much as we presumably could.

Photography is a line of sight means of imaging items and is not as sophisticated as many of the new types of imaging equipment, some of which you have just seen here. It does provide an inexpensive source of information, it is an unbiased source of information and we can record it at a known point in time. It also has excellent archival qualities. It can be kept for long periods of time and referred to as often as necessary. In developing our photo-interpretation approaches to land use inventories, one of our first steps has always been to look at the needs of the user of the information. What does he want to get out of the imagery and the corollary question is "How much money can be afford to spend?" The next step is to find the trade-off point where we can get the most information that will be satisfactory to the user for the amount of money he has available. In reality you can go to extreme detail if people want to spend enough money. On the other hand, you can get a tremendous amount of output at a very low cost if it is information that can be of use in rather coarse patterns.

Another consideration is the quality and experience of interpreters that you are going to use on the job. I have heard a great number of papers, as I'm sure you have, on what kind of background for photo-interpreters is essential. In practice we have found that a wide variety of backgrounds seems to be our best answer to this question. A background in economics may contribute some knowledge that no other background provides and a young man with a background in history may have a point of view that no one in agronomy or forestry would have. Therefore, we should not restrict ourselves to any one area of expertise for air photo-interpreters.

There are three ways of considering the levels of application of interpretation. One, the most common, is using air photo-interpretation as a means of identifying things. Simply by looking at a photo you can do a great deal of this in mono-coverage as well as in stereo-coverage. For example, you can locate a bridge, a farm house, or a cottage. If we can measure things this way, we can say how big something is or whether it's large or small in proportion to the other items of its same type. This is actually a common use of air photo imagery. The second level of application is interpretation. This is less widely used than the previous level. In this case we would look at the same bridge, determining its size and something of its importance. What kind of a road does it serve, does it connect two major cities or minor cities or farmland from one side of the stream to the other are further considerations. If you look at a cemetery it is quite obvious if it is a new or an old one and you can tell whether the cemetery is growing or not. A third level of interpretation is the inference level. Here we are not actually measuring directly from the air photo or the imagery but are taking the information we can see and directing it through the processes of the brain to draw conclusions.

Let's go back to the bridge. From the inferential approach, a geologist would see a lot more in the location of that bridge than I would. A transportation engineer would see it differently than the geologist, and an economist would see something different from either of the other parties. A cemetery does not get larger in a town where everybody is leaving, so the sociologist would infer that increase in the size of the cemetery is an indication that the population is either growing or is getting older and dying out quite rapidly. These are inferential applications which go beyond anything that we can do by means of direct interpretation or through automatic processing.

Another favorite topic for speakers at conventions is the question of scale. Many papers have been given on this topic, but when you come down to the final result most conclude logically that the scale demanded depends upon the use you want to make of the information. The future holds a great deal of new experience for all of us in terms of scale recognition. The standard scale which most of us rely on is provided by the U.S. Department of Agriculture and most inventories so far have depended on the 1:20,000 ratio. Another ratio which is very commonly used for tax mapping, and by city planners, and foresters is 1:10,000. Another one we like to use when we get into heavily urbanized areas is 1:5,000. These are straight line subdivisions of the 1:20,000 ratio.

What are some of the minor things we can see at a ratio of 1:20,000? It is quite easy to see the white stripes on the road. They are about four or five inches wide. You can see such things as the little round lights along airport runways which are about eight inches in diameter. It is not too difficult to get down to the level of recognition of very small items and areas at this scale of imagery. If you want to go into much greater detail, forestry researchers in Canada have found a way to detect images of brush in wooded areas to determine the fire potential of the landscape. They have very fast-line equipment that will give rapid recognition down to one inch.

I would like to contrast these kinds of scales and recognitions now with some of the work that we have been able to do recently. In a paper we prepared for the U.S. Department of Agriculture, Information Bulletin No. 352 (in print now and available), we reported on a project in which we tried to exhaust the capability of recognition of various patterns of landscape at different scales. Thinking in terms of the negative to earth ratio, we were able to approach a scale of 1:2,500,000 before we lost recognition of usable information.

I think the satellites are going to be able to do much better than this but this means that we have gone to one extreme. At least we know something about one of the parameters we are trying to work with. In doing that work, we took a number of different kinds of commerically available film and we tried a number of exposures, processes, and camera equipment to try to exhaust the capability of each factor involved in developing the prints. The capability level of our enlarging equipment was the first thing that failed. If better enlarging equipment becomes available, the ratio of 1:2,500,000 may be exceeded.

In practically all cases, however, we can say that users do not exhaust the capability of the scale of imagery they choose. For the 1:2,500,000 imagery we were able to classify land into seven classes of use. I think we could improve upon that in the future.

The new high altitude photography is excellent. Although we are still working mostly with ratios of 1:20,000, the high altitude aircraft can provide imagery with ratios of 1:40,000; 1:60,000; 1:80,000, or 1:100,000, with excellent negative production allowing excellent enlargement processes. These will be available in the near future.

In the argument over the best kind of film to use, the logical answer is to search out the one that provides the best information for the needs of the user. The most common one is broad spectrum, Panchromatic, black and white film. There are, in addition, infrared films, infrared color, and various kinds of color films. At present, we do not find that films create the limitation of image recognition or interpretation. We are much more apt to have difficulties in terms of enlargement and the quality of the imagery in the enlargement process.

There are many things that haven't been tried in the use of regular air photos. For example, we have a great many photographs flown in May, June, July, August, and September but I have seen no cases where unique characteristics have been determined by unique situations. One illustration would be the determination of difference between seasonal residences versus year-round residences along a lake front. But if you have the equipment available and the imagination, this can be done by flying the lake front on the morning after the first major snowstorm. Everyone that has to get out to work will shovel his driveway or at least make some car tracks in the yard. You will then know how many houses are being lived in on a year-round basis. Actually, for most of our work, the land use information is more readily available on late season air photos. The reason for this is that the activity on the land during the summer months creates a large number of signatures that we can recognize as characteristics of certain kinds of land use. These include the dust patterns that are kicked up by machinery use or through recreational use which are very evident late in the season. I think we have all been in a park area where the ground seems to be literally beatten to death. This shows up well on the air photos and we can even determine to some degree how much activity has been carried out in that area. But we do not get that kind of information out of photography that is flown early in the spring, when the runoff and snow cover has essentially washed out most of the characteristics that we like to work with.

There is another major point that we must concern outselves with in the extraction of information from air photos. The kind of classification which we want to talk about needs to be considered in terms of the user--the people who have a demand for the information. We have to consider the varieties of demands that will be made on our information, the users' interests, the amount of money he can spend and the size of the unit that he wants to map. We also have, in addition, three basic ways in which you can measure things from air photos in any one time span. The first one is area measurement which is quite commonly used. The second one, not as commonly used, is point information--that is the exact location of something. The third one, which is quite obvious, is the linear measurement--the length of various items in the format.

Currently the work being done in this field is based on manual operations. There are many research efforts underway to retrieve this kind of information using a more automated process. Success in this, if not already with us, is, in some cases, very close.

A major problem of concepts has developed over time. The classification of land use is commonly generated in terms of the needs of information for a particular classification system. We tend to take an existing classification system and turn to our remote sensors and ask how much of this can you give us? To make more rapid progress, we should take the reverse approach. We should ask ourselves what information about land use can be gotten from air photos for example rather than designing first a comprehensive and complete land use classification and then going to the air photos to find how much information they will provide.

Land use classifications that will give you several hundred items of information can be generated from air photos. In the New York State Land Use Inventory we had over 200 items, most of which were derived from air photo-interpretation. We have designed other inventory systems that provide well over 300 items of information about land use that can be derived from air photo-interpretation. In contrast we have tested this against the familiar Standard Land Use Coding systems derived from other kinds of information. When we compared the amount of information that we could get from air photos with the Standard Land Use System we found that of the sixty-seven categories in the System at digit level two, 29 can be identified on air photos. At digit level three, there are 294 categories, of which 88 can be identified on air photos, and at digit level four, there are 772 categories of which 206 can be identified from air photos. That is still a large amount of information. Obviously it would be more appropriate for us to develop a classification that looks first at the information available on the photos and then relies on earth sources for supplemental information. In developing the land use categories and land use classification system for the New York State project we progressed through a number of steps in developing the interpretation process. It is very easy for each one of a large group of interpreters to make a decision but difficult to make all of them agree on the decision. However, with adequate training and supervision, this can be accomplished. We were able to classify an area of 50,000 square miles in a period of about two years with a total of about 135-150 man-years of time and effort involved. The big difference in our approach was that we used a lot of manpower. The other major difference is that it was a very inexpensive operation. We did this job for about $10 per square mile.

In the back of the literature that was handed out for this Conference there is a comparison of four different land use classification schemes and the New York State Inventory System is in the right-hand column. We used both point and area measurements as Dr. Anderson indicated and we had a large number of classification units for most kinds of land use. These are not exhaustive, and they could be broken down into other subdivisions beyond this. For example, orchards could just as well be broken down to identify dwarf apple trees, semi-dwarf and standard trees, or into high quality or poor quality orchards. However, this would be time consuming and would cost more. The people interested in agricultural land said they would accept a good inventory of the orchards and worry about sub-dividing that class later. Essentially this same pattern could be developed for almost any item in the listed land use categories.

To determine quality characteristics is a more difficult task than straightforward identification and measurement. In the housing category, with most any of the area measurements we have used, you could qualify the kinds of housing that you are looking at, the density levels of housing, whether it is a good section of the city, an old section, an improving or deteriorating section, etc.

We had 14 major categories, each of which can be broken down into a great number of sub-categories. These can be aggregated to indicate the total landscape. The detail that can be obtained in this manner is great. In the decision process we used areas of about 1¼ acres. Essentially every acre of land in the state was looked at and mapped and information about it was recorded in detail.

There are other areas of use that have not been exploited to any extent and could be undertaken using regular air photos. One of the major ones in which we are interested is tax mapping. Tax mapping and land use are so closely associated that I would like to heartily recommend that we consider tax mapping as a major feature in our discussions at this Conference. City and regional planning is another area that can make great use of air photo-interpretation. I would never propose that any one inventory is going to provide all of the answers to the information needs of the various kinds of agencies, planners, and interests.

We can improve on existing inventory techniques. Without criticising the population census, it is an easy task to assign population to townships much more accurately than just by aggregating a total for the whole town. Using air photos, you can assign a number of people for each house and then determine where the houses are in a township. You may have large areas in that town with no population density and very small areas of very high population density. With today's environmental concern this kind of information can be much more significant to us in planning and resource management than the simple knowledge of the total number of people in the town. There are major needs for air photo-interpretation in local government activities, especially in development programs and in the area of land management.

Not everything can be done with air photos, and it is only appropriate to point out at least two or three things that are not possible. One is that we cannot identify ownership. There are a few cases where you can--it is quite obvious that major airports are owned by government units, but it is not possible to say that I own a certain parcel of land and my neighbor owns another one. The use of certain crops for different kinds of purposes also cannot be identified. If corn is being raised in an area and part of that production is being used for corn oil porduction and another part for livestock feed, we can't determine from an air photo the decision which the owner of that crop is going to make in regard to its use.

This is but a partial summary of how we can use conventional aerial photographs for land use classification. Many inventories have been carried out in this manner, and the process, although slower than desired, has been used enough to be considered a tested approach.

* * *

GEO-INFORMATION SYSTEMS AND THE USE OF COMPUTERS IN HANDLING LAND USE INFORMATION

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Commission on Geographical Data Sensing and Processing
International Geographical Union

The initial step in understanding how computers can be used in the handling of land use information is to appreciate that the normal facilities which computers can bring to handling practically any kind of data can equally well be applied to those data which describe the use of land.

Specifically, when data are first handled by a computer, they can be edited for internal consistency and for inclusion within predetermined parameters. Lists can be checked for completeness, illogical conditions can be identified and indicated, numerical data can be verified by using a check character, and incorrect formats can be identified. The computer can also be used to reduce and codify raw data. The resulting storage can be very compact.

A data bank of information in a computer can be readily up-dated, i.e., additions of new material can be made, and errors can be corrected, without renewing the entire storage. When existing data are put into computer-readable formats, their retrieval is greatly facilitated. The computer speeds manipulation of the data that it has in its storage. In simplest terms, this is the provision of summaries and comparisons between data sets. Simple extension of these functions results in the capability for measurement (such as amounts, numbers, distances, areas and inclusions) and interpolation of values in the recorded data sets (such as location of contours on a matrix of points). More sophisticated types of manipulations can be handled when the data are submitted to multivariate analysis, trend surface analysis, linear programming and simulation models. The computer can also be used to organize its data to produce a great variety of both alphanumeric and graphic displays.

The application of these functions to a particular data handling task requires the design and use of a system incorporating both hardware and software elements. The particular selection of hardware and software depends on the task. The criteria that determine which system should be used include: the volume of information which has to be handled; the required response time to requests; the frequency of each request; the similarity of inquiries; the volume of inquiries; and the peak load conditions. The application of the capabilities of a computer to data handling imposes a particular discipline on the thought and design of the process. It requires a clear understanding of the inter-dependence of the elements in the continuum of data gathering, reduction, storage, analysis and presentation. It also requires a clear understanding of the use or uses to which the information will be put.

The essential difference between most data and those describing the earth's surface is that the latter frequently have a location identifier

Figure 1

	Population
Able County	20,406
Baker County	11,902
Charles County	11,603
Dog County	15,117
Easy Township	146,724
Fox Township	90,197
Harold County	42,176
Iris County	33,948
Jig County	10,462
King County	5,693

Location only known by reference to the map (i.e. to an external index.)

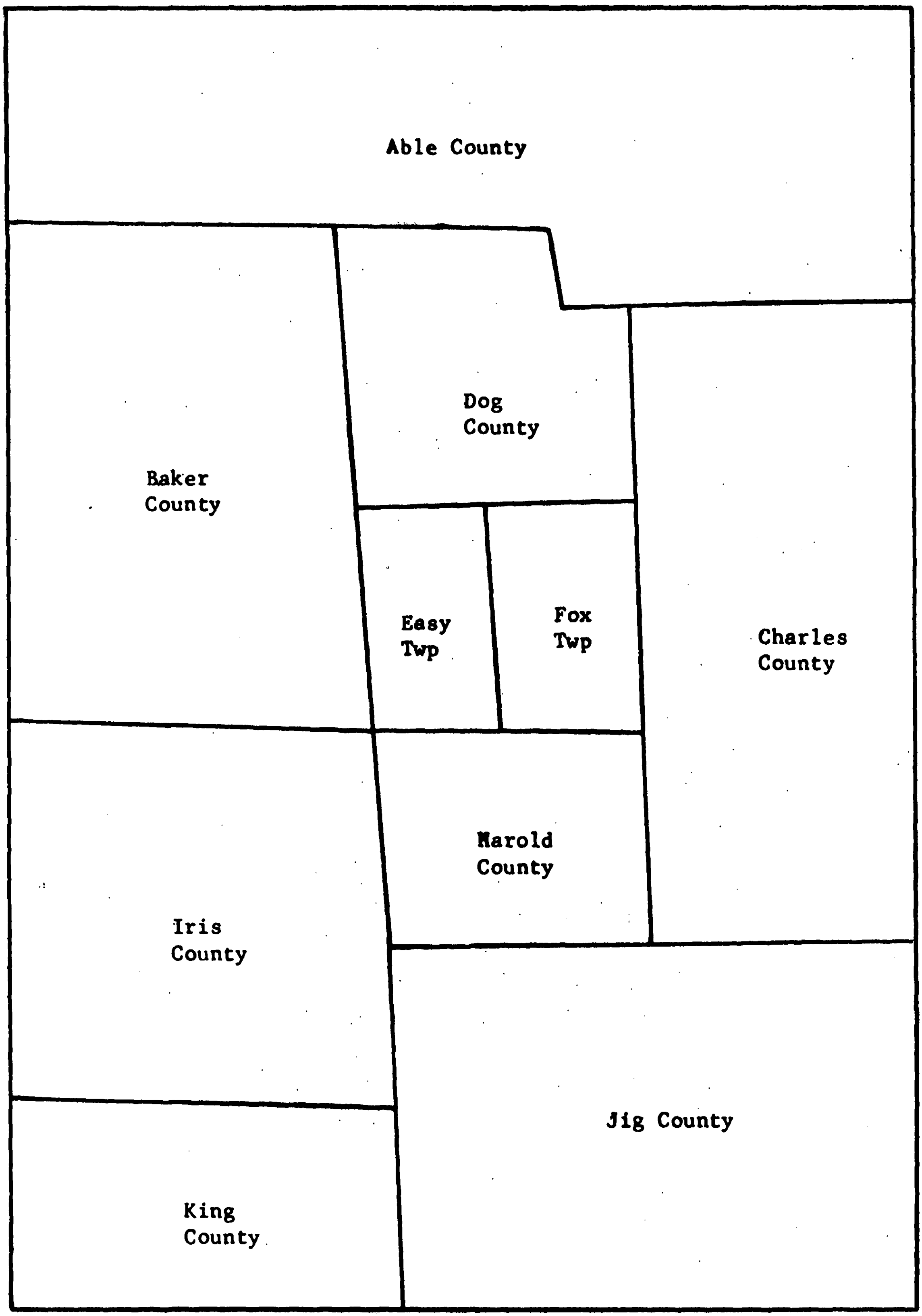


Fig. 2 Map showing location of counties and townships

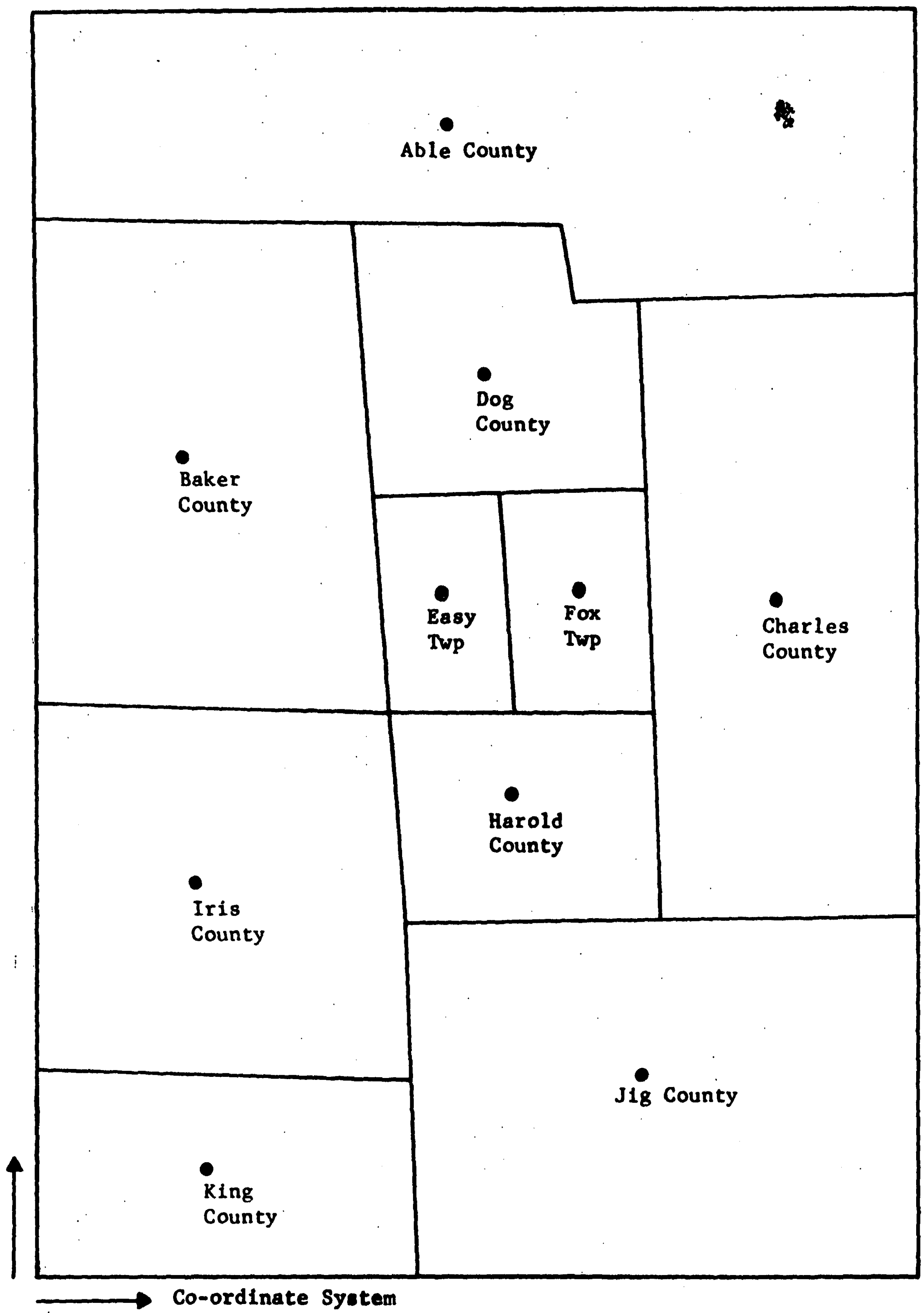


Fig. 3 Map with a centroid in each different area.

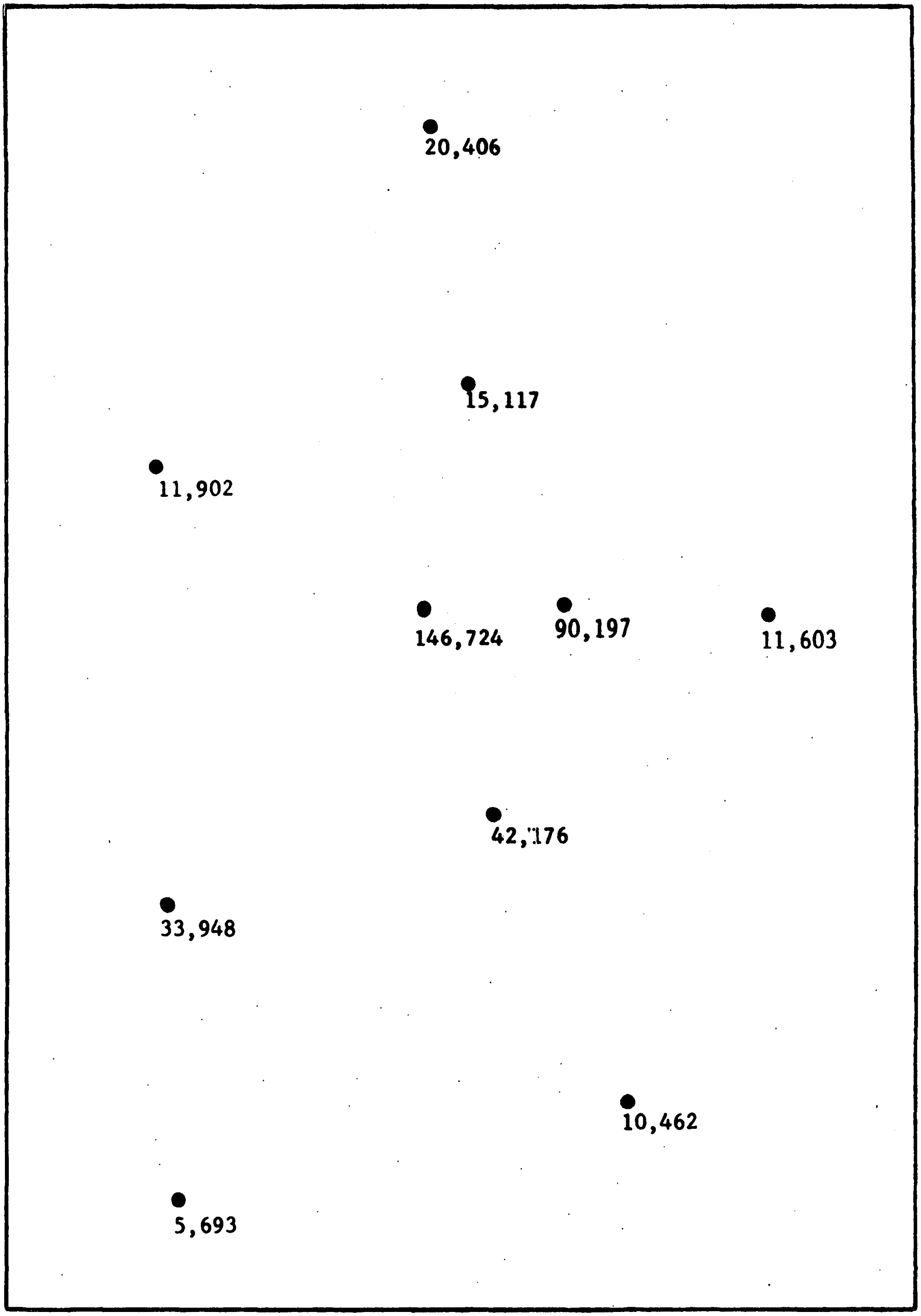


Fig. 4 **Population shown at centroid locations**

as part of the data element. For the purposes of this paper, "geographical data" are those which are specific to location. "Geographical information systems" or "geo-information systems" are those which allow this location value to be manipulated in concert with the remaining value of the data. It is useful to think of the location identifier simply as part of the value that makes up one data record. As with the other values in the data record, the location identifier is amenable to editing, compaction, summary, comparison, measurement and display. In the same way it is one of the criteria that decide which system should be used from the point of view of volume of information, time for response to requests, interaction of values within the data bank, similarity of inquiries, and so forth. In the following paragraphs the various categories of methods for identifying location of data will be briefly outlined.

External Index - No Boundary Known to Computer System

The simplest type of geographical data handling is that which manipulates data lists on the basis of a location specific index. An agricultural census listing of present land use by enumeration area or by census tract would fall into this category. The location specific identifier that can be applied to individual data elements, or to groups of elements, can be generally descriptive; examples are administrative areas, street addresses, the numbers or names of a postal zone, electoral district or census tract, ward definitions and codes (political), cadastral ward numbers, traffic sectors, enumeration areas and traffic zones. These descriptive indexes (Fig. 1) can be used for purposes of grouping, but the relative position of the elements and the boundaries between them cannot be determined without reference to a master index (typically a map) (Fig.2) showing the boundaries of the named areas. Thus, lists can be handled in a computer but the position of the data handled is not known to the computer system.

Co-ordinate Reference - Central Point Known to System

A more recent development is the assignment of a unique earth surface co-ordinate to each data element (Fig. 3) or group of data elements. This approach allows the relative positions of the central points of the data elements to be determined without reference to a master index of coded areas. Co-ordinate indexed data can be subjected to many types of analysis, from simple grouping within arbitrary polygons to insertion in the most elaborate spatial simulation processes. Display is usually limited to data positioning on existing base maps or to the construction of location diagrams (Fig. 4). The systems using maps this approach commonly use a tracing-type digitizer to provide the index co-ordinates from existing cadastral maps. A medium to large scale computer is most often used to store and manipulate the data. The techniques used involve the initial creation of a set of co-ordinate points which can be used as index points for the data sets or discrete data. Various approaches can then be used to relate data to the co-ordinate points.

The application of this approach for handling urban land use data is to allocate one co-ordinate value to each parcel within a city. The land use descriptors relating to that parcel are then assigned that co-ordinate value. The levels of cadastral mapping available in most cities are frequently adequate to allow parcels to be so identified, and the process of relating one address to one co-ordinate point is usually computationally simpler and less error prone than that of assigning multiple addresses to one co-ordinate point. The approach is not tied to civic addresses and can be used in either urban or rural areas where the parcel boundaries are mapped.

The use of a co-ordinate index system in rural areas is just as simple in concept as it is in urban areas. Point data such as location of industrial sites, camp sites, and junctions of roads and similar networks are adequately handled, but the limitations of the co-ordinate indexing system become more apparent as areas so indexed get larger and more irregular in shape. As the size of the area increases, however, and particularly as the configuration of the areas becomes more complex (such as for riverside land use), the co-ordinate index system is little better than a descriptive name and sometimes can be definitely misleading (Figs. 5 and 6).

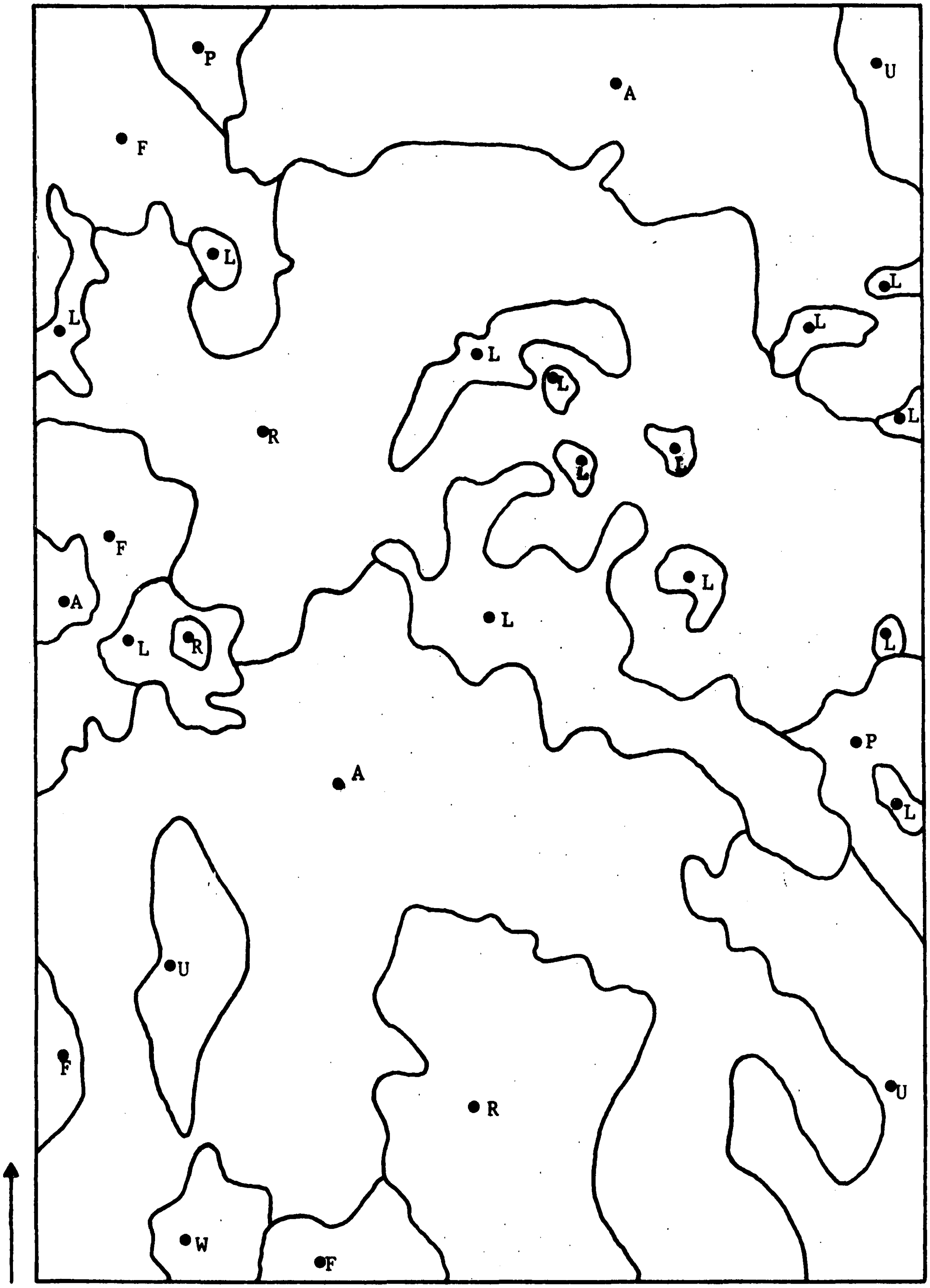
The characteristics of geographic information systems utilizing co-ordinate indexes are: slow, semi-manual creation of the original geographic reference base; computationally simple linking of the data sets to the index; easy retrieval by an arbitrary polygon or network; easy display of the data on a line printer; and an ability to handle large data sets related to the same index. The usefulness of the co-ordinate index for large or complicated areas is poor. Response time to requests can be rapid enough for day-to-day queries involving data summary by area. Frequent requests would be amenable to a standardized query format. However, these systems tend to be incompatible with one another and with other systems, and there has been no significant effort to standardize them.

These characteristics lead to the adoption of co-ordinate indexes for geographic information systems handling quite complex and closely spaced data sets from relatively small areas. They are commonly developed to handle urban data and can be used in small scale representations of rural data.

Arbitrary Grid - Implicit Boundary Known to System

The most elementary form of location indexing, where the boundary of the areas is implicitly known to the computer system, is a uniform-area index, typically using an arbitrary grid of rectangles placed over the area concerned (Fig. 7). All data are presented as totals of items, or averages of conditions, within the rectangles. This method has the advantage of being a simple approach to data storage which allows the relative position to be determined without reference to a master index of named areas. After the initial counting, summarizing or averaging has been done, it is a trivial computational task to store the results by reference to the rectangle and subsequently retrieve or display it. Criticisms of this approach center around the fact that it generally imposes an unreal structure (Figs. 7, 8, 9, & 10) on the data for the sake of ease of storage and manipulation. As time passes and it becomes easier to store and manipulate data in units other than rectangles, the criticism gains strength.

The disadvantages are particularly apparent when large rectangles are employed and the summary or averaging process degrades the detail and fidelity that the original data may have had. A further disadvantage is



Co-ordinate system

Fig. 5 Land use map with land use type shown by code at centroid

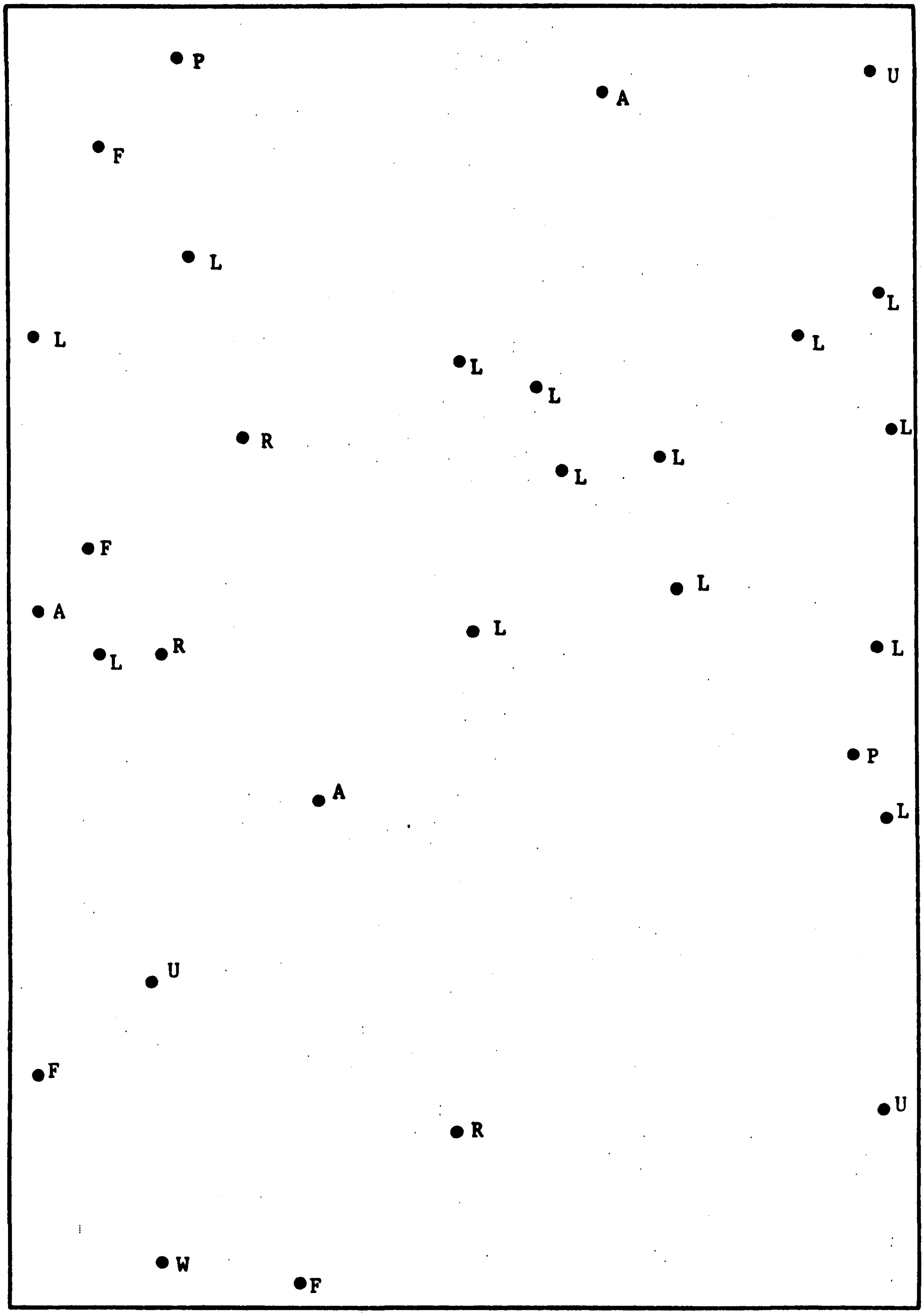


Fig. 6 Land use shown at centroid location

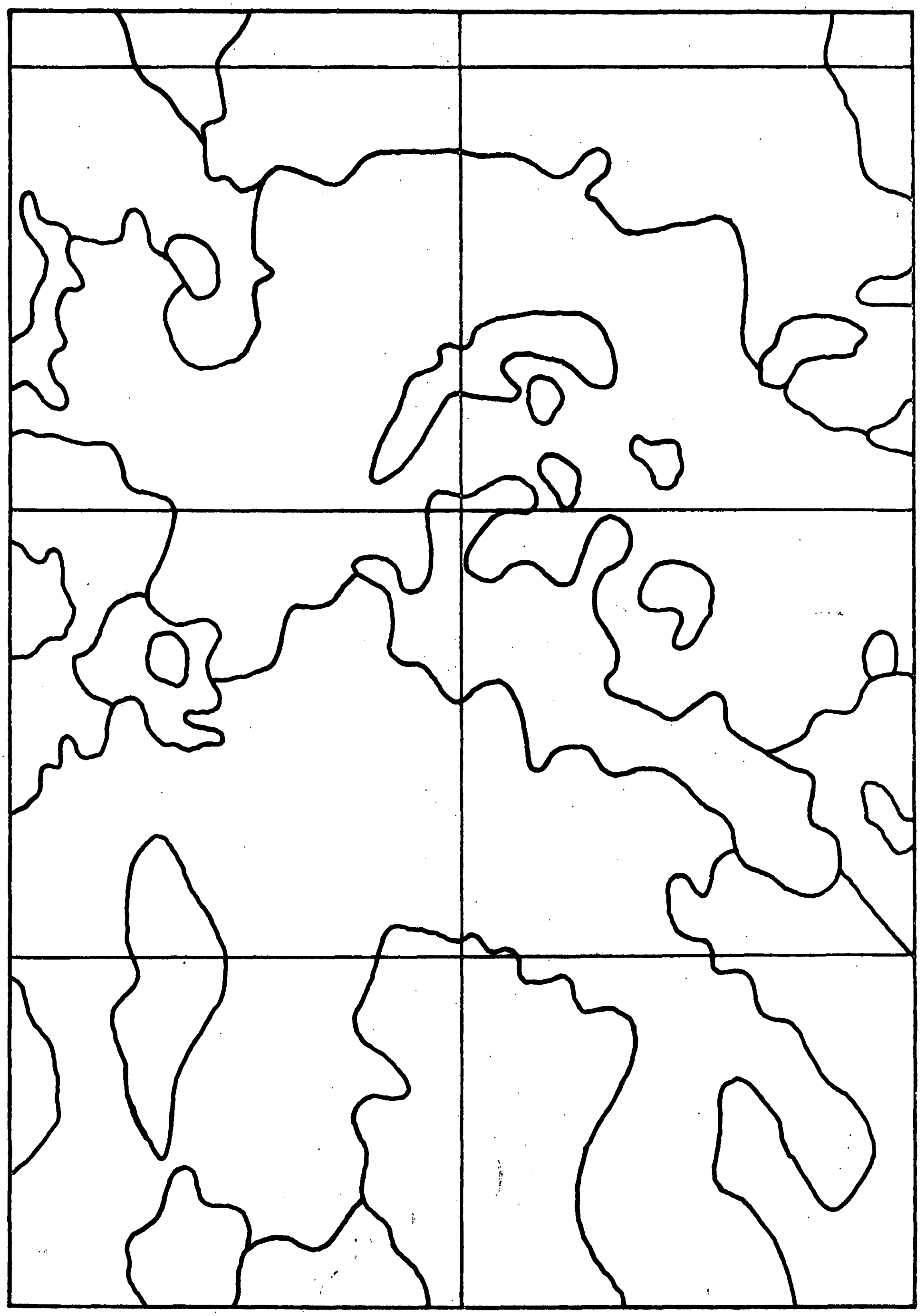


Fig. 7 Overlay of rectangular grid on land use pattern. "Average" land use in each grid is then determined and stored.

