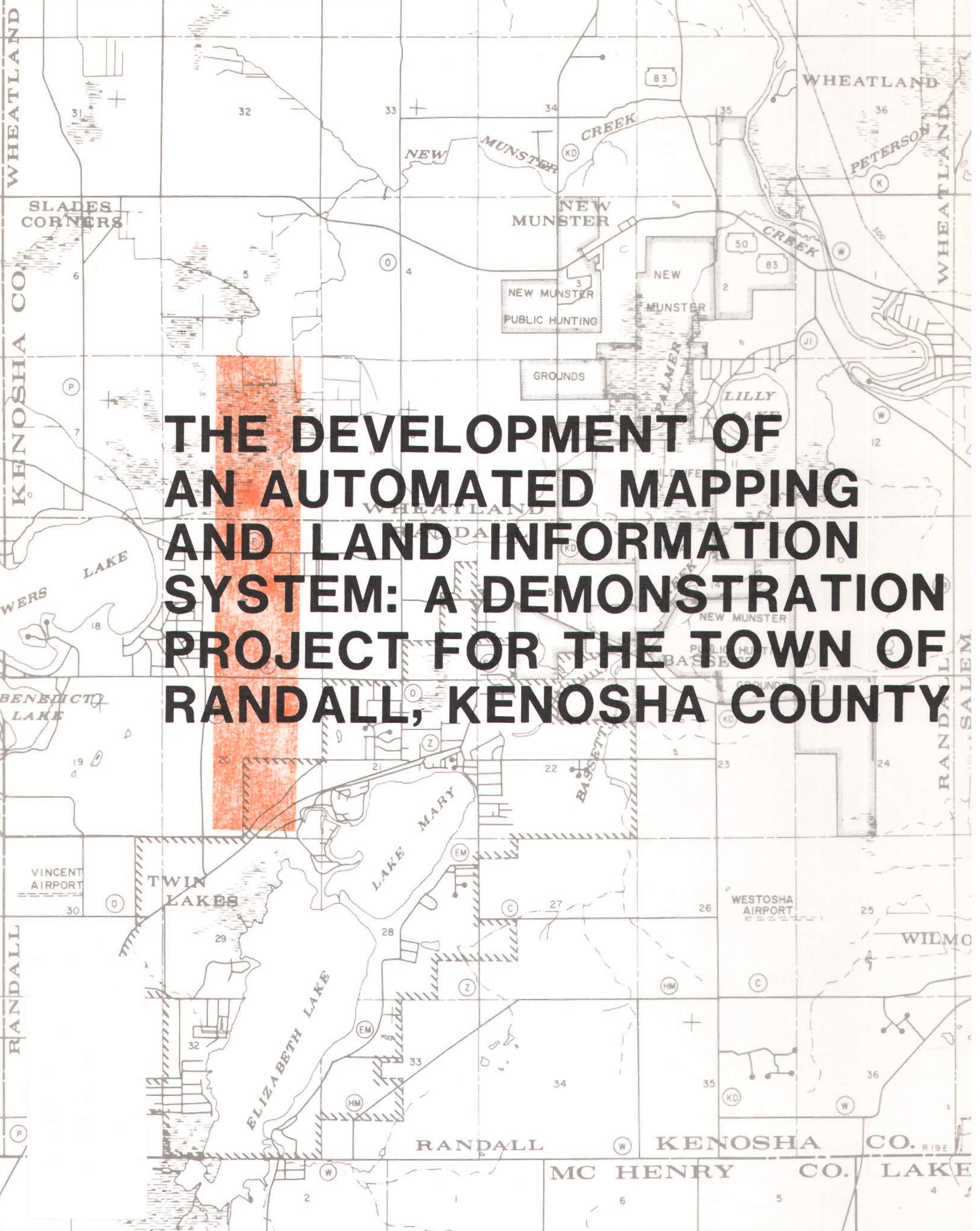
TECHNICAL REPORT NUMBER 30

THE DEVELOPMENT OF AN AUTOMATED MAPPING AND LAND INFORMATION SYSTEM: A DEMONSTRATION PROJECT FOR THE TOWN OF RANDALL, KENOSHA COUNTY



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TECHNICAL REPORT
NUMBER 30

THE DEVELOPMENT OF AN AUTOMATED MAPPING AND LAND INFORMATION SYSTEM: A DEMONSTRATION PROJECT FOR THE TOWN OF RANDALL, KENOSHA COUNTY

Prepared by the

Southeastern Wisconsin Regional Planning Commission
P. O. Box 769
Old Courthouse
916 N. East Avenue
Waukesha, Wisconsin 53187-1607

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September 1985

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SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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September 30, 1985

STATEMENT OF THE EXECUTIVE DIRECTOR

There is a growing interest in the United States in land data systems. This interest ranges from a more narrowly focused concern about the need to modernize land title recordation systems to a much broader concern about the need to create entirely new land-related data banks for multi-purpose application. This growing interest has involved many disciplines, ranging from surveyors, abstractors, assessors, and attorneys narrowly concerned with the fiscal and legal administration of real property, to planners, engineers, utility managers, and public administrators more broadly concerned with community development and resource management. Much of the interest is centered around the use of electronic computers for the storage, manipulation, and retrieval of the data and, more recently, on the use of computer-assisted graphics collection and display hardware for the reproduction of the data in mapped as well as tabular form.

The demonstration project reported herein was carried out within the context of this increasing interest at the national, state, and local levels in the development of land-related information and related automated mapping systems. The project was jointly conceived and developed by representatives of the Wisconsin Departments of Development and Agriculture, Trade and Consumer Protection and the State Cartographer's office; the Southeastern Wisconsin Regional Planning Commission; Kenosha County; and the Town of Randall. The project was intended to develop and demonstrate a limited-purpose land-related information and automated mapping system, the primary focus of which was zoning administration. This system was to provide a working model for a high-quality automated procedure that could: 1) provide land-related data essential to the sound administration of comprehensive and special-purpose zoning ordinances; 2) provide an effective method of monitoring zoning changes; 3) promote the cooperation of regional, county, and local capabilities in carrying out comprehensive county/town zoning programs; 4) demonstrate the proper and effective relationship between planning and zoning; and 5) provide a basic system that could readily evolve into a countywide, multi-purpose, land-related information system. This evolution would proceed in two important ways: first, through the geographic extension of the limited system demonstrated to eventually encompass all of Kenosha County; and second, through the addition of more land-related information files. Such an evolution would enable the system described herein to, over time, evolve into a true multi-purpose cadastre.

The described system has been developed in accordance with the procedural model for the development of multi-purpose cadastres proposed by the Panel on the Multi-Purpose Cadastre of the National Research Council. This model consists of the following five basic elements: 1) a geometric reference frame consisting of a geodetic survey network: 2) a series of current, accurate, large-scale base maps properly related to the geographic reference frame; 3) a cadastral map overlay delineating all cadastral parcels which is also properly related to the geographic reference frame; 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 cross-referencing with information in other land data files. Additional elements in the form of maps and records of land-related information can be readily added to this base over time.

The specific findings of the demonstration project are set forth in the report. Perhaps the major finding to emerge from the project is the knowledge that the implementation of a limited-purpose automated mapping and land information system as described herein is feasible with existing technology and that the development of such a system can be accomplished, at least in Kenosha County, at what are judged to be affordable costs. Typical costs for system implementation based upon project experience are also set forth in the report.

Respectfully submitted,

Kurt W. Bauer
Executive Director

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State of Wisconsin

December 20, 1985

STATEMENT OF COOPERATING STATE AGENCIES

We are cooperating in the transmission of this report along with the local agencies involved. We encourage you to read the report and consider its content and recommendations. It includes a thorough analysis of one productive approach to improving and organizing various land records to facilitate local land use decision-making and implementation of state programs.

We became involved with this project as an outgrowth of our responsibilities for and involvement in the planning and mapping activities of the Wisconsin Farmland Preservation Program. We were interested in supporting a demonstration project that would achieve the following objectives:

A. Provide a working model of a high quality automated process of preparing and updating zoning and related resource maps;

B. Provide an effective method of monitoring zoning changes toward a more effective, long-range farmland preservation program;

C. Implement a cooperative project that coordinates regional and county capabilities with a county/town zoning program; and

D. Demonstrate effective coordination of planning and zoning by use of an ongoing, automated process.

We feel this project meets these objectives. A project to improve the management and use of land information involves considerable technical skills and resources. We are pleased that this project demonstrates how the necessary skills and resources can be provided through the cooperation of the governmental units involved.

We hope that you will share our interest and enthusiasm in the project described in this report.

Sincerely,

James T. Flynn
LIEUTENANT GOVERNOR
Department of Development

LaVerne Ausman
Secretary
Department of Agriculture Trade and Consumer Protection

Art Ziegler
State Cartographer
University of Wisconsin-Madison

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Chapter I

INTRODUCTION

There is currently a growing interest in the United States in land data systems. This interest ranges from a relatively narrow concern about the need to modernize land title recordation systems to a relatively broad concern about the need to create entirely new land-related data banks for multipurpose application. This growing interest has involved many disciplines, ranging from surveyors, abstractors, assessors, and attorneys narrowly concerned with the fiscal and legal administration of real property to planners, engineers, public utility managers, public administrators, and elected officials broadly concerned with community development and resource management. Much of the interest has centered around the use of electronic computers for the storage, manipulation, and retrieval of the data and, more recently, the use of computer-assisted graphics collection and display hardware for the reproduction of the data in mapped as well as tabular form.

As interest in the area of land data systems has grown, the topic has become increasingly prominent as a subject of professional papers, reports, conferences, and the meeting programs of various professional organizations. This interest, and the increasing need for land-related information by all levels of government and by the private sector, induced the National Research Council to examine the issue. In 1979 that Council instituted a Panel on a Multipurpose Cadastre to review the status of cadastral activities at the federal, state, and local governmental levels and in the private sector and to review a number of demonstration projects that had been undertaken at various locations. In 1980 a report[1] was issued, the principal finding of which was that:

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

The report identified existing land-information systems and the multipurpose cadastre as representing a basis for a dynamic public process that effectively collects, maintains, and disseminates land-related information. It identified the land resource-related problems faced by public and private organizations and outlined the nature of a multipurpose cadastre that could help to remedy these problems. However, the report did not address how governments, especially local governments, could carry out the recommendations made in the report.

To address the questions left unanswered by its 1980 report, the National Research Council prepared a second report, which set forth a set of recommended procedures and standards for the design and implementation of a multipurpose cadastre.[2] It was the intent of this report to assist the local governments wishing to pursue the development of cadastral records systems for their own jurisdictions and also the many other regional, state, and federal agencies, as well as private businesses, whose participation will be needed for the development over time of true, multipurpose cadastres.

PURPOSE OF THIS REPORT

The project reported herein was carried out within the context of the increasing interest at the national, state, and local levels in the development of land-related information and automated mapping systems. The project was jointly conceived and developed by representatives of the Wisconsin Department of Development; Wisconsin Department of Agriculture, Trade and Consumer Protection; the State Cartographer's office; the Southeastern Wisconsin Regional Planning Commission; Kenosha County; and the Town of Randall. Funding for the project was provided by the Wisconsin Department of Development, Kenosha County, and the Southeastern Wisconsin Regional Planning Commission, with the major work ele-

[1] *National Research Council, Assembly of Mathematical and Physical Sciences, Committee on Geodesy, Panel on a Multipurpose Cadastre, Need for a Multipurpose Cadastre, National Academy Press, Washington, D. C., 1980, 112 p.*

[2] *National Research Council, Assembly of Mathematical and Physical Sciences, Committee on Geodesy, Panel on a Multipurpose Cadastre, Procedures and Standards for a Multipurpose Cadastre, National Academy Press, Washington, D. C., 1983, 173 p.*

ments being carried out by Kenosha County and the Southeastern Wisconsin Regional Planning Commission.

The state agencies are particularly interested in the project because of the continuing involvement of the Regional Planning Commission, Kenosha County, and the Town of Randall in the Wisconsin Farmland Preservation Program. With the assistance of the Regional Planning Commission, Kenosha County prepared and adopted a farmland preservation plan in 1982 and exclusive agricultural zoning in 1983. The Town of Randall subsequently adopted the County's exclusive agricultural zoning amendments. The long-term success of farmland preservation in Kenosha County will be dependent in large part on the effective and efficient administration and enforcement of the County's zoning ordinance. Such administration and enforcement of the ordinance requires current information from property, land use, natural resource, assessment, and zoning records. Developing and demonstrating a land information system that automates and integrates those records should contribute substantially to the success of exclusive agricultural zoning and farmland preservation in the Town of Randall, Kenosha County, and other Wisconsin counties and communities that can benefit from the experience gained in this project.

The project was intended to develop and demonstrate a limited land-related information and associated mapping system. This system was to provide a working model of a high-quality, automated procedure that could: 1) provide land-related data essential to the sound administration of comprehensive and special-purpose zoning ordinances; 2) provide an effective method of monitoring zoning changes; 3) promote the cooperation of regional, county, and local capabilities in carrying out comprehensive county/town zoning programs; 4) demonstrate the proper and effective relationship between planning and zoning; and 5) provide a basic system that could readily evolve into a countywide multipurpose, land-related information system. This evolution would proceed in two important ways: first, through the geographic extension of the limited system demonstrated to eventually encompass all of Kenosha County; and, second, through the addition of additional land-related information files. Such evolution would enable the system described herein to evolve, over time, into a true, multipurpose cadastre.

The automated mapping and land records project described in this report was developed by the staff of the Regional Planning Commission, using the procedural model recommended by the National Research Council Panel on a Multipurpose Cadastre, and was completed under the review and direction of a technical advisory committee established specifically for this project. The membership of this technical advisory committee is set forth in Appendix A.

Chapter II

COMPONENTS OF AN AUTOMATED MAPPING AND LAND INFORMATION SYSTEM

INTRODUCTION

This chapter describes the major elements of a multipurpose cadastre and discusses such a cadastre within the more general context of land information systems. Since it is generally assumed in the development of a multipurpose cadastre that the relevant land-related information will be transformed into a computer-readable format, this chapter also describes the process whereby land-related information stored in the form of maps and aerial photographs is converted into a form whereby it can be manipulated by computer. This process is commonly referred to as "digitization." Finally, the chapter describes the remonumenting and base mapping efforts previously carried out in the Region and in Kenosha County which provide the essential base for the establishment of an automated mapping and land information system. A glossary of some terms commonly encountered in automated mapping and land information systems is provided in Appendix B.

THE CADASTRE AS PART OF A LARGER SYSTEM OF LAND INFORMATION

A cadastre may be defined as a record of interests in land, encompassing both the nature and extent of these interests. Historically, cadastres have been created and maintained for the purpose of taxing these interests, and evidence of the existence of cadastres goes back through hundreds of years of human civilization. It is possible to develop an automated version of a cadastre defined in this more narrow, historical sense; and, in fact, the development of such single-purpose cadastres has been advanced on the premise that the development of more complex multipurpose cadastres and land information systems ought to begin with the development of single-purpose cadastres relating only to the value of real property as a basis for taxation and, perhaps, the registration of land ownership, being extended later in an evolutionary manner to other applications.

Thus, the development of a more narrowly defined cadastre can be considered as a preliminary step in the development of a broader land-related information system. Additional information can subsequently be incorporated into such a system: for example, on land use; certain natural characteristics of the land such as soil and geologic conditions; natural hazards such as flooding and shoreline erosion; and environmentally sensitive areas such as woodlands and wetlands, to name just a few. These broader land information systems are considered to contain, in addition to the information considered to be part of a single-purpose cadastre, all types of land-related information both cultural and natural.

The project reported herein is considered to be of a type intermediate between the extremes of a narrowly defined automated cadastre and the more broadly defined land information system. Increasingly, such intermediate systems are identified in the professional literature as "multipurpose cadastres." The focus of the system developed under this project is zoning administration; therefore, in addition to information about interests in land, both natural resource and cultural information essential to efficient and effective zoning administration are contained within the system. In this way, the project also demonstrates the wide variety of land information that can be successfully integrated into, and used within, such a system. The specific types of land-related data considered, and the means of integration of these data into the system, are discussed in Chapter III of this report.

ELEMENTS OF A MULTIPURPOSE CADASTRE

A multipurpose cadastre can be conceptualized as a public, operationally and administratively integrated, land-related information system which provides continuous, readily available, and comprehensive information at the ownership parcel level. The Panel on a Multipurpose Cadastre of the National Research Council has proposed the procedural model shown in Figure 1 for the development of multipurpose cadastres. This model consists of the following five basic elements: 1) a geographic reference frame consisting of a geodetic survey network; 2) a series of current, accurate, large-scale base maps properly related to the geographic reference frame; 3) a cadastral map overlay delineating all cadastral parcels which is also properly related to the geographic reference frame; 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 cross-referencing with information in other land data files. Additional elements in the form of maps and records of land-related information can be readily added to the base over time.

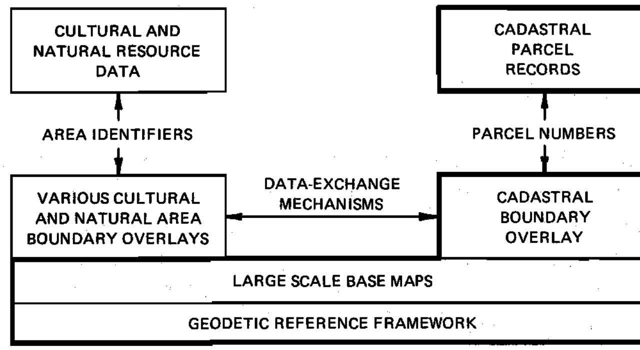
Geodetic Reference Framework
A reference frame, consisting of a system of survey monuments having geodetically based coordinates, is necessary for defining the relative spatial location of all land-related data, and as such comprises the first component of a multipurpose cadastre. Unfortunately, in the United States two different, and heretofore largely uncoordinated, systems of survey control have evolved. The first of these two systems, the State Plane Coordinate System, is founded in the science of measurement and is intended to be utilized as a basis for the collection of earth science data and the preparation of earth science maps, such as topographic, geologic, soils, and hydrographic maps. The second of these two systems—the U. S. Public Land Survey System—is founded in the principles of property law, as well as in the science of measurement, and is utilized for the collection of cadastral data and the preparation of cadastral maps, such as real property boundary line maps.

U. S. Public Land Survey System: For most of the United States, the federal government has provided the basic survey control system for cadastral mapping in the form of the U. S. Public Land Survey System. Under regulations imposed by Congress, the U. S. Public Land Survey System has been extended into 30 of the 50 states, including Wisconsin.

This system is founded in the best features of the English common law of boundaries, superimposing on that body of law systematic land survey procedures under which the original public domain is surveyed, monumented, and platted before patents are issued; legal descriptions are by reference to a plat; lines actually run and marked on the ground control boundaries; adjoiners are respected; and the body of law in effect at the time of the issuing of the deed is controlling, and forever a part of, the deed. Unlike scientific surveys, which are made for the collection of information and can be amended to meet improved standards or changing conditions, the original government land survey in an area cannot be legally ignored, repudiated, altered, or corrected as long as it controls rights vested in lands affected.

Figure 1

COMPONENTS OF A MULTIPURPOSE CADASTRE



The basic elements of a multipurpose cadastre (in heavy outline) provide a ready framework for the incorporation of additional land related information in the form of maps and records.

Source: National Research Council and SEWRPC.

The U. S. Public Land Survey System is one of the finest systems ever devised for describing and marking land. It provides a basis for a clear, unambiguous title to land, together with the physical means by which that title can be related to the land it describes. The system is ingenious, being simple and easy to comprehend and administer; and without it, the nation would unquestionably have been poorer. The "rectangular" land survey system, however, has one serious flaw. Its use requires the perpetuation of monuments set by the original government surveyors, the positions of which are not precisely related to the surface of the earth through a scientifically established map projection.

State Plane Coordinate System: A strictly scientific survey control system designed to provide the basic control for all federal—and most private—topographic and other earth science mapping operations exists separately from the U. S. Public Land Survey System in the triangulation and traverse stations established by the National Geodetic Survey (formerly U. S. Coast and Geodetic Survey). The triangulation and traverse stations established by this agency comprise a nationwide network connecting thousands of monumented points whose geodetic positions, expressed in terms of latitude and longitude, are known. In order to make the National Geodetic Survey control network more readily available for local use, the U. S. Coast and Geodetic Survey devised the State Plane Coordinate System in 1933. This system transforms the spherical coordinates—latitudes and longitudes—of the stations established in the National Geodetic Survey into rectangular coordinates—eastings and northings—on a plane surface. This plane surface is mathematically related to the spheroid on which the spherical coordinates of latitude and longitude have been determined. The mutual relationship, which makes it practicable to pass with mathematical precision from a spherical to a plane coordinate system, makes it also practicable to utilize the precise scientific data of the National Geodetic Survey control network for the reference and control of local surveying and mapping operations. A limitation on such uses, however, is imposed by the relatively wide-spaced location of the basic triangulation and traverse stations and the difficulties often encountered in the recovery and use of these stations.

Large-Scale Base Maps

To satisfy the growing need for an integrated land-related information base, a system capable of handling a variety of information, ranging from such earth science-related data as flood hazard boundary line locations to such cadastral-related data as real property boundary line locations, is required. It is also mandatory that field work, data resolution, and information presentation be consistent with the most detailed level of land-related decision-making, that of the individual proprietary parcel. These requirements call for base maps at scales significantly larger than generally available in the United States as the second component of a multipurpose cadastre.

Cadastral Overlay

The third component of a multipurpose cadastre is the cadastral overlay. Preparation of the cadastral overlay requires identifying and delineating the most fundamental unit of land—a cadastral parcel. This unit of land becomes the basic building block for maintaining real property boundary line information, including information on rights and interests. A cadastral parcel is, therefore, an unambiguously and uniquely defined unit of land within which rights and interests are legally recognized and for which there is a unique and complete group of rights. 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.

Parcel Number

The fourth component of a multipurpose cadastre is the parcel identifier, defined as a code for recognizing, selecting, identifying, and arranging information to facilitate storage and retrieval of parcel records. It may also be used for spatial referencing of information and as a means of referring to a particular parcel in lieu of a full legal description. There is general agreement that the identifier system used should provide for the assignment of a unique code to each parcel, should be easily understandable and usable to the general public—or at least to that segment of the public that may have cause to use the system, should be capable of serving a variety of different uses, and should be reasonably permanent.

Land Information Files

The fifth and last component of a multipurpose cadastre consists of the land information files, or land data files, which contain facts about the land parcel in question and are related to the cadastral map through the parcel identifier. The various types of information that may be compiled about the land are potentially voluminous, and may include both natural and cultural—man-made—features of the parcel. Perhaps the most familiar land information files are those of local land-title records systems and tax assessment and collection records systems.

CONVERSION OF GRAPHIC DATA INTO A COMPUTER-COMPATIBLE FORMAT

Much of the current interest in the modernization of land data systems has been centered on the use of electronic computers for the storage, manipulation, and retrieval of the data and, more recently, the use of computer-assisted graphic collection and display hardware for the reproduction of the data in mapped as well as tabular form. Nongraphic land information—parcel identification numbers, legal descriptions, and assessment information, for example—can be entered into a computer through standard "key punch" data entry procedures. Land information that has traditionally been maintained in the form of maps—such as real property boundary lines—however, must be converted into a numeric, or digital, format before it can be entered into a computer. This is most often accomplished by a device, sometimes itself computer controlled, called a "digitizer."

A digitizer, therefore, is a machine system which transforms mapped information into a computer-readable form to facilitate information manipulation and display. A digitizer is usually comprised of the following hardware components:

1. A controller, which is often a small to medium-size computer.

2. An on-line data storage device.

3. An operator work station which consists of a keyboard for entering commands and non-graphic data into the system and a graphic display screen or screens for viewing collected information.

4. A digitizing board or tablet which allows the accurate relative location of a point identified on the surface of the board to be determined using a device—a cursor—which is able to move freely over the surface of the board.

Additional equipment may include a printer and computer tape unit. Each component can vary greatly in size and capability depending on requirements of the particular system. The technical specifications of the system used for the project described in this report are contained in Appendix C.

The transformation of mapped information into computer-readable information requires maps which are related to some system of geometric control and which have at least two points for which an x-y coordinate pair can be determined. The coordinate system utilized can vary from an arbitrary scale unique to the base map to some more universal system such as the State Plane Coordinate System. Once the base map has been placed on the digitizer board, the coordinates of the known map points are entered into the digitizer and located on the base map with the cursor. When this operation is complete the map is said to be "scaled," and positions of other points on the map can be established based upon their relative positions to the known points.

Each line on the map is defined as a series of connected points. The cursor is used to identify each point, which is then assigned an x-y coordinate pair based on the position of the point relative to the known base points used to scale the maps. Each map line is then stored in the system as a series of x-y coordinates. Each line or segment can be stored separately or combined with other segments to form closed polygons with defined attributes and measurable areas. Base map accuracy is an important consideration when digitizing. A digitizing system does not improve the accuracy of a base map but only replicates the map features, including errors and discrepancies.

Once the initial map data are transformed into digital form with the digitizer, a variety of manipulations become possible. Data mapped at one scale can be reproduced at different scales, provided that the accuracy limitations of the original maps are recognized in any enlargement, as opposed to reduction, in scale. Graphic base files collected from different sources can be merged and reproduced at a uniform scale. Data for special study areas can be identified, reproduced, and measured. Information on the base maps can be identified in such a manner that only selected portions of that information are reproduced at a time.

EXISTING FRAMEWORK FOR THE DEVELOPMENT OF MULTIPURPOSE CADASTRES WITHIN SOUTHEASTERN WISCONSIN

It should be noted that the first three elements of the procedural model for the creation of a multipurpose cadastre as proposed by the National Research Council have long been embodied in the Regional Planning Commission's recommended large-scale base mapping program. Recognizing the importance of good large-scale maps and attendant survey control to sound community development and redevelopment, the Commission has, for over two decades, encouraged the preparation of large-scale topographic and cadastral maps within its 2,689-square-mile planning region. These maps are based on a unique system of survey control that combines the best features of the U. S. Public Land Survey System and State Plane Coordinate System. The large-scale maps and attendant survey control system, where they already exist, provide in a highly cost-effective manner the technical foundation for the creation of multipurpose cadastres within the Region. Because of their critical and central importance to the implementation of a multipurpose cadastre, these three elements—the geodetic reference frame, large-scale base maps, and the cadastral overlays—are discussed in greater detail in the following sections.

A Composite System for the Geodetic Reference Framework

From the preceding brief discussion of the U. S. Public Land Survey and State Plane Coordinate Systems, it is apparent that two essentially unrelated survey control systems have been established in the United States by the federal government. One of these—the U. S. Public Land Survey System—is founded in the legal principles of real property description and location and was designed primarily to provide a basis for the accurate location and conveyance of ownership rights in land. The other—the State Plane Coordinate System—is founded in the science of geodesy and was designed primarily to provide a basis for earth science mapping operations and for the conduct of high-precision scientific and engineering surveys over large areas of the earth's surface. Both systems have severe inherent limitations for use as a geographic framework for a local land data system. By combining these two separate survey systems into one integrated system, however, an ideal system for the geometric control required for land data systems is created.[1] This ideal system includes the relocation and monumentation of all U. S. Public Land Survey section and quarter-section corners, including the centers of sections, within the geographic area for which the land data system is to be created and the utilization of these corners as stations in second-order traverse and level nets, both nets being tied to the National Geodetic Datum. The traverse net establishes the precise geographic positions of the U. S. Public Land Survey corners in the form of state plane coordinates, while the level net establishes the precise elevation above mean sea level of the monuments marking the corners.

Such a system of survey control has at least the following three advantages as a geographic framework for a multipurpose cadastre:

1. It provides an accurate system of control for the collection and coordination of cadastral data since the boundaries of the original government land subdivision form the basis for all subsequent property divisions and boundaries. As all subsequent legal descriptions and plats must be tied to the U. S. Public Land Survey System, accurate reestablishment and monumentation of the quarter-section lines and corners permits the ready compilation of accurate property boundary line data and the ready maintenance of these data in current form over time. These data can be readily and accurately updated and extended since, in Wisconsin, all new land subdivisions must by law be tied to corners established in the U. S. Public Land Survey and since the accuracy of the surveys for these subdivisions can be readily controlled by state and local land subdivision regulations. The recommended survey control system thus fully meets the needs of a narrowly defined cadastre for the fiscal and legal administration of real property, yet this cadastre can be developed readily and soundly into a multipurpose land data system.

2. It provides a common system of control for the collection and mapping of both cadastral and earth science data. By relocating the U. S. Public Land Survey corners and accurately placing them on the State Plane Coordinate System, it becomes possible to accurately correlate real property boundary line information with earth science data. This placement of property boundary and earth science data on a common datum is absolutely essential to the sound development of any multipurpose land data system. Yet, such a common control datum is rarely used. The establishment of state plane coordinates for the U. S. Public Land Survey corners permits the correlation with mathematical precision of data supplied by aerial and other forms of earth science mapping with property boundary line data compiled through the usual land surveying methods. Only through such a common geometric control system can all of the information required for a multipurpose land data system be accurately collected for, and correlated in, the system.

3. It permits lines and areas entered into the data base to be accurately and precisely reproduced upon the ground—whether these lines represent the limits of land to be reserved for future public use, the limits of land to be taken for immediate public use, the limits of districts to which public regulations are to be applied, or the location and alignment of proposed new property boundary lines or of proposed constructed works.

The specific geometric framework described herein is applicable only to those parts of the United States covered by the U. S. Public Land Survey System. The fundamental concept involved—that is, the need to place both cadastral and earth science data on a common geometric base—is, however, applicable to any area. In those portions of the United States that have not been covered by the U. S. Public Land Survey System, the application of this concept may well be more difficult and costly, requiring the incremental placement of the corners of the individual real

[1] *See K. W. Bauer, "Geometric Framework for Land Data Systems," Journal of the Surveying and Mapping Division, Proceedings of the American Society of Civil Engineers, Volume 107, Number SU1, November 1981.*

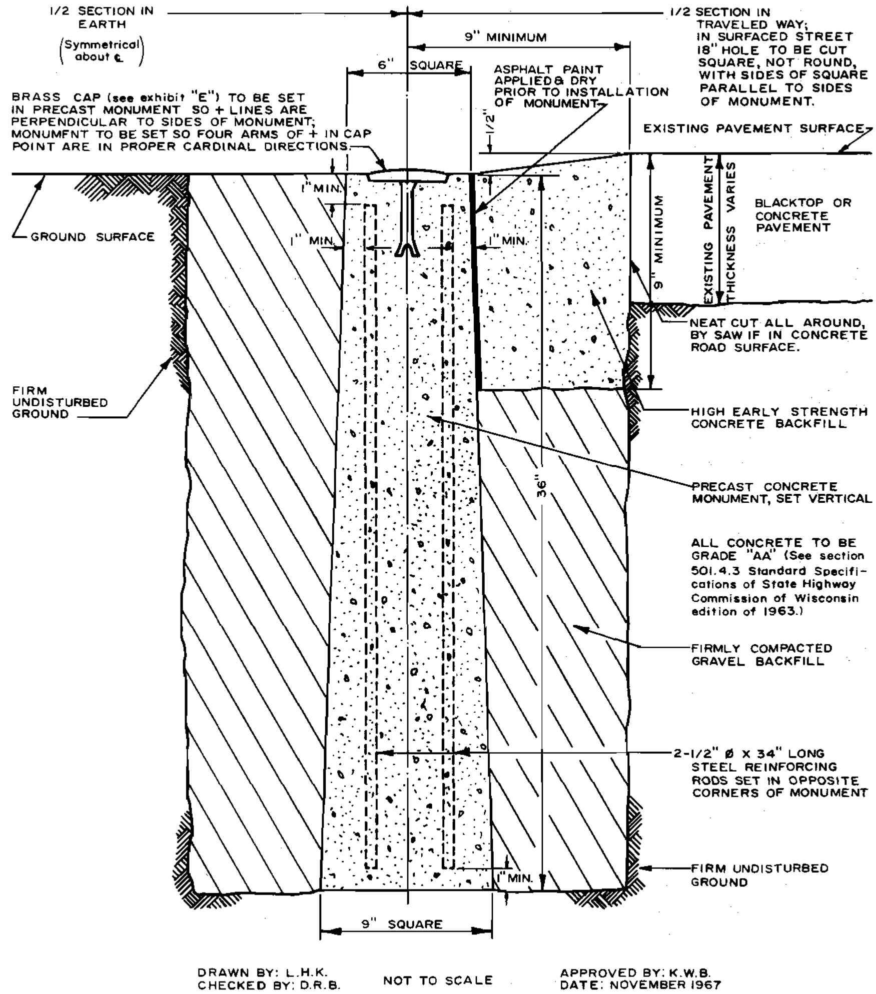
property boundaries on the State Plane Coordinate System, but is just as essential if a comprehensive land data system is to be created over time.

Commission Specifications for Geometric Framework and Base Maps

As already noted, the Regional Planning Commission has, since 1961, promoted the preparation of large-scale topographic and cadastral base maps based upon a survey control system which combines the U. S. Public Land Survey and State Plane Coordinate Systems. The maps and attendant control survey system, in addition to providing essential municipal planning and engineering tools, were intended to provide the foundation for the eventual development of automated, multipurpose cadastres within the Planning Region. Since the Commission-specified base maps and survey control system provide two of the basic elements of the cadastre developed under this project for the Town of Randall, a description of those specifications herein is warranted.

Figure 2

DETAIL OF MONUMENT INSTALLATION FOR SURVEY CONTROL STATIONS



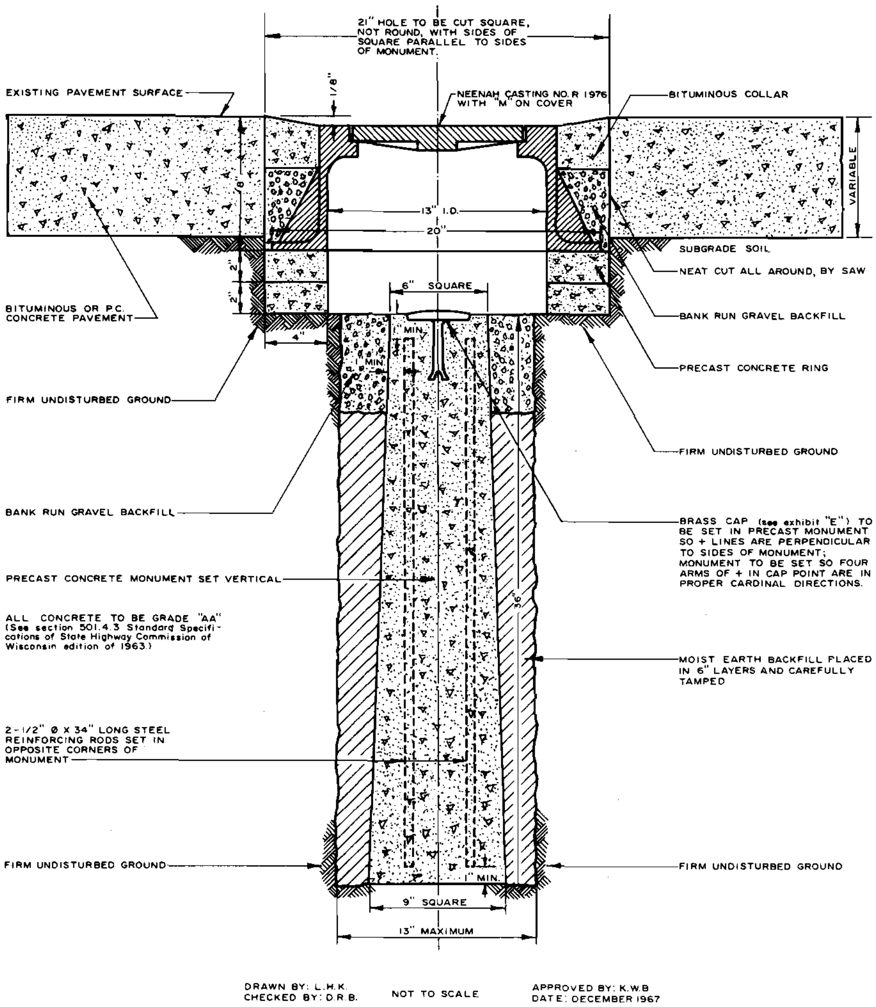
Source: SEWRPC.

