NEED FOR A MULTIPURPOSE CADASTRE

Panel on a Multipurpose Cadastre
Committee on Geodesy
Assembly of Mathematical and Physical Sciences
National Research Council

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Preface

The increasing demand for land information at all levels of government and in the private sector, and the increasing involvement of federal agencies and programs in the development and maintenance of land-information systems, induced the federal agencies to request the National Research Council to define a federal role in the development of a multipurpose cadastre applicable on a national basis. Rather than attempting to resolve all land-information systems problems, it was decided to consider the basic components (reference frame, base map, and cadastral overlay) of a multipurpose cadastre, which, if properly established and maintained, would provide the common framework for all land-information systems. In the process of defining a federal role, the roles of the state and local governments and those of the private sector (companies and citizens) were considered germane. With these roles established and the multipurpose cadastre conceptualized, the relationship of land data files to the multipurpose cadastre was considered.

The present status of cadastral activities at the federal, state, and local governmental levels and in the private sector was examined, and a number of pilot projects were reviewed. This background material was gleaned from the literature and from contacts at various levels of government. The material was reviewed by individuals in the academic community, the state and local governments, and the private sector.

This report is the product of a one-year study. It primarily emphasizes the basic components of a multipurpose cadastre, particularly the reference frame and base map for which great expertise exists at the federal level. However, other aspects of the cadastre, which are the prime responsibility of others,

are also considered. The major federal input in these other areas, such as technical assistance, land data, and personnel development, are discussed. Early in this study, it was determined that the development of a multipurpose cadastre that would be applicable on a national basis would depend on the realization by all participants that the benefits to be derived from the free flow of information among all users far exceeded the value of a nonaddressable local cadastre.

The technical details of the multipurpose cadastre, alluded to in this report, need to be developed further. It is recommended that specialized panels be formed to consider these aspects.

Comments on this report and recommendations for follow-on activities addressed to the Committee on Geodesy, National Research Council, 2101 Constitution Avenue, N.W., Washington, D.C. 20418, would be appreciated.

Acknowledgments

This study was undertaken late in 1979 by the Panel on a Multipurpose Cadastre of the Committee on Geodesy in the National Research Council's Assembly of Mathematical and Physical Sciences. The work is supported by the Department of Defense, the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, and the U.S. Geological Survey. The free distribution of this report has been made possible through grants from the Bureau of the Census, the Bureau of Land Management, and the Department of Housing and Urban Development. The Panel appreciates the interest and support of these agencies. We are also grateful to the liaison members for their assistance.

We also appreciate the contributions and suggestions of outside reviewers. However, the responsibility for the content of this report lies with the panel members.

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Executive Summary

There is a critical need for a better land-information system in the United States to improve land-conveyance procedures, furnish a basis for equitable taxation, and provide much-needed information for resource management and environmental planning.

Land-information systems in the United States can be characterized in general as title and assessment records systems, most of which have undergone relatively small changes in the last hundred years, and land-planning and -management systems, which have evolved in the last 20 years.

Problems inherent in our present system may be categorized as accessibility, duplication, aggregation, confidentiality, and institutional structure (see Section 2.2). Resolution of these problems would reduce recording-office costs, which from 1971 statistics amounted to $137 million, and the land-transfer costs for residential and farm real estate, which were estimated to amount to more than $17 billion in 1974. Because of the inadequacies of our governmental records system, a number of institutions such as title insurance firms, abstractors, mapping companies, and utilities have developed their own duplicative land-information systems.

The concept of the multipurpose cadastre is a framework that supports continuous, readily available, and comprehensive land-related information at the parcel level. The components of a multipurpose cadastre are the following:

1. A reference frame consisting of a geodetic network;
2. A series of current, accurate large-scale maps;
3. A cadastral overlay delineating all cadastral parcels;
4. A unique identifying number assigned to each parcel that is used as a common index of all land records in information systems; and

5. A series of land data files, each including a parcel identifier for purposes of information retrieval and linking with information in other data files.

While this report is primarily concerned with the reference frame, base maps, and cadastral overlay components of the multipurpose cadastre, the other elements of the cadastre are discussed, albeit briefly, in order to provide a complete picture of the system.

There is a considerable amount of activity directed at improving our land-information system (see Sections 2.3–2.6). Programs instituted at the county level to improve land-recording procedures, indexing, computer data handling, computer mapping of utilities, monumentation of public-land survey-system corners, and physical mapping have been in progress for a number of years. Several states have under way control surveying and base-mapping programs and have developed land data files, which are necessary components of an efficient land-information system. Federal agencies have developed special programs for particular land-information areas, such as the Taxable Property Values Survey by the Bureau of the Census and the Real Estate Settlement Procedures Act studies by the Department of Housing and Urban Development. Federal agencies have funded a number of land-information pilot projects and have assisted local and state agencies in their surveying and mapping activities (see Section 2.6.2). The most extensive land-information system on this continent has been developed by the Maritime Provinces of Canada (see Section 2.5.4.1); it provides a well-developed model for others to consider.

Creation of a multipurpose cadastre requires input from many different sources at all levels of government. Existing governmental offices and private institutions will provide the fundamental components of the system. The land surveys required for the reference frame and the parcel boundaries will be performed by government and private surveys. The base maps will be prepared from several sources. The cadastral overlay (see Sections 2.4.3, 2.5.3, and 2.6.2) is the result of work by surveyors, abstractors, title attorneys, zoning organizations, and courts; this overlay presents the property parcels. There may also be related overlays that present one or more land records (Figures 1.1 and 3.1); these might more properly be called thematic maps, which are linked to the land records (Figure 3.1). The cadastral overlays, thematic maps, and land records represent the multipurpose cadastre. It is essential that technical standards and specifications be developed and enforced for information that is entered in the multipurpose cadastre. Chapter 3 of this report describes the terms associated with the cadastral parcel and suggests specifications and methods for some of the technical operations required for the development of a multipurpose cadastre.

In order to relate other land information to the basic components, linkage mechanisms are required. Essential items in this integrating mechanism are standard definition of the parcel unit, a unique parcel identifier, approximate geographic location of the parcel, a parcel index map, a computerized index of parcels, and links with nonparcel data that are geographically related (see Section 3.4).

Development of a multipurpose cadastre will require reorganization and quality control of existing governmental functions, rather than creation of new functions. Gradual, phased implementation is necessary because the legislative and budgetary processes of local, state, and federal governments tend to address short-term, readily identifiable problems rather than long-range improvements (see Section 4.1).

Federal, state, and local governments as well as private contractors have an important role in the development of a multipurpose cadastre. The basic control surveys for the geodetic network should be done by the federal agencies, intermediate control monuments should be established by state agencies, and the close-spaced monuments should be set by local agencies (see Section 4.2.1). Small- and medium-scale mapping by federal agencies should be supplemented with state and regional maps by state agencies, and large-scale maps should be prepared by local agencies. The basic cadastral surveys of federal land should be performed by federal agencies, while state land should be surveyed by state agencies. Local property boundaries will be established by private surveyors (see Section 4.2.2).

We recommend that federal legislation be prepared to authorize and fund a program to support the creation of a multipurpose cadastre in all parts of the Nation.

We recommend that the Office of Management and Budget designate a lead agency for the multipurpose cadastre.

In addition to their basic surveying and mapping functions, each level of government can make material contributions to the development and maintenance of the multipurpose cadastre. Federal agencies should conduct technical studies, recommend standards, offer financial support through cooperative programs and grants, and ensure that work performed by federal agencies is compatible with the multipurpose cadastre (see Sections 4.3.1 and 4.3.2).

We recommend that technical studies continue to be sponsored by the federal government to identify consistent land information and display standards for use among and within federal agencies and between federal and state governments. These studies should rely on the authority of state governments to adopt the standards and organize the data collection, in cooperation with the federal government to ensure compatibility on a national basis, delegating these functions to local governments where appropriate.

Each state must act, in cooperation with the federal government, as a coordinating organization by providing guidance to local governments through such mechanisms as model specifications, standards, regional control surveys and maps, and basic source files. A state office should serve as a focal point and clearinghouse for communications with federal agencies and other states (see Section 4.3.3).

We recommend that each state authorize an Office of Land Information Systems, through legislation where necessary, to implement the multipurpose cadastre.

Much of the work in developing and maintaining a multipurpose cadastre will occur at a local level. Coordination of local efforts should be handled by an Office of Land Information Systems, which would be responsible for the standardization of procedures, monitoring production and maintenance of base maps and cadastral overlays, and creation and maintenance of land-parcel registers (see Section 4.3.4).

We recommend that each county government (or municipality where appropriate) create an Office of Land Information Systems in coordination with such offices as the recorder of deeds, county surveyor, assessor, planner, and county abstractor, if any.

The content of land records is often considered more related to functions of local government than to those of the state or federal agencies. However, there is a rapidly increasing need by regions, states, and federal government for the land data that would be provided by a multipurpose cadastre. Most of the operations as to specific land parcels occur at the county or municipal level. In addition to the traditional record-keeping offices, the primary users of data about specific land parcels are the average citizen who is involved in a real estate transfer, zoning hearing, or construction of a building and the local government department or utility that is planning a transportation system, drainage system, or other municipal function (see Section 4.1.1).

We recommend that local governments be the primary access point for local land information.

There is considerable concern that the qualified personnel required to perform the functions inherent in a comprehensive land-information system will not be available at all levels of government and in the private sector. The panel believes that means must be found to develop the qualified personnel and to encourage and support university research and development activities and programs (see Section 4.3.7). Therefore:

We recommend support by the federal government for the establishment of a center or centers of excellence in land-information science, for the purpose of providing a program that develops scholars and professionals. The curriculum should include direct experience with land-data-systems problems.

1
Introduction

1.1 ORIGINS OF THE CADASTRE CONCEPT

A cadastre may be defined as a record of interests in land, encompassing both the nature and extent of these interests. An interest in land (or property right) may be narrowly construed as a legal right capable of ownership or more broadly interpreted to include any uniquely recognized relationship among people with regard to the acquisition and management of land. According to the French etymologist Blondheim, the term cadastre is probably derived from the Greek word *katastichon*, meaning notebook. (Von Simmerding, 1969). In Latin, the term gradually evolved to *captastrum*, or register of territorial taxation units into which Roman provinces were divided.

Precursory cadastral arrangements may be traced to the earliest agricultural settlements along the Tigris, Euphrates, and Nile Rivers. In the pristine Egyptian state, revenues for the Pharaohs and the priesthood were met principally by taxes on the land. For purposes of taxation, the land was measured and the boundaries demarcated. Clay tablets unearthed from the ancient ruins of Sumerian villages provide records of charges against the land, maps of towns and tracts of land, area computations, and, most notably, court trials adjudicating ownership and boundary disputes. The Greeks and Romans established elaborate land-record systems primarily in support of land taxation policies (Richeson, 1966).

One of the most famous cadastral projects was the Domesday Book of Norman England. The Domesday Book was primarily a collection of facts about the land and its improvements made for fiscal purposes. The actual

collection of data was carried out during 1085-1086 and covered all of England with the exception of the four northern counties and the cities of London and Winchester. Similarly, Louis VI provided for the first measurement and assessment of French lands in 1115.

The origins of what has come to be accepted as the modern cadastre concept are found in the development of the cadastre systems of Continental Europe during the eighteenth and nineteenth centuries. Like the earlier efforts, these were fundamentally designed for taxation or fiscal purposes. The Milanese cadastre mapping program conducted between 1720 and 1723 was one of the earliest efforts to establish a fiscal cadastre in the modern sense. This program generated a series of estate maps at a scale of 1:2000 for the Italian provinces of Milan and Mantua shortly after they were acquired by the Austrians. Somewhat later, the program was expanded when Emperor Joseph II ordered a cadastral survey for the entire territory encompassed by the Austro-Hungarian monarchy. This survey was made over a period of 5 years (1785-1789) and resulted in plans and descriptions of all individual land parcels in the monarchy (Rinner, 1969). In 1807, Napoleon appointed the mathematician Delambre to chair a Commission given the task:

> To survey . . . more than 100 million parcels, to classify these parcels by the fertility of the soil, and to evaluate the productive capacity of each one; to bring together under the name of each owner a list of the separate parcels which he owns to determine, on the basis of their total productive capacity, their total revenue and to make of this assessment a record which should thereafter serve as the basis of future assessment . . . . (Simpson, 1976.)

Some scholars have suggested that most of these eighteenth and nineteenth century European efforts to develop land taxation or fiscal cadastres were motivated by the economic principles of the Physiocrat movement. The Physiocrats held that the earth is the basis of all riches and that the revenues for the maintenance of the community should be derived from taxing the land. This concept was widely accepted, and most state revenues came to be obtained by "levying a ground tax, ultimately based on the taxable revenue of the separate ground parcels, and buildings, subdivided according to their different use such as agriculture grounds, meadows, orchards, woods, houses, factories, workshops . . ." (Henssen, 1973). This "ground-tax" concept evolved over time into complex differential tax-assessment systems, based in part on differing land uses. These complex systems required land-parcel information arrangements capable of supporting them. Dobner (1973) has argued that almost all the early European cadastres were established in response to this need for fiscal information.

In addition, it appears that as early as the seventeenth century, the Europeans developed an understanding and appreciation of the cadastre concept for purposes beyond taxation. Henssen (1973), for example, has traced the

evolution of the legal or juridical cadastre from this period. The juridical cadastre was conceived as a system for recording and retrieving information concerning the tenure interests in the land that, as with the fiscal cadastre, required the identification of the people holding an interest in the land and the location of those interests. However, the juridical cadastre required a more rigorous delineation of these interests in order to provide for the secure transfer of the land.

1.2 EVOLUTION OF THE NORTH AMERICAN CADASTRAL ARRANGEMENTS

The early North American cadastral arrangements were designed to promote quick, efficient, and secure land settlement. The alienation of public or crown lands, as a means of inducing European emigration, was from the outset recognized as a basic function of government in the English colonies. In support of this policy, three uniquely North American land-record tools were developed: the American recording system, the commercial abstract, and the public-land survey system (albeit, the latter was only developed in the western portion of the continent).

English land-conveyancing practices at the time of the American colonization were dominated by two characteristics:

> First, the substantive law had reached its technical worst, and, second, the structure of institutions and practices employed were still fluid, relatively undeveloped, and in a state of transition and experimentation. (Payne, 1961.)

As a result, the colonial land-record systems that evolved in the New World were a strange mixture of old English private conveyancing practices and some entirely new institutions. Among the English practices adapted were the concept of a conveyancing profession and the abstract of title. These were blended with two new institutions, the American recording system and the commercial abstract. The form of the American recording system was first described in the early seventeenth-century recording statutes of the Plymouth, Massachusetts; Virginia; and Nova Scotia colonies. These statutes had four characteristics that persist today in the deed-recording laws of the United States and the eastern provinces of Canada:

1. The instrument of transfer, such as deed and mortgage documents, must be acknowledged before a public official before recording;
2. The entire instrument must be recorded;
3. Legal priority is generally assured the grantee by the act of recording; and

4. The instrument is operative without recording, with the title passing before the instrument is recorded.

The actual granting or patenting of the land, together with the delineation and demarcation of the boundaries, was initially the responsibility of the colonial Surveyor-General. This was a particularly prestigious appointment, and it was not uncommon for him to report directly to London. But, if the position of the Surveyor-General was one of special importance in the early years of the colonial era, it was not always reflected in the resources allocated to his surveying mandate. In some instances, particularly where large tracts of land or townships were granted to the land companies and proprietors' councils, extensive surveys would at least be made of the township perimeters. Initially such surveys were often made by British army engineers well versed in the art and practice of surveying. Later these engineers were supplanted by deputy land surveyors, men of mixed experience and expertise, who were locally commissioned by the Surveyor-General. In addition to executing the township perimeter surveys, these pioneer surveyors often provided some internal control by traversing along navigable waters and monumenting the frontages of individual lots (a common practice in a large township of perhaps 100,000 acres or more was to arrange tiers of individual parcels in layers moving back from a navigable stream or river).

In many instances individual grants were made strictly on the basis of a written description, without benefit of boundary demarcation. Sometimes the settler would contract for a private survey, more often he established and maintained his own boundaries. In some cases, particularly where the tenure arrangements were stable and the boundaries physically maintained, this unsystematic survey system provided an adequate base. But in many instances the lack of adequate surveys created havoc. Marschner (1960), in a study prepared for the Agricultural Research Service, U.S. Department of Agriculture, examined some of the resulting difficulties:

> Running of boundary lines in wild and heavily wooded country, with the simplest instruments and frequently by unskilled operators, did not make for precision. Boundaries were poorly marked and could not be identified. Frequently, contiguous grants were not recognized and overlapping of grants resulted. Cases in which a settler developed a part of his neighbour's property, although it was not within the limits of his grant, were not uncommon.

The lack of adequate surveys presented special difficulties in the laying out of town lots. As early as 1634, for example, committees were established in New England to set out the boundaries of unsurveyed towns and to settle boundaries in dispute.

The difficulties attributable to the unsystematic system in the Eastern

United States were to influence the policy of alienating the federally owned public lands in the West. One concept that was central to the discussions that preceded the passage of the Northwest Ordinances was the need to have an actual field survey of the territory before issuing any grants (Ford, 1910). This was accepted in the recommendations of a committee under the direction of Thomas Jefferson, which urged the adoption of a systematic rectangular survey system. The concept of the rectangular survey was adopted in the Land Ordinance of May 20, 1785. Provision was also made in this ordinance for the establishment of the six-mile-square township, which was to become the basic survey unit. In 1804, additional provisions were made for the creation of baselines and meridians to control the location of the townships.

In many ways the idea of the rectangular survey system was not new. Many of the early American cities, such as Charleston, New Orleans, and Philadelphia, had been laid out in a rectangular grid fashion. Similarly, the plans of the early Carolina and Pennsylvania proprietors, which dated from the mid-seventeenth century, had acknowledged the value of rectangular surveys. Nevertheless, the development of the Public Land Survey System was to rank as one of the major government decisions of the post-Revolutionary period and was to have a profound impact on the nature of western settlement. The American rectangular survey system, with minor variances, was subsequently adopted in Canada as the basis for the settling of the Canadian Northwest.

These cadastral institutions, designed primarily for the initial alienation of the federally owned public lands, have changed remarkably little over time. Payne (1961), for example, has noted that the basic legislation regulating the form of the land records have remained essentially unchanged since the time of the American Revolution.

1.3 NEEDS FOR IMPROVING THE CADASTRAL INSTITUTIONS

While concern about the quality of existing cadastral institutions has been voiced for some time, it is only within the last two decades that an awareness of the magnitude of the economic and social costs incurred by the continued public reliance on these outmoded arrangements has surfaced. Although these costs have been incurred in many and varied areas of human activity, they are most apparent in the processes of land transfer, property assessment and land-use regulation, and in the quest for a better understanding of the land-tenure institution itself.

The land-transfer process in North America is founded on the principle of publicity, the concept that all information relating to the nature and extent of interests vesting in a legal parcel of land must be available for public inspection. The costs associated with the acquisition of this information, the

subsequent negotiations based on differing interpretations of the information, and the enforcement of the consummated transactions constitute the land-transfer economic costs. These costs must be borne by the parties to the transaction. It has been estimated that these land-transfer costs in 1974 exceeded $17 billion in the United States for residential and farm real estate (Moyer, 1977). Included in these transfer costs are charges for the creation and maintenance of public records pertaining to the transfer documents. In 1971, recording-office costs in the United States were estimated at $137 million according to statistics compiled from the National Survey of Real Estate Transfer Records (Wunderlich, 1973).

Other major sources of difficulty in the land-transfer process are related to costly searches resulting from inadquate indexing of documents and to the costs incurred from faulty descriptions. Judge John E. Fenton, Jr. (1976) of the Massachusetts Land Court has stated that

> . . . the land tenure system presently used in the United States is a rudimentary deed registration system, negative in nature and formulated to fit a rural, agrarian society. As land and building development exploded across America, with its attendant public controls and successive transfers of title, public registries became crowded with those who needed information about the land. Owners, buyers, realtors, investors, conveyancers, surveyors, mappers, title abstractors, assessors, foresters, planners, environmentalists, conservationists, census takers, utility personnel, among others, literally nudged one another in small areas to absorb and chronicle information about the land.

These problems are extensively documented in a major report prepared for the Department of Housing and Urban Development pursuant to Section 13 of the Real Estate Settlement Procedures Act of 1974 (Booz, Allen and Hamilton, Inc., 1978).

The importance of adequate cadastral information for equitable *property assessment* has been of major concern since the beginnings of the modern fiscal cadastre concept in seventeenth-century Europe. A fiscal cadastre record not only provides the basis for the valuation of the land by including information about parcel size, shape, location, tenure rights, and restrictions but also provides a means of ensuring complete and equitable assessment of the improvements to the land. Inadequate cadastral records contribute to the cost of carrying out the assessment mandate and enhance the chances of error or omission.

Recent court rulings in Alabama, Arizona, Missouri, Massachusetts, New York, Tennessee, and Virginia have focused attention on the inadequacy of the existing cadastral records. The "Sudbury" decision of the Supreme Judicial Court of Massachusetts, for example, directed the State Department of Corporations and Taxation (now the Department of Revenue) to enforce a constitutional requirement for uniformity and fair-market valuation throughout the state (Supreme Judicial Court of Massachusetts, 1974). Many locali-

ties in Massachusetts had become dependent on the de facto differences in rates of taxation inherent in the outdated and nonuniform assessments. The voters approved a constitutional amendment in November 1978 that allows the classification of properties into four categories for maintaining differential rates of taxation: residential, commercial, industrial, and open space. The statutes to implement this arrangement were revised by the state legislature in 1979 (Chapter 797), to make such classification a local option and to give the state administration broad powers for enforcing standards for uniformity of property records and assessments. This focus has been amplified by the findings of agencies such as the Massachusetts Land Record Commission, which concluded:

> Local real estate assessors typically must maintain the most extensive record of current conditions of individual land parcels of any single governmental agency, and in many cities have automated their files; both for their own purposes and for reference by other agencies of local government. However, their work has proceeded without the benefit of a standard, statewide format for coding, filing and retrieval of this data, and typically without a supportive role by the registry of deeds in providing machine-readable files regarding current ownership of the parcels. Where re-evaluations become necessary, the assessors must normally proceed without the benefit of a history of title and encumbrances to the land, given the cost of assembling this information from the present files of the registries of deeds. (Barr, 1975.)

Professional assessment organizations, such as the International Association of Assessing Officers (1978), have also urged that such reforms be effected.

The increasing problems associated with *managing the publicly owned lands* demonstrate yet another need for improved land records. In addition to federally owned public lands, the General Services Administration and the Department of Defense own or lease many parcels throughout the United States. The Department of Housing and Urban Development through its rent-subsidy program and the various federal agencies that guarantee mortgages are concerned with parcels. Unfortunately, the federal records as to guaranteed mortgages have not been adequate to meet the problems that arise from numerous defaults. Federal agencies as assignees of the mortgage after default must not only deal with defaults but with foreclosures, which often result in purchase and ownership of the property by the federal agency.

The rising demand for the identification and protection of natural and cultural resources is resulting in pressures to develop new programs for (1) the acquisition, transfer, and withdrawal of publicly owned land; (2) the protection of such lands from vandalism and trespass; (3) planning and management for alternative (and often competing) uses; and (4) the regulation of these uses. Effective management of publicly owned lands requires a complete and accurate inventory of all such lands pertaining to boundaries, acreages, existing use, soil types, vegetation types, and other parameters. Modern land

records and a supportive continuing system are necessary to satisfy these needs (Bureau of Land Management, 1976).

Modern ownership-based land-record systems are also required for environmental and land-use planning purposes. In the last 15 years there have been numerous attempts to develop land-planning information systems relating cultural and resource information to a geographical framework. The primary purpose of the efforts has been to organize extensive and varied planning data within a common spatial framework, so that the complexities and interdependencies of the land-planning problem can be represented. These systems have met with limited success, especially at the regional and local level, in part because of inappropriate design assumptions, limited development, poor data resolution, and simple inattention or lack of information at the time of the design of the systems to user needs and institutional precedents. Despite the relatively recent influx of required environmental considerations, the significance of the ownership land unit as a basic land organizational or reference unit is as important as ever. This may be illustrated by citing the results of a series of county Critical Resource Information Program Workshops held in Wisconsin (Clapp *et al.*, 1975). The goal of these county workshops was to obtain, from local participants, a list and the geographic locations of potentially critical resources within the county. The reference that was used the most and on which most of the discussions were concentrated was the plat of the ownership units. Even in those frequent cases in which the resource under discussion (e.g., a prime farming unit or a wetland) was not directly comparable with a particular ownership unit, the participants could identify the resource unit from the ownership units represented on a plat.

In North America, the more-intensive use of limited land resources, a wider diffusion of holdings, and the appearance of new forms of *land tenure* have taxed the capabilities of existing tenure institutions. As used here, land tenure encompasses all the many relationships that govern (1) control and access to land resources, (2) the use of these resources, and (3) the claims on goods and services that flow from these relationships. These tenure institutions were developed to address much simpler questions that required much simpler analyses. Recent discussions concerning a number of land policy questions demonstrate the shortcomings of the current land-information system. These policy questions include such items as foreign ownership of U.S. real estate, farming by corporations, and protection of prime agricultural lands from nonfarm uses.

Congress and many state legislatures have recently expressed concern about the extent and impact of foreign ownership of U.S. real estate. Specific concerns have included the amount of such ownership, where it is located, and the likely or potential impacts of such ownership. Of particular concern are how foreign land ownership affects the U.S. balance of payments, land prices,

access to farmland by young farmers, community viability, use of conservation practices, and intensity of land use. Results of studies completed thus far emphasize two points: (1) more data are necessary on the incidence of foreign ownership of U.S. land, and (2) a more complete, more uniform data base on U.S. land ownership in general is needed, in order to provide an adequate base for decisions by policymakers, including Congressmen and state legislators (Wunderlich, 1976). These conclusions are also valid as to other land-tenure questions noted above. The multipurpose cadastre system outlined here can provide both the framework and data for dealing with these questions.