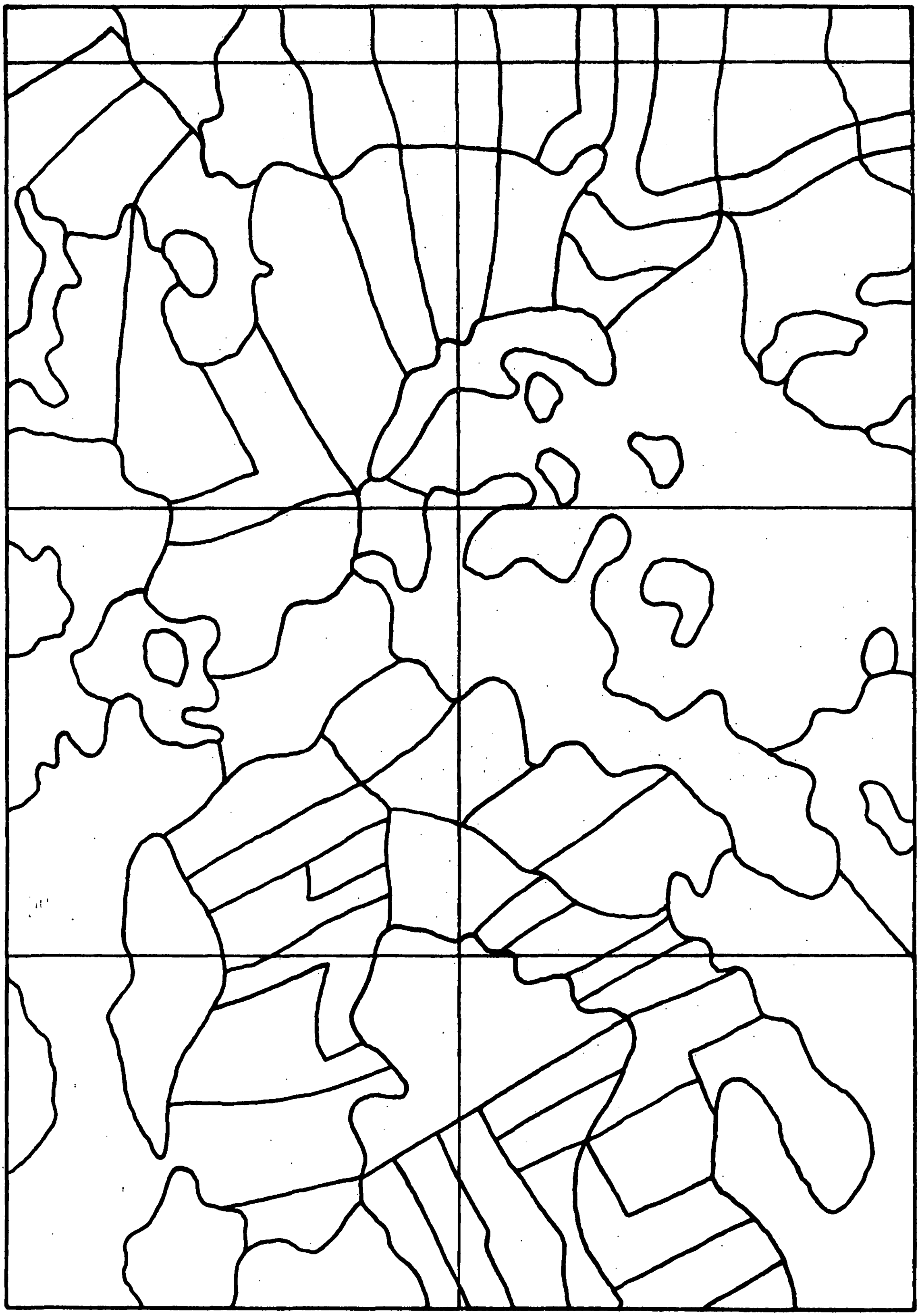


Fig. 8 Overlay of regular grid on more detailed land use pattern

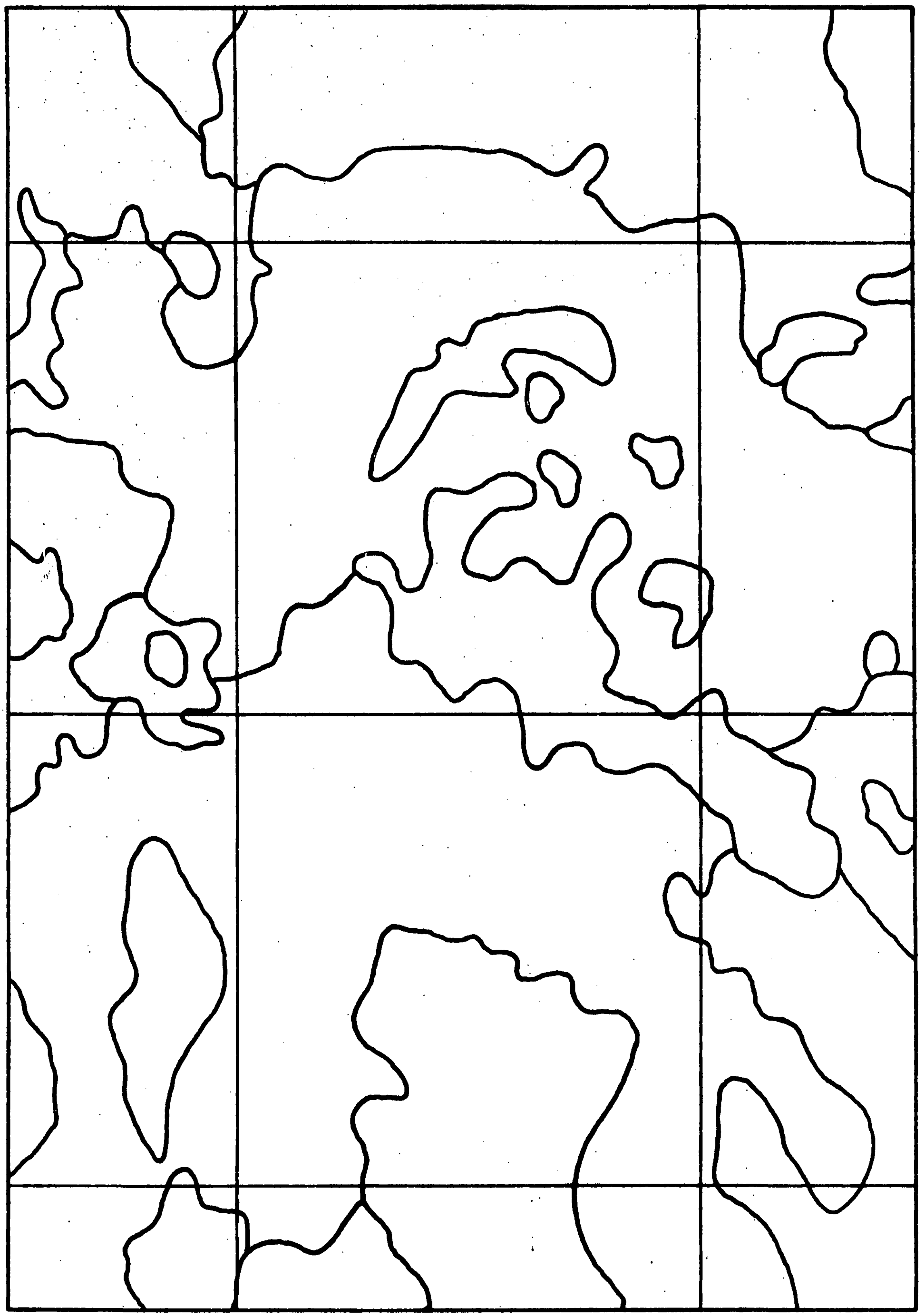


Fig. 9 Different placing of the arbitrary grid can change the average values in the grid units and may affect the overall analysis of the land use data.

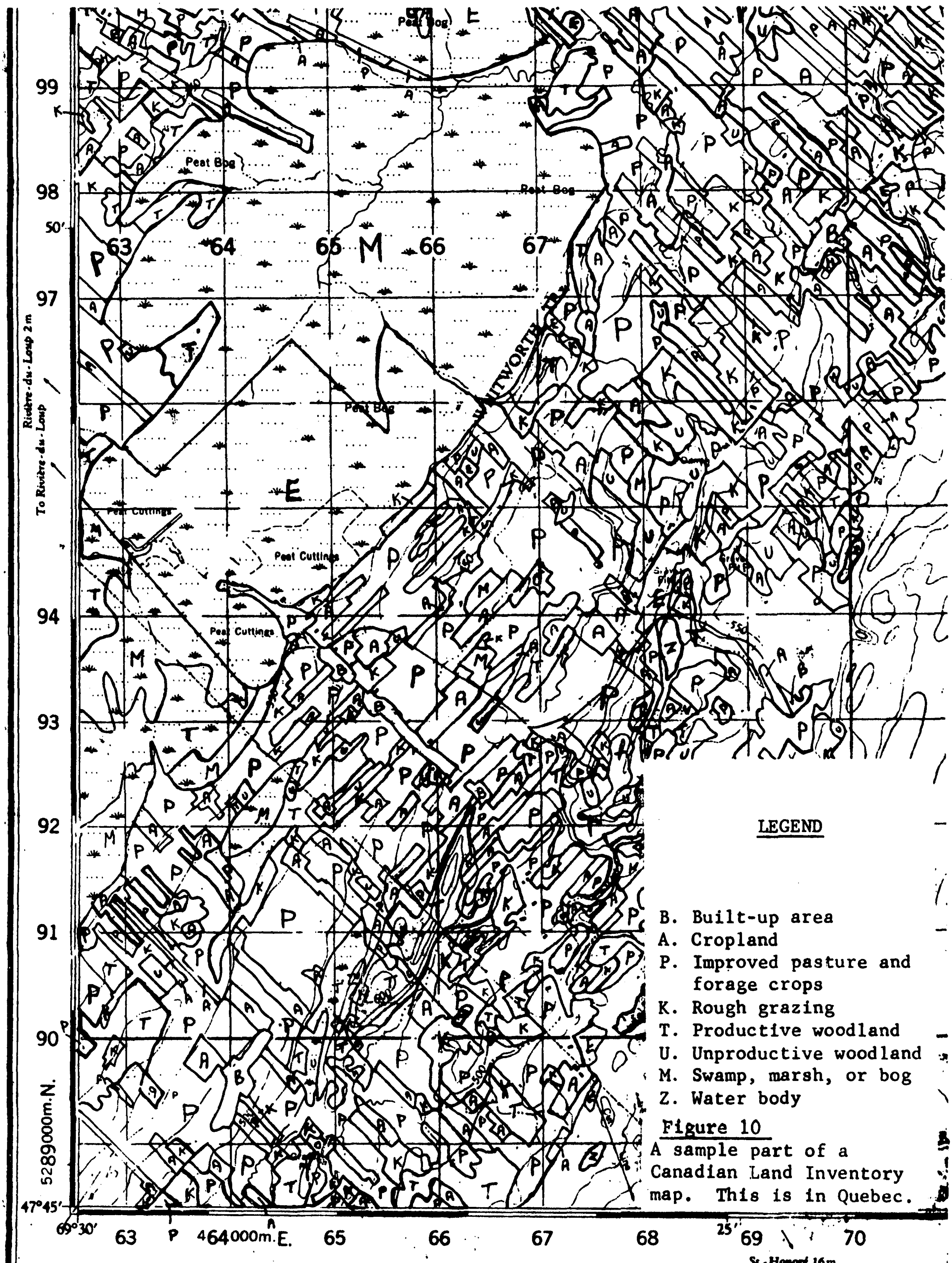


Figure 10
A sample part of a Canadian Land Inventory map. This is in Quebec.

Produced and printed by the SURVEYS AND MAPPING BRANCH, DEPARTMENT OF MINES AND TECHNICAL SURVEYS, 1958, from air photographs taken in 1948.

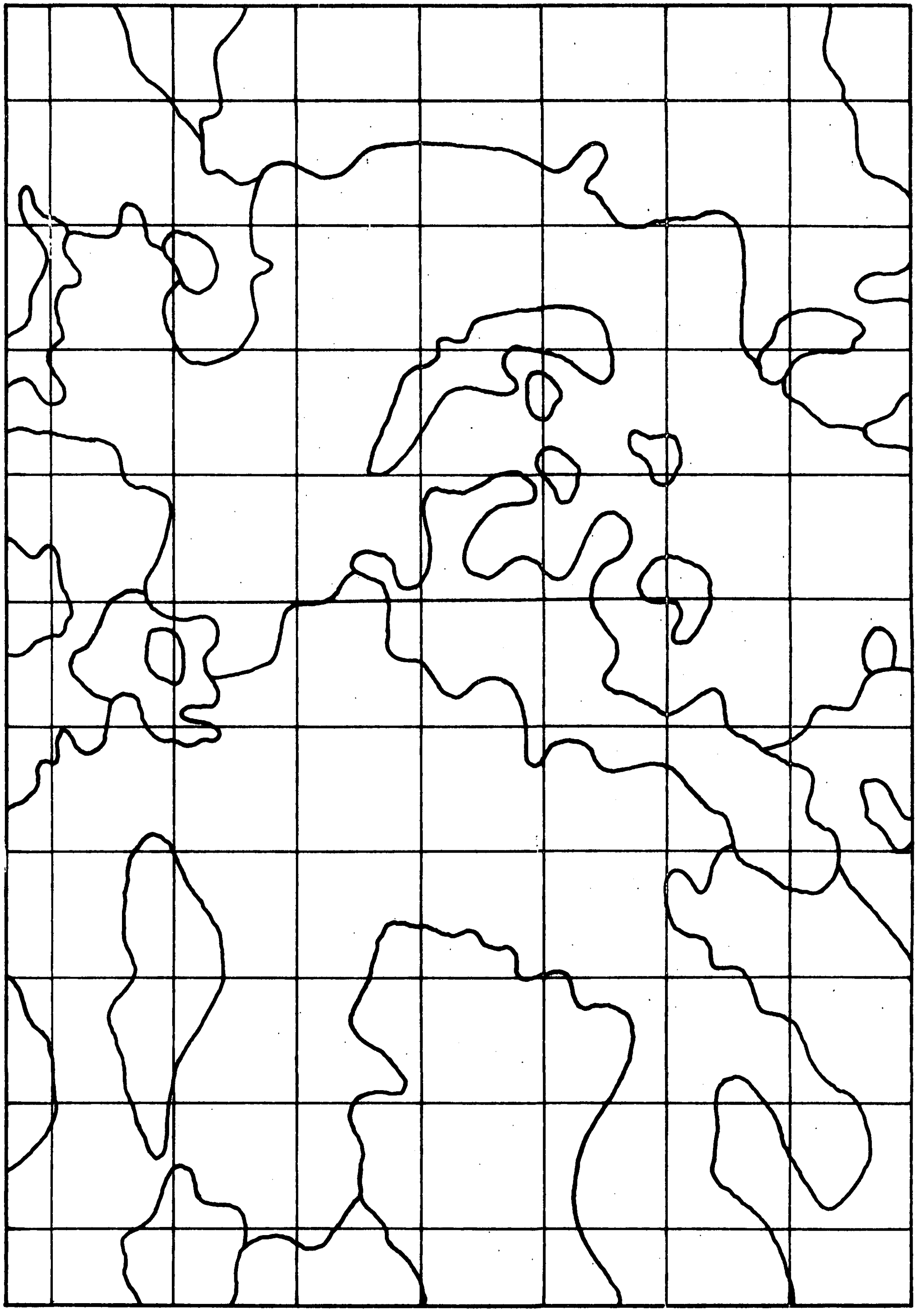


Fig. 11 Use of smaller grid may reduce aggregation error but can increase input workload

the manual effort involved in reworking existing data sets to conform to the rectangular "pigeonholes." Reduction in size of the rectangular units removes some of the weakness of this method (Fig. 11) and initial collection and summary of point data (e.g., census data) on the basis of such units obviates the task of manually reworking data to conform to the grid. The disadvantages of applying the approach to data already in the form of irregularly shaped, homogeneous areas, such as soil maps or present land use maps, the impossibility of further sub-coding, the limited capability for line representation of such items as roads, rivers and railway networks and the doubt that this type of data structure will be adopted for many data sets appear to outweigh the advantages of information systems being developed along these lines.

Small Grids - Implicit Boundary Known to System

Reduction in the grid size allows the arbitrary grid to be useful for handling simple data. Single data sets whose location is known, for example, a single-level present land use classification, can be stored in arbitrary grid cells and can be manipulated by computers. The results can be displayed as line-printer character maps.

SYMAP V (Fig. 12) and its derivatives are the best known and most widely used of the programs in this category. Essentially the map of the area concerned is overlaid with an arbitrary rectangular grid, although plane co-ordinates can be used. The cells can be of any size, but are usually of the size taken up by a symbol on the line-printer available. Areas to which data relate can be recorded as clusters of grid cells. The grid provides a coarse co-ordinate system for the identification of point or area data. Storage inside the computer is one the basis of one character per grid cell. Several types of data manipulation can be carried out on this grid cell storage matrix. Values provided at grid co-ordinate points can be spread homogeneously over areas (clusters of grid cells), previously described to the system. Isolines (contours) can be calculated for any specified intervals over the range of values of point data provided on the grid and can be internally superimposed on the grid. Spatial units can be defined by nearest-neighbor methods from point information (where each grid cell is assigned the value of the point data nearest to it, and boundaries are assumed along the line where the values change). Some systems allow logical combinations of the factors from different data sets on a grid-cell-by-grid-cell basis, areas of which can be measured. SYMAP V has a wide number of statistical support options linked to the mapping system which permit calculation of such analysis as means, standard deviations, histograms and percentile groups of the data. Graphic display of the results of data storage and manipulation can be provided by simply printing out each grid cell as a symbol on a line-printer. Lines can be approximated with printer characters and areas can be shaded with up to ten progressively darker shades, created by overprinting two or more characters.

The earlier versions of the simple grid manipulation approach used larger scale computers (e.g., IBM 7094). The current systems can use medium scale computers (e.g., IBM 360/40) and limited versions run on smaller machines. Preparation of data for input relies on manual methods leading to punch card input. Display uses standard line-printers. No special equipment is required.

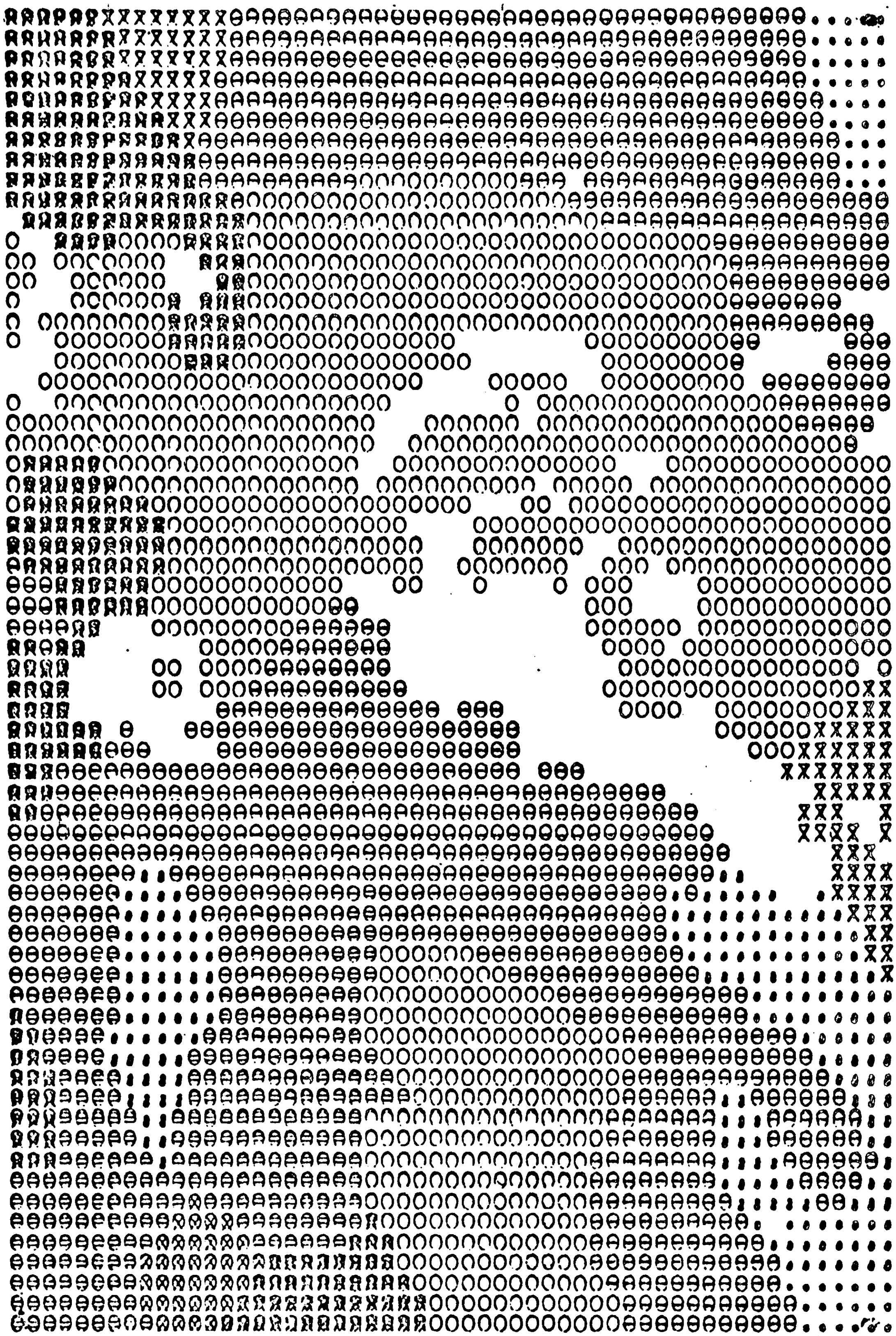


Fig. 12   Symap type map showing use of small grid to represent land use pattern

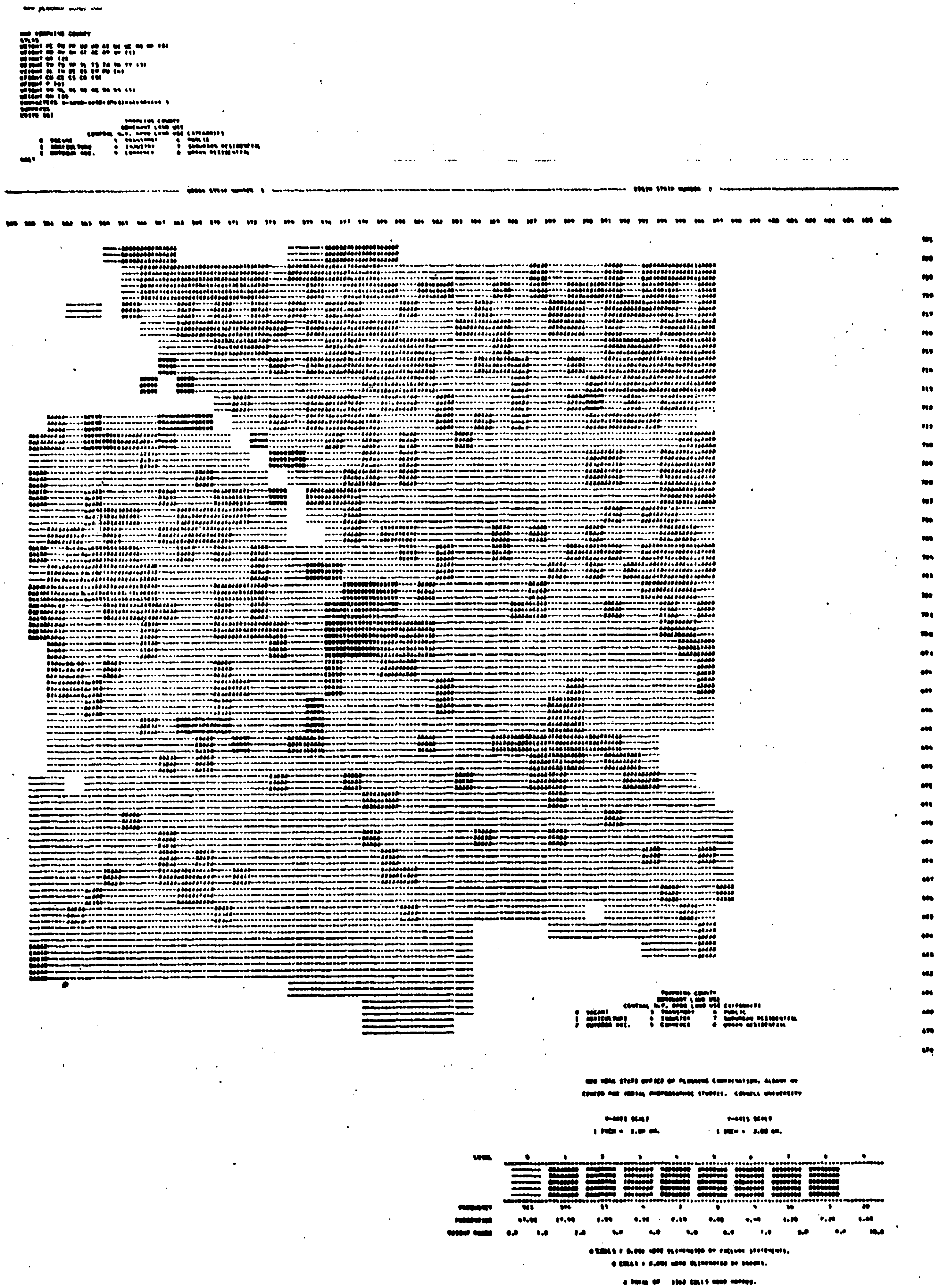


Fig. 13 An example of a LUNR printout for a county in New York State

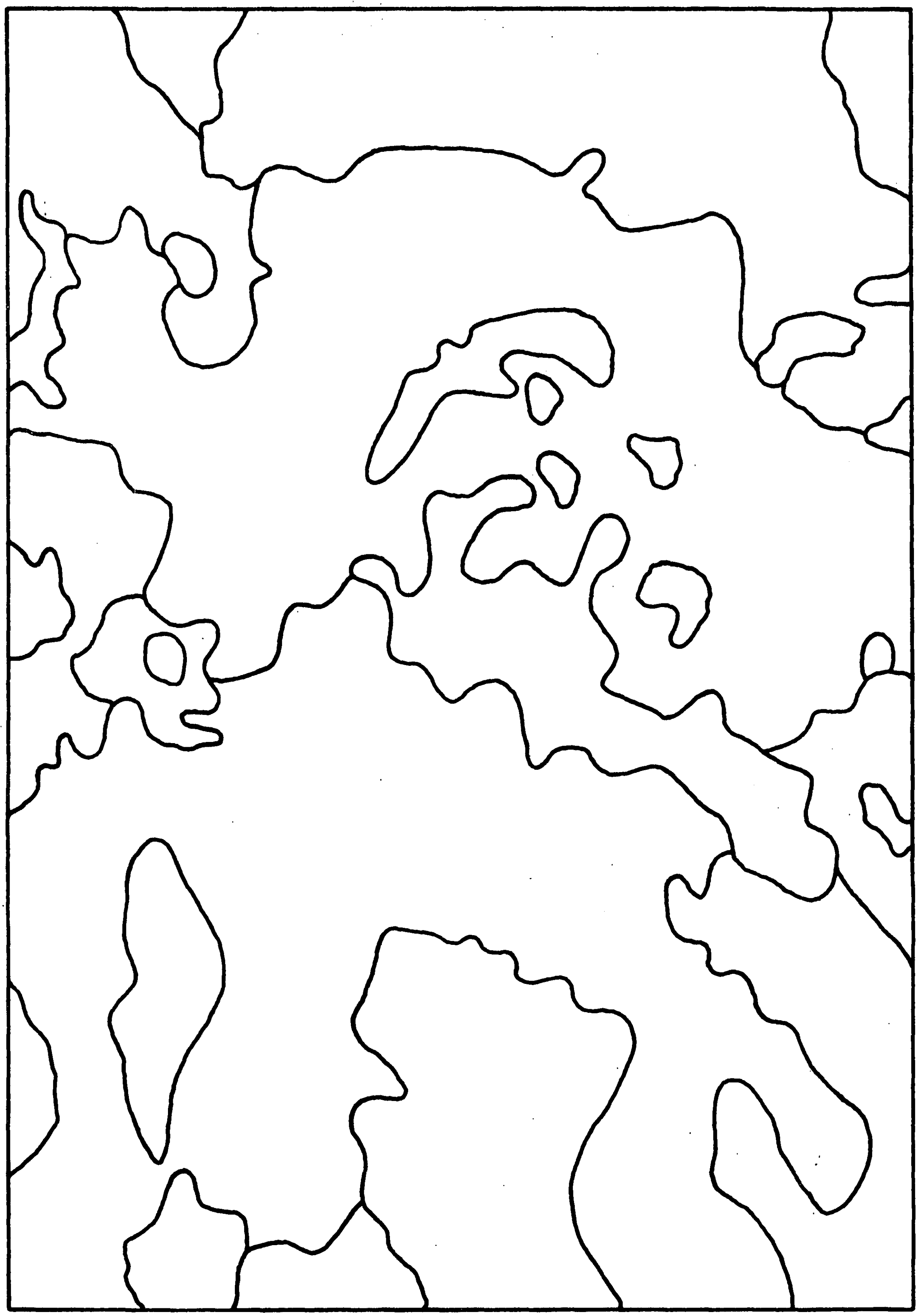


Fig. 14 Boundaries represented by original land use map

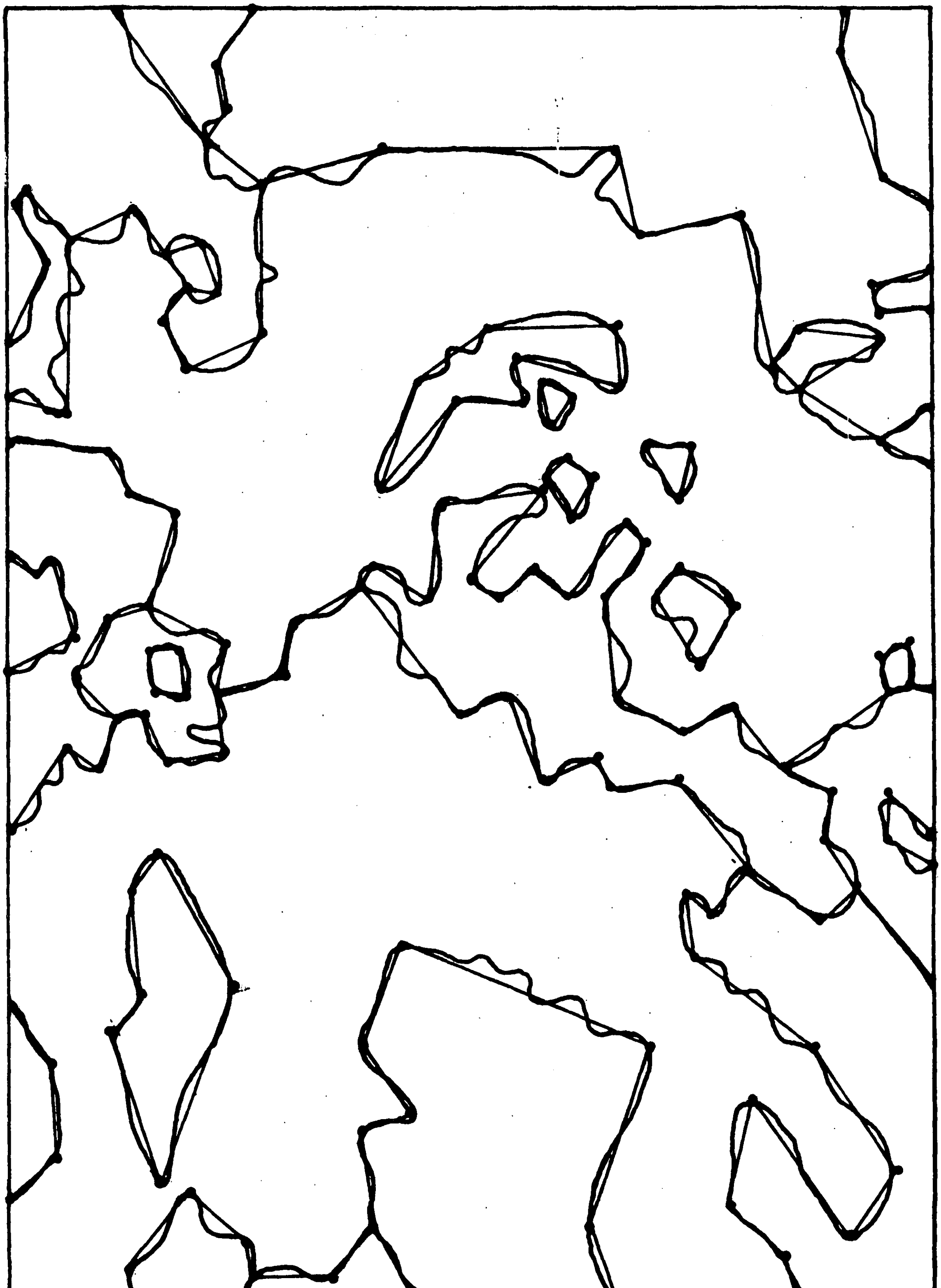


Fig. 15 Comparison of nodal representation and original land use map

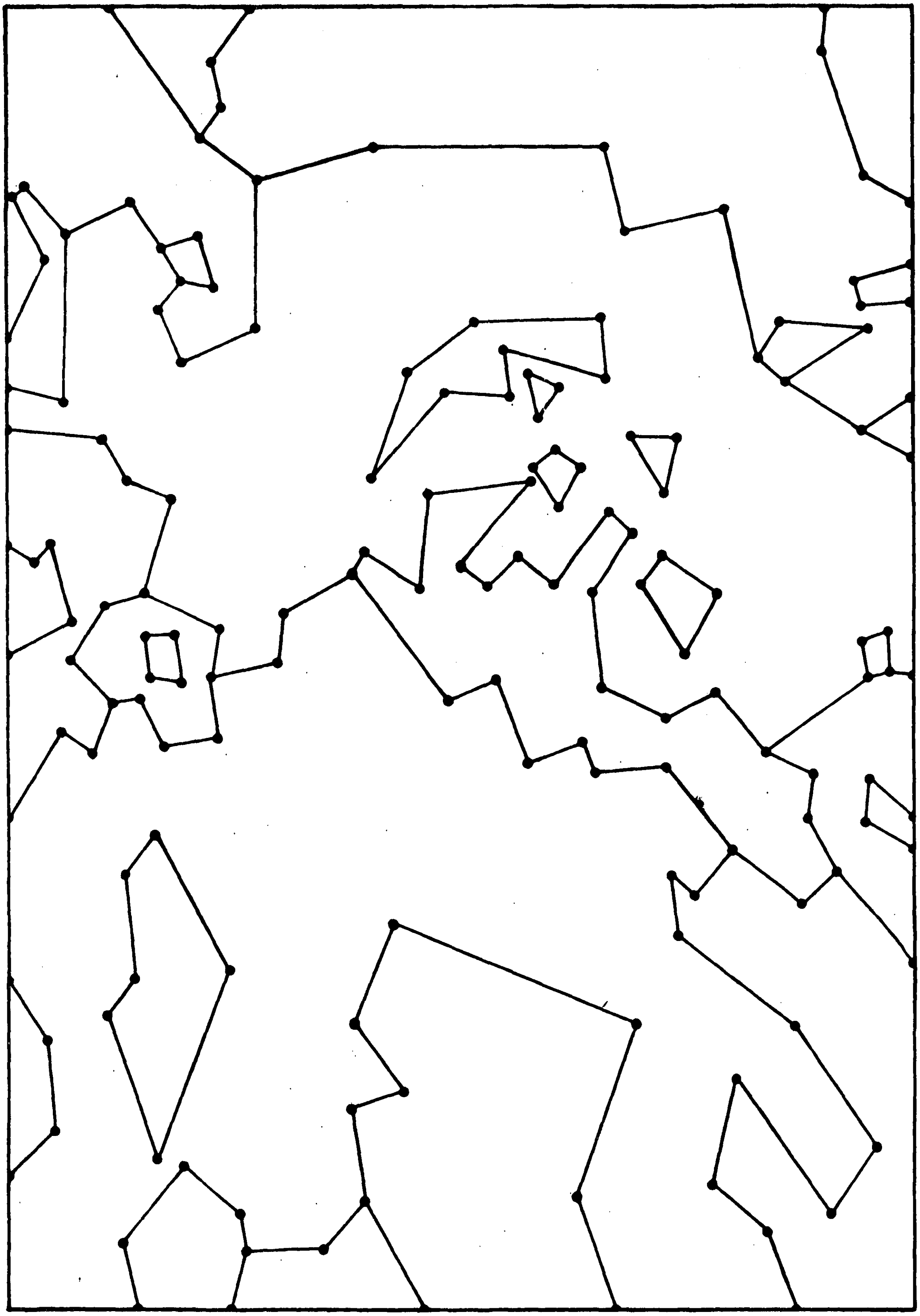


Fig. 16 Boundaries represented by nodal points

The characteristics of the systems are: laborious preparation of the basic grid data; relatively coarse data representation (Fig. 13) (use of larger scales to achieve better resolution multiplies the manual preparation necessary); straightforward computational operations; simple but useful data manipulation capabilities on the very simple data sets that they are able to handle; inability to handle complex data sets; and a simple graphic capability by the system. The data are usually transferred to and handled in the punch-card form. Storage is not compact. The time required to respond to requests for manipulation and display of selected data sets is within a daily time frame, provided the base map is previously coded. Computation times are low. Cost of data preparation is frequently four or five, and sometimes many more, times higher than subsequent computational cost of manipulation and display of the same data set.

These characteristics lead to the application of the simple grid manipulation approach to geographical tasks that involve few base map sheets and simple data sets of point or area data. The manipulation and display of land use data for urban areas is a typical application that falls into this category. Similar small scale display of wider data distributions such as small scale land use maps of a state can be effectively handled.

Explicit Boundary Handling Systems

While maps are an efficient way to store and display present land use data, there are two limitations on their use. The first is the physical limitation on the amount of present land use data that can be stored and displayed on any map. The classification and generalization that must be employed to reduce earth data to a sensible pictoral format all too often result in a loss of detail during the transition from a quantitative to a qualitative data record. The second limitation is that the map format, as we know it, demands visual and manual retrieval of any of its information. Measurements are laborious, and quantitative comparisons are slow and expensive. Any large collection of cartographic material presents a formidable task of reading and analysis for even the most simple understanding of the material that is stored.

Computers can be used to store the boundary data (Figs. 14, 15, 16) found on existing maps and similarly to handle the related present land use identifier. The capabilities of computers for measuring and analysis can then be used on the stored data.

Any attempt to make sources of present land use data on maps amenable to machine-to-machine processing must contemplate the possibility of processing large volumes of material. The basic data sets available from the Canada Land Inventory, for example, for input to the Canada Geographic Information System, comprise approximately 14,000 map sheets, with a further 6,000 in production, of which total, about one-fifth are present land use maps. These maps typically contain between 500 and 4,000 faces whose boundaries can total approximately 2,000 to 10,000 lineal inches per sheet. The manual digitization approach to this type of data base must be considered a long term and very expensive process. It is in this type of system, therefore, that there is reason to experiment with more sophisticated types of input drum scanners and flying spot scanners. The oldest of the more sophisticated methods is the automatic line follower, though the flying spot scanner and the drum scanner were probably applied to cartographic input first. Of the latter two, the drum scanner seems to have proved to be the more satisfactory, though this is a field of active research and development.

When large amounts of areal data are digitized, it is necessary to have sub-divisions of the file to allow more direct access to data for retrieval purposes. The MAP/MODEL system uses discrete polygon storage, all line segments and descriptive data being contained within arbitrary polygons. The Canada Geographic Information System uses a block numbering system (the Morton Matrix) which is so arranged that any sequence of consecutively numbered blocks creates an even larger area to the north and east of the first block in the sequence; this minimizes the sequential search time for data in adjacent blocks or groups of blocks.

When large data files describing line segments are contemplated, normal XY co-ordinates containing eight or ten characters are an extremely inefficient method of recording the data (Fig. 17). Efficient forms of compact notation have been devised which retain the original detail and fidelity of the co-ordinate system, yet substantially reduce the storage and character handling necessary. Typical of these is a compact notation that begins at a point identified by a block co-ordinate and is traced by change in direction and length of straight line section to the next line junction, which is again identified by a block co-ordinate.

When the present land use data are in a format that is amenable to computer handling, the manipulations which characterize a geographic information system can be performed by the computer. Typical of these capabilities are those of search, measurement, comparison and statistical manipulation.

Search is essentially the ability to read the entire file of geographical data and retrieve any required data by location, name, description or part of description. The important element here is the ability to use the cartographic base as an index to the descriptive data, to summarize the descriptive data and display the result; and conversely, to search the descriptive data for the items required and then group them by their locations. This ability to align the boundaries of the cartographic base with related data files is a basic characteristic of geographic information systems. The problem of creating one large cartographic base file from numerous separate input documents such as maps clearly has an impact on the ease with which searches can be made. Many of the graphic data handling systems and map compilation systems are actively engaged in the process of sheet matching by computer to allow this to occur. Extensions of the search capability that can be foreseen are the provision of nearest-neighbor search and a search-in-context facility. The former is self-explanatory, the latter refers to the ability to retrieve an item only if it is found in context with a prescribed set of other data, i.e., the request to identify all non-farmed land surrounded by farmed land.

Measurement is the capability of providing previously unmeasured values from the geographic data. This includes area, lengths, numbers of items and summaries of these. Coupled with the search capability, it allows

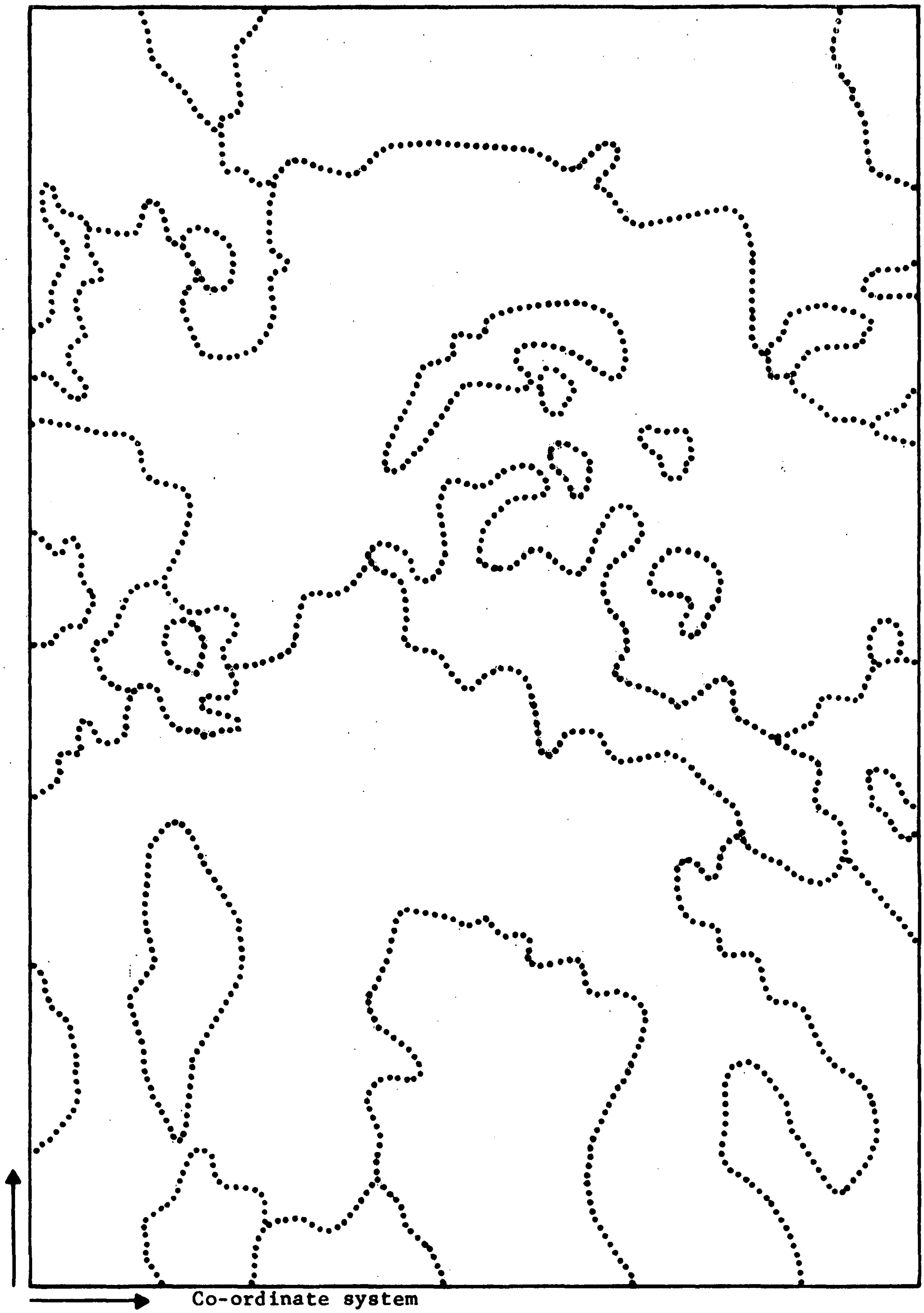


Fig. 17 Land use boundaries stored in computer as closely spaced coded co-ordinate points.

answers to questions such as: how many acres of agricultural land in how many different patches are there within a certain radius of a given place? The ability to carry out such simple measurements on a national scale or on a sub-national scale is very desirable.