Specifications for Relocation, Monumentation, and Coordination of U. S. Public Land Survey Corners: The Commission specifications governing the creation of the necessary survey control network require the relocation of all U. S. Public Land Survey corners in the areas to be mapped, and the marking of the relocated corners by reinforced concrete monuments having engraved bronze caps imbedded in the tops (see Figures 2 and 3). The bronze caps are stamped with the corner notation—quarter section, town, and range. The monuments placed are referenced by ties to at least four witness marks. The specifications require that the survey engineer provide a dossier on each control station established in order to permit its ready recovery and use. The dossier sheets provide for each station a sketch showing the monument erected in relation to the salient features of the immediate vicinity, all witness monuments together with ties, the state plane coordinates of the corner, its U. S. Public Land Survey description, the elevation of the monument, and the location of appurtenant reference benchmarks referred to National Geodetic Vertical Datum of 1929 (see Figure 4). These dossier sheets are recorded with the County Surveyor as well as with the Commission, and are thereby readily available to all land surveyors and engineers operating in the area mapped.

The specifications require the control survey data to be summarized by means of a control survey summary diagram showing the exact grid and ground lengths and grid bearings of the exterior

Figure 3

DETAIL OF ALTERNATIVE CONTROL SURVEY MONUMENT INSTALLATION IN SURFACE TRAVELED WAY OF STREETS AND HIGHWAYS



Source: SEWRPC.

boundaries of each U. S. Public Land Survey quarter section; the area of each quarter section; all monuments erected; the number of degrees, minutes, and seconds in the interior angles of each quarter section; the state plane coordinates of all quarter-section corners, together with their Public Land Survey System identification; the benchmark elevations of all monuments set; and the basic National Geodetic Survey control stations utilized to tie the Public Land Survey corners to the horizontal geodetic control datum, together with the coordinates of these stations. The angle between geodetic and grid bearing is noted, as is the combination sea-level and scale-reduction factor (see Figure 5).

All the work necessary to execute the control surveys and provide the finished topographic maps described below has been done in southeastern Wisconsin on a negotiated contract basis with an experienced photogrammetric and control survey engineer. In this regard, it was considered essential to retain a photogrammetric and control survey engineer familiar with higher order field methods and procedures and with the attendant geodetic survey computations and adjustments, and whose crews were properly equipped with state-of-the-art survey instruments. Electronic distance — measuring equipment was employed in the work, as well as optically reading theodolites and appurtenant traverse equipment, automatic levels, and precision level rods. Indeed, the control survey system used is made economically feasible only through the application of these relatively recently developed instruments, particularly the electronic distance-measuring devices. It should be further noted that emerging technologies and techniques—such as the use of satellites in earth orbits to establish ground survey station locations—offer the prospect of continued reductions in the cost of establishing suitable geodetic reference frameworks for multipurpose cadastres.

Although the specifications governing the work make the photogrammetric engineer responsible for overall supervision and control of the mapping work, as well as for the quality of the finished maps, they require that the actual relocation of the Public Land Survey corners be done by a local land surveyor—the County Surveyor in the case of Kenosha County—employed as a subcontractor by the photogrammetric engineer or as a contractor by the Commission directly. The specifications thereby recognize that this portion of the work requires expert knowledge of local survey custom and boundary and title law, as well as the assembly and careful analysis of all authoritative survey information—such as title documents and attendant legal descriptions, land subdivision plats and certified survey maps, survey records, and, of cardinal importance, records on existing land survey monumentation and land occupation—in order to arrive at the best possible determination of the location of the land survey corners. In the areas mapped, the land survey portion of the control survey work requires a very high degree of professional competence, as almost all of the Public Land Survey corners fall under the federal definition of either obliterated or lost corners. The importance of this phase of the work and its impact on real property boundaries throughout the community can hardly be overemphasized.

Figure 4

A TYPICAL U. S. PUBLIC LAND SURVEY CONTROL STATION DOSSIER SHEET

RECORD OF U.S. PUBLIC LAND SURVEY CONTROL STATION

U.S. PUBLIC LAND SURVEY CORNER 24|19 / 24|19 T 1 N, R 18/19 E, KENOSHA COUNTY, WIS.

GEODETIC SURVEY BY: AERO-METRIC ENGINEERING, INC. YEAR: 1980

STATE PLANE COORDINATES OF: QUARTER SECTION CORNER

NORTH 198,197.35

EAST 2,456,906.93

ELEVATION OF STATION: 830.066

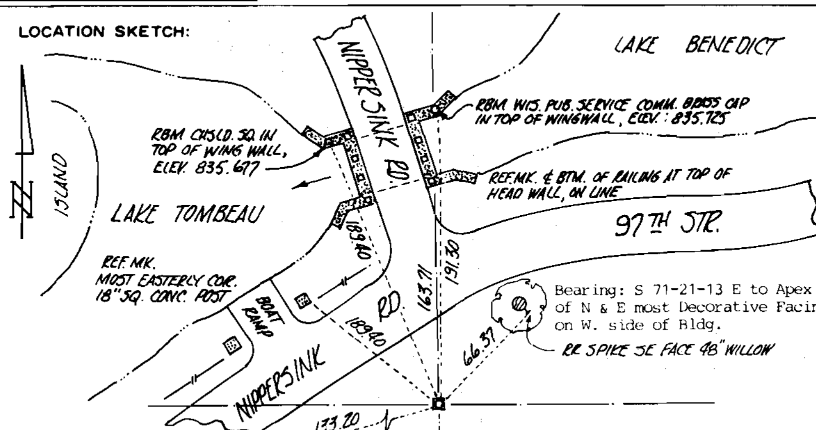
HORIZONTAL DATUM: WISCONSIN STATE PLANE COORDINATE SYSTEM, SOUTH ZONE

VERTICAL DATUM: NATIONAL GEODETIC VERTICAL DATUM OF 1929

CONTROL ACCURACY: THETA ANGLE: +1-09-53

HORIZONTAL: THIRD ORDER, CLASS I VERTICAL: SECOND ORDER, CLASS II

LOCATION SKETCH:



SURVEYOR'S AFFIDAVIT

STATE OF WISCONSIN) SS
WAUKESHA COUNTY)

I HEREBY CERTIFY THAT I found a concrete monument with brass cap as set by William A. Marescalco, S-826, in January, 1980 to replace a 3/4 inch diameter iron pipe as set by J.F.Degen, S-242, to mark this corner, and that I referenced the same as shown hereon.

DATE OF SURVEY: October 24, 1985 Kurt W. Bauer S-157
REGISTERED LAND SURVEYOR

WISCONSIN K. W. BAUER MILWAUKEE, WIS. LAND SURVEYOR

FORM PREPARED BY SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

Source: SEWRPC.

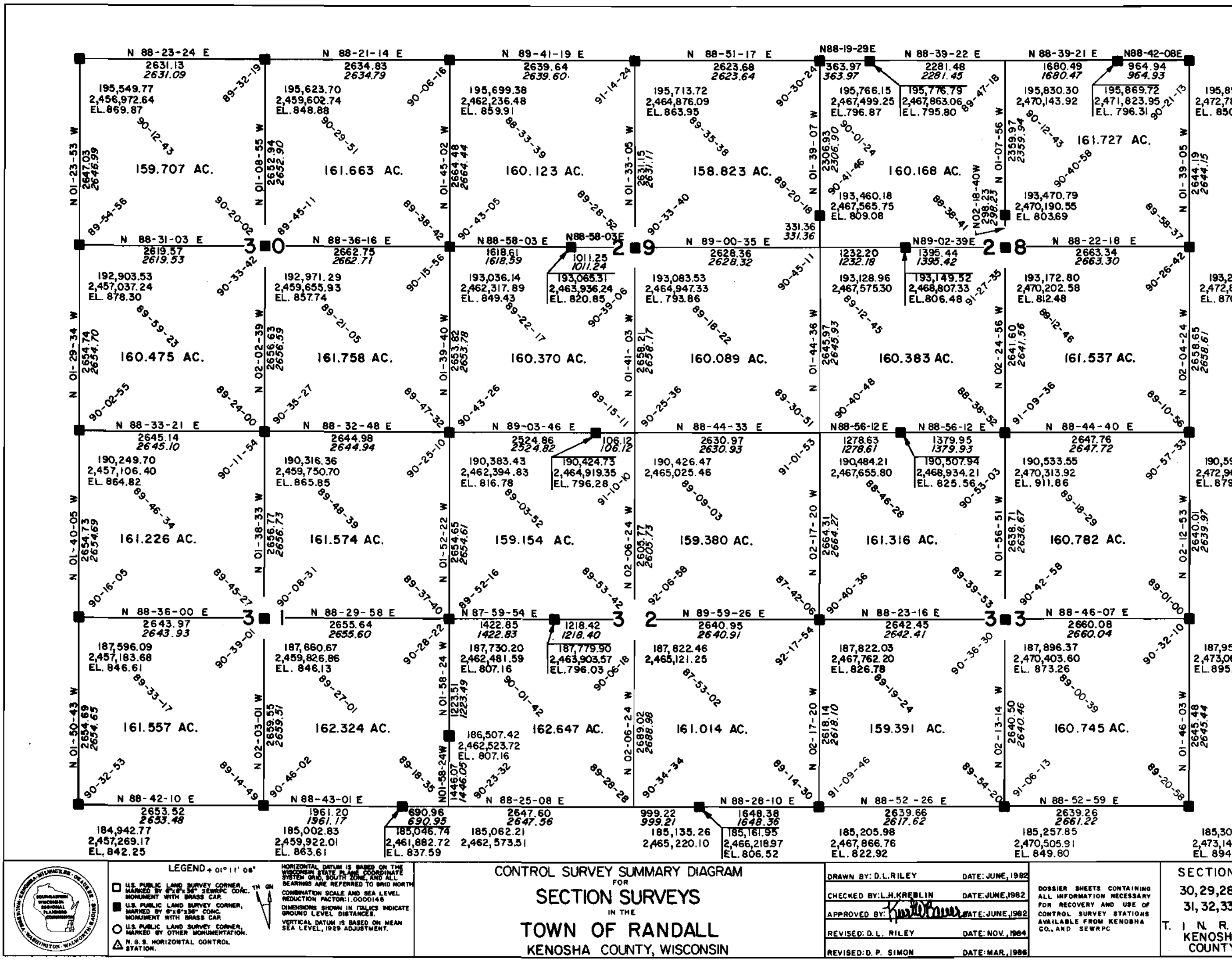
Specifications for Topographic Mapping: The specifications provide for the completion of finished topographic maps that can serve as the base maps for the preparation of a multipurpose cadastre by accurately recording the basic geography of the area mapped. In addition to showing the usual contour information, spot elevations, planimetric and hydrographic detail, and coordinate grid ticks, the maps show, in their correct position and orientation, all U. S. Public Land Survey quarter-section lines and corners established in the control surveys (see Figure 6). The specifications require that the maps be prepared to National Map Accuracy Standards. Thus, all state plane coordinate grid lines and tick marks and all horizontal survey control stations must be plotted to within 1/100 inch of the true position as expressed by the coordinates for the control survey stations, and 90 percent of all well-defined planimetric features must be plotted to within 1/30 inch of their true positions, and no such features may be off by more than 1/20 inch. Ninety percent of the elevations indicated by the solid-line contours must be within one-half contour interval of the true elevation, and no such elevation may be off by more than one contour interval. A combination sea-level and scale-reduction factor and the angle between geodetic and grid bearing are noted on each map sheet, as is the equation between any local datum and mean sea level.

Specifications for Cadastral Mapping: The Commission's specifications visualize the preparation of real property boundary line maps, complementing the topographic maps, by the respective local units of government concerned, utilizing resident engineering and planning staffs or consultants. The property boundary line maps are compiled at a scale matching that of the topographic maps, each map sheet covering, like the topographic maps, a U. S. Public Land Survey section or quarter section.

As the topographic maps are being compiled, the Commission specifications require that the photo-

Figure 5

A TYPICAL CONTROL SURVEY SUMMARY DIAGRAM



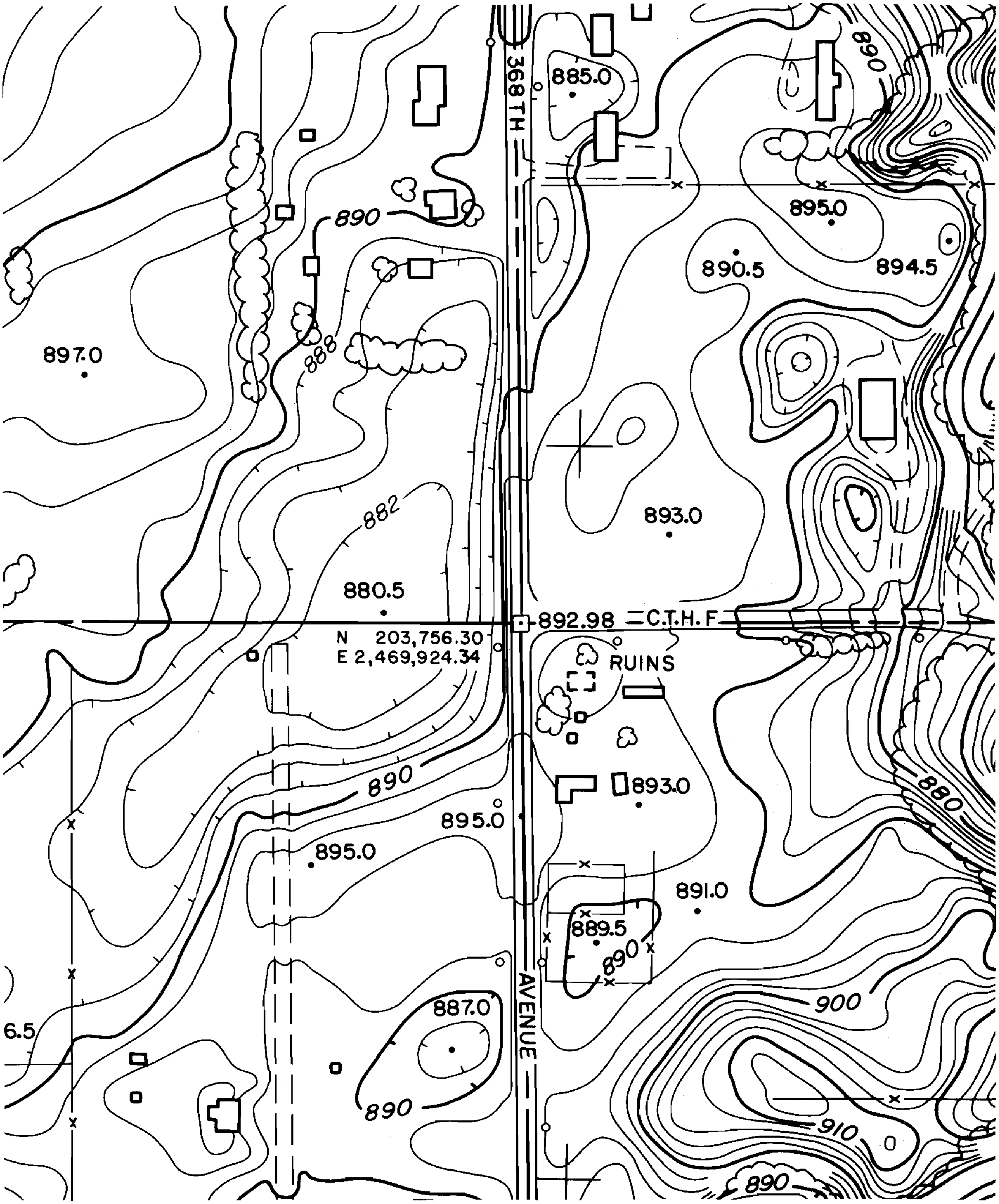
Source: SEWRPC.

grammetric engineer provide cadastral base sheets. These sheets consist of reproducible duplicates of the partially completed topographic maps showing, in addition to the state plane coordinate grid, the U. S. Public Land Survey section and quarter-section lines and corners in their correct position and orientation, together with the attendant ground lengths and grid bearings, and such salient planimetric detail and hydrographic features as may be helpful in the subsequent plotting of real property boundary lines, including railway tracks, electric power transmission lines, principal structures, wetlands, and such hydrographic features as streams and lakes.

Utilizing recorded subdivision plats, certified survey maps, and legal descriptions, all real property boundary lines, including street right-of-way lines and major utility easement lines, are then constructed on the base sheets working within the framework of control provided by the ground lengths and grid bearings of the U. S. Public Land Survey quarter-section lines. The property boundary lines are constructed in a manner that parallels the location of such lines on the surface of the earth, following land surveying practice in the State of Wisconsin. The specifications require that all real property boundary lines be plotted within 1/30 inch of their true position based on analysis

Figure 6

A PORTION OF A TYPICAL LARGE-SCALE TOPOGRAPHIC MAP PREPARED
IN ACCORDANCE WITH THE COMMISSION'S RECOMMENDED SPECIFICATIONS



Shown here at drafted scale (1 inch equals 200 feet) is a portion of the topographic map prepared for Section 16 in the Town of Randall, Kenosha County. The figure is roughly centered on the center of the section and encompasses an area of approximately 50 acres, or about 8 percent of the area covered by the full map. A cadastral map of the same area is shown in Figure 7.

Source: SEWRPC.

of all authoritative information available. Dimensions are shown for all platted areas as shown on the recorded subdivision plats. Wisconsin Statutes have long required that such plats be prepared to an accuracy of 1 part in 3,000, as compared to an accuracy of 1 part in 10,000 required by the specifications for the basic survey control network. Any overlaps or gaps between adjoining property boundary lines, as indicated by the constructions and plotting of those lines, are noted on the cadastral maps. Finally, a cadastral parcel identification number is added.

The property boundary line maps thus show the ground length and grid bearing of all quarter-section lines; the state plane coordinates of all quarter-section corners; the monuments marking these corners; the recorded dimensions of all street lines, alley lines, and boundaries of public property; recorded street widths; platted lot dimensions; and a parcel identification number. In unplatted areas real property boundaries are shown by scale alone. Railway tracks, electric power transmission lines, principal structures, fences, wetlands, lakes, streams, and drainage ditches are also shown (see Figure 7). As previously noted, these boundary line maps can be readily and accurately updated and extended as new land subdivision plats and certified map surveys—utilizing the survey control—are made and recorded.

It should be noted that the finished cadastral maps, as prepared under this project, reflect a theoretical inconsistency. This theoretical inconsistency is the result of showing on the face of the cadastral maps both state plane coordinate sea level grid distances and ground level distances. The finished cadastral maps show state plane coordinate values for the U. S. Public Land Survey corners, together with the sea level grid distances between the corners, consistent with good survey engineering practice. The cadastral maps, however, also show dimensions of real property boundaries, which are, in fact, ground level distances, thus reflecting traditional land surveying practice. In order to calculate precisely the state plane coordinates of individual property boundary corners from the mapped data, it would be necessary to reduce the ground level property boundary distances shown to sea level grid distances using the combination scale and sea level reduction factor given in the title box on each map sheet. In order to emphasize this inconsistency, the ground level distances between the U. S. Public Land Survey corners are also given on the maps along with the sea level grid distances.

As a practical matter, however, this inconsistency may be ignored when utilizing the topographic and cadastral maps graphically; and this inconsistency was accordingly ignored in converting the maps to digital form. This practical expedient is possible because the differences between sea level grid and ground level distances in Kenosha County range from a maximum of 0.08 foot in 2,640 feet along the south County line, through zero along an irregular line through central Kenosha County, to a maximum of 0.07 foot in 2,640 feet along the north County line. Thus, the differences in the sea level grid and ground level distances will range from zero to a maximum of 0.08 foot in 2,640 feet—the approximate length of the U. S. Public Land Survey one-quarter section lines—and from zero to a maximum of less than 0.01 foot per 100 feet within Kenosha County.

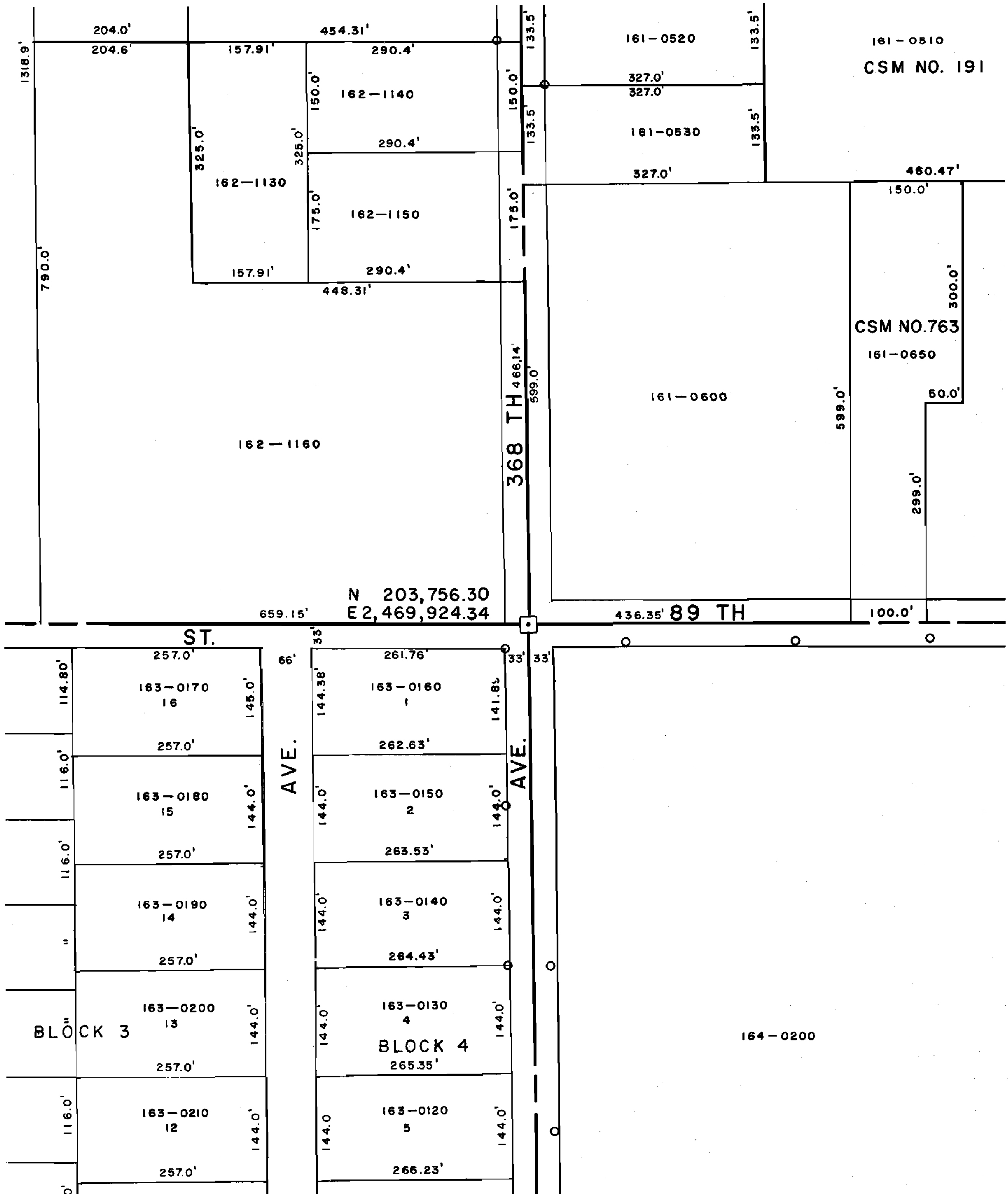
Indeed, within the entire Southeastern Wisconsin Region, these differences range from zero to a maximum of 0.32 foot in 2,640 feet, and from zero to a maximum of 0.01 foot per 100 feet. These differences are small enough to be ignored in the graphic displays and related digitization. It should be noted, however, that precise, theoretically correct, state plane coordinate positions can be readily computed for real property boundary corners from the mapped data should this level of precision be required.

The Kenosha County Remonumentation and Large-Scale Base Mapping Program

As previously noted, the Commission has long recognized the importance of good large-scale maps to the proper administration of local government functions, and has encouraged counties, cities, and villages within the Region to prepare such maps. Accordingly, in 1980 Kenosha County undertook a program which will eventually result in the completion of large-scale topographic maps and the attendant relocation, monumentation, and coordination of all of the U. S. Public Land Survey corners within the County. The County Board assigned the responsibility for the preparation of the necessary contract documents and specifications and for the supervision of the work to the Executive Director of the Regional Planning Commission, a responsibility which includes the field inspection of the completed control survey monumentation and the quality control of the land and control survey work, as well as assistance in obtaining available state grants in partial support of the work. Accordingly, all of the control survey work and attendant mapping in Kenosha

Figure 7

A PORTION OF A TYPICAL CADASTRAL MAP PREPARED IN ACCORDANCE WITH THE COMMISSION'S RECOMMENDED SPECIFICATIONS

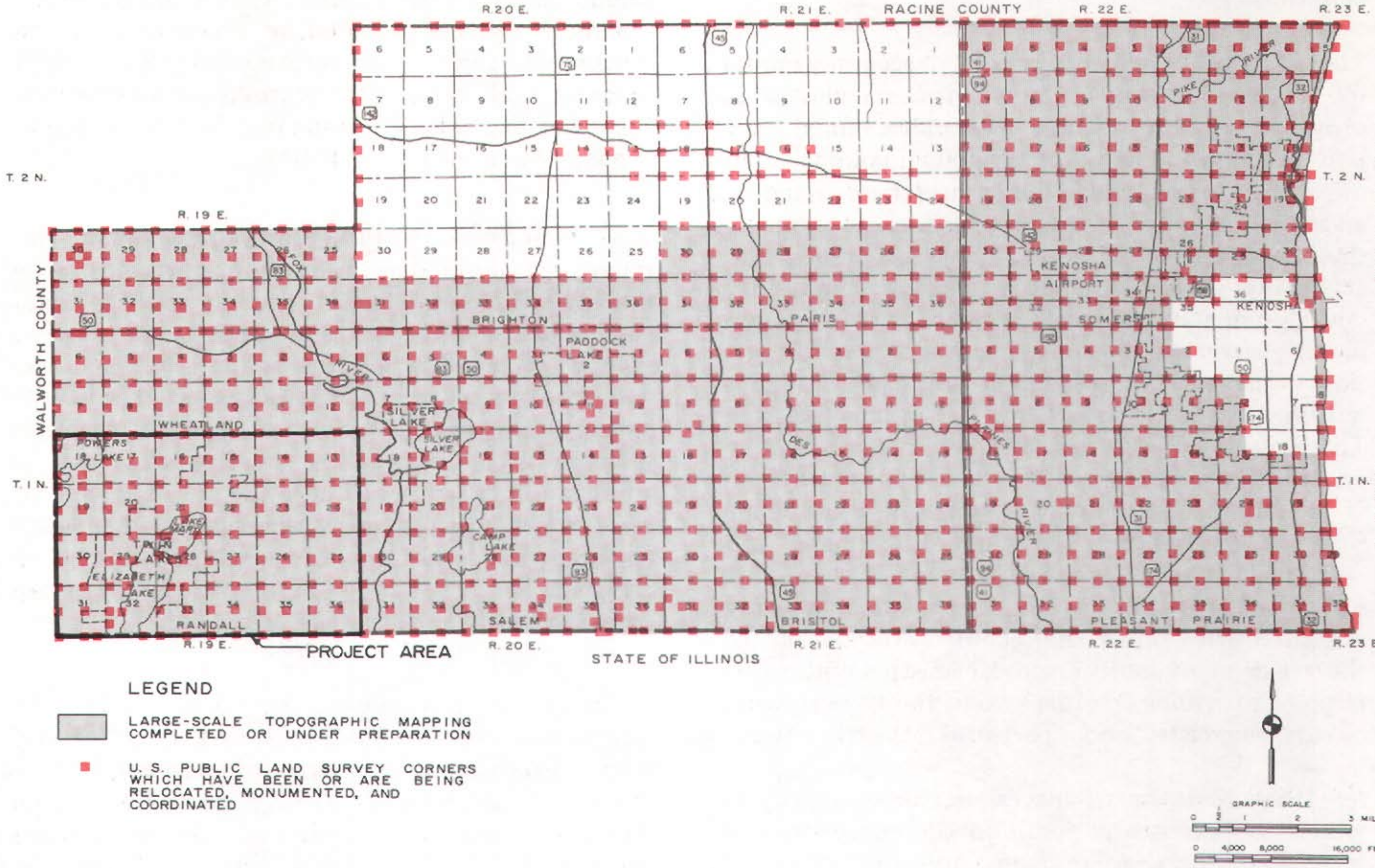


Shown here at drafted scale (1 inch equals 200 feet) is a portion of the cadastral map prepared for Section 16 in the Town of Randall, Kenosha County. The figure is roughly centered on the center of the section and encompasses an area of approximately 50 acres, or about 8 percent of the area covered by the full map. A topographic map of the same area is shown in Figure 6.

Source: SEWRPC.

Map 1

STATUS OF LARGE-SCALE TOPOGRAPHIC MAPPING AND THE RELOCATION, MONUMENTATION, AND COORDINATION OF U. S. PUBLIC LAND SURVEY CORNERS IN KENOSHA COUNTY: DECEMBER 1984



Source: SEWRPC.

County have been carried out in accordance with a standard set of specifications developed by the Commission. These specifications call for the preparation of photogrammetrically compiled topographic maps that meet National Map Accuracy Standards at a scale of 1:2400, with a vertical contour interval of two feet, the maps being based on the previously described survey control system. To date, this survey control area mapping system has been extended into approximately 215 square miles, or approximately 77 percent, of Kenosha County, including the Town of Randall area; and a total of 1,015 U. S. Public Land Survey corners have been relocated, monumented, and coordinated, representing over 84 percent of such corners in the County (see Map 1).

SUMMARY

A multipurpose cadastre can be conceptualized as a public, operationally and administratively integrated land information system which provides for continuous, readily available, and comprehensive land-related information at the parcel level. The National Research Council has proposed that multipurpose cadastres consist of the following five elements: 1) a geographic reference frame consisting of a geodetic network; 2) a series of current, accurate, large-scale topographic base maps properly related to the geographic reference frame; 3) a cadastral map overlay delineating all cadastral parcels, which is also properly related to the geographic reference frame; 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 cross-referencing with information in other land data files.

The first three elements of the procedural model for the creation of a multipurpose cadastre as proposed by the National Research Council have long been embodied in the Regional Planning Commission's recommended large-scale base mapping and attendant survey control program. Recognizing the importance of good large-scale maps and attendant survey control to sound community development and redevelopment, the Commission has for over two decades encouraged the preparation of large-scale topographic and cadastral maps within its 2,689-square-mile Planning Region. These maps are based on a unique system of survey control that combines the best features of the U. S. Public Land Survey System and State Plane Coordinate System. The large-scale maps and attendant survey control system, where they already exist within the Region, provide in a highly cost-effective manner the technical foundation for the creation of multipurpose cadastres within the Region, providing the first two of the five elements of such a cadastre, and a part of the third element.

In 1980 Kenosha County undertook a program which will eventually result in the completion of large-scale topographic maps and the attendant relocation, monumentation and coordination of all of the U. S. Public Land Survey corners within the County to Regional Planning Commission-recommended standards. The County Board assigned the responsibility for the preparation of the necessary contract documents and specifications and for the supervision of the work to the Executive Director of the Regional Planning Commission, a responsibility which includes the field inspection of the completed control survey monumentation and the quality control of the land and control survey work and of the finished topographic maps. To date, this survey control and mapping system has been extended into approximately 215 square miles, or approximately 77 percent, of Kenosha County, including the Town of Randall area; and a total of 1,015 U. S. Public Land Survey corners have been relocated, monumented, and coordinated, representing over 84 percent of such corners in the County. The county mapping and control survey program thus provided the basis for the development of a multipurpose cadastre for the Town of Randall.

The demonstration project reported herein has thus been developed utilizing a portion of the County's already existing survey control and large-scale mapping effort. The demonstration system is of a type intermediate between the extremes of a narrowly defined automated cadastre and a more broadly defined land information system. The focus of the developed system is zoning administration; therefore, in addition to information about interests in land, both natural resource and cultural information essential to efficient and effective zoning administration are contained within the system.

Much of the information incorporated into the system has traditionally been stored in the form of maps. Conversion of map information into a digital, or numeric, format where it can be manipulated and operated upon by a computer requires the use of a device called a "digitizer." Once the initial map data are transformed into numeric form with the digitizer, a variety of manipulations become possible. Data mapped at one scale can be reproduced at different scales, provided that the accuracy limitations of the original maps are recognized in any enlargement, as opposed to reduction, in scale. Graphic base files collected from different sources can be merged and reproduced at a uniform scale. Data for special study areas can be identified, reproduced, and measured. Information on base maps can be identified in such a manner that only selected portions of that information are reproduced at a time.

Chapter III

DEVELOPMENT OF AN AUTOMATED MAPPING AND LAND INFORMATION SYSTEM FOR THE TOWN OF RANDALL

INTRODUCTION

This chapter describes the procedures utilized to develop an automated mapping and land information system for the Town of Randall in Kenosha County. The sources of the information—maps, aerial photographs, and other paper records—incorporated into the system are identified and described, the manner in which the various information sources were rendered into a digital format is described, and the manner in which the various information types—both graphic and nongraphic—were integrated into a system of land information is discussed. Specific applications utilizing the system and demonstrating some of its capabilities are contained in the following chapter.

PROJECT AREA DESCRIPTION

The Town of Randall is located in the southwestern corner of Kenosha County. The Town was created by action of the Kenosha County Board of Supervisors in 1860. As originally constituted, the Town of Randall consisted of all that territory contained in U. S. Public Land Survey Sections 13 through 36 of Township 1 North, Range 19 East, an area of about 24 square miles. The territory of the Town of Randall remained unaltered until 1937, when the Village of Twin Lakes was incorporated to include Lake Elizabeth, Lake Marie, and adjacent land area formerly in the Town of Randall. Between 1937 and 1984, the Village of Twin Lakes annexed some additional territory from the Town of Randall, so that in 1985 the Town of Randall was about 18 square miles in areal extent (see Map 2).