1.4 THE CONCEPT OF THE MULTIPURPOSE CADASTRE

North American cadastral arrangements to date have evolved in response to specific and limited user requirements. For example, the fiscal information necessary for property valuation purposes has generally been compiled by and for assessment officials. Land-recording offices have been designed primarily for providing notice of the existing ownership arrangements specifically to the parties involved in a real property transaction or, more often, to their agents and for providing the state with a means of regulating the transactions and resolving potential problems of entitlement.

In some instances, these fiscal and juridical cadastral facilities have attempted to provide at least a minimum level of service to external users of land-tenure information. For example, it is not uncommon in those American jurisdictions where rudimentary fiscal cadastral systems have been developed for assessment purposes to find many of the records, assessors' maps, and work sheets available for public inspection. The difficulties in gaining knowledgeable access to these records, except by professional practitioners such as surveyors, appraisers, and lawyers, however, coupled with the specific nature and limited qualities of the documented information, have greatly limited their usefulness. The result has been a dearth of accurate, publicly available ownership-related information resulting in the serious problems discussed above.

The multipurpose cadastre system is designed to overcome the difficulties associated with these more limited approaches by (1) providing in a continuous fashion a comprehensive record of land-related information and (2) presenting this information at the parcel level. The multipurpose cadastre is further conceptualized as a public operationally and administratively integrated land-information system, which supports continuous, readily available, and comprehensive land-related information at the parcel level. Its components are the following (Figure 1.1):

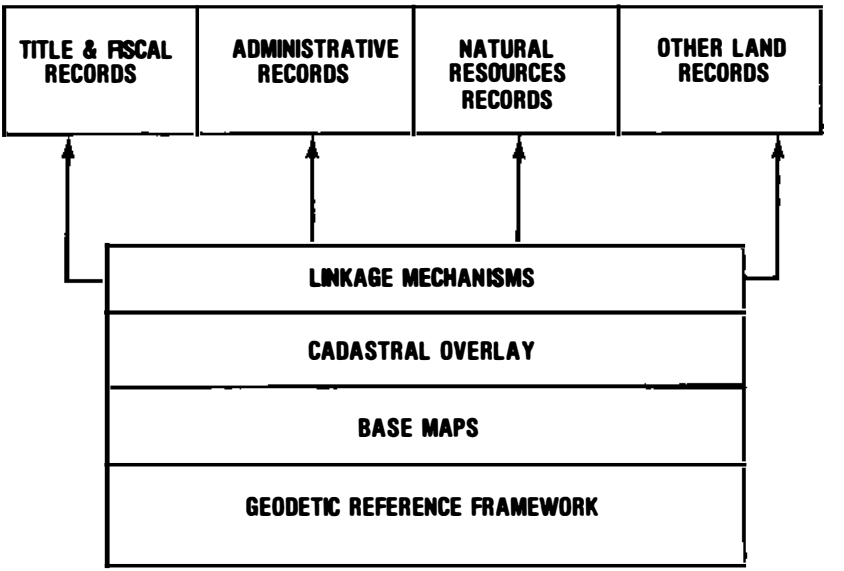


FIGURE 1.1 Components of a multipurpose cadastre.

1. A reference frame, consisting of a geodetic network (Section 3.1 and subsections);
2. A series of current, accurate large-scale maps (Section 3.2 and subsections);
3. A cadastral overlay delineating all cadastral parcels (Section 3.3);
4. A unique identifying number assigned to each parcel; and
5. A series of registers, or land data files, each including a parcel index for purposes of information retrieval and linking with information in other data files (McLaughlin, 1975).

The reference frame, consisting of a system of monuments having geodetically derived coordinates, will permit defining the relative spatial location of all land-related data. The large-scale mapping series will consist of a family of planimetric and topographic maps at scales from 1:500 to 1:25,000. These maps will permit the graphical representation of the land-related data.

The cadastral overlay will consist of a specialized series of maps delineating the current status of property ownership. The individual building block for the overlay will be the cadastral parcel. This is an unambiguously defined unit of land within which unique property interests are recognized. Associated with each cadastral parcel will be a unique identification number.

The unique parcel identification number will provide a key for linking

each cadastral parcel to various land data files or registers. These records may contain information about land ownership, use, cover, assessment, and such other attributes as may be required in making decisions about the management of land resources. Other identifiers, either existing or to be introduced, may be used to assist in accessing and manipulating these land-information records.

2

Current Status of Cadastral Efforts

While the need for an integrated land-information system, or multipurpose cadastre, has been set forth, implementation of improvement activity has been largely characterized by single-purpose approaches to only selected segments of the total system. In other words, these efforts proceed without a concept of a land-information system as the foundation. This situation is evidenced by the disparities in current efforts to improve land-record systems. Some of the more notable efforts are described in this chapter without attempting a comparative analysis.

2.1 THE UNIMPROVED STATE OF AFFAIRS

Land-information systems in North America today can be characterized in general as *title- and assessment-records systems*, most of which have undergone only relatively small changes in the last 100 years, and *land-planning and -management systems* which have evolved largely since the mid-1960's.

Title- and assessment-records systems are labor intensive and do not provide necessary information about the land in a timely, unambiguous, authoritative, and economical manner. Land-management information cannot readily be integrated with title and assessment data. Foremost among the problems inherent in the current arrangement of these systems is that required information is generally not accessible in any one location (Ayers and Wunderlich, 1973; Clapp and Niemann, 1977). A study in Wisconsin, entitled *Land Rec-*

ords: The Cost to the Citizen to Maintain the Present Land Information Base, A Case Study of Wisconsin, was designed to report the costs associated with obtaining and maintaining governmental information about land. As reported by Epstein (1978), Wisconsin residents in 1976 paid approximately $17 per person ($34 per taxpayer) for information about the state's 35 million acres of land. At the county level, the form of land-title recording remains essentially unchanged from the 1800's. At the state and federal levels of government, many different agencies collect a great deal of raw data without effective coordination or integration, thus collecting again and again the same basic information about essentially the same areas of land (Larsen *et al.*, 1978).

2.1.1 Land Transfer

The land-ownership system that has developed in the United States depends almost entirely on the recording of documents as evidence of land ownership and land-ownership transfer. A typical land-title-recording system is a register of evidence of title. Access to individual documents usually is obtained by searching alphabetical indexes of the names of grantors and grantees or by searching a tract index. The tract index is usually not a parcel index but an index by block or township. The location of a particular document in the register often is indicated by a numerical identifier that refers to the appropriate volume and page of the register. Other times, the reference is a document number (Almy, 1979).

Land-title recording typically is a function of county government, except in three New England states (Connecticut, Rhode Island, and Vermont), in which it is a function of city and town governments. Hence, there are about 3000 land-title-record systems organized on a county basis and about 500 organized on a city or town basis. Land-title recording may be the responsibility of a separate, often elected, official, such as a recorder or registrar of deeds, or the responsibility of the county, city, or town clerk or other official with additional duties. Estimates of the annual number of transfers of real property range between 4.5 million and 8.1 million (Almy, 1979).

The efficiency of the system has been severely threatened by more widespread ownership of land, a faster turnover rate in ownership, use of the vertical space dimension in the division of rights in condominiums and for mineral and air rights, and use of the temporal dimension in which a single parcel, such as an apartment in a resort area, may have different owners for specified time periods of each year (Moyer and Fisher, 1973).

Land-title recording and the related conveyancing process use and produce the most important data about land. There is an ownership turnover of nearly 10 percent of all parcels in the United States each year, resulting in transfer costs for real-estate brokers, attorneys, abstractors, title insurers, lending in-

stitutions, and other information service professionals. These costs in 1974 were estimated to exceed $17 billion in the United States for residential and farm real estate (Moyer, 1977). In addition, operation of land-title-recording offices and other government offices maintaining land-ownership information add substantial expenditures to the total land-record-system cost. In Wisconsin, for example, land-related data files maintained outside the recorders office include (Moyer, 1977) (1) delinquent taxes and special assessments (County Treasurer); (2) judgment liens, mechanic liens, and pending court actions (Clerk of Circuit Court); (3) judgment liens (Clerk of Special Courts of Records); (4) inheritance liens and probate proceedings (Probate Branch of County Court); and (5) zoning ordinances and building codes (County Clerk).

A land-title record specifies a certain property right and identifies the person claiming the right. Each parcel of land has several current records that contain information about the status of title. Title records include various claims ranging from ownership based on deeds and wills and security interests based on judgments, mortgages, and construction liens to easements and utility rights of way. A transfer may occur in the entire bundle of property rights or one or more of them. In each land transaction, a complete examination of the status of the land title is usually required (Moyer and Fisher, 1973). Tracing the transaction history is performed typically by an attorney, an abstractor, or title insurance personnel using the grantor-grantee index, tract index, or title plant. The recording process throughout most of the United States is primarily a manual operation, with not more than 15 percent of the jurisdictions reporting use of electronic data-processing equipment in 1971 (Bureau of Census, 1974).

The basic elements of the recording process are (1) receiving and entering, (2) indexing, (3) transcribing and reproducing, (4) storage of work and security files, and (5) retrieving.

The most important phase of the recording operation to the system user is document retrieval. The use of computerized indexes and microfilm reader-printers has significantly reduced the time and costs to local government for storing these records. However, the use of this technology has often, in fact, delayed addressing the real problems of long-needed reform in both land-title-recording techniques and land-transfer processes.

Over 25 percent of the jurisdictions still hand copy or type some of their documents. Although photocopying in one form or another is widely used, it is often expensive and poorly managed and involves much manual operation. In general, the methods used in the offices of recorders and registrars remain little changed from those of 100 years ago. Not only have most recording offices failed to modernize the procedures associated with conveyancing, but practically all of them also have failed to combine their functions with those of other local government offices (Ayers and Wunderlich, 1973).

2.1.2 Property Assessment

Property assessors are responsible for (1) locating and describing properties, (2) appraising or estimating the value of properties, (3) keeping records linking properties to their respective owners, and (4) designating the official value of properties for tax purposes. To perform these functions, assessors collect, store, retrieve, and analyze information that is related to the ownership and use of land parcels. Separate files, linked by parcel identifiers, are commonly maintained in the areas of legal descriptions, property characteristics, market data, and ownership data (Almy, 1979).

The basic framework of a property-tax system is established by the statutes of each state, with local government responsible for the administration of the property tax laws in all states except Hawaii, Maryland, and Montana. However, Hawaii plans to revert to local administration of the property tax in about 1982. Largely because of overlapping assessment districts, the precise number of districts is not known. Recent estimates total 13,432, with 9205 at the township level, 1777 at the municipal level, and 2444 at the county level (Almy, 1979). Property taxes in 1977 produced six out of every ten municipal tax dollars and eight out of every ten county tax dollars, decreases of 14 and 12 percent, respectively, from fiscal year 1967. Property taxes accounted for 22 percent of all state and local general revenue in fiscal year 1977, down from a corresponding 28.6 percent in 1967 (Behrens, 1980a).

Equitable assessment remains a primary concern; even as revenue shifts, inflation and other influences on value estimation hinder its achievement. The first requirement of a good assessment system is a complete set of tax maps. Assessment maps are now required by law in 32 states. A standard parcel identification system is required in 14 states, and 15 other states have a recommended system. State requirements provide a measure of standardization of assessment maps and parcel identfiers within states. There is, however, little evidence of standardization among states.

Computerization of assessment maps has been limited to system development in a few locations. Computerization of assessment records, on the other hand, has grown significantly since the mid-1960's. Results from a survey made in 1975 indicate that over 70 percent of assessment districts make use of electronic data-processing equipment, with the responses revealing a high correlation between computer use and jurisdiction size. Of those districts making use of the computer, over 70 percent are involved in the printing of assessment rolls and valuation notices, over 11 percent support the appraisal process (e.g., regression analysis), and nearly 7 percent are devoted to sales analysis, including assessment-ratio studies (Almy, 1979).

The need exists for improved cooperation between the offices of assessor and the recorder or registrar of deeds. Both handle much of the same

land data and normally occupy offices in the same government building. Consolidation of data files and handling activities would greatly assist the modernization process.

2.1.3 Land Management

Land management encompasses a broad range of activity that revolves around the land-resource assessment, planning, and regulation processes including zoning. In addition to policy decisions in connection with the management of land and environment, local communities, particularly cities, need detailed land data by parcels and points for the day-to-day operation of their street, water, and sewer departments and the administration of building, zoning, and other land-use ordinances.

Many land-management information systems have been developed since the mid-1960's to support regional, state, federal, and private decision making. In most cases these systems are highly automated. They are designed, however, to meet requirements that are limited in scope. While land ownership and valuation are important factors in land management, much of the data of concern, such as geology, soil and vegetation types, available natural resources, flood plain areas, wildlife habitats, and other environmental patterns, are not naturally attributed on a land-parcel basis. Therefore, these data are often organized using a grid cell structure, based, for example, on a selected cell size such as 2½ acres. The principal flaw is that systems covering the same geographic region are not able to integrate their land information. Duplication of data and gaps in data lead to waste in spending and to decisions based on inadequate information (Clapp and Niemann, 1977).

Significant in the data-collection process for land-management-information systems have been the volumes of remote-sensing data collected since 1972 by the Earth Resources Technology Satellite and Landsat systems. The 185 km x 185 km photographic coverage of a single frame is a useful format for multicounty urban planning agencies, often organized in Standard Metropolitan Statistical Areas.

2.1.4 Private and Public Boundary Surveys

An area of concern, as property values escalate, is the general poor quality of existing property boundary surveys and records. A reliable boundary survey, properly recorded, serves again and again as the basis of legal reference with each succeeding transaction, thereby relieving future buyers from that portion of escalating costs due to resurveys. But, precise boundary surveys are costly, which presents the present land owner with the unfortunate dilemma

of bearing the entire cost for such a survey even though the land parcel may be sold many times in a decade.

The failure to distinguish between precise and unreliable surveys or the different classes of survey reliability of land records and to attach proper warning signals to plats further aggravates the problem. Mulford (1912) stated that in the solution of boundary problems, no general rules can be laid down and that "each man must work out his own salvation." Unfortunately, even today, established accuracy standards are seldom enforced. Also, because of the absence of a cadastral survey authority, isolated land surveys, where standards are adhered to, are of limited value to the general public.

Thirty states have been created out of the public domain and are functioning under the Public Land Survey System. Millions of acres have been deeded to private owners since 1785. Modern subdivision and suburban land development tend to move away from the rectangular boundary system toward irregular boundary lines for private land holdings. Precise surveys in such cases are more difficult to achieve, but in all cases there is an urgent requirement for accurate property boundary referencing procedures.

The Bureau of Land Management estimates that over 50 million acres in the western states are urgently in need of resurvey. This is due in part to fraudulent or inadequate original surveys done prior to 1910 (Committee on Appropriations, 1979).

A 1977 Agricultural Department audit of the Forest Service land line location program found that failure to locate and mark boundaries properly had resulted in over 50,000 cases of trespass on national forest lands. It was estimated that it will cost $112 million to resolve those problems (Committee on Appropriations, 1979).

2.2 PROBLEMS

The problems that characterize current land-information systems may be categorized as those of accessibility, duplication, aggregation, confidentiality, and institutional structure (Larsen *et al.*, 1978).

Accessibility problems arise when a government official or private citizen cannot obtain information for a variety of reasons. The information may simply not be available, or an unreasonably lengthy search is required. Specific gaps exist in what is known about the land, or how the land or water is actually being used. Who owns the land? Are all lands identified and assessed for taxation purposes? The information to answer these questions may not be held by public agencies. Too often the data are structured in poor classification systems with data arrangements and files that limit access to existing

information. Specialists often do not know the extent of publicly held land information. Information rightly available to the public can often only be retrieved by specialists and therefore is only available to those who have the financial resources to ferret it out. Some government information is so inaccessible that it is nearly "confidential." Ultimately, public and private land decisions are made in ignorance of the facts.

Duplication problems occur when the same land information is collected and/or maintained by two or more governmental or private entities. One organization is not aware of what land data another may already have or is planning to collect in a mutually suitable time frame. Data classification systems are not compatible between user agencies, thereby resulting in the judged need for duplicate coverage. The obvious result of duplication is excessive waste.

Aggregation of land information is a problem resulting from the fact that our current information systems are generally not designed to serve the needs of individuals, while continuing to meet the needs of local, state, and national agencies. Information is often gathered at the national or state level, with products provided to smaller governmental units. However, at the county, town, and municipal levels, where basic decisions are made, the prevalent reaction is that state and federal products are too general or inappropriate in scale, resolution, and information detail. The flow of information downward occurs because we have problems integrating records at the local level. These problems prevent the aggregation of information upward. Different types of data relating to the same geographic area are described in different ways. Physical land data describing the geology and soil type, for example, are generally not related to land parcels, as are land title and assessment.

Problems of confidentiality occur because access to some segments of a land-information system should legitimately be restricted. Concern over these restrictions, and the ability of a system to guarantee them, limits the information available to the system. In addition, unclear or conflicting standards specifying just how public so-called "public information" really is lead to variation in the accessibility of information.

Institutional problems arise from the apparent mismatch between the typically vertical structure of existing governmental organization and the inherently horizontal nature of land information. For example, in state governments there typically are several offices organized around land-related tasks such as property assessment, highway planning, and solid-waste management. Each of these offices requires land information, and each typically maintains its own system separate from the others. In the private sector, parallel operations also exist within the utility companies and title insurance companies, resulting in further duplication of information-systems activity (Larsen *et al.*, 1978; Epstein, 1978).

2.3 IMPROVEMENT ACTIVITY

Recognition of the need for improvement in land-information systems has resulted in activity for nearly two decades at local, state, and federal levels of government, in the private sector, and within meetings of concerned professional organizations. Recent activities for improvement of land-information systems among professional organizations began in the early 1960's. There followed the Tri-State Conference in 1966 at the University of Cincinnati College of Law (Cook and Kennedy, 1967) and in 1968 the Mackinac Workshop in northern Michigan (White, 1968). Also in 1968, the Canadians convened their first general conference on the subject at the University of New Brunswick in Fredericton, New Brunswick (Canadian Institute of Surveying, 1968). In 1972, the Conference on Compatible Land Identifiers–the Problems, Prospects and Payoffs was held in Atlanta, Georgia (Moyer and Fisher, 1973), and a second Canadian Conference was held in Ottawa in 1974 on the Concepts of a Modern Cadastre (Canadian Institute of Surveying, 1975). In the fall of 1974, the North American Institute for Modernization of Land Data Systems was incorporated and held its first conference in Washington, D.C., in the spring of 1975 (North American Institute for Modernization of Land Data Systems, 1975). A Land Records Symposium was then held in Orono, Maine, in 1976 (University of Maine, 1976), a joint Symposium on Modern Land Data Systems was conducted by the American Congress on Surveying and Mapping and the American Society of Photogrammetry (1977) in conjunction with their annual meeting in March 1977, and in October 1978 the North American Institute for Modernization of Land Data Systems (1979) held its second North American Conference. The Land Information Institute had its organizational meeting in March 1978 and later joined the Surveying and Mapping Division of the American Society of Civil Engineers (1980) to cosponsor a Specialty Conference in June 1980 on The Planning and Engineering Interface with a Modernized Land Data System.

The forum of these conferences has provided a means of idea exchange and an opportunity to monitor some of the projects in which improvement activity is being implemented. In general, however, implementation of improvement activity in the United States has been characterized by single-purpose approaches to selected elements of the total system. These efforts have addressed specifically the problems in land transfer, property assessment, or land management. Only tangentially have the problems related to the reference frame, base maps, and cadastral overlay been considered.

Numerous efforts elsewhere in North America are under way in continuing attempts to modernize land-information systems. The largest and most comprehensive is the Land Registration and Information Service of the Maritime Provinces (New Bruswick, Nova Scotia, and Prince Edward Island) in Canada.

Other Canadian efforts include the Province of Ontario Land Registration Information System; activities in the cities of Calgary and Edmonton, Alberta; and the City of Toronto's Central Property Register, an operational computerized file system referencing all property-related data from assessment and taxation records to zoning regulations and building permits. In Mexico an automated, multipurpose land-record system has been under development for over a decade.

2.4 STATUS AT THE FEDERAL LEVEL

The following paragraphs describe the complexity of the federal activities in the three basic components of the multipurpose cadastre—reference frame, base maps, and cadastral overlay. Primary responsibilities for geodetic control, base maps, and cadastral surveys of federal lands are clearly assigned to the National Geodetic Survey, the U.S. Geological Survey, and the Bureau of Land Management, respectively. However, there are many other federal agencies whose programs require geodetic, mapping, and cadastral support and that maintain land information and data files.

Strong efforts are being made toward effective coordination. Various proposals have been made for the consolidation of the major groups into a single group—a civilian agency for mapping, charting, geodesy, and surveying—yet no action has been taken. For the three basic components of the multipurpose cadastre—reference frame, base maps, and cadastral overlay—to respond to a single land data system, it is essential that the key federal services be unified. The strategy of the federal government with respect to a multipurpose cadastre must include recognition of this need for reorganization plus the requirement for enabling legislation that would delegate the lead authority for each of the basic components.

In an effort to achieve the maximum coordination within the present organizational structure for these activities, the Executive Office of the President, through its Office of Management and Budget, has designated lead agencies for two of these functions—geodetic surveying and topographic mapping. The Administrative Directive, Office of Management and Budget Circular No. A-16 (4/21/75, #1753), fails to recognize the fundamental role of the Public Land Survey System. This omission, plus others, would suggest the need for a major revision of the document.

We recommend that the Office of Management Budget designate a lead agency for the multipurpose cadastre.

2.4.1 Geodetic Reference Network

The Office of Management and Budget Circular No. A-16 does recognize "National Networks of Geodetic Control," assigning the responsibility for coordi-

nation to the Department of Commerce, which has in turn assigned this responsibility to the National Oceanic and Atmospheric Administration. The geodetic and related surveying activities of the federal agencies are coordinated through a Federal Geodetic Control Committee, with representation from various agencies such as the U.S. Army Corps of Engineers, the Defense Mapping Agency, the Federal Highway Administration, the Forest Service, the International Boundary Commissions (U.S. representatives), the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration (NOAA), the Soil Conservation Service, the Tennessee Valley Authority, and the U.S. Geological Survey. The U.S. Geological Survey, as the representative for the Department of the Interior, transmits the requirements of the Bureau of Land Management and the National Park Service. The Federal Geodetic Control Committee Coordinator is the National Oceanic and Atmospheric Administration (NOAA) Assistant Administrator for Oceanic and Atmospheric Services, and the Deputy Coordinator at present is the Director of the National Geodetic Survey in the National Ocean Survey of NOAA.

To conform to the directives of the Office of Management and Budget Circular No. A-16, the Federal Geodetic Control Committee (1974, 1980) has published two documents: (1) Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys and (2) Specifications to Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys. The National Geodetic Survey (NGS) has the responsibility for the development and extension of the national horizontal and vertical control networks and provides technical direction to federal, state, and local agencies for field surveys. Most of the primary work is accomplished by NGS personnel. A great amount of the secondary work, which is referenced to the national nets, is accomplished under cooperative agreements with other federal agencies or with state groups.

Supplemental surveys, which are made by the U.S. Geological Survey for its mapping programs, by the Bureau of Land Management for its cadastral survey of Alaska, and by the National Ocean Survey for nautical charting, are reviewed for quality control and adjusted into the national networks by the NGS. The results are then made part of the geodetic data base. The Federal Highway Administration, through its close liaison with state highway departments, is a primary user of geodetic control and contributes to the national geodetic data base. The Washington office of the Federal Highway Administration encourages the state and local offices of the respective highway departments to take an active part in these programs, and by such action can contribute to the effectiveness of a national cadastre. The planning of new highway routes, the acquisition of property, and the monumentation of the rights of way benefit from and contribute to the national geodetic data base.

The maintenance of these geodetic networks is a significant task. The loss of monuments due to natural causes or to acts of man exceeds 5 percent per year. The NGS with its limited field force is unable to keep up with this maintenance and so seeks the cooperation of other surveying and engineering groups (federal, state, local, and private) in re-establishing these marks. If it is known that a survey monument is to be destroyed because of construction, its coordinates and/or elevation can be transferred to a new monument at a small fraction of the cost of resurveying from a distant point.

In addition to classical surveying techniques, analytical aerotriangulation and Doppler satellite and inertial surveying systems can be used for densification of control. These systems provide positions in three dimensions and promise to be of economic benefit for the development of a multipurpose cadastre. The Global Positioning System, to be fully operational in the mid-1980's, will also provide an accuracy in three-dimensional positioning of a small fraction of a meter with only 2 or 3 hours of observing time.

An engineer who is providing the control surveys for a local project will frequently criticize the federal system for the lack of control near his project. This is especially true for land surveyors. The recommended spacing of primary and secondary control generally conforms to the value of the land. The minimum density for various orders of control as specified by the Federal Geodetic Control Committee (1974) is much less than that suggested by McLaughlin (1975) and Ziemann (1976a) for the support of an ideal national cadastre, but actual needs should be reviewed and specifications prepared.

To meet the requirement for closer spacing of geodetic control, local (or state) governments seek the cooperation of the federal government. Recent examples of cooperative programs are those between the NGS and Cook County, Illinois, and the NGS and the states of Connecticut and Georgia. A similar cooperative program is described in Section 2.6.3.1.

The data incorporated in the horizontal and vertical geodetic networks have improved with the development of more-precise instrumentation; application of corrections for systematic effects; and improvements in observing, computing, and analysis techniques. To provide a more consistent geodetic network, the NGS has undertaken new adjustments of both the horizontal and vertical control networks. It is anticipated that the new horizontal datum for North America will be available in 1983; the new datum will involve a shift in latitude and longitude at each control point. In addition to new latitude and longitude, coordinates in the State Plane Coordinate System and the Universal Transverse Mercator Coordinate System (standard 6° zones), in feet and in meters to 1983 and only in meters after 1983, will be available for each horizontal control point. The new adjustment of the vertical control network will be completed at a later date.

