8 ORGANIZATIONAL CONTEXT

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The roots of county government, like many institutions of American government, can be traced to English history, with some significant influences from several European countries (Duncombe 1966). Historical differences help explain the existence of counties in many states, parishes in Louisiana, the dominance of town government in much of New England, and boroughs in Alaska. Many forces have helped shaped these county and other local governments over the years, and new forces, such as automated land information systems, will likely continue to do so into the foreseeable future. The typical local government today is defined by its organizational characteristics, processes, textual records, and graphic records.

ORGANIZATIONAL STRUCTURE

Many local governments have changed relatively little since the individual states were first organized during the first 100+ years of the Union. Many counties grew out of similar organizations in territories that later became states. As in other organizations, a long period of relative stability tends to be self-reinforcing, producing a resistance or hesitancy to change. To further complicate the situation, many county departments and functions are described in considerable detail in state constitutions and statutes. The resulting statutory mandates tend to limit activities of departments and discourage changes.

Outdated organizational structures and procedures incline to foster autonomous departments and hence limit communications

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between personnel. This lack of interaction often produces duplication of effort and, at the same time, hinders discussions across departmental lines that could identify possible overlaps and lead to corrective measures. The net result is a system built to satisfy the mandate of each agency, department, or division. Viewed from outside, the resulting system seems to be the result of "collective irrationality" (Wunderlich and Moyer 1988). These systems, however, are "the outcome of very rational behavior at the individual institutional level" (Niemann 1988, p.43).

This compartmentalized government structure also affects the attitude of the various participants in local government as to changes that might be appropriate. One study revealed that the need to improve the land record system is not a commonly held belief (Niemann 1988, p.46). People who typically use land information for a specific purpose, and for a purpose for which the system was initially developed, are usually satisfied with the land information procedure as it is. To the contrary, other users, who must integrate data from several sources to do their job, exhibit a high level of frustration with how local government collects, stores, and makes available land information. This latter group includes planners, zoning officials, surveyors, and individual property owners.

In essence, local government information systems are the result of, and respond to, mandates. Some of these mandates can be traced to the legislation that established the various offices. Other mandates result from program responsibilities that are added to the work load of government offices from time to time. Environmental, planning, and taxation work have often been the mandates that have led to the development of automated or integrated land information systems over the last 20 years.

MANDATED RESPONSIBILITIES

Mandates in local government offices (as well as state offices) can often be traced to the legislation that established various offices. Other mandates result from program responsibilities added to the work load of government offices from time to time. Most of these mandates are documented in legislation or mission statements of agencies and departments. A recent examination of legislation and mission statements found that in Wisconsin, "agencies at all levels of government had legal mandates to collect, maintain, and disseminate information about various aspects of land" (Ventura 1988, p.1). As is usually the case, these mandates pertained to two primary kinds of data -- graphic (or map) and nongraphic (textual or attribute).

Mandates are often looked at narrowly by both individuals and groups. This "narrowness of scope" view results from many factors, but most importantly results in failure to "examine the potential benefits of cooperation" that could result if a shared data base were in place (Ventura 1988, p.4). The narrowing of scope is often exacerbated by bureaucratic tendency for self-perpetuation. Especially in times of change and for elected officials, the tendency is to support the status quo, rather than risk anything that would alter positions or influence.

Looking specifically at land information, local governments (counties and municipalities) are usually mandated with the responsibility for recording information about land at the most detailed level, i.e., land ownership parcels. Indeed, it is because of this land information responsibility that many see local government as a key factor in the development and operation of a shared land information base in an MPLIS.

With these mandates in mind, it is important to be aware of several perceived characteristics of an MPLIS that affect the organizational context. These are:

- a goal of an MPLIS is to serve a variety of land information mandates at the local and state levels,

- many agencies and departments will share the information in the MPLIS,

- a custodian will be needed for each data file,

- the MPLIS will most likely be developed in an incremental fashion (i.e., over a period of time),

- data in the MPLIS will be of two major types: graphic and nongraphic,

- the system will likely be automated, at least over the long run, and

- coordination must take place on both technical and institutional levels.

PARTICIPANTS IN AN MPLIS

Numerous functions and offices in local government are likely candidates to participate in the development and operation of an MPLIS. For example, both title recording (ownership) and tax assessment (tax parcel) functions maintain and use parcel data. Zoning and planning officials at several levels of government are both providers and users of information about zoning restrictions that apply to use parcels, wetlands, floodplains, and similar areas. Government surveyors, engineers, and public works officials rely on recording of up-to-date surveys, the re-monumentation of survey corners and points, and the accurate ties of these monuments into survey control networks. These prospective participants should certainly be encouraged to be part of any effort to implement an MPLIS.

However, any MPLIS development should also encourage the participation of many other offices, agencies, and individuals in local government. Wide participation is very important since many believe that 75-90% of all data produced and used by local government has a geographic aspect to it. Furthermore, recent market research indicates that LISs are very seldom acquired and developed by a single department (Juhl 1989, p.11). This means that purchases of hardware and software will probably involve several departments. Therefore, the general rule should be to include as broad a group in development and implementation efforts as possible.

ORGANIZATIONAL BARRIERS TO AN MPLIS

MPLIS is often seen as using new technology to solve a particular problem. Technology is only one part of any such solution, for organizational and institutional factors are just as important. In examining reasons for GIS/LIS failure, one commentator has noted that these "systems seldom fail for technical reasons. The technology works; institutions often fail to organize to use it effectively over the long term" (Foley 1988, p.608). It is important, then, to understand the barriers to MPLIS development that exist as a result of current governmental organization. Recognizing these barriers should be helpful in developing a program to move from current manual or semi-automated procedures to an MPLIS, and managing it in such a way as to ensure its long-term success. Potential barriers to watch for include departmentalization, interprofessional barriers, resistance to change, and lack of access to necessary management and design skills.

DEPARTMENTALIZATION

Most local government departments and agencies are established along functional lines. Mandates are often used to establish subgoals for the department, and members of the department become committed to these subgoals and organization-wide goals become secondary (Brown and Friedley, 1988, p.608). Such tendencies often become exaggerated in local government, as functions are assigned to several levels of government and to separate agencies. Some departments and agencies may report to individual elected officials, such as the property appraiser, the county clerk, or the register of deeds. At the same time, most parts of the local government may report to a county administrator, executive, commission, or county board. These varying and sometimes illogical lines of communication and control tend to reinforce the tendency to emphasize division of office goals, and to discourage a broader view that would rely on common goals to drive policy and action.

Sometimes just developing an organizational chart is a useful step toward land records modernization. These charts can show discrepancies between hierarchical organizational and functional relations (e.g., data flow lines). Brown County, Wisconsin, developed such a chart of departments that use land records, and the chart stretched across 12 feet with standard typewriter-sized print! County officials were able to use the chart to more effectively organize departments around functions, instead of existing, traditional lines.

INTERPROFESSIONAL BARRIERS

An MPLIS project brings together a wide variety of professions, a more diverse group than for nearly all other county activities. In some jurisdictions, the development of an MPLIS may involve the knowledge and skills of planners, engineers, surveyors, mappers, computer scientists, conservationists, programmers, lawyers, and financial managers coming from many disciplinary backgrounds. At the outset of an MPLIS project, this group will lack a common technical vocabulary and a common set of values and expectations. Specific efforts will need to be made to overcome these barriers, and to build a common foundation on which to communicate and work.

What are some of the issues that can result in conflict arising from varying needs of professions and difficulties in communication? Spatial accuracy is certainly one area in which differences abound. Land surveyors tend to expect more precise measurements than others, often down to 0.1 or 0.01 of a foot. Engineers may be satisfied with much less accuracy -- up to several feet of tolerance -- and may be willing to acquire greater accuracy, often by re-surveying, only in those specific cases where a project requires it. Planners are more interested in a data base that is fairly complete and that has good relational accuracy (i.e., accurate in terms of the location of one feature with respect to another).

Mappers rely on annotations on their maps to describe its spatial accuracy, and National Map Accuracy Standards (NMAS) are typically used to measure the accuracy of the map itself. (NMAS are based on statistical sampling, a technique which makes some professions nervous, such as those with a broader definition of accuracy, including attribute accuracy and completeness of information).

The management of computer resources on which an MPLIS relies is another area in which conflict might arise. An MPLIS will encompass existing applications such as property appraisal, building permits, and title recordation. These functions may be automated and the computer resources may be managed by two or more data processing groups or departments. The advent of the microcomputer has tended to spread control of hardware across a wider group of managers. In this environment, the integration of hardware, software, communications networks, data, and particularly, standards presents difficult technical and management problems.

The appropriate role for the data processing (DP) department and computer scientists and engineers is another point at which conflicts often arise. Line departments and those headed by a separately elected official often want to develop data processing capabilities within their own department. DP departments prefer that control of all automation remain with their department. At the same time, DP expertise has historically been within single-purpose systems that rely on text-based information. The linkage of text and graphic data in an MPLIS adds substantial complexity to systems that DP departments have often not dealt with before. The need to retrain existing staff and the need to continue to support existing systems and applications present problems for DP departments that cannot be solved overnight. The key is to integrate the expertise of the DP department with the requirements for the MPLIS as identified by user departments, and combine both of these with knowledge about the potential and needs of an MPLIS.

The question of access to data in the MPLIS, vis-a-vis the right to privacy regarding certain files and records of individual citizens on certain items, is another area in which professions differ. The intent of public record laws should be carefully considered when developing an MPLIS. Some states are considering the revision of public records laws, for example, to tie access to a user fee to provide greater flexibility in financing the development of an MPLIS.

RESISTANCE TO CHANGE

Personal inertia is a factor that must be considered in MPLIS planning. Individuals in participating departments may view changes as threatening to their current job, difficult, unnecessary (in their view), or a mistake. They may not see, particularly in the beginning, the benefits that an MPLIS produces. On the other hand, proponents may see many benefits of an MPLIS, but fail to foresee or plan for the many changes in work patterns, individual jobs, and departmental structure that often result.

Careful planning and thorough communication are needed to convey to individuals what they are to do and to help ensure that the new system will actually help completion of tasks for which the staff is currently responsible, as well as new tasks not done before. To overcome resistance to change, the benefits of an MPLIS must be understood by each participant and there must be an open system for communicating the importance of new procedures. If at all possible, the system should provide incentives to participants, supporting them in their day-to-day activities.

Organizations may have inertia to overcome also. There may be resistance to change if there is substantial investment in existing procedures. For example, an organization with several wet-ink cartographers faces the prospect of re-training (or replacing) them and rendering many thousands of dollars of equipment obsolete. There may also be organizational resistance because there is something to hide. The examination of records and procedures prior to automation could reveal years of poorly managed or incomplete data. Again, education and communication are the most effective tools for allaying fears.

MANAGEMENT AND DESIGN SKILLS

Because the MPLIS is a complex system, both technically and organizationally, new management techniques and skills will be required. The use of old techniques and skills in a new, more complex environment may also be required.

Management issues that need to be addressed include:

- What organizational structure is needed?
- How should it be managed?
- How should it be funded?
- How should the cost of the system be shared?
    - and still assure that funds are applied to solutions of user problems
    - and be sure that participant priorities are met.
- How can the transition be managed to minimize disruption?

To be effectively managed, the MPLIS concept and the wide variety of components that make up the system must be thoroughly understood. One of the keys to this understanding is a detailed needs assessment and system design (see Chapter 16).

ORGANIZATIONAL KEYS IN MOVING TOWARD AN MPLIS

A variety of organizational and institutional factors can affect the development and adoption of an MPLIS. Among these are institutional, economic, personal, technical, and personnel factors. These factors played roles in the development of a prototype MPLIS in one Wisconsin county.

INSTITUTIONAL FACTORS

Under the umbrella of broad institutional and organizational factors are a handful of concerns that are particularly applicable. These include management support, steering committees, cost sharing, and system location.

Management Support

Experience from the implementation of information systems in the business community has demonstrated the importance of top-level management support (Ginzberg 1981; Benson 1983). Such support is equally important in government, but even more difficult to obtain, often as a result of frequent changes in leadership in elected offices. Chronic shortage of funds is often perceived by management as a reason (or excuse) not to embark on new programs such as an MPLIS. Still, it is possible to obtain high-level support for MPLIS, and every effort should be made to get such commitments before, or at least early in, the development process.

However, the lack of such support should not be viewed as a fatal flaw in MPLIS development efforts. Experience in Dane County, Wisconsin, provides insight as to how individual departments can work together to build the needed support, even in the absence of initial upper-level management support.

Departments in Dane County developed a cooperative project that relied on informal technical interchanges and cooperative agreements. Individual departments developed budget requests as they needed funds to continue development of their own parts of the MPLIS. These budget initiatives created the main points of interaction between upper level management (i.e., the county executive and the county board of supervisors) and departmental implementors.

Committees to Support MPLIS Development

A mechanism to guide the development and operation of the MPLIS is another important institutional consideration. When efforts are underway, system developers usually find the need for two kinds of committees, or similar groups, to provide the support and guidance needed. One such committee is a steering committee or policy board. Initially, the steering committee might hire a project manager or a consultant to coordinate the activities involved (e.g., deciding what should be in the shared data base, converting existing maps into digital form, developing a data base maintenance and update procedure, and acquiring and putting hardware and software in operation). A second committee that often shares in the oversight function is a technical committee that, as the name suggests, deals with technical aspects of the system, such as hardware and software specifications, data sharing mechanisms, and standards needed for digitizing and other manipulations of the data base.

Most of these issues should be defined in a needs assessment. The nature and development of a needs assessment is fully covered in Chapter 16. As an issue of institutional support, one must recognize that the needs assessment is a critical component of any effort to develop an MPLIS. Guidance of the MPLIS development effort, including the needs assessment, can be handled with either in-house personnel or with outside consultants. There are advantages and disadvantages to each approach.

For example, advantages of using in-house personnel to conduct a needs assessment include using the knowledge base of current employees who are familiar with goals of the agency, what is needed to achieve these goals, and what procedures are currently used in the conduct of agency business. Further, by using in-house personnel, the knowledge gained during the needs assessment will be readily available to the organization.

Use of outside consultants also has a number of advantages. First of all, consultants can bring a fresh approach to a needs assessment. They are generally familiar with effective techniques for doing the assessment and also can approach the task without restrictions fostered by the "we've always done it this way" syndrome. Consultants usually have considerable experience with similar situations (i.e., counties and local agencies) and can often complete the task more quickly and thoroughly than in-house personnel, since consultants can devote full-time to the task. In deciding on which approach to use, complexity of the task and the capabilities and time available of in-house staff will usually lead to the selection of a logical approach.

Cost Sharing

An alternative to acquiring the up-front budgetary support necessary for an MPLIS is to bring together a group of participants, to agree on the scope of the MPLIS, and to develop a mechanism that specifies how the costs of the MPLIS will be shared. Each of these steps is complex and the development of a way to share costs is no exception.

An effective way to develop a cost-sharing program is with the use of a formal memorandum of understanding or a contract. Such an agreement should be developed and approved by all participants. Cost sharing might be based on frequency of use, amount of data required, size of the jurisdiction or agency, or resources available (e.g., tax base or annual revenues of a utility). "In-kind" resources can be considered, but a way to establish their value needs to be clearly established.

System Location

Another important institutional decision is where, within county government, to locate the responsibility for an MPLIS. Placing all of the responsibilities in an existing user department (such as planning or engineering) can lead to inefficient utilization of resources within the organization and also cause problems with which management may not be prepared to deal (e.g., highly technical matters). On the other hand, placing all of the responsibility for the MPLIS in the data processing department can lead to problems as well. DP departments are often not familiar or comfortable in dealing with the unique geographic and cartographic features that are such a large part of the MPLIS. Also, the MPLIS might not be given as high a priority in the DP department as users would like. Such conflicts tend to be frustrating for both users and providers.

Two approaches have been used to successfully overcome the problem of where to locate the MPLIS. One approach is to create a whole new organization to take responsibility for developing the MPLIS project and eventually operating the system. A second approach that has proven successful is to divide the responsibility for the MPLIS: putting hardware and software in the DP department, and responsibility for data in each functional unit assigned the responsibility of maintaining the records for that particular file. This usually provides the best solution to data base maintenance as well, since the department that uses and is most familiar with the data is more likely to keep the data up to date. Whether the MPLIS resides in a separate department or is dispersed among several departments, communication and coordination among the involved parties is critical. Trust in and respect for other cooperating departments is also important.

ECONOMIC FACTORS

Economic factors are often a key in obtaining support for an MPLIS. Management needs to know how much the system will cost, what current costs will be displaced (i.e., what the cost savings will be), and what other benefits can be expected to accrue to the MPLIS. One of the approaches that is usually effective in building the level of management support necessary is to carefully document the costs of the current manual system. When management has been made aware of these usually substantial costs, obtaining approval of the MPLIS costs can be much easier.

Another useful technique is to document the costs of one or more mandates that have recently been imposed on a government or department therein. The likelihood that, based on past history, additional mandates can be expected to continue to add to the work load in the future should also be highlighted for management.

Suggested ways to conduct economic evaluations of MPLIS, both before they are implemented and after they are in operation, are discussed in Chapter 15, which also contains examples of techniques used by specific jurisdictions.

TECHNICAL FACTORS

There are numerous ways that technical factors (both real and perceived) can influence the implementation and use of an MPLIS. While many people believe institutional factors present the most difficult problems for MPLIS development and use, technical factors also present substantial challenges. These factors include the form of existing records (already automated, readily automated, or difficult to automate) (see Chapter 9); the quality, form, and density of existing geodetic control (see Chapter 18); the suitability of existing hardware and software for new or expanded applications; the system design (see Chapter 16); the availability of technical expertise (currently in-house, upgrade of existing staff, or new hires) (see Chapter 14); and the success rate for similar ventures in other departments or jurisdictions (see Appendices).

Sometimes it is possible to acquire help from nearby universities (either free or at a reduced cost) or to obtain assistance from consultants and vendors. The willingness to use such resources often depends not only on the cost, but also on past experience with use of similar assistance.