For the purposes of the project reported herein, the land information incorporated into the described system was digitized for the entire 24-square-mile area comprising the Town of Randall and the Village of Twin Lakes. This included the geographic reference framework, the topographic base map data, the cadastral data prepared under the project, and data on land use, soils, floodplains, and hydrography which had been previously identified and inventoried, and did not require special compilation for the project area. The project area contains a sufficient variety of urban and rural development patterns and natural resource features to provide an area quite suitable for a sound demonstration of the concepts and procedures involved in the creation of a multipurpose cadastre.

GEOGRAPHIC REFERENCE FRAMEWORK

The geographic reference framework—as described in Chapter II—is an important and necessary element in the development of an automated mapping and land information system. It is the key device by which integration of various types of land information taken from sources such as maps, aerial photographs, and other paper records is properly accomplished.

The geographic reference framework for the project was constructed within a computer by key-entry of control survey records prepared as part of the Kenosha County U. S. Public Land Survey System remonumentation and large-scale topographic base mapping program. In this manner, the full precision of the control survey system described in Chapter II could be maintained and utilized in the establishment of the geographic reference frame.

Establishment of the Map Projection

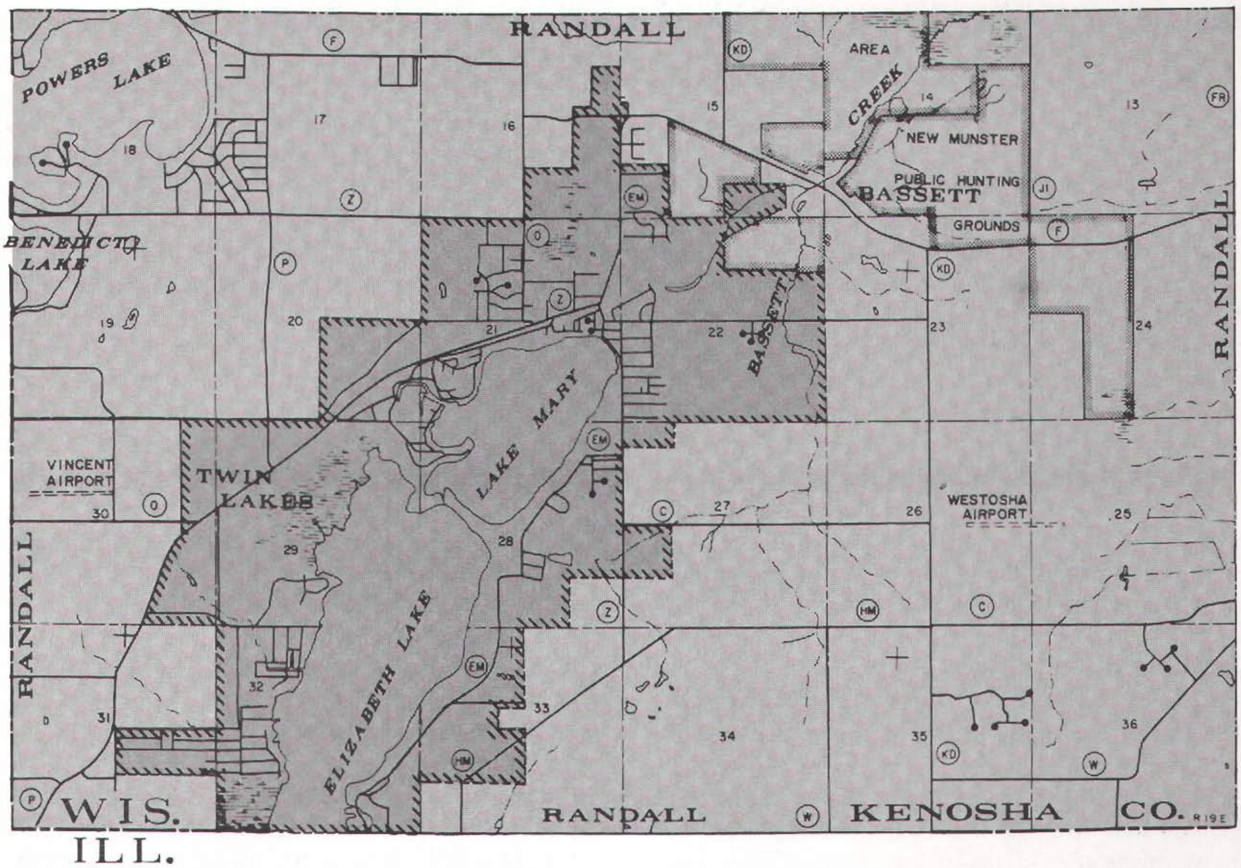
The Wisconsin State Plane Coordinate System, south zone, was utilized as the coordinate system for all map information in the project. Accordingly, the construction of a State Plane Coordinate grid to be used as the basic map projection for the project was another basic requirement of the project. The grid was constructed by computer, using the basic plane geometry relationships involved, and once created was stored for recall and utilization as the map base for all land information integrated into the land information system. The resulting map projection grid—which is geodetic, or earth based—is shown in Figure 8.

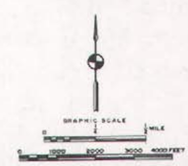
Placement of the U. S. Public Land Survey System on the Map Projection

The U. S. Public Land Survey System provides the basic geographic reference system for information about land ownership. Integration of land ownership information with earth science information requires the placement of the U. S. Public Land

Map 2

THE PROJECT AREA





Source: SEWRPC.

Survey section and quarter-section corners on the State Plane Coordinate System. As already noted in this report, the geographic positions of the Public Land Survey corners in the form of State Plane Coordinates had been previously determined in the project area, with the necessary corner monumentation and horizontal and vertical control survey work being done to Commission-prepared specifications, and with Commission staff review of this work to ensure compliance with these specifications.

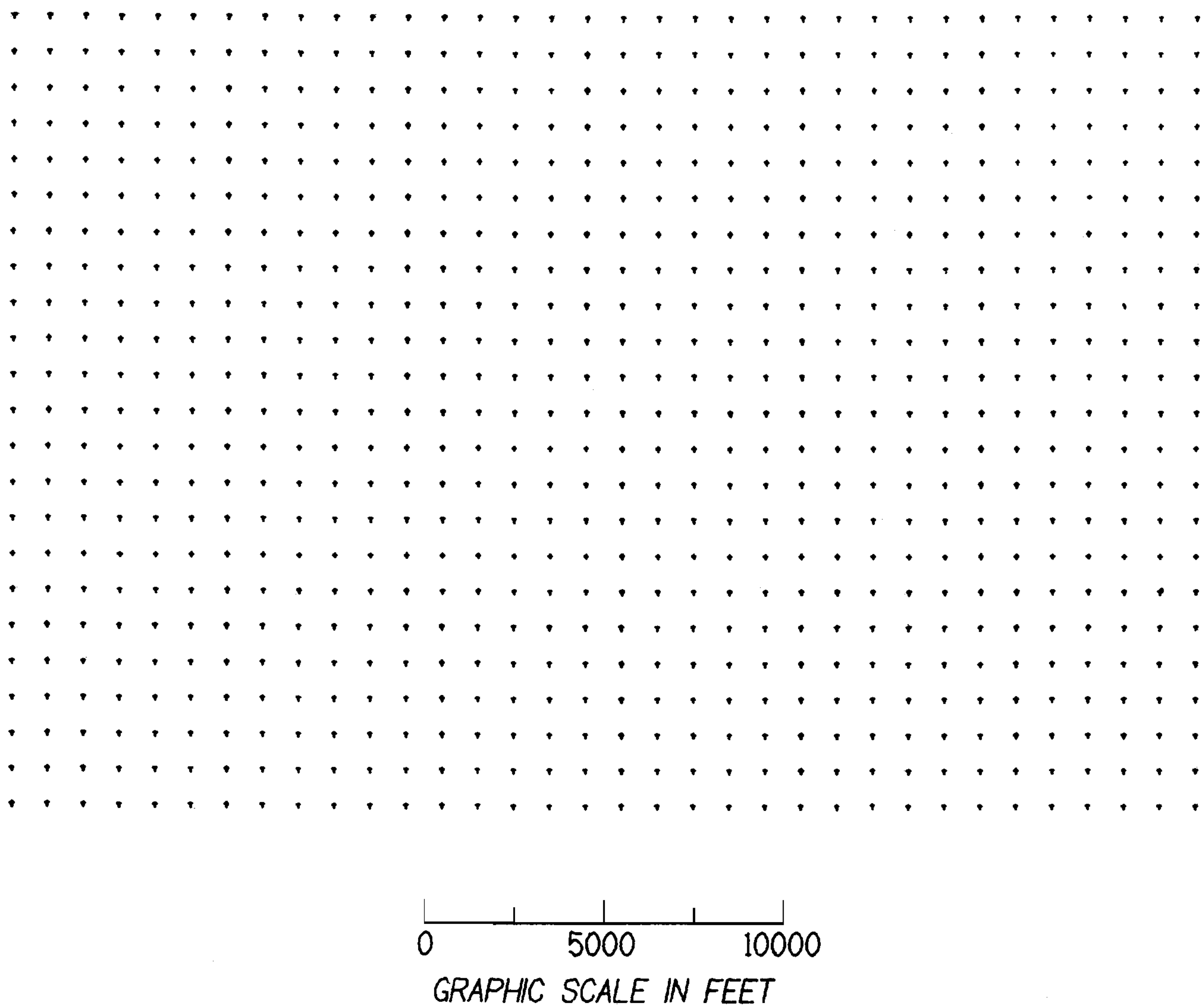
The coordinates of the corners were key-entered into a computer to the nearest 0.01 foot, and placed by the computer upon the State Plane Coordinate grid previously constructed. Under the control survey system utilized, the U. S. Public Land Survey corners were integrated into the geodetic control network by field surveys meeting Third Order, Class I accuracy standards—and thereby converted into a geodetic, or earth-based, control network as well as a real property boundary survey control network. The quarter-section lines connecting the corners were also plotted on the State Plane Coordinate grid at this time. The placement of the U. S. Public Land Survey System as it exists in the Town of Randall on the map projection grid is shown in Figure 9.

BASE MAP FEATURES OBTAINED FROM EXISTING LARGE-SCALE BASE MAPS

As was noted in the preceding chapter of this report, Kenosha County is currently involved in a

Figure 8

THE MAP PROJECTION GRID FOR THE PROJECT AREA



Source: SEWRPC.

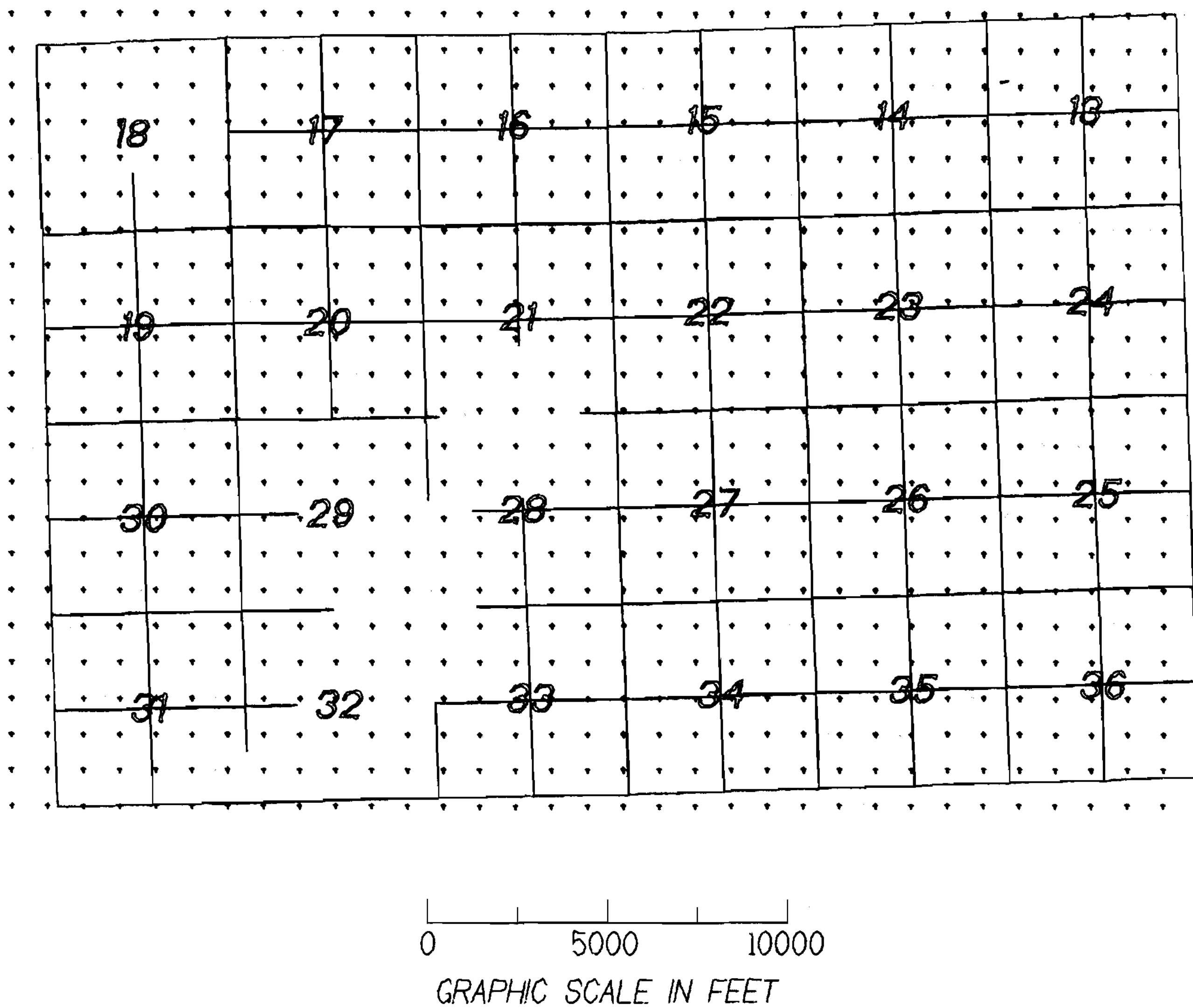
program to prepare 1 inch equals 200 feet scale topographic maps on dimensionally stable base material for all of Kenosha County as part of a comprehensive program of control survey remonumentation and base map preparation. These maps are being constructed to Commission-prepared specifications, with Commission staff review and field checking of the completed maps to ensure compliance with these specifications. The maps meet or exceed National Map Accuracy Standards. The Executive Director of the Commission has been designated by the Kenosha County Board of Supervisors as the Project Manager for this work. The large-scale base maps produced in the study area as part of this ongoing program provided the source for the digitization of surface water and stream channels, for the digitization of traveled ways—pavements—of public streets and highways, and for the digitization of structure outlines.

The locations of surface water areas and stream channels, pavements, and structure outlines were determined by photogrammetric methods during the original compilation of the large-scale topographic maps, and appeared on the finished maps. Figures 10 and 11 show, respectively, the digitized hydrography and the public street and highway network within the project area on the map projection grid previously constructed.

The large-scale base maps contained principal structures that existed as of the date—April 1980—of the aerial photography flown for the photogrammetric compilation of the topographic base

Figure 9

THE U. S. PUBLIC LAND SURVEY SYSTEM IN THE PROJECT AREA



Source: SEWRPC.

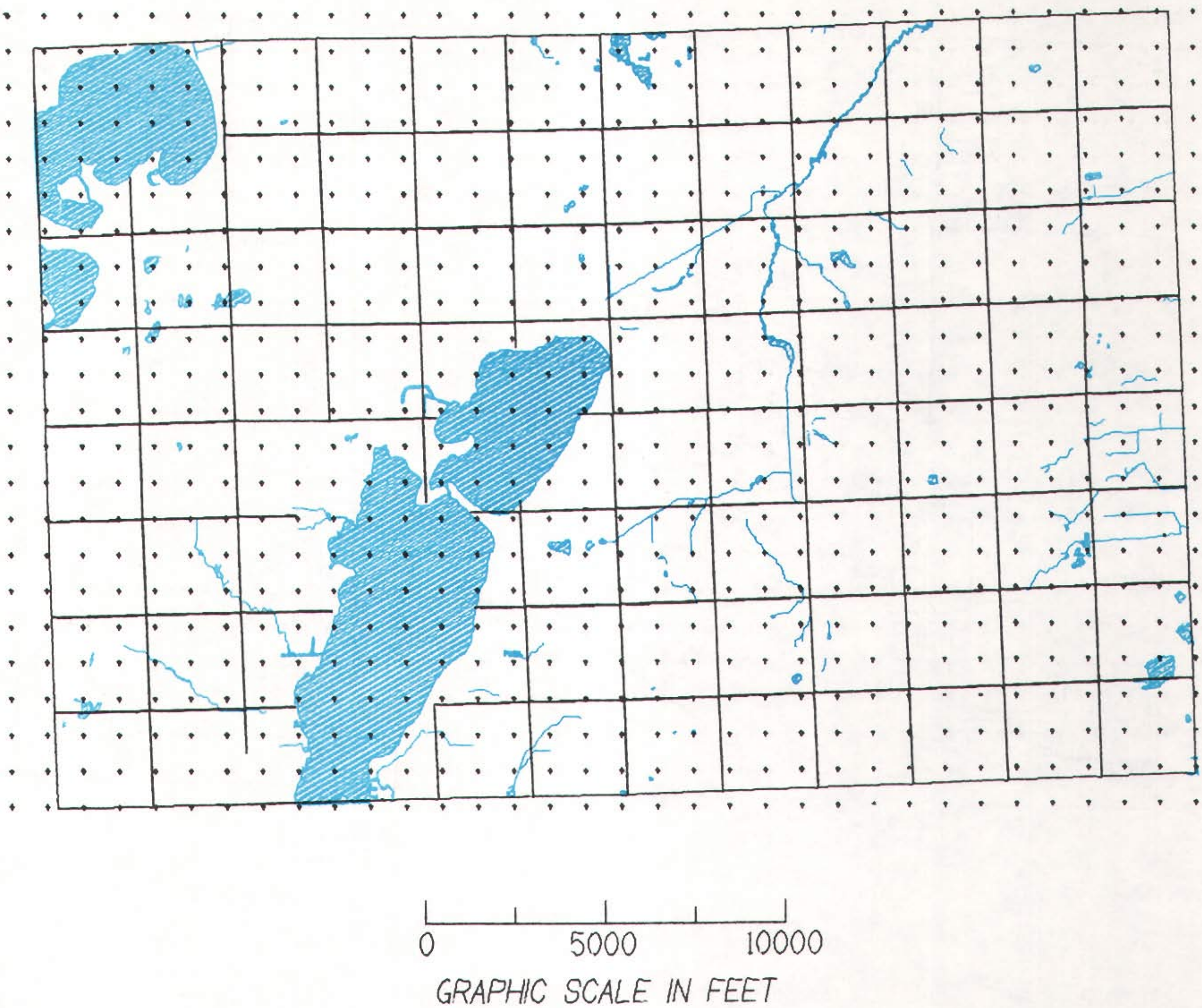
maps. Plats of foundation surveys prepared by Registered Land Surveyors showing all principal buildings constructed since the date of the aerial photography were used to carry this record forward to the current date. It should be noted in this respect, however, that the conduct of a foundation survey has been required by county ordinance only since May 7, 1983; therefore, these records were not necessarily complete for 1980, 1981, 1982, and 1983. Where information on structure demolitions was available, it was utilized, and the appropriate structure outlines deleted from the maps.

PREPARATION OF CADASTRAL MAPS AND DIGITIZATION OF CADASTRAL MAP FEATURES

Although cadastral base sheets had been prepared for the project area as part of the Kenosha County survey remonumentation and large-scale topographic mapping program, cadastral maps had not been prepared for the project area at the time of project initiation. Accordingly, it was necessary to prepare cadastral maps as part of the demon-

Figure 10

HYDROGRAPHY OF THE PROJECT AREA



Source: SEWRPC.

stration project. This work was carried out to specifications prepared by the Regional Planning Commission by a consultant retained by the Kenosha County Planning and Zoning Administration Department, with Commission staff review of the completed maps to ensure compliance with these specifications. The Kenosha County Surveyor also reviewed the information related to real property boundary lines and the completed cadastral maps, and, importantly, provided consultation on particularly difficult problems encountered during the compilation and preparation of the maps.

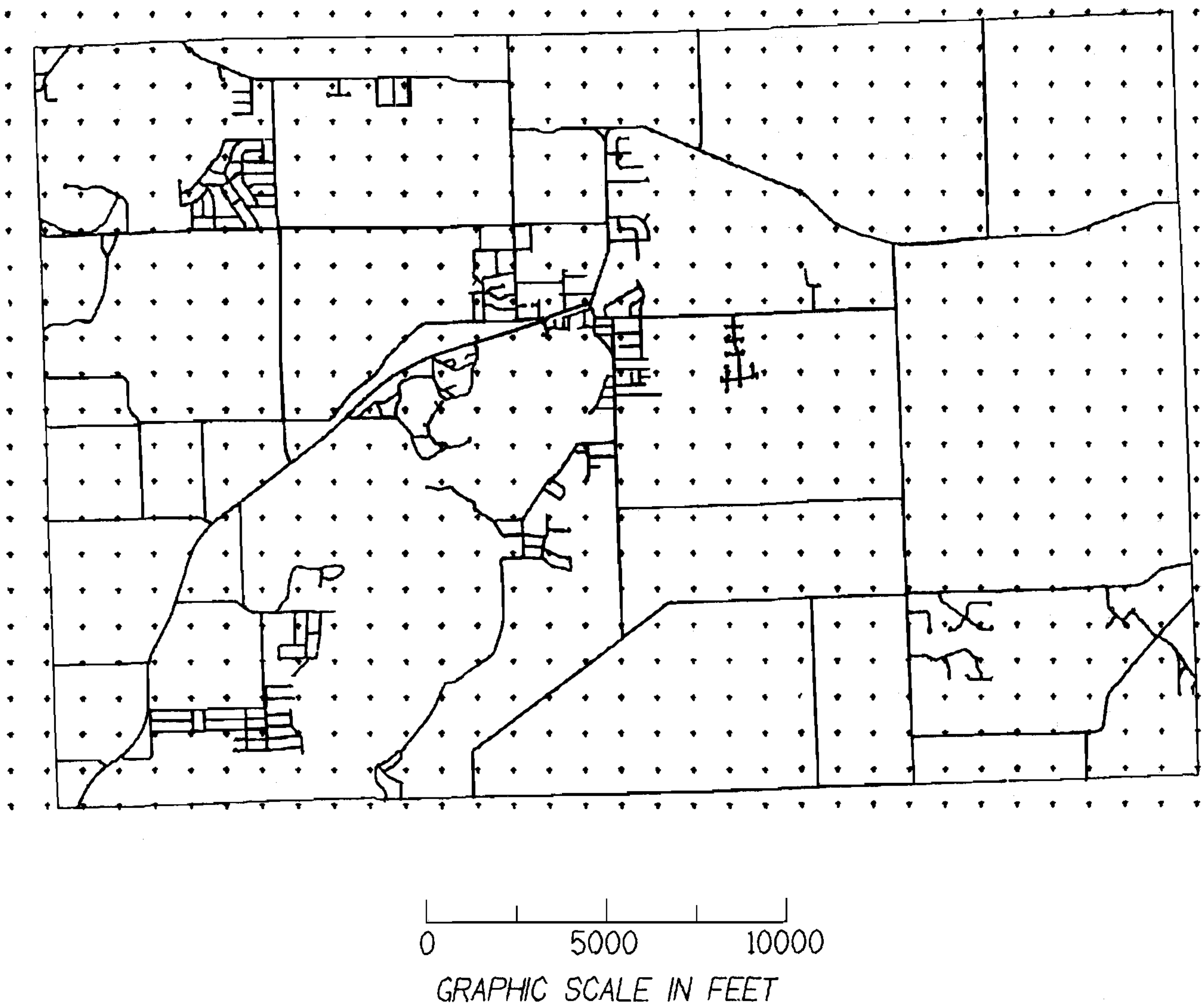
Sources of Information for the Preparation of the Cadastral Maps

A variety of sources were used to locate real property boundary lines and related information, such as easement right-of-way and corporate limit lines.

Civil Division Boundary Line Locations: For the mapping effort, the civil division boundary line between the Town of Randall and the Village of Twin Lakes was determined as the trace of the outer limit of all property parcels located for each

Figure 11

PUBLIC STREETS AND HIGHWAYS IN THE PROJECT AREA



Source: SEWRPC.

of the two jurisdictions as part of the cadastral map preparation. This boundary was cross-checked against a current legal description of the boundary of the Village of Twin Lakes provided by the Village Clerk.

Real Property Boundary Line Locations: The primary source material for the location and alignment of real property boundary lines consisted of recorded subdivision plats and certified survey maps showing real property boundaries within the area for which cadastral maps were to be prepared, and the abbreviated legal descriptions maintained as part of the tax assessment records of the County Assessor for all real property boundaries in the area to be mapped not included within recorded subdivision plats or certified survey maps. Surveyors' field notes on file at the County Surveyor's office were also consulted as necessary. The real property boundary lines were constructed on the maps in the same way a land surveyor would construct those lines in the field. This was possible because of the framework of control provided by the known location of the U. S. Public Land

Survey corners on the State Plane Coordinate System and the attendant known grid lengths and grid bearings of all quarter-section lines.

Street and Railway Rights-of-Way: The location and alignment of street and railway rights-of-way were determined by examination of subdivision plats, certified survey maps, legal descriptions, recorded easement descriptions, and, where available, plats of right-of-way locations.

Major Utility Easements: While the specifications for the project called for the identification on the cadastral maps of all easements for major, cross-country electric power and natural gas transmission lines, examination of the records and of the existing situation in the Town of Randall subsequently disclosed that all existing utility easements were for local distribution rather than for major transmission lines. Accordingly, the finished cadastral maps for the Town of Randall area do not show any major, cross-country utility easements, although these could have been readily shown had any existed in the area.

Preparation of Cadastral Map Sheets

Following delivery of the predrafted base map sheets to the consultant and utilizing the sources identified in summary form above, the consultant prepared preliminary cadastral maps for delivery to Kenosha County. Preparation of these preliminary cadastral maps included the plotting in pencil on the predrafted base map sheets of all the real property boundary lines and related information in their correct position and orientation, and of all street right-of-way lines.

In the construction of these maps, it was recognized that the recorded dimensions and orientation of real property boundaries plotted on the base map sheets would not always agree with the horizontal control data shown on these sheets. This lack of agreement was due to a number of factors, including that some descriptions were written without benefit of field survey data; some descriptions incorporated errors and blunders in field surveys; and some descriptions were incorrectly written. As a result, overlapping or separated property boundary descriptions were expected and were indeed found to exist in some situations. The property boundary line maps were to record all dimensions as contained in the official records of the County Register of Deeds and wherever an overlap, or gap, of 2.5 feet or more existed, such overlaps or gaps were to be shown as mapped lines. Overlaps or gaps of less than 2.5 feet are evident only from the examination of the property line dimensions recorded on the maps.

After review of the preliminary cadastral map sheets by the County Surveyor, the consultant prepared final map sheets in India ink containing the following information in a neat and orderly manner for all recorded subdivision plats and certified survey maps: 1) subdivision name or certified survey map number; 2) block and lot numbers; 3) street names; 4) street, alley, and other public right-of-way widths; 5) recorded lot dimensions; 6) easement right-of-way widths together with the purpose of the easement; and 7) the Kenosha County tax assessment key number of all identified parcels. For all properties other than those contained in a recorded subdivision plat or certified survey map, the map sheets contained the following information: 1) street names; 2) street, alley, and other public right-of-way widths; 3) recorded property dimensions; 4) easement right-of-way widths together with the purpose of the easement; and 5) the Kenosha County tax assessment key number of all identified parcels.

The predrafted cadastral base sheets for the project area had been prepared on dimensionally stable base material at a scale of 1 inch equals 200 feet as part of the Kenosha County large-scale base mapping program. For much of the project area, this scale was satisfactory for compilation of the cadastral maps. For certain intensively developed areas, however, property boundary lines were compiled at a scale of 1 inch equals 100 feet, using cadastral base sheets for one-quarter sections prepared by the digitizing system on dimensionally stable base material. These base sheets were prepared utilizing the U. S. Public Land Survey monument and quarter-section line locations, the water features, and the structure outlines previously digitized from the large-scale base maps. Utility pole locations—which are often useful in checking right-of-way locations—were also digitized from the large-scale maps for these 1 inch equals 100 feet cadastral base sheets, although digitized utility pole locations were not utilized in the demonstration project, nor were they digitized for any of the areas where cadastral maps were compiled directly onto the predrafted cadastral base sheets at the 1 inch equals 200 feet scale. Following compilation of property boundary line and right-of-way locations at 1 inch equals 100 feet, these special cadastral base sheets were photographically reduced to a scale of 1 inch equals 200 feet, with all inking of lines and annotation also done at a scale of 1 inch equals 200 feet to maintain a consistent appearance of the finished cadastral maps.

Upon delivery of the completed cadastral map sheets from the consultant, the Regional Planning Commission staff reviewed all sheets for conformance with the specifications, and any areas found to be not complete or not in conformance were returned to the consultant for correction. A portion of a completed cadastral map is shown in Figure 12.

Digitization of Cadastral Map Sheets

The finished cadastral map sheets were then digitized as a part of the demonstration project. All line features were digitized directly from the cadastral maps. Textual information was key-entered from the cadastral maps and was "placed" by the digitizing system in its appropriate location on the digitized maps. A portion of a digitized cadastral map is shown in Figure 13.

PARCEL IDENTIFICATION NUMBERING SYSTEM

The parcel identification number provides the link between the cadastral maps, which show the location of a particular parcel, and the records, either computer-readable or traditional paper records, that contain information about the parcel. The parcel identification scheme utilized in the project has been established by the Kenosha County Assessor's office for the keeping of records concerning assessment of property for tax purposes, and is the scheme recommended by the Wisconsin Department of Revenue for use throughout the State. The scheme is of a type known as a "location identifier" and utilizes the basic framework of the U. S. Public Land Survey System in the assignment of the parcel number. The identifier is a 12-character number with the format shown in Figure 14.

"A" is the location east or west of the Fourth Principal Meridian of the U. S. Public Land Survey. The value of "4" in this position in the parcel identifier indicates a location east of the Fourth Principal Meridian; a value of "2" indicates a location west of the meridian. In the project area and in all of Kenosha County, the value of "A" in the identifier is always "4."

"BB" identifies the displacement north of the east-west base line—in the case of the State of Wisconsin, this line is the boundary between Illinois and Wisconsin—used in the original government survey of the nominal 36-square-mile survey township in which the parcel lies. In the case of the project area, this displacement is one township north of the base line, and the value of "BB" in the identifier is always "01."

"CC" identifies the displacement east or west of the Fourth Principal Meridian of the nominal 36-square-mile survey township in which the parcel lies. In the case of the project area, this displacement is 19 townships east of the Fourth Principal Meridian and the value of "CC" is always "19."

"DD" is the identification of the nominal one-square-mile section within the nominal 36-square-mile township identified by the code "ABBCC" in which the parcel lies. In the case of the project area, valid codes for this field are "13" through "36."

"E" is the identification of the quadrant of the section in which the parcel lies and "FFFF" is a number—unique within the one-quarter section—that identifies an individual parcel. Parcels extending from one quarter section into another are numbered with the quarter section which contains the greater portion of the parcel.

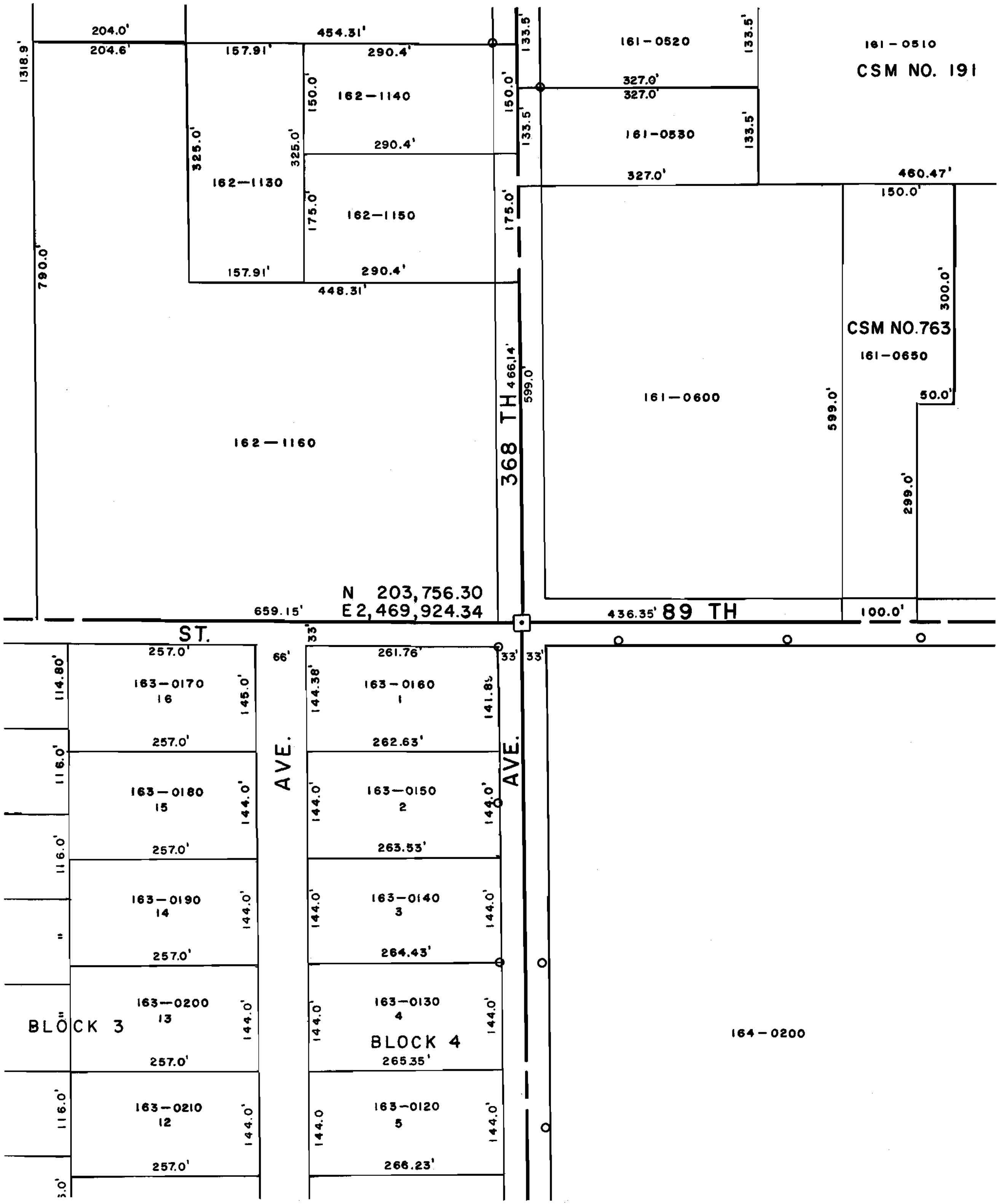
On the cadastral maps, only the right-most seven digits—the section, quarter-section, and parcel identifiers—of the full parcel identification number are used, there being sufficient legend information on the cadastral map sheets to establish the values of the left-most five digits. For ease of reading, the parcel identifiers on the maps use a hyphen between the section/quarter-section identifiers and the parcel identifier. Use of the associated computer files, however, requires the use of all 12 digits of the parcel identifier to identify the appropriate information correctly.