2.4.2 Base Maps

Under Office of Management and Budget Circular No. A-16, "the Department of the Interior is responsible for the National Topographic Map Series . . . including governmentwide leadership in assuring coordinated planning that all mapping activities financed in whole or in part by federal funds contribute to the National Topographic Mapping Program . . . ." Within the Department of the Interior, this responsibility has been assigned to the U.S. Geological Survey (USGS). In cooperation with other mapping agencies and with professional societies, National Map Accuracy Standards have been developed (American Congress on Surveying and Mapping and American Society of Civil Engineers, 1972). In 1978, in support of the national program, 38 states and Puerto Rico had cost-sharing cooperative agreements for selected mapping in their respective jurisdictions. The 7.5-minute topographic map series, 1:24,000 scale (1:25,000 for new metric series), is currently the primary USGS series and provides the principal source material for the multipurpose cadastre base-mapping program. Another source of information is the 1:24,000-scale orthophotoquad series, a basic type of photoimage map prepared in the USGS 7.5-minute quadrangle format. Photoimage maps at 1:2400 scale were also produced for four pilot project areas to demonstrate utility as an urban-area base map (Baxter and Mattingly, 1975). A set of guidelines for large-scale mapping has been prepared by USGS based on studies of these projects. In further support of the national cadastre, special reference is made to the USGS program for establishing a digital cartographic data base. By 1979, there were more than 3000 files of 7.5-minute elevation model data.

In addition to the topographic mapping responsibility of the USGS, their Resource and Land Investigations (RALI) program has been concerned about the availability of adequate land-use data and land information within government for land and resource planning and management. As part of this concern, RALI funded a project with the Council of State Governments to identify problems with USGS mapping and data-collection and -dissemination systems for the purpose of making recommendations for improving federal responsiveness. Case studies in Texas, Connecticut, and Wisconsin were selected.

The National Ocean Survey produces nautical charts of the coastal areas and the Great Lakes. The Department of Housing and Urban Development (HUD) funded a pilot project (1969–1974) to produce Flood Insurance Maps for the coastal flood plain. Storm Evacuation Maps have been prepared for the National Weather Service. In cooperation with the USGS and state agencies, the National Ocean Survey has produced maps (1:10,000 scale) along coastlines, depicting the high-water line. The hydrographic surveys of the offlying areas and the photogrammetric surveys along the shorelines provide

sources of data essential for a national cadastre. The National Ocean Survey, in cooperation with the Federal Aviation Administration, produces a broad series of aeronautical charts; the cartographic data base for these charts also contributes to a national cadastre.

The Corps of Engineers, through its civil works construction and maintenance programs, has a broad requirement for various types of mapping. The maps that are produced can contribute directly to a national cadastre, particularly with respect to property boundaries and related problems. Likewise, a national cadastre could contribute significantly to the preparation of such maps and to other local requirements associated with construction projects. The U.S. Army Corps of Engineers, through its organization by Divisions and Districts (representing local or regional rather than national programs), could be one of the major federal groups utilizing a multipurpose cadastre.

Other federal agencies preparing and using similar scale maps include the Soil Conservation Service, the Bureau of Land Management (BLM), the Forest Service, National Park Service, the Federal Highway Administration, and the Bureau of the Census.

The excellence of the technical capabilities for producing large-scale maps and charts has been demonstrated. The budgetary support has been good but could be greater. Cooperative programs with state and local governments have been established. Mapping and charting techniques have been highly automated, making use of extensive cartographic data bases. In spite of these achievements, there remains a requirement for more very-large-scale mapping to support a national cadastre. The needs are local (or state) rather than national. The map series should be of the order of 1:1000 or 1:2000 (some planners suggest 1:500 in densely populated areas). The federal agencies can give guidance to the counties and states. Federal funds could be made available to initiate and sponsor these activities at the local level.

2.4.3 Cadastral Overlays

The third component of the multipurpose cadastre system is the cadastral overlay. The primary federal agency involved in cadastral surveying is the BLM, which is responsible for the survey of federally owned lands (approximately one third the area of the United States) and for the Outer Continental Shelf. When practical, these surveys are referenced to the national geodetic network. As an example, in Alaska, where the BLM has the responsibility for approximately three fourths of the area of the state, several Doppler satellite receivers are being used to tie the rectangular land system to the geodetic network. The agency has also purchased three inertial survey systems for establishing intermediate points within the Doppler network.

The BLM also provides direction and coordination to the state offices of

its organization or to special state groups that it has designated. The plats, maps, field notes, and other data relating to the Public Land Survey System, which are available as public records in the state offices, are essential to a multipurpose cadastre. Other federal agencies involved in cadastral surveying, such as the Forest Service and National Park Service, perform such operations under BLM direction and coordination.

The BLM, in response to the Federal Land Policy Management Act of 1976, formed an automation data-processing steering committee, which created a Strategic Plan for Information Systems Management. This plan was further strengthened by the creation of the Bureau Resource Information Management Systems (BRIMS) concept. BRIMS uses cadastral overlays based on coordinates. In May 1979, this Bureau instructed its 12 field offices to make direct geodetic ties from all new rectangular surveys to the 1927 North American geodetic horizontal control datum, and this policy is now being implemented. The BLM also initiated, in October 1979, three projects in Georgetown, Colorado, where they are investigating the requirements for classical geodetic and Doppler satellite surveys in support of the May 1979 instructions. Plans to implement BRIMS include the testing and evaluating of interactive computer support at Georgetown, Colorado. The Denver Service Center Branch of Micrographics will conduct tests of available digitizing systems in the scanning of field notes and plats. Long-range plans call for computer storage of digitized federal-land-status information for graphical display use with flat-bed plotters.

2.4.4 Improvement Implementation at the Federal Level

In the United States at the federal level, the Urban Information Systems Interagency Committee (USAC), chaired by the Department of Housing and Urban Development, was established in 1969 and supported demonstration projects to develop complete or partial Integrated Municipal Information Systems in six cities with populations between 50,000 and 500,000. Charlotte, North Carolina, and Wichita Falls, Texas, were selected to develop complete systems. Reading, Pennsylvania, was chosen to develop an information system for physical and economic development of local government; Long Beach, California, for public safety; St. Paul, Minnesota, for human resources; and Dayton, Ohio, for finance. Approximately $22 million of local, state, and federal funds were invested over a 5-year period in the USAC demonstration projects, providing experience for later efforts in multipurpose land-information systems (Hemmens, 1975; Moyer, 1977). Among the program benefits, it can be noted that the system now in operation in Wichita Falls makes it possible for the assessor-collector to conduct assessment–sale ratio studies annually, citywide and by neighborhood.

The Real Estate Settlement Procedures Act (RESPA) of 1974 directed HUD to establish and place in operation, on a demonstration basis, model systems for the recordation of land-title information in a manner to facilitate and simplify land transfers and mortgage transactions and reduce the cost thereof, with a view to the possible development of a nationally uniform system of land-parcel recordation. This RESPA Section 13 program has been funded at a level of $2.5 million for two phases over a 2-year period. Phase I, covering state-of-the-art research, was carried out by Booz, Allen and Hamilton (1978), resulting in several research reports. Phase II provided for the dissemination of the research findings through seven model systems projects funded at $100,000 to $400,000 each. Sites selected were St. Louis, Missouri; Pinal County, Arizona; Warren County, Ohio; three counties in North Carolina; the Southern Middlesex Registry in Cambridge, Massachusetts; Summit County, Colorado; and Hennepin County, Minnesota. Reports from these demonstration projects are scheduled for September 1980.

With the enactment of the International Investment Survey Act of 1976, there was also recognized the special difficulty of obtaining information on direct investment in real estate, and provision was made for study of the feasibility of establishing a nationwide multipurpose land-data system. The Economics, Statistics, and Cooperatives Service of the U.S. Department of Agriculture has carried out the feasibility study based on an evaluation of four alternative scenarios in terms of technical, economic, administrative, legal, and institutional criteria and constraints. The following four alternative sources of information on foreign investment in U.S. real estate were considered (Moyer *et al.*, 1979):

Type 1. A centralized federal registration system with the burden of responsibility of registering on the foreign entity or his representative.

Type 2. A federal system utilizing available sources (Securities and Exchange Commission, Federal Trade Commission, Internal Revenue Service) to which foreign investors may already be or would be capable of reporting.

Type 3. A national multipurpose land-data system, including data on foreign direct investment, oriented to local government records, principally tax assessment but including title records, land-use records, and county offices of federal agencies.

Type 4. Periodic statistical surveys, to provide standard nationwide data on land ownership, such as those of the Bureau of Census and the U.S. Department of Agriculture rural land-ownership survey.

The study report was completed in October 1979, but to date the conclusions have not been published.

The U.S. Bureau of the Census conducts a national sample survey of much

of the information related to the land-transfer and property-assessment components of the multipurpose cadastre, which provides summary statistics on land-ownership parcels for their purposes as a user of state and, more often, local land records. One such activity is the Taxable Property Values Survey, completed for each quinquennial Census of Governments by the Census Bureau. Since the survey is the only one of its kind, producing results widely used by state and local officials and the general public, a summary of pertinent aspects follows.

Beginning in 1957, and in each year ending in 2 or 7 as directed in Title 13 of the U.S. Code, the Bureau of the Census has sampled two listings of real property parcels contained in local public records, as the basis for publishing statistics on property values, assessment levels, and property taxation. Bureau enumerators actually visit local recording and assessing offices in approximately 2000 primary assessing jurisdictions (usually counties) throughout the country. From the public records of transfers (e.g., the grantor–grantee index), enumerators obtain for each of 250,000 randomly selected sales of realty the parcel identification, transacting parties, and date of sale. From the public record (usually the "assessment roll") at the assessor's office, enumerators obtain the assessed value for each of the above sales and for sales in large places the tax bill as well. Then they separately enumerate, from the same roll, and other records if necessary, a sample of approximately 1.5 million realty parcel assessed values, together with parcel identifying and actual use data. Subsequently, questionnaires to parties (usually buyers) involved in the above sales produce data for 120,000 measurable sales. A separate mail canvass of the state officials involved produces benchmark aggregates for each assessing jurisdiction.

Published findings include de facto assessment levels (assessment–sale price ratios), dispersion coefficients, and effective tax rates for local assessing jurisdictions nationwide, estimated distributions of assessed values and numbers of parcels among seven realty-use categories for the entire country and for each state and its metropolitan portion, and similar assessed-value distributions for many local jurisdictions.

As a natural survey consequence, the Bureau of the Census has acquired a familiarity with local recording and assessing personnel, records, and procedures nationwide that is unique. Survey data constitute the only nationally consistent summations of values and parcels and of indicators of assessment uniformity and property-tax burdens. Cooperating with the Bureau are thousands of state and local recorders, assessors, tax collectors, and data processors involved in the mapping, valuation, transfer, and taxation of realty. Thus, the survey is validly regarded as a unique institutional resource, not only for substantive data but also for user familiarity with local environments replete with variation (Bureau of Census, 1978; Behrens, 1980b).

The Bureau of the Census has also been a leader in the development of improved techniques of geographic referencing for the collection, organization, and processing of data from the Census of Population and Housing. This includes design and development of the Geographic Base File (GBF) using the Dual Independent Map Encoding (DIME) approach, providing file coverage of the urban cores of most Standard Metropolitan Statistical Areas of the United States. The framework of the GBF/DIME system is attractive in its uniform format over a large percentage of the population distribution. DIME has two components, one with standard geographic elements (e.g., street address), the other with locally supplied data elements (e.g., crime statistics, public-health data). Use of DIME makes it possible to match records in two files via street address or to process incoming data by means of geocoding. To the extent that DIME affects geographic identification of street address, it makes possible tabulation of data related to parcels so identified (Silver, 1978). Specific related efforts to apply DIME capability to individual parcels were undertaken in the city of Omaha, Nebraska (Kinzy, 1979). DIME's basic frame of reference is a block face or enclosed area (e.g., area enclosed by four streets).

2.5 STATUS AT THE STATE LEVEL

2.5.1 Geodetic Reference Network

Responsibility for the coordination of geodetic control activity at the state level varies from effectively no organization or coordination in some states to the existence in other states of strong state geodetic survey agencies. In many states, leadership resides within the state Department of Transportation, Division of Surveying and Mapping (or equivalent). In 17 states, there is the Office of State Surveyor (or equivalent), which has been established by state statute to coordinate surveying activity. In February 1979, the American Association of State Surveyors was organized to provide for formal interaction among the state surveyors; by March 1980, 11 of the 17 state surveyors had affiliated with this organization (Myers, 1980).

Technical support and cooperation from the National Geodetic Survey (NGS) is available to the state surveying organizations in their geodetic control extension and densification programs. This support particularly aids the state-level organizations in their use of proper geodetic control survey techniques. Historically NGS has entered into cooperative agreements with government agencies without regard to type of agency or level of government. Agreements with state Departments of Transportation in Georgia and Connecticut are recent examples in which NGS provided manpower on a reimburs-

able basis to survey first- and/or second-order control networks and instructed the state surveyors to provide further densification. In an agreement with the Maine Department of Transportation, NGS provided only a skeleton field party, which was supplemented by state personnel to simultaneously survey first- and second-order networks.

The trend in cooperative agreements is toward only providing general advisory services or specific inspection or instruction services. New York, Georgia, Louisiana, Arizona, and South Carolina currently have resident state geodetic advisors provided by the NGS on a cost-sharing basis. Several other states have agreements for reimbursable advisory services on an as-needed basis.

2.5.2 Base Maps

There are at least 12 states that are actively involved in establishing statewide property maps: Alabama, Florida, Maryland, Minnesota, Montana, New Hampshire, New Mexico, New York, North Carolina, Oregon, South Carolina, and Vermont. The programs in each of these states provide a wide variety of assistance to local jurisdictions, from funding of aerial photography for mapping projects to complete statewide property-ownership mapping programs. State involvement has encouraged the applications of modern technology into the mapping process, particularly in the areas of automated (computerized) mapping and map maintenance. Some of these attempts at automation, however, have not been entirely successful or cost effective. Often inadequate attention is given to the maintenance of mapping systems once the initial front-end costs have been absorbed. While National Map Accuracy Standards exist for map production, there currently are no national standards for map maintenance.

2.5.3 Cadastral Overlays

Several states, most notably North Carolina, Oregon, and Massachusetts, have made significant progress in their efforts to prepare enabling legislation and to modernize their land-records information systems. In 1976, then President-Elect Ellsworth Stanley of the American Congress on Surveying and Mapping (ACSM) wrote a letter to each of the 50 state governors identifying the recommendations from the Symposium on User Requirements for Land Records and Resource Information, held in Orono, Maine, in August 1976. Stanley urged each governor to seek the accountability from the public agencies in their state for their expenditures for land-based information and for the quality of the results. He also suggested that ACSM could work with any of the states toward their development of land-based information systems. Seven substantive responses were received from Florida, Massachusetts, Missouri,

Montana, New York, North Carolina, and Tennessee. Many of the remaining 27 replies were cordial acknowledgments of the receipt of the information. This apparent lack of concern at the state level indicates one of the major problems in the development of a multipurpose cadastre.

A principal concern at the state level should be the coordination of land-information improvement efforts in the areas of land transfer, property assessment, and land management. Few states are combining or coordinating the activities of land-transfer and property-assessment improvement programs. No state has attempted to coordinate all three of the major components (reference frame, base maps, and cadastral overlays) of a multipurpose cadastre.

Leadership exists at the state level for the improvement of boundary surveys in the organizations of the Professional Land Surveyors. Through the initiative of ACSM, these groups have banded together to voice opposition, at the national level, to legislation that has not been in the best interests of land surveyors. Under the leadership of their state land-surveyor societies, several states have written legislation establishing statewide surveying standards. These standards specify minimum levels of accuracy for various types of surveys and dictate requirements for tying surveys into the State Plane Coordinate System. This legislation may serve as a model for enabling legislation necessary in the evolution of a modernized land-data system. The state organizations of land surveyors could provide the necessary support for such legislation.

2.5.4 Improvement Implementation at the Provincial and State Level

Three representative examples of improvement activities are described. They reflect a concern for the development of provincial and state-level land-information systems based on cadastral parcels.

2.5.4.1 Maritime Land Registration and Information Service

The Maritime Provinces of Canada encompass an area of approximately 52,000 square miles with over 1.6 million population and an estimated 800,000 legal parcels of land (Roberts, 1980). The first step in the long process of cadastre modernization in the Maritime Provinces was the statement of need in 1944 by the New Brunswick Forest Products Association to the New Brunswick Committee on Post-War Reconstruction for "the organized and supervised survey of property boundaries with adequate monuments so that boundaries can be renewed without dispute . . . for up-to-date accurate property maps for municipal taxation purposes. Control surveys are necessary as a framework for making line maps, and the survey of municipal and prop-

erty boundaries can be combined with control surveys and used for this purpose." The development of electronic distance-measurement instrumentation in the mid-1950's allowed for the economical beginning of such a densified control system. In 1958, the New Brunswick Coordinate Survey Program was formally organized within the provincial Department of Land and Mines; and in 1967, a provincial Surveys Act was passed, legally defining a control coordinate system and providing for its continued maintenance. In 1968, the Canadian federal government committed $4 million to the Atlantic Provinces to underwrite a two-year effort for a control-surveys, base-mapping, and land-registration program, followed by another $5 million in 1970. In 1971, the provincial governments of New Brunswick, Nova Scotia, and Prince Edward Island agreed to establish the Council of Maritime Premiers, through which they could provide a formal framework for promoting unity of purpose, for improving intergovernmental communications, and for implementing joint programs. An early area of interest for the new Council was the matter of land use and land ownership. In 1973, the staff previously employed in survey programs by the provinces formed the nucleus of a new regional organization, the Land Registration and Information Service. The Council of Maritime Premiers succeeded in gaining strong support from the federal government through the Department of Regional Economic Expansion, which provided funding for 75 percent of the program cost through mid-1979.

The Land Registration and Information Service program consists of four component phases:

Phase I. Extension and densification of a second-order control survey system based on the primary geodetic survey network provided by the Federal Department of Energy, Mines and Resources. The primary network consists of 396 monuments at an average spacing of 30 km. It is intended that all properties and land-related information be integrated with this system. Density of monumentation depends on land value and the extent to which the transportation systems in the country have been developed. As a general guide, monument spacing (both horizontal and vertical control) in urban areas is 400 m, in suburban areas is 750 m, and in rural areas is 4 km, or each 1 km along highways. The final secondary network contains nearly 41,000 monumented stations, with coordinates and their associated confidence information available. Over 12,000 new monuments have been placed by this program.

Phase II. Production of a uniform series of resource, urban, and property maps with scales varying from 1:1000, 1:2500 and 1:5000 for urban line maps with contour intervals of 1 m and 2 m to 1:10,000 for resource orthophoto maps with a 5-m contour interval. Property maps are compiled on the resource map series in rural/forested areas and on the urban series, where the

parcel density is higher. Nearly 5000 resource and urban maps have been produced since 1973, more than doubling the map base available. As of April 1979, 64 percent of the resource mapping, 77 percent of the urban mapping, and 39 percent of the property mapping had been completed.

Phase III. Implementation of an improved system of land-title registration utilizing modern technology for storing, retrieving, and processing land registry data. Reference of a parcel to the control reference system (Phase I), using current ownership maps (Phase II), supports development of a computer-based land-title system which will be progressively updated from the present grantor–grantee indexing to a parcel index system and then to a land-title system fashioned on the Torrens principles of title registration (Bureau of Census, 1974). All title information will be stored on computer files and be immediately accessible from any land registration office within the Maritimes. The cost of producing only the land-parcel computer file and associated property maps was estimated in 1978 at $23.60 per parcel.

Phase IV. Establishment of a computerized land data bank, integrating information on land use, resource, geology, soil, and other factors with the ownership data, thus developing the multipurpose cadastre records.

In addition to the $9 million funding of the Atlantic Provinces Surveying and Mapping Program in 1968 and 1970, costs since 1973 are estimated at $27 million, shared principally by 75 percent Canadian federal funding and 25 percent through the Council of Maritime Premiers (McLaughlin and Clapp, 1977; Ogilvie, 1977).

2.5.4.2 North Carolina Land-Records-Management Program

The North Carolina General Assembly enacted legislation in 1977 creating a state land-records-management program to provide assistance to counties desiring to improve their land-records system. This legislation provided for the implementation of a system of land-parcel identifier numbers and established a program to provide financial assistance to counties for the modernization of their land-records system and for the preparation of new base maps and property maps. The three bills passed by the General Assembly were the culmination of effort at the state level that began in 1974 when the North Carolina Bar Association created a special committee to study land records. Funds were raised through donations, and the Institute of Government of the University of North Carolina was retained to conduct the study. The report of the study recognized that (1) there was little uniformity among the state's 100 counties in the handling of land records; (2) the current system was insufficient to meet current and future demands; (3) the costs to the individual counties to improve their systems would be great, and 100 separate and incompatible systems might develop if a statewide study was not conducted to

induce uniformity; (4) only five counties had high-quality mapping systems, and 32 counties had no mapping systems; and (5) the recording of maps was not uniform. In 1975, the study group unanimously recommended that a legislative study commission be created, resulting in the Legislative Research Commission of the General Assembly forming the Committee on Land Records Information Systems, made up of both legislators and public members. The General Assembly appropriated $150,000 in 1975 to the State Department of Administration for the purpose of research and development of a modernized land-records-information system. The General Assembly apportioned $125,000 of the funds in support of a pilot county project in Forsyth County (Winston-Salem area, 419 square miles, 140,000 parcels) (Ayers, 1980); the remaining $25,000 supported the Legislative Research Commission Study. Forsyth County has received another grant of $210,000 ($10,000 from the Department of Housing and Urban Development and $200,000 from the Appalachian Regional Commission) (Ayers, 1980).

The Forsyth County Land Records Information System had been conceptualized in the late 1960's by Register of Deeds Eunice Ayers, with active development beginning in 1974. The system has had as its goal the centralization of records and maps that have historically been kept by eight different departments in three separate buildings. The system features an automated parcel indexing system, automated grantor–grantee indexing system, parcel-level base maps, standard recording forms, rapid instrument processing, and micrographics storage and retrieval. The system is being implemented on a Burroughs 6800 computer, with both the City of Winston-Salem and the public school system also sharing in its use. Title-related data are on-line and accessible in the Register of Deeds office and the Tax Supervisors (assessors) office. A 30-year chain of title has been captured, and as deeds are recorded the new ownership and deed book and page are added to the system via on-line terminals. Tax records for each parcel are also accessible on-line by owner's name or tax block and lot. Eventually parcel identifiers and property address indexes will be added.

Since 1974, nearly $3 million has been budgeted for the software development, data conversion, and digitizing of the property parcels. This figure does not include expense for editing, monumentation, and ground control.

Property maps are being prepared on orthophoto base maps using photography flown in 1974 and referenced to geodetic control of the National Geodetic Survey and the North Carolina Geodetic Survey. The property maps have been digitized, and an interactive graphics system has been purchased to support the need for updated graphic products (Ayers, 1978; Jones, 1978; Forsyth County Land Records, 1975-1976).

A critical impetus in the favorable reception that land-records improvement legislation received in North Carolina was the requirement for property

revaluation every eight years and the concern at the local political level for equitable property assessment, given the widespread lack of good property maps. With the passage of legislation in 1977, the North Carolina Department of Administration's Land Records Management Program distributed documentation to assist individual counties in preparing a long-range plan for county land records, including regulations governing State Grants for Improvement of Land Records. Also distributed were documentation for Model Specifications for County Base Maps, Model Specifications for Cadastral Maps, and Practical Aspects of the Uniform Parcel Identifier.

Base mapping scales used are 1:1200 in urban, 1:2400 in suburban, and 1:4800 in rural areas. The 14-digit land-parcel identifier specified for use is based on the North Carolina State Plane Coordinate System.

The State General Assembly has appropriated $75,000 each of the last three years for distribution as grants to counties for the improvement of their land records. Thus far, 15 of the 100 counties in North Carolina have benefited from the program (Campbell, 1975; De Ramus, 1978; North Carolina Department of Administration, 1978).

Also established in North Carolina as a result of the State Land Policy Act of 1974 was the Land Resources Information Service to support the planning activities at all levels of state government. A minicomputer interactive graphics system has been operational since 1977 digitizing available orthophoto and topographic map products geographically based on the North Carolina State Plane Coordinate System. A common working scale is 1:24,000 though both smaller and larger scales are used for various requirements.

2.5.4.3 Oregon Department of Revenue Standard Cadastral Map Program

In order to achieve equalization and uniformity in *ad valorem* taxation, in 1951 the Oregon State Legislature approved a statewide reappraisal program. It was immediately found that the real property inventory in most counties was incomplete and that the cadastral maps were inadequate for appraisal purposes. Furthermore, there was no uniformity between county map systems. Tax administrators realized that equalization could not be achieved by reappraisal alone; map standards had to be developed and employed in a massive statewide reappraisal program. In 1952, the Legislature authorized the State Tax Commission to install and assist in the preparation and maintenance of map standards, cadastral maps, and standard record systems in the offices of the assessors, also providing for the sharing of expenses of the map and records projects. Thus began a cadastral map program, which has now evolved into the Computer-Assisted Mapping System, developed and operated by the Urban-Rural Mapping Unit of the Assessment and Appraisal Division of the Oregon Department of Revenue. The responsibility of the Urban-Rural

Mapping Unit is to (1) develop and maintain Oregon State cadastral map standards; (2) prepare and install standard cadastral map and record systems in the offices of the county assessors, on a 50-50 cost-share basis; (3) make status studies of county cadastral map systems and recommend procedures for correcting system deficiencies; (4) assist county assessors and cartographers with technical map and ownership problems; (5) train county cartographers, appraisers, and other assessment officials in the preparation, maintenance, and use of cadastral maps; (6) maintain tax code maps; (7) make soil-type maps; and (8) maintain cadastral map and record systems in 13 counties where workloads are insufficient to require a full-time cartographer. These responsibilities are carried out by a work force of 18 cartographers and one clerical assistant under the direction of a manager and an assistant manager.