Comparison between data sets and the application of the search and measurement capabilities to the process is an essential function for a working geographic information system. This function is easily carried out when all the data are contained in the same cells on the same map base, but if the different data sets relate to different types and shapes of areas on different maps, as, for example, a comparison between the present land use series of maps and a series of soil maps, then the comparison requires the ability to overlay one set of data on the other and compare their relative position. Both the Canada Geographic Information System and the MAP/MODEL system have the ability to perform the overlay function on a polygon-on-polygon, or map-sheet on map-sheet basis.

As with manual overlay of one map on another, there are dangers in interpretation of the results. If distributions within areas are compared with similar data on another map, homogeneity must be assumed and the resulting errors understood. If many overlays are made, or if a limited number of maps with extremely closely spaced and complex data are overlaid, measurement of individual items of the resulting patterns can be both inaccurate and misleading, and can exceed the capacity of the largest computers today. This problem can be solved in a number of ways, which are currently being developed.

Even the simplest overlay capabilities, however, are useful. It is possible to overlay administrative boundaries, watershed boundaries, or any other boundary data sets, within such reference areas and retrieve and summarize data within them.

Output from current geographic information systems is usually in the simplest form that will adequately convey the information to the user. Listings of averages of measurements by named areas, produced on a line-printer, are as significant as graphic output. With the overlay function it is possible to dissolve unwanted lines on combined maps to produce new maps showing only the required information. This type of information is plotted out on plotting tables or on other display devices employed the type of technique used in map compilation systems. While there is no reason why efforts should not be made to provide maps of high cartographic quality and excellent appearance as an end product of a geographic information system, the information can usually be provided to the user in a simpler manner.

The characteristics of geographic information systems are: the ability to accept boundary data and related simple or complex descriptive data in large quantity; input procedures which can range from simple to sophisticated, depending on the volume of the data; the ability to edit and update the data in storage; compact storage; excellent capability to search, measure, retrieve, compare and generally manipulate the data in storage and list and display the data in any form required. High cartographic standards of output are not usually implemented, though they could be if required. Computation during the creation of a data bank is sophisticated, but during retrieval it can vary from trivial to sophisticated depending on the manipulation required. The handling of large files requires the use of large computers to be efficient (IBM 360/50 or larger). Response time to requests for information is with a two-day period and can be within two or three hours. Frequently recurring requests can be standardized for non-programming staff, and many forms of data manipulation can be carried out by specifying the required manipulation with a computer program written for the purpose.

These characteristics lead to the application of geographic information approach to geographical tasks that involve many map shsets, and may also include much related descriptive data. Tasks with smaller numbers of map sheets are approached when the data manipulation requirement is high. The primary capability is the ability to carry out search, measurement, comparison and retrieval of data from the sorted geographical data base, particularly when such analysis relies on the manipulation of the areal boundaries of the data. If such data examination is not required, a geographic information system is not necessary.

The organization of the above is essentially on the basis of the categories of location identifier that can be used to record data about land surface. As mentioned in the opening paragraphs of the paper, the parameters of any system of handling geographical data include the volume of the data that has to be handled and the manipulations that are required to be performed on it.

To summarize* the types of system that handle geographical data, it is convenient to think of three system parameters of location, volume and manipulation as the axes of a cube (Fig. 18). The types of location are summarized on the Z axis (Fig. 19). The arbitrary categories of volume of data at any one location point are distributed along the X axis (Fig. 20). The hierarchy of increasing complexity of manipulation facilities are given along the Y axis (Fig. 21).

The parameters are combined in Fig. 22 and the approximate location of some typical systems has been indicated within the framework. The diagram itself is not, and cannot be, thought of as a precise tool for relating system capabilities, though the conceptual framework that it provides allows some observations to be made.

The diagonal OS (Fig. 23) essentially represents the potential capability of a file structure to handle information in any location specific information system. Progression along the diagonal from O to S is a progression of file structure design sophistication combined with machine data handling capability.

If the diagonal axis is divided arbitrarily between O and S into ten equal parts, the area of the cube passed through by the lower three units encompasses parameters that together may be considered as the area where current manual methods of storing and analyzing data are economic and satisfactory to the user.

* A more detailed description of the parameters of geographic information systems is given in "Environment Information Systems," edited by R.F. Tomlinson, published by the University of Saskatchewan Press, Saskatoon, Saskatchewan.

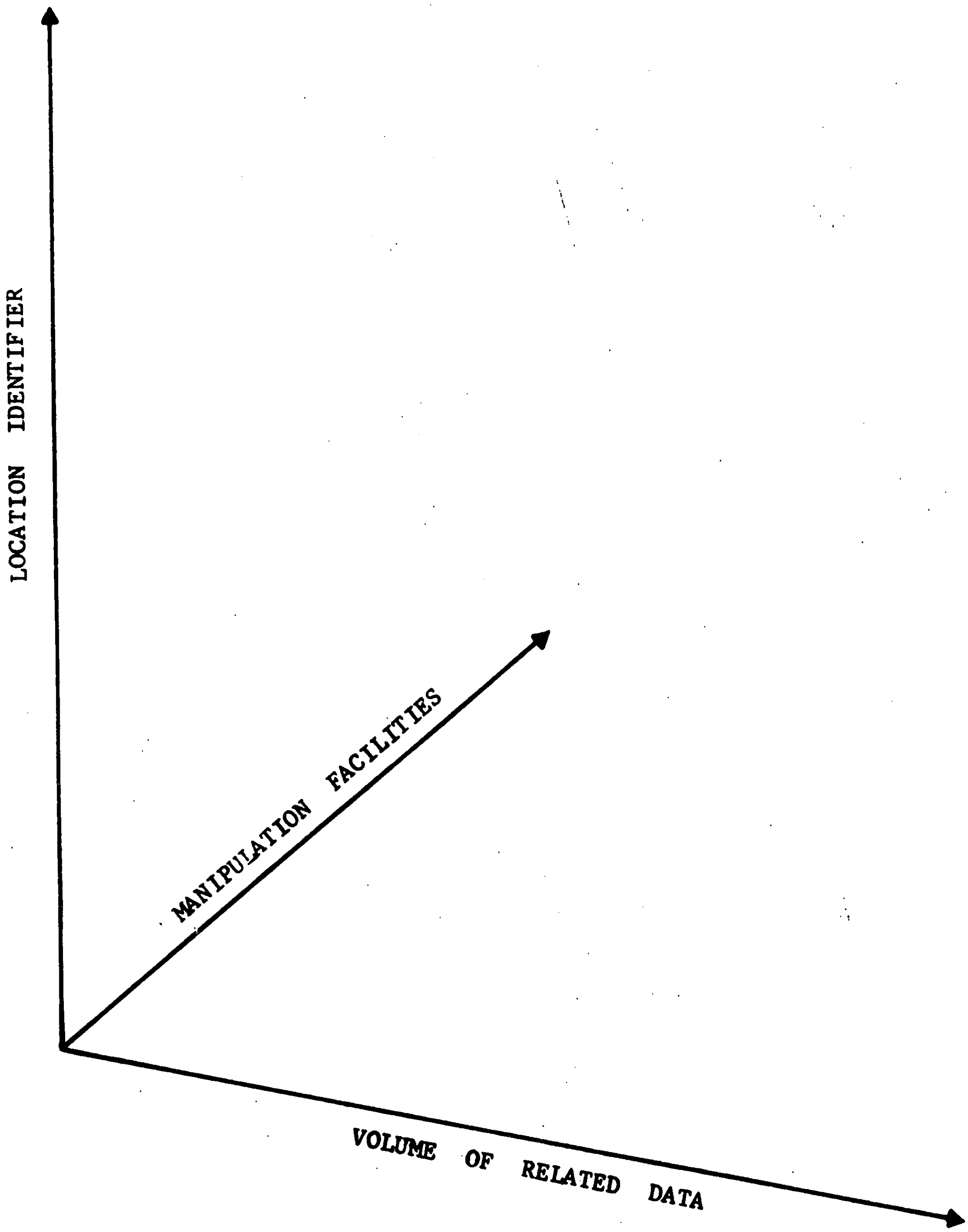

LOCATION IDENTIFIER
MANIPULATION FACILITIES
VOLUME OF RELATED DATA

Fig. 18

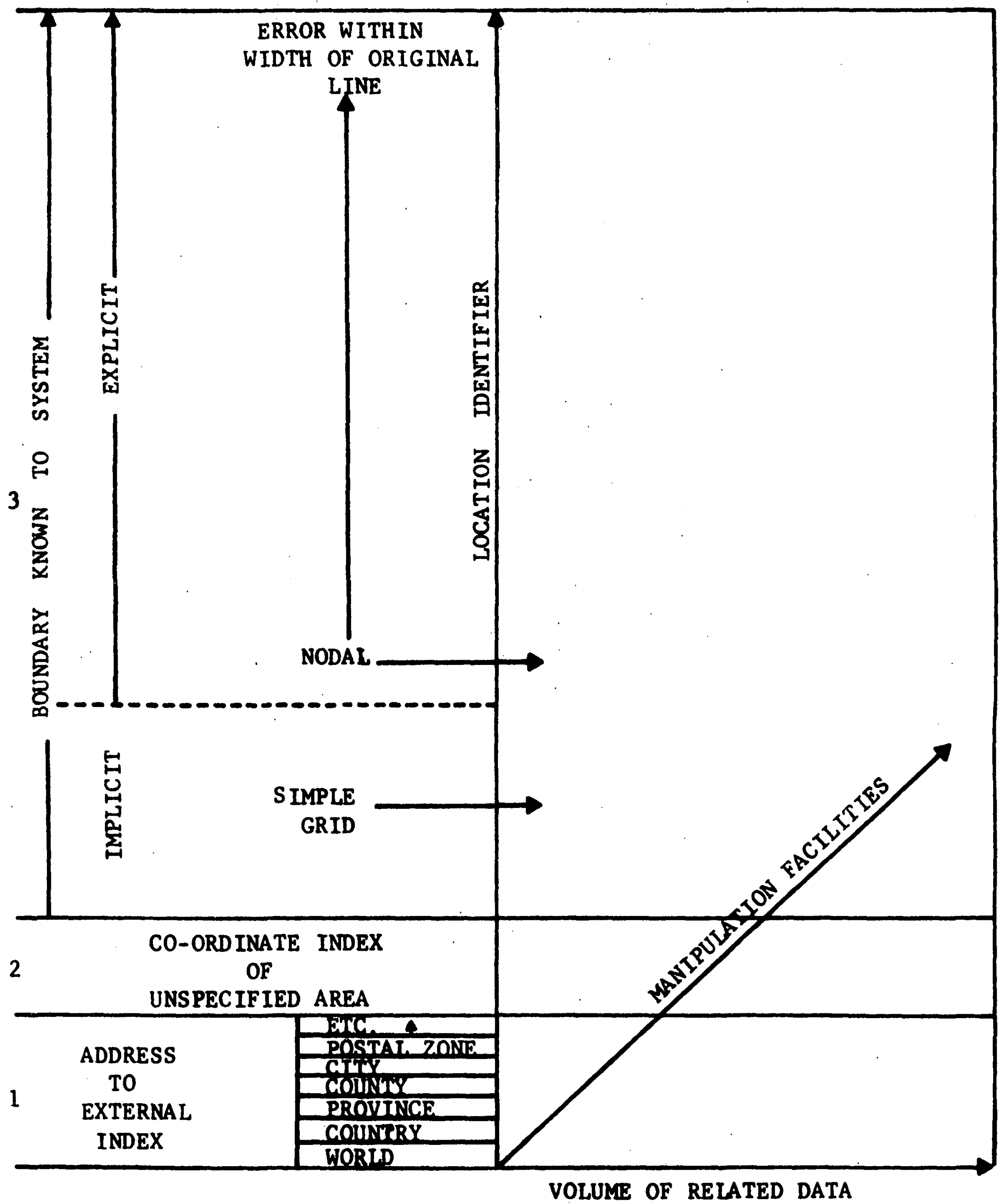
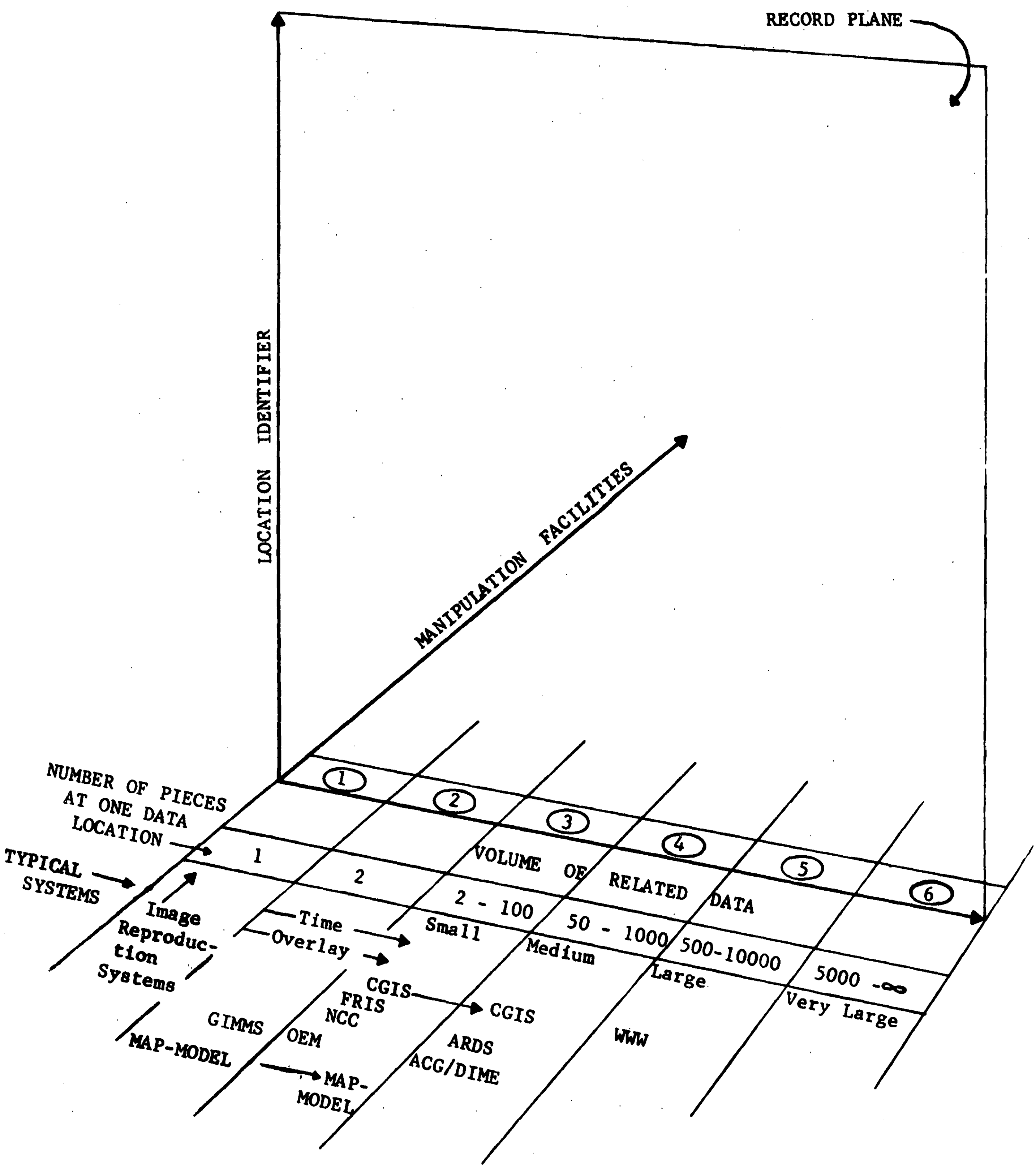

ERROR WITHIN
WIDTH OF ORIGINAL
LINE
BOUNDARY KNOWN TO SYSTEM
EXPLICIT
IMPLICIT
LOCATION IDENTIFIER
3
NODAL
SIMPLE
GRID
MANIPULATION FACILITIES
CO-ORDINATE INDEX
OF
UNSPECIFIED AREA
2
ADDRESS
TO
EXTERNAL
INDEX
1
ETC.
POSTAL ZONE
CITY
COUNTY
PROVINCE
COUNTRY
WORLD
VOLUME OF RELATED DATA

Fig. 19



RECORD PLANE
LOCATION IDENTIFIER
MANIPULATION FACILITIES
NUMBER OF PIECES AT ONE DATA LOCATION
TYPICAL SYSTEMS
1
2
3
4
5
6
VOLUME OF RELATED DATA
1
2
2 - 100
50 - 1000
500-10000
5000 -∞
Small
Medium
Large
Very Large
Image Reproduction Systems
Time
Overlay
CGIS
FRIS
NCC
CGIS
GIMMS
OEM
ARDS
ACG/DIME
WWW
MAP-MODEL
MAP-MODEL

Fig. 20

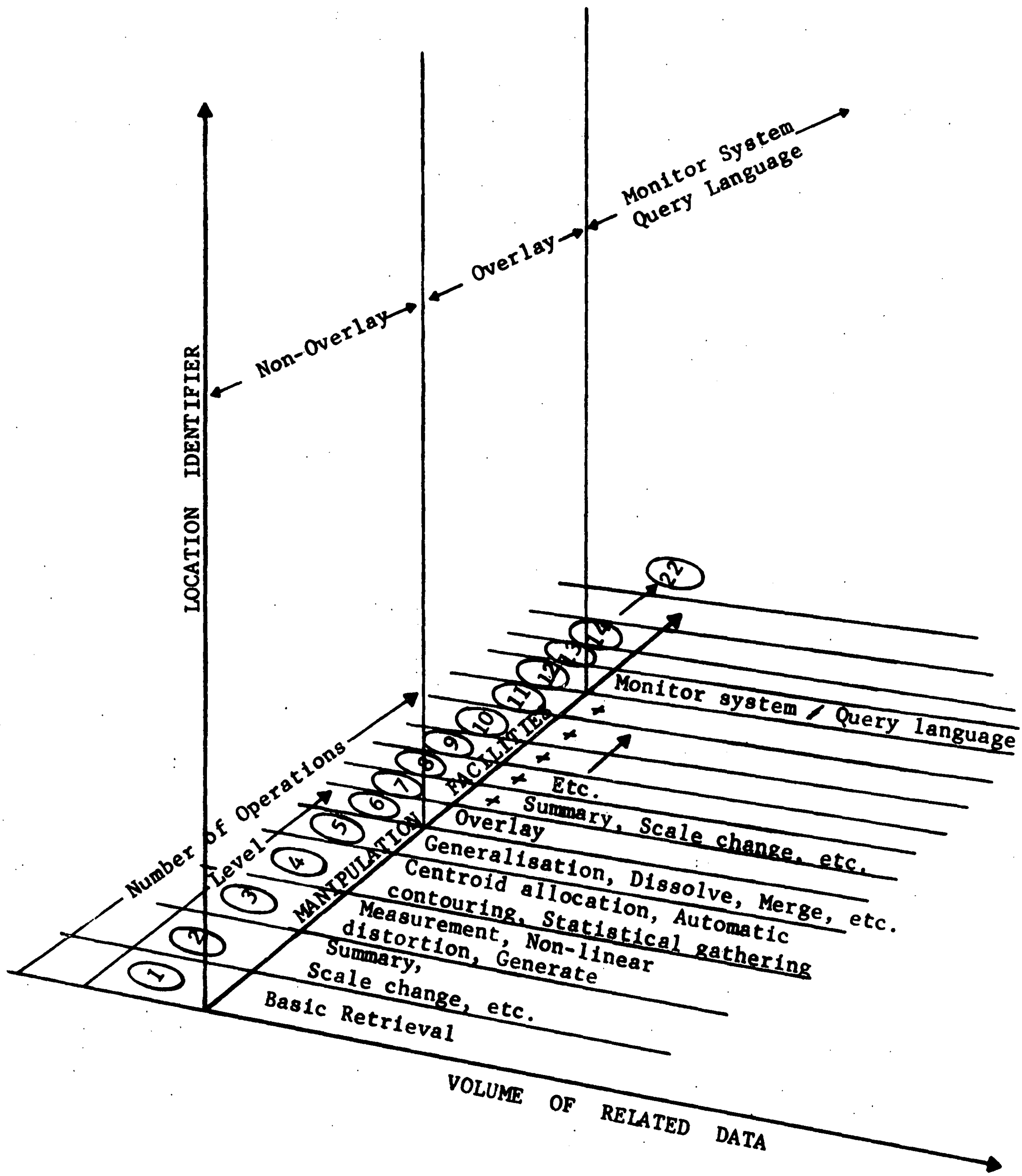

LOCATION IDENTIFIER
Non-Overlay
Overlay
Monitor System
Query Language
Number of Operations
Level
MANIPULATION FACILITIES
1
2
3
4
5
6
7
8
9
10
11
12
13
14
22
Monitor system / Query language
Etc.
Summary, Scale change, etc.
Overlay
Generalisation, Dissolve, Merge, etc.
Centroid allocation, Automatic
contouring, Statistical gathering
Measurement, Non-linear
distortion, Generate
Summary,
Scale change, etc.
Basic Retrieval
VOLUME OF RELATED DATA

Fig. 21

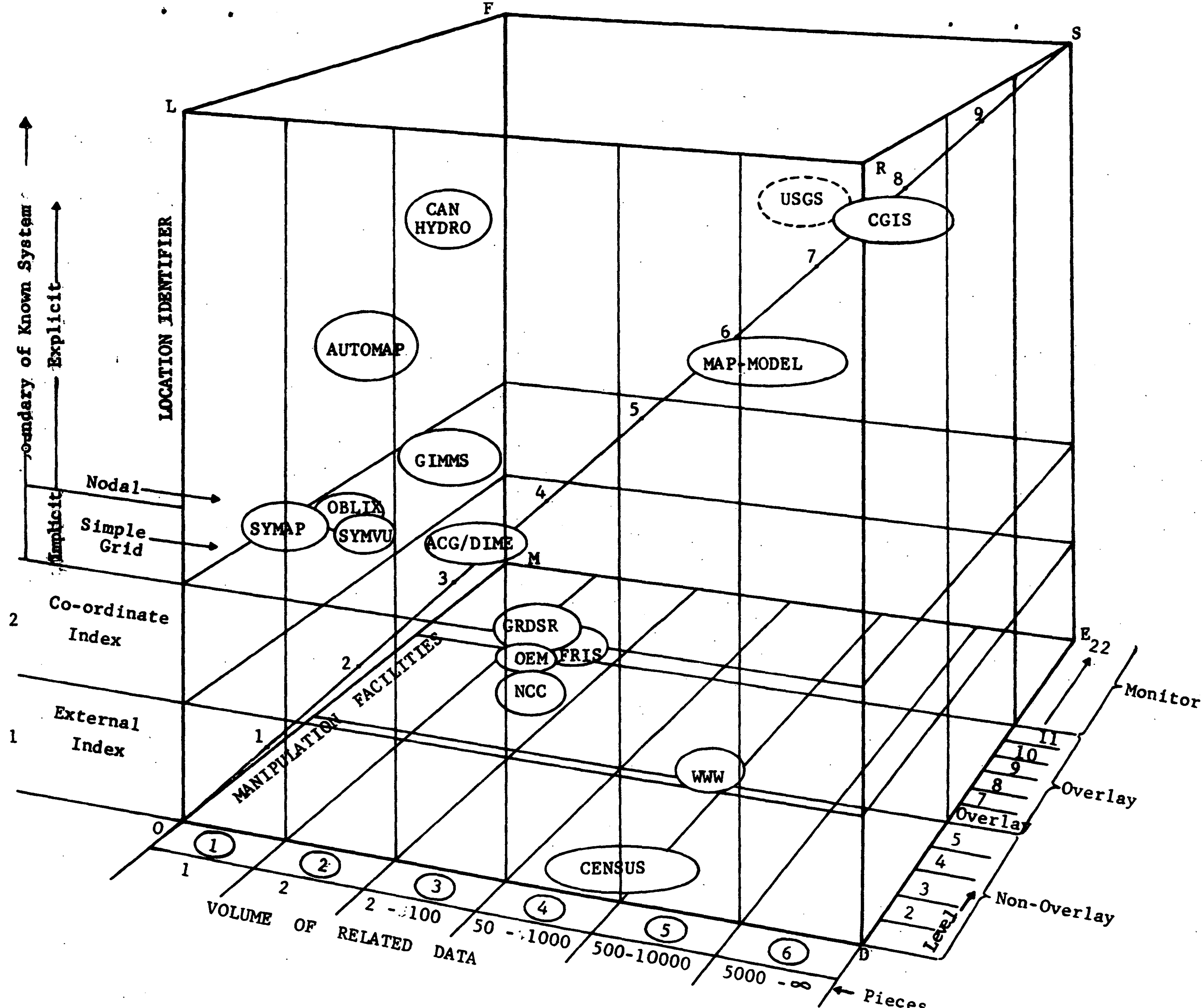

Boundary of Known System
Explicit
Implicit
LOCATION IDENTIFIER
Nodal
Simple Grid
2
Co-ordinate Index
1
External Index
L
F
S
R
M
E
D
O
1
2
3
4
5
6
7
8
9
CAN HYDRO
AUTOMAP
GIMMS
SYMAP
OBLIX
SYMVU
ACG/DIME
USGS
CGIS
MAP-MODEL
GRDSR
OEM
FRIS
NCC
WWW
CENSUS
MANIPULATION FACILITIES
VOLUME OF RELATED DATA
1
2
2 - 100
50 - 1000
500-10000
5000 - ∞
Pieces
22
Monitor
11
10
9
8
7
Overlay
Overlay
5
4
3
2
Level
Non-Overlay

Fig. 22

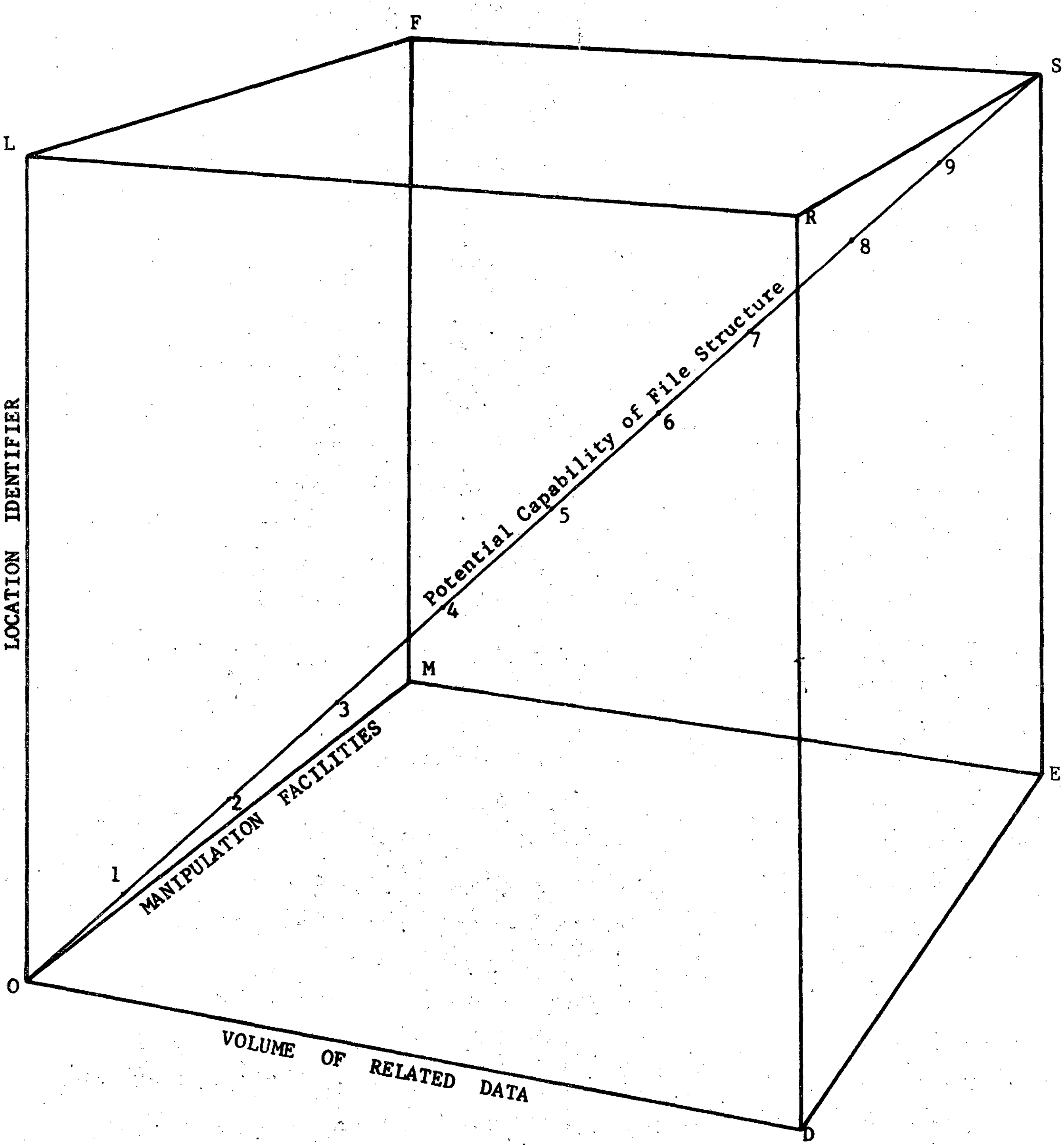

F
S
L
R
9
8
Potential Capability of File Structure
7
6
5
4
LOCATION IDENTIFIER
M
3
MANIPULATION FACILITIES
2
1
E
O
VOLUME OF RELATED DATA
D

Fig. 23

In the area of the cube between levels three and four on the diagonal, are the proliferation of systems that represent the current state of the art, according to their need to handle images or related data sets. These include the SYMAP, SYMVU, ACG/DIME, and GIMMS type of group on the image side and the GRDSR, OEM, NCC, and FRIS type of group on the related data side. These probably represent the level of the file structure design coupled with machine capability that has currently found economic acceptance. The development of further systems with the various parameters that fall into this category should find no difficulty in being implemented or being efficiently used.

As one proceeds up the diagonal the file structure necessarily gets more sophisticated. The type and capacity of the data processing machine that must be used, coupled with the degree of skill with which it must be used to achieve efficiency, similarly increase. Typical of the systems at the five to seven level are the image handling systems of AUTOMAP, the Canadian Hydrographic System and the MAP/MODEL system.

Perhaps at one level higher is the type of system represented by the CGIS, by reason of the fact that they attempt to carry more related data than the systems predominantly concerned with the manipulation of images. At this level, efficiency of operation is totally related to file structure and the optimum use of current computing facilities.

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A REMOTE SENSING SYSTEM FOR DETECTING GROSS LAND USE CHANGE IN METROPOLITAN AREAS 1/

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Introduction and Summary of Census Cities Project

This paper discusses developmental aspects of a system already underway for detecting gross land use changes in a sample of U.S. metropolitan areas. One aim of the research is to identify for such application the operational role of remote sensors aboard aircraft and satellites.

Launched a year ago, this work became known as the "Census Cities Project." It is an integral part of the Geographic Applications Program of the U.S. Geological Survey. It is part of the Department of the Interior's EROS Program and it has been largely financed and provided with timely overflight data by NASA's Earth Observations Program. The Census Cities Project is more fully described in my paper given at the Third Annual Earth Resources Program Review (NASA Manned Spacecraft Center, Houston, December 1970), so I shall merely outline the experiment here and discuss some operational aspects related to change detection.

The U.S. cities under study are among the twenty-six named on the map of urban and regional test sites(Figure 1). For twenty of these sites, the U.S. Air Force Air Weather Service and NASA's Manned Spacecraft Center acquired multispectral, high altitude aerial photography at the time of the 1970 decennial census. The census returns serve as one form of 'ground truth,' and one form of initial inventory for change detection.

An alphabetical list of the urban test sites appears in Figure 2. Each square symbol represents one type of sensor data acquired for one test site. There are nine columns listing nine different combinations of film, spectral bands, and image scales. Simulation of imagery from the Earth Resources Technology Satellite (ERTS) is included. Photography was from the RB-57 F aircraft flying at 50,000 feet or 15.2 kilometers above terrain. This combination of census and sensor data is an unparalleled opportunity for comparative urban study!

The basic overflight data for urban change detection is the color infrared photography. It is recorded by an RC-8 metric camera at an image scale of 1:100,000. In one view of the Washington test site, for example, the Potomac River and National Airport are easily recognized, but automobiles in parking lots can also be discerned. A controlled photo mosaic of acceptable positional accuracy is being made from this film-and-camera combination. We aim to procure similar aircraft photography over the same urban test sites when the ERTS satellite is launched in 1972. This will provide not only the basis for the urban change detection, but also for the intepretation and evaluation of the satellite imagery.

1/ Publication authorized by Director, U.S. Geological Survey.

Comments on Operational Aspects

A portion of a controlled and gridded photo mosaic of the Washington test site is shown in Figure 3. Some further cartographic annotation of selected point and line features will be shown on an overlay or overprint. The format shown is a page from a looseleaf Atlas of Urban and Regional Change and it represents an early phase in environmental inventory. It also simulates one form of a user oriented end-product. As the sprocket holes suggest, the sheet-size is a standard computer printout page. The square image space accommodates modular maps or mosaic units at different scales. One such module will be a mosaic section, 20 km by 20 km, reproduced at 1:100,000. The one-kilometer grid is in the Universal Transverse Mercator (UTM) rectangular coordinate system. The panel at the right is for legends, including those to be added by users.

The mosaic is used for locational control, area measurement, pagination in the Atlas, and also as an underlay for computer processed thematic maps. The mosaic is not intended to be the principal base for image interpretation, although it has some value for that purpose. We are preparing a detailed procedural manual to document all of these operations.

Another simulated Atlas page, or overprint, appears in Figure 4. It shows boundaries and labels of census statistical areas. For cities, the basic data area is the Census Tract, an urban change detection device which has been operable for several decades. A tract is a piece of real estate, usually bounded by streets, that remains essentially the same from one census to the next. The average tract has about 5,000 persons. As pieces in a jigsaw puzzle, tracts can be combined to make up larger areas. Tract boundaries which are emphasized here are boundaries of cities, states, or other political divisions. These are the jurisdictions of decision-making 'user' groups. So, it is appropriate to report remotely sensed land use data for such areas, even if they were not also useful for ground truth and change detection control. Tract data can also be assembled for the functional urban area without regard to political divisions.

Land use classes in the Washington prototype are shown at the right. There are two nested groups: Urban and Non-Urban. These can be expanded or contracted to meet operational constraints. Land use changes obviously taking place are annotated without our having to wait to detect them on later imagery.

The land use classification scheme used here is based primarily on visible land use, not on knowledge of land ownership. This makes the system more sensitive to observable change, but it is one more example of the classification dilemma confronting a prospective user of data from remote sensors. The planner, for example, who might be tempted to use remote sensing for current land use information is probably already operationally dependent on land ownership records to classify land use. This problem is not insurmountable, but it does need to be recognized. One way to deal with this problem, and others closely related to it, is not to expect a classification scheme to serve all likely needs without some modification for each. To do this, a user-analyst adds another mosaic overlay (or equivalent in the computerized data format) to explain the land use interpretation and/or to introduce data from other sources. Most deficiencies of any basic land use classification scheme intended for multiple uses can be remedied in this way.

An example of the next page in the Atlas is shown in Figure 5. The image shown here is a photograph of the actual land use interpretation for a portion of Washington. Supplemental annotations are not shown. In this example, land use is recorded by colored pencil on a transparent film overlay fitted to the color infrared photo at 1:100,000. Interpretation is done with the aid of a hand lens and light box; stereo examination also is possible. The smallest unit of observation is a "use pattern" (I do not mean 'grid cell') that is not smaller than four hectares or ten acres. At photo scale, this is about the size of the blunt end of the colored pencil. This unit is larger than the resolution capability of the aircraft imagery, but it may test the resolution limits of the ERTS imagery. Factors affecting usable informational detail include not only image resolution but also interpreter experience and available ground truth, the scale and minimum-area size of recording unit, the relative complexity of the areal phenomena being studied, and the range of uses of the information being acquired.

Land use interpretations are transferred to a rectified and gridded base--either map or mosaic--for area measurement and digitization of locations. Area measurement is done by eyeball method and dot planimeter at the present time. Land use interpretation and area measurement by semi-automated means are receiving some attention, but no immediate application is foreseen. The first land use overlays for reproduction as pages in the Atlas of Urban Change are now being negative scribed by some of the same USGS geographer-cartographers who prepared thematic maps for the National Atlas. We expect the first page proofs by November 1971.

After land use is interpreted, the urban area is delimited. That is, the definition of "urban" and "non-urban" is actually done after the land use interpretation. The procedure for doing so seeks to define, for a given area, comparable urban real estate at different times, or for different urban areas at a given time. Within the area so delimited we will match the census data and the land use data, and then try to recognize and to classify intra-urban environments. With these building blocks we hope to construct a model to assess changes in environmental quality.

After the 1970 land use has been mapped and measured, the data are prepared for computer storage and retrieval. Shown in Figure 6 is an example of an experimental computer land use map for one census tract. This is from work on the Boston test site by geographers at Dartmouth College under contract with the Geographic Applications Program of the U.S. Geological Survey. Each digit displayed represents four hectares of coded land use in a square grid cell whose location is known. The letter "S," for example, represents "single family residential land use." The sum of the digits, counted by computer, is also an area measurement. The total area of this tract is 2550 hectares, or 25.5 square kilometers. A similar map would be made for the 1972 land use. Then, we could instruct the computer to print out, cell by cell, or tract by tract, an analysis of change from 1970 to 1972. This would tell us where to look for evidence of this change on the ERTS imagery.

Other parameters could also be mapped by computer. In the San Francisco Bay test site, for example, there is urgent need to know the location and amount of residential land use on the Young Bay Mud. This is a formation characterized by unstable slopes under certain hydrological conditions.

This computer map may not seem to be very sophisticated technical information, but it does illustrate how area data from both graphic and non-graphic sources are entered into a common information system. It also illustrates one form of end product. The system of gridded Atlas pages makes this possible. The page also serves as a place to record changes and to describe their location in useful environmental contexts. It also provides the user with a place from which to attack his own operational problems, whether or not remote sensing can contribute further to their solution.

Some Thoughts on "Change Detection"

"Change detection" was an earlier application of that part of remote sensing represented by conventional air photo interpretation. Then, it was part of what was called "damage assessment" in military operations and it implies pre-event inventory as well as post-event analysis of change. There are similar applications in assessing sudden environmental changes resulting from fire, flood, earthquake, civil disorder and civil defense. There are similar applications to the more gradual changes resulting from day-to-day constructive and destructive ecological processes, including pollution of land, water, and air resources.

There are two noteworthy existing systems for detecting change in urban and regional environments, only one of which uses remote sensing. The first of these is the census tract, or other statistical area, for which comparable census data are reported for successive censuses. The other is the modern, 7½-minute topographic map, published by the U.S. Geological Survey, which shows by magenta overprint selected planimetric additions (mostly works of man) which were not present on the earlier edition where conventional classes of features are shown in traditional ink colors. The basis for the new map information is an interpretation of more recent aerial photography--one form of remote sensing. Any comprehensive system of urban change detection ought to provide the basic "what-ness," "where-ness," and "when-ness" of both the census tract and the magenta map overprint. This is what the Census Cities Project and Atlas of Urban and Regional Change attempt to do, including the basic pre-event inventory. The experiment also exploits the change detection attributes of remote sensing and an analysis and interpretation of change itself. Eventually, advances in image interpretation technology may provide automated short cuts to the somewhat primitive interpretive operations used to develop the prototypes.

As for the mechanics of urban change detection in the Census Cities experiment, there are some concerns that directly involve the land use classification scheme. One approach which we are testing involves as few categories as will separate the areal differences to be identified. These categories are arranged in order of decreasing intensity, roughly from "livelihood" to "residential" to "other." At the modest scale and generalization we are considering, these classes range, respectively, from those with most specialized structures and singleness of use to those least specialized and multipurposeful in use. A "change possibility matrix" can be constructed by listing the land use classes in the same order, horizontally then vertically. Each cell in the matrix represents a possible change, including change pairs such as "from agriculture to industry" and "from industry to agriculture." These possibilities can be grouped into three classes: "more likely," "less likely," and "least likely." A letter code can be assigned to each change and used for identifying a <u>location</u> on the mosaic overlay where the change has been detected. This code can also be used in the computerized form of the same information. This suggests how we propose to deal with <u>kind</u> of change.

For those cells along the diagonal of the matrix where the "from-to" pairs are identical, no change in kind is indicated. However, change in <u>intensity</u> may be detected. So, a numerical code would be assigned and recorded on the overlay. Code 1 (for "same") would be omitted. Codes 2 and 4, etc., would be recorded on the overlay at locations where magnitudes of increased intensity are detected. Code 0.5, or even zero, would indicate magnitudes of decreased intensity. Another code would be assigned to represent a detected error in the earlier classification. Such observations would correct the data base without introducing a bias in the analysis and interpretation of change. Weights would then be assigned to these value judgments in projecting new population estimates, or environmental impact of some systematic ecological process to which the updated data base is subjected.