PERSONAL FACTORS

There are many personal factors that can influence the participation in development of an MPLIS. These factors include level of education, exposure to and experience with computing in general and LIS in particular, and motivation of persons involved (Drury, 1983; Dutton, 1982). These factors were examined in an attempt to explain differences among individuals in three departments that participated in the MPLIS development in Dane County, Wisconsin, discussed previously. All three had similar exposure to computing (none of the departments had automated systems), and the educational levels of the staff in all three departments were comparable (all had at least a bachelor's degree). Staff in one of the departments (Planning) appeared to distrust computing, possibly fearing displacement of their jobs by automation or distrusting the results of computer-based analysis. The most striking difference in Dane County appeared to be motivation of the individuals in various departments. The head of the Land Conservation Department quickly recognized the potential of an MPLIS and became an active promoter, both within his own staff and to other related departments. The Land Records and Regulation Department participated in some experimental work, but only focused on the automation of their manual procedures.

Evidence from other pioneering jurisdictions indicate that early adopters of modern LIS must be willing to take some risks (personal correspondence: Eunice Ayers, Forsyth County, North Carolina, Murray Rhodes, Wyandotte County, Kansas, and Richard Allen, City of Milwaukee, Wisconsin). The importance of a "champion," someone willing to forge ahead in spite of criticism and opposition, is common to the adoption of many new technologies. Until a few innovators have lead the way to show that a new technology is feasible, few others are able to stand up to the critics and continue to seek support until the system is successfully in place.

PERSONNEL FACTORS

In addition to the personal factors are the personnel factors. Two problem areas must be met head-on in any MPLIS effort. One is the need to train or hire the competent staff necessary. Second is the need to keep the quality staff, once it is in place.

Before an MPLIS staff can be put together, a plan is needed as to what positions are required to develop and operate an MPLIS. Below are suggested descriptions for seven staff functions that are essential to an MPLIS staff. When the personnel plan is developed, decisions must be made as to which positions can be filled from within the organization (often supplemented with additional training) and which will require hiring from outside the organization.

Smaller organizations will sometimes be able to combine two or more of these functions in one staff position. Larger organizations may need several staff for the individual functions. The salary ranges are included to provide suggestions as to the relative salary of the various positions. Because salaries in the MPLIS field vary widely by area of the country, local market demand, and other factors, the salary ranges included here should be used with caution.

Careful thought is necessary, not only to assure that the right positions and skills are in place for the MPLIS, but also to assess the impact on the system that various staffing options will produce. For example, hiring from outside could affect the overall acceptance of the system. There might be trade-offs among knowledge about data bases, personalities, and users needs of current staff, versus bringing in new people from outside who will have a fresh perspective.

A good personnel plan is necessary to properly classify staff needed for the MPLIS. This often is difficult, given existing personnel classification schemes and the difficulty in fitting positions such as "GIS manager" or "GIS Analyst" into an existing personnel system. Whereas the changes needed are often difficult to put into place, it is usually worth the effort, since future personnel actions will likely be based on the attributes and skills and career ladders included in the new GIS/LIS personnel structure.

Finally, an on-going training program is needed to keep staff up-to-date, as well as challenged on the job. This is true even if initial hires are made primarily from outside the agency. Training will be needed to keep up with the latest technology (in hardware and software). Also, new uses and users will continue to appear and will need to be included in overall MPLIS activities. Allocation of adequate resources to meet these training needs will go a long way in assuring a successful MPLIS.

Specific MPLIS Personnel Functions

MPLIS Manager

An MPLIS project is complex, involving many different people in a number of different organizations (users, vendors, policy-makers, managers, the press, etc.) It is therefore important for the manager to be a full-time position and for there to be only one manager. This provides a single focus and responsibility.

The MPLIS manager is responsible for three major areas:

- management of the project as it moves from study to implementation,
- management of the system itself once it becomes operational, and
- management of the people involved throughout the entire process.

The manager provides the pivotal point around which all activities of the project revolve. He is responsible for clear, definitive directions and actions during and after implementation. Important qualifications to look for in an MPLIS manager, therefore, include:

- the ability to communicate with people at all levels of the organization,
- a comprehensive understanding of the departments involved in the project, and how the technology involved in MPLIS can be effectively used in them, and
- the likelihood that the person will remain in the position on a long term basis.

Managers with experience are difficult to find, since only a small number of systems have been implemented to date. MPLIS managers often command an annual salary in excess of $50,000.

MPLIS (or GIS) Analyst

The MPLIS analyst's role has similar counterparts in most data processing departments. The analyst must:

- understand the users' world (needs, procedures, missions, and working environments) and

- be able to use technical expertise to apply computer technology in such a way as to improve the users' world.

The analyst studies potential applications, translates the requirements of these applications into technical specifications, and then works with the technical people, vendors, and users to ensure that technical specifications are successfully implemented and used. This position is not necessarily a highly technical one, but the analyst must be able to effectively communicate with users, understand their needs, and prepare clear specifications for technical staff. Therefore, both written and verbal communications are important in this position (technical training on a specific vendor product can be obtained as necessary, often at a later time). Many analysts do have a strong technical background and are able to roll up their sleeves and write computer software code when the job demands it. Analysts currently earn between $30,000 and $50,000, with one to five years experience.

MPLIS System Administrator

The MPLIS system administrator is the captain of the team once the system is installed and operating. While the manager acts as coach, managing the people, planning the work, and dealing with upper level management, the system administrator is responsible for day-to-day operation of the system. The system administrator is responsible if the system or a workstation "goes down," if a file is lost or cannot be accessed, if a new software product must be installed, if a new piece of hardware needs to be added, or if any other problems of system operation arise. This, then, is a highly technical position, requiring a solid computer programming and operating system background. If a network-based system is installed, the system administrator will also need communication experience. System administrator salaries are similar to those for analysts, in the range of $30,000 to $50,000 per year. Because of the rapid rate of change in computer technology, technical expertise is much more important than number of years experience in this role.

MPLIS Data Base Administrator

This person is responsible for the technical design of the data bases that are part of the MPLIS. This position is parallel to those of the system administrator and analyst; the data base administrator is responsible for the data bases that support each application. The data base administrator must ensure that the logical design of each data base is appropriate for the hardware and software of the system. Data base administrator tasks include:

- organization of digital map features into specific layers,
- development of standards and coding structures for nongraphic data,
- establishment of standard symbols and text fonts for maps,
- documentation of data that are stored in the data bases, and
- other data activities (such as data quality control and training on data base management software).

Specific experience with MPLIS is not necessary, but experience in data base administration in other more traditional systems is important. Experience in programming, systems design, and data base management is also an important skill. Salaries for data base administrators are in the range of $25,000 to $40,000, depending on the complexity of the data bases and software.

MPLIS Programmer

Most analysts, system administrators, and data base administrators were programmers at one time in their careers. They may have acquired programming skills through a computer science degree, on-the-job training, or formal training on a specific product by a specific vendor. A programmer is typically adept at using a computer to produce results specified by an analyst, in terms of input, output, and processing specifications. The programmer understands the system software (operating system, communications, data base management, vendor-supplied programs, and general purpose programming languages). The programmer uses the features of this software to produce such things as special purpose programs, specially designed menus, macro-level commands, input screens, and output products. These items are either implemented in the user applications or used to improve the operation of the system.

The work of a programmer is very detailed and requires good concentration and logical skills to analyze problems and processes. Programmers often begin with little programming experience, but usually have a college degree related to a technical field. Salaries in the $25,000 to $35,000 range are common.

MPLIS Processor

This is the least standard job classification discussed here, but can best be thought of as a "super user." The processor often has some programming skills, but his or her main focus is on specific applications, has been fully trained on the system, and can usually implement a simple application without the aid of a programmer or analyst (although regular communication with programmers and analysts is quite common). This position is most effective when located within the user function itself, rather than, for example, in a data processing department. The processor often has been with the organization for some time and therefore understands how it works, but also is very interested in the technology and how it can help other users in the functional unit. The processor will often have a job title related to the function of the unit to which he or she is assigned, but also will act as liaison with the technical support staff of the entire MPLIS project. Depending on skills and training on the system, processors may design user menus, produce ad hoc reports and maps, develop standard operating procedures for specific applications, and even program simple applications. For functional units with high system utilization, this position can either be created as new, or can be converted from other positions that are not needed, once the system becomes operational.

The salary of a processor depends heavily on the salary structure in the functional unit, but generally is comparable to a programmer or analyst (i.e., in the $25,000 to $45,000 range).

MPLIS Digitizer

Digitizers operate work stations that are used for the entry and maintenance of the digital map information. They spend long periods of time at the digitizing table and work station screen, paying careful attention to the map features and their digital representation on the system. Digitizers also often serve as data entry specialists, entering non-graphic data at the keyboard for storage in the data bases. More experienced digitizers also perform edit checks (at the work station or at a backlit table) on data after it is entered into the computer. Drafting skills are useful, but it is more important that digitizers have good knowledge of mapping and drafting products and standards used in the organization. A college degree is generally not required for the digitizing position. Salaries range from $10,000 to $25,000 per year.

Other MPLIS Positions

A number of other positions may be needed in a particular MPLIS installation, depending on the size and complexity of the system and applications implemented. These positions might include:

- cartographers (might be needed to design and produce high quality map products),
- draftsmen (might be required to design highly technical engineering drawings and construction plans), and/or
- photogrammetrists (might be needed to compile and integrate cartographic data from aerial photography onto map manuscripts for digitizing).

SUMMARY

Traditional organization of government, particularly at the county level, presents some significant barriers for implementing MPLIS systems. Other factors, including institutional, economic, technical, personal, and personnel, need to be considered by any entity contemplating the development of an MPLIS. A detailed needs assessment, coupled with a well-thought out plan, can go a long way in overcoming the impediments identified here. Finally, because the roles of LIS and GIS "experts" are new to government offices, implementors need to be familiar with the functions necessary in developing and maintaining an MPLIS. As these new positions become standard in government, personnel offices will need to work hand-in-hand with other departments to ensure the success of an MPLIS in the context of local government.

REFERENCES AND ADDITIONAL READINGS

Duncombe, Herbert Sydney, 1966: "County Government in America," National Association of Counties Research Foundation, Washington, D.C., 288 pp.

Benson, D.H., 1983: "A Field Study of End User Computing: Findings and Issues," *MIS Quarterly*, December, pp. 35-45.

Brown, Patricia M. and Friedley, Dale, 1988: "Assessing Operational Preparedness for a Comprehensive, Distributed LIS/GIS," *Proceedings of the 26th Annual Conference of the Urban and Regional Information Systems Association*, Volume 3, pp. 22-36, Washington, D.C.

Drury, D.H., 1983: "An Empirical Assessment of the Stages of DP Growth," *MIS Quarterly*, June, pp. 59-71.

Dutton, W.H., 1982: "Eighty Thousand Information Systems: The Utilization of Computing in American Local Governments," *Computers, Environment, and Urban Systems*, Vol.7, pp. 21-33.

Foley, Maurice E., 1988: "Beyond the Bits, Bytes, and Black Boxes," *Proceedings of GIS/LIS 88* (San Antonio, TX), Urban and Regional Information Systems Association, Washington, D.C., Vol. 2, pp. 608-617.

Ginzberg, M.J., 1981: "Key Recurrent Issues in the MIS Implementation Process," *MIS Quarterly*, June, pp. 47-59.

Juhl, Ginger, 1989: "GIS: Implementation and Use in City/County Government," *Market Research Results*, Utility Graphic Consultants, Englewood, CO, 14 pp.

Niemann, Bernard J., Jr., 1988: "Social and Institutional Issues in Modernization," *A Primer on Multipurpose Land Information Systems*, edited by Bernard J. Niemann, Jr. and D. David Moyer, Institute for Environmental Studies, Land Information Report No. 133, University of Wisconsin-Madison, 176 pp.

Wunderlich, Gene, and Moyer, D. David, 1988: "Economics of Land Information," *A Primer on Multipurpose Land Information Systems*, edited by Bernard J. Niemann, Jr. and D. David Moyer, Institute for Environmental Studies, Land Information Report No. 133, University of Wisconsin-Madison, 176 pp.

Ventura, Stephen J., 1988: "Institutional Constraints to Land Records Modernization: The Case of Dane County, Wisconsin," Association of Collegiate Schools of Planning 30th Annual Conference, State University of New York at Buffalo, October, 8 pp.

9 LAND DATA: TYPES AND REQUIREMENTS

Earl F. Epstein, Patricia M. Brown, and D. David Moyer

INTRODUCTION

Land data can be categorized in a number of ways. However, one of the most important distinctions is between graphic and nongraphic data. While the difference between graphic and nongraphic sometimes becomes blurred, graphic data can be displayed to depict their spatial characteristics and nongraphic data generally apply to the attributes of a spatial object. This chapter examines these two categories of land data, including functions for which data are used, specific kinds of data, form and content of various land records and land record files, compatibility, and data management. The ability to link graphic and nongraphic data is critical to the development of an MPLIS and the usefulness of both types of data. This topic is discussed in Chapter 10 (Linkages). Land records have wide use in both the public and private sectors in the United States. However, in this discussion, attention is focused on local government functions that use and rely on land information. Throughout the chapter, we draw distinctions between graphic and nongraphic data, and explain why the distinction is so important in the MPLIS. This chapter should be useful in the evaluation of existing data and future data needs, a critical step in the design and implementation of an MPLIS.

CURRENT DATA TYPES

NONGRAPHIC DATA

Nongraphic, or textual, data are the dominant type of land data found in the vast majority of local government files today. Nongraphic data include attributes of a parcel, such as value, owner name, area, address, building type(s), and use. These attributes are often derived from other records that summarize field observations or conditions, such as a measurement of spatial area or type of building on the parcel.

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Nongraphic records are words and/or numbers that describe, summarize, or generalize natural phenomena. These phenomena are often continuous and as such, can be represented as graphic (i.e., map) data. However, for efficiency or other reasons, these data may be generalized in the form of a single attribute, such as the dominant land cover type over a parcel. For instance, soils are one data element that can be handled this way, with the soil for a parcel or field coded textually as the one soil type that predominates for that spatial area. Admittedly, the efficiency that is gained in amount of data stored is offset by the loss of detail that exists in the graphic (i.e., a map) of soils that shows the extent of all soil types that are found within a parcel or field.

Nongraphic data can also represent attributes of a particular location. For example, a record may contain an alphanumeric description of a manhole cover, a power or telephone pole, or a street intersection. These records have a spatial character in that they relate to a place, parcel, or coordinate, but they contain much data that is nongraphic. The key for an MPLIS is to make these nongraphic records compatible with graphic records.

The form of nongraphic records is an important factor in their compatibility with graphic (map) records. Nongraphic records come in several forms:

a. *Words, phrases, sentences, and/or paragraphs.* Deeds, documents, court records, and similar records contain a variety of material that may be used directly in the land information system. It may also be referred to by reference or summarized and used in an abbreviated form.

b. *Codes.* Words, phrases, and sentences may be summarized or generalized in terms of a code. Such codes may be assigned as an attribute to a parcel or other land area polygon. Such codes may be derived from planning and zoning maps, soil maps, value assessment records, and similar records. The sources may vary, but each set of codes consists of assigned attributes that are derived from original material and becomes a new set or file in the MPLIS.

c. *Tables of numbers.* Tables can be used as an alternative form of codes. For each parcel or polygon area, or for a spatial location such as a coordinate point, a table of number codes may exist. For example, for a polygon area, a table can be set up to designate a set of utility facilities such as manholes, telephone and power poles, transformers, and substations.

d. *Indexes to record location.* Indexes may be viewed as codes, but they also can be viewed as a separate, particularly important form of nongraphic records. An index indicates the location of other land records that apply to parcels, areas, location, and owners. Examples include tract and grantor/grantee indexes for ownership records and similar indexes for court records and zoning documents.

SOURCES OF NONGRAPHIC DATA

The sources of information that go into an MPLIS are another measure of the scope of the system. As suggested above, a wide variety of information is needed to describe all of the various interests in land and to support the various operational and managerial functions that involve land. Even for nongraphic data, the data exist in a variety of forms. Land data may be in public or private files, in digital format in an automated system or on traditional hardcopy media in a manual system. A couple of examples illustrate the range of data sources that should be considered when designing and building an MPLIS.

Survey data on which to base land boundary files for an MPLIS are particularly dispersed and difficult to compile. The data to build the geodetic reference framework are primarily found in public agencies, although private sources are often an important source as well. (See Chapter 3, "Introduction to Geodetic Reference Frameworks," Appendix 3-2.) Within local government, geodetic data are most likely to be found with the county surveyor or county engineer. Information leading to geodetic data can sometimes be traced through remonumentation of Public Land Survey System (PLSS) section corner projects, as well as aerial photography and mapping projects that are part of the graphic portion of the MPLIS.

Many other local government offices often conduct surveying activities. These offices include those involved in engineering, public works, utility, zoning, and recreation. Private surveying, engineering, and even land title firms maintain substantial land survey data bases, but they are often reluctant to share information they see as providing a competitive advantage. These private firms may be willing to share the data with government, but they are concerned that open record laws will allow their competitors to capture data from government with very little cost.

Vertical survey data provide the base for elevation, slope, and drainage information. The importance of these vertical data is increasing in direct proportion to the increase in concern and controls related to environmental hazards and water quality. Historical and archeological information may also be important in certain areas.

GRAPHIC DATA

Graphic data come in a variety of forms, including maps, photographs, drawings, and images (such as digital orthophotographs that include characteristics of traditional maps, photographs, and digitally generated images).

There are two aspects of graphic data for an MPLIS. One is current data that are stored on hardcopy maps or other graphic materials. These graphic materials can often be digitized and thereby used as input to the graphics base of an MPLIS. The second aspect of graphic data is output that can be created and displayed as output from an MPLIS. The graphic outputs of an MPLIS may range from a simple map containing an index to nongraphic parcel data to a complex, multi-layered overlay of many different land data files.

A wide variety of maps, drawings, and images can be used in an MPLIS. Maps range from large (e.g., 1:500) to small (e.g., 1:100,000) scales. Maps may cover all of an area or only a small portion thereof. Graphic information may be as detailed as a reference map to a particular area or as simple as a thematic map designated to convey information about only a single topic or subject area.