Base-mapping scales used range from 1:1200 for urban areas to 1:24,000 for resources mapping. Geographic referencing for all maps is the Oregon State Plane Coordinate System.

Two counties in Oregon have, or are in the process of developing, advanced systems. These are Lane County, including Eugene, and Marion County, including Salem (Mead, 1977; Penfold, 1978).

2.6 STATUS AT THE LOCAL AND PRIVATE LEVELS

2.6.1 Geodetic Reference Network

At the regional, county, and local levels, geodetic control activity is carried out most commonly by private surveyors and engineers in response to the needs of specific projects and long-range objectives of regional and municipal control densification. As at the state level, technical support and cooperation from the National Geodetic Survey is available to support regional and local control densification. Recent cooperative agreements have been designed for Jefferson County, Colorado; Portage County, Ohio; King County, Washington; Ada County, Idaho; Ingham County, Michigan; three counties in both Florida and New York; and the Chicago, Illinois, and Washington, D.C., metropolitan areas.

2.6.2 Base Maps and Cadastral Overlays

Most states and many local governments have active mapping and land-record programs that could be incorporated into a multipurpose cadastre. Generally, these efforts are undertaken to solve mainly local problems without considering the need for compatibility with systems in adjoining jurisdictions or at the

state and federal levels. State mapping efforts are usually undertaken in cooperation with the USGS, but the very-large-scale maps are accomplished under contract to private surveying and mapping companies. Cadastral overlays prepared in local offices range from being complete and up to date to being barely usable.

One of the major functions of each of the Offices of Land Information Systems, proposed for local and state governments elsewhere in this report, will be to examine the status of base maps and cadastral overlays within its jurisdiction, determining items of commonality and building on these a compatible network of multipurpose cadastres.

2.6.3 Improvement Implementation at the Local and Private Level

There are many improvement activities at the local level within county jurisdictions. Notable examples are in Forsyth County, North Carolina; Lane County, Oregon; Fairfax County, Virginia; Racine County, Wisconsin; Hennepin County, Minnesota; Nassau County, New York; and the City of Houston, Texas. Significant cooperative efforts are also being carried out at the local level in Memphis, Tennessee, under the Computer-Assisted Mapping and Record Activities Systems Project and in Southeastern Pennsylvania under the Regional Mapping and Land Records Program.

Several local governments have minicomputer-based interactive graphics systems implementing automated mapping. Among the earliest such installations was that of Nashville and Davidson County, Tennessee, in 1974 for the creation and maintenance of a comprehensive planimetric digital data base for all 700 square miles of Davidson County. The data base includes topographic data, parcel boundaries, and utility inventory, all correlated to the State Plane Coordinate system. The data base was developed over a one-year period from a 1:2400 map series, with 2800 individual one-quarter-square-mile map segments.

Other interactive graphics systems have been implemented in Santa Rosa, California; Milwaukee, Wisconsin; Virginia Beach, Virginia; and Chicago, Illinois (Kevany, 1979).

In the private sector, numerous title insurance and utility companies are the proponents of land-information-systems improvement.

2.6.3.1 Southeastern Pennsylvania–Regional Mapping and Land Records Program

The Regional Mapping and Land Records (RMLR) program is an example of a cooperative effort between private and public utilities and local government.

The participants in RMLR are the Delaware Valley Regional Planning Commission; the Pennsylvania counties of Bucks, Chester, Delaware, Montgomery, and Philadelphia; Philadelphia Electric Company; Bell of Pennsylvania; Philadelphia Gas; Philadelphia Suburban Water; Pennsylvania Power and Light; and the Philadelphia City Water and Sewer Departments. Following preliminary informal discussions beginning in 1972, RMLR was initiated in 1976. To help determine the best approach for achieving accurate base maps for common use by the participants, a 50-square-mile pilot project in Norristown, Pennsylvania, was defined. The $100,000 cost of the pilot project was shared by the participants, with no participant contributing more than $15,000. Geodetic control densification was carried out, in cooperation with the NGS, placing 50 new first-order stations. A private contractor was selected to perform the pilot project. Base mapping scales of 1:500 and 1:1000 in urban and 1:2000 in both suburban and rural areas were used. Products also include orthophotography, digital planimetric mapping, digital contour overlays, and digital property mapping. Production of the digital data base is accomplished using direct stereo digitization of each stereo model. The mapping is performed at 8x magnification, producing the 1:2000-scale mapping from 1:16,000-scale photography and the 1:500-scale mapping from 1:4000-scale photography. Property boundaries are scissor drafted onto the orthophotography base and then digitized for input into the digital data base. The interactive graphics software provides great flexibility in looking at selected segments of the digital data base for any specified map area (Byler, 1978).

The RMLR Norristown pilot project concluded in August 1979. Based on cost data collected during that project, the City of Philadelphia conducted a detailed cost analysis that initially indicates a favorable cost-benefit ratio in land-data modernization. The City of Philadelphia has also defined its own center city project covering 25 blocks in center Philadelphia, in cooperation with the major utility companies (Hadalski, 1980).

2.6.3.2 Memphis, Tennessee–Computer Assisted Mapping and Record Activities Systems Program

The Utility Location and Coordination Council of the American Public Works Association was authorized in 1976 to form a special task force on computer mapping and records systems. The task force was charged to determine an American Public Works Association–Utility Location and Coordination Council standard for computerized mapping and to prepare a problem description and definition report describing a test system for demonstration and development of procedures and standards. As a result, the American Public Works Association initiated in 1977 the Computer Assisted Mapping and Record Activities Systems (CAMRAS) program in Memphis, Tennessee, at a funding

level of $1 million over a three-year period, supported by over 20 agencies. The stated objectives of the program are (1) to develop, promulgate, document, and implement suggested procedures, standards, and specifications for jointly funded and shared-used computer-assisted geobased local record systems and (2) to assist city, county, and utility interests in initiating, developing, testing, and operating a working system to provide a wide range of measurable and user-oriented data. Base mapping scales of 1:1200 for line maps (3200 acres) and 1:2400 for orthophoto maps (325 square miles) were selected, with maps of both scales being digitized (Bathke, 1978).

The ultimate objective of CAMRAS is technology transfer to the sponsoring agencies through a series of over 25 technical reports. The first three CAMRAS documents have been released and are entitled *Aerial Photography for Photogrammetric Mapping, Procurement Specifications for An Interactive Graphics System*, and *File Format for Data Exchange Between Graphic Data Bases*. Other reports will deal, among others, with such items as vendor evaluation, data capture, and user guidelines and will be published as they are completed (Hinkle, 1980).

2.6.3.3 Metropolitan Common Data Base, Houston, Texas

The city of Houston, Texas, has introduced the Metropolitan Common Data Base (METROCOM) system, an integrated collection of spatially related municipal data (Hanigan, 1979). All data are indexed to digitized versions of planimetric base maps, which are being produced using standard photomapping techniques. The data-base development is being accomplished using local resources: a registered land surveyor for the ownership data base, a title company for boundary research and ownership verification, a mapping firm for tax map compilation, an appraisal firm for property improvements and revaluation, and a professional engineer for facility mapping.

The geobase for METROCOM are the more than 5000 survey markers implanted at intervals of approximately 610 m, whose coordinates have been determined from second-order, class II horizontal and vertical control surveys (Federal Geodetic Control Committee, 1980). The 1:1200-scale maps are produced in planimetric and topographic series, compiled from 1:6000-scale color aerial photography. All maps are compiled to the National Horizontal Map Accuracy Standards of 1/40 in. at map scale for 90 percent of well-defined points (American Congress on Surveying and Mapping and American Society of Engineers, 1972). At present, planimetric map data are entered into the data base at ten data levels: roadways, railroads, drainage, sidewalks, driveways, fences, parking lots, buildings, miscellaneous cultural detail, and annotation. In the building and maintaining of the METROCOM data base an interactive graphic mapping system is used.

Major emphasis during the first year of the project has been on the development of the geobase from available high-quality planimetric base maps. The ready availability of these acceptable data provided Tax and Public Works Departments with time to familiarize themselves with the digital mapping system's capabilities and limitations. At present, the nongraphic data file for creation of ownership maps is under development, and work is under way on design of the file structure for facility mapping (Hanigan, 1979).

2.7 CONCLUSIONS

Although great progress in land-information systems has been made in some localities, it is apparent that without constructive action at the various levels of government, the land-record and land-information systems will become increasingly unmanageable. A multipurpose cadastre, compatible on a national basis, would go a long way toward resolving this situation. Input data to the cadastre will develop at all levels of governments and from private individuals and institutions. The free flow of data and information among all users requires a compatible system of multipurpose cadastres that will make up a national network.

To achieve the degree of compatability required for a workable network of multipurpose cadastres, improvements are needed in local, state, and federal organization; in surveying and recording practices; and in local, state, and federal legislation. The technical problems to be resolved are discussed in Chapter 3; the organizational problems are considered in Chapter 4.

3
Technical Requirements

The creation of compatible multipurpose cadastres requires the input from many different sources. Transactions and records of municipal, county, state, and federal agencies feed into the system. The major federal participants will include the Bureau of Land Management, the Land Acquisition Section of the Department of Justice, the U.S. Geological Survey, the National Geodetic Survey, the Bureau of the Census, the U.S. Department of Agriculture, the Department of Housing and Urban Development, the U.S. Forest Service, and the U.S. Army Corps of Engineers. The effectiveness of the multipurpose cadastre network will depend primarily on the degree of participation by municipal, county, and state governments and in their conception of the benefits to be gained at these levels of government from the free flow of data and information. A major share of the benefits will accrue to private conveyances. Since most contributors will also be users, it behooves all to maintain rigid quality-control standards. The network of multipurpose cadastres must be properly coordinated, organized, and maintained. A well-thought-out linkage mechanism will make it effective nationwide. Based on the elements of Section 1.4 and Figure 1.1, the details of such a cadastre and how it can function serving needs and different purposes are illustrated in Figures 3.1(a) and 3.1(b). Representative acquisition modes (geodesy, field surveys, and photogrammetry) are presented that lead to the elements of the multipurpose cadastre reference frame as described in Section 3.1. Similar information is presented (acquisition modes and elements) for the multipurpose cadastre base map and cadastral overlay described in Sections 3.2 and 3.3, respective-

ly. With these three components of the multipurpose cadastre in place (completely or partially), the elements of the linkage mechanisms, discussed in Section 3.4, are given, which will connect the land information and data files to the three basic components of a multipurpose cadastre. A network of compatible multipurpose cadastres will permit the free flow of information among all levels of government, private individuals, and institutions.

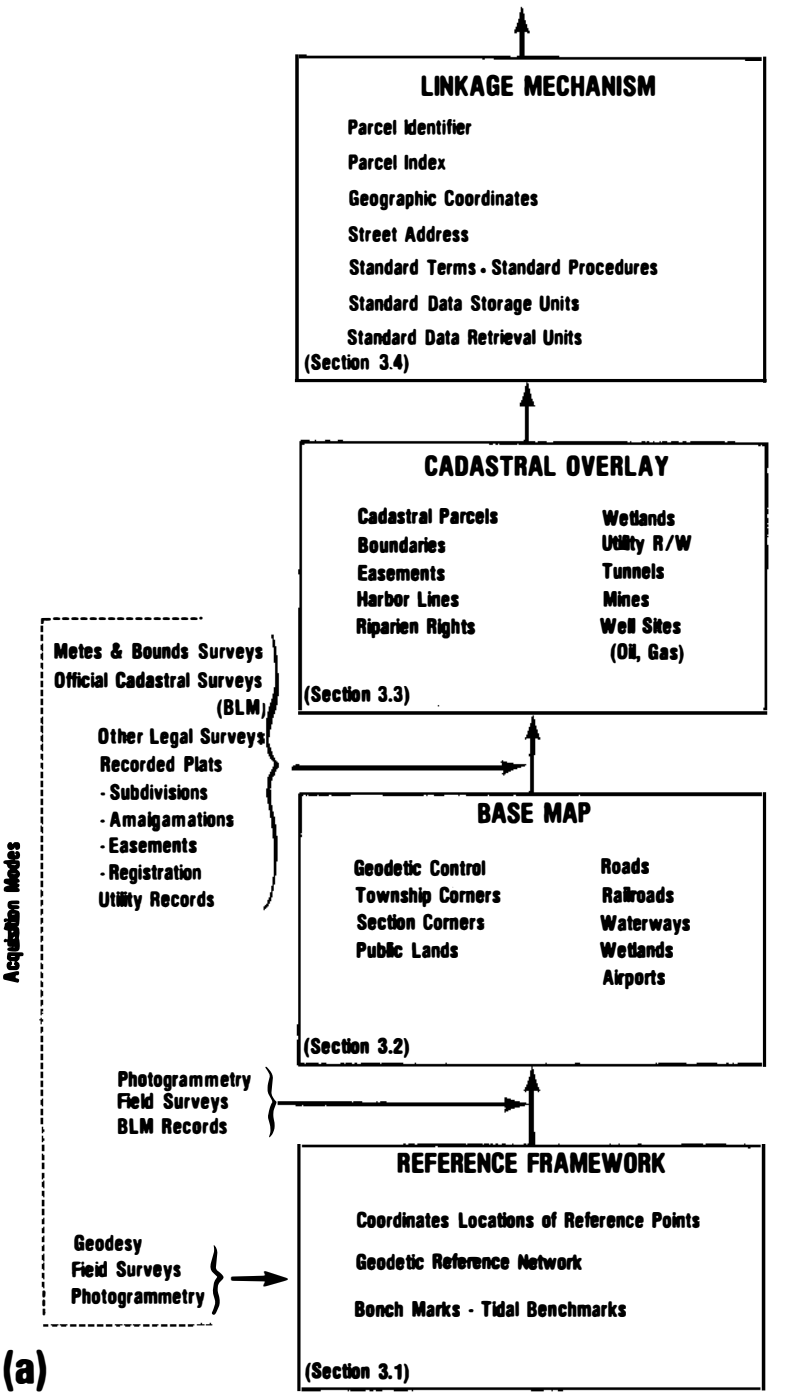
The sections following give more detailed descriptions of the technical requirements for the reference frame, base map, and cadastral overlay aspects of a multipurpose cadastre; introduce mechanisms that may be considered in development of multipurpose data systems; discuss some needed improvement in surveying practices that will establish the cadastre on a firm basis; and consider the roles of public and private utilities.

3.1 GEODETIC REFERENCE NETWORK

A survey control base is needed to create an integrated land-records and -information system. Monumented points whose coordinates have been determined with respect to the national geodetic control system constitute such a system. This system permits spatial reference of all land data to identifiable positions on the earth's surface. It can be used to form a common index for the land-records and -resource information when that information contains a coordinate reference to the earth's surface.

The most stringent spatial requirements to be imposed on the system will determine the design of the survey control base. For example, property owners, developers, or contractors might want to establish or determine the location of property boundaries, rights of way, or utility lines within a tolerance of a few centimeters. A highly accurate base is a prerequisite for such precise position determination. Also, as land values and competition for the use of land increase, the acceptable measurement error will likely become smaller, Therefore, not only present but future requirements must be designed into the system.

Maintenance of the survey base is a requirement, since portions will be lost each year, if adequate maintenance is not provided. The establishment and maintenance of the survey base, whether by federal, state, or local agencies, consistent with federal standards (Federal Geodetic Coordinating Committee, 1978) would increase its reliability and provide the consistency desired for a network of compatible multipurpose cadastres. Recent improvements in surveying technology can provide the means of establishing and maintaining the survey base economically.



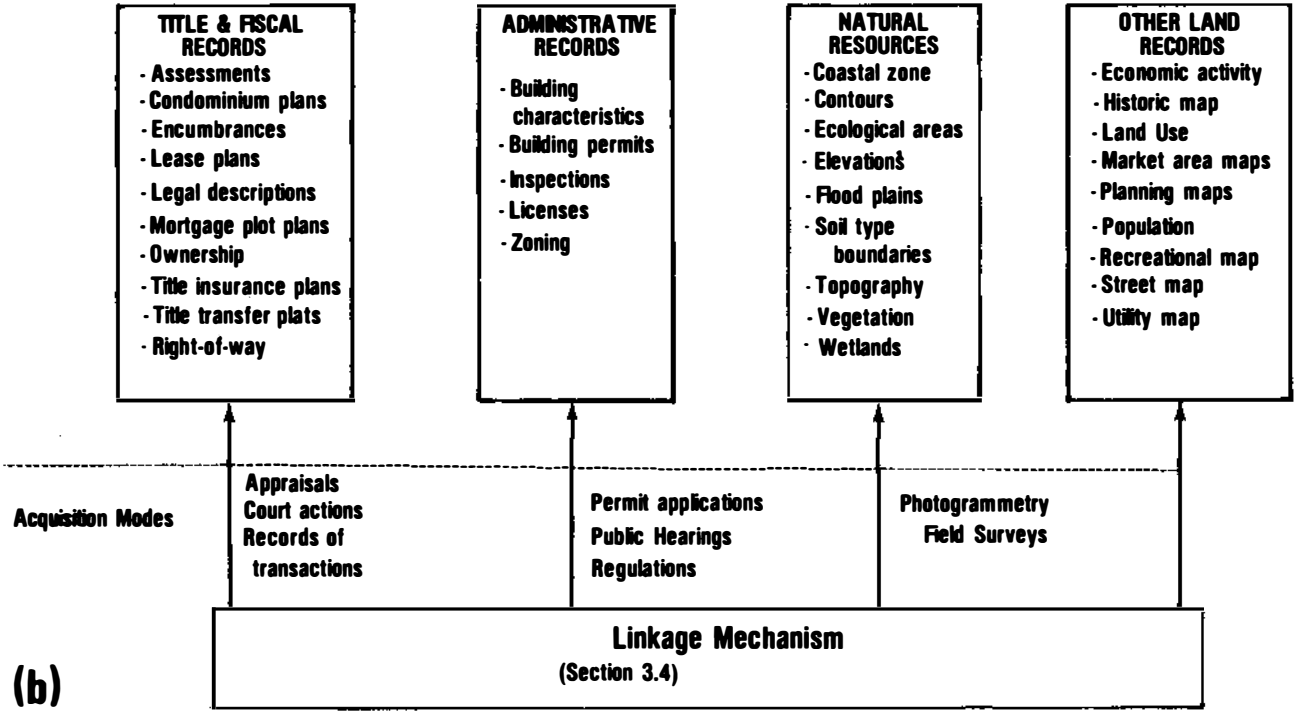


FIGURE 3.1 (a) and (b) Details of a multipurpose cadastre.

3.1.1 Local Densification of the National Geodetic Net

All coordinated reference points should be tied to the national geodetic system. This is the thrust of standards proposed in the preliminary report of the North American Institute for the Modernization of Land Data Systems' Ad Hoc Committee formed by representatives of the American Bar Association and the American Congress on Surveying and Mapping (Chatterton and McLaughlin, 1975). In Section 5.3 of that report the following is recommended:

> The committee has concluded that "all descriptions of land parcels, easements, and other interest in land required for conveyancing, taxation, and any other purposes should be ultimately tied to the state/provincial plane coordinate system." Only in this way can the consumer be afforded acceptable protection . . . .

The practical implementation of these recommendations can be achieved only if a sufficiently dense network of permanent survey monuments, constituting a survey base, is established throughout each appropriate jurisdiction unit. Where an appropriate survey base is in place, it becomes equitable and economically feasible to require by law that property surveys be tied to the system. At present, in only about 15 percent or so of the 500 counties in the United States, designated by the Department of Commerce as "primary" counties in terms of population density, are there in place segments of the national geodetic network of sufficient density to serve as a logical starting point for densification to a level that would support a cadastre.

It is clear that formidable obstacles need to be overcome for the realization of a sufficiently dense geodetic network that can serve the needs of the cadastre. Even where the primary geodetic system is already in place, its densification by conventional ground traversing is a costly and time-consuming undertaking. Nevertheless, conventional ground surveying can generate the geodetic data base necessary for the establishment of a cadastre, provided that the surveyor maintains adequate standards. Several examples exist of successful projects executed conventionally in the United States and Canada. These include projects in the Maritime Provinces of Canada (Greulich, 1979); Racine County, Wisconsin (Bauer, 1976); and Monroe County, New York (Moore, 1970).

Because of cost constraints, widespread implementation of the cadastre may well depend on the development and application of new technology. Within the past five years, three emerging technologies have achieved recognition as practical and cost-effective alternatives to conventional ground surveying in significant applications; these are Doppler satellite surveying, high-precision photogrammetric surveying, and inertial surveying (Mueller and Ramsayer, 1979). The Doppler system is reviewed and adopted (within defined limits) as an acceptable method of geodetic surveying by the Federal

Geodetic Control Committee (FGCC) (1980). Such status should help considerably in promotion of more widespread use of this new tool. Adoption of high-precision photogrammetric surveying and inertial surveying should be considered by the FGCC. As pointed out by Brown (1979), other powerful, pertinent developments can be expected to emerge in conjunction with the forthcoming Global Positioning System, projected to achieve full operational status by the mid-1980's.

Within the 1980's cost reductions associated with newer technologies can be expected to more than offset effects of wage and salary inflation. This should render increasingly more attractive the execution of large-scale projects of geodetic densification.

In addition to horizontal control, there is a need for densification of vertical control. A dense network of second- and third-order vertical control stations will assist the development of a reliable cadastre. For coastal areas the establishment of tidal benchmarks from which a surveyor can determine the high- and low-water lines, is a prerequisite to the division of public from private land ownership and responsibilities.

3.1.2 Horizontal Geodetic Control for Property Boundaries

Further densification of the local geodetic system will create a reference framework suitable for boundary control. In both remote and rural areas the existence of evenly spaced accessible geodetic control is essential for the designation of ownership parcels. Bauer (1976) has reported that Racine County, Wisconsin, has established second-order geodetic control monuments at all section and quarter-section corners. State plane coordinates are, therefore, spaced at about 800 m throughout the county. The ten-year program has created a unique blend between the Public Land Survey System and the State Plane Coordinate System. McLaughlin (1975), Ziemann (1976a), and others have recommended spacing of geodetic control monuments, but actual needs should be reviewed and specifications prepared.

Much of the responsibility for the densification of the geodetic system will fall to the local land surveyor, who should be familiar with acceptable procedures for establishment of additional control points and proper use of geodetic data. The appropriate state agency, in conjunction with the local professional surveyor/engineer society, should develop strict guidelines for the maintenance and use of this control. The standards for first-, second- and third-order horizontal geodetic control surveys published by the Federal Geodetic Control Committee (1974) should be the minimum acceptable standards.

We recommend that standard practice manuals describing specific survey methods and rules of adjustment for reliable determination of coordinates for

property boundary corners be made available to the local land surveyor and enforced at each government level.

We encourage the establishment of survey data depositories at the county level and the linkage of such depositories with those at higher levels of government.

3.1.3 Vertical Geodetic Control

Concurrent with increased concern for environment and energy is the need to define land ownership rights in vertical as well as horizontal terms. There are many uses or restrictions that must be described by the third vertical dimension. Three-dimensional coordinates are required to fix air rights, oil wells, mining activity, tunnels, wetlands, flood plains, flood hazard zones, offshore development, solar-energy easements, and other resource or environment-oriented human endeavors. Condominiums are legally described in three dimensions. Underground utility locations are fixed horizontally and vertically.

The U.S. Water Resources Council emphasized that "It should be recognized that flood plains have unique and significant public values, including wildlife habitat of recreational, esthetic and scientific value, open space and groundwater recharge" (Corps of Engineers, 1974).

Judge Richard S. Lowe of Pennsylvania, in upholding a flood-plain zoning ordinance, concluded in 1969 that "unbridled freedom of individual choice has resulted in improvident and ludicrous land use patterns which have obstructed the free flow of surface waters and thereby necessitated inordinately expensive public works or equally expensive disaster relief measures" (Corps of Engineers, 1974).

Land-use planning, including flood-plain zoning, depends on a reliable third dimension. It follows that a network of vertical geodetic control monuments (benchmarks) is necessary. Classifications and standards for first-, second-, and third-order levels have been established (Federal Geodetic Control Committee, 1978). Every cadastral agency should establish a lasting network of third-order benchmarks in its district. They should be conveniently located and the data published, to be of maximum use to the surveying engineer.

Engineering departments of many cities and towns have established their own local vertical datum referenced to an elevation other than sea level. For construction drawings of public works and particularly underground utilities or subway systems, some organizations find it more convenient to refer elevations to a local datum either to reduce the number of digits in describing an elevation or to eliminate negative elevations.

All local datums (except tidal datums) should be tied to the latest National Geodetic Vertical Datum (currently 1929), and the conversion constant from

the local to the National Datum should be published. This will permit aggregation of environmental data for regional or statewide planning and management. Established leveling procedures and standards should be followed (Federal Geodetic Control Committee, 1978).

We recommend that local vertical datums be referenced to the latest National Geodetic Vertical Datum.

3.1.4 Tidal Benchmarks

The Office of Coastal Zone Management (1978) has recently published a Coastal Mapping Handbook. It states: "Boundaries in the coastal zone range from the limits of private property to the international boundary. All of them are affected to some degree by tidal datums along the coast and along island shorelines. Corresponding boundaries in the Great Lakes area are fixed either by treaty or by acts of Congress, or are controlled by a lake level. Of all these boundaries, those between private and sovereign lands cause the greatest problems."