ASSOCIATED LAND INFORMATION FILES

The final step in the development of an automated mapping and land information system for the Town of Randall consisted of the development of files of land-related information useful in zoning administration. Six files of such information were incorporated into the system: 1) the property ownership and assessment records maintained by

Figure 12

AN EXAMPLE OF A FINISHED CADASTRAL MAP FROM THE PROJECT AREA

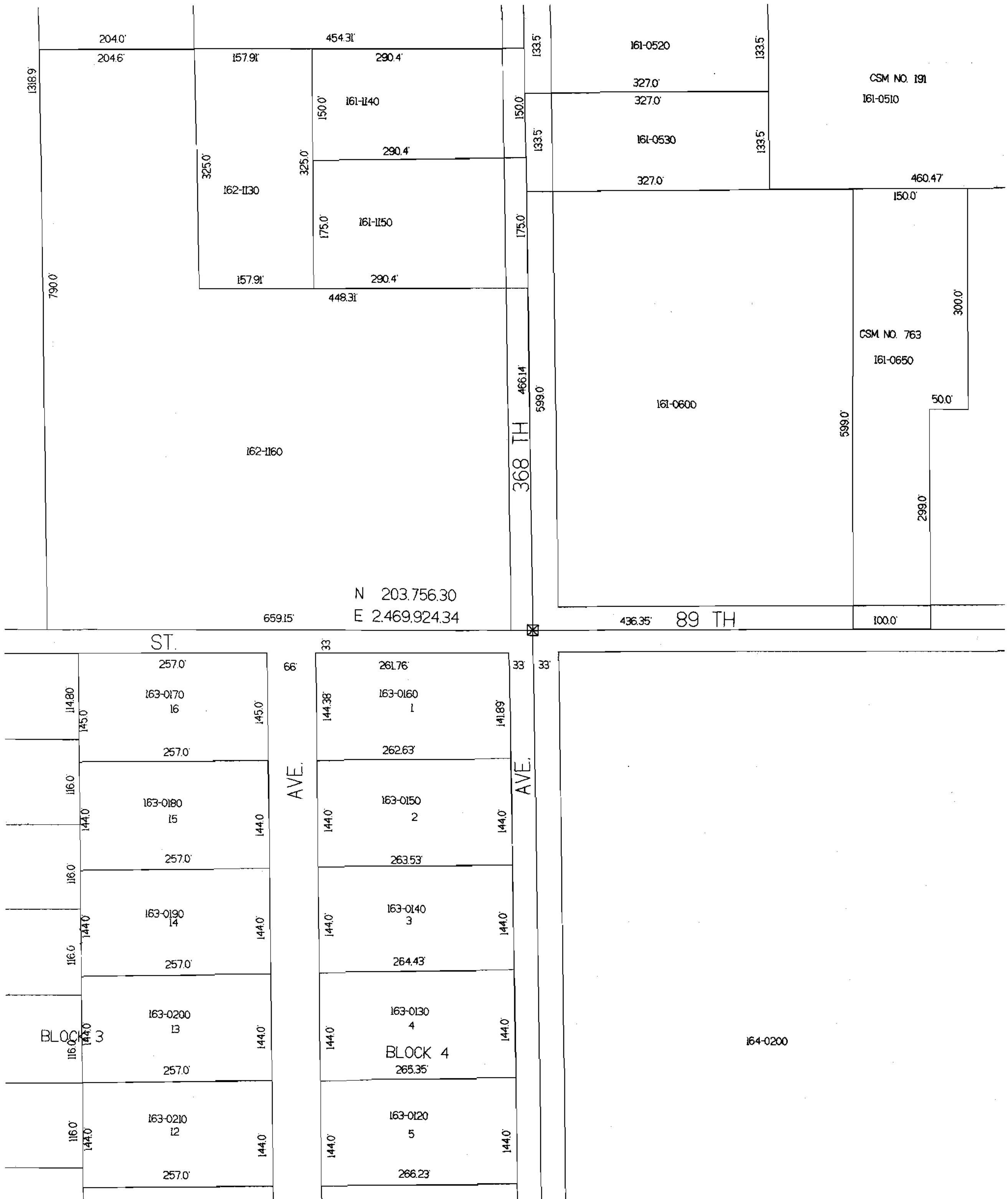


Shown here is a portion of the cadastral map prepared for Section 16 in the Town of Randall, Kenosha County. The map was drafted at a scale of one inch equals 200 feet and the portion of the map contained on this figure is reproduced at the same scale. A portion of the machine-drafted map covering this same area is shown on Figure 13.

Source: SEWRPC.

Figure 13

AN EXAMPLE OF A DIGITIZED CADASTRAL MAP FROM THE PROJECT AREA

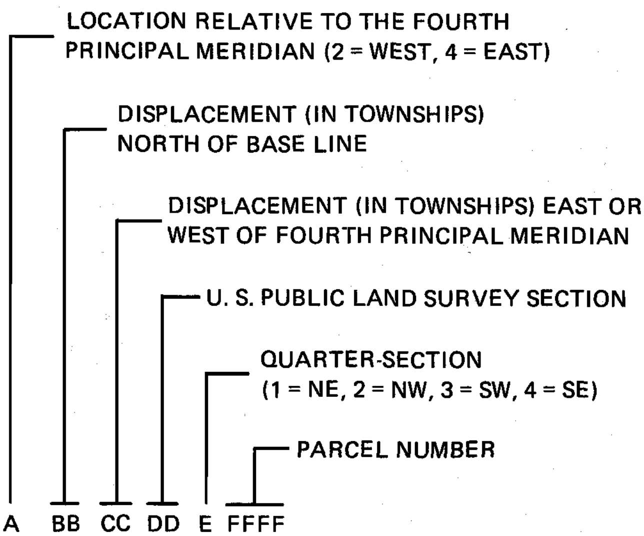


Shown here is a portion of the digitized cadastral map prepared for Section 16 in the Town of Randall, Kenosha County. The map was machine-drafted at a scale of one inch equals 100 feet and photographically reduced to a scale of one inch equals 200 feet for reproduction in this report. A portion of the hand-drafted cadastral map covering this same area is shown on Figure 12.

Source: SEWRPC.

Figure 14

FORMAT OF THE PARCEL IDENTIFICATION NUMBERING SCHEME IN THE PROJECT AREA



Source: Wisconsin Department of Revenue and SEWRPC.

the County Assessor's office; 2) land use; 3) zoning districts; 4) soil units; 5) flood hazard areas; and 6) shoreland areas. Two of these files, the property ownership and assessment records and the land use file, were in existence prior to the initiation of the project and their incorporation into the project required merely that appropriate computer-programming mechanisms be established for their use. The remaining four files—zoning districts, soil units, flood hazard areas, and shoreland areas—were created for purposes of the development of the system. The property ownership and assessment records are nongraphic information files. The land use, zoning district, soil unit, flood hazard, and shoreland files are graphic files maintained in the form of map overlays.

Property Ownership and Assessment Records

The property ownership and assessment records maintained by the County Assessor's office already existed as computer-readable files at the time of the initiation of the project. These files contain such information as an abbreviated legal description, owner's name and mailing address, property address, acreage of the property, and assessed value of the land and any improvements to that land. These records were integrated into the automated mapping and land information system in the Town of Randall in a straightforward manner utilizing the previously described parcel identification numbering scheme which is common to both the maps and the records. The only operational step required for this integration was the establishment of proper programming access to the computer files of assessment records for the purpose of "reading" them.

Land Use

The land use information utilized in the development of the automated mapping and land information system for the Town of Randall consisted of previously digitized land use maps prepared by the Southeastern Wisconsin Regional Planning Commission. These maps had been digitized from interpreted 1 inch equals 400 feet scale ratioed and rectified prints of aerial photography flown for this purpose by the Commission in 1975. The ratioing and rectification of the photographs was controlled to the U. S. Public Land Survey System corners as those corners had been coordinated with the State Plane Coordinate System. The digitized land use maps were subsequently updated using aerial photography flown in 1980. Because the land use maps prepared by the Regional Planning Commission utilized the same geographic reference framework as that developed for the Town of Randall project, they were already "integrated" with the other land information in the system. It was only necessary to copy them.

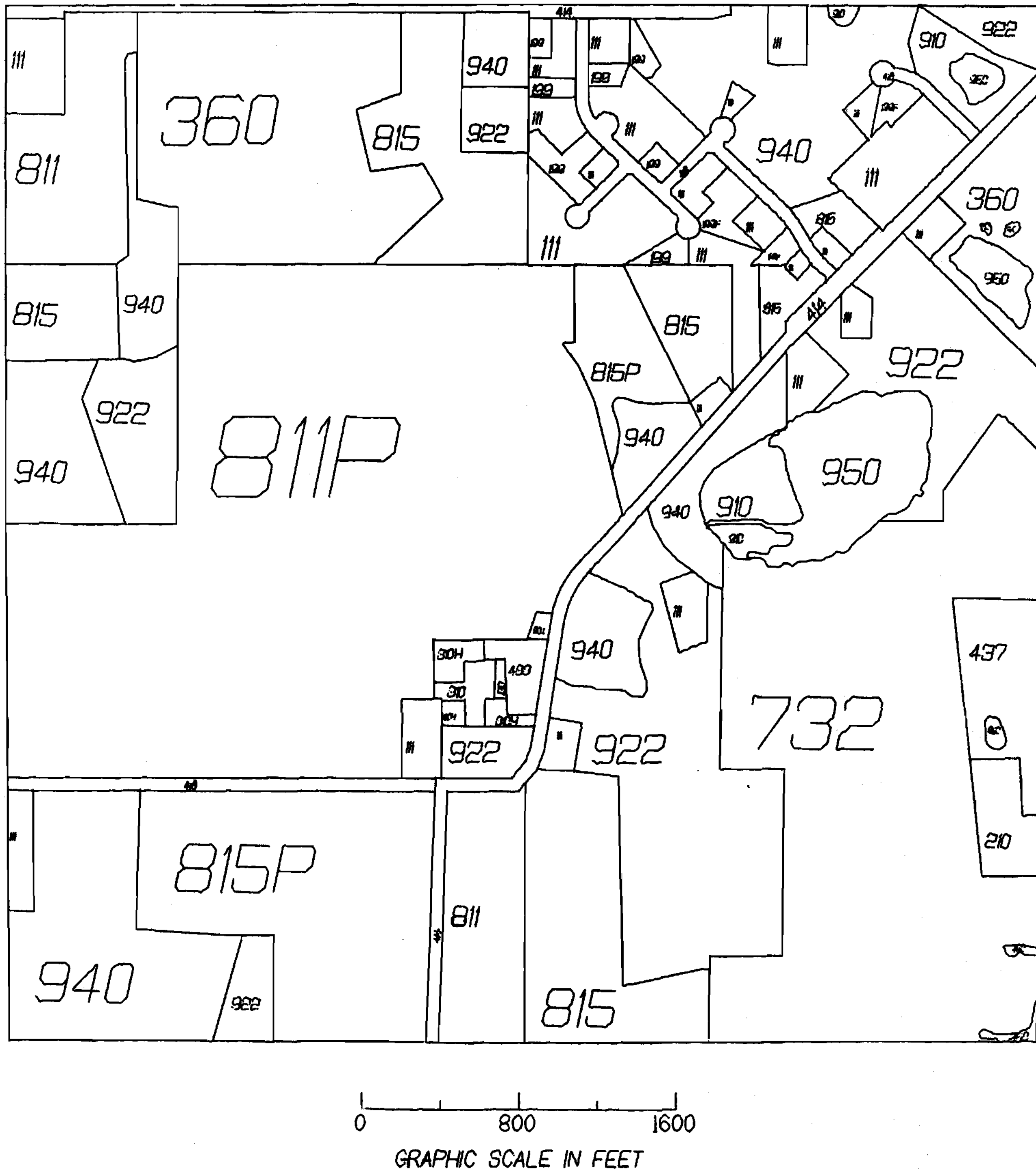
The aerial photo enlargements upon which the land uses were originally delineated had been ratioed and rectified to provide, in effect, "photo maps" upon which distances and areas could subsequently be accurately scaled and measured. Some distortion due to relief still exists in aerial photographs after ratioing and rectification, however. Accordingly, the cadastral maps were used to establish "ground truth" for the land use maps. Where discrepancies were noted between right-of-way and land/water boundary lines on the land use and cadastral maps, they were resolved in favor of the positions recorded on the cadastral map and adjoining land use lines were adjusted accordingly. The land use inventory was rechecked and reviewed and, in some cases, changed on the basis of the cadastral map information, which was not available when the original land use interpretations were made. An example of a digitized land use map from the project area is shown in Figure 15.

Zoning Districts

The zoning district map overlays were prepared from source maps compiled for this purpose by the staff of the County Planning and Zoning Administration Department. It was determined by examining the zoning district boundary maps currently

Figure 15

AN EXAMPLE OF A DIGITIZED LAND USE MAP FROM THE PROJECT AREA



Source: SEWRPC.

maintained by the Department that a majority of the lines necessary to identify zoning district boundaries had been previously digitized as part of either the cadastral maps or the land use maps. Accordingly, the land use maps were mechanically overplotted on the cadastral maps and these plots were utilized by the Department staff to identify those cadastral or land use lines that were congruent with zoning district boundaries. Any additional lines to be digitized as zoning district boundaries were drafted onto the plots at that time.

A zoning district map overlay was then prepared by "copying" appropriate line segments from the cadastral and land use maps and digitizing any additional line segments needed. An example of a digitized zoning map from the project area is shown in Figure 16.

Soil Units

A detailed operational soil survey for all of southeastern Wisconsin was conducted by the U. S. Soil Conservation Service in 1963 under contract to the Regional Planning Commission. The soil survey conducted in southeastern Wisconsin departed from the standard soil survey conducted in other areas of the State and United States in one important respect; namely, the type of aerial photography used as a base map for the field operation. The work specifications prepared by the Commission required that the boundaries of all soil mapping units be identified on prints of then current (1963) Commission aerial photographs. These photographs were to consist of ratioed and rectified enlargements to a scale of one inch equals 1,320 feet of Commission one inch equals 6,000 feet scale high-altitude photographic negatives. Each field sheet base map covered six U. S. Public Land Survey sections. The specifications also required that the Commission be furnished with reproducible half-tone positives of the field sheets on dimensionally stable base material at a scale of one inch equals 2,000 feet. The reproducible positives were to be suitable for the preparation of clear blue-line or black-line prints by diazo process, and were to show clearly the soil mapping units with delineations and identifying symbols so that the prints could be used in conjunction with a published Commission report on the soils of southeastern Wisconsin. The specifications further required that finished photo maps be prepared to accompany the published soil surveys at a scale of one inch equals 1,320 feet, also using the negatives of current photography provided by the Commission. Key planimetric features, such as major highways, railroads, streams, and lakes, were to be identified on the finished photo maps, as were all U. S. Public Land Survey township, range, and section lines.

These base mapping specifications for the soils mapping program in southeastern Wisconsin were unique in that the normal U. S. Soil Conservation Service practice up to that time had been to prepare controlled photomosaics for the soil mapping. The revised base mapping procedure required by the Commission, consisting of the preparation of ratioed and rectified enlargements to eliminate all distortion except that due to relief, provided instead "photo maps" on which distances and areas could subsequently be accurately scaled and measured. Such distances and areas cannot be reliably obtained on controlled photomosaics.

Soil mapping unit boundaries were digitized from the 1 inch equals 1,320 feet scale photo maps for use in the project. This material was chosen over the 1 inch equals 2,000 feet scale photos for two reasons. First, the half-toning of the 1 inch equals 2,000 feet film positives made them more difficult to interpret than the photo print positives; and, second, the 1 inch equals 1,320 feet scale photos, being a larger scale material, were more convenient for the digitizer operators to scale and interpret. Because the salient features of the U. S. Public Land Survey System had been previously marked on these photos, they were readily scaled for digitization using the previously computed State Plane Coordinates for the section and quarter-section corners. An example of a digitized soil map from the project area is shown in Figure 17.

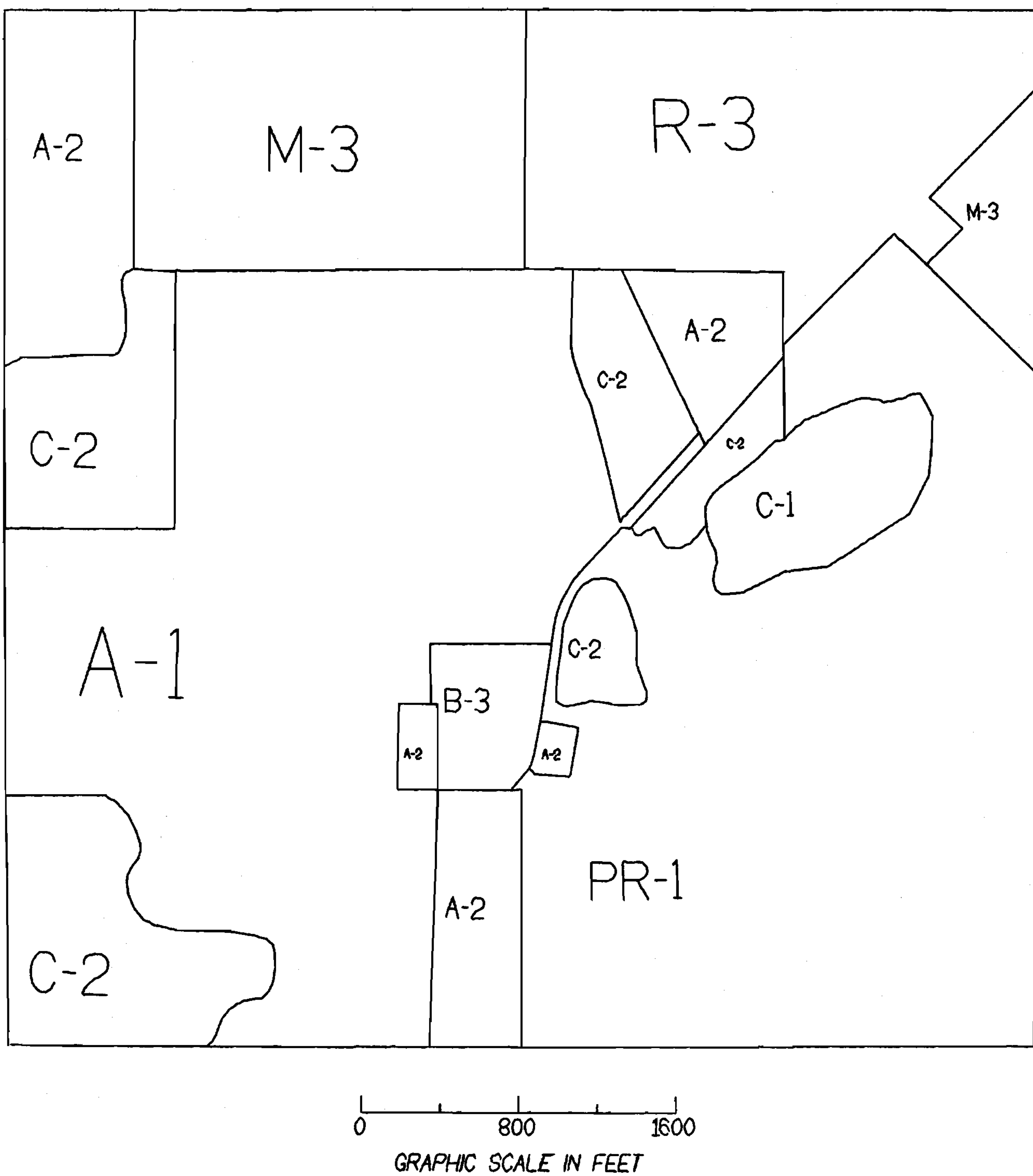
Flood Hazard Areas and Shoreland Areas

The digitization of surface water and stream channels was discussed in a preceding section of this chapter. Two additional water-related areas which often occur in conjunction with one another and which have implications for zoning administration—floodland and shoreland areas—are discussed here. In Wisconsin, floodland and shoreland zoning is jointly exercised by the State in cooperation with the counties, cities, villages, and towns.

Flood Hazard Areas: The limits of the floodlands in the project area were determined through an examination of the federal flood insurance study maps, which in the Town of Randall area included both floodlands delineated through detailed engineering studies and floodlands delineated through approximate methods. These areas had

Figure 16

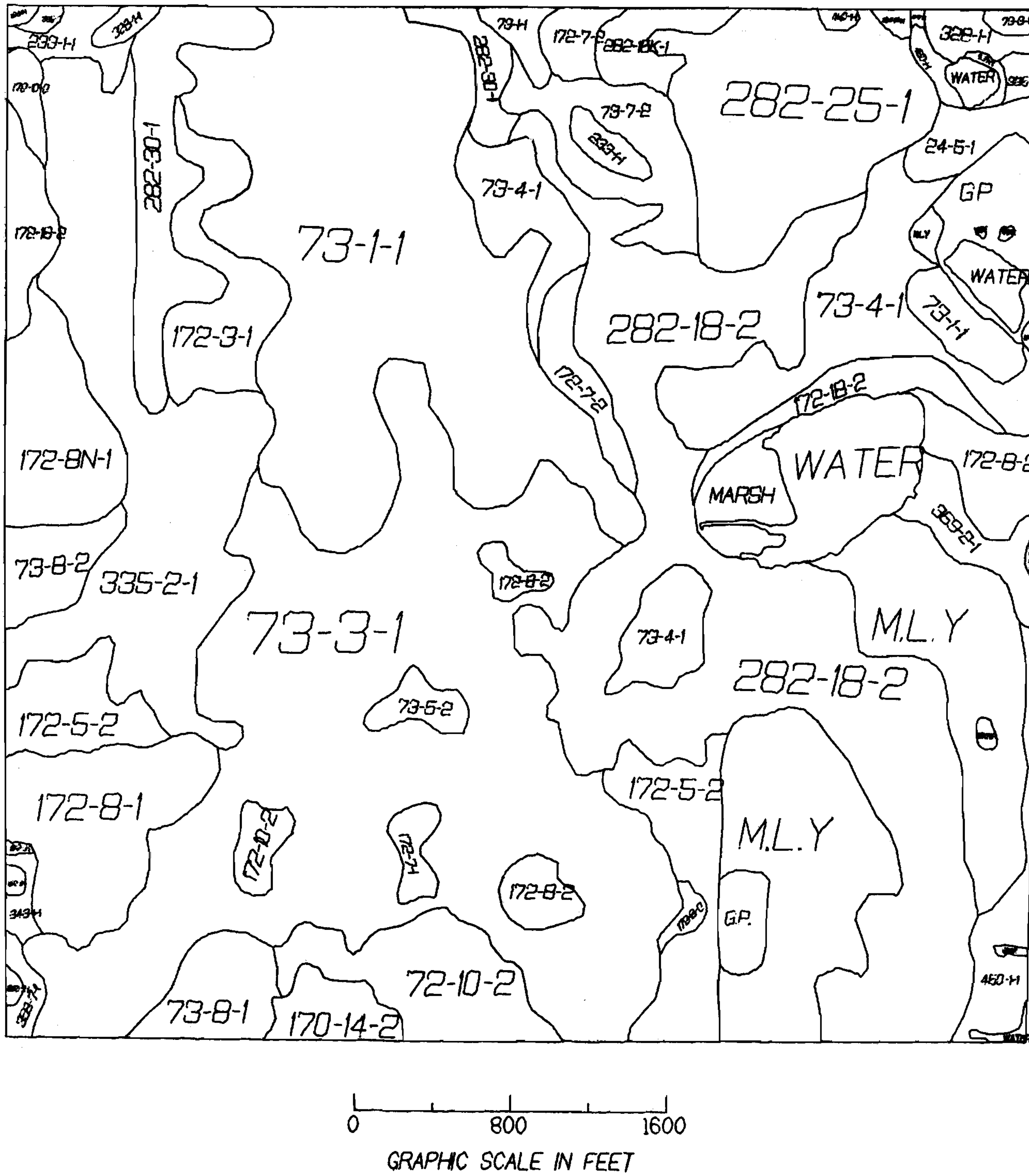
AN EXAMPLE OF A DIGITIZED ZONING MAP FROM THE PROJECT AREA



Source: SEWRPC.

Figure 17

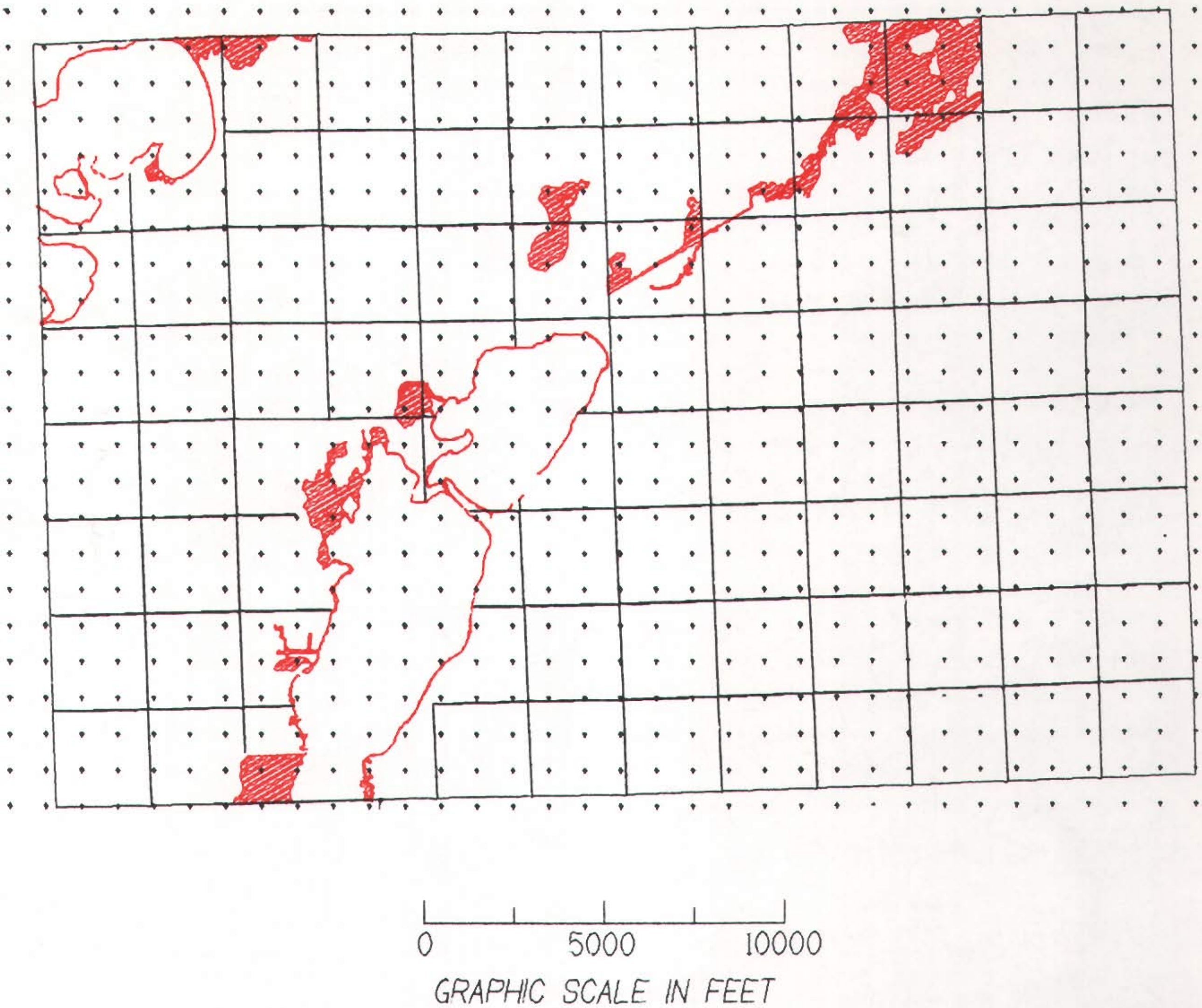
AN EXAMPLE OF A DIGITIZED SOIL MAP FROM THE PROJECT AREA



Source: SEWRPC.

Figure 18

THE LOCATION OF FLOODLANDS IN THE PROJECT AREA



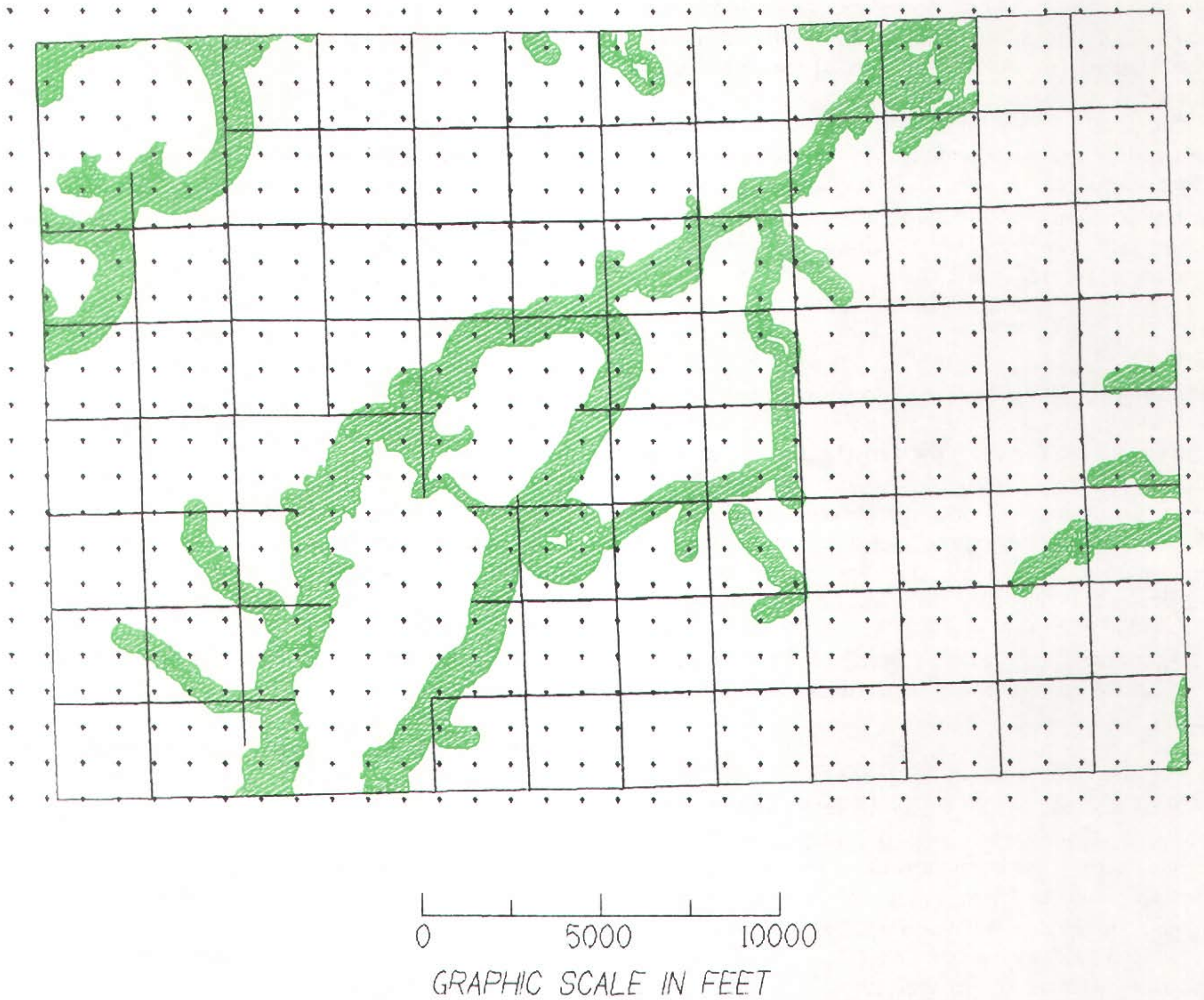
Source: SEWRPC.

been drafted onto the topographic base maps of the project area prior to the initiation of the project described herein. Generally, although not always, floodlands were delineated by engineering studies carried out along all perennial streams and bodies of ponded water in areas of urban development or with a perceived potential for urban development. These engineering studies resulted in the determination of the limits of the floodlands based upon the stages attendant to the peak rate of discharge of the regulatory—or 100-year recurrence interval—flood event and the ability of the stream system to convey that flow. Approximate methods for the delineation of floodlands were generally used in the project area along perennial streams and ponded bodies of water where there was no perceived potential or demand for urban development. These methods relied on field surveys which took account of such factors as soil type and condition and vegetation patterns, and also utilized historic information pertaining to flood events. A digitized map of the delineated floodlands in the project area is shown in Figure 18.

Shoreland Areas: As had the flood hazard area boundaries, the limits of the shoreland areas had been drafted onto the topographic base maps before the current project was begun. Shoreland areas are determined by certain specified statutory distances from waters which are navigable, with the exception that lands adjacent to farm drainage ditches are not subject to shoreland ordinances if: 1) such lands are not adjacent to a natural navigable stream or river; 2) the drainage ditches were

Figure 19

THE LOCATION OF SHORELAND AREAS IN THE PROJECT AREA



Source: SEWRPC.

nonnavigable streams before ditching or had no previous stream history; and 3) such lands are maintained in nonstructural agricultural use. Navigable waters have been defined by the Wisconsin Supreme Court as waters which are capable of floating any boat, skiff, or canoe used for recreation purposes. The determination of navigability is made by the Wisconsin Department of Natural Resources based upon field studies carried out on an as-needed basis. Consequently, navigable lakes and streams cannot be identified and mapped on an areawide basis in advance of Department determination, and a surrogate identification must be used for shoreland area delineation. For this purpose in the project area, all lakes and ponds shown and named on, and all perennial streams shown on, U. S. Geological Survey standard quadrangle maps were assumed to be navigable and used to delineate shoreland areas.

Until 1981, the delineation of shoreland areas was required by State Statutes only in unincorporated areas; however, legislation adopted in that year will require the eventual delineation of shoreland areas in incorporated municipalities as well. In the project area, shoreland areas had been delineated only in the Town of Randall when this project was begun. Shoreland areas were delineated in the Village of Twin Lakes as part of the project. A digitized map of the delineated shoreland areas in the project area is shown in Figure 19.

There is a relationship between floodlands and shoreland areas which should be noted here. Floodlands are always wholly contained within shoreland areas where shoreland areas have been delineated. The administrative rules that have been promulgated for the delineation of shoreland areas provide that the limits of these areas shall include all the land: 1) within 1,000 feet of the ordinary high-water mark of navigable lakes, ponds, or flowages; or 2) within 300 feet of the ordinary high-water mark of navigable rivers and streams, or to the landward side of the floodplain, whichever distance is greater.