<u>Opportunity for Comparative Urban Analysis: Remote Sensing in an Operational and Program Context</u>

One model of U.S. urban areas is illustrated graphically in Figure 7. It expresses the relationship between total land use, area-size (on the vertical axis) and population-size (on the horizontal axis). Each dot represents one urban area. Each triangle represents one of the urban test sites. From the operational experience which is being acquired, this model might be used to compare urban areas, to describe systems of cities, and even to project estimated cost of the analytical operations to other urban areas. As I have already suggested, pre-event analysis is essential for damage assessment as well as for routine change detection. It is fair to assume that risk from environmental hazards is concentrated in urban areas, where eighty percent of the U.S. population lives. But, these areas make up only one percent of our total land area. So, it really seems quite feasible to think of undertaking systematic area analysis, by remote sensing techniques, of all of our more hazard-prone urban areas. This model, and the work that is already underway, can help to block out the dimensions of this task. Another use of this model, once it has been calibrated for settlements in a region, is to estimate their population from areas measured on satellite imagery. Some countries lacking adequate census data acquired by conventional means are interested in aircraft and satellite remote sensing techniques for this very application.

A model of an operational environmental monitoring program is shown in Figure 8. The program is ultimately concerned, as shown in the panels at the right, with improving the quality of urban and regional environments. In the panels at the left, it shows the role of remote sensing in data acquisition. The panels in between represent some of the operational sequences described here. The Atlas pages represent some of the client-oriented end-products, which are represented by the panels labelled "products." In our work to date we have identified some uses and users, in addition to ourselves. These are represented by the large bottom panel. Some users are already working directly with us, or we with them. We hope before long to stage a critical review of our efforts by a wider group of potential users.

Meanwhile, we see a host of challenging operational urban applications beyond the goals of the immediate experiment. We expect to document some of these in the near future. The analytical procedures outlined in this experiment for urban change detection may illustrate the role of remote sensing techniques in monitoring environmental change, and the implications for land use classification and area analysis at regional as well as urban scales.

* * *

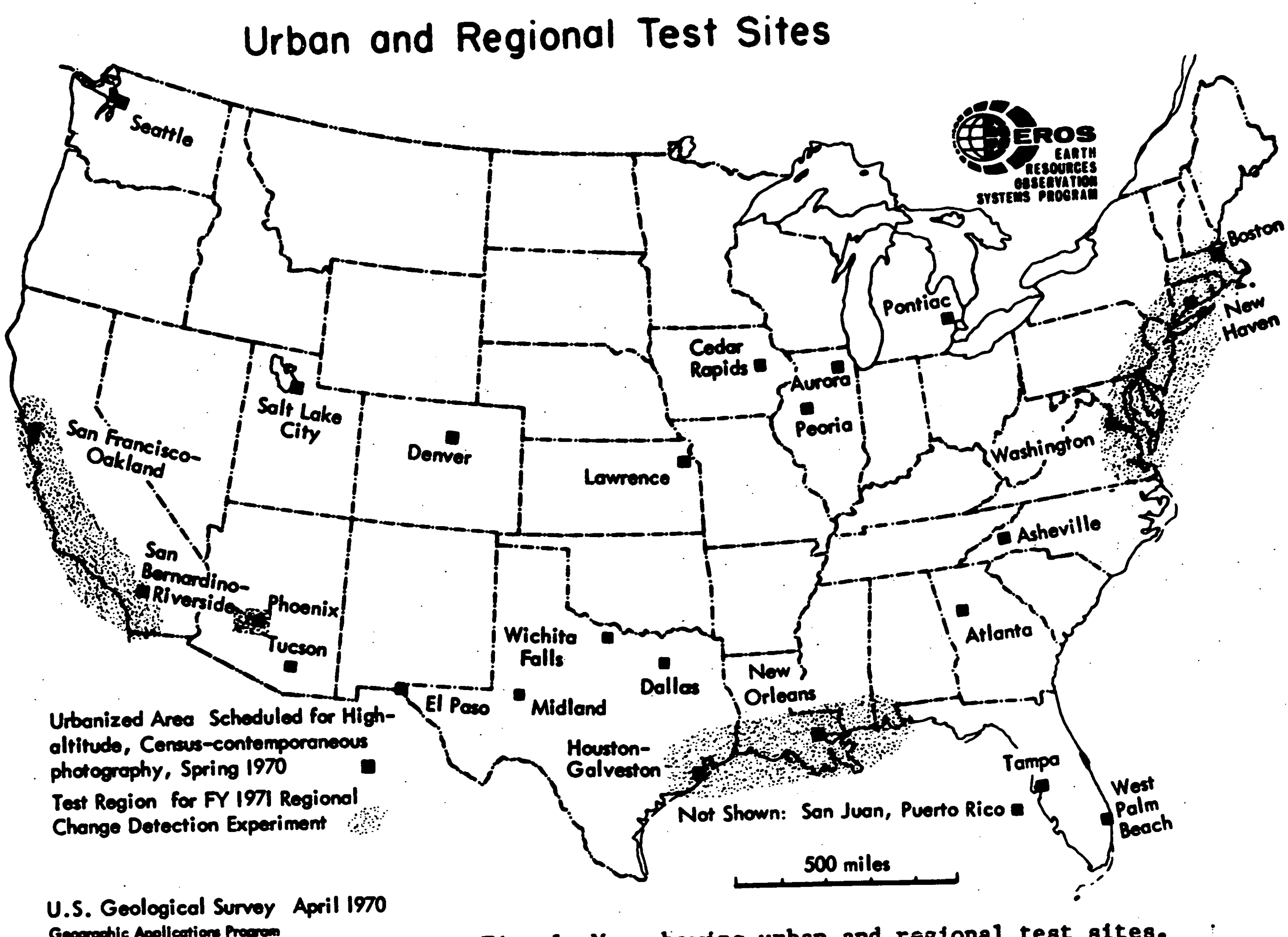

Fig. 1--Map showing urban and regional test sites.

EROS Census-Contemporaneous Imagery for Urban Test Sites

EROS EARTH RESOURCES OBSERVATION SYSTEMS PROGRAM

Test Site	No.	NASA MSC RB-57F Fx No.	1970	Camera Frame 9"x9" B-W panchr. 2402/12 ●	Camera Frame 9"x9" Color infrared SO117/12 ●	Camera Frame 9"x9" Color infrared SO-117/D ○	Camera Frame 2.2" x 2.2" 1/382,000 ● Black-and-White panchr Green ⊛	Black-and-White panchr Red ⊛	Black-and-White IRfilm IRband ⊛	Color IR 12 fil ⊛	Color panchr 2E fil	Color panchr 3 fil
Asheville	46	128a	5- 4	■	■	■	■	■	■	■	■	■
Atlanta	217	128a	5- 4	■	■	■	■	■	■	■	■	■
Aurora	232			-	-	-	-	-	-	-	-	-
Boston	187	128d	7- 7	■	■	■	■	■	■	■	■	■
Cedar Rapids	234	128c	6- 7	■	■	■	■	■	■	■	■	■
Dallas	996	128a	5- 2	■	■	■	■	■	■	■	■	■
Denver	194	128d	6-27	■	■	■	■	■	■	■	■	■
El Paso	994	128b	5-23	■	■	■	■	■	■	■	■	■
Houston-Galveston	175	128a	4-21	■	■	■	■	■	■	■	■	■
Lawrence	85	128c	6- 7	■	■	■	■	■	■	■	■	■
Midland	228			-	-	-	-	-	-	-	-	-
New Haven	229	128d	6-28	■	■	■	■	■	■	■	■	■
New Orleans	132	128a	5- 4	■	■	■	■	■	■	■	■	■
Peoria	226	128c	6- 7	■	■	■	■	■	■	■	■	■
Phoenix	29	128b	5-22	■	■	■	■	■	■	■	■	■
Pontiac	231	128b	7- 5	col ■	■	■	-	-	-	-	-	-
Riverside-SanBern.	225	128b	5-14	■	■	■	■	■	■	■	■	■
Salt Lake City	235	128b	5-22	■	■	■	■	■	■	■	■	■
San Francisco	211	128b	5-15	■	■	■	■	■	■	■	■	■
San Juan	92			-	-	-	-	-	-	-	-	-
Seattle	236			-	-	-	-	-	-	-	-	-
Tampa	233			-	-	-	-	-	-	-	-	-
Tucson	30	128b	5-22	■	■	■	■	■	■	■	■	■
Washington	230	128d	6-28	■	■	■	■	■	■	■	■	■
West Palm Beach	182			-	-	-	-	-	-	-	-	-
Wichita Falls	227	128a	5- 2	■	■	■	■	■	■	■	■	■

Camera, at 50,000 feet:
● RC-8, 6 in. lens, 1/100,000, 200 sq.mi., stereo.
○ Zeiss, 12 in. lens, 1/50,000, 50 sq.mi.
● Hasselblad, 40 mm, 1/382,000, 172 sq.mi., stereo.

⊛ ERTS-A simulation.
U.S. Geological Survey Oct 1970
Geographic Applications Program

Fig. 2--Census-contemporaneous imagery acquired for urban test sites.

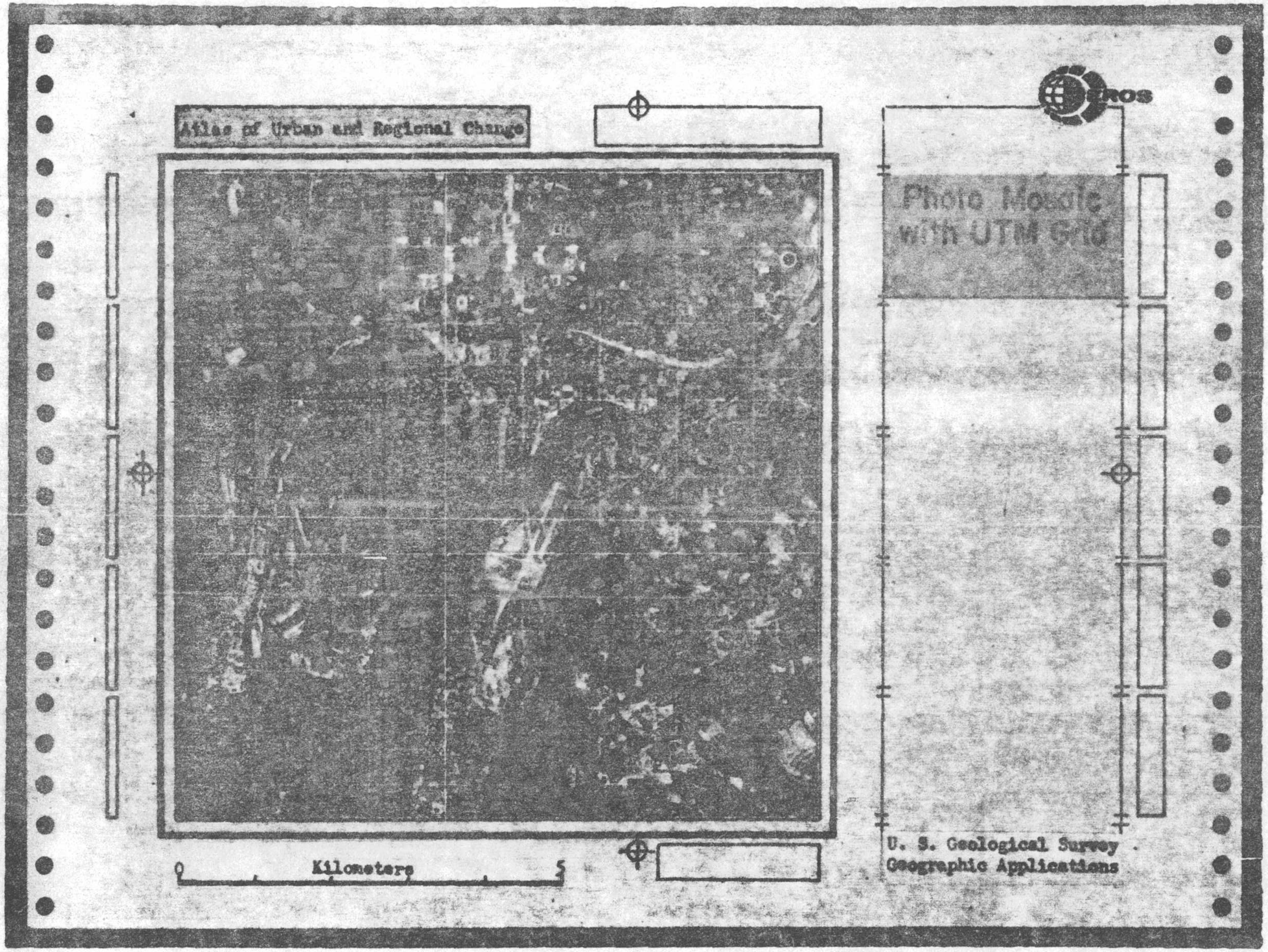

Fig. 3--Simulated page for Atlas of Urban and Regional Change showing photo mosaic with UTM grid.

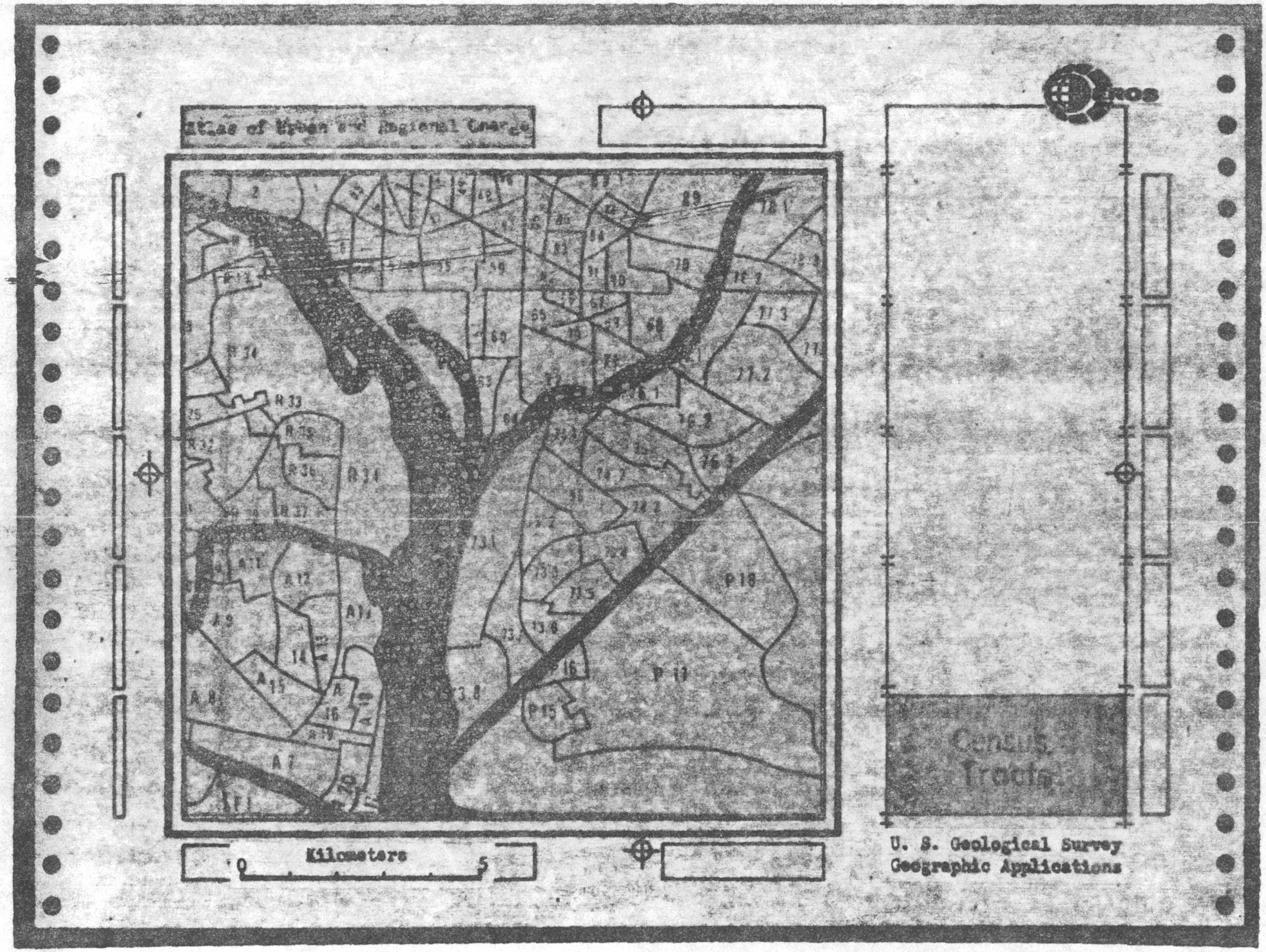

Fig. 4--Simulated page for Atlas of Urban and Regional Change showing census tracts.

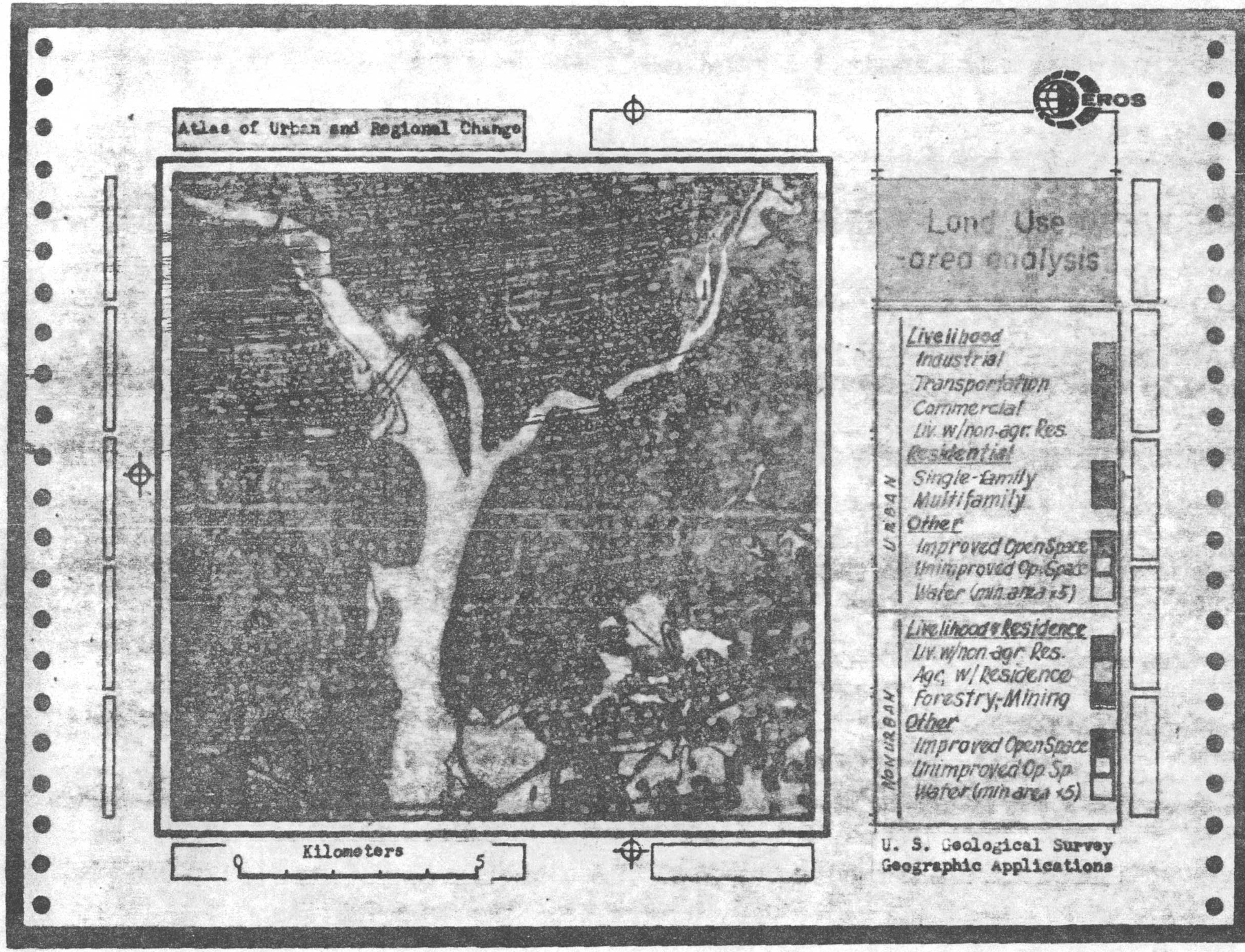

Fig. 5--Simulated page for Atlas of Urban and Regional Change showing one prototype land use analysis.

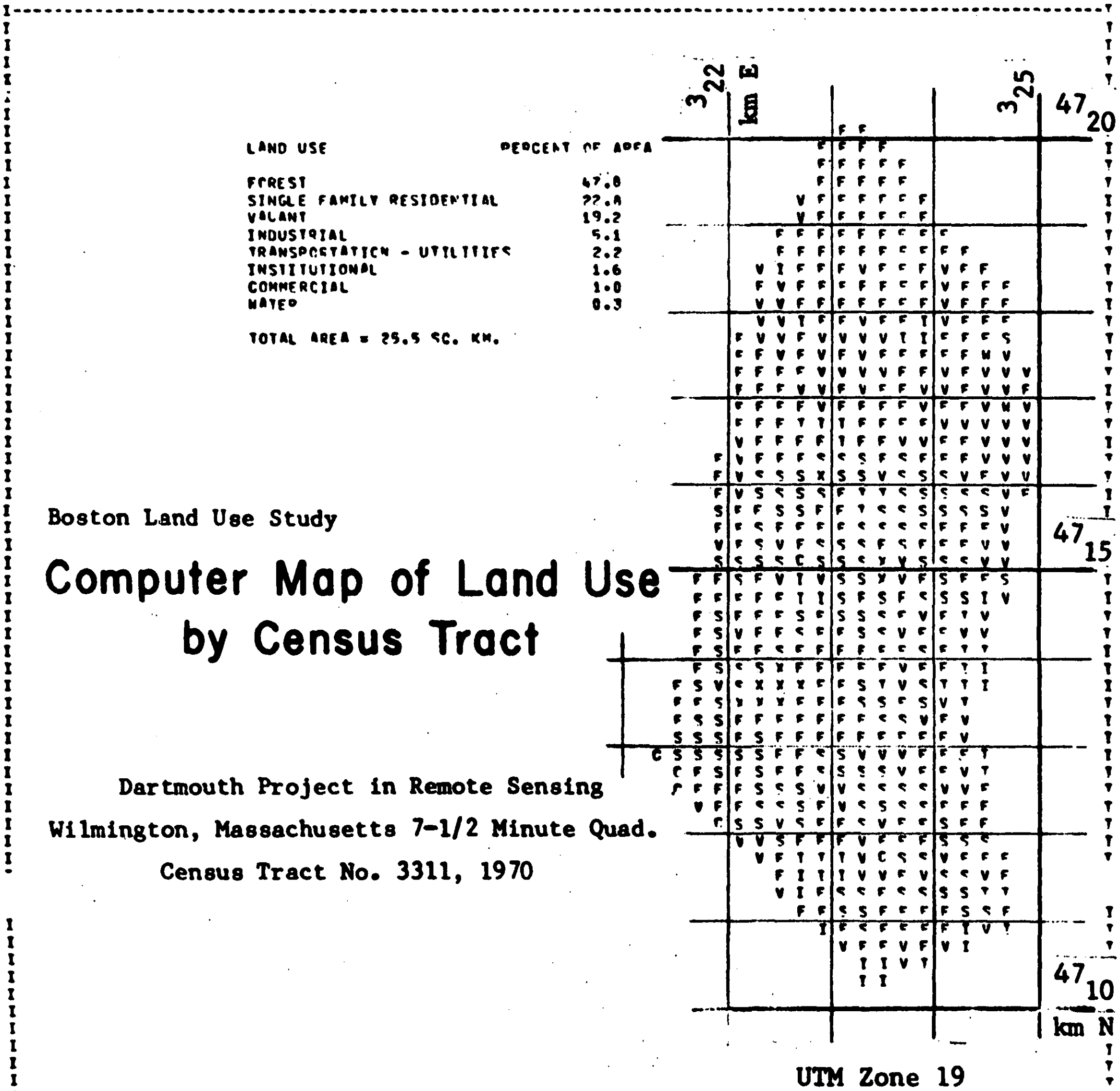

Fig. 6--Sample computer-printed land use map for one census tract at the Boston Test Site. Note relation of digits to UTM grid, for location control. Each digit is four hectares.

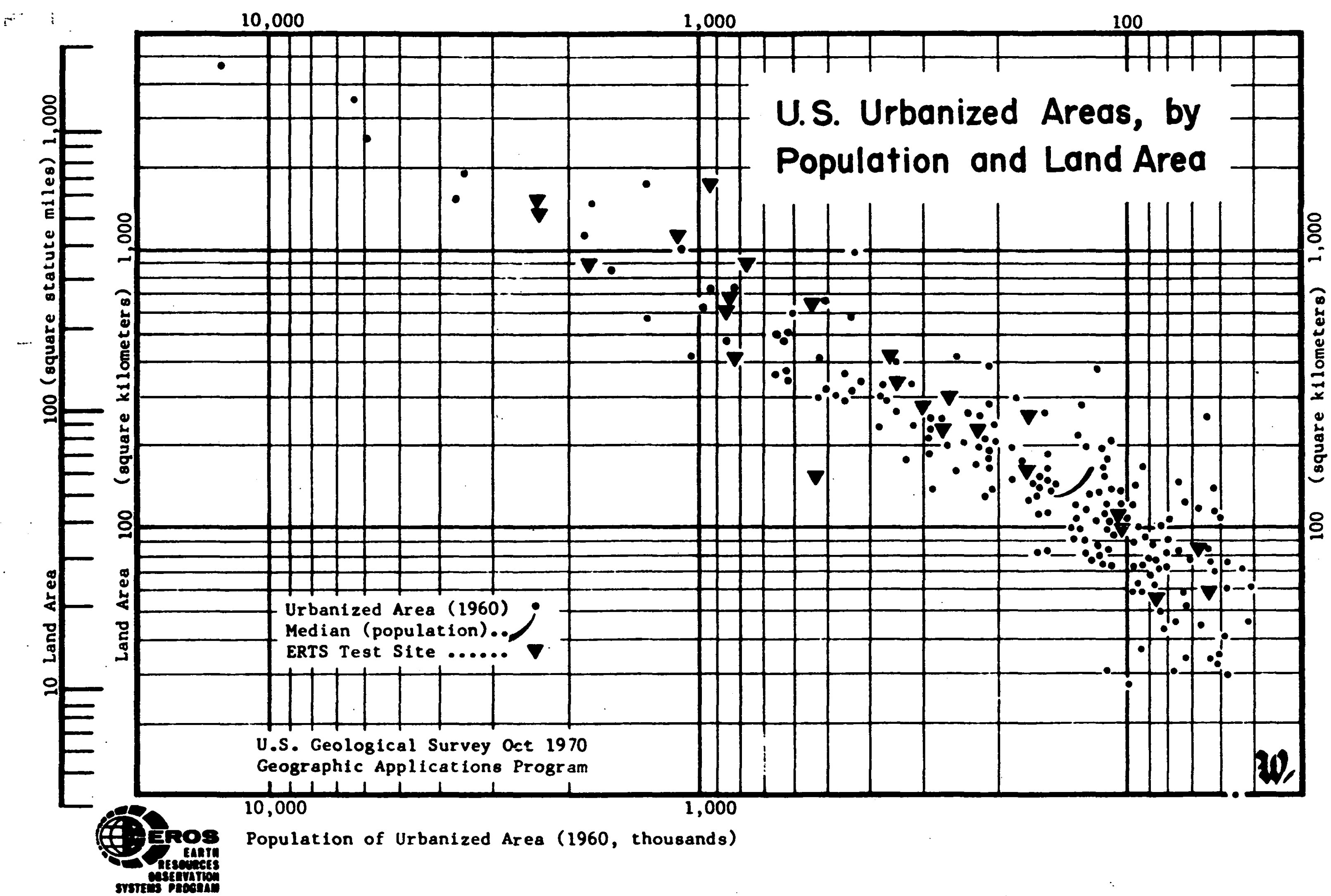

Fig. 7--One model of U.S. Urbanized Areas (1960 Census) showing the relationship between population size and land use size.

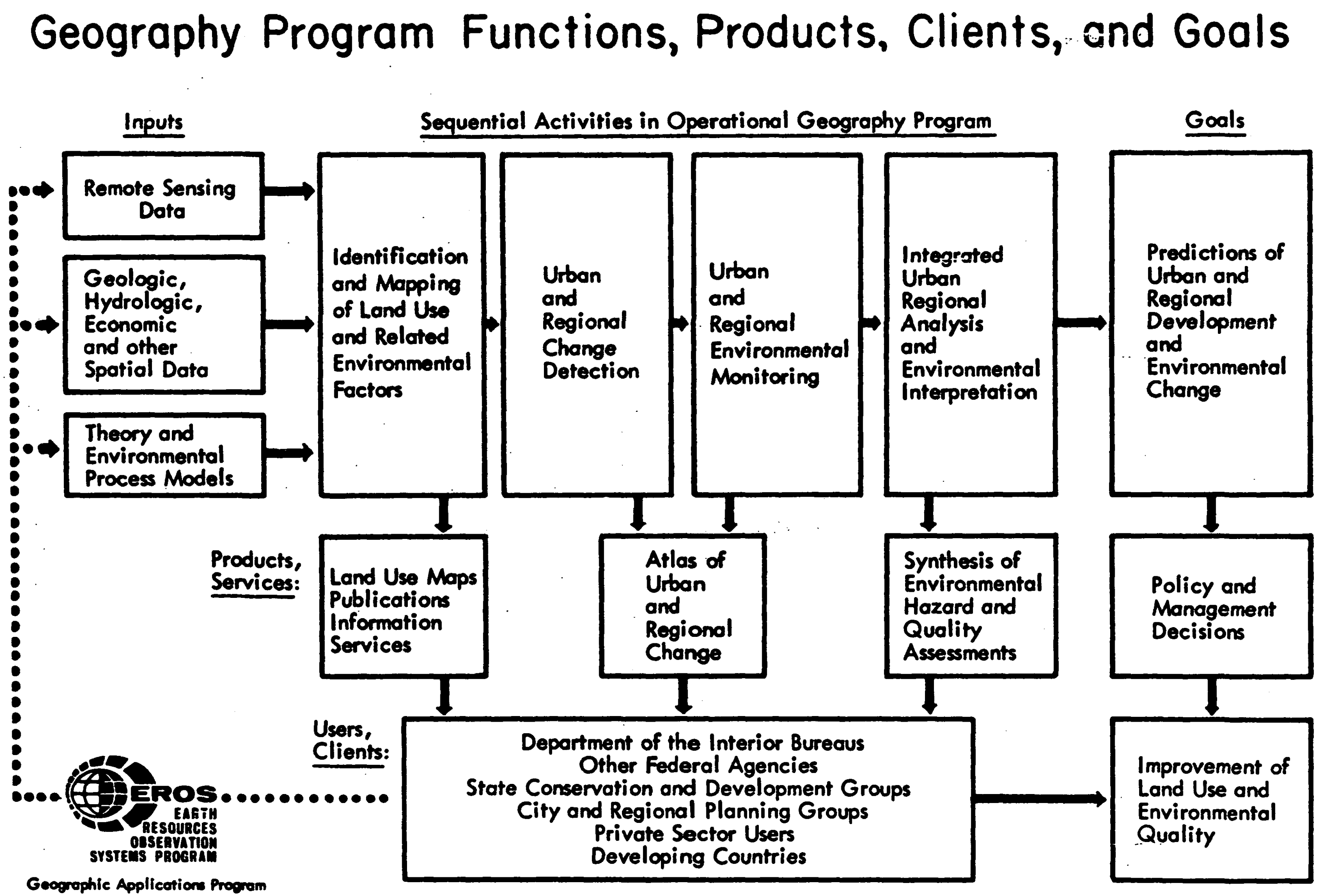

Fig. 8--One model of an operational program for monitoring urban and regional environments.

CONFERENCE ON LAND USE INFORMATION AND CLASSIFICATION

SESSION REPORTS

LAND USE INFORMATION AND CLASSIFICATION CONFERENCE

OPENING SESSION

June 28, 1971

William M. Johnson, Soil Conservation Service, reviewed the purpose of this Conference and commented briefly on the tasks before the participants. He charged the participants as follows:

First, let's look at the plan and organization of these seven sectional meetings or sessions. You are requested to select for attendance those sessions of particular interest and concern to you. This doesn't mean that you can't change from one to the other--of course you can do so.

This afternoon, three sessions will meet concurrently, so it is not going to be possible for anyone to attend all three. The first of the afternoon sessions will meet here in the auditorium and will discuss "General Planning Activities and Land Use Information Needs." By general planning activities we mean national and international planning needs and activities on a very broad scale. Session 2 will meet in Rooms 2126-2130, on the second floor, and will deal with "Administration of Public Works Programs and Their Land Information Needs." Included are public works programs of the Department of Agriculture, the Department of the Interior, the Department of Defense, and other Federal, state, and local agencies. The third session deals with "Property Evaluation and Tax Assessment and the Land Information Needs" of those activities. I think that that session may be perhaps the smallest of the section meetings, but it will make up in vigor what it lacks in number of participants. Session 3 will meet in Room 6322.

Tomorrow, and on Wednesday, there will be two concurrent sessions for the entire day.

Now, as regards the staff and organization of these meetings, there will be a chairman and a reporter for each session. In addition, a tape recorder and stenographer will be used to record the discussions and presentations. In addition to those people, a team of specialists will work with each meeting to provide expertise in classifications systems, in computer technology, and in remote sensing technology. I am not going to give you the entire list of these people, I'll simply mention the chairman and reporters for each team. In Team A, Dr. Gerlach and Dr. Place will function as chairman and reporter; in Team B, I shall be the chairman and Mr. Alexander will be the reporter; in Team C, Dr. Anderson is the chairman and Mr. Gockowski is the reporter.

Now, just a few words about the function of the sessions. Although many agencies and institutions are both users and producers of land use data, and my own agency, the Soil Conservation Service is a pretty good example, in these meetings we are particularly anxious to display and discuss the needs of users. We want your ideas, your thoughts, and your criticism. In this way, we believe, we shall have a basis for evaluating the feasibility and usefulness of a standardized classification of land use and we shall then have the means of defining the framework of a classification that could serve a wide array of needs. We hope that all of you will feel the responsibility to speak out about your needs for land use information, about the kinds of information you need, and the form in which you need it. We urge you to speak about the experiences you have had in using one or more of the existing classifications, and about the extent to which one of the four classifications systems described in the Conference background material or some other system meets your particular needs. Towards the end of each session, the chairman will endeavor to summarize the discussions and to express any concensus that may have appeared.

GENERAL PLANNING ACTIVITIES AND LAND USE INFORMATION NEEDS--STATE, REGIONAL, AND LOCAL

SESSION 1

June 28, 1971, 2:00 p.m.

James R. Anderson, University of Florida, Chairman; Jerome Gockowski, USDA Soil Conservation Service, Reporter; Arch B. Park, NASA Headquarters and Ronald Shelton, University of Illinois, Technical Advisors.

Mr. Anderson requested that the people present should indicate their user needs, the ways in which they use land use information, and later respond to key questions which will be raised for discussion.

Mr. Anderson called upon Marion Clawson of Resources of the Future, Washington, D.C., for an offhand introductory statement. Mr. Clawson first stressed his research interest in land use statistics. He is particularly interested in studying the changes in land use that are taking place as a way of pinpointing problems and as a means of starting off in making projections for the future. It is quite disgraceful, Mr. Clawson thinks, that in this country we have so much land use data that are of relatively poor quality. In referring to the report on Land Use Information--A Critical Survey of U.S. Statistics Including Possibilities for Greater Uniformity (Johns Hopkins Press, 1965), Mr. Clawson pointed out that activity on the land was stressed in that report as a common dimension in the study of land use. He went on to state that there is a general need to recognize the availability of data on land use that are regularly collected in connection with a wide array of administrative activity. These data should be used more effectively. Remote sensing is a very valuable source of information about land use, but it is only one of several sources that may be used. Mr. Clawson emphasized that two key items are required in a land use classification system: 1) the identification of land use or activity on the land in great detail in order that data can be aggregated in many different ways; 2) the association of land use activities in detail with specific tracts of land. There is an enormous range of interest in land use, thus an effective land use classification and information system must provide easy accessibility to data and also considerable flexibility for use. If an overall system can be set up which is flexible and usable at different levels, a significant contribution will have been made to the collection and handling of land use information.

Mr. Anderson then requested agency representatives or others who had comments to present them to the group.

George Farnsworth, Bureau of the Census, proposed that any land use classification and information system be tied into Census blocks, tracts, or other areal units for which census data are available.

George Nez, Dept. of Commerce, Economic Development Administration, has worked for more than three years on developing a grid type of system for compositing information in layers. This system is based on the use of a four-square mile cell. The problem gets down to how to use the new remote and traditional aerial sensor imagery. Mr. Nez estimates that there are over 6,500 socio-economic characteristics in all parts of the country generally available by counties. Some of these data are now being made available by minor civil divisions. The socio-economic data must be integrated with information obtained from imagery and pinpointed geographically or you will not have effective data for planning. He also believes that the users must understand some of the techniques of remote sensing in order to update the land use system effectively, however, planners and users will not generally be able to familiarize themselves with the fine points of remote sensing.

Ronald Shelton asked what base was used for the four-square mile grid. Mr. Crittenden, also of the Economic Development Administration, answered that they are using the 1:500,000-scale aeronautical charts published by the National Ocean Survey as a base for their composite mapping system.

William Harting, Tri-State Regional Planning Commission, which is a legislative body that includes parts of New York, New Jersey, and Connecticut adjacent to New York City, discussed the work that agency has been undertaking. The jurisdiction of this body covers 8,000 square miles. The initial survey was completed in 1963. At that time they used 900 people to walk around every block in the urban area of some 4,000 square miles and record land use activity. In New York City, they used records of tax assessors. In rural areas they used air photos as a source of information. Their problem now is to maintain that inventory and monitor the dynamics of the region to determine how it is changing. They do not use very detailed data as they do not plan on a local level. A big task is to make the information held by the individual counties compatible with the data of the Tri-State Planning Commission. They have nine major land use categories and use a one-square mile grid cell. They will utilize data supplied by the 1970 Census that ranges from data at the block level in the central areas to data available at the enumeration district level for the outlying areas. They have a converter file which converts census areas into one-square mile grid cells.

Mr. Nez inquired whether compositing was being done in the Tri-State Planning Regional Commission area. Mr. Harting replied that at the moment they are using county maps and that they gather information on land use activities in various ways. Data on residential use are obtainable from the Bureau of the Census. They also have used photo interpretation on the original survey photos to obtain change in non-residential areas and this is being recorded. Recreation areas are obtained from maps supplied by the states and by counties. Mr. Harting stated that the one-square mile grid cell was adequate for regional planning purposes. The Commission has one basic land use file which is a record for every square mile.

Kenneth Dueker, University of Iowa, presented some of the problems which Iowa has encountered in developing a land use data system. He is working on the systems design side of land data analysis and is approaching the design from a cost-effectiveness point of view. The first of the problems encountered is that of the user-data relationships. Mr. Dueker is particularly concerned with his inability to measure the pay-off on having land use data available in the system. Users are being classified by national, state, and local level and then sub-classified into categories such as those concerned with community development, economic development, human resources, and physical environment. He is trying to assess subjectively the needs of each of these users for land use data and is trying to determine at what level of classification detail and at what spatial detail or grid size such data are needed. He is identifying user requirements ranging from the Federal level which generally needs the one-digit level of classification detail and at the county level of spatial aggregation clear down to the four-digit level of classification detail and the spatial scale of parcels needed for most local studies of economic development, etc. Thus, you have a rather broad continuum in both land use classification and spatial detail.

The second part of the problem being encountered by Mr. Dueker is that of system relationships. Here he takes issue with the premise of this conference by stating that we must consider the needs of all the users and that we cannot work out a detailed system which will satisfy everyone. Mr. Dueker does not think that we can independently decide upon the land use classification detail. This is an inter-dependent decision with other important system variables in the land data system such as the spatial units or the grid size and the land use classification detail having to be decided together. Otherwise, we fall into the trap of the very detailed land use classification scheme for very large areas. From Mr. Dueker's perspective such a combination does not meet many of the user requirements. Two other important system variables pointed out were those of the source data or the imagery scale and the area type, whether it be urban, rural, or non-used desert for example. He is presently working to develop relationships between these variables, check for consistency in terms of the systems designer's decisions in each of these areas, and then checking to make sure that these are consistent decisions.

John Estes, University of California, Santa Barbara, suggested that a listing of user agency needs which can be obtained by remote sensing would be very helpful.

Robert Keith, University of Oregon, who has worked on land use classification systems, believes that the basic size of the cell depends on how you store the data. He thinks it is unrealistic to insist that the entire country be on one system. For example, he might want data in one system for developing a transportation system and in a different system for other studies. The need for data in an agricultural area are completely different from what you would need for an urban area and to insist that they be identical is not realistic. The systems should be compatible within the agency, but the data should be interchangeable so we will have a workable system.

George McGimsey, American Institute of Planners and Regional Planning Council of Baltimore, Maryland, asserted that planners cannot afford to collect their own data and therefore they are at the mercy of those who do collect data. Planners should not, however, be in the data collection business. We do need to think about new types of planning that are coming into being such as law enforcement and criminal justice planning, comprehensive health planning, and manpower planning. Most data that we have had to work with in the past at the metropolitan and local levels have been data that we could take from data systems developed for solving major national problems. They really were not urban data systems. He thinks that planners can probably get a lot of mileage out of remote sensing technology in the development of urban data systems. He places a high priority on the development of geographic base files tied into remote sensing. However, we need to go beyond our classification system further than in the past. A lot of our classification systems have been oriented toward economic activity particularly such as agriculture or those activities represented by the standard industrial classification code. We need to think in terms of classification systems for services, which is a growing section of our economy, particularly for government. We do not have a classification system for governmental activities. This will require a lot of hard thinking. In regard to the high cost of collecting data, Mr. McGimsey pointed out that we are looking for "end runs." How can we build an information system without burying ourselves in a data orgy that gobbles us up so that we won't have time to do any analytical work? He thinks remote sensing may be such an "end run" if used creatively.

Albert Guttenberg, American Institute of Planners, stated that we must determine what remote sensing can tell us. What can it give us in terms of what we need to know to accommodate our various interests and needs. To him, there appeared to be three sides to this conference. The first is concerned with the standardization of land use classification; the second is the capacity of remote sensing to pick up usable information; and the third is the relationship between the two. This relationship, Mr. Guttenberg considers to be especially critical. He proposed that experts in the field of remote sensing get together with persons with various interests in land use data. He thought that such a meeting or series of meetings should be at the working level and a careful appraisal be made of just how much inferential and direct information can be obtained from remote sensing.

Mr. Anderson asked Ronald Shelton how they went about getting the users to indicate their data needs in the New York study. Mr. Shelton indicated the use of a three-way analysis. First, they looked at what they could get from the 1:24,000 black and white photography taken in April which they were using. Then, they checked the compatibility of handling this classification of certain land uses with computer processes and the need for land use data to be expressible in quantitative form as output from the computer. Thirdly, the classification scheme had to be comprehensive, since 50,000 square miles were being surveyed.