A cadastral survey along shorelines requires a tidal datum in order to determine legal boundaries. Vegetation boundaries of coastal wetlands are depicted on maps and charts requiring horizontal and vertical ground control.

The Coastal Zone Management Act of 1972 (Public Law 92–583) declared it national policy "to encourage and assist the states to exercise effectively their responsibility in the coastal zone through the development and implementation of management programs to achieve wise use of the land and water resources of the coastal zone, giving full consideration to ecological, cultural, historic, and esthetic values as well as needs for economic development."

Coastal-zone management is currently hampered by the lack of tidal benchmarks. Recent court cases in New Jersey (Porro and Weidner, 1978) as well as the Dolphin Lane Case of Long Island, New York (Greulich, 1978a) have focused attention on the need to define the mean high-water line. The U.S. Supreme Court in *Borax Consolidated, Ltd.* v. *Los Angeles* (296 U.S. 10, 1935) established the method for determining the ordinary high-water mark, which is the division between private and public land in states formed from the public domain.

For further reference see National Ocean Survey (1975) and the American Congress on Surveying and Mapping and American Society of Civil Engineers (1972).

We recommend that tidal benchmarks be established along the east, west, and Gulf coasts at adequate intervals to permit local land surveyors to define riparian boundaries correctly and accurately.

3.2 BASE MAPPING

3.2.1 Large-Scale Maps

To satisfy the growing need for integrated land records and information, a system capable of handling a variety of information on a large scale, from the survey base to title transfer, is required. It is also mandatory that fieldwork, data resolution, and information presentation be consistent with the level of land decision making, that of the individual proprietary parcel. This process requires maps at scales significantly larger than those generally available in the United States.

Governments now generate some large-scale maps for specific geographic regions and for specific purposes. Large-scale maps (1:500 to 1:25,000) can and should be used for many government purposes, from zoning and planning to identifying forests and wetlands to locating taxable parcels and historic features. The U.S. Geological Survey has undertaken a large-scale base-map use study, which has led to several pilot projects (Scher and Southern, 1969).

To provide large-scale maps for an entire region or for a state will require concerted effort by several governmental jurisdictions. Money for the multipurpose, large-scale maps could come from savings through elimination of duplication in mapping and information gathering. Resource and environmental information, which is frequently reduced to map display, must be capable of being disassembled to the parcel they cover. This provision is in keeping with the recognition that the status of natural resources is intimately related to the legal interests associated with the ownership parcels. The need for an estimation of the accuracy of land information, referenced to the earth's surface, is consistent with the increasing digitization of map-based information, increasing use of geodetic coordinates as a means of carrying map-based information with geo-references, and continuing development of data-processing techniques as the medium for storage of all this information.

3.2.2 Base Maps

A base map at a scale of 1:1000 (some planners suggest 1:500 in densely populated areas) should be created for every urban community. In rural areas with large estates, base-map scales of 1:2000 to 1:5000 may be more practical, while for remote and undeveloped parts of the country scales up to 1:25,000 may be sufficient. This may be accomplished by grid-oriented photogrammetric mapping. New base maps should be tested and certified by a Registered Land Surveyor or photogrammetric engineer to ensure compliance with U.S. National Map Accuracy Standards (American Congress on Surveying and Mapping and American Society of Civil Engineers, 1972).

Where available, existing, up-to-date, grid-oriented municipal maps can be used instead of new photogrammetry, provided that they meet U.S. National Map Accuracy Standards. The Massachusetts Land Records Commission has developed guidelines to qualify existing maps for the purpose of assigning land-parcel identifiers (Greulich, 1976).

Base maps can be conventional photogrammetric line maps or orthophoto maps. The original base map should be preserved as the basic source map from which all other specialty maps can be derived by either the overlay method or by a digitized computer plot.

It is well known that maps become obsolete quickly, and therefore continuous updating of the base map should become one of the functions and responsibilities of the cadastral agency.

We recommend that base maps be grid oriented, tied to the national geodetic control system, and updated regularly.

3.2.3 Cadastral Maps

The cadastral office that is assigned the task of maintaining the cadastral file described in Section 3.3.3 should incorporate existing and new survey data in its permanent record files. These data, including field notes and survey plans, should be reviewed for accuracy and compliance with adopted cadastral standards. When coordinated and accepted by cadastral standards, existing, recorded plats of land parcels can be plotted on a true copy of the new base map. From it will gradually develop the new cadastral map. During the transition period, it will show many blank spots. But eventually all properties will have been surveyed, reconciled, coordinated, and become plottable. This will follow from the mandatory recording of cadastral surveys. It is essential that this map be updated as new survey data are acquired and reviewed.

Since a parcel identifier (Section 3.4.1) will be assigned to each parcel, noted on cadastral maps and referred to on all accompanying documents, each item can be indexed, filed, and retrieved by computers. Besides the parcel identifier, the cadastral map should depict monuments and such legal lines as property boundaries, easements, public ways, railroad rights of way, transmission lines, pipelines, bodies of water, waste-disposal areas, and wetland. The map should show all geodetic control points and official benchmarks identified by number and symbol.

To preserve its clarity and simplicity, the cadastral map should not be encumbered with such items as coordinates, areas, buildings, and land-related data. These types of information can be stored in computer banks and/or displayed on overlay specialty maps. A wide range of information can be stored in and retrieved from a system that is based on comprehensive, uniform, and accurate cadastral maps. To be effective, these specialty maps and stored data must be updated continuously.

3.2.4 Specialty Maps

To attain geometric fidelity on the large-scale cadastral and specialty maps, more-efficient and less-expensive surveys of the ground must be utilized. These maps display such items as the extent of land resources, watershed areas, crop acreage, the results of studies of coastal interactions and change, and boundary surveys for mineral and energy deposits. To limit the expense of new surveys, full advantage should be taken of the vast amount of existing land information and the new technologies available for field surveys. Among these promising technologies are remote-sensing systems and the Global Positioning System.

Remote sensing is defined as "The science involved with the gathering of data about the earth's surface or near-surface environment, through the use of a variety of sensor systems that are usually borne by aircraft or spacecraft, and the processing of these data into information useful for the understanding and managing of man's environment" (Williams, 1979). To be useful, the remote-sensing data must have a metric quality consistent with the value of the resource being sensed, the environmental data being monitored, and the survey base being developed. The American Society of Civil Engineers (1979) recognizes the value of metric-quality remote-sensing data and considers it a function of the surveying and mapping communities "to provide geometric fidelity to remote sensing imagery."

The Global Positioning System (GPS) will be fully operational in the late 1980's. Williams (1979) has described the great potential of remote-sensing technology, particularly when the GPS receiver is combined with an inertial surveying system, as a powerful tool that will dramatically improve "the contributions that state, county and municipal engineers and surveyors can make to our national goals by integrating remotely sensed source materials into feasibility studies, long-range projections and possibly, even basic decisions processes."

These new technologies tend to produce large quantities of data. The efficient use of computerized data banks will make this avalanche of information manageable, provided the data are properly evaluated and organized. In a well-functioning multipurpose cadastre, such data can be stored, retrieved, and manipulated at relatively low cost. The printed cadastral and specialty maps then can be rapidly revised and maintained current.

3.3 CADASTRAL PARCEL

3.3.1 Definition of the Cadastral Parcel

A cadastre requires a fundamental unit of land—a cadastral parcel. This unit of land becomes the basic building block for maintaining land information,

including the information about rights and interests. An ideal building block is any common and natural reference for land information and a division of the earth's surface whose location and boundaries are known and maintained.

A cadastral parcel is an unambiguously defined unit of land within which rights and interests are legally recognized. Therefore, the cadastral parcel envelops a contiguous area of land with a history of legal interests (McLaughlin, 1975).

The cadastral parcel for a multipurpose cadastre is that unit of land for which there is a unique and complete bundle of rights. Public lands, railway, highway, and utility corridors, as a matter of convenience, may also be partitioned into cadastral parcels. This concept of a cadastral parcel has been formulated by Robert N. Cook:

> A parcel is a (continuous) area of land described in a single description in a deed or as one of a number of lots on a plat, separately owned, either publicly or privately; and capable of being separately conveyed. For ease of indexing data, a segment of a street, highway, railway right of way, pipeline, or other utility easement may be treated as though it were a parcel (Moyer and Fisher, 1973).

To determine where the boundaries of a cadastral parcel so defined actually fall on the land may require a sorting out of various other interests in land that are legally recognized. The boundaries of these other interests may or may not be coterminus. The primary type of interest, for this definition, is land ownership, associated with that set of rights and interests that may be acquired and transferred. Normally one cadastral parcel will include all land to which one complete bundle of rights may be assigned. However, in certain cases it may be necessary to demarcate only that land associated with a subset of rights, such as an easement.

For some types of data in a multipurpose system, special overlays with other types of additional boundaries may be needed. Land operation, for example, may be associated with units of land for which there is a uniquely recognized use or management of land resources. An agricultural operation is such a unit.

3.3.2 The Role of the Cadastral Parcel

The role of the cadastral parcel in land-information systems is indicated by an examination of existing cadastral systems.

Cadastral systems are generally classified according to the nature of information maintained in the individual files, registers, or subsystems. These data files contain *juridical, fiscal, public-land-use and regulation, special assessment, and resource and environmental records.*

Juridical (Title) Records are the records that determine the legal interests

in land. They are established by statutory and common law regarding estates in land, real estate and survey practice, and related activities.

These records are organized according to a unit of land within which a set of rights and interests are recognized and held by a defined person, persons, or corporation. A parcel of land held in fee simple is an example. We recognize such a unit as the individual proprietary parcel.

Title information in the United States is generally obtained from a system described as rudimentary deed recordation. Because recording does not in itself effect transfer of title, legal methods have evolved to assign priorities to evidences of transfer. The essence of these methods and the use of public registries are associated with doctrines of notice. These doctrines have led to indexes, both grantor-grantee and tract. However, the nature of these public systems creates a privilege held by lawyers, title examiners, and insurers in the drafting and warranting of title documents.

Parcel boundary information is distributed throughout title documents and in the files of surveyors. Occasionally, the information is reduced to graphical form and deposited in a public registry. However, there is generally no specific repository or file for this information. Thus the parcel boundary record is less well developed than that of the record of interests.

Fiscal (Assessment) Records should contain the information needed for equitable and efficient valuation of land. They also provide for the continued assessment of improvements to land. The fiscal parcel and record are characterized by an "assessable parcel of land" and by the information used to produce a valuation of this parcel. In most cases the parcel for fiscal records is the same parcel as for juridical records.

The nature of the title or interest record system has influenced the system of assessment records. Frequently, ownership information for valuation purposes is compiled by assessment officials. The assessment offices have become the primary source of maps of property parcels, although such maps for defining parcels for purposes associated with a knowledge of rights and interests are not always sufficient.

Thus, despite their unique responsibility, rooted in the valuation function for maintaining comprehensive data on the entire inventory of land parcels, tax officials often have a limited need for strictly ownership information. They need resource, environmental, zoning, and special assessment information, and they need to relate that information to well-defined parcels. After that, they need the name and address of a person to whom they can successfully send a tax bill.

Public-Land-Use and Regulation Records are statements of society's interest in land. As zoning laws or building codes they typically appear as statements about land use for a parcel or as standards for an area of land that may encompass a number of land parcels.

Zoning and planning officials are concerned with well-defined parcels and with the associated rights and interests. They are concerned with boundary changes and other activities that may influence land activities. Their need for information encompasses all activities, legal and otherwise, which enables them to plan properly and to oversee compliance with existing law. They rely on many maps as sources of information, but they also need additional information, such as the recording of a subdivision, in order to monitor compliance with zoning laws.

Zoning and planning offices are also important sources of information about rights and interests in parcels of land. However, zoning restrictions are not considered part of the record of encumbrances on land for title purposes. Yet these restrictions are often as important or more important to the traditional title than the privately arranged encumbrances.

It remains a difficult task to assemble a complete picture of the rights and interests in a parcel from the many separate juridical and public land-use and regulations records.

Infrastructure Records include those for highways, sewer lines, transmission lines, and similar parcels, which are divisions of land often carved from larger property parcels. Property law expresses the relationship legally in such terms as appurtenant or restrictive easements. The parcels that sustain such easements may be described independently, but a symbiotic relationship exists between the two.

The infrastructure records are widely dispersed. They have come to be the property of various public and private agencies. It is often difficult to determine who has the records for a particular parcel, even after determining that such records exist.

Public and private utilities spend large sums of money to acquire, assemble, and store infrastructure records (Clapp and Niemann, 1977).

Resource and Environmental Records are typically concerned with the natural division of land that may not necessarily coincide with the individual land parcels. Examples are records of soils, water courses, land cover, waste-disposal sites, and wetland. These resource and environmental records can be and often are maintained without reference to man's divisions of the land. A map is the most common expression of these records, whether in a traditional map form or in the form of geo-referenced information.

The demand for resource and environmental information has led to a great expansion in these data files. This activity is related to the increased awareness of man's relationship to and influence on the natural world. This interrelationship between man and the environment leads to the need for resource and environmental information at the ownership or property parcel level. For example, management of surface and groundwater systems relies on a knowledge of the natural water courses and networks, which depend only on the

natural division of the land; their management also depends on a knowledge of the legally recognized riparian rights of landowners, which depend on the property parcels. Another environmental concern that can be related to the property parcel is that of water pollution.

In a subject-area oriented society, it is no wonder that a vast array of physical, resource, and environmental information is collected, assembled, stored, and disseminated with little coordination among agencies. Common definition of terms, formats, map scales, notation, and related items are rare. Each agency proceeds according to its own perceived needs and efficiencies. Frequently, resource and environmental information is collected without a clear understanding of how it is to be used for purposes of planning or administration of regulations. These purposes and existing records systems point to the need to relate resource and environmental information to a fundamental unit of land–the individual property parcel. It is the unit used for many records and for which land decisions are made or implemented. Thus references to the property parcel are required for information related to both natural and man-made land divisions. This is the only choice that imparts to the system the stability associated with the legal process. The choice of an arbitrary cell of land, as has been made for some land-information systems, creates an inherently unstable system, although at lower cost in the short run. This choice fails to recognize the ultimate use of land information in land planning by failing to recognize the importance of the rights and interests held by the land owner.

3.3.3 Delineating the Cadastral Parcels

Legal and survey practice are crucial to the description of a cadastral parcel. Both the nature of the interests associated with the land and the spatial extent of these interests and of natural features of the parcel must be defined.

The legal and surveying practices, and the records that result, are a function of many factors, many associated with ancient tradition. A detailed discussion of required improvements in the legal regime of title records is beyond the scope of this report. It is a subject under investigation by many groups, including the American Bar Association (Chatterton and McLaughlin, 1975). Suggested improvements include those associated with the proposed Uniform Simplification of Land Transfer Act (National Conference of Commissioners on Uniform State Laws, 1977), Marketable Title and Curative Acts (Basye, 1970), title registration (Shick and Plotkin, 1978), and others.

The *physical delineation* of the cadastral parcel depends on surveying law and practice. A survey process for parcel delineation includes the following steps:

1. Gathering of information relating to parcel boundaries,
2. Analysis of this information,
3. Establishment of boundary markers on the ground,
4. Assignment of official identifier numbers to each parcel and recordation or registration of parcel identifier numbers and boundary information,
5. Storage of the parcel inventory and boundary information, and
6. Dissemination of this information (McLaughin, 1975).

The first three steps constitute a legal survey as the term is now understood.

We recommend that there be created a new cadastral file containing the records of boundary information referenced to the identifer number of each cadastral parcel. The file could be maintained as a separate file of information, as an addition to existing files, or in the form of references to boundary information in existing documents. A well-defined file of boundary information can be an object of attention and assurance similar to the attention and assurance given the file of title information.

We recommend improvements in survey and boundary law giving greater priority than now exists in the use of coordinates for boundary descriptions. A coordinate description of parcel boundaries does not necessarily replace the use of natural and artificial markers. Markers continue to provide physical awareness of the boundaries. When a marker is lost, the coordinate system, supported by all other monumented points, provides the relocation and replacement mechanism.

3.4 MECHANISMS REQUIRED TO SUPPORT MULTIPURPOSE DATA SYSTEMS

The technical requirements for the multipurpose cadastre system were outlined above (see Sections 3.1–3.3). These requirements were stated in terms of the three basic components of the multipurpose cadastre: reference frame, base maps, and cadastral overlay (see Figure 1.1). This section presents several additional requirements necessary to link various parts of the cadastre.

The discussion here is limited to linkages between only two levels, the cadastral overlay and various land-record files (registers) that make up the multipurpose cadastre system. Ways of integrating among the various land-record files, both within a unit of government (at one level) and among various levels of government, are also included. Linkages between the reference frame, base maps, and cadastral overlay are covered elsewhere.

3.4.1 Integrating Mechanisms: Standard Indexing and Referencing Systems

The overriding integrating mechanisms needed for successful implementation and operation of multipurpose cadastre systems are standards, indexing, and referencing systems for data. The mechanisms apply specifically to standardization of terms, procedures, and data storage units throughout the multipurpose cadastre. A number of these critical standardized items are included below.

Parcel Unit. As a general rule, the basic unit for data handling is the cadastral parcel. In most cases, the cadastral parcel is isolated on the basis of separate ownership, as described in Section 3.3.1. Parcels that are capable of transfer to another owner are the most common example.

Parcel Identification. A number of systems are used to identify parcels in the land data files currently maintained by governmental units. While each of these identifier systems may be adequate for a given governmental department, the existence of several noncoordinated systems often prevents the widespread use of the land data. Therefore, to ensure data coordination and facilitate multiple use of data files in the cadastre, each parcel should be identified by a unique number.

It is important that the cadastral system provide not only for the unique parcel identifier but also for the continued use of other systems used at present to identify parcels and related land data. Therefore, cross-indexing tables should be included so that users can access the cadastre, using procedures with which they are familiar. (Street address and block and lot number are examples of land data identifying systems that are used by many local government agencies.) The geocode is one example of a unique numbering system that makes possible the integration of data from two or more data files within a local government or between two or more local governments.

A computerized index of parcel identifiers will assist in linking data from various files. It will also vastly improve the ability to retrieve data from individual files, particularly in land-title recording offices.

To assure and facilitate the use of the unique parcel identifier, each parcel identifier number in the land-parcel register should become the official, legal reference to all title documents affecting that parcel, that is, the general index number used by the recorder of deeds, at least for all documents filed on or after the date the register becomes available. Such use of the parcel identifier would be sufficient for legal descriptions of parcels, as proposed in the Uniform Simplification of Land Transfers Act (National Conference of Commissioners, 1977).

The lack of a parcel index in many parts of the United States is one of the primary shortcomings of the present system of land conveyancing. Grantor–

grantee indexes (arranged alphabetically by the name of the seller and buyer) are inefficient tools for locating records pertaining to a particular land parcel. To overcome this inefficiency, many counties are now using a tract index that groups all records for a particular parcel on one page of an index. Title insurance companies that maintain title plants are also organized by the tract index system (Moyer and Fisher, 1973).

A substantial volume of literature has developed concerning the design and administration of "the ideal" parcel numbering system (e.g., Moyer and Fisher, 1973; Ziemann, 1976b). Selection of a specific reference system should probably be left to the individual states. This flexibility in design is desirable in order to adapt most easily the parcel number to existing files and practices of each local cadastral jurisdiction. The power of modern computers makes it possible to relate parcel records across several jurisdictions having different numbering systems.

Parcel Locator Numbers. Many land data files include a single number giving the geographic location of a convenient point within the parcel, typically the "center" as determined visually. These may be referred to as parcel geocodes and typically express the coordinate location of the chosen point to the closest 10 feet or 1 meter. A listing of geocodes for each parcel will facilitate graphic displays of parcel data, sorting of parcels into large regions for analytical purposes, location of individual parcels visually on a map, and various other procedures. Some localities have chosen to use geocodes as the unique parcel identifier numbers. The advantages of the geocode parcel identifiers probably exceed the disadvantages because of possible need for changes in the code due to resurveying, remapping, and datum readjustment.

Parcel Description. As the multipurpose cadastral system evolves, a coordinate-based description of each parcel should be added. The coordinate system used for description purposes ideally should use the same coordinate system as is used for parcel location.

Uniform Data Identification. All relevant parcel and parcel-related data should include the unique parcel number as one of the identifiers for all such data. Data files for which such identification are important include title, assessment, land-use controls, land-use planning, and environmental protection. Local offices responsible for these data files should be linked electronically. This will improve efficiency of government since the impacts of changes in one data file often impact on the data file and/or work activities of another office. Also, such interoffice linkages will facilitate a rapid, accurate response to citizen requests for information that requires retrieval from two or more data files.

The use of parcel numbers for indexing title records is central to the model recording system published recently in the Uniform Simplification of Land Transfer Act (National Conference of Commissioners on Uniform State Laws,

1977) and also is a required element of all seven of the model land-title-recording systems being demonstrated by the U.S. Department of Housing and Urban Development, under Section 13 of the Real Estate Settlement Procedures Act of 1974. By requiring that the identifier number be indicated on all documents recorded, the recorder of deeds is able to spot the creation of any new parcels that did not previously exist. This will trigger the updating of the register itself and also will help in the enforcement of local subdivision control requirements.

Parcel Index Map. A map showing parcel boundaries and parcel identifying number should be available in each local government office containing land-record files. This map index will assist in both the filing and retrieval of parcel data and be particularly useful to citizens attempting infrequent retrieval of information.

Nonparcel Data Links. The locations of many of the natural attributes of land that are critical for land management bear no particular relation to land ownership and must be described by boundaries determined independently of cadastral parcels. Examples of these attributes are listed in Section 2.1.3.

Nevertheless, the interactions of such phenomena, and their changes over time, with individual land ownerships must be considered in the use of resource and environmental records, as explained in Section 3.3.2. This will be possible only if the boundaries of both the cadastral parcels and the natural divisions of the land are located using the same coordinate system. This permits a visual display of the natural areas that fall within each parcel by overlaying the separate sets of boundaries, either with transparent map sheets or by a computer plot of the digitized boundary locations. It also permits cross-indexing of the natural areas present in each cadastral parcel, or vice versa, as needed.

However, cadastral parcels should not be used as the units for analysis or computations of natural phenomena but only for presentations of the results of such analyses and their implications for land owners. Cadastral parcels can only provide rough approximations of the geographic distribution of natural phenomena and may be totally inadequate for this purpose in more remote areas where the individual ownership parcels typically are large.

The technology of analysis and presentation of environmental data has been revolutionized by computers and software that became available in the 1970's. The methods of comparing data that relate to different geographic breakdowns of the same land area are a major subject of study for the new field of land-information science described in Section 4.3.7.

3.4.2 Quality Control

In order that users of the multipurpose cadastre be confident about system content, it is important that standards of quality concerning file content be

clearly understood. Such confidence is necessary both to obtain cooperation on data-maintenance activities and encourage use of available data by all potential users.

Such quality-control standards should include spatial accuracy as well as the validity of specific data items. Therefore, some minimum standards are required for data and information to be accepted into the system. This does not necessarily impose criteria for identifying acceptable data. Rather, the data themselves should carry the qualifications or limitations on how they can be used. Responsibility for assigning limitations may reasonably rest with the unit that introduces the data into the system.

3.4.3 Privacy and Confidentiality Safeguards

To ensure maximum integration of information through linkage of data files, a clear understanding of how and why data are or are not available to all system users is imperative. The problem of confidentiality can be met if the land-record system is defined to include only information that is public. Public information should be accessible and correctable by the individual. Confidential information remains in the possession of agencies traditionally responsible for such information. This information can be segregated and protected from the common and accessible land records in the information system. In some cases, aggregations of specific and confidential information may be introduced into the public record, but the specific information remains confidential and separate.

3.4.4 Phased Implementation

The complete development and implementation of any comprehensive land-information system should proceed gradually. This is true both in regard to elements in the system and to the area covered by the system. Fully implementing or phasing in the system within any region or state may take several decades. Gradual, phased implementation is necessary, too, because the legislative and budgetary processes of local, state, and federal governments tend to address short-term, readily identifiable problems rather than long-range, intergovernmental improvements. Implementing a comprehensive land-information system requires foresight, commitment, and cooperation among our legislative and agency officials.

Prototypes for interim cadastral systems that can serve during implementation periods are outlined in Section 4.4.

3.5 IMPROVEMENTS IN SURVEYING PRACTICE

The material that follows sets forth specific problems in surveying practice that require improvement in order to delineate physically the cadastral parcel.

These problems are identified so that the reader who is a nonsurveyor may sense the importance of higher standards in surveying for the development of a multipurpose cadastre. Specific standards for improved practice are indicated.

3.5.1 Accuracy Standards

Accuracy standards for property surveys should be established. These standards should be based on need, both present and anticipated. However, need is most difficult to establish, as its importance to present land owners and present land-use managers may become obsolete with changes in ownership and changes in local administration. A new owner's or a new administration's intended use of the land may increase or decrease accuracy requirements. In addition, for example, development of surrounding land, building of a new highway or a new power line, or establishment of a new industry in a town can have an impact on all properties, not only those directly involved. Although such changes are difficult to predict, a cadastre must allow for them and the improved accuracy required in parcel delineation engendered by changes in land use.

The responsible cadastral agency at the local level should anticipate the public's needs for accurate property surveys. Individual consumers or users of land generally do not appreciate the difficulties involved in making accurate measurements. Because property boundaries are subject to both mathematical and legal scrutiny, unrealistic accuracy expectations must be avoided (Greulich, 1977; McLaughlin *et al.*, 1977). It is imperative that practical, but lasting, standards of accuracy be set. It will take vision and the expertise of the surveying professional to implement these standards, and it will take vigilance and perserverance of the cadastral agency to enforce and maintain them.

We recommend that the surveying community, through its professional societies, with the cooperation of the local cadastral agencies, undertake the establishment of reasonable and practical standards of accuracy. These standards should, as a minimum, meet those advocated by the Federal Geodetic Coordinating Committee.