SUMMARY

This chapter has described the procedures utilized to develop an automated mapping and land information system for the Town of Randall in Kenosha County. The sources of the information—maps, aerial photographs, and paper records—incorporated into the system were identified and described, the manner in which the various information sources were rendered into a digital format was described, and the manner in which the various information types—both graphic and nongraphic—were integrated into a land information system was discussed.

The Town of Randall is located in the southwestern corner of Kenosha County and in 1985 consisted of an area of about 18 square miles. The project area—which in addition to the Town of Randall includes the adjacent Village of Twin Lakes—contains a sufficient variety of land uses, residential development patterns, and natural resource features to provide an area quite suitable for a demonstration project for the creation of a multipurpose cadastre.

The geographic reference framework for the project was constructed within a computer by key-entry of control survey records prepared as part of the Kenosha County U. S. Public Land Survey System remonumentation and large-scale topographic base mapping program. In this manner, the full precision of the control survey data could be maintained and utilized in the establishment of the geographic reference frame. All aspects of the Kenosha County remonumentation and base mapping program have been carried out to Commission-prepared specifications, with Commission staff review and field checking of the completed maps to ensure compliance with these specifications. The Executive Director of the Commission has been designated by the Kenosha County Board of Supervisors as the Project Manager for this work.

The Wisconsin State Plane Coordinate System, south zone, was utilized as the coordinate system for all map information in the project. The coordinate system grid was constructed by a computer using basic plane geometry relationships and, once created, was stored for recall and utilization as the map base for all land information integrated into the system. The resulting map projection grid is geodetic, or earth based.

Integration of land ownership information with other types of information about the land required the placement of U. S. Public Land Survey section and quarter-section corners on the State Plane Coordinate System. Coordinates for the corners were key-entered into a computer to the nearest 0.01 foot and placed by the computer upon the State Plane Coordinate grid previously constructed. Under the control survey system utilized, the U. S. Public Land Survey corners were integrated into the geodetic control network by field surveys meeting Third Order, Class I accuracy standards, and thereby converted into a geodetic, or earth-based, control network as well as a real property boundary survey control network. Quarter-section lines connecting the corners were also plotted on the State Plane Coordinate grid.

Large-scale base maps produced for the project area as part of the Kenosha County survey remonumentation and base mapping program provided the source for the digitization of surface water and stream channels, the traveled ways—pavements—of public streets and highways, and structure outlines. The locations of surface water areas and stream channels, pavements, and structure outlines were determined by photogrammetric methods during the preparation of the large-scale topographic maps and appeared on the finished maps.

Cadastral maps for the Town of Randall and the Village of Twin Lakes were prepared as part of the demonstration project. This work was carried out to specifications prepared by the Regional Planning Commission staff by a consultant retained for the project by the Kenosha County Planning and Zoning Administration Department. The Kenosha County Surveyor reviewed the completed cadastral maps and provided consultation on particularly difficult problems encountered during the compilation and preparation of the maps.

A variety of sources were used to locate real property boundary lines and real property boundary line-related information, such as easement and right-of-way lines. Sources utilized in this phase of the project included recorded subdivision plats, certified survey maps, abbreviated legal descriptions, recorded easement descriptions, plats of right-of-way locations, and surveyors' field notes. Following drafting of the cadastral map sheets, the information contained upon the sheets was digitized.

The parcel identification number provided the link between the cadastral maps, which show the location of a particular parcel, and the records, either computer-readable or traditional paper records, that contain information about the parcel. The parcel identification scheme utilized in the project has been established by the Kenosha County Assessor's office for the keeping of records concerning assessments of property, and is the scheme recommended by the Wisconsin Department of Revenue for use throughout the State for this purpose. The scheme is of a type known as a "location identifier" and utilizes the basic framework of the U. S. Public Land Survey in the assignment of the parcel number.

The final step in the development of an automated mapping and land information system for the Town of Randall was the development of files of land-related information useful in zoning administration. Six additional files of this type were incorporated into the system: 1) the property ownership and assessment records maintained by the County Assessor's office; 2) land use; 3) zoning districts; 4) soil units; 5) flood hazard areas; and 6) shoreland areas. Two of these files, the property ownership and assessment records and the land use file, were in existence as computer-readable files prior to the initiation of the project and their incorporation into the project required merely that appropriate computer programming mechanisms be established for their use. The remaining four files--zoning districts, soil units, flood hazard areas, and shoreland areas--were created as part of the system development. The property ownership and assessment records are nongraphic information files. The land use, zoning district, soil unit, flood hazard, and shoreland files are graphic files maintained in the form of map overlays.

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Chapter IV

SELECTED APPLICATIONS

INTRODUCTION

This chapter describes some typical planning and zoning administration applications which can be derived from an automated mapping and land information system such as the one developed for the Town of Randall. The first section of this chapter presents a general discussion of the system capabilities, such as the manipulation and display of map elements and the production of area measurements from map polygon sets. This is followed by examples of how these capabilities can be utilized in some typical situations. It should be noted that the applications presented are intended to be illustrative rather than exhaustive. The system is capable of supporting a myriad of uses.

MAP MANIPULATION, DISPLAY, AND MEASUREMENT

The ability to prepare both general-purpose and special-purpose maps quickly and easily and to quantify mapped information is the most immediate benefit of implementing an automated mapping and land information system. In an automated system these operations can generally be accomplished by using a few computer language commands. In manual mapping systems, the preparation of special-purpose maps in particular tends to be labor intensive and time-consuming, and may be restricted by the available general-purpose base maps. Quantification of mapped information—such as determining the areal extent of various land—is also a labor-intensive process, relying, as it does, on the use of planimeters or dot screen techniques.

Feature Selection

One of the first steps in creating any map is to determine the information to be displayed. The purpose for which the map is being created should be carefully considered in such a determination, ensuring that adequate information for that purpose is displayed. The users of a particular map should be considered so that the final map is clear and informative to everyone who has need for the displayed information. Finally, available map space and final map scale must be considered so that the map does not become overly cluttered and complicated. As discussed previously, each category of information described in Chapter III is stored in a computer data base as a separate element accessible by a user. The categories of information which will be needed for a specific purpose or project can be selected from the information layers available in the computer data base and produced as a machine-generated map. These data can be readily merged into a single, spatially accurate map because two necessary conditions have been established. First, all map data elements have been tied to a single, high-precision, geographic reference framework; and second, both the large-scale base maps and the cadastral maps have been prepared to the same map accuracy standards—in this case, the National Map Accuracy Standards.

The ability to select only those map features required on a particular map and then to produce the map both quickly and easily is of central importance to any automated mapping system. Each agency and department in the county government requires a specific, often different, set of mapped information for the completion of assigned duties. A coordinated mapping system can prepare these specialized maps easily and quickly while eliminating costly duplication and map data inconsistencies which can occur when maps are prepared at different times, at different scales, and at different levels of precision by different governmental units and agencies.

Map Scale

Once the information to be displayed on the map has been selected, a map scale must be selected. Selecting the scale at which to produce a particular map is very important in manual drafting, since redrafting a map at a different scale can be expensive and time-consuming.

Changing map scales with an automated mapping system, however, is a simple computer program function and requires only the time needed to regenerate the map on a plotter—typically a matter of a few hours. Maps with a specified amount of information can be generated at any user-defined scale. Such considerations as the scale of an existing map to which comparisons are to be made, size of the study area, and amount of detail to be displayed can all be used to determine the scale at which the map is to be produced. In addition, multiple copies of the same map can be produced at various scales if desired by the user.

It should be noted that certain map design considerations, such as map scale, affect the visual appearance and legibility of maps. This is as true of hand-drafted maps as it is of machine-drafted maps, although it tends to be more visually apparent in machine-drafted maps due in part to the manner in which mechanical display devices such as cathode ray tubes and mechanical plotters are designed and manufactured. Wherever possible, the mechanically plotted figures reproduced in Chapters III and IV of this report are shown at drafted scale; that is, they have not been photographically reduced or enlarged for printing. As a result, some figures appear "coarse," and smaller text annotations may be illegible. In those instances where legibility could be obtained only by photographic reduction, this fact has been noted in the figure caption. Map features could have been visually improved by preparing the figures at a larger scale and then photographically reducing the scale of the figures for publication to "sharpen" the image. It was determined not to use such a procedure, however, except where necessary and then as noted, since this would give an impression of image quality not, in fact, obtainable on the equipment used in this demonstration project.

Data Inventory and Measurement

Computerized mapping information systems are useful for collecting and quantifying inventories of existing land-related conditions. Areas with common attributes, such as soil type, land use, or zoning, can be identified and measured. Since area measurements can be readily calculated for irregularly shaped areas, precise measurements can be obtained for each attribute. Figure 20 displays all soil types as delineated for Section 14 in the Town of Randall. Table 1 sets forth area measurements, in acres, of each soil mapping unit found in Section 14. Figure 21 displays the zoning districts in Section 14, with Table 2 setting forth the area of each zoning type. Land use areas for Section 14, Town of Randall, are delineated in Figure 22, with the land use measurements set forth in Table 3.

An additional advantage of a computerized mapping information system is the ability to redefine and remeasure areas based on a combination of one or more attributes. Figure 23 displays the ownership and tax parcel boundaries and floodplain limits in Section 14, Town of Randall. For every parcel, the area within the delineated floodplain can be calculated by machine. Table 4 sets forth the area in acres, measured within and outside the floodplain, for each tax parcel in Section 14. This information can be used for determining use limitations of a parcel by the Planning and Zoning Administration office, as well as for determining the assessed value of a parcel by the Assessor's office.

Attribute Classification and Display

In addition to measuring areas with like attributes, area classification can be completed. The inventories which were collected for the Town of Randall demonstration project contained a high level of detail. This amount of detail is not needed for all applications. The publication of an inventory map at a scale much smaller than the original data collection scale may, in fact, make the use of a less detailed classification scheme necessary. When a less detailed file can be used, areas can be automatically classified and grouped into more generalized categories. The newly defined categories can be displayed through color-coding or cross-hatching on a map. Since these newly classified areas constitute a new layer of information in the data structure, they can either be displayed separately or be merged with other information. Further discussion and examples of this process are presented later in this chapter as part of a specific application.

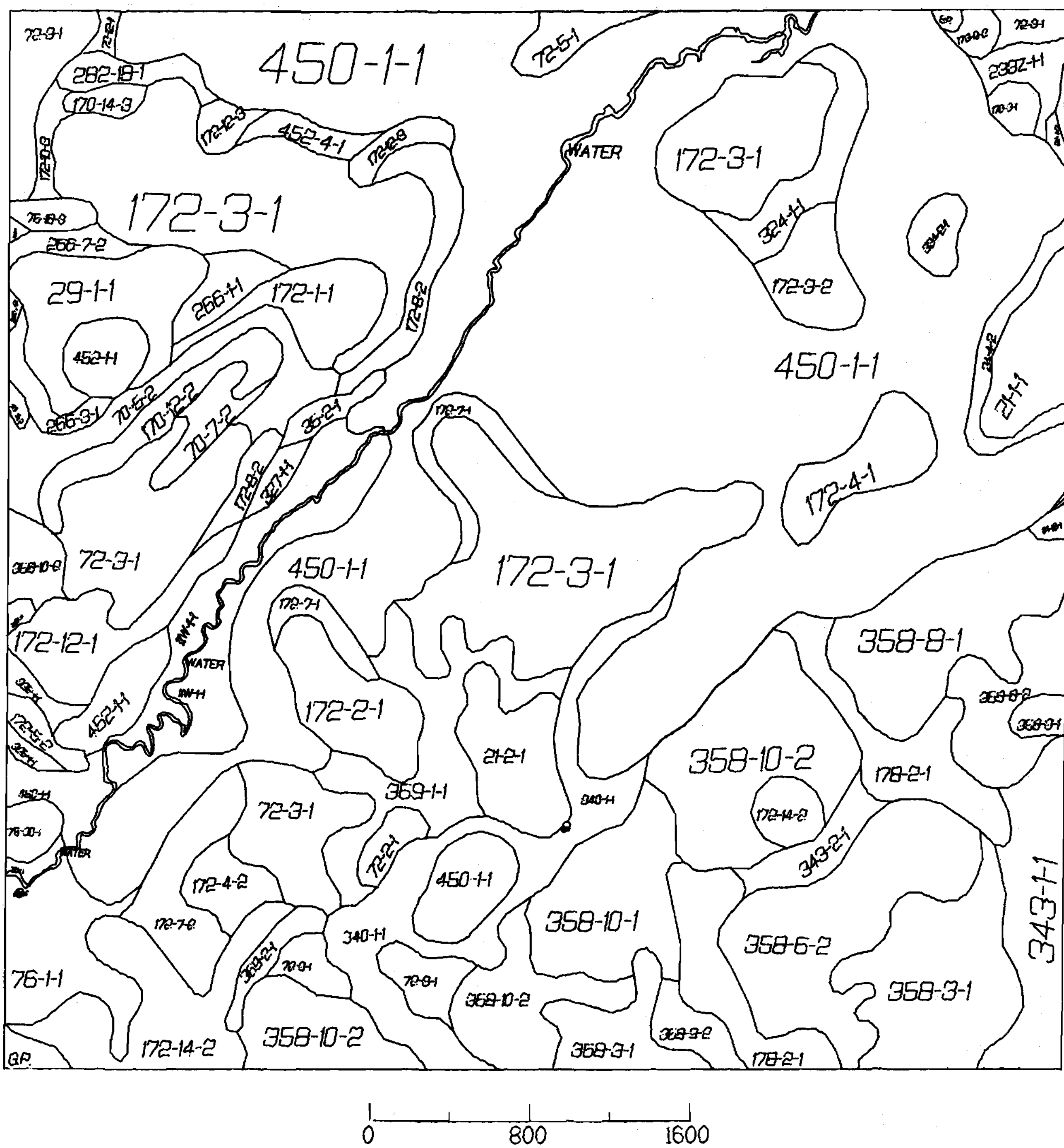
AN EXAMPLE OF SYSTEM USE IN THE WISCONSIN FARMLAND PRESERVATION PROGRAM

Recognizing a need to preserve agricultural lands in Wisconsin, the State Legislature adopted Chapter 29, Laws of 1977, commonly called the "Farmland Preservation Act." The Act is designed to encourage individuals and local units of government to take action toward the preservation of Wisconsin farmland. Under the Act, a farmland owner whose land is subject to an exclusive agricultural zoning ordinance becomes eligible for tax relief in the form of a state income tax credit.

Land areas which have been designated for exclusive agricultural use in the Town of Randall are defined and identified in SEWRPC Community Assistance Planning Report No. 45, A Farmland Preservation Plan for Kenosha County, Wisconsin, adopted by Kenosha County on February 16,

Figure 20

A DIGITIZED SOIL MAP FOR SECTION 14, TOWN OF RANDALL



Source: SEWRPC.

Table 1

AREAL EXTENT OF SOIL UNITS IN SECTION 14, TOWN OF RANDALL

Soil Name	Soil Type	Percent Slope	Degree of Erosion	Area (acres)	Percent of Total
Houghton Mucky Peat	450	1	1	199.4	30.9
Fox Loam	72	3	1	30.0	4.6
Fox Loam	72	2	1	1.7	0.3
Fox Loam	72	5	1	2.4	0.4
Casco Loam	172	9	2	1.0	0.1
Casco Loam	172	3	1	61.6	9.5
Casco Loam	172	3	2	4.8	0.7
Casco Loam	172	4	1	6.0	0.9
Casco Loam	172	7	1	5.4	0.8
Casco Loam	172	2	1	7.3	1.1
Casco Loam	172	4	2	3.1	0.5
Casco Loam	172	7	2	6.5	1.0
Casco Loam	172	5	2	1.4	0.2
Casco Loam	172	8	2	6.2	1.0
Casco Loam	172	10	3	1.4	0.2
Casco Loam	172	1	1	6.0	0.9
Casco Loam	172	12	3	3.0	0.5
Casco Loam	172	12	1	7.0	1.1
Matherton Silt Loam, Clay Substratum	233Z	1	1	2.6	0.4
Casco Sandy Loam	170	3	1	1.3	0.2
Casco Sandy Loam	170	12	2	5.1	0.8
Casco Sandy Loam	170	14	3	1.2	0.2
Hebron Loam	21	1	1	6.8	1.1
Hebron Loam	21	2	1	7.2	1.0
Hebron Silt Loam	24	4	2	3.6	0.6
Hebron Silt Loam	24	10	2	--[a]	0.0
Hebron Silt Loam	24	18	1	0.5	0.1
Ionia Loam	324	1	1	5.5	0.9
Ionia Loam	324	2	1	2.0	0.3
Ogden Muck.	456	3	1	--[a]	0.0
Miami Loam.	358	8	1	15.2	2.4
Miami Loam.	358	8	2	7.0	1.1
Miami Loam.	358	3	1	20.8	3.2
Miami Loam.	358	10	2	32.8	5.1
Miami Loam.	358	6	2	18.2	2.8
Miami Loam.	358	9	2	2.5	0.4
Miami Loam.	358	10	1	11.6	1.8
Crosby Silt Loam	178	2	1	14.9	2.3
Celina Silt Loam	343	2	1	3.4	0.5
Celina Silt Loam	343	1	1	10.1	1.6
Navan Silt Loam	340	1	1	16.7	2.6
Mosel Silt Loam	369	1	1	11.9	1.8
Mosel Silt Loam	369	2	1	1.8	0.3
Sebewa Silt Loam	76	1	1	9.1	1.4
Abington Silt Loam.	326	1	1	2.1	0.3
Adrian Muck	452	1	1	6.9	1.1
Adrian Muck	452	4	1	1.9	0.3
Alluvial Land, Wet.	11W	1	1	14.4	2.2

Table 1 (continued)

Soil Name	Soil Type	Percent Slope	Degree of Erosion	Area (acres)	Percent of Total
Wallkill Silt Loam	327	1	1	1.1	0.2
Yahara Very Fine Sandy Loam	35	2	1	1.4	0.2
Fox Sandy Loam.	70	5	2	8.1	1.2
Fox Sandy Loam.	70	7	2	2.7	0.4
Fox Sandy Loam.	70	12	1	0.5	0.1
Sisson Silt Loam	266	3	1	2.0	0.3
Sisson Silt Loam	266	7	2	2.0	0.3
Sisson Silt Loam	266	1	1	2.7	0.4
Saylesville Silt Loam	40	9	2	0.4	0.1
Colwood Silt Loam	29	1	1	9.9	1.5
Casco-Rodman Loams	282	18	1	2.4	0.4
Rodman Gravelly Loam	75	30	1	1.7	0.3
Rodman Gravelly Loam	75	18	3	1.4	0.2
Water	--	--	--	3.2	0.5
Gravel Pit.	--	--	--	1.3	0.2
Total	--	--	--	646.0	100.0

[a] *Less than 0.05 acre.*

Source: SEWRPC.

Table 2

AREAL EXTENT OF ZONING DISTRICTS IN SECTION 14, TOWN OF RANDALL

Zoning District		Area (acres)	Percent of Total Area
Code	Name		
R-2	Suburban Single-Family Residential	5.8	0.9
B-2	Community Business	5.9	0.9
R-4	Urban Single-Family Residential	1.6	0.2
M-1	Limited Manufacturing. . . .	0.4	0.1
PR-1	Park-Recreational	115.8	17.9
C-1	Lowland Resource Conservancy	268.8	41.7
A-2	General Agricultural	106.2	16.4
A-1	Agricultural Preservation. . .	104.3	16.1
R-1	Rural Residential	8.2	1.3
C-2	Upland Resource Conservancy	29.0	4.5
Total		646.0	100.0

Source: SEWRPC.

Table 3

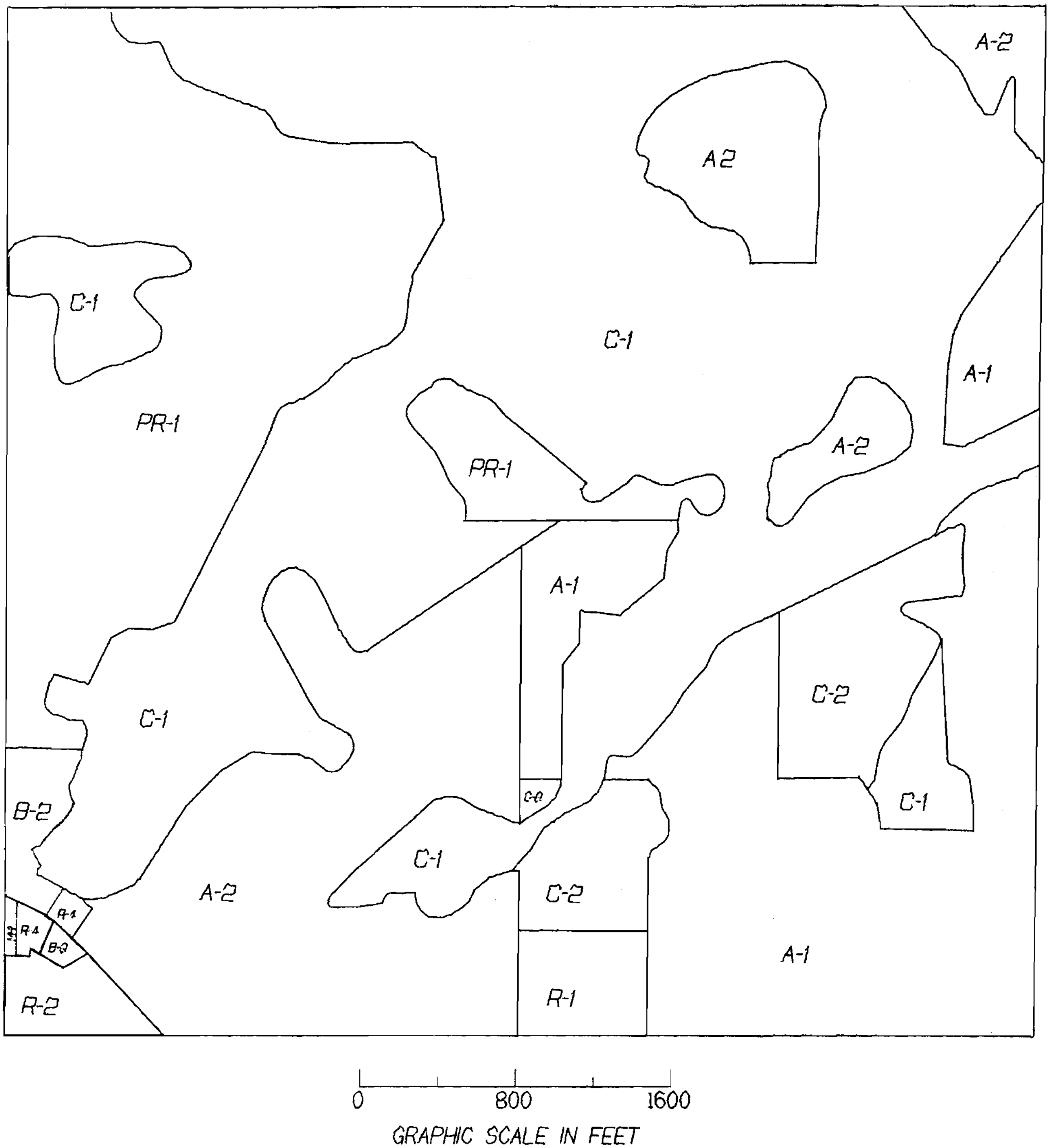
AREAL EXTENT OF LAND USE IN SECTION 14, TOWN OF RANDALL

Land Use		Area (acres)	Percent of Total Area
Code	Name		
111	Single-Family Residential–Nonfarm. . .	3.6	0.6
113	Single-Family Residential–Farm	1.9	0.3
210	Retail Sales and Service–Intensive	0.5	0.1
340	Wholesaling and Storage . .	2.5	0.4
414	Arterial Street and Expressway	1.7	0.3
418	Local and Collector Streets	3.8	0.6
811	Agricultural Cropland . . .	265.1	41.0
815	Other Agriculture and Pasture.	59.3	9.2
871	Farm Building	6.0	0.9
910	Wetland	251.5	38.9
922	Rural Unused Lands	12.3	1.9
940	Woodlands	37.8	5.8
Total		646.0	100.0

Source: SEWRPC.

Figure 21

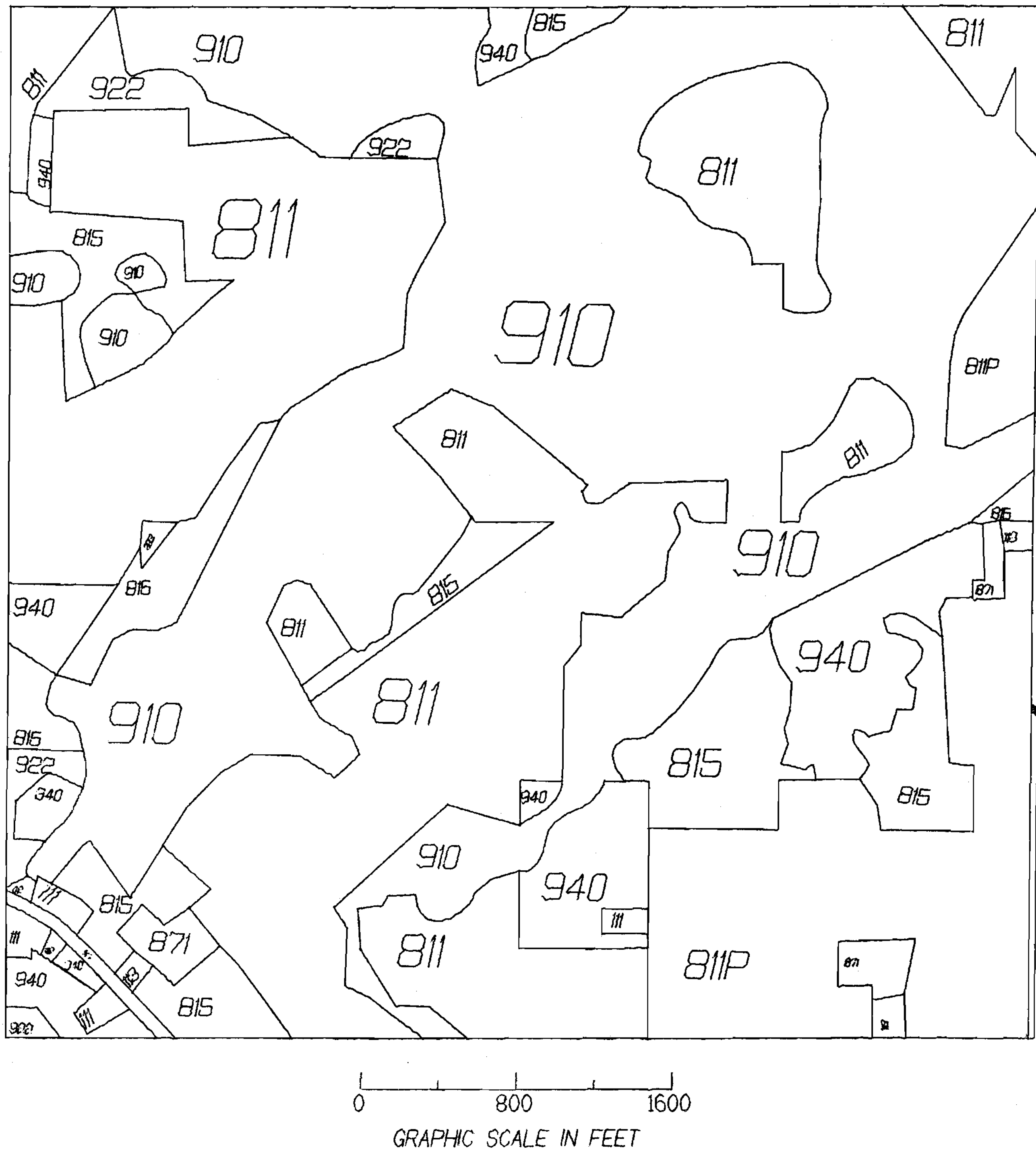
A DIGITIZED ZONING MAP FOR SECTION 14, TOWN OF RANDALL



Source: SEWRPC.

Figure 22

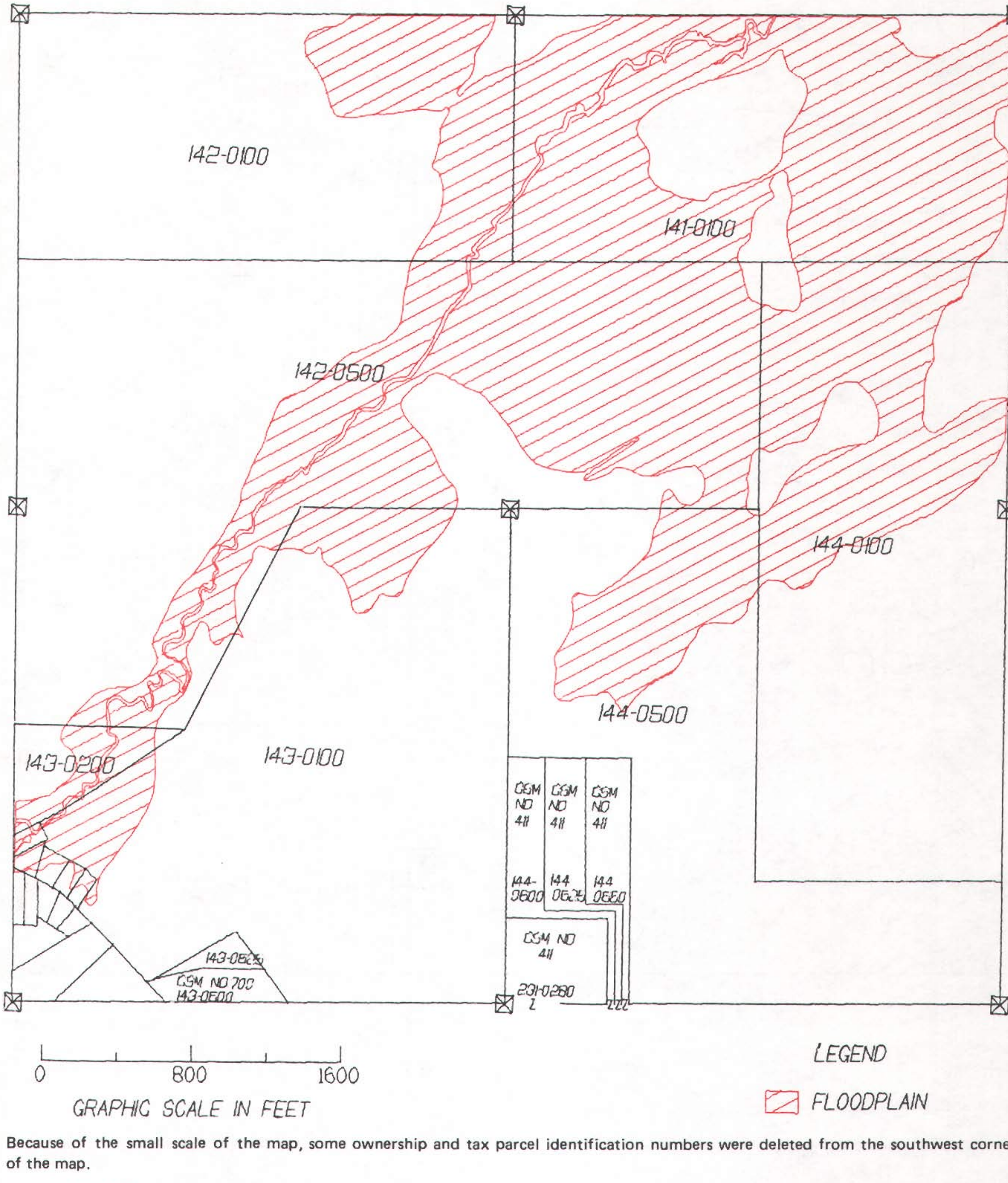
A DIGITIZED LAND USE MAP FOR SECTION 14, TOWN OF RANDALL



Source: SEWRPC.

Figure 23

OWNERSHIP AND TAX PARCELS AND DELINEATED FLOODPLAIN AREAS FOR SECTION 14, TOWN OF RANDALL



Because of the small scale of the map, some ownership and tax parcel identification numbers were deleted from the southwest corner of the map.

Source: SEWRPC.

Table 4

AREA IN A FLOODPLAIN BY OWNERSHIP AND TAX PARCEL FOR SECTION 14, TOWN OF RANDALL

Tax Parcel Number	Area in Floodplain (acres)						Area Not in Floodplain	Percent of Total	Total Parcel Area (acres)
	Water Surface	Percent of Subtotal	Land	Percent of Subtotal	Subtotal	Percent of Total			
141-0100	1.2	1.9	62.8	98.1	64.0	78.7	17.3	21.3	81.3
142-0100	0.2	1.1	18.8	98.9	19.0	23.6	61.4	76.4	80.4
142-0500	1.5	2.2	66.7	97.8	68.2	44.3	85.8	55.7	154.0
143-0100	0.1	0.9	11.3	99.1	11.4	10.3	99.3	89.7	110.7
143-0200	0.3	7.7	3.6	92.3	3.9	60.0	2.6	40.0	6.5
143-0250	0.1	20.0	0.4	80.0	0.5	100.0	0.0	0.0	0.5
143-0275	0.0	0.0	0.3	100.0	0.3	75.0	0.1	25.0	0.4
143-0300	0.0	0.0	0.2	100.0	0.2	40.0	0.3	60.0	0.5
143-0325	0.0	0.0	0.1	100.0	0.1	25.0	0.3	75.0	0.4
143-0350	0.0	0.0	0.1	100.0	0.1	33.3	0.2	66.7	0.3
143-0400	0.0	0.0	0.1	100.0	0.1	20.0	0.4	80.0	0.5
143-0410	0.0	0.0	0.0	0.0	0.0	0.0	0.4	100.0	0.4
143-0420	0.0	0.0	0.0	0.0	0.0	0.0	0.4	100.0	0.4
143-0430	0.0	0.0	0.0	0.0	0.0	0.0	0.4	100.0	0.4
143-0440	0.0	0.0	0.0	0.0	0.0	0.0	0.3	100.0	0.3
143-0450	0.0	0.0	0.0	0.0	0.0	0.0	1.0	100.0	1.0
143-0500	0.0	0.0	0.0	0.0	0.0	0.0	2.1	100.0	2.1
143-0600	0.0	0.0	0.0	0.0	0.0	0.0	2.5	100.0	2.5
143-0625	0.0	0.0	0.0	0.0	0.0	0.0	1.2	100.0	1.2
144-0100	0.0	0.0	32.5	100.0	32.5	32.1	68.8	67.9	101.3
144-0500	0.0	0.0	15.6	100.0	15.6	19.3	65.3	80.7	80.9
144-0600	0.0	0.0	0.0	0.0	0.0	0.0	4.8	100.0	4.8
144-0625	0.0	0.0	0.0	0.0	0.0	0.0	4.8	100.0	4.8
144-0650	0.0	0.0	0.0	0.0	0.0	0.0	4.8	100.0	4.8
231-0280	0.0	0.0	0.0	0.0	0.0	0.0	5.8	100.0	5.8

Source: SEWRPC.

1982. The Kenosha County zoning ordinance as adopted on May 6, 1983, placed all areas to be preserved in exclusive agricultural use in the A-1 Agricultural Preservation Zoning District.