For example a graphic image may show:

- planimetric or topographic features,
- surveys, subsurface features such as groundwater or geology,
- population, land use, or other cultural data, or

political or statistical boundaries such as county, city, state, census tracts, voting districts, taxation districts, or traffic zones.

Drawings of interest for an MPLIS usually pertain to planning and engineering tasks. Recorded plats almost always are a key component in building and maintaining parcel and base maps. Utility design and as-built drawings are essential for maintaining a utility or infrastructure layer. A few examples of sharing of graphic data between government, utilities, and the private sector are now starting to appear.

Photographs, video, and other image media have a strong potential to contribute to an MPLIS, but their use in government, particularly at the local level, is the exception rather than the rule at the present time. However, the use of image media is growing. Photographs and video have been used to document land value appraisal. Videos are also being used to record the condition of roads (i.e., photologging) and the condition of sewers and other underground pipes. Computer systems are now available (and in use in a few jurisdictions) that support the integration of video images, maps, drawings, and nongraphic data, thereby improving access to these data and increasing the flexibility of their use.

SOURCES OF GRAPHIC DATA

Graphic data resources can be found in many local, regional, state, and federal government offices and in many private companies. The sources of graphic data are important in the design of an MPLIS, as well as in consideration of how the data base that is an integral part of the system will be maintained. These graphic data can be grouped into four categories, based on who creates and maintains them and the purpose for which they are generated.

1. *Graphic data that are created and routinely maintained by local governments themselves.* Among data in this category are large scale maps and images, such as property appraiser's parcel maps, compiled subdivision maps, a set of aerial photographs, a medium to small scale (1" = 1,000' to 1" = 5,000') map set, and a street atlas. Also, local governments often have "overlay" maps to which zoning or utility data have been added to one of their basic graphic data bases. These map series are valuable, often representing years of transactions to the data base in a

graphic form. The information is critical to the operation of local government and difficult to reproduce. Since these data are typically the product of the efforts of many individuals over a relatively long period of time, the data vary in quality due to varying standards and specifications. In spite of these shortcomings, they are easy to use and are used widely.

2. *Drawings, aerial photographs, and maps that are submitted by applicants as part of regulatory processes.* These materials are part of site plan reviews, subdivision reviews, re-zoning applications, and the enforcement of various codes. These graphic products play a major role in the update and maintenance of the graphic data side of an MPLIS.

3. *Drawings, images, and maps that are acquired by government for a particular project or purpose.* These graphic materials may enhance the data created as part of the first two preceding categories by adding detail, accuracy, or currency to a particular area. Because of their accuracy, detail, and currency, these data are often useful in building the initial graphic data base for an MPLIS.

4. *Maps and images created, maintained, and published by other organizations.* These organizations include private companies and regional, state, and federal agencies. The graphics are typically available as paper copy, but the publication of the graphics in digital formats is increasing. Among the graphic data that are available to local government from other agencies and companies are:

- 7-1/2 minute quadrangle maps from the U.S. Geological Survey
- Soils maps from the U.S. Soil Conservation Service
- National Wetlands Inventory from the U.S. Soil Conservation Service
- Demographic maps from the U.S. Bureau of the Census
- Flood prone area maps from the Federal Emergency Management Agency (FEMA)

PARCEL INDEX MAP

One of the most important maps generated and maintained by local government (i.e., category 1 above) is a parcel index map. This map typically shows the boundaries and identifying number for each parcel of land in their jurisdiction. This is an index to the contents of land record files and should be available in each office of local government that maintains land record files. A parcel index map is helpful in both filing data in the system and retrieving data from the system. It is particularly useful to citizens who are infrequent users of the system.

CURRENT LAND DATA REQUIREMENTS

An inspection of the kinds of data currently maintained and used by local government is one measure or view of the data needs of an MPLIS. As indicated by Figure 9-1, parcel data (on the right side of the figure), are a major component of an MPLIS. At the local government level, parcel data are the most frequently occurring and most frequently used class of data. Examples of functions that rely heavily on parcel data at the local level include:

- property appraisal
- title recording
- building inspection
- emergency vehicle dispatch
- zoning and planning
- land surveying
- utility planning and management
- voter registration.

Parcel data actually contain several kinds of parcels. Zoning parcels may vary from ownership parcels (i.e., they may not be coterminous, with two or more parts of an ownership parcel having different zoning). Appraisal and utility parcel maps may also vary, with multiple units or multiple service units located on one ownership parcel.

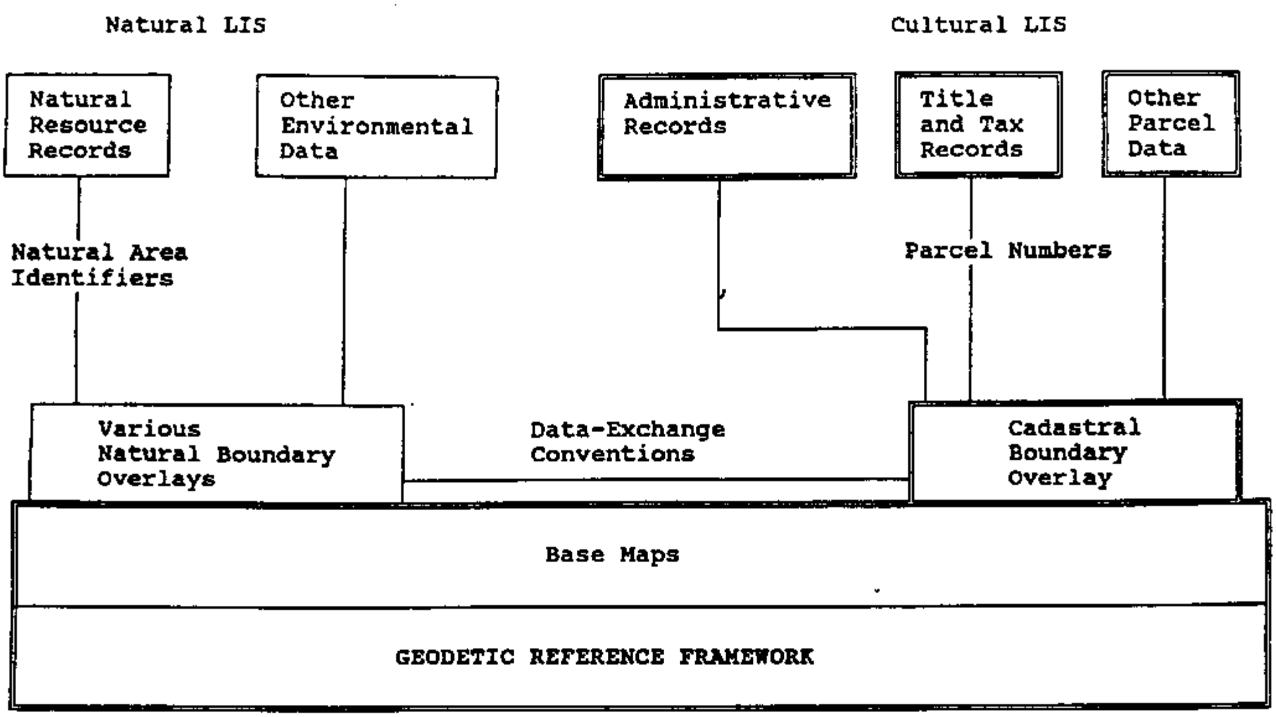

Figure 9-1: Components of a MPLIS (from NRC, Procedures and Standards for a Multipurpose Cadastre, 1983)

In addition to parcel data, some local government functions also use polygon data. For example, property appraisal may use resource polygon data (e.g., for soils, depth to bedrock, or depth to groundwater) as a data resource to assist in appraising the value of an ownership parcel. Planning functions may require the use of both ownership parcel and resource polygon data as well. Such planning may use soils and other resource polygon data as well as polygons developed as part of the planning process itself, such as for school districts, water districts, and watersheds.

FUTURE LAND DATA REQUIREMENTS

The development of a detailed inventory of future land data requirements is a task that is rife with uncertainties. However, the appearance of new requirements in the future is a certainty. New mandates and new opportunities to manage physical resources more effectively will continue to appear. These mandates and opportunities will impact on local and state government, as well as private sector data systems users. It is thus safe to say that the MPLIS of the future will:

- require a large volume of data
- require more detailed data
- be subject to more frequent use
- have much greater impacts on the decision-making process
- have much greater impacts on individual users of the results that the LIS produces.

Therefore, the best approach is to build the most complete, most accurate, data base possible, in order to effectively serve these as-yet-unknown future needs. Future demands for accurate data systems make it very important that each MPLIS be built on a sound foundation of accurate geodetic control. Current technology makes such a foundation affordable and future demands for data and analyses will provide substantial benefits to those who make the relatively small additional investment for accurate geodetic control.

MANAGEMENT OF LAND DATA

A major task in the development of an MPLIS is management of the land data, including access, security, confidentiality, quality control, and maintenance. A short discussion of each of these topics follows here with more detailed discussion to appear in later chapters.

ACCESS TO LAND DATA

Improvement in accessibility to data is one of the major objectives of developers of an MPLIS. In the past, and currently in most jurisdictions, access was closely tied to storage equipment and methods for land information. It is assumed that much of the data in an MPLIS will be stored in a computer in digital format. However, in order to fully understand current and future needs, and provide access to all users, a full understanding of the storage and retrieval media for data is necessary.

STORAGE AND RETRIEVAL MEDIA

The media used to store data is a basic factor in accessibility. Currently, textual records are stored on a wide variety of media.

Each medium has a number of physical characteristics that affect the useful life of the data; the space, equipment, and procedures that are used to store, retrieve, duplicate, update, and distribute the data; and the suitability of the data for specific user needs, whether it be merely reading the file, summarizing the data in the file, or performing a detailed analysis.

Paper has been and, in most jurisdictions, continues to be the most common medium for public records. Most land information users are familiar with paper records and many legislatures require that paper copies be maintained and available to the public. However, many statutes are being changed and the opportunities to convert records from paper to film and digital media are increasing.

Conversion from paper to other media reduces space and storage costs, sometimes by as much as 90 percent. Retrieval of paper documents from off-site locations is another cost that can be reduced by switching to other media.

Mylar, vellum, linen, and film have all found traditional uses for maps and drawings. These materials contain much graphic material, but also contain nongraphic information as well. Since these media are generally more stable than paper copies, they provide an important base for reproduction of copies for a variety of users. Variation in initial costs, copy costs, update costs, and costs to the user all need to be considered in evaluating various media resources.

Data storage via electronic media is expanding rapidly. Electronic media include not only magnetic tape and diskettes typically used with smaller computer systems, but also hard disks, optical disks, and compact disks (CDs). These methods are the media of choice for the vast majority of MPLIS data.

The most important reason for the move to electronic media is the speed and flexibility they provide for storage, retrieval, display, and analysis. A computerized system is capable of using a single entry to locate via a number of cross references and a nearly limitless variety of section criteria, and to display the results in either summary or detailed formats. As long as records are properly coded, they are relatively safe from loss or misfiling, especially compared to paper records. Electronic media also provide flexibility, particularly as to map data, by allowing the display at a wide variety of scales.

QUALITY CONTROL

If users of an MPLIS are to be confident in the contents of the system, standards of quality concerning the file content must be clearly understood. Such confidence is important both to encourage system use by all potential users and to obtain the cooperation necessary on data maintenance activities. Chapter 20 provides details on standards and specifications that should be considered. A few basic suggestions are included here to help ensure the basic data needs of the users of an MPLIS are met.

Quality control standards for the MPLIS should include spatial accuracy as well as validity of specific data items. One approach that is useful, particularly when building the initial data base for an MPLIS, is to include the qualifications (or limitations) on how the data can be used as part of the data file. This "truth in labeling" approach thereby allows the data base to be built more quickly than if specific criteria were set as limits of entry. Responsibility for assigning limitations can reasonably be placed with the office or unit that originally places the data in the system. This labeling technique can also be used to explain how and why data are available, or are not available to all systems users. This truth in labeling approach is used in the draft Spatial Data Transfer Standard (SDTS), recently released by the National Institute of Standards and Technology (NIST) (SDTS, version 12/90).

SECURITY, OPEN RECORDS, AND PRIVACY

Limits on access to government records are regulated by a variety of freedom of information and privacy statutes and ordinances. Problems of confidentiality in land information systems can be limited by only placing information that is public in the system. These public records need to be accessible to all data users and should also be correctable by the individuals involved (e.g., owners and leasers). Access to confidential information is limited to the agencies that are responsible for the information. Such information is segregated and protected from the open and accessible files that also make up the system. In some cases, aggregations of restricted data may be linked with public records, but all detail and specific information remain confidential.

Many types of parcel data, such as title records, require procedures to assure that individual records are secure and that information on the date and time of any changes is maintained as part of the permanent file. To fulfill these requirements, procedures need to be devised that assign responsibility for specific tasks (i.e., develop an audit trail), restrict access to some data in the records, prevent unauthorized changes, prevent loss of records (and/or assure that a back-up file is available), and minimize the possibility of malfeasance, as well as inadvertent errors and changes to records.

In manual record systems, security can be assured by placing records in a secure location, restricting access to authorized personnel, and maintaining information on people who do have access to the records. The problems of security in computerized systems increase substantially, but a much wider variety of measures can be employed to assure such security. In particular, access to certain tables in an assessment system may be restricted to prevent unauthorized persons from changing valuations. Similarly, access to data about finances of individuals and companies is often restricted due to such information being excluded from the public record. Transaction logs or journals may also be maintained, to provide "audit trails" about each change, noting what change was made, when it was made, and who made it.

MAINTENANCE OF DATA BASE

Ultimately, the requirements of users of data in the MPLIS depend on the regular, dependable maintenance of the data base on which the system relies. A careful review of data needs will usually reveal a wide range of data that users will frequently request (see Chapter 16). No matter how convincing the arguments for including data may be, there is one over-riding principle that must be considered: If you don't have the resources (time, money, people, and equipment) to maintain a data file, don't include it when building the initial data base. Loss of confidence in a system due to incomplete, out-of-date, inaccurate data is a failure that can be extremely damaging, or even fatal, to your MPLIS development efforts.

SUMMARY

While recognizing the requirements of other sectors, this chapter focuses on the data types and needs of local government, current and future.

Two kinds of data, graphic and nongraphic, are basic categories of land data found in land information systems. Suggestions as to how development of an MPLIS and the new demands on government are affecting the data needs of local government are also considered.

The chapter concludes that data requirements of local government are evolving, due to changing resource management needs and the availability of new technologies, many of which support the development and use of MPLIS. Because of the critical importance of the data base in the MPLIS, it is recommended that a detailed needs assessment (see Chapter 16), be completed before embarking on the implementation of an MPLIS.

REFERENCES AND ADDITIONAL READINGS

American Public Works Association Research Foundation, 1981, Guidelines for System Analysis of User Requirements, Chicago, Illinois.

Moyer, D. David, and Kenneth P. Fisher, 1973, Land Parcel Identifiers for Information Systems, American Bar Foundation, Chicago, 600 pp.

National Conference of Commissioners on Uniform State Laws, 1977, Uniform Simplifications of Land Transfer Act.

National Research Council, 1983. Procedures and Standards for a Multipurpose Cadastre, National Academy Press, Washington, DC, 173 pp.

North Carolina Department of Administration, 1981, North Carolina Land Records Management Programs.

U.S. Department of Agriculture, 1979, Monitoring Foreign Ownership of U.S. Real Estate, A Report to Congress, Volume 2.

10 DATA LINKAGES IN AN MPLIS

Timothy L. Nyerges

INTRODUCTION

A multipurpose land information system (MPLIS) commonly consists of a set of interconnected data bases to support operational information applications. Examples of those applications include review of land development permits, street maintenance scheduling, and health center facilities location. The extensive investment that local governments have made in computerizing data over the last 30 years prohibits a complete restructuring of data bases to create a single data base to support such application environments. Combining all information into a single data base would create a land information management nightmare from an institutional perspective, and adversely impact the applications for which the systems were originally built. However, the diversity in applications of data does not prohibit an organization from bringing together diverse sets of data for more effective use. As long as data contain a data linkage among the elements, there is no need to combine all location-related data into a single data base. Whether the data linkage is to support a tight or loose integration of information, a carefully devised plan, including a justification for developing data linkages, can help create a fully interactive, interconnective set of data bases (Nyerges 1989).

Data linkages are important for several reasons. Technically, data linkages can reduce or eliminate redundancy by systematically relating various data sets. The data linkage can support easy access to data when such access is permitted. Economically, data linkages reduce the cost of data maintenance, and information use becomes more effective through a broadened information context. Institutionally, data linkages tend to foster cooperation among parts of an organization (or organizations) regarding land information issues.

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THE NATURE OF DATA IN AN MPLIS

The raw data stored in an MPLIS data base can be described using three fundamental categories of characteristics: spatial, thematic, and temporal. Spatial data include geographic shape information in terms of x,y geometry, as well as relative location information in terms of topological information as shown in Figure 10-1. Topological information deals with adjacency considerations such as what is next to what in space -- e.g., parcels or blocks -- and what is connected to what across space -- e.g., parcel boundary intersections or roadway intersections.