3.5.2 Monuments and Coordinates

Originally the legal description in a deed was a means to an end, enabling the reader to retrieve corner monuments of a land parcel. Monuments or land boundaries were thought to be permanent and everlasting. Over 300 years of land use in the so-called metes and bounds states has proven otherwise. Any monument is subject to destruction or disappearance. In time, the written description survived as the only source of evidence for many parcels of real

estate. In the absence of an integrated survey system, this led to what has been called the "floating island disease" (Greulich, 1978b; 1978c) of properties.

Written legal descriptions of common boundaries of abutting parcels do not always lead to the same corner. Quite often they are deliberately vague or in direct conflict with each other. Mulford (1912) deplored "that the original record, while an invaluable general guide, is only approximately accurate." The situation has not improved much in the intervening years and, although Thompson (1976) and others have predicted that the land surveyor of the twenty-first century "will discard his transit and electronic distance measurement equipment" and replace them with a hand-carried inertial package, the need for careful ties and adjustment into geodetic control will not be eliminated. In addition, at some stage of a boundary survey, the surveyor will continue to have to walk the land in order to determine legal corners mathematically or to mark legal corners physically.

Among the metes and bounds states, it appears that the Massachusetts Land Court is the sole agency that since 1898 has regularly decreed property boundaries binding on both petitioner and abutter. A decree is issued by this court for every parcel registered; the decree is based on surveys made in accordance with strict Massachusetts Land Court instructions (Woodbury, 1971). Monumentation is one of the requirements. Because land court registration of land has remained voluntary, it, too, created islands of good surveys, perhaps less floating, but too isolated to be of significant value to the public.

In the public-land states, cadastral surveying has been a method of "permanently" defining the boundaries of land by establishing monuments on the ground and identifying their locations in field notes and plats (Bureau of Land Mangement, 1978). Although the permanence and inviolability of corner monuments is generally recognized, the Bureau of Land Management's experience shows that vast numbers of marked points have been obliterated or lost. Nevertheless, physical monuments of legal status are an absolute necessity in the lawful and peaceful use of the land.

The Bureau of Indian Affairs reported that the lack of legally established physical boundaries in many areas of its jurisdiction "is having an adverse impact on Indian resource development" (Committee on Appropriations, 1979). Similar problems affect lands owned by local, state, and federal governments.

Standards should ensure that only one monument for each corner retains legal status. A distinction between so-called permanent, semipermanent, and temporary monumentation must be made.

Establishment of standards would help to avoid the pitfalls of the past. Therefore, we recommend that

1. Permanent monuments be set when surveying new lots.

2. Permanent monuments be set at previously unmarked or insufficiently marked corners during resurveys of existing properties.

3. Monuments be officially recognized by all interested property owners.

4. Coordinates for all monuments be determined.

5. Local cadastral agencies be empowered to enforce protection and maintenance of monuments.

6. Public works departments in cooperation with the cadastral agency make provisions in their specifications and contracts that would prevent destruction or enable accurate replacement of monuments.

Unfortunately, monuments provide only partial security for a land-records system. Even collateral evidence, although helpful and often necessary, is no guarantee that an original corner is reproduced in its exact and true original position. Horizontal coordinates are needed not only for identification, indexing, and aggregation of data but also for retrieval, recovery, and replacement of boundary lines. They will bring true permanence to the system. Even if large numbers of monuments are lost, a well-placed geodetic control system will enable the surveyor to replace them accurately. The recent abandonment of railroad right of way and removal of railroad tracks has caused a serious and consequential loss of legal "monuments" for many north central states. Even at this late date, coordination of existing "monuments" could avert expected future losses. McEntyre and McNair (1963) recommended that coordinates of all township corners be established by first-order methods and all section corners become second-order geodetic control stations (Federal Geodetic Committee, 1978). They also stated that in the description of real property, State Plane Coordinates "can be made more definite, certain, and material than other systems."

The Bureau of Land Management. long ago, recognized the value of including coordinates in their data files. Mining claims and irregular land lines are frequently tied together and depicted on "Connected Sheets" for clarification (Bureau of Land Management, 1978). Although these diagrams have no legal status, they are, nevertheless, an important working index tool (Meek, 1971).

The greatest weakness of the Public Land Survey System is the failure to provide monumented points in a coordinate system that is connected to the national geodetic network. In a recent study, the Bureau of Land Management (1979) found that "there is a need to more closely integrate the Cadastral Survey program with other national geodetic and mapping reference systems." The use of coordinates tied to a national network offers a means for offsetting the physical vulnerability of legal corners.

Upon completion of the new adjustment of the geodetic horizontal control network of North America in 1983, the National Geodetic Survey, U.S. Department of Commerce, will publish new latitudes and longitudes for all control points. For each of these points, State Plane Coordinates and Universal Transverse Mercator Coordinates (Standard 6° Zones) will be available in meters. Surveyors and government entities can obtain assistance in the use of these coordinates from the National Geodetic Survey.

We encourage cadastral agencies to plan for the use of State Plane Coordinates or Universal Transverse Mercator Coordinates in describing monuments and property boundaries.

3.5.2.1 Connections to Geodetic Control Points

It will be necessary to prescribe detailed methods for connecting boundary points to geodetic control points. All boundary points should be connected to at least two geodetic control points through closed loops. Figure 3.2 depicts examples where new boundary points (circles and black squares) are properly connected to two or more geodetic control points (triangles), whereby the accuracy of the boundary survey can be checked. Open-ended spur traverses and one-sided connections should be avoided. Figure 3.3 depicts examples where new boundary points (circles and black squares) are connected to only one geodetic control point (triangle), which does not permit an adequate check on the boundary survey.

Whenever possible, monuments should be set before undertaking the survey connection to the geodetic control point and before computing their coordinate values. The setting of monuments at predetermined positions is a frequent source of errors and should be avoided.

For property under construction, the survey should originate at an off-site third- or higher-order geodetic control point (Federal Geodetic Control Committee, 1978) in order to minimize loss of a critical point during construction. With assurance that this geodetic control point will not be disturbed during construction, the replacement of property corners, without having to rely on questionable deed descriptions of abutting lands, would be facilitated. In addition, the connection of the local survey to two or more geodetic control points will enhance the legal status of this survey. In time, metes and bounds could be deleted from the legal description; one need only to refer to a parcel identifier of a well-established land-records system. This would save time and money and would eliminate a frequent souce of errors.

3.5.3 Evidence

Accurate record keeping can resolve the age-old question of primary evidence. Which should carry more weight, coordinates or monuments? Neither should be "primary" by or in itself. In the past, the problem has not been monuments versus coordinates but rather monuments versus improperly determined coordinates, improperly determined both during the original and the retracement survey. If monumented and coordinated geodetic points are the foundation for the original legal description of a parcel of land, the surveyor's field notes are of great importance. If these notes indicate that a monument has been set based on predetermined coordinates in a subdivision, the coordinates

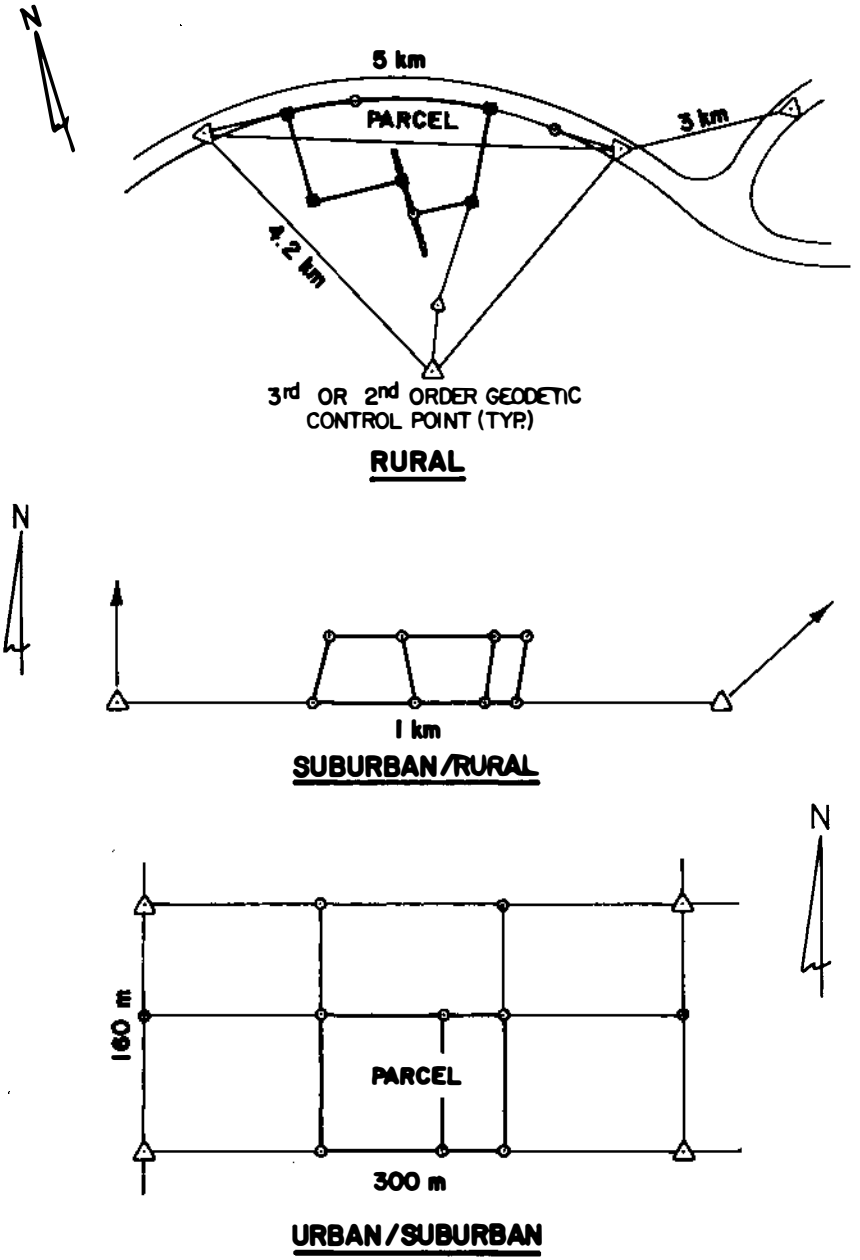
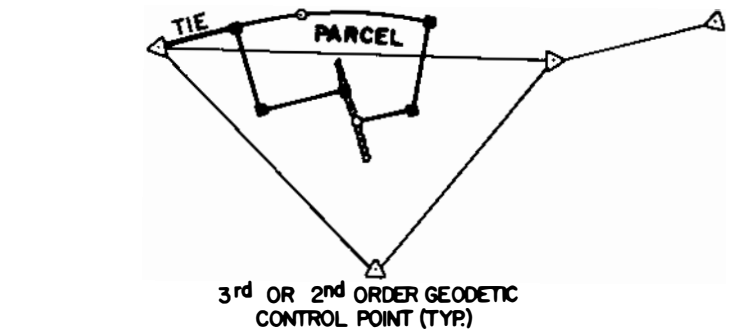
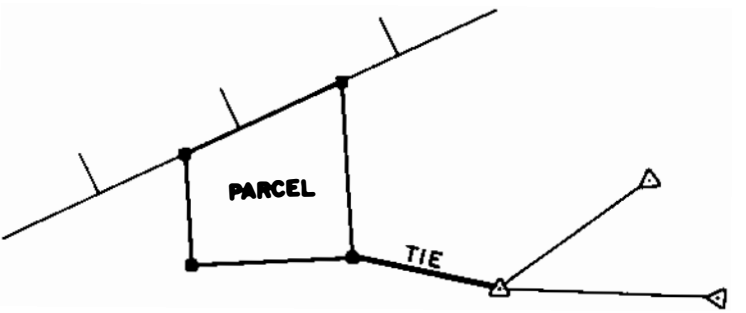


FIGURE 3.2 Examples of acceptable ties of boundary control to geodetic control points.





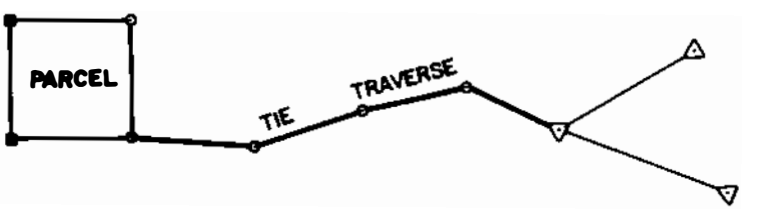


FIGURE 3.3 Examples of unacceptable ties of boundary control to geodetic control points.

will carry less weight than if the existing monument is resurveyed and its coordinates determined in accordance with acceptable practices; the location of an undisturbed monument will have greater acceptance because of the small differences in coordinates one could expect to determine from a resurvey. The significant advantage of coordinates is evident if a monument is lost or destroyed.

The surveying profession has not established a rigorous approach to the computation of monument coordinates in common boundary surveys, a requirement that is essential for a comprehensive cadastral system to be efficient. Mulford (1912) noted that the surveyor's most difficult task is often "to find the land" to be surveyed. He also stated: "Surveys, when made, were very crude, little attention was given to the establishment or the maintenance of boundaries. Loose, faulty and ignorant conveyances, the use of perishable landmarks or no landmarks at all, the temptation to build fences 'off line' for a dozen reasons, good and bad, and innumerable other things have conspired to render the boundaries of land the most uncertain of all things." Many of the same problems are inherent in boundary surveys today.

The question of monuments versus coordinates was considered by a joint committee of the American Bar Association and the American Society of Civil Engineers (1941). They reported:

> Many lawyers place great reliance upon the old maxim that metes and bounds control courses and distances. They ask if the use of plane coordinates will interfere with the application of this maxim. In answering this question, the engineer must first consider the fact that the maxim is not recognized by the courts to the same extent as in the past. The tendency of judges is not to be bound by fixed rules when they lead to absurdities upon the facts before them. They are likely to believe that such absurdities can better be avoided by considering the particular facts. Courts have adopted a more flexible doctrine, that where there is a dispute in the description of real property, that which is more definite, certain, and material will control.

The application of coordinates to section corner monuments in the State of Wisconsin has served to "perpetuate and revitalize" the long-established, but badly neglected, Public Land Survey System (Bauer, 1976).

Once the surveying profession adopts standards of accuracy (see Section 3.5.1) the arguments over monuments and coordinates as primary evidence will disappear.

3.5.4 Recorded Plats and Plans

The assembly of the cadastral map will start with the many plats and plans already on file with registries of deeds, county courthouses, and other public repositories. Since a resurvey of all parcels of land will be impossible, selective use of existing information is mandatory. Starting with recorded plats or

plans, a distinction must be made between "compiled" plans of record and plans based on a field survey.

We now define various types of existing information that might be included on the cadastral map.

Compiled Plans have no claim on accuracy or reliability. They serve as general information only and, if included in the cadastre, should be maintained current, but assigned a low order of accuracy.

Survey Plans of single lots may conditionally be incorporated in the multipurpose cadastral system; property lines are subject to final determination and reconciliation by field surveys in accordance with cadastral standards to be issued. *Title Insurance Plans* would fall into the latter category.

Subdivision Plans, which are based on field surveys, can be partially accepted, providing no major errors that could cause legal complications are discovered. All interior lot lines can, on verification, be fully incorporated in the new cadastre. Perimeter lines and corresponding perimeter lots should be treated like survey plans and be reconciled in the field before final acceptance. There are two unique boundary-survey evaluation programs that should be emulated by all cadastral agencies—those of the Bureau of Land Management (BLM) and the Massachusetts Land Court. Boundaries and plats that are based on the official cadastral survey and accepted by the BLM and boundaries determined by decrees of the Massachusetts Land Court can each be incorporated in a cadastral system without further verification.

The multipurpose cadastre will thus have started with three types of boundary data: final, conditional, and temporarily undefined (based on deeds without survey plans).

Following the lead of the Modernization of Land Data Systems (MOLDS) II conference (North American Institute for Modernization of Land Data Systems, 1979), *we recommend that*

1. Lawyers and surveyors promote state legislation that would make the recording of survey plans for conveyance or subdivision mandatory; all new deeds be based on a reliable survey, similar to those required by the plat laws or section corner filing acts that exist in some states; and the American Congress on Surveying and Mapping and the American Society of Civil Engineers propose model standards.

2. Title insurance companies agree that all future policies be accompanied by a survey plan; and the American Land Title Association and the American Bar Association propose model standards.

3. All title insurance surveys be recorded for the benefit of abutters and future users; and the American Bar Association and the American Land Title Association propose model standards.

4. All boundary-survey plans show deed references of land owners and adjacent land owners until a parcel identifier system has been adopted.

These interim but immediate steps would assist in the construction of a cadastral map. They would be of substantial benefit to the future cadastral system, without adding a burden on the taxpayer.

3.5.5 Field Notes

Another prerequisite to reliability will be the mandatory filing of field notes, either originals or certified copies. Many plat filing laws in the public-land survey states, as well as the Massachusetts Land Court, require that ties to existing monuments be shown on the recorded plat or document. That is not sufficient. A plat or plan is a third-generation document. In fact, it is largely the product of a draftsman–a survey technician.

The original and first document of boundary records is the surveyor's field notes. His worksheet or computer printout is the second-generation document. The final plat or plan is a summary that depicts the surveyor's findings and conclusions in a form more presentable than the field notes.

The Bureau of Land Management (1973) in its instruction manual emphasizes the "importance, or legal significance, of the plats and field notes" by referring to an opinion by the Department of the Interior (45 L.D. 330, 336) based on a decision of the U.S. Supreme Court (*Cragin* v. *Powell,* 128 U.S. 691,696). The Court said: "It is a well-settled principle that when lands are granted according to an official plat of the survey of such lands, the plat itself, with all its notes, lines, descriptions, and landmarks, becomes as much a part of the grant or deed by which they are conveyed, and controls so far as limits are concerned, as if such descriptive features were written out upon the face of the deed or the grant itself."

In light of this decision, the cadastral agency should require the recording of the surveyor's, both government and private, original field notes together with the to-be-recorded plan. The field notes should be cross-referenced by parcel identifier and made available to other surveyors and the public. The notes will enable the agency to verify and check the surveyor's work. It will be necessary to adopt minimum standards for field notes. They serve to support a permanent public record and should be certified by the registered land surveyor responsible for the survey.

We recommend that the cadastral agency adopt minimum standards for field notes and mandatory filing thereof.

3.5.6 Surveyor's Plan

For all new surveys and subdivisions, the surveyor should submit to the cadastral office a certified plan of land showing all monuments found and/or set and indicating those monuments whose positions were held fixed in the sur-

vey computations. Their precise mathematical relationship to each other and to the official state-adopted coordinate system should be shown. Distances, angles, bearings, or azimuths between corners should indicate their compliance with official tolerances. The plan should clearly identify all survey lines and geodetic points used to determine boundaries. It must show the official parcel identifier of an ownership parcel as well as that of the abutting properties. The plan should be similar to that currently required by title insurance companies or by the Massachusetts Land Court, with enlarged subsketches for critical dimensions and offsets.

Previously determined boundary data that have been officially accepted by the cadastral agency must not be altered, if they fall within recommended tolerances. Deviations found should be shown, together with the applicable maximum tolerances.

Reconciliation of existing boundaries or the creation of new boundaries should take place in the field. Where abutting deeds remain in conflict, an administrative procedure, based on a physical examination of the property, should be available to resolve the issue.

The plan should be accompanied by a certified calculation sketch or working drawing indicating thereon all new measurements as well as all dimensions and angles found in various old plans and deeds of record. This will enable the cadastral officer and future surveyors to better understand and verify the present surveyor's conclusions.

For clarification, it may be necessary to include a control diagram on a separate sheet. A computer printout of relevant calculations, as well as certified field notes, should accompany the plan.

The registered land surveyor should sign and seal his plan together with a certificate that the survey was done by him in accordance with current cadastral standards.

3.6 PUBLIC AND PRIVATE UTILITIES CADASTRE

"The multiplicity of utility ownership and competition leads to many conflicts for space," reported the American Public Works Association (1974). Lack of reliable underground utility location information is considered a "nationwide problem." A survey on the status of municipal utility records revealed that only 35 percent reported complete and up-to-date records, and only about half of those reflect as-built conditions.

A joint American Public Works Association and American Society of Civil Engineers (1974) committee concluded that "problems have arisen over safe and economical allocation of utility location space because of lack of effective coordinated practices by, and between, privately and publicly-owned utilities." The committee recommended the adoption of a broad information

retrieval system and the creation of both a street master file and a parcel master file and also concluded that compatibility of scale and "regular exchange of base maps" would "facilitate coordination." Today, we know that the cadastre will accomplish this coordination automatically.

There is no reason why the multipurpose cadastral base map cannot fulfill the needs of the utility industry. Earthquakes in Alaska and the Great Blizzard of 1978 along the New England coast have shown the urgency of knowing exact locations of these lifelines of our society. Increased use of plastic pipe has rendered metal detectors ineffective. Cooperation between public works departments and cadastral agencies could achieve safe and economic utilization of space. Channels of prompt communication between these two important agencies must be established.

Specifications for construction of underground utilities should provide for measuring and locating of as-built structures before backfilling of trenches. The cadastral office should develop standards for connecting surveys to horizontal geodetic control points and the national vertical datum. As-built location plans at a scale compatible with the official cadastral base map should be prepared and certified by a survey engineer.

Surface structures, such as manholes, catch basins, gate covers, hydrants, and utility poles should be identified by street and State Plane or Universal Transverse Mercator Coordinates, numbered by utility, indexed, mapped, and filed in the data bank.

Accuracy standards for the location of each utility may vary but should be standardized. Location cards (generally called tie cards), which display horizontal and vertical positions and measurements to relevant objects and sketches, should be simple but effective for retrieval and quick recovery on the ground. Current tie cards for underground utilities are often useless because they were prepared by workers untrained in the art and science of measurements. Ties to opposite markers or to temporary structures should be avoided. Additional ties to geodetic control points are as beneficial to utilities as they are to property owners and land-management organizations.

Cadastral agencies must set rules in cooperation with public works departments and utility companies that will assure constant and accurate updating of the utility map. Only thus will it be possible to protect lives as well as provide space for additional life lines so vital to our future.

We recommend that professional organizations such as the American Public Works Association, American Society of Civil Engineers, American Congress on Surveying and Mapping, American Society of Photogrammetry, American Bar Association, and American Right of Way Association should jointly develop practical methods for the creation of a utility cadastre.

4

Organizational Requirements for a Multipurpose Cadastre

The preceding chapters have described the many ways in which multipurpose cadastral records systems can serve the public interest, the types of resources now available to build such systems in the United States, and the technical and operational requirements. This chapter suggests how the responsible public agencies should organize to build a network of such systems to eventually serve all 50 states. The benefits of modern cadastral systems have been clearly demonstrated in other nations. The purpose of this chapter is to show what it would take to build systems that would be of equivalent value to the United States, tailored to the unique institutions of government in this country.

4.1 PROPOSED APPROACH

To build a modern multipurpose cadastre will require reorganization and quality control for existing governmental functions, rather than creation of new functions. Each of the components of a modern cadastral system already operates somewhere within each of the 50 states. Many of the required data already are being generated in the legally established functions of local government. The most cost-effective way to build a multipurpose system is to link these many existing operations together so that the outputs of data available from each of them can be shared and made available as inputs for others. Some degree of adaptation will be needed in the land records of each participating agency, for example, in definitions of terms, in accuracy and precision

of the data, and in frequency of updating files, to achieve compatibility with the related records of other agencies.

The management of the cadastral records system should be undertaken as a joint venture of federal, state, and local governments, with the participation of the largest users and contributors in the private sector. The institution of compatible multipurpose cadastres throughout the country will require the assistance and leadership of a federal lead agency. As each level of government and the private sector develops a multipurpose cadastre based on its requirements, the federal lead agency should assist the various Offices of Land Information Systems in making its cadastre compatible with the national network. Compatible cadastres should be based on acceptable standards such as the Standards and Specifications for Geodetic Control (Federal Geodetic Coordinating Committee, 1974) and National Map Accuracy Standards (American Congress on Surveying and Mapping and American Society of Civil Engineers, 1972). Responsibility for maintaining each element of the system, in accordance with mutually acceptable national guidelines, should be assigned by legislation within each state, responding to local needs and available resources. The major problems, in the early stages of the program, will be the development of a nationally applicable system and the coordination of functions through intergovernmental arrangements. As these are resolved in each state, the work should shift to the definition of technical standards and procedures that can be instituted on a national basis. The localities that take the lead in resolving the technology of local land-records systems will be those where land values are higher and, therefore, more likely to be better equipped for early participation in the system. Meanwhile, the economics of bringing other governmental operations in more rural areas up to the technical standards will control how quickly this becomes a national cadastral system.

4.1.1 Roots of the System in Local Government

The content of land records is more related to functions of local government than to those of state or federal agencies. For any given parcel of land, there is more likely to be data already on file in the local property-assessment, county surveyor, municipal engineer, building department, and recorder's offices to support current functions than in state or federal offices. When there is a concern for location of the boundaries of a land parcel, the official record is the deed or plat on file at the deed recorder's office. For evaluation or interpretation of that record, one goes to the office of the local surveyor. If the land in question is a recent subdivision, the local engineering or planning office normally will have reviewed the survey and plan of the boundaries prior to official recording.

The investments being made by local governments every year in extending

and updating their files on land parcels are substantial. The file contents may seldom be maintained in a form adequate for engineering of a new federal project or for merger with data from neighboring areas in a regionwide or statewide analysis. Nevertheless, the files of local government agencies define the "state-of-the-land records" in most areas, and it would be folly to duplicate them rather than build upon them in a national program.

We recommend that local governments be the primary access point for local land information.