Joseph Sizer, Minnesota State Planning Agency, presented some information about the Minnesota Land Management Information System.

He stated that:

1. Current land use is one of several characteristics of land included in the system.

2. Approximately 83,000 square miles of land are being surveyed.

3. Interpretation of aerial photos was used as the main approach to obtaining land use data.

4. Forty-acre data units or cells were used. Each cell shows ownership, current use, and minor civil division identification. Minnesota is now storing soils information in the system as well. Mr. Sizer indicated that current land use is only one of several items in the total system. They have about 1,285,000 units.

James Lyons, Dept. of the Interior, Bureau of Outdoor Recreation, stated that BOR is encouraging the states to develop a comprehensive view of their functional problems regarding outdoor recreation. As a user of these data, it appears we must have some uniform or consistent means of classification from the Federal government on down. Part of the problem is to develop a definitive classification system to be used at all levels. He hopes that when the data are finally available to the users it will be in a format that is consistently useful.

Olaf Olson, Watershed Management, U.S. Forest Service, stated that the Forest Service is presently planning in about three time-frames or categories for the national forests. One is the long-range planning which is more or less concerned with resource allocation. This is looking ahead 20, 30, or 50 years. The short term time-frame is for specific timber sale areas and for specific haul areas. The third frame is that being used for project design. The Forest Service is making resource inventories which would serve all three purposes, but they are working particularly on short term planning with a 5-10 year planning span. They are working at scales of about 2 inches to the mile.

Ben Spada, U.S. Forest Service, discussed the forest inventory of the United States. It was pointed out that in addition to the inventories being carried out on the 187 million acres of national forests, the Forest Service is also responsible for conducting inventories of other forest land in the United States. A national sampling system which is operated from about seven regional centers of the Forest Service is being used. This system is not uniform in design but it does have a uniform informational output. More detailed mapping of forest resources, which was formerly used, had to be abandoned because of very high costs. In its inventory the Forest Service is very much concerned with how and where changes in forest use are taking place.

Richard Ginn, Tennessee Valley Authority, indicated that within TVA there is a wide variety and use of land use information. Mr. Ginn works at a program level with the regional, local and state agencies.

Assuring compatibility of the various programs of the numerous agencies operating within the 201-county area of TVA is a major need that must have careful and continuing attention.

Robert Otte, Dept. of Agriculture, Economic Research Service, pointed out that the Natural Resources Economic Division of ERS and its predecessor agencies have for a long time been conducting a land use inventory at five-year intervals. Mr. Otte thinks that imagery of the type to be obtained from ERTS-A will make it possible to make a gross land use inventory of the country.

Julius Mai, Dept. of Agriculture, Soil Conservation Service, reported that the second Conservation Needs Inventory for all privately owned land has been published. This inventory is based on an average two percent sample. It also includes a small watershed inventory and is most useful for broad area planning.

Mr. Anderson indicated that he had worked on the first inventory in 1957-1959. Mr. Farnsworth asked whether remote sensing data could not be used to refine the land use categories and provide an effective approach to updating the Conservation Needs Inventory.

Sherman Winings, Agricultural Stabilization and Conservation Service, indicated that we also need to be talking about capabilities. The ASCS is preparing a data base for all agricultural land in the United States.

Robert Skirkanich, Grumman Aerospace Data Systems, talked about combining resource and area taxonomic systems in the land use classification system. He feels that the land use classification is only a portion of the total needs.

This session closed with the Chairman indicating that the major problem in the land use scheme is that of urbanization. He also indicated that this group will meet again on Wednesday morning, June 30. He pointed especially to topic A-4 in the list of questions for discussion which had been distributed.

* * *

ADMINISTRATION OF PUBLIC WORKS PROGRAMS AND LAND USE INFORMATION NEEDS

SESSION 2

June 28, 1971, 9:15-11:30 a.m.

William Johnson, Soil Conservation Service, Chairman; Robert H. Alexander, USGS Geographic Applications Program, Reporter; and Roger Tomlinson, IGU Commission on Data Sensing and Processing, Technical Advisor.

Mr. Johnson opened the session by introducing Mr. Alexander, Mr. Tomlinson, and William Fischer, Manager of the EROS Program of the Department of the Interior. He then asked all present to identify themselves and their agencies.

Mr. Johnson distributed copies of a list of questions pertaining to the major objectives of this Conference. He reviewed these questions, as listed below, and asked for comments from the participants.

1. How can the needs of Federal agencies be met for an up-to-date overview of land use throughout the country on a basis which is uniform in date, scale, and categorization at the first and second order levels?

2. How can we utilize the best features of existing, widely used classification schemes?

3. How can we best devise an open-ended classification which permits further development at third and fourth digit levels and still have compatibility with a national system of classification?

4. What classification framework will be most receptive to data from instrumented satellite and high altitude aircraft platforms?

Wesley Smith, Tennessee Valley Authority, said that TVA has recently completed a study of changes in land use in the TVA area from 1958 to 1967, based on data from the Conservation Needs Inventory. They were particularly interested in determining the kinds of land that went into change status, and what uses were being made of the land. He felt that one of the most important things needed in his agency is to be able to identify, not only in terms of agriculture but also in terms of urban requirements, various physiographic classes of land. They need such information in order to make decisions concerning such things as housing developments, recreation areas, etc. Another problem they have is to differentiate farm lands from state parks or other recreational areas. Although they have used census records to aid in interpretation of data, he feels they still need to have more data on ownership of land. Mr. Smith proposed that the first category of the draft land use classification, "Urban and Other Related Uses," should be expanded to include more detail. He mentioned in particular transportation networks. Mr. Johnson pointed out, however, that as mentioned by Mr. Anderson earlier today, when you put two or more unlike things into the same category it lowers the valid interpretation potential. Also, ownership is not normally part of a land use classification system, although Mr. Johnson agreed it certainly was an important attribute of land. He commented, however, that there seems to be a strong tendency today to devise a functional classification rather than a morphological one which reflects present active land uses such as farm land, grazing, highways, residential, etc.

Mr. Johnson asked Mr. Smith if what TVA actually needed was a monitoring system which would give them rapid, up-to-date information on land use changes? Mr. Smith agreed. In this case, Mr. Johnson said, the classification scheme proposed at this Conference is one which can be used by many Federal agencies to obtain basic land use data from high altitude aircraft and satellite overflights on a rapid, up-to-date basis. Such a classification would provide comparable data on a nationwide basis at the first and second levels while giving individual agencies freedom to expand the scheme according to their own needs.

Mr. Smith commented that TVA had found the Department of Agriculture's Conservation Needs Inventory classification scheme very useful, but he asked Mr. Johnson if it would be possible to acquire more information about the potential uses of land. Mr. Johnson explained that the Soil Conservation Service is presently working on a publication which will contain information on soil series and types not presently included in the Conservation Needs Inventory. Such information will provide data about potential productivities of the soil and limitations for such uses as housing, highways, recreation, etc.

H. N. Holtan, Agricultural Research Service, commented that his work concerned hydrologic research. He reported that the International Hydrologic Decade, now in its sixth year, will close with an estimate of all water in the world. One of the categories to be contained in the estimate will be for soil moisture which will be reliant upon knowledge of land uses, soils, etc. They have found that "land capability" is an important factor in determining hydrologic computations. Mr. Holtan said that in urban hydrologic studies, he felt it would be useful if they could get a breakdown of land use into residential, industrial, etc., because such uses affect hydrologic computations. William Fischer, EROS Program Manager, asked him if this was actually what he needed, or did he need the measure of the impervious surface in an urban area? Mr. Holtan responded that a number of things affect their figures, and the hydrologic measurements might well be entirely different in an industrial area than in a residential area. Mr. Fischer commented that this illustrated a problem they have found in making decisions on methods of data processing and information extraction. As an example, he showed a high altitude aircraft photo which had all parking lot areas extracted, and he suggested that although such information could be of value it might not strictly be considered land use data. Mr. Johnson said, however, that this, indeed, was land use information because it demonstrated a function of the land. Mr. Fischer mentioned that Mr. Anderson had suggested at the Plenary Session of this Conference that surrogates might be used in interpreting land use data, and Fischer asked if the classification scheme should reflect such surrogates. Perhaps, he suggested, alternate categorizations, with the same meaning--one of which could be interpreted in one way and the second in a different way--should be included in the scheme.

George Orning, University of Minnesota, mentioned that in their State Information System Project they have been trying to integrate well log data which are collected on a regular basis by the USGS, with soils information. If these data could be integrated and coded, they might present a more complete hydrologic overview of an area and its potential land uses. This was discussed briefly by Mr. Fischer, Mr. Orning and Mr. Tomlinson with agreement that such data would be valuable if they could successfully be obtained.

Mr. Johnson, in referring to the list of questions previously distributed at the beginning of the session, asked "What kind of land use data are most needed?" "What are the key categories?"

Edward Hanses, Corps of Engineers, said in their work in the Environmental Resources Section Planning Branch, they are preparing master plans for reservoir areas, vegetation management in such areas, etc. He said they would like to get more land use capability data, as well as data on land use changes. In the field of hydrology, Mr. Hanses said that in planning reservoirs, or land reclamation and flood control projects, they need to know more about the land capability. In general, they need information which will aid their planning for good water management of an area.

Harold Rib, Federal Highway Administration, commented that he felt there were two ways of approaching land use classification and mapping: 1) to map what is there, and 2) to interpret it or break it down into categories. Mr. Rib felt that it is in the interpretation of land use that we continue beyond its classification. Mr. Tomlinson said, however, that the ability to analyze or interpret the data depends on its identification and categorization. One of the problems in interpretation, Mr. Fischer commented, is that we learn to interpret certain things through prior knowledge of the area or a similar area. There followed a short discussion of problems of analyzing and interpreting data for urban hydrologic uses.

Mr. Orning commented that in their work in Minnesota they have been using a very basic, nine-category, land use classification system. For example, all of the state owned land in Minnesota has been standardized and computerized, as well as all of the federally owned land. He felt a basic classification scheme could be used and combined with information from various agencies. For example, he said you could combine U.S. Forest Service data for Minnesota with State information. Mr. Orning felt that the standardization of records and data kept by various agencies was one of the most important steps in rapidly obtaining valid, up-to-date information for a particular area. The information they have extracted and computerized in Minnesota can now be automatically updated. At the state level, Mr. Orning said they have integrated and computerized a lot of different data which can now be used to solve many land use problems. He suggested that a centralized computer data bank, compatible with state or regional data banks, might be extremely useful to many planners and administrators.

Mr. Johnson continued with another question: "How can we most rationally relate the first order classification categories with the second level categories?" In Mr. Anderson's scheme and in the Standard Land Use Coding Manual, and in fact in all of the four land use classification schemes presented in the Conference background material, each one is a multi-category system in which various levels must be related. Mr. Hanses commented that he had a basic problem with these categories because he was more interested in potential land uses than in the present use which is illustrated in the classification scheme. Mr. Johnson responded that he, too, was interested in the problem of identifying potential uses, however, it was still extremely necessary to achieve agreement on categorization of present land uses as a basis for identifying future or potential uses. How shall the land be classified, how shall it be presented, and at what scales? These are the questions we must restrict ourselves to at this meeting.

Wesley Smith asked if the Standard Land Use Coding Manual was in general use. Mr. Johnson responded that several agencies other than SCS are using it; for example, the Department of Transportation. Mr. Smith felt that some of its categories were too restricted to be used on a national basis and that the ultimate use of land was an important factor which should be reflected in a classification scheme. Mr. Tomlinson said that perhaps we should define exactly the purpose of the Conference discussions. In Canada, he said, they have developed five different types of maps for the Canada Land Inventory area--four of these map types portray land suitability for certain categories of use but the fifth shows present land use. Is present land use the topic we are concerned with at this Conference? If the agency is interested in furthering its knowledge about present land uses, what type of information does it need?

James Brittenham, Arizona Highway Department, said that due to the large amount of data becoming available through high altitude and satellite coverage of Arizona, they have found it a real problem to put all of the data to effective use. Another problem is to get current information on land use changes and land ownership. Mr. Brittenham commented that although their information needs are great, he doesn't feel he can offer any suggestions in regard to the land use categories. He said he would like to listen and learn more about the subject.

Edward Davis, Bureau of Outdoor Recreation, said they break down information into two categories--one is the prospective user of a recreational area, and the other is for areas of potential recreational value. Mr. Johnson asked Mr. Davis if any of the schemes under consideration at this meeting would be of value to his work. Mr. Davis commented that he was most familiar with the Standard Land Use Coding Manual but that, in his work, he has not used such basic information as is represented in the first two levels of the land use classification. Mr. Johnson commented that if the classification scheme is properly designed, it could be divided into as many sub-categories and sub-levels as is necessary for the user, even to assigning ownership to a particular plot of land.

Warren Myers, Agricultural Stabilization and Conservation Service, said that basically their needs fall generally into two groups. The first is for general planning purposes, and the second need is for more details concerning the requirements of various states in order to apply Federal aid in the proper areas. Mr. Myers felt that they needed as much detailed information as is possible to obtain. He commented that he was very interested in land use classification because the Agricultural Stabilization and Conservation Service is currently considering the expansion of their computer system and it would be important that such land use data might be made compatible with other computerized data systems. He felt that there is a definite need to coordinate systems of collecting, interpreting, filing, and retrieving land use and other data in all agencies.

J. Robert Krebill, Iowa Office for Planning and Programming, said that his office is not using land use information in the type of planning work they currently are engaged in. They are, however, trying to design all of their state-wide information systems to be compatible with each other. Mr. Krebill felt that they have a definite need for land use information, particularly in doing economic development and environmental impact studies of areas in Iowa. He also mentioned the necessity for interfacing a land use classification and information system with other types of information systems.

In reviewing the tentative classification for the first two levels as proposed by Mr. Anderson, Mr. Johnson said that one of the problems in interpretation and use of the scheme is that everything must be assigned to either one or the other of the categories. This usually leads to a "catch-all" type category and he asked if there were any comments on this problem. Is there any better way of dealing with such miscellaneous items, some of which may not fall easily into any of the categories?

Mr. Tomlinson commented that in the Canadian Present Land Use Survey classification, which is very simple, they use the term "unproductive land" as a catch-all category. Idle land, which is not being used at the moment, might be put under rangeland. Tomlinson said, however, that even with the very simple classification scheme used in Canada, they still acquired an enormous number of pieces of land use information for the scale at which it is portrayed. Referring to the proposed present land use survey in the United States, he emphasized that the first and second level categories might well be intended for use with data from high altitude and satellite overflights and to be portrayed on a national level. These data would then serve as a basic reference which could be refined in regions, statewide, and at the local level by the agencies concerned. He asked, however, who represented here today was interested in knowing such items as where all of the arable land in the U.S. is located? Or where the major urban areas are located? These are examples of basic land use data which can be identified and categorized on a national level. They can, however, be further refined by state, regional and local agencies to fit their individual needs. Mr. Johnson agreed that this was precisely the point.

Mr. Johnson said an example of a nationwide information inventory was the Soil Conservation Service's Conservation Needs Inventory which was first compiled in 1958 and has been subsequently updated. This Inventory was based on the expansion of data from specific soil samples, randomly chosen, which were either already mapped in their Soil Survey Program or mapped especially for the Inventory. These data, which include types of soils, topography, slope gradients, etc., are included in a soil survey and the uses are clearly indicated. Then, using local experience and judgment, the needs of these lands for management or treatment in order to protect or enhance the resources are spelled out. Land use identification is only one part of these data but it is an important part.

Mr. Johnson then reviewed the land use categories presented in the classification scheme prepared by Mr. Anderson for the Association of American Geographers and asked for comments concerning the categories listed. There was a short discussion of the use of "arable" as a term as it seemed to imply land suitable for cultivation although it might include rangeland, etc.

Mr. Holtan commented that he hoped that a particular scale would not have to be decided upon and used constantly thereafter. He said that the scale might be dictated by what the information needs are, and that this would in turn influence the categories. Mr. Johnson agreed that the needs of each agency would dictate the scale at which the information would be portrayed, however, even at the reasonably large scale of the Canada Land Inventory, it is possible to include an enormous amount of detail. There was a short discussion of the question of scale in relation to interpretation and portrayal of data.

In continuing with the discussion of the AAG classification scheme, Mr. Johnson asked if it would be sufficient to know whether forest land was used commercially or non-commercially? Mr. Smith of TVA said his agency needed to have more information than this. They want to know the forest types--soft or hardwoods, etc. Mr. Johnson reminded the group that we are only discussing the first and second level categories which are for data at the national level, and that these data can be expanded or sub-divided to include more detail as mentioned by Mr. Smith.

Ronald Becker, Office of Sea Grant Development at Louisiana State University, commented that none of the land use classification schemes presented at the Conference really filled their needs for data on coastal zones which constitute about one-third of the land in Louisiana. He mentioned, in particular, the problem of identification and classification of wetlands, shellfishing grounds, marine fisheries, etc. which are not covered, as far as he can see, in the present categories. Another problem is in the area of identifying and categorizing land areas which are changing, or loss of land by dredging, subsidence, channelling, etc. Some water areas are rapidly being filled in while other land areas are being depleted.

Mr. Johnson commented that the Standard Land Use Coding system has a category for "Resource Production and Extraction" which includes along with agricultural activities, a breakdown for fishing activities and related services at the second digit level. This could be subdivided even further by individual agencies to include vertibrate and invertibrate fish as well as such industries in marshland areas as fur production. In the AAG scheme, "Water Using Activities" or "Low Activity Areas--Marshland Oriented" might include such activities. They might also be included under "Resource Production and Extraction." Mr. Becker objected to including such things under "Low Activity Areas" as these regions are often used intensively.

There was some discussion of the changes which regularly take place among water, wetlands and dry land bordering such areas, and, in particular, how these areas should be categorized in a land use scheme. Mr. Johnson said that water areas, at least to the territorial limits, are included with land areas at the first level. However, these can be refined as needed to include specific categories at the higher levels. Mr. Tomlinson commented that many countries have similar land use classification problems. For example, some countries are reclaiming water areas, and in Japan, they must classify rice paddies which are under water much of the year.

At Mr. Johnson's request, Donald Van Skiver of the USGS Topographic Division explained his interest in a land use classification scheme. He said that in their map revision program they presently use four categories of land: 1) urban, 2)suburban, 3) rural, and 4) remote or wilderness. Each of these categories has a different revision cycle, i.e., every five years for urban-suburban; every 10 years for rural, and every 20 years for remote-wilderness. They would like to be able to identify land areas which are changing from one category to another so that they could be more rapidly updated. Mr. Johnson asked if he would be interested in a map of the U.S., at a scale of 1:250,000, with eight to ten categories at the first level which could be rapidly updated with the use of high altitude aircraft and satellite data. Mr. Van Skiver agreed that such a map would be very helpful to their work.

Robert Alexander, Reporter for this session, said that he would like to comment on several points of possible interest to this group. On one hand, he said, he sees that some agency requirements tend to lead to more and more detail in a classification scheme, however, there is a potentially tremendous data handling problem even with a few basic categories. Mr. Alexander asked whether agencies which require a lot of detailed categories in a land use classification might also be helped by the information contained in the first and second levels. He also commented that much of the discussion at this session has tended to focus on agricultural land uses which are scheduled to be discussed in another session at this Conference. He asked if there were any representatives present at this session who would classify themselves as public works administrators, and, if so, would they identify which categories of land use are most useful to their work. A number of participants today have stated that they primarily attended this session to learn more about land use classification rather than to contribute suggestions or comments.

James Simpson, National Park Service, said that the Park Service would be very interested in the first level land use categories. He felt that his agency would benefit from such information as much as any agency. Mr. Simpson said they needed to know general development information, even outside of National Park areas, because such development would naturally affect their planning. As an example of such general development, he mentioned housing developments, oil exploration in coastal waters, and water uses and needs such as those areas bordering the Everglades which affect the actual or potential National Parks. Mr. Simpson said he would like to have included in the major categories, some category which would delineate natural, ecologically balanced areas of the U.S. He commented that the Park Service has often used areas such as the Badlands or White Sands for National Parks or National Monuments although these would probably be included in a land use classification category for "Unproductive Land." In conclusion, Mr. Simpson commented that agencies, such as the Park Service, which are concerned with Federal lands for recreation, management or reclamation projects must have broad, comprehensive information in order to develop background and environmental impact statements for those projects.

Mr. Johnson asked Mr. Hanses of the Corps of Engineers if he wish to comment on Mr. Simpson's remarks. Mr. Hanses said he agreed wholeheartedly with Mr. Simpson. He said, however, that although the basic, or first two levels, of the land use clasification scheme are intended to reflect the current land use, he feels that the potential or alternative land uses are very important. Such information may not be easily reflected in any land use classification scheme. Mr. Hanses said that in his agency they have to consider many alternative uses of land areas when they prepare environmental impact statements for proposed projects. As an example, an area which might be classified as forest land might also be used for timber production, and could at the same time be a wildlife refuge, as well as being used for recreational purposes. In such cases, into which land use category should that area be placed? Mr. Johnson responded that showing such multiple uses of the land was more of a mapping problem than one of classification. In illustrating such an area on a map, it could be done with a multiple-use category or a variety of symbols. However, Mr. Johnson said in deciding upon a first or second level land use classification scheme, the categories should be as few as possible. In this way, national agreement on a few categories can be reached and made useful to a majority of agencies. Below these levels, the categories can be sub-divided as necessary by the individual agencies.

George Orning, University of Minnesota, commented that he felt that a category entitled "Unproductive Land" was open to different interpretations according to the orientation of the agency. He suggested substituting "Open Land" or "Barren Land."

Mr. Krebbil, Iowa Office of Planning and Programming, said he felt he could speak for most of these present today in saying that if the Federal agencies would agree upon a first or second level land use classification scheme, the sub-levels could be decided upon by individual users.

Mr. Johnson closed the session with the comment that it had, indeed, been an interesting and informative meeting, and he thanked all for their contributions.

PROPERTY EVALUATION AND TAX ASSESSMENT AND LAND USE INFORMATION NEEDS

SESSION 3

June 28, 1971, 1:30-4:15 p.m.

Arch C. Gerlach, U.G. Geological Survey, Chairman, and John L. Place, Reporter.

Several main themes were explored in this session. Mr. Gerlach opened the session by reading suggestions from a letter from Marion Clawson of Resources for the Future. One suggestion was to contact Robert Cook of the University of Cincinnati School of Law who has been working with the American Bar Association to establish standards for tax mapping. Mr. Cook was present at this session and he spoke on the need to standardize land scale, land use mapping. He mentioned, as an example, the mapping done on Prince Edward Island, Canada, where scales of 1:1,200; 1:2,000; and 1:5,000 were used, and added that scales as large as 1:500 or 1:1,000 would be even more useful. Several session participants expressed a desire for the Federal government to take the lead in developing national standards. Marvin Scher, USGS Topographic Division, stated that the Geological Survey does not normally undertake very large scale mapping of urban areas, however, he knew of nothing to prevent the Survey's participation in establishing standards.

Robert Kitchell of the New York State Board of Equalization reported that the State was just completing a tax map with detail down to fifty feet, and he would be willing to make their standards available. Capt. Baker made a similar offer regarding standards of the National Ocean Survey. Leslie Katz of the City of New York reported that tax maps for the boroughs have been prepared, and that he would make available his building use classification. He referred the group to the Dual Independent Map Encoding (DIME) system used by the Bureau of the Census.

John Rackham of the District of Columbia Government reported that they have a need for a continuing census or inventory of properties and a statistical analysis of some. Each parcel is presently being recorded by land use code and graphic coordinates. Mr. Gerlach asked if the mapping step is being bypassed. Mr. Rackham responded that maps, mostly from the Bureau of Public Roads, are used as a base for plotting a parcel-boundary overlay. They use the HUD coding system at a scale of 1 inch to 100 feet.

Kenneth Fisher of the American Bar Foundation reported that they are getting a group of specialists together this coming January and hopefully can settle on a common coordinate system. He had heard that conversion to the UTM system from other coordinate systems is very time consuming. Several attendees replied that existing computer programs could make the conversion quickly.

Thomas Payne of Tompkins County Assessor's Office, Ithaca, New York explained that without a land use map, appraisal for tax assessment purposes is very difficult, and the map could utilize either the block/parcel system, or the point or centroid system. A big problem is processing the data--an automatic digitizer might be prohibitively expensive.

Mr. Gerlach described the sensor system aboard the NASA RB-57F aircraft and the film/filter combinations used in the NASA flight program. He asked what value such surveys would be for the tax assessors? William Mitchell, USGS Geographic Applications Program, reported briefly on the successful use of high altitude aircraft photography to create a land use map at 1:125,000 for 5,400 sq. miles surrounding San Francisco Bay, and George Skrubb, Oakland County (Michigan) Planning Commission, supported those conclusions on the basis of land use mapping experience in his organization.

Ernest Hardy, Cornell University, reported that the State of Florida is planning to rely on photogrammetric surveys in place of field surveys for mapping. He also pointed out that assessors need to have redundancy built-in to help to explain to the public how the assessments were generated. John Rackham agreed that having something visibly meaningful was needed.

Thomas Payne felt that trends in land use from one decade to another have never been adequately documented.

Marvin Scher reported that large scale, orthophoto, maps would be another tool for the assessor. He later showed some examples of orthophoto maps.

Mr. Skrubb reported that they have in Pontiac, Michigan a set of orthophotos updated with low altitude photographs on a yearly basis. The base map is at a scale of 1:48,000. On their standard data card are space for five different land use classifications, and there is room for expansion to an international code. Mr. Skrubb also pointed out the need for a better classification of idle lands.

Raleigh Barlowe, Michigan State University, suggested that remote sensing techniques might be applied effectively to groups or families of cities, and to the testing of concepts such as the Central Place Theory. Kenneth Dueker, University of Iowa, agreed that satellite photography would be much more useful for comparative analyses of large areas than for details sought by metropolitan planners. Mr. Wray, USGS Geographic Applications Program, pointed out that land use classification terms such as "institutional," "educational," etc. have little value if the land use is to be determined from what can be seen on photography.

In conclusion, Mr. Gerlach commented that tax assessors apparently need land use maps with clear and accurate property boundaries; i.e., there must be unit control as well as point control. It is also apparent that there is some disagreement on the optimum grid system, but that for national and international data banks and land use maps the UTM grid is most suitable.

METROPLITAN PLANNING AND TRANSPORTATION
AND LAND USE NEEDS

SESSION 4

June 29, 1971, 9-11:45 a.m. & 1:30-4:15 p.m.

Arch C. Gerlach, U.S. Geological Survey, Chairman, and John L. Place, USGS, reporter for this session.

The Chairman opened the session by calling to the attention of the participants the USGS Circular 616 entitled Sensor Detection Capabilities Study by John E. Wilson. This publication describes capabilities of various remote sensors which could be used aboard spacecraft or aircraft to detect common, primarily man-made, features on the Earth's surface. The supply of this Circular is almost exhausted, but it still may be possible to obtain a copy from Dr. Gerlach's office.

In order to focus attention on urban land use classification and information processing, James R. Wray of the USGS Geographic Applications Program was asked to describe the urban change detection program that he has been developing. The text of Mr. Wray's presentation is included in the set of Conference papers.

In the question and answer session which followed Mr. Wray's presentation some of the following points were raised.

Mr. Farnsworth, Southern California Regional Information Study, asked what the cost of a program like this would be? This program has a great deal of potential to supplement existing surveys. How much would these photographs cost to purchase?

Mr. Gerlach responded that costs have not yet been computered. The photographs are still for experimental use, but are being used by many investigators connected with the NASA Earth Resources Program, and they will soon become available to the public at a nominal cost from the EROS Data Center which is being established at Sioux Falls, South Dakota.

Mr. Wray commented that in Boston, land use mapping cost about $20.00 to $30.00 per square mile. Mr. Netherton of the Interior Department's Bureau of Outdoor Recreation asked what shape or format would the $20.00 product have? What does the planner get for his $20 or $30 per square mile? Wray responded that an example would be the manuscript map for Boston as shown on the board. This example is at a scale of 1:62,500, but the mapping was done on a 1:120,000 scale image and cost approximately $20-$30 per square mile. Netherton commented that he would like to determine what additional refinement of data planners would need to get a useful end-product.

Mr. Will T. Moore of the Dept. of Transportation's Federal Highway Administration said that in highway development, a planning step is necessary which involves the study of population, employment, land use zoning, and automobile ownership. In regard to land use classification, they recommend the Standard Land Use Coding Manual. Also, they have issued a bulletin in January 1971 which digests data requirements for transportation planning.

Mr. Jacob Silver of the Census Bureau commented that what we have here is "two-dimensional." How general are the land uses that you end up with? Can "residential" be broken down and measured to square feet? Is intensity of use, a third dimension, to be measured?

Wray responded that what remote sensing provides is a base of information which treats all areas the same and allows frequent examination. A time-series or a synoptic view could be supplementary to existing census programs. For example, Paul Watt of the Association of Bay Area Governments (ABAG) in San Francisco wants to survey land use by census tracts in order to measure transportation traffic flow. County planners also need to map potential growth, i.e., usability of the land.

Mr. Harting of the Tri-State Planning Commission mentioned that through the 1960's, HUD made planning grants available. Many regional planning groups were formed, and most of these have land use information in their files. He suggested checking existing files. The Tri-State Commission (New York City) prepared a plan for growth.

Ernest Hardy of Cornell University stated that soil maps can be made from photos, and these help to provide land use suitability information.

Afternoon Session

Mr. Gerlach opened the afternoon session with an invitation for further discussion by participants.

In reference to Mr. Hardy's comments during the morning session, James Lyons of the Bureau of Outdoor Recreation stated that he has been looking for an information system of the New York State type, but as he is only a one-man office, how can he get technical advice in regard to using an information system of this type?

Mr. Hardy responded that in the Cornell University system the categories should be considered as a shopping list. No one person will want all of them. The New York State system can produce hundreds of thousands of combinations of data, but it is easy to specify what you want. The form of a query for specific data is almost in plain English.

William Harting added that the Tri-State Planning Commission has a similar data bank, but uses a different system. They have off-the-shelf items, such as data books with nine major land use categories for every square mile. The broad categories are enough to start the planner off and he can then go to the computer for details.

Mr. Hardy explained that it pays to have more than one format for querying. His program uses five formats, two of which are computer generated. These five are:

1. Data books for each square kilometer in the State, including actual measurements in detail.

2. Overlay maps showing point data.

3. Overlay maps showing area information.

4. Data Lists in computer page format.

5. PLANMAP, a cell by cell configuration in map form, generated by a line printer.

Captain Baker of the National Ocean Survey stated that all of the participants appear to come from wealthy progressive areas. What about the poorer districts? Who will set up data centers there, and who will pay to maintain them? Will every state maintain only one center, or more than one?

Mr. Gerlach responded that Ted Paludin at NASA Marshall Spaceflight Center, Huntsville has been investigating this problem, i.e., how to help the poorer districts. Some of the Acts going through Congress right now could possibly aid in the solution. Perhaps the National Science Foundation or other Federal agencies or organizations could help.

Robert Cook of the University of Cincinnati stated that we need common sense and cooperation more than money. An important need is getting together and making agreements. In Ohio, very few counties could not afford the money for an information system, but they need a system which ties into the other counties, and to Indiana and/or Kentucky as well.

Mr. Gerlach repeated for emphasis the second part of Capt. Baker's question which was, "How many data banks should each state have?"

Raleigh Barlowe of Michigan State University commented that land use statistics can be used for a wide variety of purposes. This includes academic studies. Statistical analysis of land use should be tied to an areal basis, both rural and urban. Regarding the question, "Should there be one data bank or more than one?" he said that if several banks use different systems, data are less likely to be comparable, and one cannot do valid statistical analysis.

Mr. Barlowe went on to ask if Mr. Wray had found any problems with his classification scheme? Wray answered that comparability of data is the biggest problem. This is an experiment in comparitive urban analysis. Several hundred square miles have been completed using the same scheme. For example, he wanted to do Boston in the same way as Washington. Great care was taken in defining the urban limits. The graphics shown were basen upon the 1960 census and city boundaries. A concern for comparability underlies all the research. Mr. Wray commented that they must learn to define urban from rural in a way that can be used again in 1972.

Wray asked in what year the aerial photography was flown in the New York State survey and when it would be updated? Mr. Hardy answered that this photography was flown in April 1968, and his group hopes to update the survey at least every ten years, but more often--every two to five years--in selected areas. They do not expect more than 10-15 percent change in land use.

Stephen Fregger of the Florida Department of Transportation stated, in regard to Captain Baker's question, that the shortage is not money but rather administrative ability to coordinate the work. In Florida, they have tried to coordinate counties, but it is impossible to get agreement on standards. However, his department will proceed to develop the best new file on land use in the state, and they will make it easily available.

There followed a short discussion of zoning and rezoning related to transportation flows. Trip generation rates appear to be the primary measure of transportation at present. A major problem is to tie transportation to land use. Large-area transportation studies were reported to take too long to produce and thus could not provide timely information when needed. Most data needed were reported to be socio-economic.

William Harting commented that we must prepare mathematics for special studies, such as coordinate systems for irregularly shaped objects. Mr. Barlowe asked whether the English measure or metric measure system should be used? Mr. Gerlach responded that both NASA and the Interior Department EROS Program are attempting to convert to the metric system. This seems to be the direction we show go, and he asked if there was any disagreement? There were no comments to this question.

Mr. Gerlach asked what the group's reaction was to the land use classification scheme presented by James Wray. Richard Ginn of the Tennessee Valley Authority asked what were the flight altitudes and types of cameras and film used in gathering data in Wray's program? Mr. Wray responded that for the overflights made for the 26 selected census cities to date, some were flown at 50,000 feet and some at 60,000 feet. From the RC-8 camera, the scale of photography at 50,000 feet is about 1:100,000, and about 1:120,000 at 60,000 feet. Standard scales used in the research process were 1:100,000 and 1:62,500. The satellite photographs were taken from an altitude of 400 to 500 miles.

Mr. Ginn commented that tract boundaries recognized by the Bureau of the Census appear to change between 1960 and 1970. Wray explained that they do not move, but they may split, i.e., a tract may divide into two or more parts.

Kenneth Dueker of the University of Iowa felt that trip generation relates directly to land uses. The field of transportation study had been successful in relating service to land use by using network planning processes. However, the land use classification scheme used by Mr. Wray may not be entirely suitable for transportation studies. Also, Dueker felt that he would not favor the metric system in the Midwest where statistical data are tied to township and section lines. Mr. Cook commented that linear distances can be converted mathematically in a computer. The Canadians have issued a white paper recommending change over to the metric system.

In response to an inquiry about his classification system, Wray maintained that most types of land use appear both in urban and non-urban areas. He also believes that most planners work with a system that is biased. For example, parcel data records tend to ignore non-privately owned land.

Richard Ginn pointed out that we should consider the open land surrounding airports as being used for transportation.

Mr. Wray described his method of recording change. Anything in transition was recorded as being in its "before" status. A square matrix might be developed to represent the change from any one of 16 categories to any one of 15 other categories. A two-digit code, e.g., "3E" might be used to indicate any point in the matrix of change.

Mr. Barlowe felt that the category "open space" must be broken down more before it can be meaningful. Others felt the same way about the transportation categories. Wray agreed that transportation was one of several categories which needed other sources of information to supplement the photo source.

Mr. Hardy stated that we must learn to combine data, as contrasted to the biologists, for example, who need to break down information into finer and finer detail. We also need a "waste basket" subcategory with every unit in which to put things that do not quite fit. However, the biggest problem is getting individual investigators to agree on definitions.

Mr. Gerlach directed the attention of the group to the subject of "clusters of cities" as against the study of individual cities, and in particular to the problem of delimiting urban areas. Mr. Harting commented that the Tri-State Commission's method was to cluster square miles of predominantly urbanized areas. They must be contiguous and of a sufficiently high intensity of use.

Mr. Barlowe reported that, in Michigan, census data has been used, and any township with more than 2,500 people and less than 60 percent of the land in crops should be considered urban. However, with the new techniques of remote sensing, a more refined method of measurement might be developed.

In regard to the question of whether to delimit urban boundaries by political/administrative units or by clusters of uniform cells, Gerlach, Hardy and Wray agreed that both methods of delimiting urban areas should be used to meet varied needs. With computerized techniques, it is quite feasible to use both.

Mr. Gerlach asked the participants whether a group of Federal agencies should try to draw up guidelines that could be used by local governments, or should each organization stick to what it is doing now? In order to get a national view of urbanization, it was hoped that this Conference could help to develop methods for handling urban data. Has this been accomplished? Is it important at other than the Federal level?

Mr. Cook pointed out that there were several Federal agencies, e.g., Corps of Engineers and the Department of Transportation, which were interested in very large scale maps.

Mr. Dueker felt that we should be interested in user needs at national, state, and local levels. Local needs, however, should be aggregated to national needs. That is, the four-digit code should be collapsible so that we can go from fine levels to gross levels of classification.

Mr. Gerlach emphasized that the entire Conference is meant to be open-ended. It is hoped that the participants will not consider that the Conference is finished when they return home, and he hopes to continue hearing from them about these problems. Several Conference documents will be mailed to participants, e.g., a list of participants, and a set of the invited papers given at the opening session, as soon as they become available. In addition, the Steering Committee for this Conference will try to summarize the seven discussion sessions and these summaries will be issued in the Proceedings of the Conference. However, we have, by no means, completed our task during these sessions.

The session closed with a request from James Wray for help in thinking about how to monitor the quality of the environment. Perhaps first we have to difine environment. What role can remote sensing play in monitoring the environment?

AGRICULTURE AND NATURAL RESOURCES AND LAND USE INFORMATION NEEDS

SESSION 5

June 29, 1971, 9:15-11:30 a.m.-1:15-4:00 p.m.

William Johnson, Soil Conservation Service, Chairman; Robert H. Alexander, Reporter; and Roger Tomlinson, Technical Advisor.

Mr. Johnson opened the session by reminding those present that, as Mr. Anderson had pointed out earlier during this Conference, a national land use classification scheme should:

1. Satisfy the needs of Federal agencies for an up-to-date overview of land use throughout the country on a basis which is uniform in date, scale, and categorization at the first and second digit levels.

2. Utilize the best features of existing, widely used classification schemes.

3. Provide an open-ended classification system that will enable regional, state, and local agencies to develop more detailed land use classification schemes at the third and fourth digit levels to meet their particular needs, and still be compatible with each other and with a national system.

4. Be receptive to data from instrumented satellite and high altitude aircraft platforms.

He, then, invited participants to express their views concerning the classification scheme presented in Mr. Anderson's paper at the Conference Plenary Session and comment, if they wished, on a proposed national land use classification system. Mr. Johnson also asked if any of the four different land use classification schemes presented in Conference background materials would suit the needs of those present?

Neil Stout, Bureau of Outdoor Recreation, commented that he felt that the Canadian scheme did not have outdoor recreation placed in the best category.

Wesley Smith, TVA, commented that he found it hard to compare the categories of the different land use classification schemes presented in the Conference background materials. Mr. Johnson illustrated on the blackboard the first, second and third levels of the category for agriculture in the Association of American Geographers' scheme. These are:

Agriculture
1. Cropland
    a. grain crops
        a.1 small grains
        a.2 coarse grains
    b. root crops
    c. fiber crops

Mr. Anderson then described the process of using such a classification scheme and how he had developed it for the AAG.

George Nez, Federation of Rocky Mountain States in Denver, commented that the schemes under discussion seem to be developed primarily to be used with remote sensing data. However, he continued, there are many land uses which are not easily determined through remote sensing and he felt that the scheme should also reflect these. Mr. Nez mentioned that many data needed by city and regional planners must be obtained from sources other than remote sensing. He felt that it would be impossible to select one particular land use classification scheme to fit all needs. As an illustration of this, he mentioned that the New York State scheme uses only eight or nine first level categories which are broken down at the second level with only three types of urban land use, two types of rural land use, and two types of public land use, etc. In using the scheme, he felt that a lot of improvisation would be necessary. He suggested that remote sensing data from high altitude aircraft and satellite overflights be interpreted and computerized for users, and made available from a central source or data bank.

Mr. Johnson thanked Mr. Nez for his comments and asked if anyone would like to comment further on this question.

Robert Alexander reported that there will be at least two centers for dissemination of remote sensing data to users, although interpretation will have to be done by the users themselves. These are: 1) the NASA Goddard Space Flight Center in Greenbelt, Md. for primary distribution, and 2) the Department of the Interior EROS Data Center located at Sioux Falls, South Dakota for general distribution to the public. Mr. Alexander commented that agreement on the broad, first and second level categories would aid tremendously in making remote sensing land use data available to users in a nationally compatible and acceptable format. Mr. Johnson agreed that concensus on basic land use classification categories was an important step in making high altitude aircraft and satellite data valuable to a wider variety of users.

George Orning, University of Minnesota, commented that in their work of classifying state land uses they found it necessary to gather most of the data themselves because they were either not otherwise available or not compatible with data already acquired.

H.N. Holtan, Agricultural Research Service, commented that the amount of detail in the land use classification scheme bothered him and perhaps other participants too. On the other hand, Sherman Winings, Agricultural Stabilization and Conservation Service, felt that it was too simple because some categories include several different uses at the primary levels. This would make interpretation difficult in different agencies. He suggested that the first two levels of the classification scheme be broadened.

While it is possible that more than one land use be included in a category, Mr. Johnson indicated that such multiple land uses could be noted on the map or in other types of data when they were issued to the public.

Gene Wunderlich, National Resources Economic Division, Department of Agriculture, mentioned that in defining land uses for a classification scheme you are faced with deciding upon a hierarchy of those uses. Mr. Anderson agreed that this was an important point. Mr. Orning mentioned that in his work on the State Land Information System at the University of Minnesota they have found this same problem. He explained the Minnesota land use classification system, and that they have compiled a list of many variables to aid in their analysis. Joseph Sizer, Minnesota State Planning Agency, commented that some data, such as geologic data, supply potential as well as present land uses. Mr. Anderson agreed that current land use is just one aspect but it is an important one to consider.

While discussion of these problems is of interest, Mr. Johnson said, it would take more time than we have at this Conference to resolve them so we must return to consideration of the land use categories.

Loyd Young, USGS Conservation Division, commented that what they need is data that are both repetitive and historical in order to indicate trends.

Edward Fernald, Florida State University, indicated he felt it was important to establish the scale at which information will be given. He suggested that the Conference decide upon scales at each classification level, and establish a guide or formula for the generalization of categories in the land use scheme.

Mr. Johnson commented that there are two types of information under consideration for land use classification--1) maps such as geologic, soils, vegetation, etc., and 2) computerized data in a wide variety of formats. These two sources of data, of course, meet in a computerized data bank but the problem is that such land use data banks are not yet operable and may not be for several years. In order to achieve at least a national overview of land use it will be necessary to reach agreement on the land use classification scheme at the first two levels. Such agreement will enable land use information to be uniformly interpreted, analyzed, digitized and retrieved from computerized data banks.