A landowner is eligible to claim a tax credit under the Farmland Preservation Act if the following three general criteria are met:

1. The landowner is a legal resident of the State for the entire year;
2. The land produces a crop valued at $6,000 or more each year, or a total of $18,000 over the past three years; and
3. The land is subject to exclusive agricultural zoning.

Two additional criteria are required to begin, or continue, participation in the program:

1. There must be at least 35 acres of land subject to exclusive agricultural zoning within a single tax parcel; and
2. Each structure or improvement on the land must be directly related to the agricultural use of the tax parcel or related to agriculture in general as outlined in the Kenosha County zoning ordinance.

The Kenosha County Planning and Zoning Administration office is responsible for determining the acreage of land zoned for exclusive agricultural use within the tax parcels owned by a landowner applying for tax credits under the Farmland Preservation Act, as well as for determining whether the structures and improvements located within areas in the A-1 Agricultural Preservation Zoning District conform to the general agricultural uses as required by the Kenosha County zoning ordinance.

Planning and Zoning Administration staff currently use a set of one inch equals 400 feet scale, ratioed and rectified aerial photographs on which zoning district boundary lines and tax parcel boundary lines have been delineated. The zoning area boundary lines have have drawn directly on the surface of the aerial photos. The parcel boundary lines were created on each aerial photo base during map reproduction by overlaying the photo base with a one inch equals 400 feet scale reproducible tax parcel map prepared by the County Assessor's office. Although the aerial photography and the parcel boundary base maps are at the same scale, differences in the geometric control of the two source materials, as well as distortion in the photograph due to relief, result in the photograph and map not always registering correctly. Adjustments for these differences and inconsistencies must be made by staff members during the measurement process.

Area measurements are currently derived from the 1 inch equals 400 feet scale, ratioed and rectified aerial photography using an electronic planimeter. The operator key enters into the planimeter the scale of the base map which is being measured. The exterior boundaries of the area in the A-1 Agricultural Preservation Zoning District within a selected tax parcel are then traced using a pointer attached to the planimeter. When all areas in the A-1 Agricultural Preservation Zoning District have been traced, the planimeter calculates the total acreage of land in the tax parcel zoned for agricultural preservation.

An inspection of the county zoning administration records is then made to determine whether a zoning variance has been granted to permit a nonconforming use on the property. If no nonconforming use permits or variances have been granted, all buildings are assumed to conform to the uses permitted by the exclusive agricultural zoning. Once this review is completed, the land acreage in the Agricultural Preservation Zoning District and the structure and improvement compliance are entered on a Wisconsin Farmland Preservation Act zoning certificate. This form is then approved by the zoning administrator and used by the landowner when filing a state income tax form to claim tax credits from the State of Wisconsin on the property taxes paid on the land within the exclusive agricultural zone and accepted in the farmland preservation program.

An automated land information system can be used to provide the area measurements needed to complete the zoning certificate. Figure 24 displays tax parcel boundary lines, tax parcel identification numbers, zoning district boundary lines, and zoning area identification numbers for Section 14, Town of Randall. This map was produced by merging two information layers into a single machine-generated map. Figure 25 displays tax parcel 144-0100—a parcel currently in the farmland preservation program—with all zoning districts delineated within the parcel. A single system query indicates that 41.74 acres of land are zoned A-1 in parcel 144-0100. This area measurement can be entered directly on the zoning certificate as the total acreage in parcel 144-0100 which qualifies for the tax credit program. In a similar manner, the acreage of any zoning type within a tax parcel is available to the user. Table 5 sets forth acreage of each zoning district by individual tax parcel in Section 14, Town of Randall. All information in this table is available by using a system query.

Planning and Zoning Administration staff estimate that an average of about 50 requests to participate in the Wisconsin farmland preservation program are received annually. It currently requires up to one hour per application to complete the area measurements necessary to fill out the zoning certificate. This time includes retrieving the necessary source maps, setting up and calibrating the planimeter, making the measurements, and refiling the source maps. The same set of operations performed on the automated land information system require about 30 minutes.

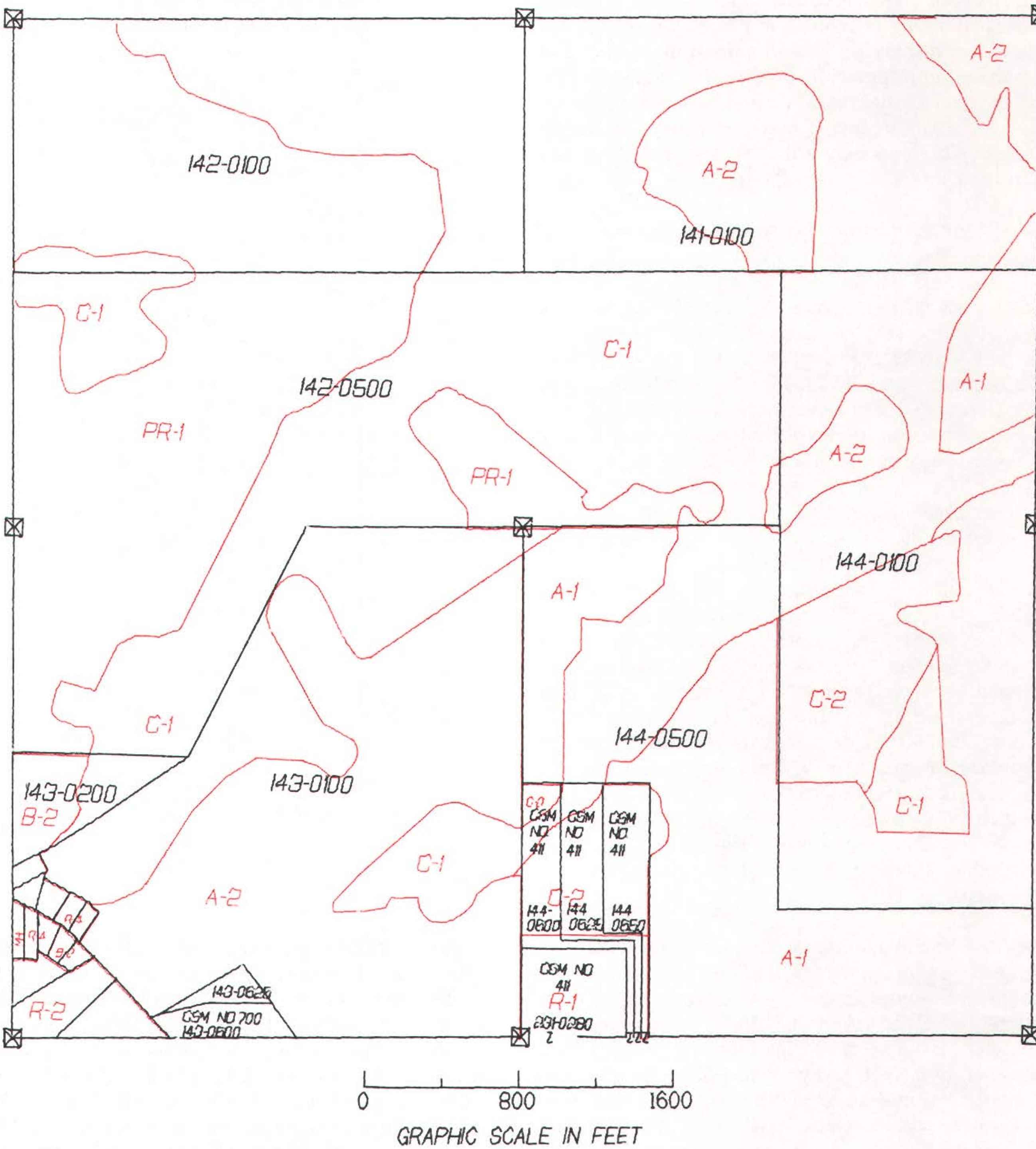
AN EXAMPLE OF SYSTEM USE IN THE PREPARATION OF MATERIALS FOR A REZONING REQUEST

Notification of a request to rezone a parcel—that is, to place a parcel in a different zoning district—must be given to each owner of land which lies within 300 feet of the parcel for which the rezoning request is to be considered. This notification consists of a letter identifying the parcel involved, a statement of the existing and proposed parcel zoning, and a site map which shows the parcel under consideration relative to the immediately adjacent land parcels.

The site maps currently prepared by the Kenosha County Planning and Zoning Administration office are usually produced from existing material

Figure 24

OWNERSHIP AND TAX PARCELS AND ZONING IN SECTION 14, TOWN OF RANDALL



Because of the small scale of the map, some ownership and tax parcel identification numbers were deleted from the southwest corner of the map.

Source: SEWRPC.

because of the limited time available for processing rezoning requests. The site maps are generally copied from the tax parcel plat maps maintained in the Assessor's office. Unfortunately, the scale of these plat maps is fixed and is not always appropriate for displaying the information needed for the proper consideration of rezoning requests. The problem is further complicated when the parcel falls along or crosses a map boundary, in which case the site maps may not show the complete area of influence of the rezoning request.

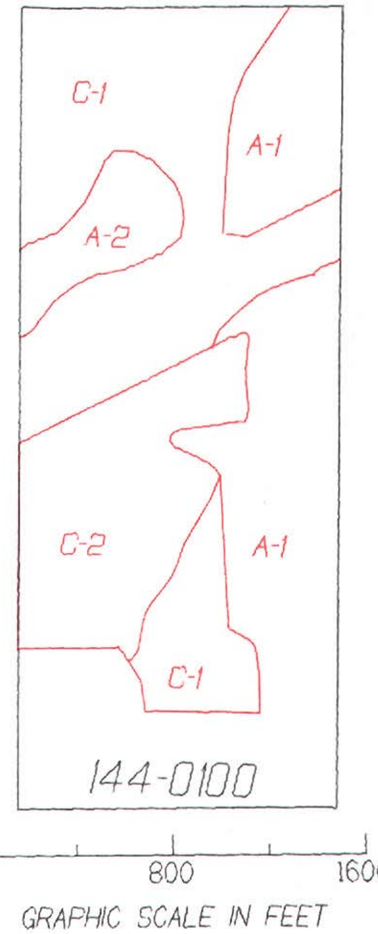
The list of landowners to whom notification of a rezoning request must be sent is presently compiled by staff within the Assessor's office. A staff person, using an engineer's scale, constructs a perimeter line 300 feet away from the boundary of the parcel to be rezoned, recording the identification number of each parcel either wholly enclosed or intersected by the perimeter line. These parcel identification numbers are then manually matched to the assessment records to determine the mailing address of each owner, and a mailing list for the notifications is compiled. Mailing labels are then typed manually.

The automated mapping and land information system developed for this demonstration can be used to prepare the materials associated with a rezoning request. The site map of the parcel to be rezoned can be reproduced at any user-defined scale, depending on the size of the area under review. Parcels lying on a land survey section boundary or even divided by a land survey section line can be merged together and displayed with the surrounding tax parcels. Figure 26 displays a sample site map for parcel 143-0300 as prepared from the digitized Town of Randall cadastral base maps.

Once the parcel site map is created by merging two adjacent cadastral maps, a line 300 feet away from the parcel boundary can be automatically constructed and displayed by the system hardware. This line is established by creating parallel line segments 300 feet away from each straight side of the parcel and an arc with a radius of 300 feet from each parcel vertex. Figure 27 displays parcel 143-0300 with a perimeter line constructed 300 feet away from all parcel boundaries. Once the perimeter line is constructed, the computer mapping system can automatically identify every parcel either wholly contained within or intersected by the perimeter line. Figure 28 displays all parcels lying within 300 feet of parcel 143-0300.

Figure 25

ZONING FOR OWNERSHIP AND TAX PARCEL 144-0100 IN THE TOWN OF RANDALL



Source: SEWRPC.

The system can then generate a list of the identifiers of all parcels so identified, as shown in Table 6. This list can then be used to prepare machine-generated mailing labels from the Assessor's computer files for each landowner to be notified of the rezoning request. Kenosha County staff estimate that two hours or more of staff time could be saved on each rezoning request by automating the process of identifying adjacent landowners and automatically preparing mailing labels.

Finally, the mapping system can be used to prepare large-scale maps for use at the Zoning Administration public hearings. The site map, prepared for mailing to landowners, can be reproduced at a

Table 5

ZONING BY OWNERSHIP AND TAX PARCEL IN SECTION 14, TOWN OF RANDALL

Tax Parcel Number	Zoning Code	Area (acres)
141–0100	A-2	23.3
	C-1	57.1
	A-1	0.9
		81.3
142-0100	C-1	36.1
	PR-1	44.3
		80.4
142-0500	C-1	82.0
	PR-1	71.6
	A-2	0.4
		154.0
143-0100	R-2	2.7
	C-1	34.9
	A-2	73.1
	C-2	0.0
		110.7
143-0200	B-2	3.8
	C-1	2.7
		6.5
143-0250	B-2	0.4
143-0275	B-2	0.4
143-0300	B-2	0.5
143-0325	R-4	0.4
143-0350	R-4	0.3
143-0400	M-1	0.4
143-0410	R-4	0.4
143-0420	R-4	0.4
143-0430	B-2	0.4
143-0440	B-2	0.3
143-0450	R-2	1.0
143-0500	R-2	2.1
143-0600	A-2	2.5
143-0625	A-2	1.2
144-0100	A-1	41.7
	C-1	36.2
	A-2	5.7
	C-2	17.7
		101.3
144-0500	A-1	61.7
	C-2	0.6
	C-1	18.5
	A-2	0.1
		80.9
144-0600	C-2	3.0
	C-1	0.6
	R-1	1.2
		4.8
144-0650	C-1	0.0
	C-2	4.3
	R-1	0.5
		4.8
144-0625	C-2	3.3
	C-1	0.7
	R-1	0.8
		4.8
231-0280	R-1	5.8

Source: SEWRPC.

larger scale suitable for display, thereby eliminating the need for preparing a separate map as is presently done.

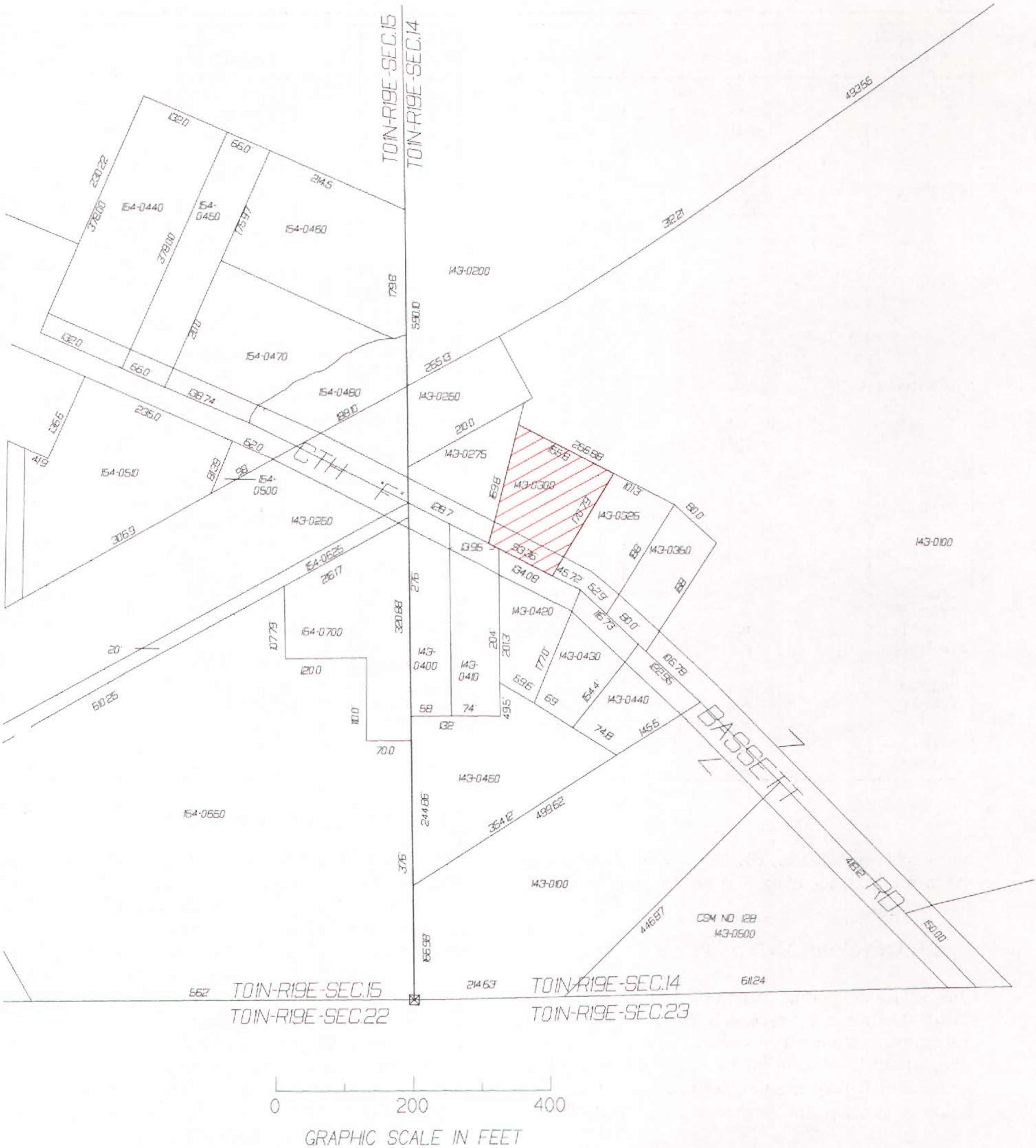
DATA ANALYSIS AND DISPLAY

One major advantage to the establishment of an automated mapping system is the ability to display information from various source materials. In addition, analysis of one of the data sources can be performed before merging with other information layers to enhance the final review and analysis.

The Kenosha County Zoning and Planning Administration staff must often review the capabilities of the soils on a parcel before acting on a rezoning request or proposed subdivision plat. Using a rating system developed by the U. S. Soil Conservation Service, each soil type can be identified as having a general soil capability—for example, a soil type may be identified as having limitations for the establishment of onsite septic systems on lots less than one acre is size. By entering the standards into the computer mapping system, each soil within the study area can be assigned to one of the general soil capability groups by machine with no manual intervention. Using graphic symbolization, a map of the various soil capabilities can be machine-generated. Figure 29 is an example of a soil capability map for Section 14, Town of Randall.

Figure 26

A SAMPLE SITE MAP FOR OWNERSHIP AND TAX PARCEL 143-0300

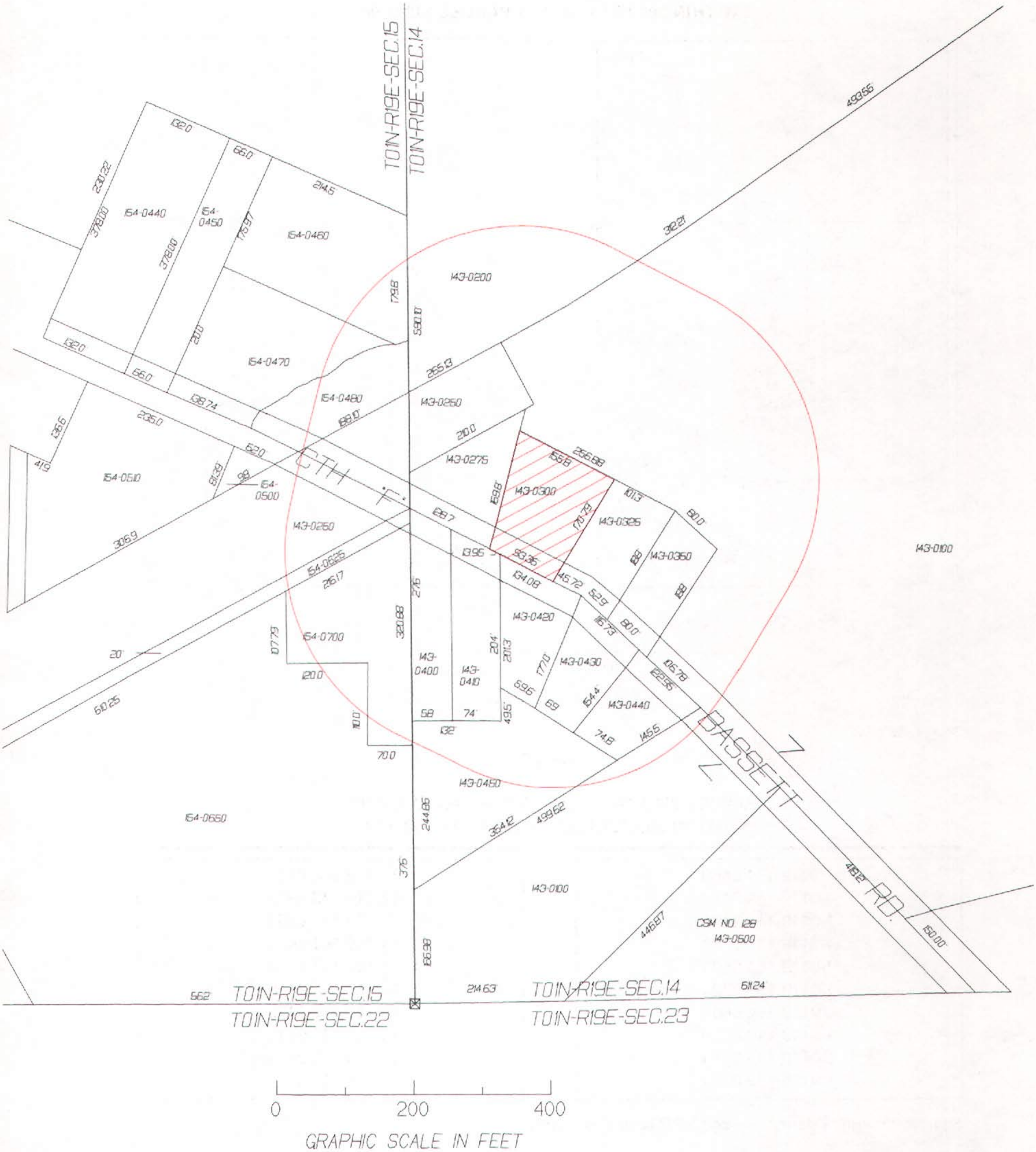


In order to maintain the legibility of the text annotation on this figure, it was machine plotted at a scale of one inch equals 100 feet and photographically reduced for printing at a scale of one inch equals 200 feet.

Source: SEWRPC.

Figure 27

OWNERSHIP AND TAX PARCEL 143-0300 WITH PERIMETER LINE CONSTRUCTED 300 FEET FROM BOUNDARIES

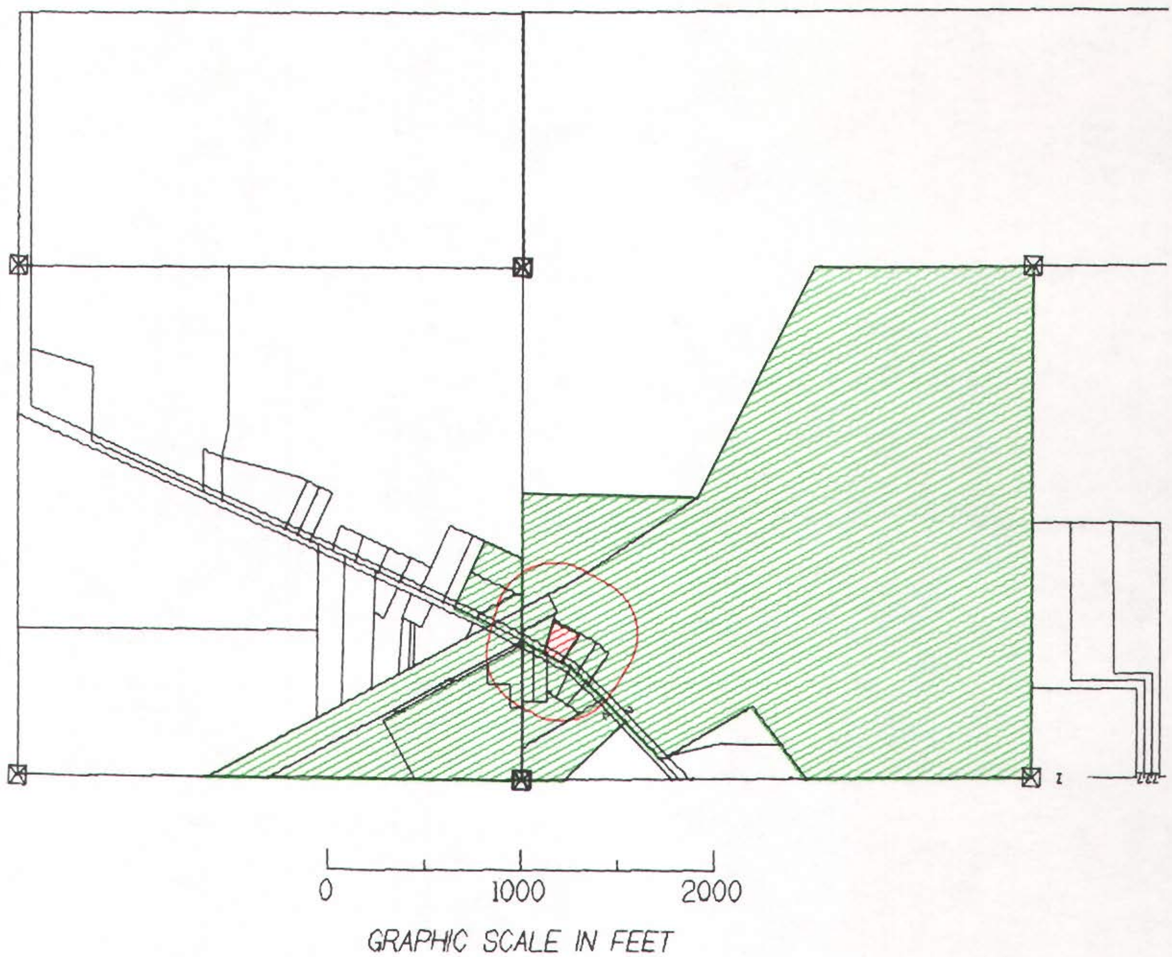


In order to maintain the legibility of the text annotation of this figure, it was machine plotted at a scale of one inch equals 100 feet and photographically reduced for printing at a scale of one inch equals 200 feet.

Source: SEWRPC.

Figure 28

OWNERSHIP AND TAX PARCELS IDENTIFIED AS LYING WITHIN 300 FEET OF TAX PARCEL 143-0300



Source: SEWRPC.

Table 6

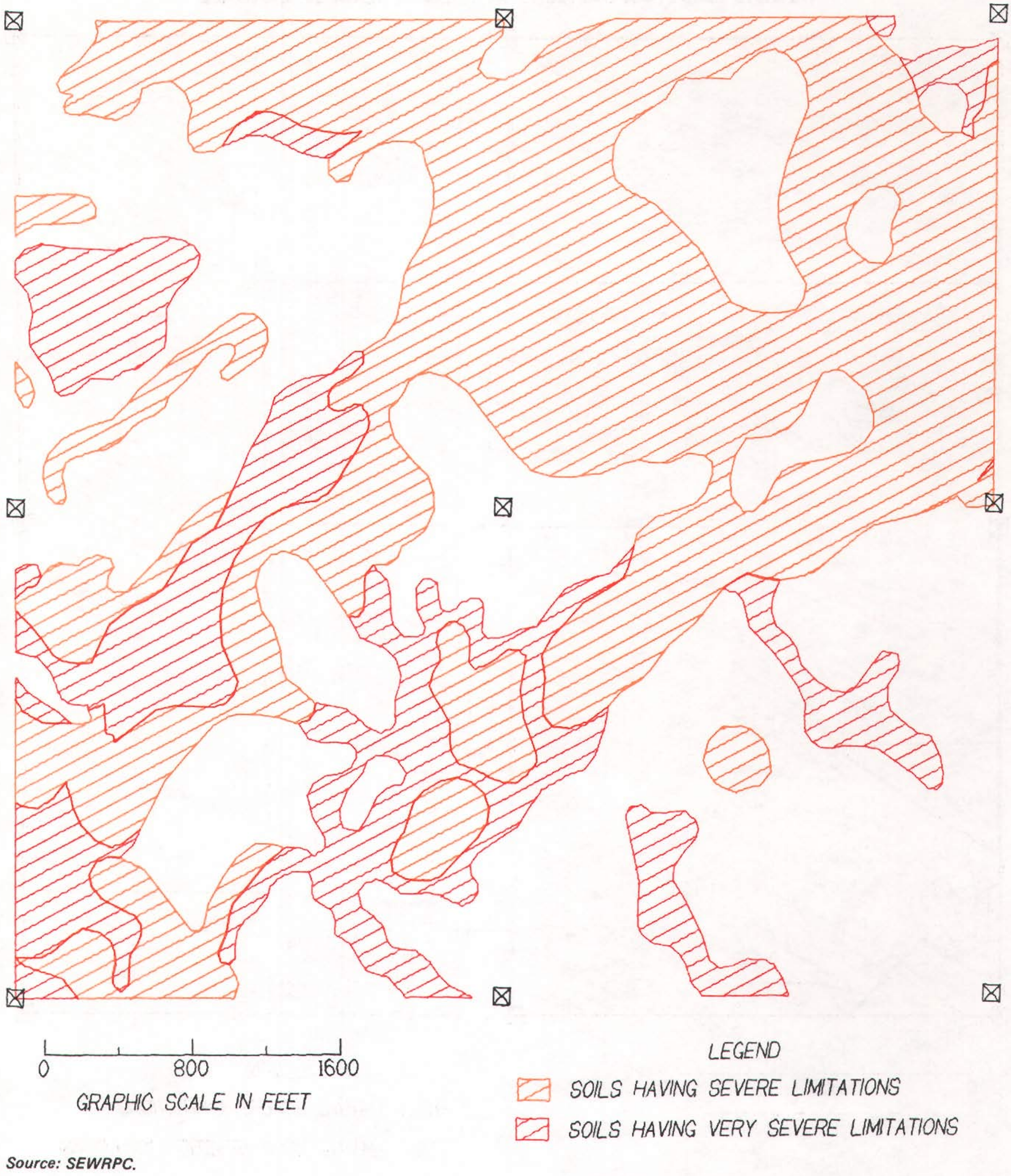
PARCEL IDENTIFIERS OF TAX PARCELS LYING WITHIN 300 FEET OF TAX PARCEL 143-0300

1-0119-154-0460	1-0119-143-0300
1-0119-154-0470	1-0119-143-0325
1-0119-154-0480	1-0119-143-0350
1-0119-143-0250	1-0119-143-0400
1-0119-154-0625	1-0119-143-0410
1-0119-154-0700	1-0119-143-0420
1-0119-154-0650	1-0119-143-0430
1-0119-143-0200	1-0119-143-0440
1-0119-145-0250	1-0119-143-0450
1-0119-143-0275	1-0119-143-0100

Source: Kenosha County Assessor's Office and SEWRPC.

Figure 29

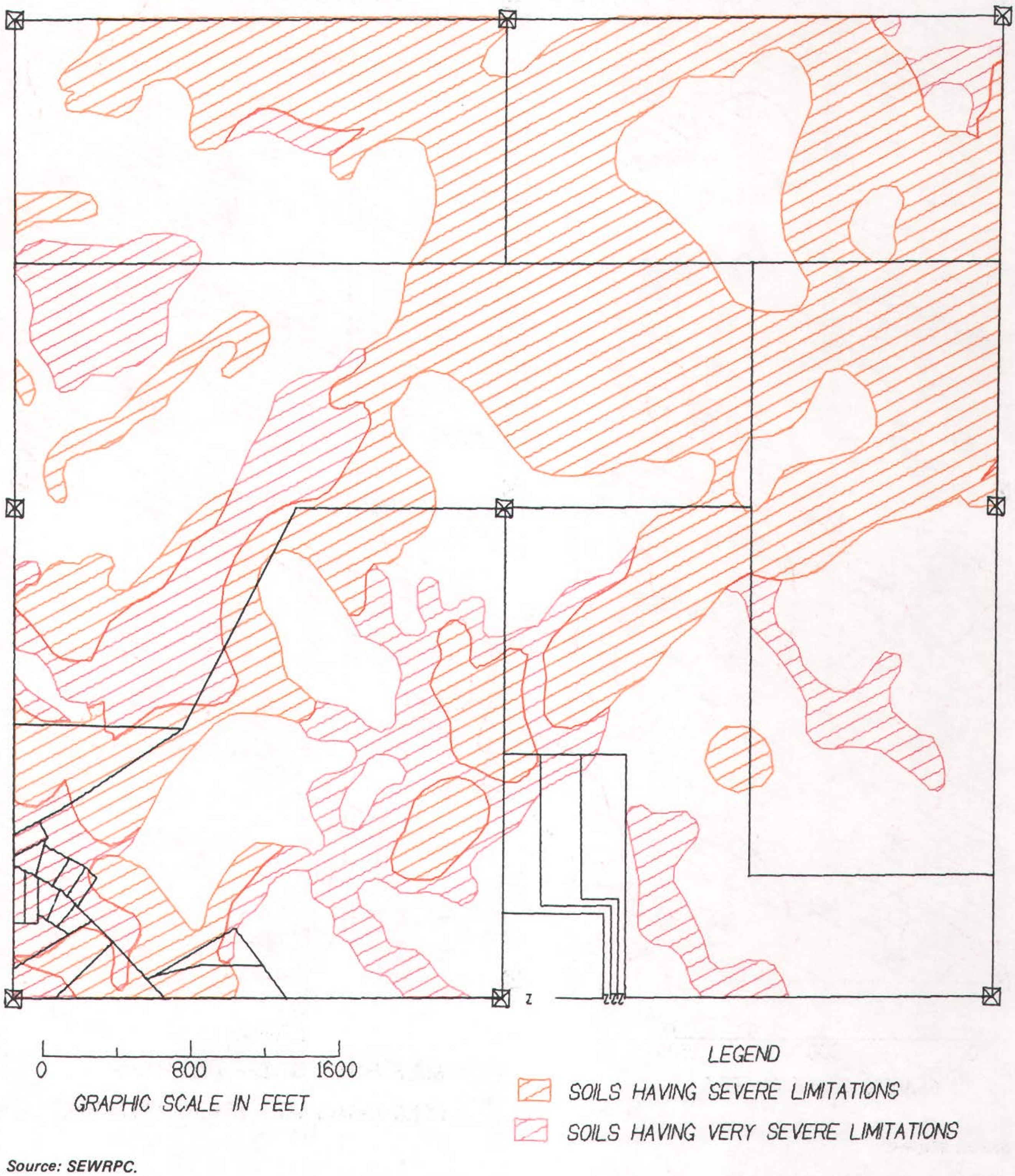
SOILS HAVING SEVERE OR VERY SEVERE LIMITATIONS FOR THE ESTABLISHMENT OF ONSITE SEPTIC SYSTEMS ON LOTS LESS THAN ONE ACRE: SECTION 14, TOWN OF RANDALL



Source: SEWRPC.

Figure 30

SOILS IN OWNERSHIP AND TAX PARCELS HAVING SEVERE OR VERY SEVERE LIMITATIONS FOR THE ESTABLISHMENT OF ONSITE SEPTIC SYSTEMS ON LOTS LESS THAN ONE ACRE: SECTION 14, TOWN OF RANDALL



Source: SEWRPC.