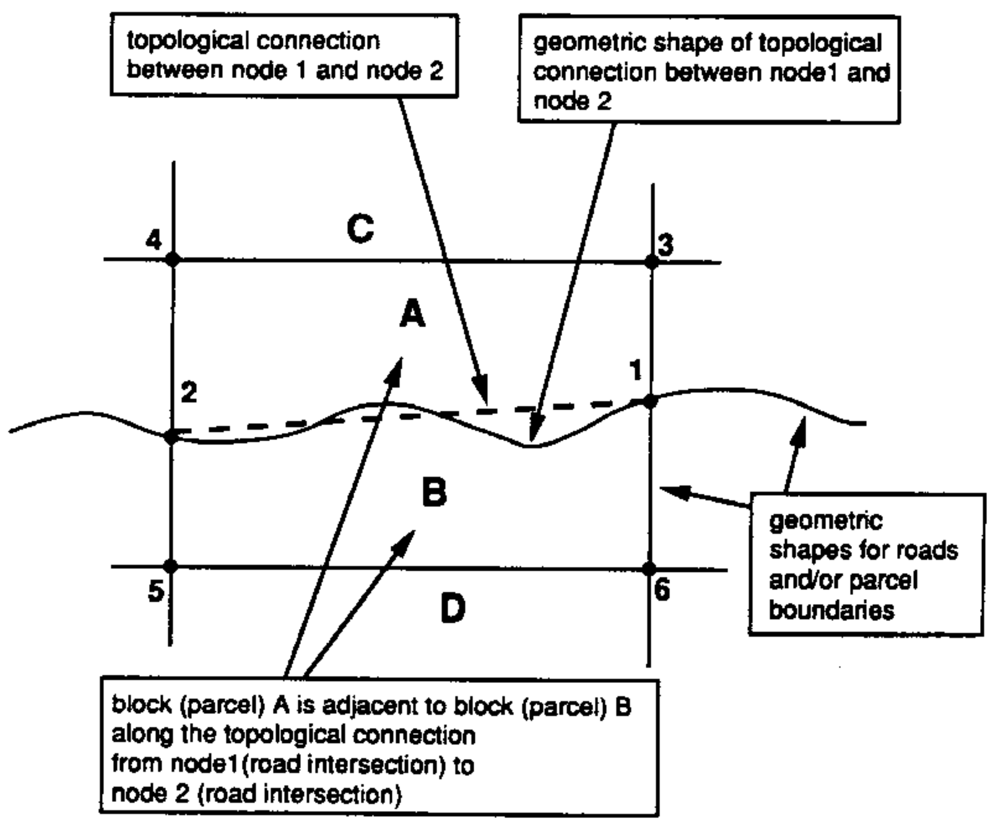


Figure 10-1: Topological information for parcel and roadway data.

Thematic attribute data include the qualities and quantities describing phenomena other than space and time -- e.g., the tax and ownership information for parcels, and the volume of traffic on a roadway. Thematic attribute data have tended to be a "catch-all" or "other" category because of the variety of data possible. Thematic attribute data constitute most of the data in most information systems. Hereafter the term "attribute" will be used without the qualifier "thematic" as is commonly accepted in a GIS context, but the reader should be aware that "thematic attribute" is what is meant, rather than spatial attribute or temporal attribute. Perhaps at some time in the future, the inconsistency in this terminology will be clarified.

Temporal data include the different aspects of time that can be measured in various contexts. For example, world time deals with time according to the sequence of events for day-to-day activities as measured by a wall clock (or calendar). Data base time deals with the time certain information is entered into a data base. In yet another context, computer time concerns the time it takes to process a computer program, several of which are sharing the processing unit. In current systems, world time is usually included as part of the thematic character of phenomena because this dimension has not yet received separate attention in the development of the GIS/LIS technology. In many applications such as infrastructure maintenance, land development permitting, and land use change, the temporal characteristic is of significance to the results of analysis. More than likely, the formal treatment of time will improve as its treatment becomes better understood conceptually to direct GIS/LIS implementations (Langran and Chrisman 1988).

Whatever the nature of data representations, all three aspects -- space, theme, and time -- are required for complete descriptions of real-world phenomena. Complete descriptions support information processing better than do incomplete descriptions. If one of the aspects is lacking, incomplete descriptions result, potentially limiting information processing. The nature of data representations to be stored in an MPLIS is determined through a process of data base design.

MPLIS data bases are designed from both a logical and physical perspective. A logical data base design focuses on the needs of users and their requirements for certain data. Logical data base designs are guided by applications, administration, or some other fundamental constraint. A physical data base design focuses on the advantages for processing performance and maintenance of data. Computer programming requirements and disk resources guide physical data base design. The focus in this chapter concerns data linkages to support logical data base designs. Physical data base design is beyond the intended scope of this chapter.

Logical data base designs specify the grouping of spatial, thematic, and temporal data. The terms "records" and "files" are often used to refer to the groups of data. However, the reader should be aware, as in any information system including MPLISs, there is a significant difference between "logical records" and "physical records," as well as "logical files" and "physical files." Logical records represent data in a way that is convenient to an application. Physical records are determined by the manufacturer of the computer operating system and require data to be stored on disk in a certain way. Since the focus in this chapter concerns data linkages as part of logical data base design, emphasis is on logical records and logical files. When reference to both records and files is meant, the term "data group" is used.

MPLIS spatial and thematic data groups, as well as the linkages among them, are created to satisfy the needs of one or more applications. Certain applications have a need for certain data to be related to other data in order to process them effectively to create information products. Data groups for parcel information and highway networks constitute the basic examples in this chapter, but data groups for any land information are pertinent in this discussion.

THE NATURE OF A DATA LINKAGE

Data linkages among separate data groups are necessary to establish and maintain the full character of phenomena to be used in information processing. Such data linkages are meant to span the administrative partitioning of information within and betweenorganizations. A data linkage is a reference from one data groupto another that allows information access across data groups. Conventionally, a linkage is used for referencing between records. For example, a data linkage can be created between the spatial data describing the location of a parcel (as stored in one record of a spatial data file) with the attribute data describing ownership of the parcel (as stored in a record in a different file). Each of the files can even reside on two different computer systems, but the reference should be bidirectional -- i.e., from one data group (record and file) to a second, and from the second data group back to the first -- rather than unidirectional. Although a unidirectional reference is better than none, a bidirectional linkage allows access to data from any data viewpoint. The latter criterion is essential in an information system when many access paths to data are unknown before analysis begins.

Many data linkages are implemented using identifiers, while others can be implemented using computer storage address pointers. Both identifiers and pointers are codes for accessing information, but they are implemented in different contexts. Identifiers can refer to locations or to arbitrary names, and are implemented by applications specialists as logical data base designers. Computer storage address pointers are a topic for physical data base design, for they are implemented by programmers and are beyond the technical scope of this chapter.

Identifiers provide an explicit approach to data linkage, with the codes for these identifiers being easily interpretable by applications specialists. (Even a citizen interested in how data are referenced by public agencies should be able to understand an identifier.) Explicit data linkages support well established references between data groups, as determined by information needs of an organization. In an MPLIS an explicit data linkage does not take the place of a coordinate reference system used as an implicit data linkage (such as in data layer overlay). Rather, the two approaches complement each other. Data linkages as spatial coincidence established through data layer overlay are discussed in Chapter 11.

Because a land information system can be examined from at least three perspectives -- technical, economic, and institutional (Dueker 1987b) -- any component of such a system can also beexamined from those three perspectives. A data linkage, therefore, can be said to involve technical, economic, and institutional considerations. The technical considerations include the nature of the linkage -- i.e., what it is and how it is implemented. The economic considerations concern the benefits and costs of implementing and maintaining linkages. The institutional considerations include privacy and security issues as well as the organizational support that will enhance or constrain the linkages.

TECHNICAL CONSIDERATIONS FOR DATA LINKAGES

Four technical considerations are important. The first concerns representation. The second concerns data grouping according to data base objects. The third deals with how linkages are implemented using data base keys. The fourth consideration involves data quality issues.

REPRESENTATION CONSIDERATIONS: WHAT'S IN A LINK?

Information representation deals with how to describe the character of a data linkage. For an MPLIS, information representation takes place in three contexts: a) meaning, specified by using entity definitions and the geographically distributed phenomena such as land parcels they are intended to describe -- i.e., using entity identifiers; b) data structures, specified by using data base objects such as polygons -- i.e., using data base object identifiers; and c) visual character, specified by using graphic symbols such as dashed or solid lines -- i.e., using graphic symbol identifiers.

Generally, each context concerns a set of identifiers to establish efficient and effective information use. Identifiers for information can be described in all three contexts, where sometimes they refer to the same element of information, but at other times do not. For example, an entity identifier refers to a specific land parcel in the world, whereas a data base object identifier refers to a polygon stored in a data base, and a graphical symbol identifier refers to a shade pattern that graphically depicts the area of the polygon (hence parcel). It is important to distinguish between these three contexts to clarify what a link represents.

The nature of an identifier is influenced by each of the representation contexts: entities, data base objects, and graphical symbols. An important example of an identifier in an MPLIS is a parcel identifier that references parcel information. In the context of the entity representation, a parcel identifier provides access to information about a parcel, including information in tax registers that contain the attribute descriptions for a parcel. It does not necessarily matter how that identifier is implemented for information processing; what matters is that the identifier distinguishes one parcel (or entity) from all other parcels (or other entities). However, a parcel identifier that can be interpreted by applications specialists (such as the location reference to section, township, range, and lot number) is sometimes more useful since it plays a dual role of both unique identification and location. In the context of a polygon data base object, an identifier as a polygon code -- e.g., an integer sequence built from coordinates -- will distinguish one polygon from another. The polygon may or may not be a parcel; it may be a census block. The nature of polygon identifiers influences how manipulable the information is for computer algorithms, rather than for humans. An identifier for a graphical symbol differentiates one symbol from another; that symbol graphically depicts the polygon, which, in turn, represents the parcel.

Criteria from each of the three representation contexts weigh in the decision on what is best chosen as an identifier to represent a data linkage, but some considerations regarding parcel entities are weighted more heavily than those for polygons, and those for polygons are weighted more heavily than those for symbols. The entity context and the data base object context are important for this discussion of data linkages. Graphical symbol identifiers are important in an MPLIS as annotation on maps and reports, but such annotations will not be treated further in this chapter because that involves human visual processing rather than computer processing.

Parcels

Representing entities or data base objects is complicated in some instances by the need to distinguish parcel-type information from network-type information. In an entity representation context, a land parcel is a real-world phenomenon that is of basic importance to many applications in local governments. However, different kinds of parcels exist, depending on the function of an organization (Horning 1990). For example, a tax parcel maintained by an assessor may not, in fact, be equal to a development parcel maintained by a building and development department, and an ownership parcel may be different from both the development and tax parcels. Entity definitions provide the explicit character of both, and these differences in character must be recognized to avoid confusion when decisions are made, or when data are borrowed and/or shared among parts of an organization.

Both computerized and manual filing systems require some way of identifying parcel entities. A parcel identifier is a code for recognizing, identifying, selecting, and arranging information to facilitate organized storage and retrieval of parcel data records. In addition, if the parcel data are partitioned among spatial, attribute, and temporal data files/records, then the same identifier should be used for these files/records to facilitate data linkage.

Three forms of parcel identifiers are common (National Research Council 1983, p. 63):

1. Name-related identifier -- often a grantor-grantee alphabetized code -- not recommended in an automated system because it does not necessarily result in a unique identifier,

2. Abstract, alphanumeric identifier -- often random numbers (without duplication) associated with parcels such as a tract index, and

3. Location identifier -- a geographic code (geocode) related to location.

Location identifiers themselves are also of three types:

1. Hierarchical identifier -- based on graded political units such as the Public Land Survey System (PLSS),

2. Coordinate identifier -- a point coordinate (in a state plane coordinate system or latitude/longitude system) within or on the boundary of the parcel, and

3. Hybrid identifier -- a combination of location graded units and coordinates such as PLSS and state plane coordinates.

Criteria for choosing an identifier take into consideration both the initial selection as well as the maintenance of the identifier. In this regard, a parcel identifier should exhibit at least the following characteristics (National Research Council 1983, p. 63):

1. Uniqueness -- one and only one parcel should have any single identifier,

2. Simplicity -- identifier should be easily understandable and usable by the public,

3. Flexibility -- the identifier should be usable in a number of contexts,

4. Permanence -- the identifier system should not be subject to change or disruption,

5. Economy -- the implementation costs and maintenance costs should not be unreasonable, and

6. Accessibility -- the identifier should be easily obtainable.

Oftentimes a single parcel identifier is not feasible because of institutional histories. If multiple identifiers are used, a cross-index must facilitate storage and retrieval of the same parcel regardless of the naming system. This is particularly true across local government agencies, but also might be the case within an agency. For example, "street address" and "section, plat, and lot number" should have a cross-reference in a look-up table. However, one of the identifiers should be institutionally recognized as the principal one. Commonly the principal one is legally defined by title according to the recorder of deeds.

Data linkages can be established for parcels at different levels of geographic resolution. Some of these might be: a) an address linked to a parcel centroid, b) a block face address range linked to a street segment with all parcels along the block face, and c) an area block, tract, or district linked to all parcels within the area of interest.

Networks

A second, more complicated example of representation for data linkage in an MPLIS deals with (transportation) network information -- i.e., information about highways and rivers. Entity identifiers for highway networks commonly take two forms: a "control-section" designation or a "route-name and milepost" (point) designation. Street-name and street addresses are very similar to the route-name and milepost, but the metric along the highway for mileposts is usually more systematic than are addresses. In the case of rivers, a river stretch provides a fixed location reference for control-sections, whereas river name and measuring stations provide a relative distance referencing system.

The control-section scheme is based on a fixed length of the highway or river being characterized by homogeneous attribute values. An identifier is assigned to the control-section to distinguish it from other control-sections. The conventions for establishing the identifiers often depend on the application, but generally a district name and reference number suffice to differentiate them. Different application groups in an organization may have different control-sections -- one for pavement management and another for highway performance monitoring, or one for sewage effluent and another for toxic chemicals. Each segmentation is homogeneous with respect to the attribute(s) of interest to an application. Using fixed-length control-section segments prohibits discrimination of any section shorter than each control-section, and causes considerable data redundancy across applications. Unfortunately, this makes data linkage among diverse applications difficult, requiring solutions to the line overlay problem for each retrieval. The solution comes in the form of a suitable referencing scheme for variable distance sampling of attribute values, and a processing approach - called dynamic segmentation -- that takes advantage of the referencing scheme.

A solution to the referencing problem for variable sampling of attribute values along a linear entity is to use a route-name and observation-point identifier scheme. The scheme works well for point-oriented observations along a linear entity as well as for line-oriented observations that start and stop at various places along the linear entity. Examples of the former where such a scheme is useful are accidents, culverts, signs, and similar occurrences at various locations along highways. Examples of the latter are pavement condition, type, depth, and width, for these characteristics begin and end at various locations along the highway. The same can be said for rivers where certain events are recorded at points along a river, and for variable stretches of the river where flows are to be described.

Milepoint and station point references provide the relative distance reference along the length of highway/river line geometry. Dynamic segmentation (Dueker 1987a) software uses the relative distance reference to produce segments of the line that correspond to homogeneous attribute descriptions. That is, each of the attribute values applies to a newly segmented portion of the line to be used for display and/or analysis purposes.

In the entity representation context, data linkage is supported by identifiers that have meaning to applications within an organization. These same identifiers can be transferred to the data base object context to provide the implementation character of a data linkage. It is also possible to construct data linkages from arbitrarily devised identifiers that have meaning only in a data linkage implementation. For example, integer numbers assigned in a sequence can be used for processing, but these are less effective for institutional contexts where entity-oriented identifiers have already been established. However, integer-sequenced identifiers are commonly constructed by software processing rather than by humans and are used to link spatial data base object types such as polygons with thematic data when other, more meaningful identifiers are not available. Regardless of the meaning of the identifier, both the integer and the entity-based identifiers are implemented for data base objects using data structures and processes set up by MPLIS software designers. The designers might be the vendors of the software or the in-house applications software staff. Regardless of design and implementation, the linkages must be continually maintained to ensure consistent and effective information retrieval.

DATA GROUPING CONSIDERATIONS: DATA BASE OBJECTS

Concerns with spatial and attribute representation occur in a data base object context as illustrated in Figure 10-2. A point is defined by a coordinate. A node is a topological junction. A line segment is a set of connected points. A link is a set of connected nodes. A chain is a connected sequence of line segments with nodes at both ends. A ring is a mathematical construct for a closed chain of line segments (points) around an area. A polygon is an (interior) area enclosed by a ring. A polygon is a mathematical (geometrical) construct useful as a general term for describing an entity of the world such as a parcel. A label point is used as a location identifier for the interior of a polygon. Detailed descriptions of these spatial object types are provided in the proposed National Spatial Data Transfer Standard (National Institute of Standards and Technology 1991) to be maintained by the U. S. Geological Survey.

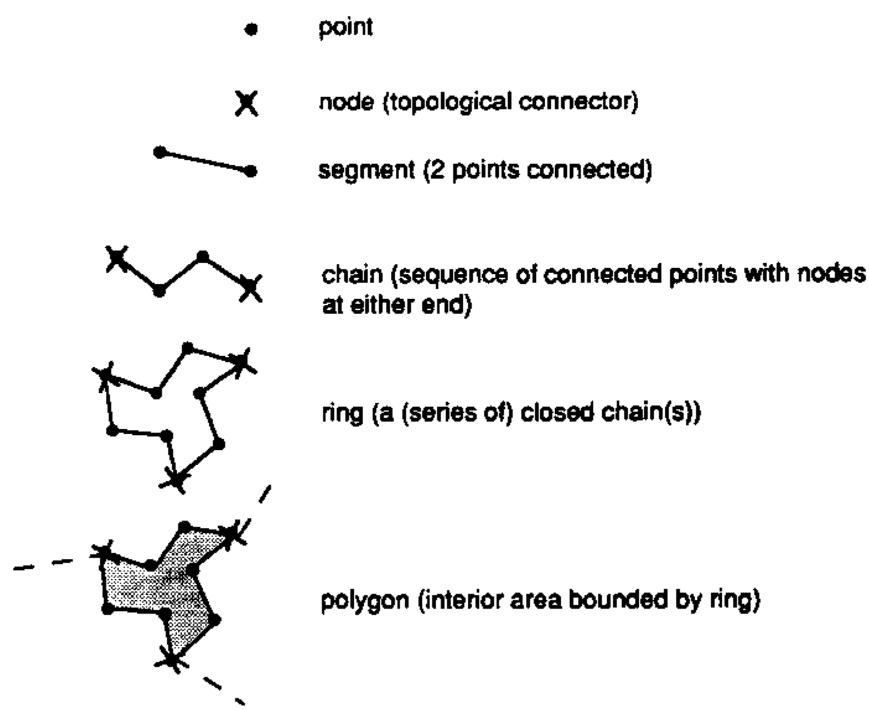


Figure 10-2: Graphic depiction of spatial database object types.