Each element of data in a local file that operates as part of a multipurpose cadastral records system should be the definitive record for that locality. There are advantages to having such records used for as many and diverse purposes as may be feasible. The more that any given data element is used, the more likely that any errors or inconsistencies in the data will be spotted, especially in local government applications.

We recommend that local governments maintain land data compatible with a multipurpose cadastre and transmit these data to higher levels of government when needed.

4.1.2 A Local Response to National Priorities

Without federal leadership, there will be little chance of compatibility among the land-records systems of the individual states. Likewise, the individual county and municipal records will become compatible with each other only where standards and procedures are resolved by a higher level of government. The status of cadastral records today confirms this point. At the opposite extreme are the systems for which the federal government has set high standards for quality and frequency of reporting of local conditions as a prerequisite for receiving federal funds. Incentives of this type, for example, in fields such as water-pollution control, hospital administration, and aid to education, have caused local administrators to respond rapidly to modernize and standardize their data systems.

To receive this kind of federal support requires a commitment of the federal government, and especially the Congress, to the new program as a matter of priority. Legislation to assign a single agency the task of coordinating the federal functions relating to the cadastre was recommended in the report by the Federal Mapping Task Force (1973) and is concurred with in 1979-1980 by a concurrent group of the National Research Council, the Panel to Review the 1973 Federal Mapping Task Force Report.

We recommend that federal legislation be prepared to authorize and fund a program to support the creation of a multipurpose cadastre in all parts of the nation.

An important group of agencies, whose early commitment to a program

for a national cadastre will be needed, is the present membership of the Federal Geodetic Control Committee as given in Section 2.4.1.

Equally critical is support from and, indeed, consequent enhancement of, the major national programs that would naturally use rather than functionally create a cadastral reference system. These programs include the environmental impact studies of the Environmental Protection Agency and, with direct pertinence, the Taxable Property Values survey, which the Bureau of the Census currently completes every five years for the Census of Governments, and the National Resource Inventory compiled by the Department of Agriculture. The responsible officials need to be convinced that a program for modernizing public cadastral records into a coordinated system actually is a building block to reach one or even several other goals that have become national priorities, such as pollution control, protection of land areas that are critical for production of energy, and inventory of how much of our land is controlled by foreigners.

The Survey of Taxable Property Values, mentioned in Section 2.4.3.2, has singular relevance because it necessarily and naturally nurtures and sustains a cooperative working relationship between the Bureau of the Census at the federal level and thousands of assessing, recording, tax collecting, and automated data-processing officials of state and local governments throughout the country. It typifies federal efforts that continue unabated by virtue of a separate and long-established validity. It thus underscores the reality that record systems are not ends in themselves, at any level of government.

Environmental responsibilities provide additional stimulus for support from the parent department responsible for the Census, the U.S. Department of Commerce. The Department's consultants on "The Effects of the National Environmental Policy Act in Corporation Decision Making" urge attention to "essential data bases for use in municipal procedures, and coordinated information about federal, state and local permits that may be needed for privately proposed actions and to coordinate any environmental reviews that may be required" (McCormick and Associates, 1978).

The overall concepts of the multipurpose cadastral system that eventually win the support of the federal government will be tailored to the special needs of the United States. Technologies from other nations more advanced in cadastral records systems will be used to the extent that they serve the needs of the locality. Data-processing systems and software will be managed by governmental units commissioned separately by the governments of each of the states. The local governments that are and will continue to be the primary operators of the cadastral records systems have been aptly described as "creatures of the state."

We recommend that each state authorize an Office of Land Information Systems, through legislation where necessary, to implement the multipurpose cadastre.

4.1.3 Precedents and Support from Other Intergovernmental Programs

A variety of other functions of state and local governments, now totally accepted throughout the nation, originally were organized using this same approach of federal incentives to local action. An early example is the federal-aid highway program. The promise of federal funding for half of the construction cost of the arterial highway system, plus associated planning and administrative costs, has been sufficient incentive for the states to adopt extensive standards for highway design, traffic control, and safety systems for the entire highway network, far beyond the routes receiving the direct federal aid. Standardization of building codes has been another federal priority that depends on response by local governments with the objective of permitting larger-scale standardization of building components and mass production of them. The U.S. Department of Housing and Urban Development has maintained a gentle but pervasive and effective movement in this direction by making some of its housing and community development assistance programs contingent on coordination of building codes across the state and by sponsoring national models.

Administration of certain federal aid programs to local governments actually requires a base of fairly accurate information on conditions in each locality affected, which then determines the amounts that each will receive. The federal revenue-sharing and block-grant programs, in particular, apportion fixed national total amounts among all localities using formulas that are weighted for local population, income levels, housing conditions, and various other factors. The federal payments in lieu of taxes to local school districts that are affected by children of employees of large federal installations depend on accurate, up-to-date reports of these local conditions.

If a locality had a multipurpose cadastre in operation, at least two current indexes would be more accurate and up to date for these present federal aid allocations formulas–housing conditions and annual estimates of population changes. Further, the availability of an organized data base containing the items on which localities already have the definitive records, such as land use, soil productivity, and construction activities, should make possible some more equitable allocations both of existing aid programs and new programs that can be anticipated in the general area of conservation of land and land-based resources.

4.1.4 General Comparison of Roles: Federal, State, Local, and Private Sectors

The reliance on local governments to maintain the cadastral records for their respective areas establishes the general pattern of roles to be fulfilled by each level of government and the private sector to support a national network of

multipurpose cadastral records for the United States. This section presents a general comparison of the roles, although they will vary somewhat for each of the four components of the system as described in more detail in the following section. Federal agencies should assume larger shares of responsibility for the components involving higher technology, standardization, and multistate integration, i.e., the primary survey control network and the systems of regional maps. Local agencies should assume larger shares of responsibility for the components that depend on unique local activities, i.e., the larger-scale cadastral maps, the land-parcel register, and the land-parcel data files.

The most important federal roles in development of a national system of cadastral records could be characterized as providing leadership and support in (1) research and technical standards, (2) financial incentives to state and local governments to organize the records systems, (3) use and support of the local records by federal agencies whose operations relate to the land, (4) monitoring and program evaluation, and (5) setting an example of excellence in federal land records. Furthermore, the multipurpose cadastre will become the official reference framework for much of the local land data used by federal agencies in their routine governmental functions, such as those listed in Section 2.1 and subsections.

The essential role of each state government will be the management of the cadastral-records improvement program for its area. State governments have the power to authorize provision of elements of the system by either state or local agencies, plus the use of standard terms and procedures, and to mandate these contributions where necessary. The state, in cooperation with local governments, should assume responsibility for a complete range of system-development activities, including organization of local programs, training and qualifying personnel, administration of financial aid to localities (including any federal funds available), coordination with other programs that generate or use the data in the local files, and the aggregation and forwarding of local data to federal programs.

It will be up to each local government to reorganize and maintain the files for its own land area, as mentioned earlier, and to take maximum advantage of them for the planning and administration of local programs. Local governments will be the operating agencies—the providers of this public service—once the cadastral-records systems are in place.

Many components of this work may be contracted out to private consulting organizations or service bureaus, depending on the technical resources available for each locality. The assistance of private consultants will especially be needed in the earlier stages of development. Many local governments may rely on contractors to own and operate all the hardware, with only the software and the file content being public property. Such contractors in effect would be "information utilities," whose contracts would extend for periods

of several years at a time but would be renewable only through competitive bidding.

At the private level, the utilities should be involved in providing data and financially supporting the cadastral system. Their input and support might be voluntary but could be mandated by the appropriate utility regulatory agency.

Meanwhile, the actual users of the cadastral system will be primarily individual land owners and private business or professional organizations in fields such as real estate, banking, utilities, law, engineering, and economic research and local, regional, state, and federal governmental agencies, regardless of whether the maintenance of the system is contracted to the private sector in a locality.

Programs for improvement of cadastral records must be tested against the existing needs and investments of the users of the records systems in each area. Public hearings will help to elicit at least the opposition to the changes. Resistance from parties reluctant to have the extent of their land holdings become known should be expected—mining and petroleum companies, for example. In addition, public-information campaigns will be needed to elicit constructive criticism from citizens who will need to use the improved systems.

4.2 RESPONSIBILITIES FOR EACH COMPONENT OF THE SYSTEM

This section suggests how the federal, state, and local governmental roles, plus the roles of private contractors and users, could best be sorted out for each of three aspects of a multipurpose cadastre: (1) the reference frame, (2) base maps and cadastral overlays, and (3) the register of cadastral parcels. However, no attempt is made to specify which agency or agencies within the federal government should assume the lead role.

4.2.1 The Geodetic Reference Network

The geodetic control used for cadastral surveys must be a single, integrated network of reference points on the ground, covering the entire area of the land parcels that are to be related to each other. For most purposes of cadastral-records systems, this means covering the entire continental United States. Any other arrangement would create intolerable confusion along the boundaries of the independent control networks. Fortunately, there are other uses of locational referencing systems, such as navigation, which require that control networks be integrated worldwide.

The reference frame for a modern cadastral records system will consist of many interlocking networks of survey control maintained simultaneously at the federal, state, and local levels, although the local networks may be provided only in the urban regions of the nation where land is more valuable. The National Geodetic Survey provides the "trunk system" of the strongest and most accurate first- and second-order control points established with reference to its continental survey network, with points now available in every state. A state agency must take responsibility for assuring that a supplementary network of control points, second order or better, referenced to the national system, can be reached within a reasonable distance of every land parcel to provide a definitive reference for local surveys. The extension and maintenance of this control network should be coordinated with the National Geodetic Survey. Further, states should delegate to their local governments the responsibility for maintaining the even more dense network of survey control points needed to confirm property boundaries, utility-line locations, and similar location-specific data, at least in the areas of relatively high land values.

The national network of first- and second-order control points is well established, and there has been constant attention to its maintenance and updating by the National Geodetic Survey, as described in Section 2.4.1. The attention given by state governments to maintaining a sufficiently dense network of supplementary control points, however, has been mixed, and quite insufficient in most states. None of the states, nor the federal government, currently maintains a network of sufficient density to meet the standards of availability of geodetic control described in Sections 3.1.2 and 3.1.3. Some have come close, at one time or another, through short-term programs to upgrade large areas to a higher standard, such as the Massachusetts Geodetic Survey sponsored by the Work Projects Administration (Massachusetts Department of Public Works, 1936). However, a network of control points gradually loses its value over time, if the responsibility for maintaining the network has not been assumed as a permanent public function. It has been estimated that an average of 5 percent of the points in a survey control network are lost each year because of accidental or careless destruction of survey monuments.

A statewide survey program of densification of survey control does not require that state agencies do all the work. One of the more successful state programs, in New Jersey, provides state assistance to county governments that will densify second-order control networks to state standards. The essential role of the state is management and coordination of the overall improvement and maintenance program, providing state aid where necessary. The role is seldom effective unless all of these resources and responsibilities are coordinated by a single state agency.

A state program can take advantage of monumentation placed by others along transportation corridors or major utility lines, for example. On federally owned land, the federal Bureau of Land Management has been responsible for placement and maintenance of section corner monuments in 30 of the states, although these functions are being transferred to a responsible state agency wherever possible, as provided in 43 USC 55. The Bureau of Land Management has issued instructions in 1979 and 1980 for planning the integration of section corner monuments on these federal lands into the national geodetic control network.

We recommend that the Bureau of Land Management proceed with its plans to position the network of Public Land Survey monuments that mark the corners of sections and quarter sections that are located on federal land and to integrate them with the national geodetic control network.

For the maintenance of geodetic control points, local governments that have sufficient resources, such as counties with substantial urbanized areas, may serve as partners with the state. In many parts of the nation, however, there is no survey or engineering capacity at either the county or municipal level. The state control survey agency should take responsibility for arrangements to serve such areas, tailored to local conditions. Maintenance of the control points may be assigned to the state agency itself for many such areas; others may be able to rely on the agencies that manage large public tracts to maintain much of the network, for example, the Bureau of Land Management for the federal holdings that cover much of the western United States.

A special task that is more uniformly a local responsibility is the inspection and approval of private development plans to assure that they meet public standards for land subdivision. These standards should include placement of appropriate monuments at the key points along new streets, for convenience of affirmation of property boundaries. Traditionally, stone monuments have been preferred, located where the property lines intersect at each corner of a street intersection. However, experience has shown that such locations are often vulnerable during construction. A more ideal system for modern survey equipment is a single monument buried about one-half meter below the pavement at each street intersection, with a removable cover for access. Local monumentation at street intersections is of particular value to utility companies that maintain buried lines. An arrangement for effectively sharing the cost of maintaining the system between the local government and the private utility companies should be considered.

4.2.2 Base Maps and Cadastral Overlays

The cadastral mapping function, to be cost effective, must be closely linked to the functions of local government. The primary uses of the property maps

among the agencies of local government are (1) property assessment, (2) planning and engineering, (3) legal indexing of deeds and other title records, and (4) management of public utility and service systems. Each of these functions has its own, special demands for the accuracy or completeness of the map system. Together, they can readily justify and support a modern system of base maps and cadastral overlays. However, when each is left to provide for its own needs, one typically finds that separate, incompatible map systems are produced for the assessment function and for the engineering and management functions, with added expense to the taxpayer, and with neither system as valuable to other users as would be an integrated, modern cadastre. Therefore, to provide for national compatibility, the development of base maps should be coordinated with the U.S. Geological Survey and the development of cadastral overlays should be coordinated with the Bureau of Land Management or a designated federal cadastral agency.

These local functions that make heaviest use of cadastral maps also control, in their daily operations, the transactions that must be reflected in the continuous updating of the individual cadastral overlays. Where the transactions involve changes of boundaries of private properties, powers of approval over the new boundaries and other improvements required of the developer have been given to local governments in most urban areas and should become a standard practice nationwide. This normally involves an engineering review of the subdivision plans, which is the logical time for assigning the new or changed parcel index numbers that are essential for the property register and data files, as described in the following sections.

In most parts of the United States, it is the county governments that can best assume responsibility for production and maintenance of the cadastral map (or "property map") system and for organizing the land-records office for this and other related functions serving the county. Recording of deeds is a county function in 47 states (the only exceptions being Connecticut, Rhode Island, and Vermont), and property assessment is also a general county function in 33 states, although shared with a few municipalities in four of them (U.S. Department of Agriculture, 1979). Many counties also perform the functions of local governments described in Section 4.1.1.

The land-records improvement program legislated in 1977 by the State of North Carolina is a model of this approach. As described in Section 2.5.4.2, the program is managed by a small state office, part of the Department of Administration, which provides technical assistance and leadership in the organization of a land-records office in each county. Responsibilities of the county land-records offices include property mapping and parcel identification services supporting the four types of user agencies listed above. The State of New York also has invested heavily in a system of property maps produced and maintained by counties for their assessment functions but without the

direct involvement of the recorders of deeds, which has been noteworthy in the North Carolina program.

Some states will find that their support for the production and maintenance of the map system will need to go further than just technical and financial assistance. In Vermont, for example, all four of the functions listed at the beginning of this section are assigned to the cities and townships, rather than counties, few of which had made the effort to acquire adequate cadastral maps prior to 1974. At that point, the state undertook the Vermont Mapping Program, which so far has blanketed about half of the state with orthophoto base maps, at a scale of 1:5000, with larger scales for built-up areas. Drawing of the cadastral overlays on these base maps is left to local officials, typically the assessors. The results are of great value for administering the unique regulations of land use and development enforced by the State of Vermont, as well as in local government.

It would be valuable for other states that lack a broad-based system of county government, particularly in New England, to emulate Vermont's leadership in establishing a standard base-map system, but they should go even further in organizing and monitoring the completion of the cadastral overlays. A state agency should designate some local office to take responsibility for the cadastral overlays and parcel identification for each area, whether it be an office of the city, the county, a special regional district, a regional office of a state administrative agency, or a combination of these that draws on the best resources available in each part of the state.

The cost of producing and maintaining accurate and complete property maps has been perhaps the greatest single obstacle to organizing a modern cadastral records system in most localities. It also is an obstacle that must be overcome early in the local improvement program. Federal financial assistance for cadastral mapping by local governments will be especially important if there is to be progress in every state toward establishment of a cadastre. Further, a mapping program has other attributes that make it a logical candidate for federal assistance. Under a federal program, map production is more likely to be coordinated for broader areas, allowing the maps to be produced more efficiently using the new technology described earlier in this report. Supervision of this type of operation may require specialists from time to time, who could be trained and dispatched by the responsibile federal agency as needed to assist the state officials in managing the mapping contracts. The maps are a tangible product, and output can be readily monitored for both quality and productivity of the federal investment. Further, benefits will be enjoyed by a wide range of activities of local, state, and federal government and in private land use and development, far beyond the functions of local government, which would be the direct recipient of a federal assistance program for cadastral mapping.

4.2.3 The Register of Cadastral Parcels

The land-parcel register essentially is the inventory of all land in the given district, with records of boundary locations and acreage of each parcel, kept current and accurate to serve the multiple purposes of a cadastral records system. Its purpose is to identify all land-ownership parcels, using numbers that then serve as indexes to other records where descriptions of the land, its ownership, and its resources can be found. By including all streets and other public tracts as well in this total inventory of land parcels, a check of the sum of the acreage figures against the total land area of the district is possible. The register provides the "minimum data set" on land parcels–the definitive framework to which all other data files on land then can be attached.

Maintenance of the land-parcel register is logically a function of the county land-records office, or its equivalent in that locality. Changes in both the register and in the cadastral overlays maintained by that office should be simultaneous. An early warning of any impending changes normally will have been received during the review of subdivision plans by the local planning or engineering office, when the cadastral office is consulted regarding the tentative identification numbers that should be assigned to each proposed new parcel. The new numbers will remain tentative in the records of the cadastral office until confirmation is received from the recorder of deeds that the division of property creating the new parcel has been officially recorded.

Each parcel identified in the land-parcel register should be supported by a land-parcel description file containing the recorded plat, plans, field notes, and any other results of surveys that also are part of the public record, all filed or at least referenced under the same identification number. Extraction of the digital data from these records forms a data base for producing cadastral parcel maps. Standards for these survey records are described in Section 3.5. At present, the contents of this file normally are kept by the recorder of deeds but should be transferred to the county land-records office once it is established. The completion of these survey records to high, professional standards is one of the most important roles of the private sector in building a multipurpose cadastre.

4.3 NEW COMMITMENTS AND RESOURCES NEEDED

The performance needed in each component of the multipurpose cadastre has been discussed at length in previous sections. This section indicates which units of government should be called on to provide the necessary policy support and resources, grouped according to the commitments needed.

4.3.1 Federal Technical Studies to Identify Standards

An integrated system of land information must have clear standards for the collection, maintenance, and representation of land data. Many of these standards must be established on national and statewide bases to ensure compatibility. Among these are standards for mapping, filing, and recording land data. Because a common index depends on a survey base, it is appropriate that standards for land survey and section corner monumentation be at least of a statewide nature. This does not necessarily demand a single standard but could imply a series of well-defined standards, each appropriate to particular types of local jurisdictions. Some standard setting can remain at the local level but should be coordinated with national procedures for accessing the data.

We recommend that technical studies continue to be sponsored by the federal government to identify consistent land information and display standards for use among and within federal agencies and between federal and state governments. These studies should rely on the authority of state governments to adopt the standards and organize the data collection in cooperation with the federal government to ensure compatibility on a national basis, delegating these functions to local governments where appropriate. The following technical subjects should be addressed:

- *Integrating mechanisms for cadastral, cartographic, engineering, and geodetic surveying for federal and federally supported programs;*
- *Integrating mechanisms for the storage and retrieval of other land information in data files;*
- *Procedures for development of local systems, leading to the distribution of prescribed methods and rules for (1) ties to geodetic coordinate systems and (2) adjustment of coordinates for property boundary surveys and related subjects; and*
- *Compatibility among the large-scale maps to be produced by the individual counties within each state.*

To recommend the technical requirements for a national system normally does not require formal organization or reorganization of any federal agencies. Such studies are completed in almost all fields of national concern from time to time, by bringing together the best available expertise from whatever source, often convened by an executive office, which has the mission to further the particular program. Agencies that now serve as important sources of expertise in cadastral systems will continue to do so, notably the Bureau of Land Management, the National Geodetic Survey, the U.S. Geological Survey, and the Defense Mapping Agency. Other member agencies of the Federal Geodetic Control Committee, given in Section 2.4.1, also will have important contributions to make. Standards for definitions of terms and accessing the

files will be of concern to many other federal agencies that will use them or whose constituents will use them; notably the Bureau of the Census, the Department of Housing and Urban Development, the U.S. Department of Agriculture, and the Environmental Protection Agency. The scope of these recommended standards eventually should reach into all areas of technical requirements described in Chapter 3.

The technical studies will be time consuming but need not be costly, in a subject area such as cadastral systems where the problems are more in the organization and assignment of responsibilities than in development of new technology. Experts from federal agencies should be available on loan, for limited time, especially if the studies are commissioned by federal legislation. The same should be true for a sufficient number of state and local governmental representatives to participate in the studies.

However, the most difficult commitment to obtain for the success of the studies will be the designation of the coordinating or host agency, preferably an agency with a new legislative mandate to foster standard procedures for a multipurpose cadastre on a definite schedule. The ideal host agency would be the one created for the other type of supportive federal role described in the following section if, and when, this can be accomplished. In the meantime, the National Research Council could provide a valuable head start in these technical studies by convening several panels to cover the technical subjects listed in the recommendation above that are not being covered by current studies of other federal agencies.

4.3.2 A Program of Federal Assistance

To gain the cooperation of the 50 states, and the commitment of their resources to a national multipurpose cadastre, will require an intelligent "soft" approach with flexibility to bargain with each state in relation to its current needs and resources. This mission is distinct from the resolution of the "hard" technical standards described in the preceding section. The agency that provides federal leadership in development of the cadastre should use the technical expertise already available in the agencies listed above but must develop its own expertise in mobilizing state and local governments with the appropriate financial and regulatory incentives.

We recommend the establishment of federal cooperative agreements with states and/or local governments to conduct, for example, survey control operations, mapping and remonumentation of property corners under federal or state guidelines and to provide technical assistance and funding for these efforts.

The urgent missions of a new federal program in its early years will be sys-

tem design and development. The classification and evaluation of existing land records in each of the 3042 counties of the United States has not been done to date in such a way as to constitute a multipurpose cadastre. There will be important feedbacks between these evaluations of existing local systems and the development of technical standards described in the preceding subsection.

Meanwhile, an important function of a new federal program, especially for building its contacts and credibility among state and local officials, will be technical assistance to local cadastral improvement projects, including referrals to other federal agencies and organizing interagency missions to local projects where special expertise is needed. This particular arm of a new federal program should be left fairly flexible to respond to whatever technical areas within the overall scope of a cadastral system appear to have the highest levels of demand from the localities. Likely, early priorities will be base mapping, criteria for delineating areas of environmental controls such as wetlands, and precise definitions of terms for compatibility among local data files.

Ties with state and local programs also can be fostered by grants to demonstrate model multipurpose cadastral systems. Ideally, these should take advantage of the innovative local projects already under way in various specialized aspects of the cadastre by funding the extension of these projects in the direction of the multipurpose cadastre. Likely candidates for research, demonstration, and technical assistance grants in some regions of the United States may be the federally sponsored multistate agencies such as the Tennessee Valley Authority and the New England River Basins Commission.

The designated federal agency for cadastral system development will need the support of the Executive Office to enforce the technical standards and adherence to administrative procedures among the other established federal agencies. This agency also should be responsible for adherence to its standards by state and local recipients of federal assistance.

We recommend that federal agencies that impose restrictions on the use of lands should be required to file those restrictions with the appropriate state or county recording office.

We recommend that all federally funded programs that produce components of a multipurpose national cadastre, such as right-of-way surveys or large-scale maps, should be required to adhere to a federal plan that establishes the format for these components or, until such a plan is adopted, to the individual state plan, if any.

Eventually, improvement of cadastral systems will depend on governmental appropriations at one level or another. However, the amount needed to bring existing records up to the new standards will vary significantly for different localities. Costs per land area will be much higher in the urban areas, where the land values and ownership parcels are highly concentrated. However, costs

per parcel or per capita will be higher in the less-developed rural areas, where there is a much higher ratio of land and resource values per person.

One preliminary reading on the level of investment required over the long run is provided by the report to Congress prepared by the U.S. Department of Agriculture (1979) on the feasibility of establishing a multipurpose land-data system, in this case as a vehicle for monitoring the level of control of land in the United States by foreigners. Rough estimates compiled for that report by the Harvard Laboratory for Computer Graphics indicated that the cost of building such a data system would be in the neighborhood of $3.35 billion, assuming that none of the existing local maps and files could be used without conversion to new bases. However, some substantial share of the existing local resources in fact should be acceptable, at least for an interim level of technical standards. In this report to Congress (U.S. Department of Agriculture, 1979, Volume 2, p. 166) it was approximated that existing records would serve for about two thirds of a new multipurpose land-data system, so that an additional $1.2 billion was estimated to be needed from other sources.

Both the total and the net cost figures suggested in the preceding paragraph will be higher when the objective is a cadastral system meeting the requirements set forth in Chapter 1, rather than a land-data system for reporting ownership. The standards for accuracy and consistency assumed for the U.S. Department of Agriculture (1979) study were somewhat lower than will be required for a system that eventually will serve as the foundation for all public records regarding the land. On the other hand, none of these amounts is actually large in relation to the losses being suffered throughout our economy because of shortcomings in our existing land-records systems, in which billions of dollars are going to be invested anyway over the period of 10 to 20 years that would be required to realize an adequate multipurpose cadastral system, as described in Section 2.1.

Furthermore, the federal participation in these costs should not need to be more than some limited percentage of matching funds, sufficient to stimulate state and local investments in updating maps and files earlier than the normal schedule and with tight quality control on the data being entered. Based on the U.S. Department of Agriculture (1979), the net new investment required nationally will be on the order of $1.2 billion spread over 10 years. An appropriate level of federal matching funds is 40 percent, contingent on a minimum additional contribution of 20 percent by each individual state. Based on these assumptions, the federal cost for this financial assistance would average $48 million per year, in 1979 dollars.