Mr. Orning and Mr. Fernald agreed with Mr. Johnson that a national land use data system would be very useful and that uniformity of a land use classification system was a necessary prerequisite.

In response to a question concerning the amount of information which may be gathered through remote sensing, Mr. Johnson said that would depend on the amount of money expended on the particular project. Remote sensors can obtain more data than are presently being used or analyzed. Mr. Tomlinson commented that in Canada they identified information from aerial photography down to at least six acre lots. John Estes, University of California/Santa Barbara, commented that the resolution of the data depends mostly on the amount of money to be expended to obtain it.

Roger Hoffer, Puedue University, commented that the ERTS satellite which is due to be launched next year may get data with a resolution of one acre.

Mr. Johnson asked if anything should be added to the AAG classification scheme?

Gloria McGregor, Metropolitan Council of the Twin Cities Area, commented that a category for idle land, which was included in the Standard Land Use Coding Manual, was not in the AAG scheme. Mr. Anderson responded that this is put into the third or fourth digit level of his classification rather than in the broader first two levels. Miss McGregor then asked how would you identify land areas not presently in use? Mr. Olson, Forest Service, and Grover Torbert of the Bureau of Land Management, also asked about public lands. Mr. Anderson responded that idle land and public lands could be placed in a category for low activity. Mr. Sizer commented that this might be a problem in identifying land for state planning purposes.

Ronald Becker, Office of Sea Grant Development, LSU, said that at the first level of classification perhaps we should consider land occupancy and then land activity. Mr. Anderson said this would be considered point data and Mr. Becker agreed.

Mr. Nez asked again about the possibility of getting a mix of different types of land use information from a central source.

Olin Bockes, U.S. Forest Service, commented that a land use data bank which contains basic national information would be of value to their work, but he did not feel it would necessarily have to include detailed information such as that at the third and fourth levels.

Govind Sharma, Alabama A & M University, questioned the need to have the recreational use of land included in a first level category as well as in the more detailed sub-categories of other first level categories in the AAG scheme.

Robert Keith, University of Oregon, commented that the standardization of land use classification certainly would be helpful to all who are working in the field. There was general agreement among the session participants concerning the need for standardization.

Mr. Johnson asked if any of the agency representatives would be interested in a map of the U.S., at a scale of 1:1,000,000, which showed eight or nine major land use categories?

Richard Allen, Dept. of Agriculture, Statistical Reporting Service, responded that his bureau would be very interested in such a map for sampling information.

Julius Mai, Soil Conservation Service, said that such information would be quite valuable in planning national programs for conservation of resources, environmental planning, etc.

Mr. Hoffer asked how often such a map could be updated? Mr. Johnson responded that it could be rapidly updated with the use of high altitude aircraft and satellite data, and the ease of keeping such data current was one of the really important points.

Mr. Hoffer then asked Mr. Anderson about including permanent and seasonal snow cover in the classification categories. Mr. Anderson replied that these probably would be covered best at the higher levels of the scheme because extensive permanent snow cover is located only in Alaska. Mr. Nez said, however, that snow cover was an important recreational factor. Mr. Johnson mentioned that various U.S. agencies keep track of snow cover, but permanent snow cover was quite limited.

Joseph Sizer said he agreed that it was necessary to reach agreement on the land use categories most needed on a national level, but he also pointed out that he felt it was necessary to agree on the size of information unit needed.

Mr. Johnson adjourned the session for lunch and said that they would consider the AAG classification system in more detail during the afternoon session.

* * *

Mr. Johnson opened the afternoon session by reading over the categories contained in the AAG classification system. He then asked for comments on each category.

I. Resource Production and Extraction.

II. Transportation, Communication and Utilities.

III. Urban Activities.

IV. Towns and other Built-up Livelihood Areas.

V. Recreational Activities

VI. Low Activity Areas.

VII. Water Using Activities.

Robert Douglass, Pennsylvania State University Dept. of Forestry, questioned the placement of recreation as a separate category and suggested that it be included under the category for resources. Mr. Johnson remarked that he believed Mr. Anderson had intended this category as a use or function of the land. Mr. Douglass agreed that this was a function of the land but felt that in the light of this morning's discussion there may be different uses or patterns for the same land areas.

Mr. Johnson agreed that there are many land areas which serve multiple uses but for a standardized classification system, the decision must be made in regard to basic uses. Mr. Tomlinson said that in the Canadian system they used the predominant use of the land as its classification. Mr. Douglass, however, felt that recreation should not be in a separate category because it might be misinterpreted.

John Antenucci, Maryland Department of Planning, commented that multiple uses of land could be distinguished through the use of computer coding.

George Nez asked Mr. Tomlinson if they had considered seasonal variations in deciding upon predominant uses of the land in Canada? Mr. Tomlinson responded that he did not have the details of the way in which such variations were considered.

Wesley Smith questioned the need for separate categories at the second level for agriculture and grazing land. Mr. Johnson replied that the scheme is activity oriented and, therefore, "agriculture" implies farming.

Grover Torbert, Bureau of Land Management, suggested that a separate category for wildlife be included in the scheme. Olin Bockes, Forest Service, mentioned that a category for fishing might be included. In this regard, Ronald Becker commented that such industries as shrimping and oystering could be included under resources, or a sub-category could be used for "mariculture" under the category for agriculture. Because of the difficulty of interpreting such things as fish or oyster beds from remote sensing data obtained from satellites or high altitude aircraft, it was suggested that these be included under the category for water at the first and second levels. Mr. Tomlinson commented that the first and second level categories are for those things which can be interpreted from high altitude and satellite imagery, while those at the third and higher levels require some prior knowledge or information from low altitude aircraft photos, field checks, etc. The more detailed the classification level, the more expensive it becomes to use. After some discussion of this point, it was agreed that the categories for the first two levels of the classification should be restricted to things which can be interpreted from high altitude and satellite data, and the third and higher levels of the scheme would include information obtained by low altitude aircraft photos, field checking, and other data sources.

Ronald Becker suggested that the second level categories for mining and quarrying be combined because it would be hard to distinguish between them. Mr. Anderson agreed that this was a good point. Mr. Becker also mentioned the possibility of including pipelines under the category for communications and transportation.

Population density, particularly in urban areas, was also discussed for possible inclusion in the higher levels of the scheme. Robert Keith, University of Oregon, mentioned that they have had problems in using the Census Bureau definition of an urban area. Tomlinson commented that in the Canada Land Inventory they used the category "Built-up" for everything that could be interpreted as such from the data. Mr. Anderson commented that the Census Bureau does not use the term "Built-up." Therefore, there is no definition for it in their work. It was suggested that urban areas and built-up areas be defined so that these areas can be uniformly interpreted. In this regard, Mr. Johnson commented that he understood the Census Bureau was not entirely satisfied with its definition of urban areas.

Continuing with consideration of the first level categories, Mr. Johnson asked for comments concerning the category for recreation. He mentioned that Mr. Douglass has already suggested that this be eliminated as a separate category at this level, and put in the third or fourth levels of the classification. Wallace Reed, University of Virginia, suggested defining recreation at this level in regard to the physical aspects of the land rather than from an activity viewpoint. Mr. Anderson commented that this question returns to the problem of primary activity of the land.

Olin Bockes suggested including unproductive land in the low activity category. Mr. Anderson said, however, that this might cause some problems. For example, the beaches in Florida are not actually productive land but neither are they "low activity" areas. Mr. Olson commented that the Canada Land Inventory defines "low activity" as land which does not support vegetation. John Estes, University of California/Santa Barbara, commented that they have a lot of sand dune areas in California which are used for recreational activities. He suggested that perhaps a change of terminology might take care of this problem.

Mr. Johnson said, too, that in Hawaii, almost barren lava areas are being used for housing and for raising certain crops. Wallace

Reed commented that perhaps we are mixing economic activities with physical characteristics--either one or the other must be decided upon. Mr. Tomlinson commented that the present land use mapping of the Canada Land Inventory was done in parallel with the four other surveys of the Inventory and in itself reflects simply the present uses of the land. After some further discussion of this problem, agreement was reached that "barren land" was preferable to "unproductive land."

After a short recess, Mr. Johnson listed the following categories for consideration:

1. Urban
2. Farming and Grazing
3. Forestry
4. Transportation and Communications
5. Low Activity
6. Water

He said that we could have a map of the United States showing only these six classifications of land uses or we could have a map more taxonomically detailed but with the same six categories. Would these six land use categories be sufficient?

Mr. Anderson felt that farming and grazing should not be included in the same category, and after a short discussion, the following categories were proposed:

1. Urban and Built-up
2. Farming land
3. Grasslands (Grazing)
4. Forest land
5. Low Activity (Wetlands, cold, barren land)
6. Transportation and Communications
7. Water
8. Mining & Quarrying (Extractive uses)

Gloria McGregor raised the problem of distinguishing between pasture and rangeland. Mr. Johnson responded that pasture is improved land while rangeland is not necessarily. Also, he said, most rangeland is also public land. Mr. Anderson disagreed, however, that most rangeland is also public land.

Mr. Antenucci asked how agricultural areas located within an urban area would be categorized? Another problem might be posed by certain industries which are located in rural areas. Mr. Johnson responded that such data be considered point rather than area data, and the category selected should reflect the principal use of the land. Mr. Hoffer suggested combining urban and industrial in one category, however, it was objected that there are both urban and rural industrial areas. Mr. Tomlinson suggested that the problem can be taken care of under the "Built-up" part of the category for urban.

Another question concerned whether the category for forestry also included wooded vegetation and Mr. Johnson said that it did. There was some discussion of the term "forestry" and it was suggested that this be changed to "forests."

Wesley Smith asked where Federal park land would be categorized, and Mr. Johnson replied it probably would go under the category for recreation. Mr. Douglass objected to putting park land under this category. This problem was discussed briefly as well as where military reservations should be categorized.

Ronald Becker questioned putting "wetlands" under the category for low activity as he said many of the wetland areas of the United States provide recreational, agricultural and industrial activities. Mr. Becker suggested adding wetlands as a sub-category under "water." There was some disagreement with this suggestion because, as Mr. Johnson pointed out, actually many of the other first level categories could include wetlands as a sub-category.

Mr. Johnson closed the session by saying that the discussions today, and all of the Conference sessions, will help provide a basis for a national land use classification scheme. The Conference Steering Committee will continue to work on the definitions of the categories and refine the scheme for use by national, regional, state and local agencies.

NATIONAL LEVEL PLANNING AND LAND USE INFORMATION NEEDS

SESSION 6

June 30, 1971, 9:00-10:15 a.m.

James Anderson, AAG and University of Florida, Chairman; Jerome Gockowski, Soil Conservation Service, Reporter, and Ronald Shelton, University of Illinois, Technical Advisor.

Chairman Anderson indicated that this session will meet until 10:15 a.m. After the coffee break, Sessions 6 and 7 will combine into a joint session and meet for the balance of the day. This will make certain that the ideas and suggestions of participants will more nearly represent a concensus of the Conference.

Mr. Anderson is hopeful that a land use scheme will be developed which will assist users in using ERTS-A data. Some participants in the Conference have suggested a follow-up meeting. Mr. Anderson felt that this is necessary and commented that surely some mechanism will be established to carry out this function, however, it isn't likely that this can be done before we need to experiment with the results of ERTS-A simulated space flights.

Items of major concern are first and second category levels and the third and fourth category levels can come later. We are trying to take existing schemes and incorporate them to see if we can come up with a scheme which can be utilized immediately. Another point to consider is the fact that there are many dimensions to the use of remote sensing data other than identification of land use. This may pose a hazard as we look only at the dimension of current use. However, because of cost factors and various other reasons we are starting with land use. The problem of multiple use of land is very much with us. The user must determine the primary use of a parcel of land regardless of its size. As Mr. Anderson indicated on Monday, the scope of this Conference may be considered too narrow by many people who would prefer a wider perspective. We are attempting, however, to keep whatever we do here as compatible as possible with existing systems.

Mr. Anderson indicated that he would like to continue discussion today of the eight categories proposed in Mr. William Johnson's session yesterday. These are: 1) urban, 2) farming land, 3) grassland, 4) forest land, 5) low activity (wetland, cold, barren), 6) transportation and communications, 7) water, and 8) mining and quarrying. Anderson asked the participants to review these categories and then we will move on to second order categories. Mr. Anderson suggested that the terminology be revised to agree better with existing land use classification schemes. He suggested adding "built-up" to the category for "urban." "Transportation, Communications, and Utilities" should remain as a separate category. He also commented that he preferred the term "agriculture" to "farming." "Forestry" is preferable to "forest land," "grazing" over "grassland," etc. if an activity oriented terminology is to be used in the classification scheme. Anderson suggested placing "fishing" at a lower level of categorization, although for certain states such as Maryland or Florida, this may be worthy of more emphasis. He felt also that "recreational" should be included as a first level category due to the millions of acres of national, state, and private parks. No change was recommended for the category on "water." During a previous session at this Conference there was much discussion of the term "low activity" as a category designation. The Standard Land Use Coding Manual uses "undeveloped," and the Canadian system uses "unproductive" rather than the designation of "low activity." Mr. Anderson then asked for comments on these categories from the participants.

Raleigh Barlowe, Michigan State University, commented that in a session he attended yesterday they had included some non-urban things within the urban category. He suggested adding another category of "service areas" to include military areas, sanitary and solid waste disposal and also cemetaries, as he feels these do not fit into any of the listed classifications. He also commented that recreation should definitely be a first order category term.

Govind Sharma, Alabama A & M University, proposed that woodland be used rather than forestry as a category designation because he felt that "forestry" tended to imply planted or commercial forests and include natural forest areas. Mr. Sharma also commented that a category for "fishing" might be misleading because interpretors cannot tell whether the water includes fish or not.

Mr. Anderson disagreed that "woodland" would be preferable to "forestry" as a category term because woodland is widely used to indicate wooded land not just forests. William Ogden, TVA Division of Forestry, agreed with Mr. Anderson that "forestry" is preferable as it describes both use and activity and is much broader in scope than woodland.

George Orning, University of Minnesota, commented that he agreed with the first level categories as they are presently listed. He felt that "recreational" as used here is good, but felt that it was a lower order activity and expressed the same feeling about "grazing" and "fishing." He commented that the first level category scheme should be kept as simple as possible. Mr. Anderson commented that we should not consider only those things which can be interpreted from remote sensor imagery as first level category features.

Ronald Becker, Louisiana State University, commented that in yesterday's session "occupancy" seemed to be primary in considering first level designations but today the emphasis seemed to be on "activity." Mr. Becker said he felt that "activity" should be considered in the second or third level categories. He also commented that the term "low activity" is somewhat meaningless as grazing, forestry, etc. are relatively low activity. He felt that "wetlands" are distinctive and should have a separate category. Mr. Becker was asked for his definition of occupancy and he replied that he felt this was the distinction between farms and farming, grassland and grazing, etc. Mr. Anderson commented that this seemed to be use of the land, and he had decided primarily on a cover approach for the first order categories he proposed.

Roger Hoffer, Purdue University, questioned whether the first order categories should only reflect the data available from remote sensing. There are two questions involved: 1) What can remote sensing provide that the users need? and 2) What do users need that remote sensing can provide? Remote sensor people are asking whether a land use classification can be set up which deals completely with a cover condition, or is a certain degree of ground truth required in order to set up a satisfactory calssfication? The answer to this question will help determine whether recreational activities should or should not be a first order category classification. Perhaps we should look again at what can and cannot be obtained from remote sensing imagery in regard to land use classification. Mr. Anderson commented that he had heard from various management people that "cover" classifications are not what is most useful to them. He asked for comments on this point.

Edward Hanses, U.S. Corps of Engineers, St. Louis, indicated that he felt that cover was important and useful in his work. Cover condition is considered a first order element by the Corps of Engineers. Mr. Hanses commented that he also felt that "recreation" should be included in the first order level, despite the fact that there are many recreational uses which would fall into the second or third levels.

Mr. Anderson indicated that he did not wish to argue the point in the context of the discussion but he believed that "use" and "cover" were not synonomous terms.

George Nez, Federation of Rocky Mountain States, Denver, asked how small an area or how far should we go in recognizing seasonal changes in identifying activities or uses?

Bob Douglass, Pennsylvania State University, commented that he wished to protect the classification rather than eliminate it. He felt, however, that if recreation is included in the first order level we will run into problems later on at lower levels, and he referred specifically to forestry. Forestry includes management of forest land for recreation. An example he cited is that in the Pennsylvania forests on the opening day of deer season there are more hunters in the forests than there are on both sides of the Viet Nam war. Therefore, he believes that recreation should be a second level category and commented that it could be included under most of the first order categories.

Jim Lyons, Bureau of Outdoor Recreation, asked if we are not forgetting an entire dimension in our thinking about classification? We are no longer dealing with a static map which is updated every 5, 10 or 20 years--we can now update information every 18 days. Should we consider the use of land for various purposes, i.e., capability of the land; in other words, how it is used at a given point in time, compared to what the land cover is as observed from imagery.

Mr. Anderson agreed with Mr. Lyons but said he was not in favor of mixing land capabilities with current land use in a classification scheme. Many are familiar with the Soil Conservation Service's land capability classification scheme, however, this would not necessarily be an effective scheme to classify land for recreation. Capability is a very subjective judgment, and "capability for what?" is a question that needs to be kept in mind. Some of the land which is in the SCS Class VIII might be our best recreational land.

Bob Keith, University of Oregon, still questioned the capabilities of remote sensing and what this technique can do for the classification of land use. He asked for an explanation of the value of remote sensing data for the benefit of those who did not know much about its potentials. If remote sensing imagery is to be the basis of the first order of land use classification, a better understanding of its capabilities is needed.

Roger Hoffer, Purdue University, undertook to explain the capabilities of the remote sensing program. He discussed the limitations and capabilities of the remote sensing systems. NASA will launch the first Earth Resources Technology Satellite (ERTS-A) in early 1972. This satellite will be equipped with a Return Beam Vidicon (RBV) system which consists basically of three television cameras aimed at the same spot on the Earth's surface. Each of these TV cameras will be sensitive to a different part of the spectrum--one in green, one in red, and one in infrared. The second system on ERTS-A will be a Multispectral Scanner (MSS) which consists of four different wavelength bands that will record data for the same spot on the ground. Since we are going to have repeated coverage every 18 days, some sort of automatic system for handling the data will be required. These data will be sent back to Earth by electronic signals and then converted into image form if needed. The spot being looked at by the sensor on the ground is about 1 acre in size. Mr. Hoffer explained the manner in which the flights would overlap day after day, thus providing synoptic data. The flight paths are about 80 miles wide. ERTS-B, to be launched in 1973, is similar to ERTS-A except that it will have a heat sensitive multispectral scanner capable of detecting heat energy. Skylab is scheduled to be launched about the same time as ERTS-B and is a manned satellite and will provide for film recovery. Many of the sensor systems on Skylab will be basically for medical and space research. The sensors on Skylab will include a 10-channel multispectral scanner which will gather data regarding material on the surface of the ground, and a 6-channel camera system. The advantage of the Skylab system will be much better resolution with film data available. The delay in getting data back and the difference in time in processing pose problems. The day following the launch of Skylab, three astronauts are to be launched and will join their capsule with the Skylab. The astronauts will remain with Skylab for 28 days, and then come down for a normal re-entry. About a 3-month turn-around time is required before the next crew can be launched. The second set of astronauts will go up for a period of 60 days and return. Then, after 30 days, a third group of astronauts will go up for another 60-day period.

Kenneth Dueker, University of Iowa, commented that planners are interested in more than one dimension and cover may be just one dimension. As a planner he is interested in how much gravel, how much forestry, how much grazing he has in a given county at one time, and also what is its capability. He has different location criteria depending on whether it is a section, a county, or a state. He may have a question regarding different points in time or a comparison of points in time.

The session adjourned at this time.

MAJOR LAND USE DATA SERVICES

SESSION 7

June 30, 1971, 9:00-10:15 a.m.

Arch C. Gerlach, U.S. Geological Survey, Chairman, and John L. Place, USGS, Reporter.

Mr. Gerlach suggested as examples of agencies which provide major land use data services, the Bureau of the Census, and the Statistical Reporting Service of the Department of Agriculture.

Benjamin Spada of the U.S. Forest Service described the records of forest inventories maintained by the Agriculture Department. They keep a computerized record of samples of the one-third of the U.S. which is forested. The data are in detail down to plot level. Particular reference was made to the Conservation Needs Inventory (C.N.I.). He pointed out that if land use maps from the USGS tell foresters only where the forests are, they do not fulfill the total information needs. What they need to know is: 1) area/volume of forest cover; 2) growth; 3) removal, and 4) ownership. They do not, as yet, have a rangeland inventory.

Sherman Winings and John Iverson described record keeping procedures of the Agricultural Stablization and Conservation Service. They have aerial photos available for virtually all of the United States, and land use records are plotted on top of the photos in the county offices. They hope to record all of the cropland for the Nation by centroids of field patterns using a UTM grid. They hope to get the centroids completed sometime this year.

Charles Crittenden reported that the Office of Planning and Program Support of the Economic Development Administration has recorded many economic factors to be used with their computerized composite map matrix on a four-square-mile grid. Either numerical or gray scale printouts can be produced. They have four states on the matrix and hope to have eventually all of the United States.

William Fischer, the EROS Program Manager, was asked to tell about the USGS-EROS Data Center being constructed at Sioux Falls, South Dakota. He reported that the EROS Program will be able to accept imagery and reproduce it in a variety of formats to meet public demand. The EROS Program will include information extraction as part of its image processing procedure. Examples of the products which may be forthcoming are:

1. Photomaps overprinted with a UTM grid.
2. Maps of the distribution of surface water.
3. Maps of the distribution of vigorous vegetation.
4. Maps of changes occurring between successive satellite images.

5. Records of mineral exploration findings.

6. Automatic data extraction of other types.

In summary, the output from the Sioux Falls facility will include raw data, cartographic products, and other information products.

Stanley Addess, EROS liaison representative to NASA Goddard Spaceflight Center, reported on the imagery to be expected from the ERTS and Skylab satellite missions. The ERTS-A satellite, to be launched in 1972, will have two sensor systems:

1. A return-beam video (RBV) system consisting of three television cameras, each operating in a different spectral band. Images from the system are rectified and calibrated so that a composite picture is possible.

2. A multi-spectral scanner (MSS) system operating in four bands, if it is ready by the satellite launching date. The MSS images will be registered automatically to produce a composite.

Both the RBV and MSS systems will operate in the visible and near infrared spectral bands. A UTM grid can be added to the images with a geographic accuracy of 60 to 100 feet.

The Skylab satellite will have three manned missions, and will return hard-copy film in a multispectral mode. Thermal infrared scanners and microwave sensors will also be utilized.

William Mitchell, USGS Geographic Applications Program, presented an experimental matrix diagram developed at the Geological Survey to measure environmental impact. Along one side of the matrix are listed commonly encountered actions of man, along the other side of the matrix are listed environmental features which might be affected by the actions. The degree of impact of each action is weighed on a scale of one thru ten. Several participants expressed concern that agreement could not be reached effectively on the definition of these weights.

The session adjourned to allow the participants to attend a closing Conference plenary session.

JOINT MEETING OF SESSIONS 6 AND 7

and

CONFERENCE CLOSING

June 30, 1971, 10:30-11:45 a.m., 1:30-3:15 p.m.

Mr. Anderson convened the joint session and turned the floor over to Arch Park of NASA Headquarters to give the participants some further background information about the remote sensor systems on the ERTS-A and ERTS-B, and Skylab satellites and on high altitude aircraft overflights. Mr. Park explained some of the characteristics of the equipment to be carried on the satellite platforms. He commented that NASA has learned quite a lot during their plans for the first experimental resources satellite (ERTS-A) and future resources satellites missions will benefit from their experience. Mr. Park indicated that NASA was more interested in the interpretation of the data than in the geometry of the data.

Mr. Park indicated that radar is feasible and the bugs have been worked out so that the image which is seen is corrected. There are, however, some problems with scanners. The curvilinear scan can be adjusted to come up to a rectilinear scan, resulting in a reasonably planimetric correct base map. Roll, pitch and yaw must be contended with in a spacecraft. Although the technology for correction has not been put together, it is available and all systems are known. A scanner mounted on the space platform will have the necessary resolution to provide imagery to make good maps. Geometrical corrections can be handled in the system but it is not cheap. Mr. Park commented that the ERTS satellite is very slow in rate and consequently the scan data does provide overlap. The best resolution would be about 200 feet.

In response to a question regarding the amount of coverage, Mr. Park answered that the United States will be covered in every pass of the satellite, regardless of cloud cover. There will be at least one complete picture of the Eastern U.S., and more than one for the West because the cloud cover is greater in the East. Mr. Gerlach asked if the entire 50 States would be covered and Park replied that all of the States and the U.S. Trust Territories would be included. Principal investigators of those research proposals accepted by NASA will be provided with their data requirements free of charge and other requesters may obtain data for a nominal fee either through the NASA Data Bank, the Interior Department for all U.S. land areas or from the National Oceanic and Atmospheric Administration for data obtained over water areas. Worldwide coverage will not be available because the satellite sensors will not be turned on at all times and the open skies policy will be adhered to. However, some foreign countries have made bilaterial agreements with the U.S. for such satellite data to be gathered. Mr. Park mentioned in particular that Mexico and Brazil have made such bilaterial agreements. The NASA Data Bank hopes to have data available to users within 10 days after the completed overflights, however, due to the time lapse in transfer, such data will not be available as quickly through other sources.

Mr. Park commented that this experiment was one of the largest NASA has undertaken and they expect to obtain about 300,000 data products a week from the overflights.

Mr. Gockowski asked Mr. Park about the resolution of the photography to be obtained by Skylab. Mr. Park said the Earth terrain camera has a resolution of about 100 feet and will have 18 film/photo combinations, with 17 filters and a polarizing filter. The lunar terrain camera has a 5-inch format, 18-inch focal length, and will provide 10-meter resolution in color. The film to be used in this camera is SO 242. It's resolution is in excess of 100 line pairs per millimeter whereas the human eye's capability is less than 5 line pairs per millimeter. Both cameras will be calibrated with the Department of the Interior and the National Bureau of Standards. Mr. Park said that a 10-acre field could be studied from resultant data, but that a 40-acre field would be easier. During Skylab orbit, pictures of star fields will be taken so that it will be possible to make measurements with the camera. The radiometer scatterometer has a scan area of 6 nautical miles and is an altimeter, radiometer and scatterometer. This device should work with an accuracy of 3 meters, however, we cannot track Skylab this closely. The L-band radiometer should not be treated as an applications instrument but frozen land can be indicated through its readings. The S-191 spectrometer will characterize the atmosphere. It operates from 0.4 to about 2 microns and has the same frequency responses as the scanner and cameras.

Mr. Anderson thanked Mr. Park for his resumé of the sensor systems and resultant data expected to be received from the NASA satellite and high altitude overflights.

Mr. Anderson then reviewed the first order categories which are to be identified mainly on the basis of land cover. These categories are:

1. Urban and built-up
2. Transportation, communications and utilities
3. Farming (agriculture)
4. Grassland (grazing)
5. Forest land (forestry)
6. Extractive
7. Water
8. Marshland
9. Tundra
10. Barren land
11. Permanent snow fields

In response to Mr. Anderson's call for comments or questions, Miss McGregor, Metropolitan Council of the Twin Cities Area, asked if marshland included fresh water as well as salt water? Anderson responded "yes." Another question concerned what was included in the "built-up" area and Anderson commented that there was a lot of "built-up" cover that did not fall into the Census Bureau definition of urban. Olaf Olson, U.S. Forest Service, asked if "grassland" included shrubs? Anderson responded that it did, but there was a possibility of adding shrub land to this category.

Mr. Anderson asked Prof. Roger Hoffer of the Purdue University Department of Forestry and Geography what his opinion was in regard to including shrub land with the grassland category. Mr. Hoffer replied that this would have to be decided upon by the users as it would be difficult to delineate boundaries.

Mr. Anderson then took up the proposed sub-categories for the urban and built-up category. These are:

I. Urban and Built-up

a. Residential
b. Commercial (trade)
c. Industrial (manufacturing)
d. Services
e. Recreational
f. Transportation, communications and utilities (only in urban areas)
g. Other (such first order categories as farming when occurring in a predominantly urban context)

Raleigh Barlowe, Michigan State University, indicated that the first order categories really describe land appearance or cover and it is the second order categories which are more important to planners and users of land use information. He commented, too, that most users will need to go on to the third and fourth levels. Mr. Barlowe agreed, however, that the first order elements as presented were sufficient for that level.

James Wray, USGS Geographic Applications Program, commented that there was a dilemma in attempting to make up a classification scheme to be used with information received from remote sensors versus information which is traditionally obtained. Mr. Wray agreed, however, with the tentative first and second order categories indicated by Mr. Anderson.

In response to Mr. Anderson's request for other comments, someone suggested "open space" instead of "recreation," however, Anderson said this would be covered in further breakdowns of the categories.

Mr. Tomlinson suggested adding "outdoor" to the recreation sub-category as there were many types of indoor recreation, i.e., movie houses, etc. which are not discernable at this level.

Ross Netherton, Bureau of Outdoor Recreation, asked what would be included under the "services" sub-category? Anderson responded that he was using this term in the context of the Standard Land Use Coding Manual, i.e., military areas, shopping centers, doctors, etc. These services are not necessarily identifiable by remote sensors. Mr. Netherton felt that perhaps this term should then be included with the other categories too.

Mr. Anderson then continued by outlining the sub-categories proposed for the rest of the first level. These are:

II. Transportation, communications and utilities.

No sub-categories proposed at this time.

III. Farming (agriculture)

a. cropland
b. pasture
c. orchards, vineyards, and horticultural areas

IV. Grassland (grazing, rangeland)

No sub-categories proposed at this time.

V. Forestry (forest land)

No sub-categories proposed at this time.

VI. Extractive (mining and quarrying)

No sub-categories proposed at this time.

VII. Fishing

No sub-categories proposed at this time.

VIII. Water

a. lakes
b. streams
c. ponds
d. reservoirs

IX Low activity land

a. marshland
b. tundra
c. barren land
d. permanent snow fields

<u>Afternoon Joint Session</u>

Mr. Anderson opened this session by stating that we are not only trying to get compatibility in land use classification in the United States but also it would be extremely useful at the international level. He asked Arch Gerlach to report to the Conference participants on the current information he has received in regard to international land use classification.

Among several foreign countries contacted by Mr. Gerlach, Japan seems to be conducting one of the most comprehensive land use survey and mapping operations. About 60 percent of Japan has been mapped.

The original purpose of the land use surveys was to provide information for reconstruction purposes after World War II. Two series of land use maps have been prepared--one at a scale of 1:50,000 and the other at 1:200,000. At the scale of 1:200,000, the land use classification used by the Japanese has categories for "Agriculture," "Grass Land," "Forests," "Parks," "Urban and Rural Settlements," and "Miscellaneous." All of these primary categories are then broken down into sub-categories. For example, "Agriculture" is sub-divided into "paddy fields," "up-land fields," "orchards," and "tea plantations." At the 1:50,000 scale the classification is much more detailed. Mr. Gerlach commented that he felt it was useful in considering the problem of land use classification to see what other countries have developed. He concluded his remarks by saying that he hoped that we could map the entire United States at a scale of 1:250,000 for land use purposes.

Mr. Anderson then continued the discussion of the land use categories he had presented earlier and he cautioned the participants not to try to get too many different sub-categories under the major categories for use on a national level.

Edward Davis, Bureau of Outdoor Recreation, commented that he did not see the necessity of having an "urban" category. He said today the definition for urban and rural land has not been too specific.

James Wray, USGS Geographic Applications Program, indicated that the classification scheme worked out in his project has two categories --urban and non-urban. These two categories are then further broken down into sub-categories.

Mr. Davis said that the Bureau of the Census has changed its thinking on the definition of urban areas. Mr. Anderson agreed this was true and commented that there is also a legal connotation to "urban."

Raleigh Barlowe said he was bothered by the definition of "built-up," particularly when areas such as Yellowstone National Park are included in such a category. He suggested we talk in terms of urban and urban oriented built-up areas. Mr. Anderson responded that national parks are not included in the urban built-up areas, although a previous inference might have been drawn on this point.

Robert Cook, University of Cincinnati, reminded the group that we are really considering categories for a 1:250,000 scale map for national land use planning and a 1:50,000 scale map for state level planning. We are not really concerned with maps and data collection for metropolitan planning.

George Orning, University of Minnesota, said that in his work they identify urban as including any 40-acre cell which contains five or more structures regardless of where they are located within the cell. Mr. Cook commented that if you are using satellite imagery it may not be possible to use the University of Minnesota definition of urban.

David Himmelberger, USDA Statistical Reporting Service, suggested combining the categories for agriculture and grassland. These could then be specified in the second or third level categories. He also commented that he believed we should define the scale of the maps in relation to the categories decided upon. Mr. Anderson asked him if he would favor putting grassland under agriculture as a sub-category? He replied that he felt it should be in the second or third level. He suggested putting cropland and pasture under agriculture at the second level and then orchards, etc. as third level categories. Mr. Himmelberger commented that he believed the Statistical Reporting Service would be very interested in having a land use map, at the first level, of the entire United States which could be updated rapidly with satellite data.

Ernest Hardy, Cornell University, said that in his experience with the New York State study, they had found it difficult to identify "pasture," and he urged that this term not be used in the scheme, at least not at the first or second levels. He commented that another problem is the transition of land from agriculture to other uses. It is a common error to consider land uses to be intensifying but this is not always true--land uses are also extensifying.

Mr. Himmelberger commented that the time element certainly should be considered because land uses are sometimes seasonal.

Mr. Gerlach commented that in the Japanese land use classification they use wild grassland and pasture as areas with hay crops, etc.

Mr. Anderson asked representatives from the University of Minnesota how they defined grassland and pasture and Mr. Orning replied that they use the term "pasture" for that area which is worked with machinery. They have not tried to identify grassland, but just use pasture and open land in their classification. Mr. Sizer commented that they try to determine what use idle land had been put to, but they do not try to predict future uses. He said a good deal of land is in a transition stage.

Mr. Barlowe commented that he was hesitent to combine the three categories of agriculture, grassland, and forestry because these categories constitute such a large area of the entire United States. He said that perhaps we would not be able to arrive at a good definition of "grazing" or "pasture" land. He questioned also where "farmsteads," "wood lots," etc. should be placed--under agriculture or under built-up?

Mr. Tomlinson felt that there should be a distinction between active agriculture and marginal farms going out of production. He commented that he believed the category for grassland should be kept.

Mr. Anderson said he felt that unless there were strong feelings to the contrary he was inclined to leave the first level categories as they are presently listed.

Mr. Anderson asked if there were any questions or comments concerning the category for forest land?

Mr. Fernald, Florida State University, commented that in Florida they had had a problem in categorizing land around Eglin AFB because much of it was forested. He suggested using a symbol to identify military areas.

Mr. Hardy suggested that the productive capacity of forest land should be indicated. There is a problem in identifying or delineating forest land from brush land. He felt that recreational uses and management decisions are not clearly visible on the surface and therefore these should not be included in the classification scheme.

Mr. Anderson felt that any land use categories for forest land should be compatible with the present U.S. Forest Service classification.

Olin Bockes, Forest Service, asked about the desirability of trying to identify areas other than those which are visible on the surface such as open pit mines and quarries. He felt that underground mines, gas and oil wells, etc. should not be included in the category for "Extractive."

Mr. Anderson commented that it might not be necessary to include "ponds" as a sub-category of water. He asked for further comments on the water category.

Mr. Bockes suggested including large water areas such as the Chesapeake Bay under the second level categories for water, particularly as such areas are readily identifiable and included important uses such as oyster and clam beds. Mr. Anderson agreed that this was a good point.

Mr. Crittenden asked about including coastal zones under this category. Mr. Gerlach commented that this was a very important land designation and perhaps it should be included in the first level. This is particularly true since the political controversey over the designation of "wetlands."

Mr. Gerlach reminded the participants that a first and second level land use scheme must be decided upon soon because the NASA high altitude and satellite overflight data must be utilized as rapidly as possible for optimum results. He thanked the Conference participants for their aid in helping to arrive at the proper decisions for the first and second level categories. In closing the Conference, Mr. Gerlach announced that several documents, the first of which will be a listing of attendees will be mailed to participants. Later, we hope to issue the set of papers given at the opening plenary session on June 28 and finally the complete Proceedings of the Conference.

* * *

PART B

A LAND USE CLASSIFICATION SCHEME FOR USE WITH REMOTE SENSOR DATA--PRELIMINARY VERSION

Prepared by

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for

Inter-Agency Steering Committee on Land Use Information and Classification

United States Department of the Interior
Geological Survey
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1972

THE NEED FOR STANDARDIZATION

The use of space borne platforms and the rapid development of remote sensing technology indicate that today the capability exists to produce a timely and accurate inventory of the current use of the Nation's land resources. It is now more important than ever before in the history of our Nation that a land use classification scheme be developed which will satisfy the majority of users in the local, state, Federal, and private sectors who deal with information on a nationwide basis. Although there are differing perspectives in the classification process and the process itself tends to be a subjective matter, there is nevertheless an urgent need for development of a standardized approach to land use classification which will meet most of the requirements of the users. Although it is very unlikely that the one ideal classification will ever be developed, this document presents a classification scheme which it is believed will meet most needs for land inventory information over all or major parts of our Nation. As will be seen later, more detailed classification will probably be required for regional users or more specific applications, e.g., forest or wildlife management, urban planning, etc.

A first approximation of a national framework for land use classification is being proposed which hopefully will:

1. Satisfy the needs of Federal agencies for an up-to-date overview of land use throughout the country on a basis which is uniform in date, scale, and categorization at the first and second digit levels;

2. Utilize the best features of existing, widely used classification schemes to the extent that the land use categories of such schemes are amenable for use with remote sensing;

3. Provide an open-ended classification system that will enable regional, state, and local agencies to develop more detailed land use classification schemes at the third and fourth digit levels to meet their particular needs, and still be compatible with each other and with a national system, and

4. Be receptive to data from instrumented satellite and high altitude aircraft platforms.

Land has many attributes or characteristics about which information is needed for planning, management, and other programs and uses. Present use is one of the characteristics of land that is widely recognized as a significant attribute, yet there is considerable diversity of opinion about what actually constitutes "land use."

One concept which has much merit and usefulness is that the term "land use" should refer to "man's activities on land which are directly related to the land." "Land cover" is another term that generally is interpreted to refer to the vegetational and artificial constructions covering the land surface. Some activities of man can be quite directly related to a specific type of land cover. For example, the presence of planted corn is likely to indicate that farming is the present land activity on a particular tract of land. Therefore, a reliable inference can generally be made from imagery on which corn can be identified as a type of land cover that farming activity, which may not actually be visible, is present. Recreational activities are often much more difficult to relate directly to particular types of land cover by use of only remote sensing techniques; therefore, direct field observation and enumeration are likely to be complementary techniques that will be needed to identify such land using activities effectively. This proposed land use classification is designed for primary reliance on remote sensing techniques at the more generalized first and second levels of categorization, therefore, the activity dimension of land use will appear at the third and fourth levels of categorization.

DEVELOPMENT OF THE CLASSIFICATION SCHEME

Several land use classification schemes designed for, or amenable to, use with remote sensing techniques served as an initial framework for the Conference on Land Use Information and Classification, held on June 28-30, 1971 in Washington, D.C. and co-sponsored by the U.S. Geological Survey, the National Aeronautics and Space Administration, and the Soil Conservation Service. Land use classification schemes initially proposed by Anderson were designed to place major reliance upon remote sensing. However, supplementary sources of information were assumed to be available for the more elaborate of the two schemes which he proposed.

From the extended discussions which took place at this Conference, the Steering Committee that planned and helped to interpret the Conference discussions proposed to test a land use classification scheme which could be used with remote sensor data with a minimal reliance on supplemental information at the more generalized first and second levels of categorization. At the same time, it was clearly recognized by those participating in Conference discussions that careful attention should be given to the need for compatibility with the more generalized levels of land use categorization found in classification schemes currently in use. Examples of currently used classification schemes are those of the Standard Land Use Coding Manual, the Inventory of Major Uses of Land and Water made every five years by the Economic Research Service of the U.S. Department of Agriculture, and the National Inventory of Soil and Water Conservation Needs, initiated in 1956 and carried out for the second time in 1966 by several cooperating agencies in the U.S. Department of Agriculture and the U.S. Department of the Interior.

In preparing a definitional structure for such a land use classification scheme, it was decided that the experience accumulated at the Center for Aerial Photographic Studies at Cornell University in carrying out the New York State Land Use and Natural Resources Inventory would serve as a valuable point of departure. Therefore, Ernest E. Hardy and John T. Roach were asked to collaborate in preparing the definitional framework presented in this report. The experience in New York State has been reviewed carefully in relation to the much more varied and complex definitional framework needed for the entire United States. As a result of this extended review, numerous alterations have been made in the definitions of land use categories used in New York State in order to make those definitions more applicable to the country as a whole.

In developing a land use classification scheme for use with remote sensor data that would be usable throughout the United States, attention was given mainly to the more generalized first and second levels of categorization. Definitions for each of the categories on these two levels of categorization were subjected to selective testing and evaluation by the staff of the Geographic Applications Program in the U.S. Geological Survey on projects using imagery obtained primarily from high altitude flights. Throughout this development and testing process, the need for more detailed land use categories at the third and fourth levels of categorization has been clearly recognized. The testing of the proposed classification scheme has been carried out on the following Geographic Applications Program research projects:

1. Central Atlantic Regional Ecological Test Site.

2. Phoenix Pilot Project.

3. Land Use Mapping for the Ozark Regional Commission.

Concurrently, research was being conducted by Lawrence R. Pettinger of the Forestry Remote Sensing Laboratory of the School of Forestry and Conservation at the University of California, Berkeley, and Charles E. Poulton of Oregon State University on "The Application of High Altitude Photography for Vegetation Resource Inventories in Southeastern Arizona," under contract with the National Aeronautics and Space Administration. This research has provided valuable insights into the land use mosaic of southwestern United States. The hierarchal classification of barren lands and natural vegetation (rangeland) for that part of the United States is a particularly significant contribution to the development of land use classification schemes and procedures amenable for use with remote sensing techniques. Some of the definitional structure for barren land and rangeland suggested by Pettinger and Poulton has been recognized in this land use classification scheme being proposed for use throughout the United States.