Once the analysis and classification of the soils data are completed, the soil capability data can become another layer of information on the mapping system which can be merged with already existing information layers. Figure 30 displays a soil capability map merged with tax parcels for Section 14, Town of Randall. This map enables a quick review of the general soil conditions for each tax parcel in the area.

SUMMARY

This chapter has described how the automated mapping and land information system described previously in this report can be applied to tasks which are currently being performed by Kenosha County staff persons. By selectively choosing data from the various information layers integrated into the automated mapping system and preparing maps of these data at any user-defined scale existing tasks can be made easier and performed more rapidly. Some typical applications were developed for the production of both general-purpose and special-purpose maps, the quantification of mapped data, the processing of applications for landowner participation in the Wisconsin farmland preservation program, and the preparation of materials for the processing of a rezoning request. The applications described in this chapter are by no means an exhaustive list but rather illustrative of the types of uses which can be derived from an automated mapping and land information system.

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Chapter V

FINDINGS AND RECOMMENDATIONS

INTRODUCTION

This chapter sets forth the pertinent findings of the demonstration project reported herein. It also reports the costs associated with the development of the digitized cadastral maps and of the various data components chosen for integration into the land information system. Finally, recommendations are presented based upon the experience gained from this demonstration. These recommendations are of two types: first, general recommendations that would be of value to any governmental unit considering the development of an automated mapping and land information system; and second, specific recommendations concerning the continued implementation and development of the reported system in Kenosha County.

FINDINGS

Perhaps the major finding to emerge from the demonstration project is that the implementation of a limited-purpose automated mapping and land information system, as described in preceding chapters, is feasible with existing technology, and that the development of such a system can be accomplished—at least in Kenosha County—at a reasonable cost. Typical costs based upon project experience are set forth in this chapter.

Establishment of a Geographic Reference Framework

One of the primary recommendations of the National Research Council was that local automated mapping and land information systems be based upon a permanently monumented and maintained geographic reference framework. Experience gained in the project reported herein supports the importance of such a recommendation. It has been noted in this report that the remonumentation work in the project area had been accomplished prior to the initiation of the project under a separate countywide remonumentation and mapping program. It has also been noted that the land use inventory was accomplished outside the confines of the reported project. The use of a common geographic reference framework in these initially unrelated activities allowed the material from various projects undertaken at different times by different agencies to be merged in an effective and economical manner.

An additional finding pertains to the manner in which a permanently monumented and maintained geographic reference framework was used to establish the map projection grid for the project area. The coordinates for the U. S. Public Land Survey corners were key-entered into a computer to the nearest 0.01 foot, and placed by the computer upon the State Plane Coordinate grid system. Under the control survey system utilized, the U. S. Public Land Survey corners had been integrated into the geodetic control network by field surveys meeting Third Order, Class I accuracy standards, and thereby converted into a geodetic, or earth-based, control network as well as a real property boundary survey control network. The practical result of this operation is that the map projection grid that is produced is essentially scale independent; that is, it could be used for any mapping scale up to and including 1 inch equals 1 inch. Such a map projection system will never be subject to precision inadequacies as a result of changes in mapping scales.

Preparation of Current Large-Scale Topographic Maps

The National Research Council also recommends that a set of current, large-scale topographic maps be prepared for use in conjunction with local automated mapping and land information systems. Again, the experience gathered in this project supports the importance of this recommendation. Through use of these maps, the location of cultural features—such as structures and pavement edges—can be accurately mapped, along with the location of naturally occurring features such as hydrography. These maps also provide the high precision base necessary for the accurate mapping of such features as the limits of floodplains and shoreland areas, in addition to providing a high precision base for the cadastral mapping effort.

Preparation of Cadastral Maps

The preparation of the cadastral maps was perhaps the most difficult part of the project. As originally envisioned, the project would have utilized the recorded records of property ownership maintained by the County Register of Deeds to produce abstracts of title suitable for mapping property ownership. It was determined prior to the initiation of the project, however, that the County Assessor's office had already performed this abstracting function as part of its legal responsibilities to prepare tax assessment rolls. Accordingly, the abbreviated tax record descriptions maintained by the County Assessor were utilized to identify individual ownership parcels. In some cases, the contents of these descriptions have been greatly abbreviated, adjoiners all but eliminated, dimensions and bearings rounded to whole numbers, and metes and bounds descriptions of remainder parcels concocted for assessment description purposes, rather than having reference to a recorded document. Nevertheless, with a modest amount of supplemental research—representing about 10 to 15 percent of the total property boundary research effort—into old surveys or recorded deeds, with reference to plats of surveys filed in the County Surveyor's office in accordance with recently promulgated legal requirements,[1] and with very limited field surveys to check or establish the location of property boundary lines on the ground, these abbreviated descriptions provided an adequate basis for the preparation of cadastral maps for the project.

It should be noted that the problems encountered in preparing the cadastral maps were not related to the use of abbreviated descriptions; rather, they were the result of difficulties that would have been encountered regardless of the source material used for the determination of property ownership boundaries. These problems include, for example, the occasional use of incorrect locations for U. S. Public Land Survey corners because of the lack of permanent monumentation of this system until about 1980 in the project area. Additional problems encountered were the result of poor land surveying practice, such as the occasional improper use of quarter-quarter corners as occupied corners, the use of fence lines to describe boundaries, and the preparation of property ownership descriptions referenced to highway and railway right-of-way lines, and containing no reference whatsoever to the Public Land Survey System.

Preparation of Digital Cadastral Maps

The cadastral maps were prepared on a high precision base to strict standards of accuracy regarding the placement of the cadastral boundary lines. In digitizing these maps, it was discovered that the system being utilized for the digitization could occasionally go out of adjustment by small amounts, such that an offset of the digitized line from its mapped position on the order of 0.05 inch, or 10 to 15 feet at the map scale, could occur. Investigation revealed that this problem has both a mechanical and an electronic component. Mechanical deflection could occur in that the design of the cursors used in the digitizing process allowed for some movement of the digitizer cross-hair relative to the electronic antenna in the cursor. Electronic deflection could occur if the voltage adjustments on certain digitizer components were not within the design tolerances. In other words, a slightly weaker or stronger electrical signal from the digitizer cursor could result in placement of a point in the digital file slightly offset from the map location. As a result, it was necessary on several occasions to recalibrate and readjust the digitizer components to minimize the deflection caused by these occurrences.

Calibration routines for the digitizer were developed to permit the presence or absence of this condition in the digitizer cursor to be evaluated on a regular basis and adjustments made as necessary. In order to determine if mechanical adjustment was necessary, the cursor was centered over a "bullseye" attached to the digitizer table, and the coordinates for the position were calculated by the machine. The cursor was rotated 90 degrees and a second set of coordinates determined. If the two sets of coordinates determined in this manner varied by more than 0.01 inch, or two feet at the map scale, the cursor was readjusted. To check for electronic deflection, a steel straight edge was attached to the digitizer table at an approximate 45-degree angle. The cursor was successively placed at each end of the straight edge, a set of coordinates calculated, and these two coordinate pairs connected by a straight line constructed by the digitizer. The cursor could then be moved along the straight edge while its position was "echoed" on the digitizer display screen. Deflection could thus be determined visually and, if necessary, calculations could be made of the magnitude of the deflection occurring, again indicating whether or not calibration of the machinery should be undertaken.

Design of a System Data Structure

The preparation of a digital map, or system of digital maps, requires the design of the manner in which individual map elements and relationships

[1] *Wisconsin Statutes Section 59.60(G).*

will be stored inside the computer memory. This system is commonly referred to as the "data structure." Careful consideration should be given to this element in the implementation of an automated mapping and land information system, as it is of critical importance that the designer of an automated mapping system fully understand both the hardware and software capabilities of a particular system as they relate to the agreed-upon system products. For example, the need to obtain area measurements as a system product requires special design considerations for some hardware/software systems. Also, the digitization of complex maps containing large numbers of map elements generally results in an increase in the complexity of the data structure design and in the relationships of the various storage elements within a data structure. It also results in an increase in the size of the computer storage necessary for a particular automated mapping and land information system.

It should be further noted in this regard that, while the use of a system of manual maps can depend, in part, on the ability of an experienced map reader to recognize implicit relationships among various map elements in making an interpretation of map features, the design of a data structure for a digital map cannot rely upon implicit relationships. Instead, all map element relationships within the data structure must be explicitly specified. This requires the sometimes complex task of enumerating and preparing explicit definitions, including all allowable exceptions, for map features. As an example, a map reader can view a mapped line and determine if it is a parcel boundary, an easement line, a roadway or railway right-of-way limit, a quarter-section line, or any other type of map feature representation. More importantly, an experienced map reader can, by reviewing the location and character of the line and its relationships to other lines and map annotation, determine if the mapped line represents more than one of these map features and, if so, how many features. The design of a data structure for a digital map, however, must provide for the explicit definition of each line by type and, furthermore, provide for any and all multiple uses of each particular line. Failure to give adequate consideration to this requirement can result in having to redesign the data structure on numerous occasions as the project progresses.

COSTS

One of the stated purposes of the project reported herein was the determination of the costs attendant to the establishment of an automated mapping and land information system. For the purposes of this discussion, costs are grouped into two categories: first, the costs of the procedures that result in the creation of the geographic reference framework and the preparation of the topographic and cadastral maps; and second, the costs of the procedures that result in the creation of the digital map files. All costs are presented in 1985 dollars. Table 7 sets forth the average costs per square mile for the different system components.

Table 7

AVERAGE COSTS PER SQUARE MILE TO DEVELOP THE DESCRIBED AUTOMATED MAPPING AND LAND RECORDS SYSTEM IN THE PROJECT AREA

System Element	Average Cost per Square Mile (1985 dollars)
Relocating and Monumenting U. S. Public Land Survey Corners, Establishing Reference Marks and Related Ties, and Preparing Dossier Sheets and Attendant Certificates. . . .	$1,400.00
Control Survey Work, Including Establishment of State Plane Coordinates and Elevations for Monumented U. S. Public Land Survey Corners	$2,200.00
Preparation of Topographic Base Maps and Cadastral Base Sheets (1:2400 scale), Including Aerial Photography Costs.	$1,960.00
Preparation of Cadastral Maps.	$1,200.00
Preparation of Digital Map Files:	
Establishment of Map Projection Grid and Computer System Data Structure	$ 62.50
Digitization of Water Features, Floodplain Boundaries, and Shoreland Area Boundaries.	80.00
Digitization of Structure Outlines.	80.00
Digitization of Pavement Edges	93.75
Digitization of Land Ownership Parcels	800.00
Digitization of Soils Inventory	112.50
Creation of Land Use Overlay	150.00
Creation of Zoning District Overlay . . .	25.00
Subtotal	$1,403.75
Total	$8,163.75

Source: SEWRPC.

Establishment of the Geographic Reference Framework and Preparation of Topographic and Cadastral Maps

It has been noted in this report that the completion of the basic land surveys, control surveys, and topographic maps had been carried out within the project area prior to the initiation of the reported project. However, since one of the stated purposes of the project was to develop an automated mapping and land information system in accordance with the procedural model proposed by the National Research Council, the costs associated with these steps—while completed outside the project reported herein—are included in the interest of completeness. Perhaps more importantly, they are summarized here recognizing that in many jurisdictions it will be necessary to complete these steps prior to the development of an automated mapping and land information system. In any consideration of such costs, the complexity of the factors influencing the unit costs must be recognized, including, in particular, the size, configuration, and character of the area to be mapped.

Within the project area, the land surveying entailed in relocating and monumenting the U. S. Public Land Survey corners, establishing the reference marks and related ties, and preparing the necessary dossier sheets and attendant certificates was accomplished at a cost of about $270 per corner. The equivalent work in other sections of southeastern Wisconsin where this work has been carried out has ranged from a low of about $80 per corner to a high of about $540 per corner, typically approximating $270 per corner.

The control survey work, including establishment of state plane coordinates and elevations for the monumented U. S. Public Land Survey corners, was accomplished at a cost of about $425 per corner within the project area. The cost of equivalent work in other parts of southeastern Wisconsin has ranged from a low of about $95 per corner to a high of about $890 per corner, typically approximating $540 per corner.

The preparation of topographic maps and cadastral base sheets within the project area was accomplished at a cost of about $1,960 per square mile for 1:2400 scale mapping, including the costs of necessary aerial photography. Costs for equivalent mapping within other areas of southeastern Wisconsin have ranged from a low of about $780 per square mile to a high of about $11,100 per square mile, typically approximating about $2,300 per square mile for 1:2400 scale mapping and $5,700 per square mile for 1:1200 scale mapping.

Within the project area, the preparation of cadastral maps was accomplished under a contract with a consultant retained by Kenosha County for approximately $4.00 per parcel. It should be noted, however, that in negotiating this contract Kenosha County agreed to provide necessary work space and equipment to the consultant for completion of the cadastral mapping, thus absorbing the overhead costs of cadastral map preparation. In other areas of southeastern Wisconsin, the costs of preparing cadastral maps utilizing a private contractor have ranged from $13 to $54 per parcel, typically approximating $13 per parcel.

Preparation of Digital Map Files

Costs for the digitization of the various map files were computed on the basis of a $25-per-hour cost for a digitizer operator working at a digitizing station. About 28 percent of this amount, or about $7.00 per hour, represents the original capital expense of the equipment—about $304,000—amortized over an assumed five-year operating life. About 49 percent of this amount, or about $12.25 per hour, represents the cost of operating the machinery, including the salaries of operators and supervisory personnel, maintenance and repair of the digitizing system, and consumable supplies. The remaining 23 percent, or about $5.75 per hour, represents indirect overhead expenditures, such as utilities and space rental. Recognizing that methods of establishing costs may vary from system-to-system, depending upon the accounting methods in effect, per-unit time requirements necessary to complete the various components of the digital files are also presented to enable costs to be computed under differing accounting schemes.

The development of digital map files for the 24 cadastal map sheets, each of one square mile contained in the study area, required that the map projection grid, the State Plane Coordinate System locations of the U. S. Public Land Survey corners, and the lines connecting those corners be established for each individual map sheet. Also required was the establishment of an appropriate data structure for the storage of the various map elements, including the ownership parcels, the various map feature overlays such as land use and zoning, and necessary annotation. This operation required approximately 2.5 hours per map sheet—each map sheet covering approximately one square mile—and thus entailed a cost of about $62.50 per square mile.

The digitization of water features, floodplain boundaries, and shoreland area boundaries from the large-scale topographic base maps was accomplished as a single operation, requiring an average of slightly more than three hours per map sheet. Accordingly, the cost for the digitization of these features was about $80 per square mile.

The digitization of structure outlines required an average of slightly more than three hours per map sheet, and thus entailed a cost of about $80 per square mile. The digitization of the pavement edges of public streets and highways required an average of 3.75 hours per map sheet, or a cost of about $93.75 per square mile.

The digitization of the land ownership parcels was one of the more time-consuming and, therefore, more expensive operations in the demonstration project, and required an average of about 32 hours per map sheet, and thus entailed a cost of about $800 per square mile.

Three files of land-related map information were prepared as part of the demonstration project: soils, land use, and zoning districts. The amount of time required to incorporate these three files into the system varied widely because of the differences in the character and complexity of the inventory maps and the density of the polygons represented by the different categories of land-related information.

The soils inventory utilized in the demonstration project featured a relatively moderate polygon density having a nonrectangular character. It required an average of about 4.5 hours per map sheet, or about $112.50 per square mile, to complete. This included, in addition to the digitizing time, the quality control and revision operations that should be instituted in any original data collection operation.

The land use overlay, as noted earlier in this report, was not digitized as a part of this demonstration project, but was a pre-existing file completed as part of the Commission's digitization of its 1980 regional land use inventory. This file has a relatively high polygon density and a largely rectangular character. For purposes of the project demonstration, selected land use lines were adjusted in the creation of this file to more precisely fit the cadastral map, taking into consideration the differences in the compilation scales and the relative precision of the two maps, and the availability of parcel boundary lines. These operations required an average of about six hours per map sheet, thus entailing a cost of about $150 per square mile.

The zoning district boundary overlay was by far the simplest of the three land-related information files to prepare, the zoning districts being much less dense than either the soil polygons or the land use polygons. In addition, it was possible in constructing the zoning district boundaries to utilize many of the parcel segment and land use lines already collected. This eliminated the need to redigitize these features, and it was necessary only to copy them from existing locations within the data structure. As a result, preparation of the zoning district boundary overlay required an average of only about one hour per map sheet, or an average cost of about $25 per square mile.

In addition to the costs associated with actual data collection, about six man-weeks of effort were necessary to program the digitizing system for the project, including writing, testing, and revising the computer code and performing controlled tests on the digitizing system for the collection, formatting, and storage of the digital map files. The cost of this work is estimated at $5,100.

Typical Costs for Complete System Implementation

On the basis of experience gained in the project area, it is estimated a limited-purpose automated mapping and land information system based upon the recommended National Research Council model can be developed for about $8,200 per square mile in 1985 dollars. It must be stressed that this cost is influenced by the character of the project area—in more rural areas the cost could be expected to be less, whereas in more urban areas the cost would be higher. Of the $8,200 amount, about $1,400 per square mile, or about 17 percent, is entailed in the land survey work involved in relocating and monumenting the U.S. Public Land Survey corners; about $2,200 per square mile, or about 27 percent, is entailed in control survey work, including the establishment of state plane coordinates and elevations for the monumented U. S. Public Land Survey corners; about $2,000 per square mile, or about 24 percent, is entailed in the preparation of 1:2400-scale topographic maps and cadastral base sheets, including the cost of necessary aerial photography; about $1,200 per square mile, or about 15 percent, is entailed in the preparation of cadastral maps; and about $1,400 per square mile, or about 17 percent, is entailed in the preparation of the digital files described in this report. In jurisdictions where some of the necessary elements for the creation of automated mapping and land information systems are already in place, the per-square-mile costs of implementing a system will be correspondingly reduced. Indeed, in the project area the cost was reduced, for this reason, to about $2,600 per square mile.

In consideration of these costs it should be noted that good local planning and engineering practice in urban and urbanizing areas already requires the preparation of large-scale topographic base maps and cadastral maps tied to a local survey control network of sufficient precision to permit the accurate location and correlation of both cadastral and earth science data. Viewed within this context, the additional cost to prepare digital files of local land records is an affordable one. In rural areas, smaller scale maps may be sufficient for local needs, thereby reducing the costs of providing the survey control network and attendant map products. But even in rural areas, an integrated system consisting of a permanently monumented survey control network and attendant topographic and cadastral maps should be established.

RECOMMENDATIONS

As a result of experience gained in the project reported herein, a number of recommendations can be made concerning the establishment of an automated mapping and land records information system. For the purposes of this report, recommendations are divided into two major categories. The first category consists of general recommendations for consideration by jurisdictions investigating the establishment of an automated mapping and land records information system. The second category consists of specific recommendations to be considered by Kenosha County for the continued development of a countywide automated mapping and land information system. While these recommendations are intended specifically for Kenosha County, they may also be of interest to jurisdictions considering the establishment of such a system.

General Recommendations

The first steps in the establishment of an automated mapping and land records information system should be the establishment of a geographic reference framework and the preparation of current, large-scale topographic base maps, as recommended by the National Research Council. The importance of the establishment of a sound geometric framework and related large-scale topographic base maps as a sound foundation for multi-purpose cadastres is apt to be overlooked by decision-makers as a technical detail in their deliberations over the other important issues involved in the creation of such systems. The establishment of a sound geometric framework and the proper preparation of the related base maps and cadastral overlays is, however, a fundmental undertaking that clearly will require much understanding, foresight, and commitment on the part of the technicians and decision-makers concerned. Failure to make the proper decisions concerning the basic technical foundation of any land data system during its formative period may well jeopardize the future utility of the system, as reform will become increasingly costly and difficult over time.

Existing property boundary maps and legal descriptions should be reviewed carefully prior to the initiation of any conversion of these records to digital format. While the existing records may, in fact, prove suitable and adequate for the conversion, the adequacy should not be assumed in the absence of a proper, comprehensive, and in-depth review of the materials.

Any program to establish an automated mapping and land records system should provide adequate resources and staff to perform review and quality control operations on all intermediate and final products produced. In this regard, the importance of performing quality control operations at various intermediate points in the project must be stressed, since problems can be corrected in a more cost-effective manner if they are discovered early in the preparation of the final product.

The implementation of any system should be preceded by a pilot project. There are two reasons for this. First, the conduct of a pilot project allows for refinement of initial map and record conversion procedures on the basis of actual experience. Second, a pilot project permits the development of better cost estimates for the conversion process. While the cost estimates provided in this report are believed to be applicable for most local efforts in southeastern Wisconsin, it is recognized that situations vary from jurisdiction to jurisdiction, and that much better cost estimates for long-term implementation of automated mapping and land information systems can be derived if they are based upon actual local situations.

Specific Recommendations for Kenosha County

On the basis of experience gained in this demonstration project, it is recommended that Kenosha County continue to move toward the establishment of a countywide automated mapping and land records information system. Initially this will require that the County continue the geographic expansion of the reported system. Over time, the County can continue to develop additional applications, perhaps based upon the digitization or incorporation of additional land-related information. The demonstration has established that the implementation of such a system is indeed feasible with existing hardware and software products.

To ensure that the information contained in the system remains current, it will be necessary to establish update mechanisms for the various information components in the system. The particular type of mechanism will vary based upon each type of information contained in the system and the source of the information.

The maintenance of current property boundary information is of central importance to the integrity of the described automated mapping and land information system. The filing of land subdivision surveys, certified survey maps, and plats of survey is currently controlled by appropriate sections of Kenosha County ordinances and Wisconsin Statutes. It should be noted, in this regard, that the Kenosha County Subdivision Control Ordinance presently requires that all newly filed land subdivision surveys and certified survey maps be tied directly to one of the section or quarter-section corners that have been relocated, monumented, and placed on the Wisconsin State Plane Coordinate System if the plat is located within a U. S. Public Land Survey quarter section where this work has been completed. Further, the exact grid bearings and distance of the tie are required to be established by field measurements, and the Wisconsin State Plane Coordinates and material of the monument marking the corner are required to be indicated on the plat. Since all distances and bearings shown on these plats are further required to be referenced to the Wisconsin State Plane Coordinate System and adjusted to the control survey, these plats will fit precisely within the cadastral maps that have been prepared as part of this project.

As filing of these documents occurs in accordance with appropriate sections of the county ordinances and State Statutes, a record of these filed documents should be maintained in a central location, with the maps and digital files to be updated on a regularly scheduled basis. It is initially recommended that the property boundary locations in the system be updated every six months; experience will determine if a different frequency is more desirable.

The maintenance of areawide inventories, such as soil units, land use, and zoning districts, will require different mechanisms. In the case of certain natural resource inventories, such as soil units, updates or revisions tend to be rare, and once these types of natural resource inventories are captured in a digital format they should seldom need to be revised. Regarding the land use inventory, this inventory is updated by the Commission about once every five years, and updated files of land use can be obtained by Kenosha County from the Commission as they become available. The revision of zoning districts is covered by Kenosha County ordinance and this information can be updated following a schedule similar to that used to update property boundary locations.

The locations of lines showing the limits of floodplains and shoreland areas are determined through special technical studies. Therefore, this type of information will be established or updated on an irregular basis, preferably following the completion of the appropriate studies and the delineation of the particular limits.

In order to establish a reasonable update mechanism, it will be necessary to budget the revision costs to the system on an ongoing yearly basis. These costs are best established on the basis of experience over time; however, in the absence of such experience, it is initially recommended that 5 percent of the original system data conversion costs, or about $125 per square mile, be budgeted to accomplish updates to the system. Over a period of several years it will be possible to better estimate the yearly cost of system updates.

SUMMARY

This chapter has set forth pertinent findings of the demonstration project described in preceding chapters, including representative costs associated with the development of the digitized cadastral maps and the various data components chosen for integration into the land information system. It has also presented recommendations for the implementation of these systems in other jurisdictions based upon project experience. The major finding to emerge from the demonstration project is that the development of limited-purpose automated mapping and land information systems, such as described in this report, is feasible with existing hardware and software systems and can be accomplished at affordable costs.

One important finding to emerge from the project is the wisdom of establishing and using a permanently monumented and maintained geographic reference frame. The use of such a system allows materials from different projects undertaken at different times by different agencies to be merged in an efficient and economical way. The reference frame also provides the basis for a highly precise map projection grid that is, in effect, scale independent.

The wisdom of preparing a set of current, large-scale topographic base maps is also demonstrated by project experience. These maps provide for the accurate location of both cultural and natural features, in addition to providing a highly precise base upon which the cadastral maps can be constructed.

The results of the demonstration project also indicated that the preparation of cadastral maps can be expected to be a time-consuming and difficult part of the implementation of a modernized automated mapping and land records system. Preparation of these maps will require careful interpretation of occasionally incomplete, and sometimes conflicting, source material and occasionally tedious and time-consuming research into old documents and surveys, and, as a last resort, may require the use of land survey crews in the field to obtain final determination of the "correct" location of mapped land ownership boundaries. Nevertheless, it was determined that the abbreviated property ownership descriptions provided an adequate basis for the preparation of cadastral maps. Indeed, those difficulties encountered were a function of factors such as poor land surveying practices and the lack, until very recently, of permanent monumentation of the U. S. Public Land Survey corners, rather than the use of abbreviated descriptions.

The results of the project indicated that perhaps the most troublesome issue to be dealt with in the development of digital files is the design of the data structure, or the manner in which all information contained in the system is organized and stored for manipulation by a computer. Particularly noteworthy, in this regard, is the need to establish very detailed, explicit relationships among the various map elements. Unlike a system of manual maps and records, which can rely upon the ability of a human operator to supply necessary implicit relationships for interpretation of various records and map elements, automated systems require the statement of explicit rather than implicit relationships.

Typical costs for the development of an automated mapping and land information system were developed on the basis of project experience. In addition, costs for the development of all elements of the procedural model proposed by the National Research Council for the development of such systems were prepared, including costs incurred outside the project reported herein. While the costs are believed to be representative of typical local conditions, it must be recognized that these costs could vary for individual local jurisdictions depending on the complexity of such factors in these jurisdictions as the size, configuration, and character of the area to be mapped.

Based upon experience in the project area, it is estimated that a limited-purpose automated mapping and land information system based upon the recommended National Research Council model can be developed for about $8,200 per square mile in 1985 dollars. Of this amount, about $1,400 per square mile, or about 17 percent, is entailed in the land survey work involved in relocating and monumenting U. S. Public Land Survey corners; about $2,200 per square mile, or about 27 percent, is entailed in control survey work, including the establishment of state plane coordinates and elevations for the monumented U. S. Public Land Survey corners; about $2,000 per square mile, or about 24 percent, is entailed in the preparation of 1:2400-scale topographic maps and cadastral base sheets, including the cost of necessary aerial photography; about $1,200 per square mile, or about 15 percent, is entailed in the preparation of cadastral maps; and about $1,400 per square mile, or about 17 percent, is entailed in the preparation of the digital files described in this report. In jurisdictions such as Kenosha County, where some of the necessary elements for the creation of automated mapping and land information systems are already in place, the per-square-mile cost to implement the system will be correspondingly reduced. For this reason, the cost in the project area was reduced to about $2,600 per square mile.

Five general recommendations are presented for jurisdictions considering the establishment of an automated mapping and land records information system. These are: 1) the establishment and use of a permanently monumented and maintained geographic reference framework as recommended by the National Research Council; 2) the preparation of a set of current, large-scale topographic base maps, as also recommended by the National Research Council; 3) a comprehensive and in-depth review of the adequacy of existing property boundary maps and legal descriptions prior to the initiation of any conversion of these records to digital format; 4) the provision of adequate resources and staff personnel to perform review and quality control procedures on all intermediate and final products produced as part of the implementation of a modernized land records system; and 5) the conduct of a pilot project.

It is recommended that Kenosha County continue to move toward the establishment of a countywide automated mapping and land records information system, building from the experience gained in the demonstration project. Initially, the County should continue the geographic expansion of the reported system, with additional capability developed as needs and experience dictate. It is also recommended that Kenosha County establish an appropriate set of update procedures to ensure that the information base is kept current. Initially, it is recommended that $125 per square mile of completed area be budgeted on a yearly basis to accomplish updates to the system, with experience being used to refine this estimate.

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Chapter VI

SUMMARY

There is currently a growing interest in the United States in land data systems. This interest, and the increasing need for land-related information by all levels of government and by the private sector, induced the National Research Council to examine the issue. In 1979 the Council instituted a panel on a multipurpose cadastre to review the status of cadastral activities at the federal, state, and local governmental levels and in the private sector and to review a number of demonstration projects that had been undertaken at various locations. In 1980 a report, Need for a Multipurpose Cadastre, was issued, the principal finding of which was that:

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

The report identified existing land information systems and the multipurpose cadastre as representing a basis for a dynamic public process that effectively collects, maintains, and disseminates land-related information. It identified the land resource-related problems faced by public and private organizations and outlined how a multipurpose cadastre could help to remedy these problems. The report, however, did not address how governments, especially local governments, could carry out the recommendations made in the report.

To address the questions left unanswered by its 1980 report, the National Research Council prepared a second report, Procedures and Standards for a Multipurpose Cadastre, which presented a set of recommended procedures and standards for the design and implementation of a multipurpose cadastre. It was the intent of this report to assist the local governments wishing to pursue the development of cadastral records systems for their own jurisdictions and also the many other regional, state, and federal agencies, as well as private businesses, whose participation will be needed for the development, over time, of true, multipurpose cadastres.

The demonstration project reported herein was carried out within the context of the increasing interest at the national, state, and local levels in the development of land information and related automated mapping systems. The project was jointly conceived and developed by representatives of the State of Wisconsin Departments of Development and Agriculture, Trade, and Consumer Protection, and the State Cartographer's office; the Southeastern Wisconsin Regional Planning Commission; Kenosha County; and the Town of Randall. Funding for the project was provided by the State of Wisconsin, Department of Development; Kenosha County; and the Southeastern Wisconsin Regional Planning Commission, with the major work elements being carried out by Kenosha County and the Regional Planning Commission. The project was completed under the direction of a technical advisory committee established specifically for that purpose.

The project was intended to develop and demonstrate a limited land-related information and associated mapping system. This system was to provide a working model of a high-quality, automated procedure that could: 1) provide land-related data essential to the sound administration of comprehensive and special-purpose zoning ordinances; 2) provide an effective method of monitoring zoning changes; 3) promote the cooperation of regional, county, and local governmental capabilities in carrying out comprehensive county/town zoning programs; 4) demonstrate the proper and effective relationship between planning and zoning; and 5) provide a basic system that could readily evolve into a countywide, multipurpose, land-related information system. This evolution would proceed in two important ways: first, through the geographic extension of the limited system demonstrated to eventually encompass all of Kenosha County; and second, through the addition of more land-related information files. Such evolution would enable the system described herein to, over time, evolve into a true, multipurpose cadastre.

A multipurpose cadastre can be conceptualized as a public, operationally and administratively integrated, land information system which provides for continuous, readily available, and comprehensive land-related information at the parcel level. The National Research Council has proposed that multipurpose cadastres consist of the following five elements: 1) a geographic reference frame consisting of a geodetic network; 2) a series of current, accurate, large-scale topographic base maps properly related to the geographic reference frame; 3) a cadastral map overlay delineating all cadastral parcels which is also properly related to the geographic reference frame; 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 cross-referencing with information in other land data files.

The first three elements of the procedural model for the creation of a multipurpose cadastre as proposed by the National Research Council have long been embodied in the Regional Planning Commission's recommended large-scale base mapping and attendant survey control program. Recognizing the importance of good large-scale maps and attendant survey control to sound community development and redevelopment, the Commission has for over two decades encouraged the preparation of large-scale topographic and cadastral maps within its 2,689-square-mile Planning Region. These maps are based on a unique system of survey control that combines the best features of the U. S. Public Land Survey and State Plane Coordinate Systems. This unique system calls for the remonumentation of all U. S. Public Land Survey section and quarter-section corners and the determination of State Plane Coordinates for all monument locations. The large-scale maps and attendant survey control system, where they already exist within the Region, provide, in a highly cost-effective manner, the technical foundation for the creation of multipurpose cadastres within the Region, providing the first two of the five elements of such a cadastre, and a part of the third element.[1]

[1] *As of January 1, 1985, this survey control system has been extended into approximately 1,171 square miles of the seven-county Southeastern Wisconsin Region, or over 43 percent of the total area of the Region; and a total of 6,149 U. S. Public Land Survey corners have been relocated, monumented, and coordinated, representing over 52 percent of all such corners in the Region.*

In 1980 Kenosha County undertook a program which will eventually result in the completion of large-scale topographic maps and the attendant relocation, monumentation, and coordination of all of the U. S. Public Land Survey corners within the County to Regional Planning Commission-recommended standards. The County Board assigned the responsibility for the preparation of the necessary contract documents and specifications and for the supervision of the work to the Executive Director of the Regional Planning Commission, a responsibility which includes field inspection of the completed control survey monumentation and the quality control of the land and control survey work and of the finished topographic maps. To date this survey control and mapping system has been extended into approximately 215 square miles, or approximately 77 percent, of Kenosha County, including all of the project area; and a total of 1,015 U. S. Public Land Survey corners have been relocated, monumented, and coordinated, representing over 84 percent of such corners in the County. The county mapping and control survey program thus provided the basis for the development of a multipurpose cadastre for the project area under the project herein reported.

The focus of the demonstration project was zoning administration; therefore, in addition to information about interests in land, both natural resource information and cultural information essential to efficient and effective zoning administration are contained within the system. Much of the information incorporated into the system has traditionally been stored in the form of maps. Conversion of map information into a digital, or numeric, format where it can be manipulated and operated upon by a computer requires the use of a device called a digitizer. Once the initial map data are transformed into numeric form with the digitizer, a variety of manipulations become possible. Data mapped at one scale can be reproduced at different scales, provided that the accuracy limitations of the original maps are recognized in any enlargement, as opposed to reduction, in scale. Graphic base files collected from different sources can be merged and reproduced at a uniform scale. Data for special study areas can be identified, reproduced, and measured. Information on base maps can be identified in such a manner that only selected portions of that information are reproduced at a time.

The project area was located in the southwestern corner of Kenosha County and consisted of an area of about 24 square miles. The project area—which in addition to the Town of Randall included the adjacent Village of Twin Lakes—contains a sufficient variety of land uses, residential development patterns, and natural resource features to provide an area quite suitable for a demonstration project for the creation of a multipurpose cadastre.

The geographic reference framework for the project was constructed within a computer by key-entry of control survey records prepared as part of the U. S. Public Land Survey System remonumentation and large-scale topographic base mapping program. In this manner, the full precision of the control survey data could be maintained and utilized in the establishment of the geographic reference frame. The Wisconsin State Plane Coordinate System, south zone, was utilized as the coordinate system for all map information in the project. The coordinate system grid was constructed by a computer using basic plane geometry relationships and, once created, was stored for recall and utilization as the map base for all land information integrated into the system. The resulting map projection grid is geodetic, or earth based.