In many MPLISs, spatial data (describing the spatial object types described above) and attribute data (describing the qualities and quantities of entities) are grouped into separate records/files for several reasons:

1. Spatial coordinates need to be accessed rapidly for display.

2. Attributes of spatial objects need to be modified rapidly.

3. Different parts of an organization have different responsibilities for maintaining data. The attribute data often exist in one or more data base management systems separate from the spatial data.

A solution for data linkage that embraces the separate data management strategies is to associate the different attribute data to spatial data, maintaining a one-to-one (or one-to-many) correspondence of the spatial data with the attribute data as shown in Figure 10-3.

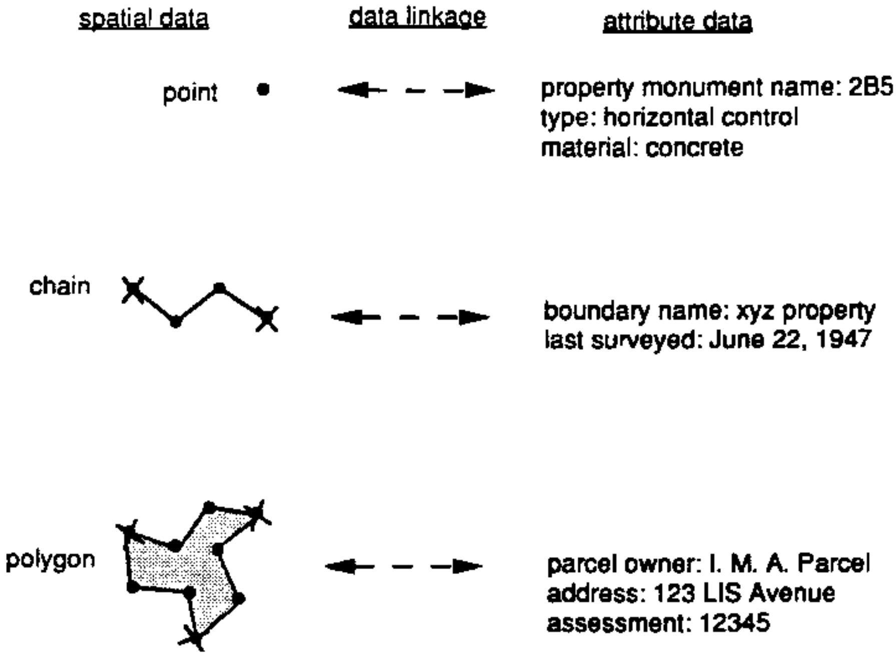


Figure 10-3: Spatial and thematic attribute data linkage for parcel information.

Maintenance of the one-to-one correspondence is relatively simple for attribute values associated with a single point, chain or polygon spatial object, but more difficult for spatial objects whose attributes vary linearly along the length of the object -- e.g., a highway or river. For example, to represent the nature of three attributes changing along a stretch, three separate segmentations must be used for the same stretch of highway as illustrated in Figure 10- 4. Maintaining separate segmentations -- i.e., the actual coordinates of all three chains -- would add tremendous data redundancy in a system. This can be avoided by a data linkage that makes use of three spatial reference schemes and is processed with software that can perform dynamic segmentation (Dueker 1987a).

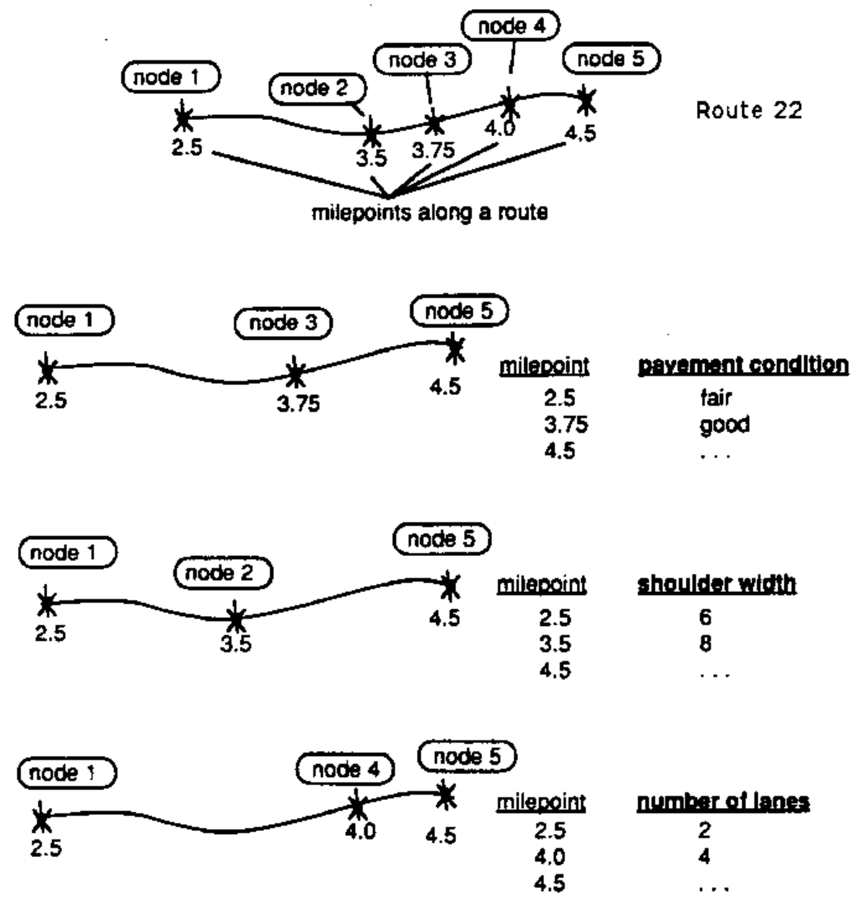


Figure 10-4: Multiple (six) chains required over the same stretch of highway to support three attributes. Two chains are required for every segmentation in this example. A node occurs at every milepoint where a change in attribute occurs.

A data linkage for linear objects that minimizes data redundancy requires a combination of three reference schemes (Nyerges 1990): 1) topological representation, 2) a sequence of x,y coordinates for linear geometry embedded in a coordinate system, and 3) route and milepoint references to the beginning and ending nodes of the chain as well as a distance function along the chain to adjust mileages (See Fig. 10-5).

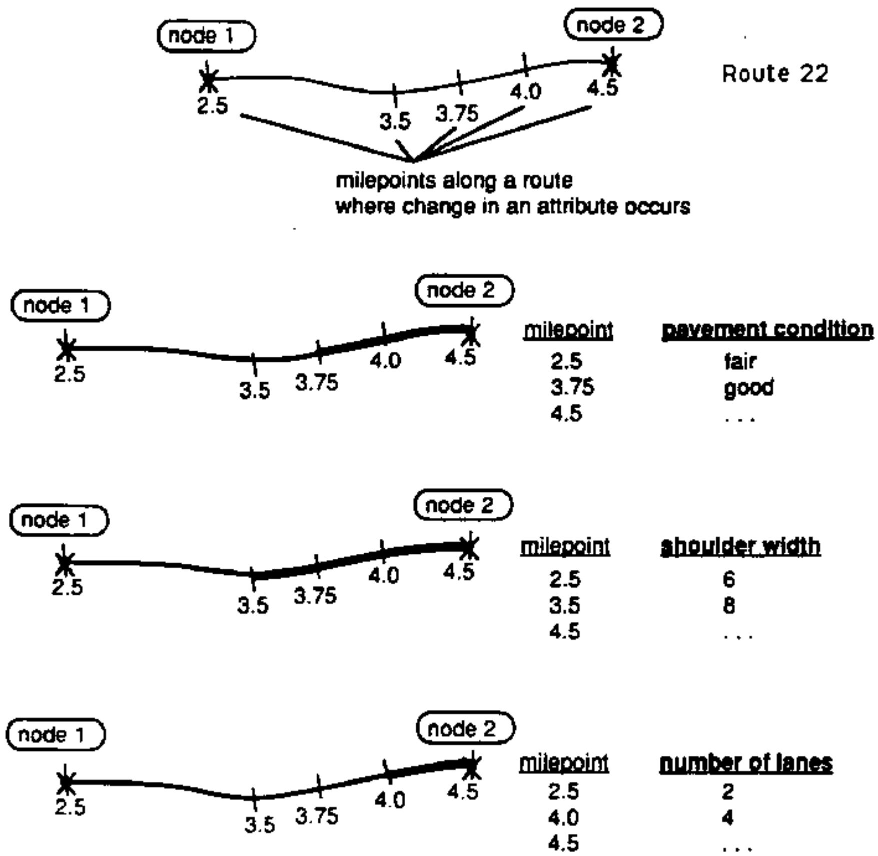


Figure 10-5: Variable segmentation of a single chain to support three different attributes.

IMPLEMENTATION CONSIDERATIONS: DATA BASE KEYS

Data base keys are used to implement linkages between spatial, attribute, and temporal data records. Keys are of three basic kinds: primary, secondary, and foreign as shown in Figure 10-6. A primary key uniquely identifies a data record for retrieval (tuples and records taken to be of a similar nature). A parcel location identifier is often implemented as a primary key in a data management environment. The key is called primary because it is the principal means of accessing the record (tuple) for data processing purposes. All other data contents in the record depend principally on the primary key for retrieval. A secondary key is used as an alternative key to the primary key for accessing data in the same record, but the secondary key may have values that are not unique (See Fig. 10-6). That is, when data are accessed via a secondary key, several records could be retrieved.

A foreign key is used in two ways, it implements a data linkage between a spatial data record (such as a chain) and an attribute data record (containing the attributes of an entity), and it implements a reference to a primary key in another data record of the same type or different type -- e.g., when a parcel record references a street record (See Fig. 10-6). The two data records are often maintained in different data management systems; e.g., spatial data are maintained by a spatial data management system and attribute data are maintained in a relational data management system.

Parcel Attribute Records

Primary (unique value)	Secondary (nonunique value)	other data items	Foreign (unique value)
Parcel ID 32	Census tract ID		Street section ID 144
⋮	⋮	⋮	⋮

Street Section Attribute Records

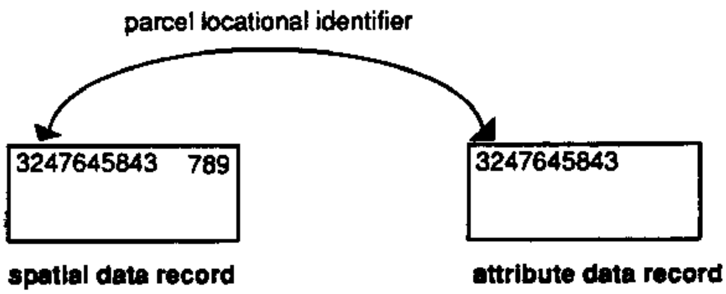
Primary (unique value)	Secondary (nonunique value)	Other data items
Street section ID 144	Census tract ID	
⋮	⋮	⋮

Figure 10-6: Primary, secondary and foreign keys for attribute records.

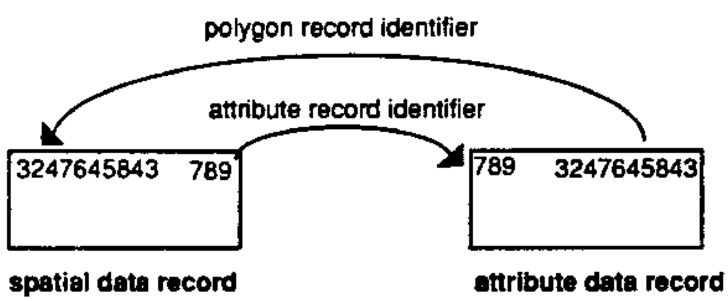
Several strategies are possible for dealing with linkages, depending on whether a one-to-one correspondence exists between spatial data records and attribute data records, or whether a single spatial data record is associated with several attribute records.

A single spatial data record -- e.g., points, polygons, and chains -- linked to a single attribute record is the simplest linkage to construct and maintain. The linkage established by embedding foreign keys supports a one-to-one correspondence of spatial and attribute records.

Several strategies are feasible. One strategy is to use the same key (such as a parcel identifier) in both records. A location identifier is often used as the single key, but an integer number would work as well as shown in Figure 10-7. This is easier to implement and maintain because of the minimum number of keys to be constructed.



(a) single parcel ID for both spatial and attribute records



(b) polygon identiter and attribute identifier embedded in corresponding records

Figure 10-7: Embedded keys–data links between data records for parcel information.

Another strategy is to embed the parcel identifier (as a primary key of the attribute data record) into the spatial data record and, conversely, embed the location identifier of the spatial data record into the attribute data record (See Figure 10-7). The advantages of embedding are fast retrieval and quality control. Keys are immediately available for processing when either the spatial data record or attribute data record are referenced; and embedding the key in the spatial or attribute data record rather than using a separate file of link indices gives a better chance that the key will remain current. The disadvantage is that embedded keys are not as easily maintained when key values are to be added, deleted, or changed to reorganize the data linkage.

Evolutionary development of information systems sometimes forces institutionalization of several identifiers, so that several keys must be maintained. This is not an optimal maintenance environment, but it is a realistic situation in many local governments because systems were implemented at different times. A linkage strategy that addresses that problem is to use a link

index as a separate storage mechanism rather than to use embedded keys. If information cannot be embedded in the data records for the spatial and attribute data records because of the number or frequent change, a cross-reference can be built that contains an integer number and a coordinate value for a location summary -- e.g., a centroid. These would be stored as a table with two entries (See Table 10-1). This strategy works well for points and polygons, for these spatial object types usually have singular location references.

The link index has several advantages. One advantage is that spatial and attribute data records can be stored in different systems with the physical interface effected mainly by two approaches. One approach is off-line tape transfer that requires a magnetic tape to be loaded when the data are needed. A second approach is by on-line communications networks, directly linking mass storage devices to the computers that perform the processing. In both approaches the logical interface can be developed using data transfer application programs. A second advantage is that spatial reference systems for the spatial data base objects do not have to correspond necessarily one-to-one with the kind of data base objects that are in the attribute file; a street file can be used to reference parcel information (See Table 10-1). A third advantage is that the link index can be maintained separately from the spatial objects file and the thematic attribute file, possibly reducing the cost of maintenance.

A chain spatial data object associated with nonhomogeneous attributes requires three spatial reference schemes for linkage tothe attributes. The three spatial reference schemes (topological chains, coordinates, and milepoints) stored in records enables interpolation along a chain at distances where the attribute values were

Table A. Link index for single attribute records with one or more parcels (parcel geocodes)

Attribute Record ID	Parcel Geocode
789	3247645843
790	0409097249
791	0000215032
792	1326581644
793	1326581644
794	1326581644

Table B. Link index for single street section linked to multiple parcels

Street (chain) ID	Parcel (polygon) ID
street_id_1	parcel_id_34
street_id_1	parcel_id_36
.	.
.	.
.	.
street_id_1	parcel_id_47
street_id_5	parcel_id_54
street_id_5	parcel_id_55
.	.
.	.
.	.
street_id_5	parcel_id_72

Table 10-1: Example Link Indices.

recorded. Figure 10-8 depicts a record structure and data linkage to retrieve and display highway data. Using this approach to spatial and attribute linkage obviates segmenting lines a priori (Nyerges 1990). The approach supports dynamic (run-time) segmentation (Dueker 1987a) and can be used to support segmentation oriented to display and/or analysis, rather than just to data capture. Milepoints and station point references provide the location reference along the length of a chain. A chain is the linear geometry for referencing the attribute data to a coordinate system. Dynamic segmentation software uses the relative distance reference to produce a segmentation of the chain that corresponds to homogeneous attribute descriptions. That is, each of the attribute values applies to a segmented portion of the chain. Furthermore, the segments are used in a temporary manner for display and/or analysis purposes only, unless a permanent file of that segmentation is requested.

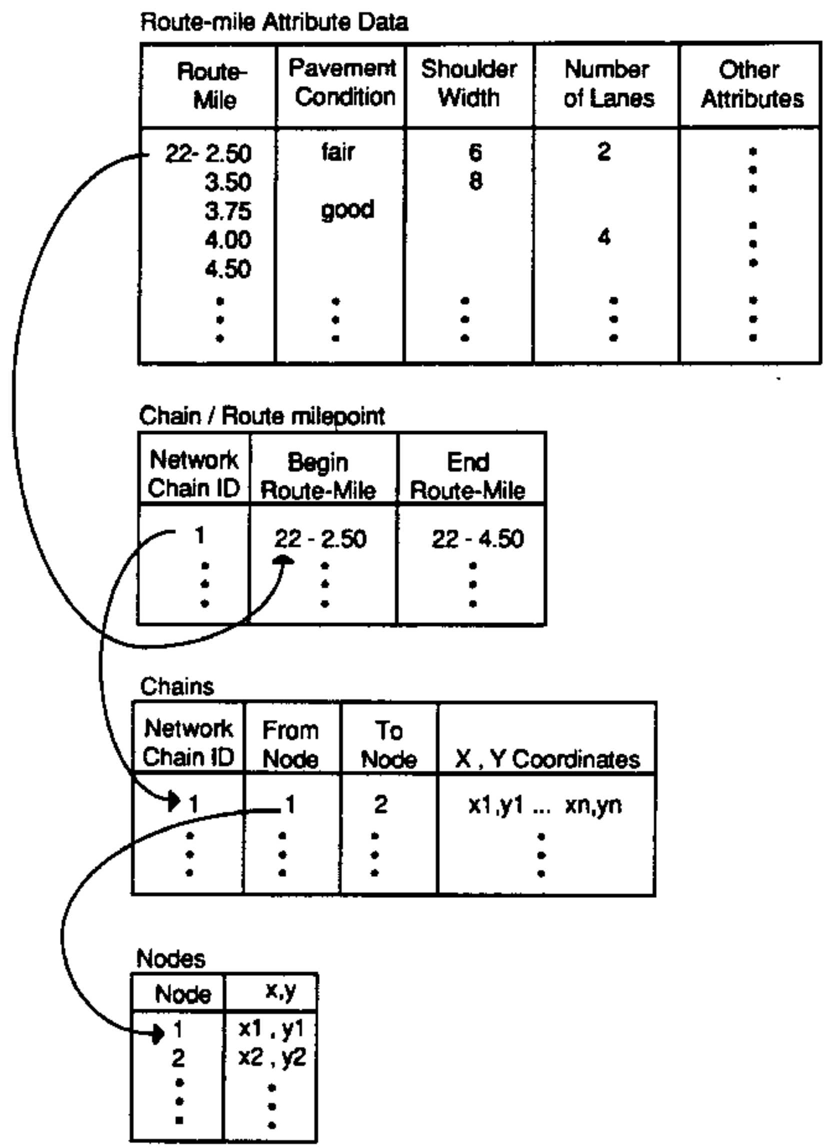


Figure 10-8: Attribute data for variable length segmentation linked to locational data.