In using the land use classification scheme presented in this report, it is important first to recognize clearly that only the more generalized first and second levels of the classification scheme are

dynamics of
resource use

presented and, secondly, that the definitional structure is a first approximation which is capable of further refinement on the basis of more extended and varied use. It also must be remembered that the principal immediate objective for developing a land use classification scheme as soon as possible is to provide such a scheme for use on a number of major research activities associated with the testing of various remote sensing techniques. As previously emphasized, a more basic long-range objective is to provide a usable standardized scheme of land use classification that can be used on a national and regional basis. The successful attainment of this second objective is quite dependent upon effective revision and improvement that should result from widespread use of this proposed scheme. Of course, it will also be possible to use this proposed scheme with large scale imagery as well as with other land use data gathering approaches such as direct enumeration and observations.

CLASSIFICATION THEORY AND PRINCIPLES

There is no one ideal inventory of natural resources. Lack of recognition of this as a factor in developing inventories has led many to the assumption that once an inventory has been established, there should be no changes or adjustments in its organization. This has not been possible in dealing with resources associated with land use. There is no logical reason why we should expect one detailed inventory to be adequate for any more than a relatively short period of time. Land use patterns change, as do our demands on the natural resources which affect the creation of the patterns of land use. Each land use classification is made to suit the needs of the user, and few users of land use information are satisfied with an inventory that doesn't satisfy at least most of their specific or major needs.

We are often challenged to explain why land use inventories cannot be generated in a manner relatively similar to the taxonomic concepts on which vegetative and biological classifications are based. There are three major reasons why such systems have not been successful in land use classification. The first major reason is that taxonomic approaches assume there can be a separate class established to accommodate each and every variable in the items being classified. Instead of such a fragmentation process, land use classification is based upon our ability to aggregate various kinds of land use into one class. The two processes are essentially oriented in opposite directions. The other two major reasons are based upon the practical problems of acquisition of information on land use for any large land mass (air photos, maps, etc.), and the variability in the needs of the users of the information.

Characteristics of the resource inventory process.

One of the major controls on land use classification is the budgetary restraints of the user. There are few cases, if any, where availability of funds is not a factor in determining: 1) the complexity of the land use inventory, 2) the source of information to be used (it is rare to be allowed to do all of the field work that would be desirable), and 3) the caliber and skill of the technical staff available for the job. In all cases, the final product must adhere to this kind of a control mechanism. The end result is that the inventory developed offers only partial definition in certain areas of classification; or the area covered is reduced to a manageable size, or some combination of both of these restraints.

Two other characteristics of land use inventories--flexibility and repeatability--create certain unique demands on the structure of the inventory. It is desirable to be able to accommodate new or variable kinds of information, or to aggregate the acquired information into a variety of groupings. These are the features that flexibility can provide, but they should be recognized in the period of creation of the inventory. It is only at the higher orders or levels of a land use classification scheme that we should not expect some demand for inclusion of different kinds of land use other than what was originally expected. Flexibility allows the desired inventory to be viable for longer periods of time and to have a longer span of usefulness.

Repeatibility is an essential characteristic if we expect to use a classification as the basis of an inventory that provides information of changes in land use over a period of time. To be repeatable, unusually high quality descriptions should be provided. Each classification unit should be so thoroughly described in words, supplemented with pictures (both ground and aerial), that a different group of technicians can repeat the inventory at a later date. This is a more complex problem than is usually recognized, and most inventories end up being "one time" inventories because of lack of attention to this problem. If an inventory is to serve its purpose of establishing a "base line" of information at the time of its creation, then it must provide descriptive material adequate to allow it to be repeated.

Sources of information.

Land use inventories, since the period when air photos have been generally available, usually involve the application of some form of air photo interpretation. This source of information is usually supplemented, to some degree, by other sources of information, including roadside or aerial surveys, other kinds of resource maps, and thematic maps of social, cultural, or economic information.

The general use of air photos in the past three decades has added another form of restraint to the inventory process. We generally are required to inventory land use on the basis of what can be seen and identified to an acceptable degree of accuracy on black and white aerial photographs. Specialized photos are available, and are often used, but frequently the budget restraints of the projects preclude their use over large areas. Air photos, however, provide some desirable features for inventory use. They are inexpensive, generally unbiased and provide information at a known point in time, and under conditions that can usually be identified. Their interpretation, however, usually varies considerably according to the skill and background of the user.

Other sources of information include the skills and knowledge of individuals working on the inventory; reports, surveys; maps, and any other sources that allow us to geographically locate the data that contribute to the inventory.

As a general rule, it is more valuable to use uninterpreted information in an inventory. It is far more valuable to include the internal drainage characteristics of the soils than to make a map of areas where soil drainage is unsuited to a particular use. Almost all users of the inventory will find some use for the former data, but few would have a need for the latter. Also, interpreted information adds a high degree of confusion unless the work has been exceptionally well documented. Without acceptable documentation, interpreted information can negate the necessary capacity to repeat the inventory.

<u>The decision process</u>.

In land use classification it is rare to find the clearly defined classes we prefer to work with. In the presentation of classification theory, an illustration is often developed using bolts, screws, and nails as a population that needs to be classified. Our task is far more complex--we find ourselves debating the fine points of how to draw the line between water and land. At first the decision seems obvious, but as one considers the problems of seasonally wet areas, or coastal tidal flats, or of marshes, swamps and bogs with various types of plants providing some degree of crown cover, the assumed simplicity of the decision becomes more and more clouded.

This is a characteristic problem of the classification process, yet it is essential to the generation of any usable inventory. Most types of land use we wish to classify in the inventory process appear in a continuous gradation from zero (or no use) to 100 (full use). The problem that must be solved is where do we place the boundaries around the use we wish to classify. How small an area of land with discarded equipment on it should we allow to be called a junkyard? How large an area should we have in any particular use before we acknowledge the presence of that use? How do we resolve the problems encountered in areas of heterogeneous mixtures of equally significant land use? These kinds of questions are not easily answered.

In the case of the problem of identifying a point in the continuous gradation scale at which we will determine a land use change occurs, documentation and description may provide the main answer to the problem. In the case of the junkyard, for example, if we wish to identify any area over a certain selected size as a junkyard, this should be stated; and identification of the size on the basis of the source of information used and the criteria for this decision process should be established.

The above illustration is one of the less difficult problems to solve. In many areas of the country where land has been released from agriculture, large areas are in various stages of aforestation. Much of the land does not yet qualify for woods or forest, but there is a continuous gradation of cover from woody plant materials that start within a few years of when the land is dropped from crop production. It is possible to find areas where there is no discernible line to be identified as the change is generated from very low, sparse bush growth up to stands of marketable timber. The solution, for example, has had to hinge on well documented decisions as to where the line would be drawn to separate brush from forest.

At first this seems arbitrary, and contradictory to some of the goals previously stated, and it could prove to be that way. But if properly documented, with adequate description and illustrations, the quality of repeatability of the inventory can be preserved. This is a necessary activity in creating the classification for an inventory, and illustrates well the previously stated situation indicating that land use classification is most often a problem of how to aggregate land used into suitable classifiable units.

The above illustration serves also to re-emphasize the significance of the user's needs in developing the classification system. Obviously a commercial interest in forestry would require a very different breakdown of land in various kinds of vegetative growth than would a regional planner or transportation department engineer. The expected use will determine where the lines of separation shall be drawn.

Other areas of major problems in the decision making process include the interface between land uses. There are found to be areas where mixtures occur. A readily identified example is the large area of urban fringe, or suburban-influenced land found around urban areas. A combination of factors, including sources of information, funds available, significance of land use area, and minimum map units will form the basis for such decisions.

Similarly, in areas where multiple uses occur (such as grazed woodland areas), a variety of factors will be used to form a decision, or, in some cases, a separate class may be used, thereby avoiding making a decision.

Problems arise also in trying to satisfy the wishes of inventory users where a conflict of use occurs involving a mixture of cover versus activity. Many recreational activities fall in this area of concern. For example, hunting is a common recreation use of land, but most hunting is done on land that is better classified in the forest, range or agricultural land uses. Consequently, hunting as a land use may require a separate, uniquely classified inventory. It will not easily fit into an inventory based on the kinds of information sources we commonly work with.

Present land use is the major information that is mapped in a land use inventory. It is usually far too expensive to include factors of ownership (for large area inventories). Land capability classification also is frequently requested, but this implies an introduction of interpreted information, so it is better considered in a separate inventory format.

In certain instances problems arise due to dual land use activities. An example is the use of caves for production of mushrooms or other products. This kind of situation is not always easily resolved, but can be approached from the point of view of "highest use" concept, significant information concept, or it may be handled on the basis of point information sources.

In other cases confusion over large areas of conflicting land use can be resolved by the use of general statement or guidelines. Technically, the grazing of cattle, whether in the East or the West, is a "rangeland" type of use. However, management practices in the East are substantially different from those in the West, and it is not a simple task to resolve the difference in the classification description. But a major decision, based on operational management, that clearly states which areas of the country or states where the term "range" will be used instead of the term "pasture" can solve most of the conflict.

The classification.

Once a classification system has been decided upon, three basic rules, or standards, serve to guide us in its creation and use. The classification must be:

1. Comprehensive.

2. Allow discreet assignment of any item.

3. Provide a unique description of each item.

The classification should be comprehensive in two ways. It should allow for the classification of all the surface areas within the study area. And it also should provide a unit of reference for each land use. This may, and usually does, require the use of one classification unit entitled "other."

By providing a thorough, unique description of each item in the inventory (one that frequently states what isn't included as well as what is included), the most severe problems of discreet assignment are usually resolved. In any event these practices, combined with sound decisions concerning the margins, or cut-off points for each class, will allow any land use area to be assigned, without question, to only one classification unit.

Geographic location and recording information.

In all inventory attempts, some form of geographic referencing system is required. This may include only a reference to USGS topographic maps of the area, or it may be based on longitude and latitude, state plane coordinates, range and township system, the UTM grid (Universal Transverse Mercator), or any other grid system desired by the user. In all cases the service to be provided by geographic referencing is used as a basis for choice of referencing system.

An inventory cannot be of much use to its users unless some form of measurements are assigned to the items classified in the inventory. There are three major means of recording mapped information. They include measurement in units representing area, length, or points. Using these kinds of measures, we are able to quantify the information in the inventory. Many tools to assist in the process of measurement are available, but will not be discussed here. Storage and retrieval of such information can be handled in a variety of ways, ranging from manual recording of forms to storage and manipulation in sophisticated computers.

LAND USE CLASSIFICATION SCHEMES USED BY SELECTED FEDERAL AGENCIES

Several Federal agencies have for many years collected land use information of various kinds. However, relatively little financial support has been given at the Federal level to the maintenance of a comprehensive inventory of land use carried out at reasonable intervals and with sufficient emphasis on the collection of land use data for areal units small enough to make such information useful for planning, management, and other purposes. Eight agencies involved in land use data collection and inventory in 1965 submitted statements to Resources for the Future for inclusion in a report on Land Use Information: A Critical Survey of U.S. Statistics Including Possibilities for Greater Uniformity. This report evolved from an extended study made by a Committee on Land Use Statistics organized by Resources for the Future. The agencies submitting a statement on their land use information inventory and related activities were:

U.S. Department of Agriculture

Soil Conservation Service
Economic Research Service
Forest Service
Statistical Reporting Service

U.S. Department of Commerce

Bureau of the Census

U.S. Department of Transportation

Bureau of Public Roads

U.S. Department of Housing and Urban Development

Housing and Home Finance Agency
Urban Renewal Administration

Agencies in the U.S. Department of the Interior such as the Geological Survey, the National Park Service, and Bureaus of Land Management; Reclamation; Sports Fisheries and Wildlife; and Indian Affairs have also been involved in much inventory activity as part of their responsibilities.

However, none of these agencies have had the responsibility for making comprehensive or complete inventories of land use that would yield usable information at the county level or for areal units sufficiently differientiated for local, state, regional, or even national planning and management purposes. The U.S. Forest Service has collected data on land use since it was established in 1905. However, the Forest Survey provides information only for that part of the Nation's land area which is classified as forest land. The U.S. Statistical Reporting Service is primarily concerned with the collection of information on the land used for crop and livestock production. The Bureau of the Census collects a wide array of data in the several censuses which are conducted at five and ten-year intervals. For example, the Census of Agriculture contains information on land in farms. In general it may be stated that it is extremely difficult to obtain comparable information about the use of land resources in the United States from the several Federal agencies which have information on land use. Because of definitional problems or because the main types of information primarily for use within the agency, the Nation does not have at the present time an effective overall inventory of land use to service a wide array of existing critical needs.

The Economic Research Service and its predecessor agencies in the U.S. Department of Agriculture have maintained an inventory of the major uses of land which has been made every five years concurrently with the Census of Agriculture. However, this inventory provides data only for states or groups of states. The inventory is made by obtaining land use information from other Federal and some state agencies that have maintained such information for management or other purposes. Some of the data must be adjusted to allow for duplication among reporting agencies. Highway and railroad mileage is converted to acres. The information that is available from several agencies at any one time has been collected or compiled by those agencies over a period of time that may amount to several years in extent. For example, information obtained from the Forest Service on forest land may have been collected as early as 1963 for some regions. The Census of Agriculture was taken in the fall of 1969, and the next inventory from the Economic Research Service will be compiled on the basis of the latest information available from the various agencies as of 1969.

The last inventory by the Economic Research Service, Major Uses of Land and Water in the United States with Special Reference to Agriculture: Summary for 1964, Agricultural Economic Report No. 149, contains the following national totals for the major uses of land included in the inventory.

MAJOR USES OF LAND, UNITED STATES, 1964 *

	Million acres
Cropland	444
Cropland used for crops	(335)
Cropland harvested	(292)
Crop failure	(6)
Cultivated summer fallow	(37)
Soil improvement crops and idle cropland	(52)
Cropland used only for pasture	(57)
Grassland pasture and range	640
Forest land	732
Grazed	(225)
Not grazed	(507)
Special uses	173
Urban and other built-up areas	(29)
Rural highways, railroads, and aiports	(26)
Rural parks	(47)
Wildlife refuges	(29)
National defense, flood control, and industrial areas	(32)
State-owned institutions and miscellaneous other uses	(1)
Farmsteads, farm roads, and lanes	(9)
Miscellaneous land (marshes, open swamps, bare rock areas, deserts, tundra, and other land generally having low value for agricultural purposes)	277
TOTAL	2,266

* U.S. Dept. of Agriculture, Economic Research Service, Agricultural Economic Report No. 149, "Major Uses of Land and Water in the United States with Special Reference to Agriculture: Summary for 1964."

In 1956, and again in 1966, a National Inventory of Soil and Water Conservation Needs, generally referred to as the Conservation Needs Inventory, was initiated in the U.S. Department of Agriculture. These inventories were carried out by the several agencies of the Department principally concerned with land resources and their use and conservation. A major objective of these inventories was to make a systematic collection of information about land and water resources for each county in the United States.

The professional staff of the Soils Survey Division of the Soil Conservation Service was given the responsibility for assembling and analyzing the basic data on soil and land use conditions obtained from field mapping of many thousands of sample plots which constituted the sample. As a result of this work there is a set of data available for the first time showing acreages of soil conditions by land uses for nearly every county in the Nation. The samples are identified so the data can be compiled by any other desired subdivision that can be located by boundaries on a map, in so far as such subdivisions are large enough to give statistically valid results when data from the sample plots are expanded to represent the particular area being analyzed.

The basic sampling rate for the collection of the information on soils and land use was two percent of the total area. As a standard procedure another set of sample units representing an additional two percent of the total area was selected for use in those counties or parts of counties where a two percent sampling rate would not yield usable data. For many areas where intricate patterns of soils and land use were found, such as in irrigated areas in the West, the sampling rate was increased appreciably above the rates just mentioned.

Land use was designated by the following major classes: cropland, pasture and range, forest and woodland, urban and built-up areas, and other land. The definitions for each of these major categories of land use, and some of the more widely used sub-categories, were published in the summary statistical reports. The land use categories for the two Conservation Needs Inventories were essentially those used in other current Federal statistical sources, particularly those of the U.S. Bureau of the Census and the U.S. Department of Agriculture. In order to apply the definitions more effectively and accurately, both enumeration and observation survey methods should have been used, but funds available for carrying out the field work did not permit the use of enumeration in conjunction with observation. Therefore, some loss in preciseness resulted, particularly in handling such uses as rotation pasture, idle land, and woodland and forest cover of little commercial value.

The *Standard Land Use Coding Manual*, which was published in 1965, is a landmark of the 1960's contributing toward the attainment of greater uniformity in classifying land use. The coding manual was released jointly by the Urban Renewal Administration and the Bureau of Public Roads. In so far as was feasible, the Standard Land Use Coding Manual incorporated the category titles and detailed identification of activities from the Standard Industrail Classification (SIC) prepared by the Bureau of the Budget and published in 1957. The standard system for coding land use activity published in 1956 is comprised of nine one-digit categories (two of which have been assigned to manufacturing); 67 two-digit categories; 294 three-digit categories, and 772 four-digit categories.

The Standard Land Use Coding Manual provides a four-digit categorization of land use developed mainly for use in urban and adjacent situations in the United States. This classification scheme was not designed specifically for use with airphoto interpretation or other remote sensing techniques. Ground observation and enumeration obviously must provide much of the information necessary to classify land use with this scheme when used in urban areas. This Urban Renewal Administration-Bureau of Public Roads report has helped to establish a guideline for standardization in land use classification schemes being used by metropolitan governments. No complete inventory of land based on this classification scheme has been made for the Nation as a whole. Such an inventory would be very expensive to complete and maintain.

SOME SELECTED LAND USE CLASSIFICATION SCHEMES DEVELOPED FOR USE PRIMARILY WITH REMOTE SENSING

Marked improvements in the capabilities and efficiency of remote sensing technology in recent years have led to its use as a major tool in carrying out inventories of land use. A brief resumé of three separate inventory efforts is presented here in order to indicate how land use inventories are being effectively carried out with primary reliance on remote sensing techniques.

The State of New York has just completed a land use and natural resource inventory with major reliance upon airphoto interpretation with accompanying computer compilation, storage, retrieval, and mapping and tabular analysis of the information obtained. This inventory was designed specifically to "identify and record how the state's land resources were being utilized," (New York State Office of Planning Coordination: Land Use and Natural Resources Inventory of New York State, 1969, Albany), in order to provide the necessary information for the long range planning of the state's physical resources.

Several aspects of the methodology of the New York land use and natural resource inventory are worth noting. In the first place, the scale of aerial photography was specifically keyed to the 1:24,000 scale of existing topographic maps for the State, thus making effective use of earlier large scale maps. Secondly, the land use classification represented a compromise between the anticipated data requirements of various potential users and the main source of information which was aerial photographs. Thirdly, both land use areas and point data were identified and mapped. For example, an agricultural area identified was orchard land. Active farmsteads is an example of the point data obtained through airphoto interpretation. In order to make a meaningful generalization of the massive amount of information contained in the 989 maps at a scale of 1:24,000 necessary for total state coverage, a summarization of data by grid cells was employed. By using appropriate referencing units, such as political subdivisions, several different statistical analyses can be made by the computer. Thus, there is a clear recognition of the importance of the prompt analysis of inventory data if such information is to be used effectively for a wide variety of existing needs.

Minnesota has also made considerable progress on a geographically oriented inventory system. The Minnesota program which is being administered by the Minnesota State Planning Agency was developed in cooperation with the University of Minnesota. Some of the main features of the Minnesota Land Information System are:

1. Data collection is by 40-acre parcels.

2. Parcel data can be summarized by state, county, township, section and/or municipality.

3. Computer generated map and tabular output will be possible.

4. The identification for a 40-acre parcel and government lot is by legal description: county, township, range and section. Identification can also be specified by the latitude and longitude of the center of a township or minor civil division.

5. The standardized identification codes have interactive potential with other information systems such as the U.S. Census and the State River File.

6. The land use classification scheme being used has the following categories: Forested, Cultivated, Pasture and Open, Water, Marsh, Urban Residential, Urban Non-Residential, Extractive, and Transportation and Communication. No second order categories are shown on the published maps.

Currently Canada is conducting a land inventory for all of Canada that has been settled, which is approximately 800,000 square miles. In this inventory an effort is being made to assess and map land "according to its capabilities for various uses" and then relate these uses to various social and economic conditions. To do this in an intelligent manner there is a "need to collect a mass of information on the land's characteristics, and to organize this knowledge so that (it) can be put to good use," (Canadian Department of Forestry and Rural Development, 1966, The Canada Land Inventory: Ottawa). The inventory is a cooperative project between the several provinces and the Canadian government, which is being conducted under the Agricultural and Rural Development Act.

Recognizing that conventional maps have data limitations which need to be complemented by other analytical techniques, a geo-information system has been developed in order to cope effectively with the storage, analysis, and presentation of many different kinds of data about the many characteristics of land and the numerous physical, social, economic, and other conditions affecting the use of land resources. Aerial photography is being used extensively in collecting the great variety of information inputs and airphoto interpretation is being used as an analytical tool for the Canadian Land Inventory.

The Canada Land Inventory employs essentially a two-digit or two-level land use classification scheme which has six major or first order categories, 12 second order categories, and two third order categories. These are listed below:

I. Urban

1. Built-up area
2. Mines, quarries, sand and gravel pits
3. Outdoor recreation

II. Agricultural Lands

1. Horticultural, poultry, and fur operations
2. Orchards and vineyards
3. Cropland
4. Improved pasture and forage crops
5. Rough grazing and rangeland
    a. Areas of natural grasslands, sedges, herbaceous plants, and abandoned farmland whether used for grazing or not
    b. Woodland grazing

III. Woodland

1. Productive woodland
2. Non-productive woodland

IV. Wetland (swamp, marsh or bog)

V. Unproductive Land (land which does not, and will not, support vegetation)

1. Sand
2. Rock and other unvegetated surfaces

VI. Water

RESTRAINTS ON SOURCES OF INFORMATION AND RANGE IN SCALE OF IMAGERY

There is a natural relationship between the kinds and amounts of land use inventory information that may be obtained from various sensors according to the altitude ratio or resolution each will obtain. There is little likelihood that any one sensor or system will produce equally good information at all ranges of altitude.

The land use classification approach described in this report has been generated on the assumption that various kinds of sensors will serve the needs of various "levels" of the classification system. In a broad sense, the following relationships have been anticipated.

Classification Level	Source of Information
I	Satellite imagery, with very limited supplemental information.
II	High altitude and satellite imagery combined with area maps and USGS topographic maps.
III	Medium altitude remote sensing (1:20,000) detailed topographic maps plus substantial amounts of supplementary information, ground truth efforts, and new support information.
IV	Low altitude imagery, with a major proportion of the information derived from supplemental sources.

This report deals only with the first two classification levels in the system. There may be additional levels developed in the future, and if there is interest, one or two "higher levels" could be established starting with a simplified classification as basic as land and water.

The capabilities of the sensors will in large part, determine the levels of accuracy obtainable at each level of the classification system. At present we are quite well apprised of the capabilities of aerial photographs with ratios of 1:20,000 to 1:50,000 or more. We have limited experience with a ratio from 1:50,000 to 1:120,000, and there is essentially no experience available to draw on for classification from imagery at ratios of more than 1:200,000. Past experience in learning how to extract information from the now common 1:20,000 ratio imagery indicates we can expect improvement in our ability to work with other ratios of imagery.

With respect to the use of this proposed land use classification scheme, it is hoped that levels of accuracy in interpretation can be reached which will make the land use information of comparable quality to that obtained in other ways. When working at the more generalized category levels proposed in this scheme, a satisfactory level of accuracy in the interpretation process is reached for many users of land use information when the interpreter makes the correct interpretation 85 to 90 percent of the time. Attainment of higher levels of accuracy will generally come at much higher costs, which may not be justified for the uses being made of the information.

Some of the categories being proposed at Level II cannot be interpreted with equal reliability. However, it seems desirable that necessary steps or precautions be taken to attain satisfactory levels of accuracy in the interpretation process rather than to emasculate or distort the categorization in such a way as to reduce the number of useful applications for the land use information obtained. It is clearly recognized that in some parts of the United States some of the Level II categories being proposed in this classification scheme may be extremely difficult to interpret from high altitude aircraft imagery alone. However, conventional aerial photography at scales such as 1:20,000 is available from the U.S. Department of Agriculture and other sources. Furthermore, it may also be desirable to supplement the interpretation process for especially difficult categories in some areas by using sources of information other than remote sensor data. On the basis of limited testing in the use of this classification scheme in three widely separated parts of the United States, it is believed that the use of such supplementary information can be held at reasonable levels of cost.

There is currently very little expertise available in the use of automatic or semi-automatic equipment for interpretation processes. Although there have been a few major and dramatic developments, for the most part they are still experimental and will not be available for general use until some time in the future. These are some of the reasons it is anticipated that classification of land use from various kinds and scales of imagery will remain a manual task for at least an indefinite period of time. As better equipment and methods become available, this will gradually change to a semi-automatic process, and in the future may become fully automatic.

With the above comments in mind, it seems evident there will be an interest in the rate of development of interpretational skills, and in the sources of information available at each level of the classification system. For the purpose of this discussion, we have considered the problems of information retrieval primarily on the basis of visual interpretation.

It would be desirable to view each application and source of remote sensing information on the basis of the qualities and characteristics of such sources. It appears, however, to be very difficult not to include at least a minimum of supplemental information. This occurs from the practice of transferring the data or area information to a base map for conversion to area measurement. No matter what our guidelines, it is difficult to use a base map without extracting at least a minimum of supplemental information. Topographic maps will have an abundance of such information and even road maps, or a detailed city map, will contribute its sources of detail beyond the capabilities of the remote sensor image employed. As the level of detail of the classification becomes progressively more complex, it is assumed greater amounts of supplemental information will be used.

Considering the different levels of classification and their corresponding relationship to various sources of data, the following comments cover, in more detail, the characteristics of the various sources of information.

Satellite imagery from ERTS-A and ERTS-B will generally be prepared for the users at a ratio of 1:1,000,000. According to instructions in the Data Users Handbook (NASA, Goddard Space Flight Center) this will be the ratio expected when enlarged from a 70 mm negative image to a 9"x 9" photographic print format. At such a ratio, one inch represents about 16 miles. Even if information is generated by transferring to much larger scale maps, it will still call for a "general" classification approach--one that recognized or is based on major differences in land use.

The same generalizations would hold for information generated from image ratios at 1:250,000 or more. Consequently, the first level of classification is considered appropriate for these sources of information. In case more information can be obtained that would be a welcome benefit.

At the next lower level, Level II, the complexity of the inventory can be increased. Instead of being concerned with only nine major types of cover mapping, greater detail will allow classification on the basis of more specific uses of land resources. Level II units of classification are based on generally treated levels of information on retrieval from imagery at a ratio of about 1:100,000.

At this ratio, information can be transferred to fairly detailed maps even to 1:24,000 USGS topographic quads, with reasonable accuracy. This provides a substantial amount of supplemental input, but it also provides a very useful scale for intermediate detail of interpretation. At a ratio of 1:100,000, one inch represents about 1.6 miles, or 8,333 feet.

Following the succession of steps, at Level III we can look forward to using substantial amounts of supplemental information, plus remotely sensed information at a ratio of from 1:40,000 to 1:15,000. At a typical ratio of 1:24,000, one inch represents 2,000 feet, and this offers the opportunity to use methods of direct transfer of information to the 1:24,000 ratio 7-1/2 minute USGS topographic quads. At this level, surprisingly detailed inventories may be undertaken, and by using both remotely sensed and supplemental information, most land uses except those of the very complex urban areas, or the thoroughly heterogeneous mixtures can be adequately located, measured and coded.

Following the step system to Level IV of a projected classification would call for much more supplemental information and much larger scales of remotely sensed data.

Although these comments are merely references to general conditions pertaining to the sources of information anticipated at each level of the inventory process, they show the general relationships concerning what is expected to be the source or sources of information at each level of classification, and the expected capabilities of interpreters to be able to carry out the classification process at each level.

Table of Ratios and Area Equivalents

Ratio	Kilometer per centimeter	Hectares per 9 square millimeters *
1:1,000,000	10.0	1,110.0
1:500,000	5.0	277.500
1:250,000	2.5	69.375
1:125,000	1.25	17.344
1:62,500	0.625	4.336
1:24,000	0.24	0.639

* 3 millimeters represents approximately 1/8 of an inch. One eighth of an inch square is the minimum area within which most draftsmen can place a reproducible symbol.

A LAND USE CLASSIFICATION SCHEME FOR USE WITH REMOTE SENSOR DATA

In developing the accompanying proposed land use classification scheme, several precautions were taken to provide a reasonable degree of compatibility with classification schemes currently employed by several of the Federal agencies engaged in land use inventory activities as outlined above. However, when complete or nearly complete reliance is placed upon remote sensing as an inventory technique, it is not possible to obtain complete compatibility with the categorization of land use employed with enumeration and observation techniques of inventorying land use. Considerable care should be exercised when data obtained by remote sensing with these proposed definitions are compared with data obtained by enumeration and observation with category definitions written specifically for use with those data collecting techniques. It is obviously quite important that the definitional structure presented in the following section of this report should be studied carefully before analyzing land use information which has been classified in accord with the accompanying scheme.

Many persons working both as individuals and for many different Federal, state, and local government agencies have been engaged in generating information about land use and in making land use maps for many years. A level of confidence in remote sensor data has now been reached which justifies the preparation of this land use classification scheme for use primarily with remote sensor data. In the past the use of aerial photography has been a significant component of land use studies and the time is now at hand for the extension of these earlier activities in order to take full advantage of satellite and high altitude imagery. It must be clearly understood that this scheme, which is only for the more generalized Levels I and II, is intended to provide a framework for the generation of land use information and the mapping of land use throughout the entire country on a basis which is uniform in date, scale, and categorization. Hopefully, this scheme will permit regional, state, and local agencies to develop more detailed levels of categorization to meet their particular needs and still be compatible with each other and with a national system. Undoubtedly some of the more detailed land use information will have to be obtained by using other data collecting techniques in conjunction with remote sensing.

This classification scheme has been developed concurrently with rapid advances in remote sensor technology and electronic data processing. The ERTS-A and Skylab missions and the high altitude aircraft program of the National Aeronautics and Space Administration offer an excellent opportunity for nationwide testing of the feasibility of using this classification scheme for the purpose of generating land use information on a uniform basis. As further advances in technology occur, it may be necessary to make some modifications in the classification scheme for use with automatic data analysis. However, the urgent existing need for more and better land use information has created an immediate demand that needs to be met.

A LAND USE CLASSIFICATION SCHEME FOR USE WITH REMOTE SENSOR DATA

Level I	Level II	Level I (Digit)	Level II (Digit)
Urban & Built-up		01	
	Residential		01
	Commercial & Services		02
	Industrial		03
	Extractive		04
	Major Transport Routes & Areas		05
	Institutional		06
	Strip & Clustered Settlement		07
	Mixed		08
	Open & Other		09
Agricultural		02	
	Cropland & Pasture		01
	Orchards, Groves, Bush Fruits, Vineyards & Horticultural Areas		02
	Feeding Operations		03
	Other		04
Rangeland		03	
	Grass		01
	Savannas (Palmetto Prairies)		02
	Chaparral		03
	Desert Shrub		04
Forestland		04	
	Deciduous		01
	Evergreen (Coniferous & Other)		02
	Mixed		03
Water		05	
	Streams & Waterways		01
	Lakes		02
	Reservoirs		03
	Bays & Estuaries		04
	Other		05
Non-Forested Wetland		06	
	Vegetated		01
	Bare		02
Barren Land		07	
	Salt Flats		01
	Sand (other than beaches)		02
	Bare Exposed Rock		03
	Beaches		04
	Other		05
Tundra		08	
	Tundra		01
Permanent Snow & Ice Fields		09	
	Permanent Snow & Ice Fields		01

DEFINITIONS

In the definitional structure presented here an attempt has been made to include sufficient detail to permit a general understanding of what is included in each category at Levels I and II. In some cases exclusions are also emphasized. It has been clearly recognized that many of the uses described in detail will not be visible on spacecraft and high altitude imagery. However, in view of the general uncertainty as to what is included in many categories, it seemed desirable to have fairly detailed descriptions. Furthermore, it is anticipated that many possible users of this classification scheme will have large scale aerial photographs and supplemental information available. The definitional structure presented here will need further supplementation in order to make it fully operational. Some recommendations are made later in the report.

I. URBAN AND BUILT-UP

Urban and Built-up land consists of cities, towns, villages, strip development along highways, clustered settlements and isolated units of built-up uses. Sub-categories are: residential, commercial and services, industrial, extractive, major transportation routes and areas, institutional, strip and clustered settlement, mixed, open and other. The mixed sub-category consists of those areas where uniformity is not sufficient for the area to be classified as one of the other sub-categories. As networks of development grow, small blocks of land of less intensive or non-conforming use are often isolated in the center of small blocks. Agricultural, forest, water areas, etc. occurring on the fringe of Urban and Built-up areas will be excluded from the Urban and Built-up category except when such uses occur as an integral part of areas of low density urban development.

Isolated Built-up areas are to be included where minimum mapping unit restrictions are met. Such areas will include the surrounding landscaped grounds, storage sheds, parking lots, and similar land the use of which is associated with the built-up area. Some examples of separate units of built-up areas are:

Manufacturing facilities such as saw, textile, pulp and paper mills

Extractive areas plus their associated buildings and facilities

Warehouses, grain elevators, storage dumps, etc.

Transportational and power facilities, railroad yards, airports, electrical generating plants, etc.

Shopping centers

Auto wrecking yards

Motels, trailer courts

Institutions: schools, universities, colleges, hospitals, prisons and other correctional institutions, etc.

Military settlements and installations

Cemeteries

The Urban and Built-up land uses supersede other land uses when indecision occurs. To illustrate, even though a residential area may have sufficient forest cover to meet forestland criteria, it will be included in the Residential sub-category if possible.

1-01 <u>Residential</u>

Residential land uses range from high density urban housing to low density areas with relatively few living units per unit area. The variation extends from the high-rise apartments generally found in larger urban centered to those houses sometimes having lot sizes of more than one acre. Residential areas with large lots often are associated with high value housing, the periphery of urban expansion, or with situations where slope or environmental limitations on housing construction exist. Housing densities generally give a better representation of spacing than lot frontage measurements due to odd size lot frontages in comparison to total site size. The development of cluster housing, where the houses are concentrated in a small section with communal green areas, necessitates a perception of total area involved in relation to the number of housing units in order to get a proper perspective on density. The higher residential densities occur in the multiple-unit structures such as high-rise apartments, 3-5 story walk-ups, garden apartments, duplexes and other multiple family dwellings. The older urban areas often have very closely spaced single unit houses. High densities are also found in trailer courts and the newer apartment complexes being constructed on the urban-suburban fringe area. However, as one proceeds away from the urban core, generally the housing densities decrease. Larger houses and lots with spaces for driveways between homes and adjacent garages occur in many of the newer residential areas. However, recent development does not necessarily equate to large lot sizes.

Areas of sparse residential land use will be included under another land use category. In some instances the boundary will be clear when new housing developments abut against intensively used agricultural areas. Conversely, the residential boundary may be vague and difficult to discern when residential development is sporadic, and occurs in smaller isolated units developed over an extended period of time in areas with mixed or less intensive uses. A careful evaluation of density and the overall relationship of the area to the total urban complex must be made. Linear residential development often occurs along major and minor routes extending out from the urban centers. These residential strips should be included as residential appendages to urban centers. However, care must be taken to identify commercial strips which occur in the same locality. The residential strips generally possess a more uniform structure, size and spacing, linear driveway and lawn areas compared to the commercial strips which are more likely to have varying building size and spacing with large driveways and parking areas. Residential shoreline development is also linear, sometimes extending back only one residential parcel from the shoreline to the first road. This type of residential development is associated with water bodies such as rivers, small streams or canals.

Other land use categories may embrace areas that meet the Residential sub-category requirement. Often such residential sections are an integral component of a mixture of uses and diligent study is necessary for proper separation. The Institutional category includes military bases containing large areas of residential units in the form of barracks, apartments, dormitories or homes. Educational institutions, particularly colleges and universities, have housing for their faculty, staff and students in the form of apartments and dormitories often in close proximity to the instructional and research buildings. Primary industries which often have temporary labor demands sometimes have living quarters for laborers near the work base. Agricultural field operations and resort facilities commonly provide lodging for their employees. Since it is often very difficult to identify such residential areas satisfactorily, and since such residential areas are generally an integral part of the institutional, industrial or other category with which they are associated, these residential areas should be included with such other uses.

1-02 Commercial and Services

Commercial areas are predominantly connected with the sale of products and services. This category is composed of a large number of individual types of commercial land use, often occuring as a complex mixture of uses. Accurate individual identification would require the use of large scale base maps or aerial photographs, supplemental information and ground surveys. The central business districts of large cities may be the most easily defined portion of this sub-category. Individual units, gas stations for example, generally will not be identifiable with the use of only high altitude imagery.

The Commercial and Services sub-category includes the main building plus secondary structures and integral areas assigned to support the basic use unit. Included are sheds, warehouses, office buildings, driveways, parking lots, landscaped areas and waste disposal areas.

The commercial use area is often abutted by residential, agricultural or other contrasting uses which may help define the commercial area. In general, common types of Commercial and Service patterns can be recognized. However, they are not being differentiated at this level of categorization.

First, there is the urban central business district around which residential, industrial and other commercial areas are located and focused. These are the "downtown" banking and commercial centers where land use is undifferentiated at this scale of generalization. Retail stores, banks, office buildings, churches and governmental buildings such as post offices, libraries, fire houses and court houses are all included in the Commercial category. Some public uses for example, cemeteries which are placed in open land, and schools which are institutional are excluded if the required minimum unit size is present.

Secondly, there are shopping centers usually located in suburban and outlying areas which have distinctive patterns of parking and stores. Shopping centers are defined by the Community Builder's Council as "A group of commercial establishments planned, developed, owned and managed as a unit with off-street parking provided on the property... and related in location, size... and type of shops to the trade areas that the unit serves... generally in an outlying or suburban territory." Shopping centers range in size from those of just a few thousand square feet to plazas covering many acres of completely developed land. Large parking areas are the common feature of all shopping centers and constitute a large proportion of the total area. The larger customer parking areas are commonly on the side or sides of main customer entrances. Docking platforms, unloading ramps, trucks and often employee parking are located on the other sides of the buildings. Covered shopping plazas are becoming more common but are still generally identifiable as shopping centers if these same basic criteria can be used.

Thirdly, there is the commercial strip development, retail and wholesale sales and services which occur along major highways and access routes to cities in more or less a single strip. Road-front access is usually present, although off-street parking is not a necessity. Contrasting land uses behind the commercial strip are particularly helpful in delineating the area. Clusters of retail establishments occurring at crossroads are included in this category if minimum unit size requirements are met.

Frequently, especially in suburban areas, residential land uses--either strip or individual houses are interspersed within commercial areas. These uses are not separated out unless they exceed about one third of the total commercial area and meet the minimum unit size requirements.

Commercial resorts are businesses which cater to vacationing clientele. The resorts range in size from converted farm houses to luxury hotels, featuring associated recreational facilities including swimming pools, ball courts, golf courses, riding stables, ski slopes and even private air strips. Only the intensively developed areas of buildings, pools, courts, parking and intervening and intensely developed green areas are included in the Commercial and Services sub-category. The more extensive golf and riding areas should be included in their respective land use category or in the Open and Other sub-category of Urban and Built-up, if in an urban setting.

A number of specific types of land uses may cause identification problems in the Commercial and Services sub-category. Recreational uses are not identified at this second category level. However, a number of recreational activities warrant attention in a commercial and service boundary situation. Recreational areas should be included within a larger unit if they form an integral part of that activity.

To illustrate, most educational institutions have a considerable area of athletic fields, tennis courts and play areas which are a part of an overall scholastic program--even grade schools have recreational playground areas; these are then Institutional. However, if the sports area is self-contained, exemplified by a stadium for professional athletic events, it is Commercial. There is usually a major visible difference in the form of parking facilities, arrangement for the flow of linear traffic and the general association of buildings and facilities. Golf courses, which are usually located on the urban fringe, are to be classed at this level as Open land. Similar extensive uses, occurring in an urban setting but not meeting other category criteria are classed as Open land. Ski and toboggan areas and parks, for example, would be included in Open land.

1-03 <u>Industrial</u>

Industrial areas include a wide array of industrial types ranging from light manufacturing and industrial parks to heavy manufacturing plants. The light industrial activities are focused on design, assembly, finishing and packaging of products rather than processing of raw materials. Materials used have generally been processed at least once. Included are facilities for administration and research, assembly, storage and warehousing, shipping and associated parking lots and grounds. Research laboratories, electronic firms, trucking companies and even industries as large as automotive assembly plants illustrate light, industrial facilities.

Identification of these "light" industries can often be based on type of building, parking and shipping arrangements and location in relationship to urban areas. These industrial areas, however, are not necessarily directly in contact with urban areas. Many are now found at airport sites or located in relatively open country.

"Heavy" industries used heavy raw materials such as iron ore, lumber or coal. Included are steel mills, pulp or lumber mills, electric power generating stations (fossil fuel, hydroelectric and nuclear), oil refineries and tank farms, chemical plants and brick-making plants. Stock piles of raw materials, large power sources and waste product disposal areas are usually visible, along with transportation facilities capable of handling heavy materials. Rail or sea transportation connections as well as good highway routes are almost always present. Extractive industries are placed in a separate category.

1-04 <u>Extractive</u>

Extractive land encompasses both surface and sub-surface mining operations. The extracted material may be used directly or further processed. Included are sand and gravel pits, stone quarries--slate, granite, limestone, etc., oil and gas wells, coal mines, iron and other metallic ore mines, as well as other mines, i.e., salt, talc, gypsum, limestone, emery, garnet, clay, potash, uranium, phosphatic rocks, etc. The recognition of these activities on the landscape vary from the unmistakable giant strip or pit mines covering vast areas, to gas wells which may be less than a foot square. Obviously, uniform identification of all these diverse extractive uses with their varied degree of expression is extremely difficult from remote sensor data alone. Industrial complexes where the extracted material is refined, packaged, or further processed are included in the Industrial category. This is true even if the plant is adjacent to the mine. Ownership of large areas of future reserves in the extractive industry is common. These tracts are included in their appropriate present use category (i.e., Agriculture or Forest Land) irrespective of the area's expectation of future extraction.

Surface mining structures and equipment may vary from the minimum of a loading device and trucks, to expansive areas with access roads, weighing stations, conveyors, elevators, crushers, sorters, stockpiles, equipment sheds, numerous vehicles and processing facilities. Speciality equipment may exist depending on the product--stone quarries for dimensional or building stone needs, cutting machinery and hoisting tools. Quarries and many other deep surface mines are terraced for material removal along vertical cleavages or to facilitate multiple faces of operation and removal of material from great depths. Sand and gravel pits have more sloping walls because of material instability. However, the larger ones require the terraced roadways for access to the pit bottom. Strip mining involves the removal of the overburden to reach underlying material. Depending upon overburden thickness, the spoil piles vary in size but are usually very pronounced features. They often accentuate the excavation depth since the mounds are adjacent to them. Spoil material and slag heaps are usually found within a short trucking distance of the major mine areas. These may be the key indicator of underground mining operations.