It would not be appropriate to begin the direct financial assistance program until the tasks of system design and development are substantially complete. During its organizational period, which could require several years, the

designated federal cadastral system development agency could operate with a budget of a few millions of dollars, a figure that should be resolved as soon as possible in the drafting of the initial federal legislation. The major financial commitment for the local assistance program would then be reconsidered by the Congress, based on the findings and proposals developed in the organization of the new program.

4.3.3 Active Participation and Support by State Governments

Section 4.1.2 indicates the need to have each state authorize a cadastral improvement program office. This section will describe in greater detail the roles of this office in the intergovernmental context.

The intergovernmental arrangements necessary for a cadastral improvement program will be impossible without active participation of a state program office. For example, a state office concerned with title and boundary records is needed, if only to provide standards for local officials, as recommended by the National Conference of Commissioners on Uniform State Laws (1977) in a model act. Adherence to such standards will permit other state agencies to realize substantial savings in their land-related operations, whether they require information regarding the land or a system for recording their own policies and actions. Coordination with many federal programs will be enhanced by having a common, standard reference system for all land-related data, for example, for establishing an atlas of environmentally sensitive areas for each municipality, as recommended for the federal environmental protection program by McCormick and Associates (1978, p. viii).

We recommend that the Office of Land Information Systems established by each state, as recommended above in Section 4.1.2, be responsible for

- *Promoting effective, efficient, and compatible land-information systems among governmental levels, in cooperation with the federal government to ensure compatibility on a national basis;*
- *Setting standards for state, regional, and local government surveying, mapping, and land-data-collection efforts, making use of federal technical studies;*
- *Providing guidance to those local offices with major responsibilities for land information, namely, recorders, assessors, surveyors, engineers, and planners;*
- *Serving as the focal point and clearinghouse for state and federal agencies collecting or mapping land information, taking responsibility for the quality of the information that is forwarded;*
- *Enlisting the resources of other state agencies having important contributions to make to the development of the cadastral system, especially those*

responsible for land assembly, construction, management of public lands, and efficiency of state administrative services; and

- *Recording and transmitting land-related documents and information filed by out-of-state groups such as private, federal, and alien organizations.*

A number of precedents are available from similar efforts to organize new state program offices in response to national priorities with federal financial assistance. One of these is in the field of public employee training programs (which actually should play some role in a cadastral improvement program). States that did not already have training offices offering programs to upgrade general skills of both state and local governmental employees organized such offices in the early 1970's in order to become eligible for federal training program grants under the Intergovernmental Personnel Act. One of the relevant federal requirements for this type of grant program is that the state establish a general plan to accomplish the desired objectives. In the case of a cadastral improvement program, such plans will involve complex technical work, for example, a plan for a cadastral map system covering the state, which most states could not be expected to complete until at least some form of federal financial assistance for the technical studies has begun to flow.

We recommend that states enact legislation to ensure the compatibility of county and local records with the multipurpose cadastre. This legislation should address such questions as

- *Regulations for recording conveyances and subdivisions,*
- *Mandatory recording of field notes and plans (or "plats"),*
- *Regulations specifying monumentation and computation of location coordinates of property boundary corners,*
- *Requirements for survey and positioning of utilities on cadastral maps, and*
- *Matching funds for local cadastral systems that meet state standards.*

Examples of the benefits of state enforcement of standards for local functions, along with technical assistance and grants-in-aid, can be seen in a great many fields, ranging from public education, which predominates many local government budgets, to traffic control structures. Grants-in-aid for local property mapping already are provided by 10 states and at least technical assistance in this function by 15 others (U.S. Department of Agriculture, 1979, Vol. 2, p. 91).

Thus, program-development offices for at least this component of the multipurpose cadastre already exist. The incentive of matching funds from a state office can be especially effective where they are supplemented by federal grant funds for the same purpose. This piggyback funding arrangement is very much desired by state agencies that administer their own matching fund programs. Supplementary state contributions should be a condition of the provision of the federal aid funds recommended earlier in this section.

4.3.4 Participation and Executive-Level Support by Local Governments

The several functions of each local government that must be coordinated with and that feed data into a cadastral system were listed in Section 4.1.1. The use of land-related data is so pervasive in the functions of local government that it will become systematic and coordinated with state standards only where this is a priority of the local chief executive. The programs of federal and state assistance should be designed to give every kind of support that is feasible to this priority.

We recommend that each county government (or municipality where appropriate) consider creating an Office of Land Information Systems, in coordination with the offices of the recorder of deeds, county surveyor, assessor, planner, and county abstractor, if any. The functions of the new office would include the following:

- *Standardization of procedures among all the responsible county and municipal agencies to assure efficient acquisition, storage, maintenance, and retrieval of land information and records within the county;*
- *Supervising, or at least monitoring, the production and maintenance of a system of county base maps and cadastral overlays that meet state standards for the multipurpose cadastre as described in Section 4.2.2; and*
- *Creation and maintenance of the land-parcel register described in Section 4.2.3, including the recording of land information or restrictions emanating from municipalities or special-purpose districts within the county, the filing of which by those other offices would be mandatory, by state legislation.*

The functions of the new land-information, or land-records, office serving each locality would in general be the maintenance of the multipurpose cadastre, which eventually would provide the full scope of services described in Chapter 1. Because this office would have ties to state-level record systems, as well as those of constituent districts of the county, it also should become the local outlet for the public-land records of the state. Eventually, with compatibility at the interstate level, it may be possible for the county land-information office anywhere in the country to respond to requests for information regarding any other county and possibly even to receive documents regarding land in other counties to be forwarded to them for their official records.

4.3.5 Policies to be Resolved with National Interest Groups

At least three general issues concerning the operation of a cadastral system will be of major interest to private parties that use such systems and should be reviewed with the national organizations representing these interests.

Perhaps the heaviest investors in cadastral information among the private industries are the utility companies. Typically, they provide base maps for themselves and in some areas even offer these gratis to the engineering departments of the smaller municipalities as the only accurate, large-scale base maps available. However, the pilot projects in both Norristown, Pennsylvania (Regional Mapping and Land Records program) and Memphis, Tennessee (Computer Assisted Mapping and Record Activities Systems program) described in Sections 2.6.3.1 and 2.6.3.2, respectively, have shown how combined, large-scale mapping and cadastral records services can be offered to both the municipal engineering office and the companies that maintain utility-system structures and distribution networks, realizing economies not possible for either organization alone. Endorsement of this approach by the state and national organizations representing the utility companies and their technical staffs should be sought.

Second, increased user fees to finance at least part of the cost of developing a cadastral system should be considered. Currently, many counties are able to cover most of the cost of operating the deed recorder's office through the fees charged for recording or registration of documents. Some municipalities charge fees for certificates that confirm the status of certain parcels of land in the municipal records, notably the status of real estate tax payments or other liens. Higher fees for these services may be justified where a cadastral system is used, since it will offer faster retrieval of data and the ability to assemble composite data for many parcels at a time. Increases in user fees will be of special concern to the real estate industry and should be discussed in advance with representatives of brokers and title lawyers.

Third, the establishment of a cadastral system will improve both the efficiency and effectiveness of title search and help to realize the objectives of the Uniform Simplification of Land Transfers Act (National Conference of Commissioners on Uniform State Laws, 1977). Representation of the American Bar Association and any other specialized associations of title abstractors or conveyancers should be engaged in review of the proposed cadastral improvement programs at both national and state levels. At the national level, liaison with these types of associations should be a special concern of the new federal cadastral system development program or, in the interim, of those who are sponsoring the new legislation.

4.3.6 Program Evaluation

The risks of misguided or misunderstood requirements and regulations, which can occur in any new governmental program, can be reduced by evaluation of each major program proposal by an independent agency. The most-likely sponsors of such evaluations, who will need them in the legislative process,

will be the appropriations committees of Congress and their counterparts in state legislatures. Some of these evaluations might best be conducted by an independent governmental unit such as the General Accounting Office or the legislative oversight committee of a state. Others might better be contracted from the executive level of the government to an independent research organization. The list of candidates for such contracts should include university faculties that are developing programs of study of cadastral-system requirements. Other candidates might be nonprofit research organizations with expertise in this area. Whatever vehicle is chosen for the program evaluations, the primary concern should be how much improvement in land-information services is being offered to the users of the new multipurpose cadastral systems, and at what cost.

4.3.7 Professional Development

A cadastre is a significant part of the larger land-information system. It contains specific information about land parcels. It also provides a framework for indexing other land records. Understanding the dynamic relationship between parts of the system and the role of the system in the decision-making process precedes system design or improvement.

Land information has characteristics that make the design problem particularly difficult:

1. Land information appears in a wide variety of forms. Parcel boundary information, zoning regulations, and wetland descriptions are examples of this diversity.
2. Individual land-information files are assembled in a form to provide answers to narrowly defined questions. What is called system design is often a response to narrowly perceived problems. The problems are often addressed in a crisis context. This delays consideration of the larger needs. It makes it difficult to assemble a broad-based solution to common information requirements.
3. Land information belongs to that class of knowledge whose value is not easily measured by traditional benefit analysts. Thus, arguments for alternative information systems are often not in a politically popular form. Rather, the arguments rely on demonstrating the cost of continuing to operate in the traditional ways. Ultimately, the arguments rest on the conviction that there is a better way to handle land information and that society's need to know the land demands serious attention to the land-information problem.
4. Land information is everyone's concern, which results in no one taking responsibility for it. Individual public data files are held as the property of individual agencies. But no agency is concerned with the problem of information flow among agencies.

There is a need to identify a federal agency committed to the improvement of land-information science and having the resources to foster this commitment. Lacking an adequate land-information science, the following scenario could develop.

Congress decides that the status of land-information records is a problem. Where are the people with the requisite perspective and knowledge to supervise or advise the formulation of a solution? This dilemma may be the most basic problem in the design and implementation of land-information systems.

The resolution of this problem requires an answer to yet another question. What institution makes available to people the conditions and time to address questions of the type that we have discussed? Where is the mechanism to train people with the broad view and deep understanding of the problem? The answer to both these questions is the university.

The current problem is that there are few people with broad experience or knowledge, while the problem is large and diverse. The immediate objective is to train scholars and teachers who will in turn prepare other professionals and workers for the variety of land-information activities. Direct experience with the problems of land-data systems is essential. We conclude that the current situation demands an effort at the top of the educational structure because there is no base to build upon.

We recommend support by the federal government for the establishment of a center or centers of excellence in land-information science, for the purpose of providing a program that develops scholars and professionals. The curriculum should include direct experience with land-data-systems problems.

A small number of disciplines should be incorporated in the university center(s). Planning, land economy, law, and surveying are essential. Several disciplines may operate at one center, or each center may emphasize one or more disciplines.

Support for faculty and research at this level within the university suggests that strategies will be devised which emphasize the resolution of immediate problems while keeping open options for the achievement of long-range goals. University centers can provide the high profile organization that focuses attention on the problem. They also provide a resource for use by the land-information professionals. Ultimately, they can produce an understanding of the concept of land-information science.

4.4 STAGES OF DEVELOPMENT OF A MULTIPURPOSE CADASTRE

The recommendations advanced so far in this section relate to the ideal multipurpose cadastre that can only be afforded in the counties with relatively high urban land values at the outset and perhaps not until well into the twenty-first century for some of the more remote areas of the nation. How-

ever, the more typical counties can realize the benefits of tying together the several components of such a system long before they have reached the ideal levels of completeness and accuracy, that is, creating something less than the ideal records system, which will be referred to here as a Class AA cadastre.

The need to define acceptable interim records systems will become clearer when the state agency responsible for managing a cadastral-records improvement program introduces the dimensions of cost and time into its statewide plans. The program should provide a scenario for each county to move toward the more ideal cadastre while providing its constituents with at least some benefits of coordinated records in the meantime. It is for purposes of such a scenario that suggested definitions of Class A and Class B cadastres, in relation to the ideal Class AA cadastre, are outlined in Table 4.1. Each class is intended to represent typical existing situations that appear to be working, rather than prescribed minimum standards.

The definition of the Class B and Class A cadastres offered here are almost identical to the "Typology of Multipurpose Land Data Systems," Level B and Level A, respectively, recommended in the Report to Congress of the U.S. Department of Agriculture (1979, specifically, Table 10D-1). However, that typology does not reach the level of legal and engineering records of locations of property boundaries and structures, for which the Class AA cadastre is recommended here as the ideal.

The first step in the typical locality will be to bring the existing record systems into conformance with the minimums for a Class B cadastre. A cadastre at this level offers a full range of data files indexed to the parcel identifiers but with a map system that is insufficient to yield accurate geographic locations of each parcel. Such a map would show relative sizes, shapes, and positions of each parcel, e.g., as do most local property maps.

The establishment of a system of accurate base maps and cadastral overlays, tied to geodetic control, will permit a locality to move up to a Class A cadastre. This will provide essentially all of the other attributes of a Class AA system aside from the legal record of the results of field surveys. Instead, locations of boundaries in either the Class A or Class B system are given by references to appropriate property maps or, where more specific measurements are required, to the survey or plat that has been recorded, to define the given parcel.

The prototype Class AA cadastre contains the official numerical records of field surveys, in addition to the other functions of the multipurpose cadastral system that would also be in a Class A system. The special value of a Class AA cadastre is direct access to the complete legal descriptions necessary for resolving any questions of property boundaries. The coordinates that locate the property boundaries become part of the official public record, computed

TABLE 4.1 Three Prototype Classes of a Local Cadastre

Class B: Property Record Files
Class A: Geographic Data Base Using Maps or Stereo Models
Class AA: Geographic Data Base Using Numerical Survey Records

Component	Prototype Class	Minimum Level of Quality	Updating Routines		Computer Used?
			Frequency	Sources	
Geodetic reference framework	B	Optional (no minimum)	–	–	–
	A	Second-order monuments within standard maximum distance	Continuous replacement, est. 5%/year	Field survey	Yes
	AA	Second-order monuments within standard maximum distance	Continuous replacement, est. 5%/year	Field survey	Yes
Base map	B	To scale, without grid (rectified air photo in flat terrain)	5–10 years	Mapping contractor	No
	A	U.S. map accuracy, with geodetic coordinates	3–5 years	Mapping contractor	No
	AA	U.S. map accuracy, with geodetic coordinates	3–5 years	Mapping contractor	Yes
Cadastral parcel overlay	B	Compiled from deed descriptions	1–12 months	Copies of recorded deeds	No
	A	Compiled from plans on record	Weekly	Copies of recorded plans	Digitized from map[a]
	AA	Plotted from coordinates	With each new field survey	Surveyor's notes	Digitized from survey record
Parcel identifiers	B	Unique assigned numbers	1–12 months	Recorded subdivisions	Yes[a]
	A	Unique assigned numbers, plus visual center coord.	Daily	Recorded subdivisions	Yes

	AA	Unique assigned numbers, plus computed coordinates	Daily	Recorded subdivisions	Yes
Legal boundary descriptions	B	Not included	–	–	–
	A	Not included	–	–	–
	AA	Boundary coordinates on record	With each new field survey	Surveyor's notes	Yes[a]
Ownership and valuation data ("minimum data set")	B	Complete	1–12 months	Copies of recorded deeds	Yes[a]
	A	Complete	Daily	Keyed to recorder's indexing	Yes
	AA	Complete	Daily	Keyed to recorder's indexing	Yes
Other parcel data	B	Multipurpose	1–5 years	Field checks by staff	Yes[a]
	A	Multipurpose	Daily	Public agency transactions	Yes[a]
	AA	Multipurpose	Daily	Public agency transactions	Yes[a]
Mechanisms for integrating resource data	B	Visual analysis of maps	–	–	–
	A	Mapped locations of boundaries	Upon new field survey	Field survey	Yes[a]
	AA	Boundary coordinates	Upon new field survey	Field survey	Yes[a]
Purposes served	B	Property assessment, tax billing, property regulation, indexing of title records, planning information systems, sampling of land owners, sampling of land areas			
	A	All of the above, plus continuous inputs of data to management information systems and to routine activity reports			
	AA	All of the above, plus construction design and engineering, and maintenance and adjustment of lower-order geodetic control points			

[a]Optional.

directly from the field survey measurements. The prototype Class AA cadastre should include computational programs for adjusting the coordinates of the network of property lines in the public records, if necessary, when new or more accurate field measurements are submitted.

The components that differ the most between the Class B and the Class AA cadastres suggested here are geodetic control, cadastral mapping, and integration of survey records. These also are the components that will be the most expensive for the typical county and are more difficult to justify for their own sakes than are, for example, the steps that permit sharing of data files on land parcels among the county agencies. Essentially, by offering Class B or Class A systems as interim alternatives, counties will be offered the option of moving more quickly toward integration of their deed records and other land-parcel data around the standard parcel identifier numbers, and stretching out the further investments in mapping of property boundaries to the higher levels of accuracy required by certain users of a multipurpose cadastre.

5
Conclusions

5.1 GENERAL CONCLUSIONS

There is a critical need for a better land-information system in the United States to improve land-conveyance procedures, furnish a basis for equitable taxation, and provide much-needed information for resource management and environmental planning. Numerous conferences have been held and reports prepared that discuss the problems with our present land-information systems, such as duplication, lack of accessibility, single-purpose data systems, lack of standards, and institutional arrangements that limit coordination among land-related functions.

The benefits resulting from the development and use of a multipurpose cadastre system have been recognized for some time. Most of the densely populated European countries have utilized such systems for many years. Multipurpose cadastre programs are being developed in portions of Canada and Mexico. Within the United States, the federal government, several states, and many communities are developing programs that provide an integral part of a multipurpose cadastre. Several states and some cities have control-surveying organizations that provide the framework for accurate mapping. Several communities have base-mapping programs that provide accurate large-scale maps with overlays depicting needed information. There is increasing utilization of computers and data systems by assessors, recorders, planners, title insurance companies, and utilities. Pilot programs are under way that will help to evaluate various components of a multipurpose cadastre.

Current technology is adequate in most cases for the surveying, mapping,

data collecting, filing, and dissemination of information. Improved surveying and mapping instruments and techniques will probably reduce the cost of some of the mapping required. Advancements in computer applications, communication networks, and copying processes offer promise of more-efficient use of the multipurpose cadastre.

The major obstacles in the development of a multipurpose cadastre are the organizational and institutional requirements. Reorganization and improved quality control for existing governmental functions will be required. Each of the components of the cadastral system already exists somewhere within our existing governmental structure. Many of the required data are being generated at the local level, and in most cases the users are the individual citizens and the local government officials and planning organizations. Each state has organizations that prepare maps and collect data that would be an integral part of a multipurpose cadastre. At present, much of this effort is directed toward a single purpose and cannot be utilized for other programs. The federal agencies conduct surveys, prepare maps, and collect information that would be required for the development of a multipurpose cadastre. The federal government has a need for vast amounts of information that must be collected through particular programs such as the Taxable Property Values Survey and the monitoring of foreign ownership of land in the United States.

The development of a multipurpose cadastre will require coordination between various levels of government—local, state, and federal—as well as that of parallel organizations at each level. New laws that relate to governmental responsibilities, practices, and finances will be required in some areas. To ensure the reliability of the information that is filed, standards and practices must be developed and uniformly adopted. Uniform indexing and common terms must be used in each community so that the information systems maintained in various offices are compatible.

Development of a multipurpose cadastre will be gradual. Many of the functions necessary for the land-information system are being performed now. Modifications of procedures and standards and progressive upgrading of maps and files will result in a cost-effective acceptable multipurpose cadastre, if carried out in coordinated, areawide programs.

5.2 SPECIFIC CONCLUSIONS

5.2.1 Local Level

The cadastral records and other data registers are more related to functions of local government than to those of state or federal agencies. The primary uses of the multipurpose cadastre are related to local activity: real estate transfer,

assessments, zoning, location of utilities, and planning. In most communities, there is no single source of the much-needed information for these activities. An integrated land-information system as outlined in this report would provide a coordinated approach that would eliminate much of the waste currently encountered in land-related activities. In addition to the savings in time and money, the decision-making process about local projects would be improved because of the ready access of all necessary information.

It is essential that local governments be the access points for local land information and that they have the primary responsibility for developing and maintaining the multipurpose cadastre in their community. There are about 3500 land-title-record systems in counties, towns, and cities in the United States. A few have developed components of a multipurpose cadastre. To provide an efficient land-information system, most communities will require the following:

1. Coordination among existing land-related functions either by establishing an Office of Land Information Systems or by designating an existing office as the lead agency.
2. Standardization of procedures and terminology to assure efficient acquisition, storage, maintenance, and retrieval of land information and records within the community.
3. Preparation and maintenance of a system of base maps and cadastral overlays that meet standards for a multipurpose cadastre.
4. Creation and maintenance of a land-parcel register, including a unique parcel identifier, position of the parcel in a common reference frame, and data from boundary surveys, including boundaries of any easements or use restrictions.
5. Coordination with private sources such as utilities, transportation systems, title insurance, and abstractors.

5.2.2 State Level

Most of the laws relating to land titles, recording procedures, zoning practices, and surveying and mapping standards are state laws. Many of these laws and procedures are unique to a particular state. Generally, the states are responsible for many land-related activities that are applicable statewide or regionally, such as transportation systems, state lands and water bodies, coastal zone management, and environmental regulations. Legislation will be required in a number of states to ensure the compatibility of county and local records with the multipurpose cadastre; committees of the American Bar Association and the North American Institute for Modernization of Land Data Systems are working on this problem. This legislation should address questions such as

1. Regulations for recording conveyances and subdivisions;
2. Surveying and mapping practices such as monumentation, computations of coordinates, and property boundaries and filing of field notes, plats, and plans;
3. Funding of local cadastral system by fees and matching funds.

Existing offices in many states are producing land-related information that would be helpful in the development of a multipurpose cadastre such as control surveys, state and regional maps, basic survey and boundary information performed by federal and state agencies, and statewide transportation and utility systems. Because of the legal responsibilities and the interrelation of land-related activities, the state agencies are vital to the development of a multipurpose cadastre. An Office of Land Information Systems should be established in each state to

1. Promote effective, efficient, and compatible land-information systems within the state;
2. Establish standards for state, regional, and local surveying, mapping, and land-data-collection efforts;
3. Provide guidance to local offices such as recorders, assessors, engineers, and planners;
4. Serve as the focal point and clearinghouse for state and federal agencies that are collecting land information;
5. Coordinate the land-related information resources of other state agencies that are responsible for surveys, maps, state-owned lands, construction, zoning, and management of public lands.

5.2.3 Federal Level

Most of the federal agencies are involved in collecting information, much of it land related or geographically oriented. In addition to being users of land information, several federal agencies generate much of the basic information required for the development of a multipurpose cadastre: control surveys by the National Geodetic Survey; maps by the U.S. Geological Survey; cadastral surveys of all public lands by the Bureau of Land Management; and surveys and maps by other agencies such as the U.S. Army Corps of Engineers, U.S. Forest Service, Tennessee Valley Authority, and Department of Housing and Urban Development. At present, there is minimal coordination of these efforts toward the establishment of a multipurpose cadastre. The most recent effort at coordination has been meetings held by the Bureau of Land Management, the National Geodetic Survey, and the U.S. Geological Survey to determine

the extent to which their current organizations can contribute to the pilot projects in Colorado.

If an effective land-information system is to be established in the United States, it is imperative that the federal effort be coordinated through a single surveying and mapping agency as recommended by the report to the Office of Management and Budget by the Federal Mapping Task Force on Mapping, Charting, Geodesy and Surveying (1973) or that a lead agency for the multipurpose cadastre be designated.

In addition to performing their present functions relating to basic horizontal and vertical control surveys, small- and medium-scale mapping, cadastral surveys of all federally owned land, and filing of land information, the federal agencies have the facilities and expertise to help in the development of a multipurpose cadastre. Although some standards and procedures are only applicable to local situations, many of the standards and procedures can be used throughout the nation. It is appropriate that the federal agencies should continue technical studies that are beneficial throughout the country. Some of the technical subjects that should be addressed are

1. Integrating mechanisms for cadastral, cartographic, engineering, and geodetic surveying for federal and federally supported programs;
2. Integrating mechanisms for the storage and retrieval of other land information in data files;
3. Procedures for development of local systems, leading to the distribution of prescribed methods and rules for ties to geodetic coordinate systems and adjustment of state plane coordinates for property boundary surveys;
4. Compatibility among the large-scale maps to be produced by the individual counties within each state.

5.2.4 Future Committee Activities

This panel has concentrated its efforts on the basic components of the multipurpose cadastre: (1) geodetic reference frame, (2) base maps, and (3) cadastral overlay. Other organizations are studying components of land-information systems, such as laws, computer applications, assessment practices, real estate transfer procedures, and computer mapping and records systems. The panel lacked the time to consider a number of subjects that developed during this study, such as detailed technical subjects and those related to other aspects of a land-information system. Further study by committees with members drawn from this panel and elsewhere should result in worthwhile recommendations about particular problems, such as

1. Evaluation of the technical standards currently available for the items listed in Section 4.3.1 as to their appropriateness for development of a multipurpose cadastre;

2. The development of a multidisciplinary curriculum leading to a graduate-level degree in the multipurpose cadastre;

3. Study and evaluation of the existing multipurpose cadastre efforts and pilot projects to determine their effectiveness;

4. Analysis of the Bureau of Land Management's Bureau Resource Information Management System activities and how they can be integrated into the multipurpose cadastre;

5. Mechanisms and suggested procedures for progressing from the rudimentary mapping and filing procedures discussed in the report to the more-advanced systems;

6. Economic analyses to determine the feasibility and cost of a federal program of assistance to states and localities for development of multipurpose cadastres as described in Section 4.3.2;

7. Development of a glossary of terms.

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