DATA QUALITY CONSIDERATIONS IN A DATA LINKAGE

Standards for the assignment and maintenance of a data linkage should be established by group consensus and applied universally to all systems of concern. The management group for the information systems should agree on the strategy for linkage and should let users know of its potential. If records in a parcel file are to be linked to spatial data, then all records are linked in the same manner using the same linkage strategy. The fields must be uniformly formatted (or at least derivable as such) to allow for easy processing to support integration and aggregation of information. Regular use helps to ensure that the linkage will be maintained adequately. The standards to be applied include encoding accuracy, data content consistency, aggregation consistency, recording completeness, and lineage.

To ensure **encoding accuracy** a linkage code should be checked for validity against a rule for code assignment. A domain of allowable attribute codes -- e.g., integer, name, or coordinate -- should be enumerated for validity checking. The meaning of the identifier in the entity context and the formatting of the identifier in the data base object context might each require a check.

Linkage codes should maintain **data content consistency** across data records. Codes consistent across data records and files means that an appropriate code is relating data records that correspond to one another -- for example, the spatial and attribute descriptions of the same entity should be linked to one another rather than an attribute record from one entity linked to a spatial record for another.

Linkage codes must preserve an **aggregation consistency** across different levels of aggregation for the same data record/file. Having codes consistent across different levels of aggregation ensures that a general data group should be derivable from a detailed group. For example, street address ranges correspond to the range of individual addresses that can possibly be aggregated.

Recording completeness requires that all records (data objects that are representations of some real-world entity) intended to have linkages will have linkages. An estimate of the amount of abstracted reality to be represented in records/files must be made to test for completeness at the data object level. For example, all the cadastral parcels in LIS County should be included as defined by the county assessor's parcel rolls.

To track **lineage**, the derivation of the data linkage should be documented. For example, a location identifier scheme was developed by a municipality in 1969 for purposes of referencing parcels on quarter-section maps; the scheme has since been changed to reflect annexations of land to the city that took place in 1988.

ECONOMIC CONSIDERATIONS

The demand for and supply of data linkages are the product of "Who wants it?" and "Who is going to pay for it?" The best way to determine whether a data linkage is practical is to enumerate the benefits and costs associated with its implementation, or lack thereof. Determining the true benefits and costs requires a context and a set of factors to compute actual numbers. However, a general set of categories for benefits and costs can be identified, and each of them can be further specified using factors and numbers peculiar to an organization.

1. Better/more reliable information. A data linkage enhances data consistency checking that results in information with fewer errors. With better information, legal issues might be resolved before going to court. An organization can estimate the benefits of more reliable information indirectly by determining how many coding errors appear in a manually developed product.

2. Reduced duplication of effort. When data are linked to other data, need for duplicate copies of data is reduced. Multiple copies of data encourage inconsistency in data. An organization can estimate the savings in reduced duplication through a survey of the number of times information is requested internally within the organization.

3. Enhanced capabilities. Data linkages enhance the availability of data to produce information products that previously might have been too time-consuming. This can encourage more effective analysis of alternatives for the decision making process. An organization can estimate the magnitude of enhanced capabilities by examining other recently introduced information processing capabilities that enhance most applications within the organization.

4. Better service. Data linkages support faster turn-around time on projects. When turn-around is faster, personnel can provide more efficient and effective service. Gaining a more direct access to spatial data through attribute identifiers allows operation-oriented personnel to answer questions for the public in less time. An organization can estimate the benefits by enumerating how much time it takes to look up spatial information and attribute information separately.

As with other elements of MPLIS implementation, data linkages offer classical benefits.

5. Increased productivity. More projects get completed in the same amount of time or the same projects get completed in less time because data are more readily available as a result of cross reference. Computing increased productivity requires an organization to specify output relative to time and/or cost for producing that output. Information products and personnel costs are part of such a computation. An organization can determine the size of an immediate increase in productivity by enumerating the costs of manually cross-compiling information -- i.e., coding parcel boundary maps by hand with the corresponding attribute data. The benefits equal the savings in costs.

6. Problem avoidance. These are often the benefits incurred by being able to avoid problems such as confusion in information interpretation. Although this benefit is difficult to compute, certain anticipated benefits can be derived indirectly through cost avoidance.

Identifying costs of a data linkage is as important as identifying the benefits. The costs include:

1. Real costs of implementation. Both internal and external labor, software, and hardware costs should be factored into the total costs for implementation.

2. Real costs of maintenance. Organizations often fail to identify the costs of maintaining a data linkage. Over the long run, the maintenance costs can be greater than the implementation costs.

3. Risk costs. If data are corrupted, there is a risk of using the data linkage without realizing a linkage is amiss, until after information products have been delivered. The cost of lost time and lost information or misinformation should be calculated.

4. Efficiency costs. If the costs of providing the solution are greater after the implementation than before, there is a cost to efficiency. The cost of such a reversal must be considered.

5. Cost avoidance. If the data linkage is not implemented, the future costs of operation could become more significant. That possibility must be addressed.

Benefits and costs are further tempered by institutional considerations.

INSTITUTIONAL CONSIDERATIONS

Institutional considerations are broader in scope than are either technical and economic considerations. The institutional considerations stem from the socio-political, legal, and cultural context of the MPLIS. These considerations can significantly enhance and/or dramatically constrain data linkages. Some of the considerations are:

1. Expertise and availability of personnel. Only certain personnel within an organization have the expertise to implement and maintain a data linkage. Such personnel are commonly in short supply.

2. Privacy protection for sensitive information. A data linkage supports access to information. Such access must be restricted to information that is of a nonsensitive nature to protect the rights of individuals.

3. Security for unauthorized use of the linkage. Access to information through the data linkage must be restricted through security measures if the information is of a secure nature.

4. Increased coordination and cooperation. A data linkage fosters increased coordination and cooperation as long as the parts of an organization agree upon the purpose of the data linkages.

5. Attitude toward technology support. A data linkage can be deemed successful if a certain number of applications and/or users are supported.

6. Belief in better information. Better information for decision makers may lead to a more equitable and/or efficient distribution of resources described by the alternatives presented to the decision makers.

Dealing with institutional considerations sometimes requires concomitant changes in organizations. Organizational change is never easy, but the results are likely to outweigh the adverse impacts of change.

CASE STUDIES

Examples of identifiers used for data linkages are provided here as a sample of what is possible. The examples include specification of land record identifiers for counties in North Carolina, a parcel identifier for King County, Washington, and parcel and street network identifiers for Bellevue, Washington, and parcel and street network identifiers for San Bernardino County, California.

COUNTIES IN NORTH CAROLINA

The parcel identifiers for counties that receive state assistance in North Carolina are described in "Technical Specifications for Base, Cadastral and Digital Mapping" distributed by the North Carolina Land Records Management Program (North Carolina Land Records Management Program 1987). The parcel identifier number (PIN) is constructed from the North Carolina State Plane Coordinate System using the visual center of a parcel -- i.e., the centroid.

The coordinate of a centroid is measured as x (Easting) and y (Northing) -- for example, E2,715,569 and N0,756,737. The digits in each number are paired by taking each easting digit and pairing it with each northing digit:

20	77	15	56	57	63	97
EN	EN	EN	EN	EN	EN	EN

The parcel identifier is arranged in the following way:

20	7715	56	5763	97
redundant lead number for any one county	number of basic map module (1"=400')	block number	lot or parcel number	utilized only to extend the capacity of the system

The North Carolina PIN is obtained by recording the middle three sets -- the middle ten digits -- inserting dashes as follows: 7715-56-5763. The two high-order digits (20) are dropped because they are redundant "millions of feet" in State Plane Coordinates within each county. The two low-order digits (97) are dropped because, in combination, they specify such a small area. The resulting number satisfies criteria for a location identifier as long as the higher-order digits are known for each county in which the parcel is located. Records of condominiums, townhouses, or other cases of diverse ownership on one land parcel can be further identified through the use of decimal digits (from 001 to 999) appended to the right of the PIN. Thus, 7715-56-5763.008 would signify unit number 8 within this land parcel.

Since a PIN is a location identifier based on the SPCS, the identifiers for finer resolution diverse ownership are difficult to create within the same location framework. Condominiums often are high-rise buildings, necessitating a third spatial dimension in the location problem. The third spatial dimension is not part of the State Plane Coordinate System. An enhancement to the location identifier outside the state plane framework is often used as a compromise between identifier simplicity and location system complexity. The decimal digits indicating diverse ownership add to PIN complexity, but not to the extent that a location specification would. The size of the decimal field, i.e. three digits, allows for a maximum of 999 units. In most cases this would be sufficient; however, it could be set higher if needed. The use of a "decimal point" to indicate the extended identifier rather than using a "dash," as in the other portion of the identifier, is a matter of design. The difficulty with a decimal identifier involves mixed-mode processing for software. However, this is a computer programming issue and not an information content issue. In either case, the simplicity of the identifier outweighs the data processing inconvenience.

KING COUNTY, WASHINGTON

The King County tax account number used as a parcel identifier contains 12 digits : XXXXXX-XXXX-XX (King County 1990). In the identifier:

- The first six digits compose the major number,
- the next four digits compose the minor number,
- the next to the last digit is the split code, and
- the last digit is a check digit for data processing.

The "major number" is a combination of "section, township, range" or is an "integer number" depending on whether the parcel is unplatted or platted, respectively. The "minor number" is a "government lot number" or a "sequence number" depending on whether the parcel is unplatted or platted, respectively. (The terms "major" and "minor" indicate significance of coded number, and have no other interpretation.) Thus, if the land is an unplatted parcel, the code takes the form:

SSTTRR-9LLL

where:

SS is the section number
TT is the township number
RR is the range number
LLL is the lot number

If the land is an platted parcel, the code takes the form:

PPPPPP-#NNN

where:

PPPPPP is the plat number assigned by the Assessor's office
is a number from 0 to 8
NNN is the sequence number assigned by the Assessor's office.

The eleventh digit (split code) has accounting uses but does not identify a distinct parcel of land. For either platted or unplatted parcels, the split code is interpreted as:

0: The parcel has undergone no boundary or tax changes since the first of the current year.

3-6: The parcel has had one or more boundary or tax changes since the first of the current calendar year.

8,9: The 11-digit parcel number represents a separate billing account (not a separate parcel), created for one of several possible reasons:

- Land and buildings are owned by different entities,
- some portion of the property is subject to an exemption,

such as a senior citizen's or church/non-profit exemption, or

- a separate tax bill is needed to collect back taxes and interest for a parcel removed from "open space" classification.

If the land is in state or public service, the major number appears as 97XXXX, where XXXX is a code for the type of service, -- for instance, a service parcel for transportation is 970XXX.

The complexity of an identifier results from the amount of information included in the identifier. Although the parcel identifier in King County may seem complex for those outside the county, the identifier must be based on local needs. Different local governments will have different interpretations of their needs.

CITY OF BELLEVUE, WASHINGTON

Two types of data in Bellevue that require linkages for many applications are parcel and roadway data (Burt 1990). Other data such as water/sewer or subareas are usually managed as a single unit so no data linkage identifiers are necessary.

The City of Bellevue has historically maintained two parcel identifiers for its parcels. It uses the King County Assessor's parcel number (as described in Sect. 10.5.2) for tracking lots. However, the lot number is stored as an annotation item rather than as a data base item. The difference between an annotation item and a data base item is that the annotation item cannot be searched, sorted, or otherwise processed as can the data base item. The assessor number is used to relate parcel location with tax information, which is received from the county on a quarterly basis.

The city also maintains a "map and parcel" number (of the form XXX-XXX) generated in the city for internal maintenance of the Storm Drainage Billing System. The "map" portion of the number is an integer identification ID based on counting the 269 quarter-section maps, with ID's ranging from 2 to 270. The "parcel" portion of the number is a sequentially increasing integer assigned at random within the confines of each map, with 3 digits assuming no more than 999. The two numbers are often "redefined" as a concatenated data linkage -- i.e., combined as

XXXXXX -- to add flexibility for data references. The single number can then be used for data referencing.

Since many assessor parcel numbers may correspond to one quarter-section map, a cross-reference index is used to determine the association between assessor parcel numbers and map parcels. The cross-reference is essentially a digital table look-up that associates the assessor parcel number with each map and parcel number for Bellevue. In addition to the assessor parcels, every map and parcel number is associated with a single site address. Site addresses are assigned from an address range scheme originating from the county, but locally maintained in the city at the time of this writing. Several applications exist that make use of the site address reference.

Several roadway data bases exist in the city for various transportation engineering, management, and planning purposes. All data bases use either a pavement ID or node ID form of identifier. Pavement IDs are assigned to sections of roadway, many of which exist between two intersections. The node ID is for places of network change, mostly at intersections. Accidents and traffic counts have been linked through the pavement ID. All new systems requiring reference to pavement information will use the pavement and node IDs.

The parcel numbering schemes have been in place for a long time and are well accepted by users because they have been effective. The pavement ID and node ID schemes are relatively new, and all users are still exploring their uses. More applications showing the effectiveness of the pavement/node data linkages are being planned.

SAN BERNARDINO COUNTY, CALIFORNIA

San Bernardino County, California, has embarked upon an ambitious $12 million multi-agency GIS project, part of which is to develop a digital basemap that will reference 650,000 parcels over a 20,000-square-mile area of southern California. Planned users of the system include county agencies, municipalities, utility companies, private sector interests, and private citizens. Developers of the system state that a key factor in the success of the multi-user system is the design and content of the basemap. The County has given a high priority to the integration of existing tabular (attribute) data within their GIS. Many geographically oriented data bases are used by the County, cities, and utilities.

It is essential that the GIS easily accommodate the linkage of existing tabular data.

The County basemap provides a framework for spatially referencing tabular data. The basemap consists minimally of survey control, tax parcels, and street rights-of-way. The two essential identifiers that will best facilitate the linkage of attribute data to the basemap are the assessor's parcel number and the situs address for each parcel.

The Assessor Parcel Number (APN) provides the means for linking several important property data bases. The APN is composed of the assessor's "Book, Page, Block, and Parcel Number" to form a unique identifier for every assessment parcel. The Book, Page, and Block are functions of the parcels' location in the assessor's map atlas. The Parcel Number must be unique for each Block but otherwise can be arbitrarily assigned. The APN is a 9-place integer field that breaks down as follows:

Column	Item
1 - 9	APN
1 - 4	Book
5 - 6	Page
5 - 7	Block
8 - 9	Parcel Number

The assessor maintains the Property Information Management System (PIMS), which stores property ownership, characteristics, assessment, and history data. These data are frequently linked to the GIS for mapping and analysis purposes. Other data such as building permit and weed abatement records are indexed by APN to facilitate linkage to PIMS and the GIS basemap.

Property documents of record such as deeds, subdivision plats, and record of surveys are referenced during property transactions or when development occurs. Managing these documents as scanned images is being evaluated by the County. If linked to the GIS base map by APN, automated spatial access to record documents could be supported.

Situs (street) addresses are an important part of the location referencing capability in the San Bernardino GIS basemap because of the large number of local government organizations that use it. The address of a structure or the address of an applicant is requested for nearly every permit, complaint, property transfer, request, infrastructure work order, or other such document. Street addresses for improved land parcels as well as address ranges to locate unimproved parcels is to be included in the basemap reference system design. In addition, street addresses are to be used as a link between intersections and related information -- e.g., traffic accidents and traffic signals -- as well as between facility records and rights-of-way through the street name reference.

Several indirect linkages to tabular attribute data bases are to be supported. Subdivision tract and lot numbers link through the PIMS, which contains APNs. Public Land Survey System (PLSS) references in attribute data bases are to be supported through a data layer of PLSS boundaries. Transportation data concerning traffic citations, pavement and facility management, and accidents are to be indirectly linked to the GIS through a street-name and milepost or route-name and milepost (Nyerges 1990) reference. Instead of street address, the milepost number locates events along the street.

Most of these issues are included in a conceptual design that enhances the current GIS capabilities of San Bernardino County. A prototype implementation of the conceptual design is being completed in the Spring of 1991 (Gooch 1990).

CONCLUSION

Identification of certain land information entities is so significant that special codes are created for that purpose. Those same codes can be used for linking data groups. Although a unique code provides a means for linking each land information entity to various data registers, it does not provide a link to all land files. A spatial reference system such as state plane oordinates or Universal Transverse Mercator, supported by a geodetic control system, should be used for special-purpose geographic integration of land data files across different coverages by virtue of the geographic position in the coordinate system. That integration is called data layer overlay and is discussed in Chapter-11.

REFERENCES AND ADDITIONAL READINGS

Burt, K., 1990: Notes on City of Bellevue, Washington, Identifiers. Personal communication.

Dueker, K. J., 1987a: Geographic Information Systems and Computer-aided Mapping, *American Planning Association Journal*, summer, pp. 383-390.

Dueker, K. J., 1987b: Multipurpose Land Information Systems: Technical, Economic, and Institutional Issues, *Photogrammetric Engineering and Remote Sensing*, Vol. 53, No. 10, pp. 1361-1365.