Abandoned or unused extractive areas do occur, however, and their identification as abandoned or inactive is difficult.

Pits and quarries often become flooded when unused. If the water body is greater than 40 acres it will be included in the Water category, probably in the Lake sub-category. It must be remembered that presence of water bodies does not necessarily mean inactive or unused extractive areas, as ponds or lakes are often an integral part of an extractive operation. Areas of tailings and abandoned pits and quarries also strip mined areas may remain recognizable for a long time. These areas may be barren for decades after deposition, unless management practices such as liming are implemented to hasten the establishment of vegetation. During the interval from discontinued use until vegetative cover occurs the parcel will be retained in the Extractive subcategory.

1-05 Major Transportation Routes and Areas

The imprint of transportation land uses on the landscape is striking. They are major influences on other land uses, and many land use boundaries are outlined by them. The types and extent of transportation facilities available in a locality determine the degree of access to the area and affect both its present and potential uses.

Communications and utilities are included in this category, although long distance transmission of fuel, electricity or water do not always constitute a predominant use of the land through or over which they pass. Communications and utilities do, however, affect present and potential uses of adjacent areas and are a significant feature. The utilities demand a "right-of-way" which dominates some forms of future development and use. Communication facilities, while not involved in transporting material products, also logically fall in this category of land use. Highways and railways have areas of activity and linear connecting patterns. Airports and seaports including major lakeport facilities occur as isolated areas of high utilization with the intervening connecting areas undefined. Some waterports are connected by canals.

Some highways as a land use are readily identifiable on high altitude imagery. Highways include areas used for interchanges, limited access right-of-way, service and terminal facilities. The restriction to the limited access highway is thought to encompass the major portion of the right-of-ways visible from such imagery sources. Limited access was used as a criterion so that a mappable width minimum would be met. The limits of the right-of-way are usually visibly marked by fence lines with variations due to mowing or brush removal or both. The center mall, pavement and sizable buffer zone should be included even if exact boundaries cannot be detected. Interchanges, toll booths, restaurants, service stations, truck and auto parking and rest areas connected with these limited access highways are placed in this Transportation category since they serve highway users.

Areas of rail oriented facilities include stations, round-houses, repair and switching yards and related areas. The area of overland track is not included unless six or more overland tracks join giving sufficient width for delineation at a scale of 1:250,000. Switching yards have multiple tracks and associated towers, service buildings and other structures. The stations encompass both the passenger and freight sections and parking lots. Repair facilities are usually part of or are located close to a switching yard and the building has tracks leading into it. Stockpiles of replacement parts may be located in the vicinity. Spur connections from an active line are included in the Industrial or Extractive categories. The factory, mine, gravel pit or other activity that created the need for installation of the spur rail line also serves as an obvious end point for the spur.

Airport facilities include runways, intervening land, terminals, service buildings, navigation aids, fuel storage, parking lots and a limited buffer zone. Civilian, military, private and mixed use airports are included. Heliports are minor in area as are the land uses associated with seaplane bases. The buffer zones surrounding airports often extend outward from the runways. However, the airport usually exists on a fairly rectangular piece of land and is not a series of lines extending out from a maximum use area. The perimeter fence around the airport area usually creates a very sharp boundary that is generally visible on imagery. Small airports such as those located on rotatable farm land are not included.

Transportation areas embrace ports, docks, shipyards, dry docks, locks and watercourse control structures designed for transportational purposes. The docks and ports include buildings, piers, parking lots and adjacent water utilized by ships in the loading or unloading of cargo or passengers. Locks, in addition to the actual structure, include the control buildings, power supply buildings, docks and surrounding supporting land use, i.e., parking lots and green areas. Land owned by the water control agency, but obviously not committed to activities associated with the waterway is not included. Waterways are included under the Water category.

Communications and utilities embrace areas of facilities involved in transport of water, gas, oil, electricity and areas used for airwave communications. Pumping stations, electric sub-stations and areas used for radio, radar, or television antennas are the major types. Small facilities, or those associated with an industrial, commercial, or extractive land use, are included within the larger category with which they are associated.

TV-radio towers, microwave stations, airport radio navigation aids including radar facilities and light houses are illustrative of communication structures. Vastly larger areas than the antenna base is committed when the distance of tower anchors or tie-down areas are considered. The on-site buildings are encompassed in the area.

Long distance gas, oil, electric, telephone, water, or other transmission systems rarely constitute the dominant land use over land which they pass. If these uses are dominant and meet the minimum width criteria, they may be identified as transportation uses.

1-06 Institutional

Educational, religious, health and military facilities are the main components of this sub-category. Small areal occurrences of many of these items; for example, churches and some secondary and elementary schools, will be included within another category such as Residential or Commercial as they will not meet the minimum area requirements. Included within a particular institutional unit are all buildings, grounds and parking lots that compose the facility. The total of these institutional components will generally be sufficiently large enough to meet minimum unit size. Those areas not specifically related to the purposes of the institution should be excluded. For example, agricultural areas not specifically associated with correctional, educational or religious institutions are placed in the appropriate agricultural categories. Educational institutions encompass all levels of public and private schools, colleges, universities, training centers, etc. The entire area of buildings, campus open space, dormitories, recreational facilities and parking are included when identifiable. Orphanages, seminaries, novitiates and libraries are treated predominantly as educational institutions. Religious institutions include churches, monasteries, rectories, and convents. Health institutions include hospitals, mental institutions, sanitariums, special care centers and major clinics. Nursing homes are generally difficult to identify and are not included unless they are relatively large.

Military facilities have a wide variety of conditions including training camps, missile sites, etc. Administration, storage, repair, security and other functional military buildings, plus the practice ranges, storage areas, equipment storage lots and buffer zones compose the institutional military facilities. Auxillary land uses, particularly Residential, Commercial and Services and other supporting uses located on a military base should be included in the Institutional sub-category.

Correctional institutions include prisons, rehabilitation centers, etc. Walls are generally evident and controlled access points exist. Historial forts may be confused due to building similarities but the historical sites have larger parking areas and often smaller landscaped or grassed areas. Even though prisons are often in isolated areas, there are usually signs of outside activity areas such as farm lands nearby.

1-07 <u>Strip and Clustered Settlement</u>

Strip development along transportational routes may extend from population centers of any size. It is often composed of mixtures of Residential and Commercial use with occasional other uses such as Industrial or Institutional. When farmsteads are intermixed with other built-up uses such as strip or cluster settlement, then such farmsteads will be included within the Built-up land. Other agricultural land uses should be excluded.

Clustered Settlement refers to smaller cities, towns and other smaller, built-up areas where separate land uses are not distinguishable. Therefore, an intermixture of various residential, commercial, institutional and other land uses is covered in this sub-category.

1-08 <u>Mixed</u>

This category consists of Urban and Built-up mixture of the second level urban sub-categories. Up to one third intermixture is allowed in the second level. However, in many instances this level is exceeded particularly by the sum of several areas. Also, the different second level units may be too small to be included. Small to moderately sized cities and towns are a case in point. Often individual institutional plots of land are small and interspersed throughout the commercial and residential areas, even though their total may be large. Commercial uses may string out along main routes with the density of such a use sporadically increasing at particular points as at intersections. In addition, shopping centers may be minimal in size in comparison to the total. Mapping of short stretches of limited access highways would be very tedious. Open land proportions vary depending on the land's physical development limitations and the areas of such open land committed to uses such as parks, golf courses, etc. These different land uses may occur in varying size and spatial relation as to necessitate use of the Mixed category.

1-09 <u>Open and Other</u> (Urban)

Open land consists of golf courses, some parks, ski areas, cemeteries and undeveloped land whose appearance gives the impression of openness. The land may be very intensively used, but will not generally be in a use having structures.

2. <u>AGRICULTURAL</u>

In a broad sense, Agricultural land may be defined as including all land that is used primarily to produce agricultural commodities of many kinds. The sub-categories of Agricultural land are: Cropland and Pasture; Orchards, Groves, Vineyards, Bush Fruits, and Horticultural Areas; Feeding Operations and Other. Frequent examples are used in stating definitions for the Agricultural sub-categories because of the variations in uses and the complexities of multiple uses encountered in different parts of the United States. The second level categories vary in the intensity of use. For example, Orchards are generally a more intensive use than Cropland and Pasture. The interfaces of Agricultural with other categories of land use may sometimes be a vague boundary consisting of an intermixture of land uses at first and second levels of categorization. If farming activities are limited by wetness, the Agricultural category may be superseded by swamp forestland or by Non-Forested Wetland or by Water. The exact boundary may be very subtle and difficult to locate.

The chief indications of man's agricultural activity are the curvilinear, rectilinear, or other straight-lined imprints made on the landscape. However, pasture and other uses, where mechanized equipment is only used infrequently, may not necessarily conform to rigid or well defined shapes. Symmetrical patterns are also representative of the Urban and Built-up category, because of street layout and development by blocks. These symmetrical patterns have often originated in the prior agricultural uses of the land. Separation between the Agricultural and Urban and Built-up categories generally should be possible on the basis of urban activity indicators and because of the associated concentration of population. The number of building complexes and the density of the road and highway network is much more limited in the Agricultural areas than in Urban and Built-up situations. Some land uses, such as parks and large cemeteries, can be mistaken for Agricultural uses under certain conditions, especially when they occur peripherally to urban areas.

2-01 Cropland and Pasture

Cropland and Pasture includes:

1. Cropland harvested, or land from which crops are harvested other than tree and bush crops, grapes, and horticultural crops.

2. Cultivated summer fallow.

3. Land on which crop failure occurs.

4. Cropland in soil improvement grasses and legumes.

5. Cropland used only for pasture or pasture in rotation with crops.

6. Pasture on land more or less used permanently for that purpose.

A great variety of crops and pasture grasses and legumes managed in many different ways are a part of the Cropland and Pasture category. For most users of land use information it is desirable to be able to make a separation between the Cropland and Pasture components of this category. However, such a separation cannot generally be made with a high degree of accuracy and uniformity from imagery alone. Ground observation and enumeration are often needed in order to make a complete and uniform separation of these two components. Since it is assumed that such observation and enumeration will not generally be available in the compilation of information on land uses at the more generalized first and second levels, these two uses have been combined. However, some definitions of the main components of Cropland and Pasture are given below.

Numerous variables must be recognized in identifying Cropland and Pasture uses of land in different parts of the United States. Field size is highly variable depending upon topographic conditions, soil types, sizes of farms, kinds of crops and pastures, capital investment, labor availability, and other conditions also vary markedly.

Irrigated land in the western states generally has a distinctive pattern that is fairly easily recognized in contrast to Rangeland or other uses with which it is intermingled. In the eastern United States, supplemental irrigation of cropland and pasture by use of overhead sprinklers cannot necessarily be detected from imagery except where distinctive circular patterns are created. Drainage or water control on land used for cropland and pasture may also create a recognizable pattern that may be helpful in identifying this type of land use from imagery.

The duration of crop growth in the field may be rather limited. A false impression of non-agricultural use in a field may result if the conditions of temporary inactivity are not recognized.

Characteristics and components of the several sub-categories of Cropland and Pasture are briefly noted below mainly to serve as a guide to effective identification of Cropland and Pasture as a category rather than for the purpose of identifying sub-categories within this overall category of land use.

(1) Cropland harvested consists of land from which one or more crops were harvested. Such crops may be grouped in various ways such as food crops (including wheat, rice, potatoes, sugarcane, sugar beets, soybeans, fruits and nuts, vegetables, etc.); feed crops (including such predominantly feed grains as corn, oats, barley and sorghums and all hay crops); and other crops (such as cotton, flax and tobacco). Another useful way of subdividing the components of cropland harvested is to consider the way in which they are grown, thus recognizing such sub-categories as inter-tilled or row crops (such as corn, soybeans and sorghums), close sown annuals such as small grains (wheat, rice, barley, oats, rye) and close sown perennials such as the hay crops.

(2) Cultivated summer fallow is cropland which is allowed to remain fallow generally every other year of cultivation to conserve moisture and control weeds and prepare for the planting of small grains. Wheat is the main crop planted on cultivated summer fallow land. Cultivated summer fallow is found mainly in the drier western part of the Great Plains, on the Columbia Plateau in Washington and Oregon, and to some extent in the Great Valley of California and elsewhere such as in parts of Utah and Idaho. The patterns formed by this practice generally consist of alternating strips of sown wheat or other grains and bare cultivated fallow. Sometimes these strips of fallow and grain are arranged diagonally to property lines in order for the strips to be at right angles to the prevailing northwest wind direction in the Great Plains. Cultivated summer fallow land often has a protective stubble surface to curtail wind erosion. Thus, cultivated summer fallow can generally be recognized except in areas where irrigated cropland may be nearby and except in the transition areas with the eastern Great Plains croplands where cultivated summer fallowing is not a common practice.

(3) Land on which crop failure occurs has received the basic inputs for agricultural production and appears as cropland to be harvested until the cause for failure occurs and becomes evident. The effects of hail, wind, freezes, flooding, or fire are dramatically apparent in a short time period. Drought, disease, pest infestations, elemental toxicities or starvations have a more variable developmental time and strength of manifestation. Even when these impairments are expressed the land remains classified as cropland.

(4) Cropland in soil improvement grasses and legumes and idle land. The identification of grasses or legumes grown for soil improvement or current crop production is impossible without management interviews. Often a leguminous crop is grown for both soil improvement and present use. Idle cropland may be left unplanted for a year or two only; however, some of it may be poorer cropland that represents abandonment for crop purposes.

(5) Cropland used only for pasture or pasture in rotation with crops. Cropland used only for pasture is a sub-category of cropland as enumerated in the Census of Agriculture. It is very difficult or impossible to differentiate this type of pasture from other pasture without a management interview. Rotatable pasture is found on land capable of being worked by agricultural machinery. Such pasture is a component of crop rotation and, therefore, the land is only being temporarily used as pasture. The major identification of this cropland component is the method of harvest, and this is not identifiable from sources of remotely sensed, small scale imagery.

(6) Pasture on land used more or less permanently for that purpose. Pasture is defined for the National Inventory of Soil and Water Conservation Needs as being land producing forage plants, principally introduced species, for animal consumption. In addition to regulating the intensity of grazing, management practices usually include one or more recurring cultural treatments such as reseeding, renovation, re-establishment, mowing, liming, or fertilization. Pastures may be on drained and/or irrigated lands. Land where the management objective is to establish or maintain stands of grasses such as bluegrass, orchard grass, or bermuda grass, either alone or in mixtures with white clover or other legumes, should be included in pastures regardless of treatment. Where forage producing lands fall predominantly within the definition of pasture, "native pasture" should be placed in the Pasture category because of location or soil limitation even though treated like rangeland.

Much of the "permanent" pasture occurs on land which is usually not tilled or used as cropland. Topographically rough land, stream bottoms, wooded areas, stony or rocky land and wetland may often be used for pasture more or less permanently, particularly in the eastern United States.

Scattered brush may suggest placement of pasture in a sub-category of Forestland. However, the decision must be based on such factors as the number of farm operations evident in the area, thickness of brush and other use indicators of pasture and rangeland have to be studied to arrive at a conclusion.

2-02 <u>Orchards, Groves, Vineyards, Bush Fruits and Horticultural Areas</u>

Deciduous fruit crops, citrus fruit crops and nut crops are grown in orchards and groves. Vineyards consist mainly of grapes. Bush fruit areas include such crops as raspberries, blackberries, cranberries, blueberries and currants. Horticultural areas include nurseries, floricultural areas and seed and sod areas used perennially and not generally rotated with other uses.

Use of only satellite and high altitude imagery as well as the scale of generalization will cause many of these uses to be included in another category, generally Cropland and Pasture. Orchards, groves and vineyards generally occur in areas possessing a specific combination of soil qualities and climatological factors. Water bodies, which moderate the effects of short duration temperature fluctuations, are often in close proximity to these types of farming. Site selection for air drainage on sloping land may also be important. Deep, well drained soils with slopes moderate enough to permit use of machinery are also sometimes chosen. Isolated orchards of a few acres in size do not constitute commercial orchards large enough to identify on high altitude imagery. Remnants of the few acres of fruit trees on the family farm are usually not in active operation, not easily recognizable and, therefore, not included.

2-03 <u>Feeding Operations</u>

Feeding Operations consist of large, specialized livestock production enterprises. Beef cattle feedlots and large poultry feeding enterprises are dominant in this sub-category but large hog and fur-bearing animal feeding operations are also included and will be visible on high altitude imagery. Poultry includes chickens, turkeys and ducks, while feeding operations associated with fur-bearing animals are exemplified mainly by mink and fox. These feeding operations have high animal populations restricted to relatively small areas, which produces large amounts of waste material that is an environmental concern. The waste disposal problems resulting from the above activities justify a separate sub-category for these relatively small areas.

Feeding Operations have a built-up appearance chiefly composed of buildings, much fensing, access paths and waste disposal areas. Some of the feedlots are geographically located near an urban setting to benefit from transportation facilities and proximity to processing plants and markets. Beef cattle feeding operations, in particular, may also have an intensively cropped area in close proximity which is used as a source of feed. The feeding of broilers and chickens producing eggs in large housing units or sheds adjacent to each other is common; therefore these should be included in the Feeding Operations sub-category. Poultry and mink production may have no crop production areas associated with them, but relatively large concentrations of such operations can be seen on imagery taken at high altitudes.

Feeding operations that are found in conjunction with another farm enterprise are not included in this sub-category. Strictly commercial operations that dominate the activity constitute this category. Also excluded are shipping corrals and other temporary holding facilities. Game farms and zoos do not meet the animal population densities to be placed in this sub-category.

2-04 Other Agricultural Land

Inactive agricultural land is an important component of this sub-category. Such land has no physical indication of present agricultural use and no natural cover, such as brush, which would curtail its ready use for agriculture. This sub-category is used when cropland and pasture use characteristics are no longer visible, although they may not be obliterated completely for a few years after use of the land for those purposes. Brush growth regeneration may also occur sporadically, often due to variations in soil or seed supply. If the minimum forest cover criteria are met, then such land shifts from Agricultural to Forestland.

Farmsteads, including holding area for livestock, farm lanes and roads, ditches and canals, small farm ponds and other similar uses also constitute Other Agricultural Land. However, such areas are generally quite small and often unrecognizable from high altitude imagery. Therefore these uses will generally be included with adjacent agricultural uses.

3. RANGELAND

Rangeland is defined as occurring generally in a geographic region west of a line running from central North Dakota to the tip of Texas. This boundary was established in the 1936 Senate report, "The Western Range: U.S. Senate Document No. 199." Also, in the southeastern United States, particularly in central Florida, nonforested rangeland may be found. The Rangeland sub-categories found in the West are Desert Shrub, Chaparral and Grass. In Florida, the Savanna (Palmetto Prairie) range is found in the vicinity of Lake Okeechobee; however this rangeland does not include the poorly drained Everglades sawgrass areas. Rangeland vegetation is mainly natural or native vegetation that is capable of being grazed. Management practices include brush control and regulation of grazing intensity and season of use. If it is revegetated to improve the forage cover, it is managed like native vegetation. Generally this land is not fertilized, cultivated, drained, or irrigated. The definition of rangeland used for the Conservation Needs Inventory, carried out by cooperating agencies in the U.S. Departments of Agriculture and Interior, describes the natural potential (climax) plant cover as being composed of principally native grasses, forbs, and shrubs valuable for forage. This includes natural grasslands and savannas such as prairies, juniper savannas, or brushlands.

Stoddart and Smith depict the range area as being sud-divided into nine categories:

Short grass	Bunch grass	Chaparral
Tall grass	Northern Desert Shrub	Pinion-Juniper
Desert grass	Southern Desert Shrub	Coniferous Forest

Many of these categories represent inclusion of non-rangeland within the range territory. The Coniferous Forest and some of the Pinion-Juniper will be included in the Forestland category. Areas too arid to support vegetation sufficient for grazing are included in the Barren Land category.

3-01 Grass

This sub-category encompasses the tall grass (or true prairie), short grass, bunch grass or palouse grass and desert grass regions. These grass regions generally represent a sequence of declining amounts of available moisture.

The Western Range Report estimates 18.5 million acres of tall grass range. Most of the tall grass region has been plowed for agriculture. The bulk of the tall grass range is now in four widely separated places--North Dakota, Nebraska, southern Kansas and Oklahoma, and the Texas coastal plain.

Short grass rangeland occurs generally in areas receiving between 10 and 25 inches of precipitation, mostly in the spring and summer. It occurs in a strip about 300 miles wide from the Texas panhandle northward to the Dakotas. At its northern extremity its extent widens; covering the western half of the Dakotas, the eastern three fourths of Montana and the eastern one third of Wyoming. Blue grass and buffalo grass are the dominent grass species.

3-02 Savannas (Palmetto Prairies)

The Palmetto Prairies found in south-central Florida to the north, west and southwest of Lake Okeechobee consist mainly of dense medium tall grasses with scattered palms and shrubs. Wire grass and saw palmetto are dominant. Many areas of this rangeland type are now in improved pasture.

3-03 Chaparral

This category includes California chaparral, the scrub oak or shinnery, and the mountain brush types. Examples are mountain mahogany, bitterbrush, ceanothus and mazanita. The term "chaparral" is of Mexican origin. It means specifically evergreen scrub oak or oak brush but has come to apply to almost any shrub type. In this classification scheme "chaparral" reflects the specific species composition mentioned above.

3-04 Desert Shrub

Vegetation of this arid and semi-arid climatic zone includes the creosote bush, sagebrush, greasewood, winter fat, desert shrub (black brüsh, acacia, horsebrush, etc.). Other species occur in areas with a differing growth environment than that of the overall territory. Bottom lands and moister flats are characterized often by dense stands of mesquite. Where alkali is high, desert saltbrush dominates wide areas. Common upland shrub species are cat's claw, mesquittillo, tar-brush, palo verde, soapweed, iron wood, canotia, ocotillo, Joshua tree, bear grass and agave. An understory of annual native and introduced plants exist and are generally of greater grazing value than the shrubs. These grasses include alfilaria or filaree, six-week fescue, Indian wheat, bur clover, annual bromes, annual oats, and foxtails and tarweed. Perennial grasses that occur in the desert shrub region, other than the dominating Aristida, Bouteloua, and Hilaria of the true desert grass lands, are bush muhly, big galleta, cotton grass, carly mesquite, alkali sacaton and lovegrass.

4. FORESTLAND

Forestland includes lands which are at least 10 percent stocked by trees of any size and capable of producing timber or other wood products, or of exerting an influence on the climate or on the water regime; land from which the trees have been removed to less than 10 percent stocking and which have not been developed for other use and aforested areas.

The Forestland category can generally be fairly easily identified from high altitude imagery, however, transitions into other uses are often difficult to delineate precisely. At Level II, forestland will be categorized as follows:

Deciduous

Evergreen (coniferous and other including tropical broadleafed evergreens)

Mixed

In order to make an effective differentiation of forestland into these three Level II categories it will be necessary to assume that sequential imagery will be needed or at least that imagery will be available during that period of time when deciduous trees are bare.

The areas having forest rotation, which may involve clear-cutting and block planting will need to be recognized as part of the Forestland area. Some species that reach marketable size, which for pulpwood may regularly occur in two to three decades in the southeastern United States, will have considerable areas that may have little or no visible forest growth. In some forest areas this pattern can be identified where logging areas occur in the midst of large forest expanses. Unless clues as to alternative uses exist, such areas should be included in the Forestland category.

A ranking of the various land use categories does exist and, though a parcel meets Forestland requirements, it will be placed in the higher priority category if it meets the criteria of that category. To illustrate, a residential area may have both the forestland and residential requirements, however, it will be included in the Residential category. This could occur frequently when older residential areas are being identified.

4-01 Deciduous Forestland

Deciduous forestland includes all forested areas having a dominance of trees from which the leaves fall off at the end of a growing period. The tree species in this category are commonly referred to simply as "hardwoods" in most parts of the United States. However, the tropical hardwoods such as mahogany and ebony are broadleafed evergreens which are excluded from the category, since the absence of leaf cover at some time during the year is the principal means of identification from high altitude imagery. Included in deciduous forestland are such species as oaks, maple, beech, ash, hickory, aspen, and such "soft hardwoods" as sweet gum, tupelo, cottonwood, and yellow poplar.

4-02 Evergreen Forestland

Evergreen forestland includes coniferous and tropical broadleafed evergreens. Although the coniferous evergreens predominate in this category, the mangrove areas of Florida and some of the forests of Hawaii are notable exceptions that must be recognized. The coniferous species are also commonly referred to, or classified as, softwoods. Included are such eastern species as longleaf, slash, shortleaf, loblolly and other southern yellow pines; spruce and balsam fir, white and red pines; jack pine; hemlock and cypress; and such western species as Douglas fir; ponderosa pine; redwood, Sitka spruce; Engelmann spruce, lodgepole pine, red cedar, larch, hemlock and white pine.

4-03 Mixed Forestland

Mixed forestland includes all areas where an extensive mixing of deciduous and evergreen species occurs.

5. WATER

The Water category includes those areas predominantly and persistently water covered. The five sub-categories at the second level are Streams and Waterways, Lakes, Reservoirs, Bays and Estuaries and Other. In some of these, Bays and Estuaries, for example, guidelines for establishing the inland limits are contained within the category description. The geographic area of this study is confined to the land mass of the United States and to the water areas included therein. The Great Lakes area in the United States is included. Embayments in either case are treated identically. The threshold width for streams and other linear features is 1/8 mile, while 40 acres is the minimum size for areal occurrences, which accords with measurement standards previously established by the Bureau of the Census.

Small water bodies are included within the land use unit in which they are located. Ponds occurring in an agricultural land use category are included in that unit. Sewerage systems and aeration or holding tanks are placed in the local larger identifiable unit. Usually treatment plants are located in the industrial fringe area of cities and, if possible, adjacent to a water body. Sewage treatment or water supply facilities are a basic part of the urban pattern and should be included there even when the unit is large enough to be identified separately as water. None of the Water sub-categories are vegetated.

5-01 Streams and Waterways

This sub-category embraces rivers, creeks, canals and other linear water features meeting the 1/8 mile average minimum width requirement. Parts of streams which occasionally are constricted below the 1/8 mile width are included to produce a continuous feature. In cases where the water course is interrupted by a control structure, the impounded area, if it exceeds 40 acres will be placed in the Reservoirs sub-category. Those streams of less than 1/8 mile width will be included with the adjoining land use. The boundary of streams with lakes, reservoirs and the ocean is handled in the same manner as the Bays and Estuaries interface. The guideline is given in the Bays and Estuaries sub-category definition. Essentially it states that embayments having headlands between one and ten miles in width shall have a straight line drawn across them. Unless they are shallower than a semi-circle, with the straight line as the diameter in which case the coastline should be followed directly. When the width is less than one mile the area is part of the Stream sub-category and when it is greater than 10 miles it is part of the larger water body into which it flows.

Streams flowing through deltas will be classified as water area as long as width minimums are met. When many distributaries are present, creating streams of less than 1/8 mile, they are included in the appropriate land use.

5-02 Lakes

Lakes are those bodies of water exceeding 40 acres in areal extent. Excluded are reservoirs. Islands within lakes which are too small to deliniate will be included in the water area. The delineation of a lake will be based on the areal extent of water at the time the imagery was taken.

5-03 Reservoirs

Reservoirs are artificial impoundments of water generally made for irrigation, flood control, municipal water supplies and hydroelectric power generation. Dams, levies, other water control structures or the actual basin excavation will usually be evident to assist in the identification of this sub-category.

5-04 Bays and Estuaries

Bays and Estuaries are those areas of marine water which occur as indentations into the land mass. Estuaries are drowned river valleys, which are enlarged due to the marine flooding. These zones are often unique in their flora and fauna and delicate inter-relationships exist.

The Bureau of the Census is setting outer limits for the United States, adopted principles pertaining to embayments and islands. The following are their applicable embayment rules for setting the outer water limits of the United States. "Where the coast line is regular it shall be followed directly.... Where embayments occur having headlands of less than ten and more than one nautical mile in width, a straight line connecting the headlands shall set the limits; however, the coast line shall be followed if the indentation of the embayment is so shallow that its water area is less than the area of a semi-circle drawn using the said straight line as a diameter." For areas less than a nautical mile in width the feature is probably linear and would be covered by the Stream and Waterway sub-category. If the headland is greater than ten miles in width, the coast line will be followed until the headland is 10 miles in width, thus meeting limitations for Bays and Estuaries.

5-05 Other

Other water areas include large farm ponds that may not be identifiable as reservoirs or other water features as well as any water features which may be a combination of other sub-categories that cannot be clearly identified.

6. NON-FORESTED WETLAND

Non-Forested Wetlands consist of seasonably flooded basins and flats, meadows and marshes, bogs, salt or saline flats and marshes. Open saline and fresh water areas, sounds and bays are included under Water. Wetlands are usually confined to relatively level areas. Uniform identification of this category is difficult since the wetland areas change due to factors such as long term drought or high rainfall, seasonal fluctuations in precipitation and diurnal tidal conditions. The observations have to be correlated with tide and weather information to produce consistent results.

6-01 Vegetated Non-Forested Wetland

Vegetated Non-Forested Wetland excludes areas whose tree cover meets the 10 percent crown cover threshold of the Forestland category. When the forest crown cover is less than 10 percent, or is non-woody, it will be included in this category, unless recent clear cutting has occurred. Cattails, tules and grasses exemplified by Indian rice grass (Zizania) and sawgrass occur in fresh water marshes, while salt-tolerant grasses, for example Spartina, grow in salt marshes.

6-02 Bare Non-Forested Wetland

Vegetation may be lacking due to the erosional effects of wind and water transporting the surface material so rapidly that plant establishment is curtailed. Also, submerged or saturated materials often develop toxic conditions of extreme acidity from sulphur generation. Tidal flats are a main component of this category.

7. BARREN LAND

Barren land has very little or no vegetation and limited ability to support life. Barren land sub-categories are Salt Flats, Sand other than Beaches, Bare Exposed Rock, Beaches and Other. Aridity is one of the most limiting factors. Concentrations of salts derived from the parent rock or through accumulative processes can produce a toxic situation. Rock may have been exposed too briefly to weathering to allow conducive rooting material to form. Vegetation requires time to grow on recently deposited material, however, and continued flooding and/or wind transport curtails plant establishment.

Barren land generally gives the impression of a denuded area with only soil, sand, surface rocks or bedrock present. Occasionally, favorable conditions, a heavy rain for example, will cause an impressive but short lived plant cover to occur. This condition is temporary. If vegetation does occur it is too widely spaced and scrubby to be placed in the Desert Shrub sub-category of Rangeland.

Land may also be temporarily barren due to man's activities. Generally this land is included in another land use category. Vast areas of agricultural land are temporarily without vegetation cover due to tillage practices. Often sites of land for urban development are stripped of their cover prior to construction. Areas of extractive and industrial land use have dumps for waste and tailings, also exhausted sources of material supply are often evident. Extractive areas presently in use as well as inactive areas are included in the Extractive sub-category. Inclusion of inactive extractive areas in the Extractive sub-category gives more direct recognition to man's prior activities. Furthermore, it is often difficult to separate active from inactive areas of extractive uses from imagery without supplemental sources of information.

7-01 Salt Flats

Salt Flats are the flat-floored bottoms of interior desert basins on which smooth, barren, sun baked microrelief prevails. They are essentially the dry lake remnant of a former base level of erosion which may be presently active. Playa is another name that can be loosely applied to a dry lake, filled periodically with a sheet of water. Salt flats or playas have no relief or vegetation, contrasting therefore with the physiography of surrounding bajadas, which are molded by badlands, ephemeral gullies, channels, shoreline remnants and fault scarps. Vertical air photographs show salt flats or playas as a white scar in the desert due to the soil, flatness and colors which cause a diffused reflectancy much higher than the albedo or any other desertic feature.

7-02 Sand other than Beaches

Sand other than Beaches includes dunes which are topographic features, according to the Encyclopedia of Geomorphology "of eolian origin composed of sand grains downwind from a natural source of sand. Dune size varies greatly, diameters ranging from a few meters to more than several thousand and heights varying from one to several hundred meters. Their shapes also display much variety." The dominant dune environment is a desert, while shore and strand lines, coastal plains, river floodplains, deltas, and periglacial environments are secondary.

7-03 Bare Exposed Rock

Bare Exposed Rock areas consist of such features as exposed bedrock, desert pavement, scarps, lava flows and other accumulation of rocks lacking vegetative cover. Exposed bedrock, when weathered, may be unvegetated due to fine soil removal by water or wind erosion. In arid areas the rocks exhibit strong angularity because weathering rates are very slow. Colluvial deposits are transported by gravity to the slope base. Slides, talus and talus trains may form such rock areas.

Desert pavement is a surface feature that may develop on the desert flats, on fans and bajadas and especially on Pleistocene lake or river terraces. Most pavements occur on the nearly level or very gently sloping surfaces.

A scarp is an escarpment, cliff or steep slope of some extent along the margin of a plateau, mesa, terrace or bench. More specific terms are cuestas, fault scarp or fault-line scarp. Scarps are either erosional or structural in nature.

Cuestas are gently sloping plains bounded on one edge by an escarpment. The steep escarpment known as scarp slopes are the portion which is included in this category. Hogbacks describe a series of steep escarpments that have a serrated appearance. Mesas are essentially flat and are scarp-bounded on all sides. Other erosional scarps are formed as wave cut cliffs along ocean or lake shores. Stream action creates scarps by headward erosion and mass wasting of valley sides.

Fault scarps and fault-line scarps refer to the cliffs created through tectonic activity. The fault scarps are fresh and the actual plane of the fault can be determined. The fault-line scarp has been modified by erosion and, therefore, the actual fault plane concealed. Wave cut cliffs and lateral stream banks have an abrupt break from the steep slopes to a horizontal surface or water. This is due to removal of slump material by water action of currents or waves. In arid climates the scarps grade into colluvial deposits or alluvial fans which are often steeply sloping. The scarp boundary is then rather indefinite and a line should be drawn approximating the limit of steeper slopes to the valley floor if the overburden was removed. The upper scarp slopes have a definite break to a fairly level or gently sloping surface. The break is used as the border line. This is true of fault, erosion and structurally formed cliffs.

"Volcanic landscapes consist for the most part of accumulations of solidified lava and of fragmentary volcanic products.... The constructional features fall broadly into two categories: a) cones and fields of cones, domes and related salient forms; b) plateaus and plains. There are, however, volcanic complexes consisting partly of extruded domes of lava and partly of volcanic plateaus" (The Encyclopedia of Geomorphology).

7-04 Beaches

Beaches are constantly affected by wave and tidal action. The fine clays and silts are washed away leaving sand and gravel. However, in protected bay and marsh areas fine soil particles from surface drainage waters may settle out. The beach area is subject to water and wind erosion. Differing beach dimensions are due to factors such as tides, soil material size, water level and wave energy, all of which vary. A stable surface is observed inland, as erosive effects of water and wind decrease. Once vegetation cover or another land use occurs, the Beach category is terminated.

7-05 Other

From high altitude imagery it may be difficult to separate some of the Barren Land sub-categories as fully as outlined above. When a mixture of Barren Land features occur or when a definitive identification of a Barren Land feature cannot be made, this sub-category will be used.

8. TUNDRA

Tundras are cold forestless landscapes. Tundra vegetation consists of moss and lichen ~~formations~~ with various grasses, dwarf shrubs and sometimes large shrubs. Lack of tree growth is due to the low temperatures and a very short and erratic frost-free season, excessive swampiness and conditions of physiological dryness. The tundra zone can be divided into three sub-zones according to vegetative cover. The arctic sub-zone is characterized by an interrupted cover of sparse vegetation of moss and lichen sedges. The typical tundra sub-zone contains various types of moss-lichen sedge vegetational associations with rare shrubs in river valleys. In the shrub tundra sub-zone, dwarf birch and willow shrubs are usual, together with mosses, sedges and grasses. Along the mountain summits, the tundra extends well to the south being enriched by Alpine flora elements. This kind is called mountain tundra. The three zones represent a progression of more favorable plant growth conditions. Lack of definitive studies in the identification by remote sensors of these sub-types of tundra precludes further sub-categorization at this time.

The interface of Tundra to Permanent Snow and Ice Fields and to Water, are fairly easily delineated if the imagery is taken in late summer. The Tundra boundaries with Forestland having light crown cover, Non-Forested Wetland and Barren Land are often difficult to establish. The transition between Forestland with light crown cover and Tundra occurs over a wide area and also unevenly. Enhanced growing conditions result in protrudences of brushland into Tundra areas. Differences in environment can be pronounced, as with elevation or more subtle as exemplified by the varying activity of organisms. Factors such as these affect rates of soil development, depth of thaw, length of growing season, etc., which in turn provide different surroundings and, therefore, plant types.

The Barren Land-Tundra interface occurs where one or several of the vegetative growing factors are deficient. Coldness or dryness are the two most likely limiting conditions. Also the temperature extremes, coupled with the soil moisture cause unique landscape features to develop in the Arctic climate. These features are the result of water expansion and movement upon freezing of the water in the soil mass. The terms pingos, ground ice mounds, hummocks and hydrolaccoliths all pertain to mounds formed through ice pressure and thawing phenomena.

The Non-Forested Wetland causes indecision when the hummocky landscape with intervening areas of standing water are examined. The proportion of flooded land compared to the existing vegetation is the main separating criteria. Also, the flooded portions vary in size due to such seasonable characteristics as depth of frost, amount of precipitation and evapo-transpiration potential.

9. PERMANENT SNOW AND ICE FIELDS

Snow and Ice Fields are self-explanatory. The term permanent is used to reflect those snow and ice fields which survive summer ablation. The average frontal position of a few years would be the desired border line. This would require physical position measurements and temperature readings over the study period. A more expedient delineation can be obtained through observations at the time of maximum retreat which is probably during August in the Northern Hemisphere.

Snow, firn, ice pack, field or cap and glacier are terms describing material which is included in this category if it is "permanent." The underlying mass may be either land or water.

The more probable abuting land use categories are Water, Barren Land, Tundra and Non-Forested Wetland. Temperatures which are sufficient to maintain snow and ice through the summer are not conducive to plant growth. Also, the summer melt water creates excessive moisture conditions resulting in flooding that hampers vegetative establishment.

Water at the ice front is common. Oceans surround many ice caps. The Barren Land occurs as scoured bedrock, recently deposited material, areas of permafrost, soil churned due to freezing and thawing, etc. The Non-Forested Wetland as an interface with Permanent Snow and Ice Fields applies to land where the water table is at or above the surface and no forest exists.

RECOMMENDATIONS

Development of the two more generalized levels of categorization of a land use classification scheme applicable for use on a nationwide basis primarily with satellite and other high altitude imagery but also suitable for use with larger scale imagery, has been carried out under the direction of a Steering Committee established to guide this work. In the course of generating the "first approximation" of a national land use classification scheme at the two more generalized levels, certain subsequent needs have become more or less obvious. The following recommendations represent the more urgent needs for continuing the development and improvement of a national land use classification scheme for use primarily with remote sensor data as recognized by the Steering Committee and the authors of this report.

1. There is a general lack of understanding of what is to be accomplished by the development of a national land use classification scheme on the part of both agencies that will need to use the classification scheme and from agencies engaged in gathering information of the kind that will be needed for a national land use inventory. This situation should be expected at this point in time, but assistance from user agencies is needed to improve the classification scheme through adjustments that may be possible to meet the needs of the user agencies and the goals of a national land use survey more effectively.

   Therefore, presentations to user and contributing agencies should be carried out immediately, offering the opportunity for discussion and contribution of ideas pertinent to the needs of the agencies and the improvement of the classification scheme. For other agencies, state government units, and groups interested in land use classification, information should be made available upon request.

2. Standardization in the classification of current land use and vegetative cover (to the degree feasible) should be encouraged. To facilitate this effort, there will probably need to be an inter-agency group or office responsible for actively promoting efforts toward standardization. Other resource inventories should also become a part of this general effort to attain more standardization.

3. Certain important parts of the land and water area of the United States have not in the past received adequate attention from researchers, or sufficient general information does not exist, to allow for development of a meaningful classification of such areas. Yet those areas have been included in this scheme to meet the basic classification requirement of comprehensiveness and to furnish at least some information about such areas. Further study is particularly needed on the classification of tundra, barren land, and vegetated wetlands.

4. It is recognized that this classification scheme has been based on the assumption that line-of-sight image sources would be used for its application. Analysis of the utility of this classification scheme using imagery from ERTS-A, ERTS-B, and Skylab should be undertaken at the earliest possible time. It is recognized that there may be a need to make some adjustment in the number and composition of classification units if unsatisfactory results are obtained. This classification is a first approximation, and adjustments are anticipated, as this scheme is tried experimentally.

5. Continuing research is recommended to improve the classification of vegetative cover and natural resources, relying on high altitude imagery as a basic information source.

6. User needs and significant applications need evaluation. Justification for programs of image acquisition needs to be considered a constant guideline for development of uses of the classification scheme. To satisfy this demand, the success, utility, costs and significance of applications should be evaluated periodically.

7. A serious problem exists in generating a classification scheme to be applied over long periods of time in that the criteria used for decision making at one time are readily forgotten, lost, or are no longer applicable at a later or different time. One aid in solving this problem is the preparation of a photo atlas. Such a photo atlas would cover all items in the inventory, and would record in description and in "ground truth" photos, the ground or normal

visual relationship of each classification unit with its corresponding image from various remote or airborne sources. The atlas should include the range of ground conditions that qualify in any classification unit, with the greatest attention given to accurate description and presentation of the central or model concept of the range of conditions. The ground truth photo atlas is given a high priority recommendation by the authors of this report.

8. A sustained research program is needed to: a) evaluate the classification scheme; b) to develop visual interpretation techniques including adoption of a uniform color scheme; c) utilize the potential of automatic and semi-automatic processing systems, and d) to determine the practices necessary to facilitate user services.

9. A sustained program of user education services (based on the type of experiences realized by the Cooperative Extension Service) should be established over time to maintain liaison with information users. Objectives would include guidance and assistance in using the land use classification information, and also to learn from users how to improve the inventory process to serve their needs more effectively.

10. The development of a manual of interpretation is an essential element of the classification process. The manual could be similar to existing efforts of this sort, such as the Soil Survey Manual developed by the U.S. Soil Conservation Service.

11. The current report identifies two levels of the classification scheme. In Level I there are nine categories which Level II further divides into 33 sub-categories. The scheme is designed to make it possible to continue with the subdividing process to Levels III and IV. We recommend that work on developing the third level of classification be undertaken at the earliest date possible. The number of possible uses of a classification system increases greatly at each level; and since it is the use made of the information at the lower levels that creates information and demand relative to the higher levels, it is important to commence work on this part of the scheme.

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