Integration of land ownership information with other types of information about the land required the placement of U. S. Public Land Survey section and quarter-section corners on the State Plane Coordinate System. Coordinates for the corners were key-entered into a computer to the nearest 0.01 foot and placed by the computer upon the State Plane Coordinate grid previously constructed. Under the control survey system utilized, the U. S. Public Land Survey corners were integrated into the geodetic control network by field surveys meeting Third Order, Class I accuracy standards, and thereby converted into a geodetic, or earth-based, control network, as well as a real property boundary survey control network. Quarter-section lines connecting the corners were also plotted on the State Plane Coordinate grid.

Large-scale base maps produced for the project area, as part of the Kenosha County survey remonumentation and base mapping program, provided the source for the digitization of surface water and stream channels, the traveled way—pavements—of public streets and highways, and structure outlines. The locations of surface water areas and stream channels, pavements, and structure outlines were determined by photogrammetric methods during the original preparation of the large-scale topographic maps and appeared on the finished maps.

Cadastral maps for the Town of Randall and the Village of Twin Lakes were prepared as part of the demonstration project. This work was carried out to specifications prepared by the Regional Planning Commission staff by a consultant retained for the project by the Kenosha County Planning and Zoning Administration Department. The Kenosha County Surveyor reviewed the completed cadastral maps and provided consultation on particularly difficult problems encountered during the compilation and preparation of the maps.

Recorded subdivision plats, certified survey maps, abbreviated legal descriptions, recorded easement descriptions, plats of right-of-way locations, and surveyors' field notes were used to locate real property boundary lines and real property boundary line-related information, such as easement and right-of-way lines. The real property boundary lines were constructed on the maps in the same way as a land surveyor would construct those lines in the field. This was possible because of the framework of control provided by the known location of the U. S. Public Land Survey corners on the State Plane Coordinate System and the attendant known grid lengths and grid bearings of all quarter-section lines.

In the construction of these maps, it was recognized that the recorded dimensions and orientation of real property boundaries plotted on the base map sheets would not always agree with the horizontal control data shown on these sheets. There was sometimes a lack of agreement because some descriptions were written without benefit of field survey data; some descriptions incorporated errors and blunders in field surveys; and some descriptions were incorrectly written. As a result, overlapping or separated property boundary descriptions were expected and were indeed found to exist in some situations. The property boundary line maps were to record all dimensions as contained in the official records of the County Register of Deeds; and wherever an overlap or gap of 2.5 feet or more existed, such overlaps or gaps were to be shown as mapped lines. Overlaps or gaps of less than 2.5 feet are evident only from the examination of the property line dimensions recorded on the maps. Following drafting of the cadastral map sheets, the information contained on the sheets was digitized.

The parcel identification number provided the link between the cadastral maps, which show the location of a particular parcel, and the records, either computer-readable or traditional paper records, that contain information about the parcel. The parcel identification scheme utilized in the project has been established by the Kenosha County Assessor's office for the keeping of records concerning assessments of property, and is the scheme recommended by the Wisconsin Department of Revenue for use throughout the State for this purpose. The scheme is known as a "location identifier," and utilizes the basic framework of the U. S. Public Land Survey in the assignment of the parcel number.

The final step in the development of an automated mapping and land information system for the Town of Randall was the development of files of land-related information useful in zoning administration. Six additional such files were incorporated into the system: 1) the property ownership and assessment records maintained by the County Assessor's office; 2) land use; 3) zoning districts; 4) soil units; 5) flood hazard areas; and 6) shoreland areas. Two of these files, the property ownership and assessment records file and the land use file, were in existence as computer-readable files prior to the initiation of the project, and their incorporation into the project required merely that appropriate mechanisms be established for their use. The remaining four files were created as part of the system development. The property ownership and assessment records were nongraphic information files. The land use, zoning district, soil unit, flood hazard, and shoreland files were graphic files maintained in the form of map overlays.

Once completed, the automated mapping and land information system was utilized for tasks currently being performed by Kenosha County staff persons. By selectively choosing data from the various information layers integrated into the automated mapping system and preparing maps of these data at user-defined scales, the existing tasks could be made easier and performed more rapidly. Typical applications were developed for the production of both general-purpose and special-purpose maps, the quantification of mapped data, the processing of applications for landowners' participation in the Wisconsin farmland preservation program, and the preparation of materials for the processing of a rezoning request.

The major finding to emerge from the demonstration project is that the development of a limited-purpose automated mapping and land information system, such as that described in the report, is feasible with existing hardware and software systems and can be accomplished by county and local units of government at affordable costs. The project also underscored the wisdom of establishing and using a permanently monumented and maintained geographic reference framework, and of preparing a set of current, large-scale, topographic base maps as preliminary steps in the development of any modernized land records system.

The demonstration project also showed that the preparation of cadastral maps can be expected to be a time-consuming and difficult portion of the implementation of a modernized land records system. Preparation of these maps will require careful interpretation of occasionally incomplete and sometimes conflicting source material, and occasionally tedious and time-consuming research into old documents and surveys; and, as a last resort, may require the use of land survey crews in the field to make final determinations as to the "correct" location of mapped land ownership boundaries.

As originally envisioned, the project would have utilized records of property ownership maintained by the County Register of Deeds. It was determined, however, that obtaining this information would require abstracting and title research beyond the scope and budget of the project. As an alternative, the abbreviated tax records descriptions maintained by the County Assessor were utilized to identify individual ownership parcels. These abbreviated descriptions provided an adequate basis for the preparation of cadastral maps. Indeed, the troublesome situations that were encountered were never the result of the use of abbreviated descriptions, but rather were the result of such factors as the use in past surveys of incorrect locations for U. S. Public Land Survey corners due to the lack of permanent monumentation or to the exercise of poor practice either in land surveying or in the writing of title descriptions.

With respect to the development of digital data files, the results of the project indicated that perhaps the most troublesome issue to be dealt with in this area is the design of the data structure, or the manner in which all information contained in the system is organized and stored for manipulation by a computer. Particularly noteworthy in this regard is the need to establish very detailed, explicit relationships among the various map elements. Unlike a system of manual maps and records, which can rely upon the ability of a human operator to supply necessary implicit relationships for the interpretation of various records and map elements, automated systems require the use of explicit rather than implicit relationships.

Typical costs for the development of an automated mapping and land information system were developed on the basis of project experience. In addition, costs for the development of all elements of the procedural model proposed by the National Research Council for the development of such systems were calculated, including costs incurred outside the project reported herein. While the costs are believed to be representative of typical conditions, it must be recognized that these costs could vary for individual local jurisdictions depending on the complexity of such factors operating in these jurisdictions as the size, configuration, and character of the area to be mapped.

Based upon the experience in the project area, it is estimated that a limited-purpose automated mapping and land information system based upon the recommended National Research Council model can be developed for about $8,200 per square mile in 1985 dollars. Of this amount, about $1,400 per square mile, or about 17 percent, is entailed in the land survey work involved in relocating and monumenting U. S. Public Land Survey corners; about $2,200 per square mile, or about 27 percent, is entailed in control survey work, including the establishment of State Plane Coordinates and elevations for the monumented U. S. Public Land Survey corners; about $2,000 per square mile, or about 24 percent, is entailed in the preparation of 1:2400-scale topographic maps and cadastral base sheets, including the costs of necessary aerial photography; about $1,200 per square mile, or about 15 percent, is entailed in the preparation of cadastral maps; and about $1,400 per square mile, or about 17 percent, is entailed in the preparation of the digital files described in this report. In jurisdictions such as Kenosha County where some of the necessary elements for the creation of automated mapping and land information systems are already in place, the per-square-mile cost to implement a system such as that described in this report will be correspondingly reduced. In the project area, the cost was reduced to about $2,600 per square mile for this reason.

Five general recommendations are presented for any jurisdiction considering the establishment of an automated mapping and land records information system: 1) the establishment and use of a permanently monumented and maintained geographic reference framework as recommended by the National Research Council; 2) the preparation of a set of current, large-scale, topographic base maps, also as recommended by the National Research Council; 3) a comprehensive and in-depth review of the adequacy of existing property boundary maps and legal descriptions prior to the initiation of any conversion of these records to digital format; 4) the provision of adequate resources and staff personnel to perform review and quality control procedures on all intermediate and final products produced as part of the implementation of a modernized land records system; and 5) the conduct of a pilot project.

It is recommended that Kenosha County continue to move toward the establishment of a countywide automated mapping and land records information system, building from the experience gained in the demonstration project. Initially, the County should continue the geographic expansion of the reported system, with the development of additional capabilities as needs and experience dictate. It is also recommended that Kenosha County establish an appropriate set of update procedures to ensure that the information base is kept current.

APPENDICES

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Appendix A

TECHNICAL ADVISORY COMMITTEE

George E. Melcher Chairman	Director of Planning and Zoning Administration, Kenosha County
Kurt W. Bauer Secretary	Executive Director, Southeastern Wisconsin Regional Planning Commission
Richard E. Ellison	County Assessor, Kenosha County
David P. Fodroczi	Director, Farmland Preservation Section, Department of Agriculture, Trade and Consumer Protection, State of Wisconsin
Gerald K. Graff	Chairman, Town of Randall
George E. Hall	Planning and Policy Analyst, Bureau of Housing and Land Use Services, Department of Development, State of Wisconsin
Bernard J. Niemann, Jr.	Professor, Department of Landscape Architecture, Land Information and Computer Graphics Facility, School of Natural Resources, College of Agricultural and Life Sciences, University of Wisconsin-Madison
Robert L. Smith	County Surveyor, Kenosha County
Arthur L. Ziegler	State Cartographer, State of Wisconsin

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Appendix B

A GLOSSARY IN LAND DATA SYSTEMS

This selected list of terms is intended to assist those considering modernization and integration of files containing official public data on land. Some familiarity with the land records of local governments is assumed. No attempt is made to define common computer-processing terms which are in general use with other types of information systems. A term that is underlined in a definition is itself defined in this glossary.

Many of the terms contained herein have been taken from "A Starting Glossary in Land Data Systems," Lincoln Institute Monograph No. 82-6, Lincoln Institute of Land Policy, Cambridge, Massachusetts. The Lincoln Institute glossary was itself partially based upon the following references:

American Public Works Association (APWA). "CAMRAS Glossary," Appendix E of the CAMRAS Manual, prepared by the Utility Location and Coordination Council and the APWA Research Foundation, Chicago, Illinois, 1981.

National Oceanic and Atmospheric Administration (NOAA). Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys, Rockville, Maryland, 1974.

Black, Stephen. "Terminology," International Geocoding '74 Colloquium Proceedings, eds. Aangenbrug and Bromberger. Lawrence: University of Kansas, 1975.

Edson, Dean T. (ed.). A Glossary of Technical Terms in Computer-Assisted Cartography, International Cartographic Association, Commission III (Computer-Assisted Cartography), 1980, available from the American Congress on Surveying and Mapping, Falls Church, Virginia.

American Society of Civil Engineers. Definitions of Surveying and Associated Terms, ASCE—Manuals of Engineering Practice—No. 34, 1978.

Accuracy: The degree of freedom from error; that is, the degree of conformity to a truth or to a rule. Accuracy is contrasted with precision; for example, a properly computed "one-place" number (i.e., with one digit after the decimal point) might be more accurate than an improperly measured three-place number.

Addressability: The characteristic of a display device which measures the number of separate positions that the control mechanism can obtain. For example, some CRT displays can obtain 1,024 positions of the beam on a horizontal axis.

Analog: Pertaining to representation of quantities or locations by means of continuously variable physical quantities, as in a physical model, or a drawing. Contrast with digital.

Attribute Data: Descriptions of the theme or nonspatial characteristics of an event, activity, or object.

Base Map: A record of the two-dimensional locations of basic reference points and lines within a given area, with sufficient accuracy for use at that scale. For example, a base map at the typical urban mapping scale of 1:1200 will normally show at least roadways (e.g., edges of pavements), railway lines, major structures, and survey control monuments, which could be plotted as a typical graphic map, or digitized in a computer memory.

Batch Processing: Computer processing in which input is followed—often minutes or hours later—by output. The user does not interact with the computer program while the processing is taking place. The program's flow of control is determined by the input data, the program, and the computer system rules. Contrast with interactive processing.

Benchmark: A reference point for measurements, normally one that is primarily used for elevation reference.

Cadastral Map: A relatively large-scale map showing the boundaries of subdivisions of land, sometimes with the bearings and lengths thereof and the areas of individual tracts, for purposes of describing and recording ownership. A cadastral map may also show cultural, drainage, and other features relating to the value and use of land.

Cadastral Parcel: The smallest legally defined piece of land for purposes of recording ownership.

Cadastre: A public register of the quantity, value, and ownership of the real property in a jurisdiction.

Cartographic (Digital) Data Base: A data base containing data elements that are referenced according to their two-dimensional locations and structured according to user needs, involving the storing, retrieving, and manipulation of such data.

Centroid: As concerned with mapping, the mathematical center of a two-dimensional area. When a reference point is needed for the location of an area, use of the paracentroid, or a visual center, normally is more convenient.

Confidence Factors: A set of numbers indicating relative confidence in the accuracy of a graphical data element. Individual numbers may represent age of source, type of source, amount of checking of source, progress of construction and inspection thereof, digitization technique used, quality of survey for surveyed points, or seriousness of need for improved accuracy.

Control Point: A point on the ground which has been monumented and the location of which has been accurately determined and recorded for referencing of future surveys.

Coordinate: A value measured along one axis of a rectangular coordinate system. An ordered set of two coordinates (often called "X" and "Y") specifies a location on a plane that is oriented by a coordinate system with two axes. See State Plane Coordinates.

Cursor: A movable device or lighted spot used to indicate a position on the surface of a device; for example, a) a hand-held device placed precisely on a map to communicate a mapped position to a computer or b) a lighted spot on a display to indicate where the next unit of input data will appear, or c) a lighted spot on a display used and moved by the operator to communicate with the computer.

Data Base: An explicit collection of data that is fundamental to an enterprise. In general, the data in a data base are highly organized to promote effective and efficient access for entry, retrieval, modification, summary report generation, and graphic output for display and plotting. Access is controlled by security features, and provision is made for preserving the integrity of the data base against accidental or malicious contamination or destruction. See drawing file and record.

Data Base Management Systems: Programs, largely automated, designed to maintain, manage, and protect the data in a data base, controlling the processes of entry, storage, retrieval, and manipulation of data.

Delineation: The description of the locations of points that mark the boundaries of a cadastral parcel.

Demarcation: The field measurements (i.e., land survey) that determine the physical locations of boundary markers of cadastral parcels on the surface of the earth.

Densification: An "infill" program to increase the number of units available in a given area, thereby reducing the distances between them and increasing their availability. In terms of land information systems this normally refers to control points.

Digital: Pertaining to recording of quantities or other references using digits which are discrete and do not form a continuum. Contrast with analog.

Digital Map: A map that uses numerical coordinates to reference the locations of its elements, rather than the plotted locations of those elements in a graphic record such as a map sheet. See cartographic data base.

Digitizer (Graphic): A device for the conversion of graphic, i.e., analog, data into digital data. The results may be recorded on some medium such as magnetic tape in a procedure called "off-line digitizing," or processed directly by a computer in the case of "on-line digitizing."

Digitizer Coordinates: The XY coordinates of a point on the digitizer plane as transmitted to the computer. For a map, they are converted to geographic coordinates by computation.

Digitizer/Plotter: A device normally used both to digitize graphics and then to immediately check the data and record graphically what has already been digitized.

Distributed Processing: An arrangement of data processing resources that relies upon a series of smaller computers under the control of individual users or small groups of users, rather than one large computer that is shared by all the users. The individual computers may be linked with one another and with a common data base. Contrast with time-sharing.

Drawing File: A temporary collection of data copied from a data base to use in making a special drawing. The data base is not initially changed, although after the drawing file is modified, it may (or may not) be used to replace or add to the data base. The drawing file may be located in a separate computer or in a separate area of the central computer.

Drum Plotter: A plotter which makes use of a rotating drum or cylinder to move the sheet of paper or film on which the image is created in the direction of one coordinate axis (e.g., the X axis) while the plotting head or beam only moves along the other coordinate direction (e.g., the Y axis). Contrast with flatbed plotter.

Field: A sequence of one or more characters which is treated as a whole. (It is the smallest unit of data which has meaning in describing information.) A specified area in a record which is consistently used for a particular category of data. For example, the reference point and figure identification would be two fields in a graphical record, and social security number and monthly salary would be two fields in a payroll record.

File: A collection of related records treated as a unit.

First Order: Refers to the highest standards of accuracy established for central surveys by the National Geodetic Survey. The standards require that the surveys provide the relative locations of two or more adjacent control stations with an accuracy of 1 part in 100,000.

Flatbed Plotter: A plotter which generates the graphic image on a medium mounted on a flat surface. Contrast with drum plotter.

Font: A complete family or assortment of characters of a given style. In computer graphics, a font is defined by detailed specifications of the strokes or dots required to represent each character in the font. The font is defined for some nominal size, and is scaled up or down as specified by the data or the operator when used to generate output.

Font Library: A collection of several different fonts for representing character information. This collection is stored in the computer system and is available for generating graphic displays and plotted output. The particular font used for output may be prespecified in the data being output or may be selected by the system operator.

GBF (Geographic Base File): A directory for translation of "name of place" to geocodes.

Geocode: A spatial index code (e.g., coordinates) identifying unique points, lines, or areas which may serve as a key to a record.

Geodetic: Of, relating to, or pertaining to the surface of the earth.

Geodetic Reference Network: A series of monumented control points located by coordinates that have been determined with respect to the national system of geodetic control points.

Geographic Coordinates: Coordinates specifying the location of a point on the surface of the earth by its distance easterly (X) and northerly (Y) from the zero point or axes of a grid on a mathematical reference surface that represents approximately the surface of "sea level." Various coordinate systems are in use, including the State Plane Coordinate System. The coordinate system should be specified in each coordinate file.

Geoprocessing: Processing of geographic or spatially referenced data.

GIS (Geographic Information System): An information system containing data which are referenced in a manner which permits their handling in a spatial context.

Grid Cell: One square unit in a rectangular coordinate grid, a geographical unit which is easy to reference and thus may be convenient for coding, manipulating, or summarizing of land data.

Gridded Data Base: Map data stored in numerical matrices. Contrast with vector data base.

Ground Truth: Information acquired by field study for the purpose of calibration or verification of geographical data.

Infrastructure: The man-made systems which provide any or all of the normal public services to the land which are characteristic of an urban area, such as water supply, sewerage, utilities, physical access, traffic control, lighting, and communications.

Interactive Processing: A type of computer processing in which the user interacts with the computer during processing to alter the flow of control in a program. Compare batch processing.

Land Data: Data which are referenced in a manner which permits their handling in a spatial context as in a geographic information system (GIS).

Land Record: A document in a public file which contains the definitive statement of some characteristic of a piece of land that is a matter of public interest. A land record may exist only in electronic storage.

Land Tenure: All of the publicly recognized rights and interests of people in specific parcels of land, some of which may not involve possession of the land.

Land Title: Legal right to the possession of real property, or the evidence of such right.

Lattice Theory: The concepts used for ordering of mapped areas according to which of them includes which others. Where the inclusions are simple and undivided, this describes a hierarchy. Lattice theory provides the framework for disclosure analysis.

Layer: A set of data classifications into which data can be entered and registered to a common geometric or geographic coordinate system for selective display and editing under access control. Layer membership is an attribute of a graphic element.

Light Pen: A hand-held cursor which detects light emitted from a refreshing display on a video screen and records the exact time of the maximum intensity within a refreshing cycle (about 1/30 of a second). This allows identification of the display element that was "seen" by the light pen for a special record or for further processing.

Menu: A device for selecting and activating interactive commands in a graphics system. It may have several realizations even on the same system. A typical menu is represented by an array of system command names mounted on a digitizing surface or appearing on a graphic display. A particular command is selected and executed by positioning a cursor over the name and pressing a key.

Microcomputer: A complete general- or special-purpose electronic digital computer, with integral processing unit, storage, and input/output bus (link), usually constructed around a single Large Scale Integrated (LSI) circuit chip or printed circuit board. It may be packaged as a desktop unit.

Microfiche: A frame or frames of microfilm, mounted in a card on which a description of the microfilm can be printed. Generally, each frame contains a 6 x 12 array of 72 images which may represent 72 pages of text.

Minicomputer: A small computer built for onsite installation. Minicomputers are often used for specific tasks of a repetitive nature, while large computers generally serve a diverse set of users and applications. The meaning of this term has been considerably blurred by increasing miniaturization, decreasing storage costs, and increasingly sophisticated software available for "minis."

Modem: Abbreviation for "modulator-demodulator." A pair of modems, one at each end of a communication line, often a telephone line, is required for operation of terminal or peripheral equipment at a remote site. Many different modems are currently on the market providing a wide variety of communication speeds and capabilities.

Monument: A physical structure which marks the location of a corner or survey point. Monument and corner are not synonymous, although the two terms are often used largely in the same sense.

National Map Accuracy Standards: A group of standards—originally promulgated by the federal government for use by federal mapping agencies—intended to establish uniform standards of accuracy for maps, as well as a procedure for determining compliance with those standards. The major provisions of these standards are as follows:

1. Horizontal accuracy. For maps at publication scales larger than 1:20,000, not more than 10 percent of the points tested shall be in error by more than 1/30 inch, measured at the publication scale; for maps at publication scales of 1:20,000 or smaller, 1/50 inch. These limits of accuracy shall apply in all cases to positions of well-defined points only. Well-defined points are those that are easily visible or recoverable on the ground, such as: survey monuments or markers, including benchmarks and property boundary monuments; intersections of roads and railways; and corners of large buildings or structures or center points of small buildings. In general, what is well defined will also be determined by what is plottable on the scale of the map within 1/100 inch. Thus, while the intersection of two roads or property lines meeting at right angles would come within a sensible interpretation, identification of the intersection of such lines meeting at an acute angle would not be practicable within 1/100 inch. Similarly, features not identifiable upon the ground within close limits are not to be considered as test points within the limits quoted, even though their positions may be scaled closely upon the map. In this class would come timber lines, soil boundaries, and similar types of features.

2. Vertical accuracy. As applied to contour maps at all publication scales, not more than 10 percent of the elevations tested shall be in error by more than one-half the contour interval, and no such elevations tested shall be in error by more than one contour interval. In checking elevations taken from the map, the apparent vertical error may be decreased by assuming a horizontal displacement within the permissible horizontal error for a map of that scale.

3. The accuracy of any map may be tested by comparing the positions of points whose locations or elevations are shown upon it with corresponding positions as determined by surveys of a higher accuracy.

Node: A uniquely identified point locating the ends of two or more line segments in a digital map.

Paracentroid: The paracentroid of a closed geometrical shape is a point near the geometrical center. The paracentroid, which can be located and assigned coordinates automatically by computer, may be used as an "address" or "label" for a property parcel or land area. Not to be confused with the mathematically defined term centroid.

Parcel: A fundamental unit of land defined for local mapping purposes. Parcels may be defined in several different ways. Two of the most common are ownership parcels, which are defined on the basis of title to the land unit (see also cadastral parcel), and tax parcels, which are defined by the local taxing jurisdiction for the purpose of establishing taxes to which the land unit is subject.

Photogrammetry: The science or art of obtaining reliable measurements by photography. In mapping, this normally refers to the technology of adjusting the imagery or the data derived from aerial photography to yield accurate determinations of locations of objects shown in the photographs, using two or more photographs of the same area taken from different positions in the same flight.

Pixel: Abbreviation for "picture element." The smallest elemental aerial unit constituting the tone of an image. May represent as much as one or two acres in imagery obtained from earth satellites. Also known as a resolution cell.

Planimetric Map: A map that represents the locations of physical objects observable on the ground such as pavements, structures, and survey control points, sometimes used as a base map.

Plat: A diagram drawn to a scale showing all essential data pertaining to the location of the boundaries and subdivisions of a tract of land, as determined by survey or protraction. A plat should show all data required for a complete and accurate description of the land which it delineates, including the bearings (or azimuths) and lengths of the boundaries of each subdivision. A plat may constitute a legal description of the land and be used in lieu of a written description.

Plot: A drawing made by a plotter. Sometimes distinguished from a "hardcopy" which tends to be smaller and less precise. The distinction between a "plot" and a "hardcopy" (and the machines used to produce them) is rapidly being blurred by electrostatic plotters of several intermediate and large sizes which can produce copies quickly.

Plotter: A device capable of generating permanent graphic images on some sort of removable medium, such as paper or film, from digital or analog input signals, typically digital coordinate values describing the geometry of the image. If the image is not removable but just displayed for a limited amount of time (e.g., on the face of a video screen), the device is called a graphic display rather than a plotter.

Polygon: A line that encloses an area.

Point Symbol: An alphabetic or numeric character or a graphic symbol from a particular symbol library, together with scaling and orientation information for displaying the indicated symbol at a specified coordinate position. Any coordinate-pair or point in the graphic data base may be assigned a point symbol.

Precision: (1) The degree of discrimination with which a quantity is stated. For example, a three-digit number discriminates among 1,000 possibilities. (2) Statistical measure of repeatability, usually expressed as variance or standard deviation of repeated measurements. Contrast with accuracy.

Raster: A regular, two-dimensional arrangement of physical or conceptual elements, e.g., electrical connections, or addressable points. Normally, the arrangement is line by line across a given surface or area, such as the face of a video screen, or as in a gridded data base. Sometimes synonymous with matrix.

Raster Converter: An electronic device which converts lines stored as vectors into a raster format. This allows printing of tiny segments of all lines which exist in a small strip across a drawing. It then prints the continuations of the lines in a succeeding small strip, and continues, a strip at a time, until the drawing is complete. Great speed is thus possible by printing many line segments "simultaneously" as paper rolls almost continuously through the plotter.

Real-Time Processing: Data processing performed immediately after the event which generates the input data, so quickly that the results can be used to generate a response from the operator who initiated the original data processing, or to influence subsequent data generation. Includes interactive processing.

Record: A collection of related fields treated as a unit by an application program. In the hierarchy of data units one might consider, in ascending order, the bit, byte (character), field, record, and file.

Reduction: (1) With respect to graphics, conversion of a graphic image into a smaller image photographically. (2) With respect to data, conversion into simpler, clearer, or more elemental forms.

Remote Site: Separated from the central processing station by a distance such that special equipment (other than cable or amplifiers) is required to communicate. See satellite and modem.

Resolution: A measure of the smallest possible difference in value or position. In a computer system this may be numerical resolution or physical resolution of the hardware. An example of the latter is the step size of a plotter.

Satellite: (1) A station in a data processing system at a remote site separated by a large distance from the central processing station—typically in another building. (2) A device placed in an earth orbit for the purpose of obtaining images of the earth's surface for mapping purposes. Some satellites have been especially designed to be used in triangulation procedures to establish the locations of features on the earth's surface.

Scanner: A raster scan digitizing device. The data obtained by scanning may be used either to calculate coordinates describing the geometry of graphic features or to recognize the quality of certain features.

Schema: A map of the overall logical structure of a data base.

Second Order: Refers to the next-to-highest standards of accuracy established for control surveys by the National Geodetic Survey. There are two classes of second order surveys. The standards require that Second Order, Class I, surveys provide the relative locations of two or more adjacent control stations with an accuracy of 1 part in 50,000. The standards further require that Second Order, Class II, surveys provide the relative locations of two or more adjacent control stations with an accuracy of 1 part in 20,000.

Secondary Annotation: Technical data which are displayed or plotted as annotation from other technical data and are not stored explicitly in the data base as text for use on a map.

Segment: A line connecting two nodes on a map. The basic unit for digital identification of map features.

Spike: Sharp deviation from the expected trend of a line, caused by erroneous data.

State Plane Coordinates: Geographic coordinates that locate a point on the earth's surface with reference to a grid on a mathematical reference surface that represents "sea level" in that state or section of a state, with sufficient accuracy for recording survey measurements. These coordinate systems have been officially adopted by the legislatures of most states in the U. S., following guidelines published by the National Geodetic Survey.

Stereoplotter: A machine which, when loaded with a pair of overlapping aerial photographs, can be used to determine precise locations and altitudes of objects (and ground levels) that appear in the photographs. Used in the production of topographic maps. See photogrammetry.

Thematic Map: A map that portrays the general patterns of the incidence of selected phenomena without necessarily showing their precise locations.

Third Order: Refers to the lowest standards of accuracy established for control surveys by the National Geodetic Survey. There are two classes of third order surveys. The standards require that Third Order, Class I, surveys provide the relative locations of two or more adjacent control stations with an accuracy of 1 part in 10,000. The standards further require that Third Order, Class II, surveys provide the relative locations of two or more adjacent control stations with an accuracy of 1 part in 5,000.

Time-sharing: Pertaining to the interleaved execution of two or more programs by a computer system. Thus, two or more programs share the time of a given piece of equipment on a one-at-a-time basis; the outward appearance is that the several programs are being executed simultaneously. This mode of operation is used when several graphic display terminals are operated from a single central processing unit (CPU). Contrast with distributed processing.

Topography: The configuration of the surface of the earth in a given area.

Topographic Map: A map that portrays the topography of an area, often by the use of contour lines, or lines that connect points of equal elevation above a specified datum such as mean sea level. Topographic maps usually also show the locations of physical objects observable on the ground such as would be shown on a base map or planimetric map. Contrast with cadastral map.

Topological: Pertaining to the geometric relationships that depend only upon whether or not the elements are adjacent and not upon their locations in space. Topology is also known as "rubber sheet geometry," because such relationships may survive even after spatial distortions.

Vector: A line stored in a computer as two nodes and instructions to join them.

Vector Data Base: Map data stored as lines represented by strings of vectors or line segments, and other land data related to specific vectors. Contrast with gridded data base.

Vertex: The intersection of two or more line segments which are the edges of planar or solid figures.

Virtual Map: Data that record the points, lines, symbols, and text that together form a complete map but which actually exist only as the stored data, e.g., in an electronic medium. See digital map.

Window: The defined outline of a section of a graphic, normally rectangular, which is intended for display or plotting. With an interactive graphics system, once the window is defined the picture within it can be enlarged to fill the display surface, or modified by various edit commands.

Z Coordinate: The coordinate representing height or elevation of a point in a three-dimensional XYZ coordinate system.

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Appendix C

DESCRIPTION OF HARDWARE AND SOFTWARE USED IN THE PROJECT

The purpose of this appendix is to provide a description of the particular hardware and software components used in the project that is the subject of this report. Descriptions are provided for both the digitizing system used to create digital files from source material in the form of maps, records, and aerial photography, and the plotting system used to create analog maps from the digital files.

DIGITIZING SYSTEM

The system used is of a type known as a "turn-key" system; that is, a system made up of both hardware and software components designed to be used in conjunction with one another and sold and supported by the vendor as a single, integrated product. The alternative to a turn-key system requires the user to separately purchase hardware and software components, to link the different components into a functioning system, and to provide maintenance and support separately to the individual hardware and software components.

The digitizing system used in this demonstration project was marketed by the CALMA Corporation under the product name "CALMA Graphic Interactive"—or CGI—as a system intended specifically for mapping applications. It was installed in January 1981, and replaced a smaller CGI system installed in 1976.

Hardware Components

The central processing unit of the digitizing system is a Data General Eclipse S-230 minicomputer with about one-half million characters of main memory storage. Attached to the central processing unit are a Perkins-Elmer low-density (800 bits per inch) tape drive, a Digital Equipment Corporation low-speed line printer, and 160 million characters of "on-line" magnetic disk storage provided by two Control Data Corporation 80MB storage devices.

Line data conversion, manipulation, storage, and retrieval is accomplished with four operator work stations which are directly attached to the central processing unit and operate in an interactive mode. Three of these work stations are used primarily for data entry and consist of a large format, free cursor digitizing table with an addressable area of 44 inches by 60 inches and a resolution of 0.001 inch; a data entry keyboard; a 19-inch storage-type cathode ray tube for line segment and map annotation display; and a 12-inch alphanumeric cathode ray tube for system communication. The fourth work station is used primarily to manipulate previously collected line segment data, and is mechanically similar to the three line collection work stations with the exception that the large format digitizing table has been replaced by a digitizing tablet with an addressable area of 11 inches by 12 inches.

Operating Software

As noted previously, the software used to collect, store, manipulate, retrieve, and display the line segment data and their annotation is an integral part of the total system rather than a separate component. The software is also proprietary, meaning that the software is not "owned" by the user but rather is "used" under the terms of a license agreement, with the vendor retaining ownership of the software. Under the terms of the particular license agreement covering the CGI software, disclosure of the manner in which the software actually operates constitutes a violation of patent and copyright protections. Therefore, the system software can be described here in only a general fashion.

The CGI software utilizes a machine-level language rather than a user-level language. In a machine-level language, a single language command results in a single machine operation. In a user-level language, a single language command may result in a single machine operation or in a number of machine operations. Accordingly, writing programs in a machine-level language can be tedious. The time-consuming nature of writing programs in machine-level languages can be reduced, however, by the use of "macros." A macro is a set of computer language instructions that can be executed by a single system command. Macros can be used for situations that are highly repetitive such as collecting a sequence of points, linking the points together with line segments, and forming a closed polygon from the line segments.

The CGI software operates directly on the hardware without benefit of an operating system, or set of software that supervises or controls the operation of the hardware/software interactions. For this reason, the minicomputer that controls the system functions essentially as a command processor, and is not capable of performing in a multiple task environment; that is, the minicomputer is capable of no task other than driving the digitizing system. The lack of an operating system, the machine-level language, and the proprietary nature of the CGI software severely limit the transportability of applications software between this digitizing system and other digitizing systems, especially those of other vendors.

The points, line segments, polygons, and annotation of the geometric elements which are collected by the system are stored in a data structure for retrieval at a later time. The data structure used by the CALMA system described here is called a "hierarchical" structure. Hierarchical structures are also known as "tree" structures due to the fact that a diagram of a hierarchical structure resembles the structure of a branching plant such as a tree. Hierarchical structures store information about a drawing in a predefined location within the structure, with entry into the data structure being possible through only a single location in this structure, hence the resemblance of the structure diagram to that of a tree.

Hierarchical structures perform well in situations where the intent is to capture and store the geometry of a graphic figure. They perform less well in situations where deriving relationships between different graphic elements—such as determining the degree of coincidence of two partially overlapping polygon sets—is an important consideration in system performance. In these situations, data structures based upon topological, rather than hierarchical, relationships of graphic elements have become increasingly favored in recent years.

DRAWING PRODUCTION

Hardcopy output from the digitizing system was provided by a drum plotter; more specifically, a Calcomp 936 plotter driven through a Calcomp 905 off-line controller. The plotter is a separate stand-alone system of hardware rather than a component of the interactive digitizing system described above. The interactive digitizing system is capable of generating a command tape which, when read by the plotter controller, causes the plotter to "draw" a map or diagram. The plotter can produce multiple-color drawings on a variety of media, including various grades of paper and dimensionally stable drafting film. Plotters are available in a variety of sizes. The particular model described here works with media fed from a roll, which limits its image area in one dimension to the width of the roll, in this case 32 inches. This particular plotter has a resolution of 0.02 inch.

The various figures reproduced in this report were designed on the interactive digitizing system described in this appendix, and were prepared using the plotter system also described herein. In the case of multiple-colored figures, the systems were used to prepare registered, color-separated map overlays which were produced in black ink on the plotter, thereby providing camera-ready artwork for the preparation of registered film negatives which could be used to prepare printing plates for the production of the color figures reproduced in this report.