Dueker, K. J. and Kjerne, D., 1989: *Multipurpose Cadastre: Terms and Definitions*, American Congress on Surveying and Mapping, Bethesda, MD. Also published in Technical Papers, ASPRS/ACSM Annual Convention, Baltimore, MD, April 2-7, 1989, Vol. 5, pp. 94-103.

Gooch, C., 1990: Summary of Issues for San Bernardino County Geographic Information Management. Personal communication. Geographic Information Management Systems, San Bernardino County, CA.

Horning, G. H., 1990: *Information Integration for Geographic Information Systems in a Local Government Context*, unpublished Masters Thesis. Department of Geography, University of Washington, Seattle, WA.

Huxhold, W., 1991: *Urban Geographic Information Systems*, Oxford University Press, Oxford, England.

King County, 1990: King County Assessor's Property Information. King County Department of Assessments, King County, WA.

Langran, G. and Chrisman, N. R., 1988: A Framework for Temporal Geographic Information. *Cartographica*, Vol. 25 No. 3, pp. 1-14.

National Institute of Standards and Technology, 1991: Spatial Data Transfer Standard. NIST, Gaithersburg, MD. Copies available from the U.S. Geological Survey, National Mapping Division, Reston, VA.

National Research Council, 1983: *Procedures and Standards for a Multipurpose Cadastre*. National Academy of Sciences, Washington, DC.

National Science Foundation, 1987: Prospectus for a National Center for Geographic Information and Analysis. National Academy of Sciences, Washington, DC.

North Carolina Land Records Management Program, 1987: *Technical Specifications for Base, Cadastral and Digital Mapping*. North Carolina Department of Health, Environment and Natural Resources, Raleigh, NC.

Nyerges, T. L., 1989: Information Integration for Multipurpose Land Information Systems. *Journal of URISA*, Vol. 1 No. 1, pp. 28-39.

Nyerges, T. L., 1990: Locational Referencing and Highway Segmentation in a Geographic Information System. *ITE Journal*, March, pp. 27-31.

GLOSSARY

attribute: a quality or quantity describing an entity (National Institute of Standards and Technology 1990).

computer-aided mapping system: a system that focuses on map design, creation, and maintenance (Dueker and Kjerne 1989).

data group: a collection of data that has a special meaning and is commonly stored together. The term here substitutes for other implementation-bound constructs such as records and files.

data linkage: an association between/among data which enhances the effectiveness and/or efficiency of information processing; a reference from one set of data to another that allows access across data. For example, spatial data records and the corresponding thematic attribute data records can be linked for cross-retrieval to support display and/or analysis.

entity: a real-world phenomenon not subdividable into phenomena of the same kind (National Institute of Standards and Technology 1990)

geocoding: the assignment of geographic codes to records, can be manual or automated (Huxhold 1991).

geographic code (geocode): 1) A data value, assigned to a spatial object, that provides information on the geographic location of the object and is used as a key to access data relating to the object (Dueker and Kjerne 1989). 2) An identifier assigned to both a map feature and a data record containing attributes that describe the entity represented by the map feature. Common geocodes include addresses, census tract (numbers), and political and administrative district (numbers). Geocodes are also referred to as "location identifiers" (Huxhold 1991).

geoprocessing: expanding geocodes to reference other features at the same location (Huxhold 1991).

geographic information system (GIS): 1) A system of hardware, software, data, people, organizations, and institutional arrangements for collecting, storing, analyzing, and disseminating information about areas of the Earth (Dueker and Kjerne 1989). 2) A computerized data base system for capturing, storing, retrieving, analyzing, and displaying spatial data. (National Science Foundation 1987)

identifier: a label that uniquely identifies a cartographic record and resides in the nongraphic record(s) for data linkage purposes (Huxhold 1991).

key: a data item used to identify or locate a record in a data file (Huxhold 1991). primary key: a key used for principal access to a unique record. secondary key: a key used as an alternative to the primary key for access to one or more records. foreign key: a primary key used to address from one data group into another data group.

land information system: a geographic information system having, as its main focus, data concerning land records (Dueker and Kjerne 1989).

location identifier: a unique code (number or combination of letters and numbers) used as a record identifier in a (nongraphic) attribute data base, and representing a unique feature (entity) that can be identified on a map (Huxhold 1991).

MPC (multipurpose cadastre): a parcel-based land information system (Dueker and Kjerne 1989).

MPLIS (multipurpose land information system): a land information system that serves two or more departments or organizations (commonly) in local government.

nongraphic data: attributes of cartographic entities needed to describe the physical characteristics of entities in the real world (Huxhold 1991).

object: a digital representation of an entity (National Institute of Standards and Technology 1990).

parcel identifier: a code for recognizing, selecting, identifying, and arranging information to facilitate organized storage and retrieval of parcel records (National Research Council 1983).

11 IMPROVED ANALYTICAL FUNCTIONALITY: MODERNIZING LAND ADMINISTRATION, PLANNING, MANAGEMENT, AND POLICY ANALYSIS

Bernard J. Niemann, Jr.

INTRODUCTION

Modern land and geographical information systems (GIS/LIS), which couple land records with improved spatial analysis, offer new opportunities for more efficient, effective, and equitable land administration, planning, management, and policy analysis. When spatial analysis capabilities such as topological overlay are also included in the GIS/LIS, management, planning, and policy analysis techniques can be used to address such issues as land-use planning, soil-erosion assessment, and water-quality estimation models. This coupling of information technology and spatial analysis offers land management professionals visualization and analytical tools much more powerful than any before. This chapter looks at examples of functions and applications, and the benefits deriving from use of GIS/LIS functions, and identifies the potential problems that errors can bring to the outcome of these analyses.

HISTORICAL CONTEXT

Public responsibility for the long-term and efficient administration, planning, management, and policy analysis of land use, its resources, and its tenure has roots reaching back to the founding of the republic. To a large extent, this process of land information management has, from a mechanical land records perspective, changed little in the past two hundred years.

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The mechanical process of using land information spatially has been primarily a manual process. Complex analyses of spatial information are attempted only on an occasional basis as a situation merits the extra social and economic investment. The use of information technology historically has been limited primarily to applications related to improving measures of efficiency.

Modern land and geographic information technology offers the opportunity to unbridle the restraints of overly burdensome procedures through improved analytical functionalities. By "improved functionality" we mean the ability to manipulate, analyze, and display spatial information through the use of automated rather than manual procedures, or the ability to manage and manipulate cartographic and geographic (spatial) data. Much of this capability lies in the analytical "operators" that provide new and creative opportunities for the land administrator, planner, manager, and analyst. Even though these operators are in their infancy, the potential analytical power is awesome compared to past manual techniques and procedures.

Land information administrators, planners, managers, and policy analysts have historically called for a comprehensive and integrated approach to land information management. These groups have had a major influence on the collection of information to address both urban and rural land planning and management.

As far back as the nineteenth century, coordinated planning of human actions and environment was called for by the likes of Patrick Geddes, George Perkins Marsh, and John Wesley Powell. Around the turn of the century, major contributions to this concept of integrated land conservation and open-space planning were made by Jens Jensen and Frederick Law Olmstead, and their land planning contemporaries. In a recently reprinted work, Geddes (1968) advocated the use of regional inventories of soil, rainfall, climate, land use, and land tenure relationships to integrate people with place.

The most succinct early understanding of the need for an integrated set of land information inventories and for developing a connection of people with place came from Warren Manning (1909), a Boston-based land planner, who wrote:

> "What we want is a general survey covering all this territory [New England], upon which the character of the soil, the subsurface water conditions...the character of the ground

cover, the age and condition of the forest plots, the boundaries of existing land holdings, and all other data [can be collected]...in order that we may know best how to develop each resource."

Parallel with these calls for inventories and integrated land information-based approaches, new visualization and spatial analytical techniques were also developed. Overlay -- one such method for land planning, management, and analysis -- is an example. Manning is credited with "...the invention of the overlay technique for integrating natural and cultural information" (Steinitz et al. 1976), which Manning documented in his 1913 Town Plan of Billerica, Massachusetts (Manning 1913). Overlay, as a spatial operation, remains a fundamental tool for planning and a primary form of spatial thinking in land planning, management, and analysis. However, as Steiner et al. (1988) point out, overlay as a spatial thinking concept can now be augmented by "...more sophisticated and powerful computer-based approaches" such as GIS/LIS.

Because of the historical technical difficulty in accounting for physical land characteristics, the human condition, and legal interests in land, the translation of Manning's conceptual ideas of information-based land administration, planning, management, and analysis has proven to be more difficult than anticipated. Demonstrated successes in integrated land planning have been few, especially in those areas where land planning is most common, "... namely in established cities and in the counties of the United States" (Steiner et al. 1988). Steiner's group also points out, historically, that land planning and management have seldom succeeded at the level of the individual's environment. This is especially unfortunate in light of his observation that "... [planners', managers', and land administrators'] ordering of the human environment may ultimately determine how successfully individuals are accommodated into the environment" (Steiner et al. 1988). Planners, managers, administrators, and analysts share the same problem: moving from micro-analysis at the individual level to a macro-understanding of the overall consequence of a set of individual actions formulated by tradition, mandates, and public policy.

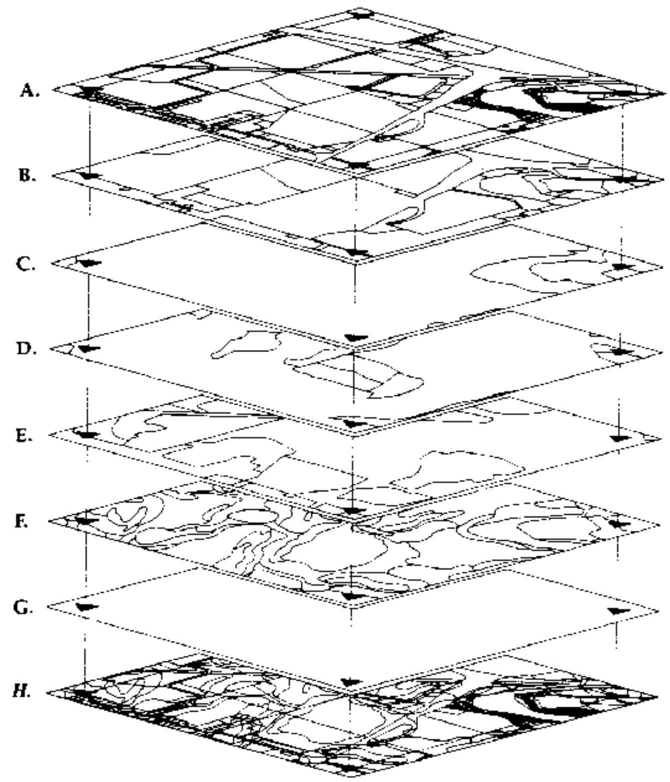
Understanding the cumulative environmental, social, and economic impacts of individual actions requires an assimilation of individual aspirations, plans, and outcomes. Subsequently, societal goals based on this understanding must be translated back to mechanisms for individual participation through laws and plans. By incorporating Manning's concepts with modern information technologies and more powerful analytical functionality, it is now possible to conduct comprehensive land information inventories and analysis consistently over large land areas in a multipurpose land information system (MPLIS) (Figure 11-1). The concept of MPLIS can be used for land planning, based upon the integration of various separate functions. The concept requires the automation of various resource layers such as soils, land cover, etc., but it also explicitly requires the automation of the land ownership layer and the modernization of the Public Land Survey System (PLSS) and the National Geodetic Reference System (NGRS) to establish a mathematical reference system (Niemann et al. 1987).

LAND INFORMATION MANAGEMENT RESPONSIBILITIES

The management of land information and associated records can be divided into four general types of responsibilities. These are those responsible for administration -- the collectors and processors of land information such as register of deeds, county surveyor, county clerk, tax assessor, data processing manager, etc.; those responsible for the use of this land information for planning -- such as the land use planner, engineer, and tax assessor; those responsible for land information management -- such as the water utility, parks department, and land conservationist; and those responsible for policy analysis and determination -- such as the county board, city supervisor, county executive, and others.

Because none of these types of land information management responsibilities is distinct, overlap is considerable. Each responsibility, however, requires different types and levels of land information and different techniques to address each entity's responsibility. These differences also require different types of analytical or spatial operator functionality. For example, those responsible for land information administration require data bases and data base management techniques that are more detailed than those for policy analysis. In contrast, those with policy analysis responsibilities require more complex analytical functionality to derive their informational needs (Figure 11-2).

If mandates for the care of the nation's resources are to have any effect, citizens and elected officials must have access to the information available regarding proposed actions. MPLIS technology, along with relevant analytical functionality and with



Concept for a Multipurpose Land Information System

Section 22, T8N, R9E, Town of Westport, Dane County, Wisconsin

Data Layers:	**Responsible Agency:**
A. Parcels	Surveyor, Dane County Land Regulation and Records Department.
B. Zoning	Zoning Administrator, Dane County Land Regulation and Records Department.
C. Floodplains	Zoning Administrator, Dane County Land Regulation and Records Department.
D. Wetlands	Wisconsin Department of Natural Resources.
E. Land Cover	Dane County Land Conservation Committee.
F. Soils	United States Department of Agriculture, Soil Conservation Service.
G. Reference Framework	Public Land Survey System corners with geodetic coordinates.
H. Composite Overlay	*Layers integrated as needed, example shows parcels, soils and reference framework.*

Land Information and Computer Graphics Facility,
College of Agricultural and Life Sciences, School of Natural Resources

UNIVERSITY OF WISCONSIN-MADISON

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Figure 11-1: Concept diagram: a multipurpose land information system

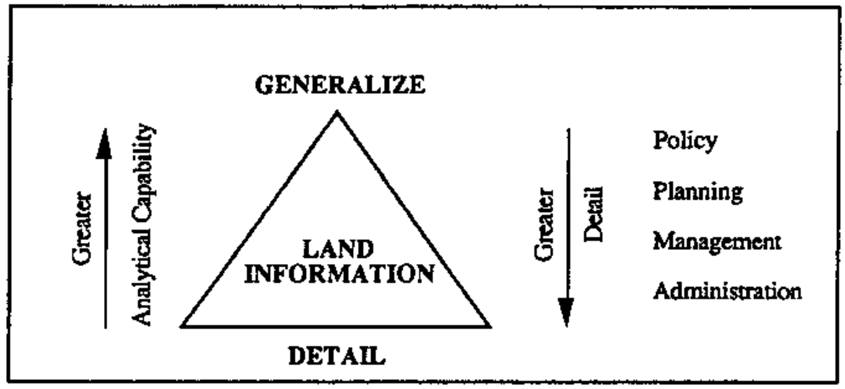


Figure 11-2: Policy analysis responsibilities require more complex analytical functionality than do other responsibilities. (from Huxhold 1991; Niemann and McCarthy 1979)

mathematical models simulating the land-use scenarios, as called for by Steiner (1989), can prove its worth in helping to predict human impact on the land. From such a data base of land information variables, people can work together to assess the alternatives, to consider the implications of development, and to make choices from clearly defined options.

ECONOMIC, ENVIRONMENTAL, AND LEGISLATIVE CONTEXT

Before we begin to explore the breadth of spatial functions now available, it is important to understand the potential impact of spatial information technology on land administration, planning, management, and policy analysis in general. Technology associated with GIS/LIS, land records modernization, automated mapping and facilities management (AM/FM) systems, infrastructure management, etc. has spawned booming U.S. and Canadian industries. Estimates vary, but most are compelling. In 1989, Dataquest, a San Jose, California, computer-marketing company, estimated the software/hardware portion of this spatial information industry in North America would be $600 million annually by 1992. In 1991, Market Intelligence Research Corp. of Mountain View, California, projected higher estimates world-wide -- up to $27 billion by 1997.

Similarly, GIS/LIS expenditures at the Federal level have also been expected to increase significantly. The U.S. Office of Management and Budget (OMB) estimated in 1989 that, by 1992, the expenditure in "electronic mapping data bases" alone would amount to $200 million annually (not including national security expenditures) (Arthur 1989). The U.S. Environmental Protection Agency (EPA) has planned to invest over $50 million in spatial information technology and impose automated geographic locational requirements on those responsible for reporting environmental conditions to EPA (GIS World 1989). The U.S. Department of Agriculture (USDA) Forest Service has said that it intended to invest about $922 million in the next 12 years to purchase GIS hardware and software to support resource management systems for all National Forests (Smith 1992). The U.S. Department of the Interior (USDI) Bureau of Land Management (BLM) has planned to employ land information systems to manage resources, maintain all the legal records associated with the PLSS, and maintain mineral rights records for all Federal lands (USDI BLM 1989). Other Federal agencies such as the USDA Soil Conservation Service have also planned major commitments to GIS technology (Liston and TeSelle 1988).

There are compelling reasons for this technological boom in land administration, planning, management, and analysis. Public, legislative, and congressional accountability for monetary investments in land planning and management are beginning to drive local, state, and Federal agencies toward the incorporation and use of GIS/LIS technology. Wisconsin citizens spend about $140 million annually to collect and administer information about land, its owners, and its value (WLRC 1987); this amounts to about $30 per resident annually. This expenditure is made with little understanding of the overall environmental, social, or economic consequences of this investment. The administrative and managerial requirements associated with this massive and continuing land records investment have become complex, requiring more efficient and effective methods. GIS/LIS tools have demonstrated order-of-magnitude shifts in increased efficiency (Chrisman et al. 1986). The State of Wisconsin, in an example of mandating individual landowner accountability, created a program to reduce soil loss (Chapter 92 of Wisconsin State Statutes 1981). The resulting administrative rule (Ag 160) states that:

> "Each [county] land conservation committee shall prepare a soil erosion control plan which does the following: ...

2. identifies the parcels *(people)* and locations of parcels *(place)* where soil erosion standards are not being met [92.10(5)a] (italicized words added for emphasis)."

In 1985, to further strengthen this public goal of soil erosion control, the Legislature created a "cross-compliance" provision between soil erosion control plans (place) and a farmer's access to farmland preservation income tax credits (people). This mandate of linking "the carrots of tax incentives with the sticks of regulation (public policy) offers a powerful tool (economic and legal)" to the land administrator, planner, and manager (Sullivan et al. 1985).

Nor did cross-compliance as a technique to implement public policy concerning conservation go unnoticed at the Federal level. The 1985 Food Security Act (FSA) and the conservation title (XIV) of the 1990 Food, Agriculture, Conservation, and Trade Act (FACTA) include mandates for the restriction of tillage of marginal and highly erodible lands, incentives for the restoration of wetlands into the Wetlands Reserve Program, expansion of the conservation reserve program (CRP) into the environmental easement, and directives about non-point and groundwater quality management as part of the Agriculture Water Quality Protection Program. To gain access to Federal farm commodity program benefits, compliance with various conservation restrictions is required.

According to Steiner (1989), the 1985 congressional mandate is "the most sweeping federal land use legislation for privately held U.S. farmland since the Homestead Act of 1862 ..." He points out that these farm-level conservation plans are:

> "... essentially physical land use plans for farms. The plans require that each landowner or manager be identified, the cropping history of each field, a resource inventory and analysis of each farm, as well as an identification of soil types, wetland condition and erosion and drainage problems at present. This information is all mapped onto aerial photographs manually at the local level. By assimilating the various factors by applying overlay-analysis, a management agreement between the land owner and the public, a map is prepared that outlines appropriate uses for each acre of the farm ..."

This overall land information and integration process is not at all unfamiliar to those trained as land administrators, planners, and managers. The process of data collection and organization focuses upon the individual farm property and field as the most fundamental land management unit. This process of determining appropriate uses for each acre is quite similar to Manning's (1909) message that knowledge about the land and its owners was essential "...in order that we know best how to develop each resource." In essence, Manning was calling for a modern multipurpose land information system, for it represented the comprehensive and integrated approach to resource management problems. What Manning could not foresee was the invention of the computer and the incorporation of spatial analysis capability such as overlay analysis. Spatial computing now provides the opportunity to implement his vision. Local, state, and Federal resource management mandates might ensure its realization.

SYSTEM FUNCTIONALITY

Software technologies associated with modern GIS/LIS are undergoing rapid change. Spatial display and analysis functions are also undergoing change, from automated forms of data retrieval, structuring and transforming, or expanding capability to automated forms of analyses in overlay, network, or matching of data. As a result, a common and agreed-upon conceptual framework and taxonomy for the various analytical spatial operator functions that are integral to an overall information system have not yet been formulated. Past attempts to clarify analytical functions are all that is available to assist those who must recommend and choose between the available alternatives. The array of spatial analytical functions in GIS/LIS software can be better understood if they are presented as five conceptual organizational schemes. Combinations of these illustrate various uses of the overall functions.

As GIS/LIS technology has matured, so has a rich and varied set of functional cartographic and spatial data handling and manipulation procedures. These operators are not to be thought of as spatial analytical functions in a traditional statistical sense, for most known statistical techniques are based on the premise of data being observed independently. Geographical data tends to have spatial dependency and this "spatial autocorrelation" invalidates most existing statistical procedures (Openshaw 1990). In this discussion, "system functionality" refers to those analytical capabilities associated with the management and manipulation of cartographic and spatial data.

EMPIRICAL MODEL

The first organizational scheme is essentially an empirical one, resulting from the study of governmental agencies such as municipalities. These studies have identified two sets of generic tasks -- procedural (e.g., administrative) and managerial (e.g., planning and management) -- associated with municipal functions (Dangermond and Freedman 1984) (Table 11-1).

Procedural Tasks	Managerial Tasks
Acquiring and disposing of property	Creating and managing mailing lists
Processing and issuing parcel-related permits	Allocating human resources
Performing inspections	Responding to public inquiries
Providing legal notification	Managing facilities
Issuing licenses	Managing inventory
Naming streets	Managing resources
Reviewing site plans	Controlling weeds
Reviewing subdivisions	Managing mapmaking
Creating street addresses	Managing drawing/drafting
Reporting events	Managing data bases
Dispatching vehicles	Tracking development
Routing vehicles	Disseminating public information
Analyzing traffic	
Siting facilities	
Administering area distributing	
Administering zoning by-laws	
Conducting land-use planning	
Conducting engineering design	
Conducting drafting	
Searching titles	
Performing tax/fee billing collection	

Table 11-1: Observed Generic Municipal Tasks

To respond to this basic generic set of municipal tasks, ten data or land record components were identified to support these analysis queries associated with each task (adapted from Dangermond and Freeman 1984). These components were:

1. Base map consisting of control data and topography.

2. Environmental overlays such as water, soil, geology, etc.

3. Engineering overlays such as the locations of roads, sewers, etc.

4. Plan/Profile drawings of such infrastructure elements as sewers and water lines.

5. Parcel maps that delineate land ownership boundaries of all public and private lands.

6. Parcel/Street address tabular data that describe characteristics about the owner of a parcel or about the parcel itself such as tax billing, building permits, etc.

7. Area tabular data that describe characteristics about block or districts such as the character of school districts.

8. Street tabular data that include a variety of data associated with the street such as address range, pavement condition, etc.

9. Street network file such as topological network.

10. Area boundary maps such as data bases that define city blocks, school districts, census tracts, and zip code boundaries. These maps correspond to the attribute data previously listed.

To address the various tasks using these components, five basic sets of analytical functions (adapted from Dangermond and Freeman 1984) were used to support the various applications:

1. *Graphic overlay*: The overlaying of various data layers or records upon each other graphically. This function allows for spatially interrelating such land record items as parcel boundaries with utility locations.

2. *Topological overlay*: The overlaying of various data layers or records by joining the geographic elements. This function provides for interrelating such land records as parcel boundary and ownership with poor soil sewerability boundaries resulting in a new data layer of parcels not appropriate for on-site waste disposal. This new characteristic of the parcel becomes part of the attribute data base about each parcel.

3. *Address geocoding*: A spatial matching procedure whereby the street address can be assigned to street segments or networks. This function provides for interrelating such tabular or attribute land records as owner's name and address with the graphical portrayal of the street segment.

4. *Polygonization*: The spatial analytical procedure of dissolving line segments between similar polygons. This function provides for interrelating such land records as parcel boundaries into a new and larger polygon such as an administrative unit (e.g., a school district or land-use zoning district) by aggregating parcel boundaries of similar zoning.

5. *Relational matching*: An analytical procedure used to relate tabular data to spatial data. This function, now supported by a variety of relational data base vendors, is used, for example, to connect such land records as owner's name from the tax assessment relational data base with the ownership polygon from the graphic file. The name can actually be displayed within the boundaries.

HIERARCHICAL MODEL

The second organizational scheme is that proposed by Burrough (1986): a hierarchy of data transformations for geographical information systems. Figure 11-3 conceptualizes how various system capabilities can be used for spatial data utilization and analysis. Functions for utilization and analysis are divided into those operations that deal with the topology or spatial aspects of data, those that act on the non-spatial attributes, and those that work on both.

- TRANSFORMATION
  - MAINTENANCE
    - Editing
    - Updating
  - UTILIZATION AND ANALYSIS
    - Topology
      - Rotation, translation
      - Scale transformation, stretch
      - 3-D Display
      - Area, perimeter calculation
    - Properties
      - Retrieval
      - Logical/mathematical analysis
      - reclassification
        - Univariate/hierarchical
        - Multivariate/statistical
    - Topology + properties
      - Retrieval
      - Overlay and intersection
      - 'Region' analysis
      - Neighborhood analysis
        - Spreading
        - Detecting shape, narrowness, etc.
        - Interpolation
          - 'Deterministic'
            - BSplines
            - Thiessen polygons
            - Contours by
            - Inverse distance weighting
          - Statistical'
            - Trend surfaces
            - Autocovariance analysis
            - Kriging, etc

Figure 11-3: Hierarchy of data transformation operations.

Burrough (1986) proposed a general model for data analysis (Figure 11-4) where the link is the data analysis function -- any set of operations that convert one or more input maps into an output map. These analytical capabilities vary from simple data retrieval

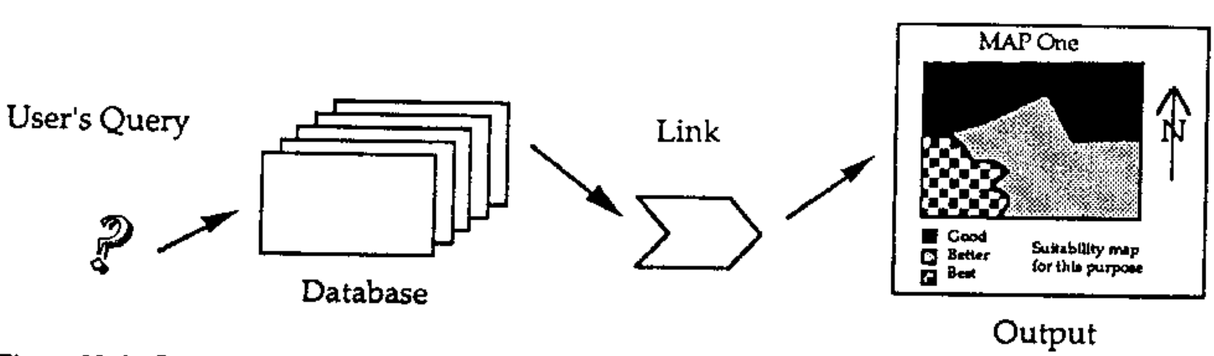


Figure 11-4: Data analysis problem.

and display functions, such as land ownership parcel boundaries merged with distances to shopping opportunities, to complex analytical tasks, such as network analysis for optimum fire truck routing. Burrough proposed an array of operators (Table 11-2).

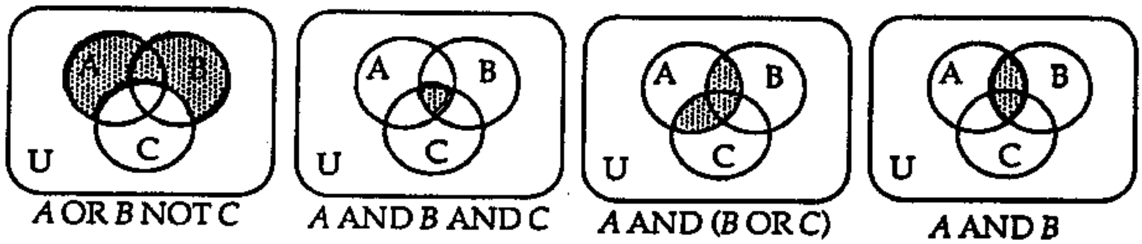
Operators	Example/Description
Simple data retrieval functionality	
Boolean logic	--Show all parcels with commercial or industrial zoning
Reclassify and display	--Show adjacent parcels with same owner as one parcel
Boolean operation on 2 or more maps	--Display all wetlands and greenspace
Map overlay functions	
Point operations (raster)	--Functions of attributes at one locus. Add attributes from Maps A and B to create Map C.
Region operations	--Properties of a region containing a locus. Give size of region A.
Neighborhood operations	--Associations of a locus with its neighbors. Show all areas visible from Point p.
Cartographic modeling functionality	
Arithmetic processes	--Adding, subtracting, multiplying maps
Logical processes	--Renumbering, clustering, reselecting portions of a map
Linking operation processes	--Combine a set of commands in a selected order to produce output

Table 11-2: Function operators (adapted from Burrough 1986).

Although Burrough concentrated on raster data structure functions, the scheme works for vector functions as well. Simple data retrieval procedures in a vector-based, layer system are straightforward. Parcel line boundaries can be displayed as the result of a simple call to the data base. The use of Boolean logic allows additional capability, using AND, OR, and XOR operators on attributes of the data elements. Venn diagrams (Figure 11-5) help visualize Boolean logic.

GOODCHILD MODEL

The third scheme is that provided by Goodchild (1989), which outlines a data model (Table 11-3) in which Type = point, line, area; Object = individual elements of a type; Class = category of each type, with attributes. In his scheme of GIS



PARCEL-ID	AREA	ZONING	VALUE	BUILDINGS
* 5041	12,000	C	$ 92,050	0
5633	3,541	R	$ 19,233	0
* 2346	23,442	C	$ 18,335	1
9743	18,276	C	$119,000	2

Figure 11-5: Venn diagrams of Boolean sets.

	Type		
	Line	Point	Area
Class	road stream boundary	well windmill gauging station	lake wetland parcel

Table 11-3: Structure of a data model (Goodchild 1989).

functionality, Goodchild (1989) presents two levels of analytical operators: Level 1 spatial analysis operators are classified as performing one or more of the following functions:

a) Attribute analysis of a single class of objects (statistical analysis);

b) Locational and attribute analysis by a single class of objects;

c) Attribute analysis of object-pairs;

d) Analysis of more than one class of objects;

e) Creation of new object-pairs for one or two existing classes of objects; or

f) Creation of a new class of objects from one or more existing classes of objects.

Level 2 classifies the types of objects being processed. Creating an area from a line is different from creating an area from a point, though both are group (f) operations. Using this kind of classification framework, a comparison can be made between the function of the operator (i.e., a-f) and the type of operator (Table 11-4).

	Analysis Function					
Type of Operator	(a) Attribute analysis by a single class	(b) Locational & attribute analysis by a single class	(c) Attribute analysis of object pairs	(d) Analysis of more than one class of objects	(e) Creation of new object pairs for one or more existing classes of objects	(f) Creation of new class of objects from one or more existing classes of objects
Boolean selection	X					
Nearest neighbor analysis		X	X			
Spatial autocorrelation		X	X	X		
Thiessen polygons					X	X
Spatial interaction modelling				X	X	X
Transport network analyses:				X		
--Shortest path analysis		X	X	X		
--Optimum tour routing		X		X		
--Location-Allocation		X	X	X		
--Transportation and transhipment problem		X				
Polygon overlay						
--New area objects					X	X
--New point objects				X		X
--New line objects				X		X
--New attributes				X		

Table 11-4: Analysis functions by operator.

GIS WORLD, INC., MODEL

The fourth organizational scheme is that provided by GIS World, Inc. (1990). The results of a survey returned by 100 vendors were published as an indication of the state of software functionality (Table 11-5). This survey has also been conducted

- Measurements
  - Straight distance
  - Curved distance
  - Proximity analysis
  - Area measurements
- Buffer generation
  - Around points
  - Around polygons
  - Along straight lines
  - Curved lines
  - Weighted
- Map algebraic functions
  - Add/Subtract maps
  - Mult/Divide maps
  - Exponential maps
  - Trigometric functions
  - Differentiate values
- Polygon operations
  - Polygon overlay
  - Point in polygon
  - Line in polygon
  - Merge/Dissolve
  - Delete spurious polygons overlay
  - Thiessen polygon generation
- Terrain analysis with TIN and DEM data
  - Compute slope angle
  - Determine compass aspect
  - Interpolate elevation
  - Line of sight viewshed
  - Generate elevation contours
  - Model drainage network
  - Generate terrain cross-sections
  - Cut/Fill calculations
- Miscellaneous
  - Analysis within corridor
  - Boolean operations multiple maps
  - Boolean operations multiple themes
  - Nearest neighbor search
  - Computer optimal path
  - Compute weighted optimal path
  - COGO operations
  - Network analysis
  - Vector to raster conversion
  - Raster to vector conversion
- User interface and display
- Spatial query
  - Curser input
  - Coordinate input
- Standards support
- Help
  - On-Line
  - Context-sensitive
- Cartographic output
- Input device support
- Output device support
- User-generated macros
- Remote sensing image processing

Table 11-5: Analysis functions in the GIS World *scheme.*

annually with an increase in the number of vendors to more than 300. The analytical functions remain similar. Data from the previous year's survey were analyzed and results published by GIS

World (1989) (Table 11-6), including a grouping of functions into classes, for an analysis of the percentage of systems containing each class of functions.

Function class	Number of functions	Percentage of systems
Distance measurement	3	74-94
Buffering	5	78-90
Map algebra	5	36-78
Boolean operations	2	80-82
COGO computations	1	40
Network tracing	1	44
Remote sensing image analysis	1	26
Terrain analysis	8	26-60
Polygon operations	6	18-82

Table 11-6: Percentage of systems by function class.

STATE OF WISCONSIN MODEL

The fifth scheme is that used by the Wisconsin Department of Administration (Ventura 1991) to develop a list of appropriate GIS/LIS software functionalities for use by local governments. This scheme, the product of a format to aid local governments in their requests for proposals (RFPs) from vendors, can demonstrate how various analytical functions assist land information managers in conducting administrative, planning, management, and policy functions and responsibilities. The analytical capabilities (Table 11-7) are abstracted in a functionality matrix (Figure 11-6) that is used later in this chapter (Section IV. APPLICATIONS) to examine the use of functions for specific applications.

ERROR ISSUES

The use of GIS/LIS technology and spatial analytical operators (functions) naturally introduces errors, a phenomenon familiar to anyone who has worked with land data -- manual or automated. In certain functions such as overlay, however, errors

- User interface
- Data base management
- Data base creation and management
  - Data automation
    - Data input
    - Topological structuring
  - Attribute data association
  - Data editing and error correction
  - Terrain and other 3-D surface representation
  - Import/Export
- Display and analysis
  - Data retrieval
    - Feature
      - Selection and display by theme or layer
      - Selection and display within window
      - Selection and display by feature name or groups of names
      - Measure location
      - Measure distance
      - Measure along-line distance
      - Measure line direction
      - Measure area shape
    - Attribute
      - Selection and display by Boolean retrievals on attributes
      - Listing of attribute items associated with selected feature classes
      - Listing of attribute values of selected features
      - Frequency distribution
      - Count
      - Statistical summaries
  - Data restructuring
    - Raster to vector conversion
    - Vector to raster conversion
    - Encoding and decompression of raster data
    - Map tile or sheet appending
    - Automatic edgematching with continuity checks
    - Interactive edgematching
    - Line thinning (point reduction)
    - Line smoothing (splining)
    - Feature generalization (area to point or area to line transformation)
  - Data transformation
    - Planar transformations
      - Conformal and affine
      - Least squares adjusted affine
      - Projective
    - "Rubber-sheeting" planar transformation
      - Polynomial
      - Inverse distance weighted affine
      - Tin-based
      - Control-point coordinate look-up
      - Projection conversion
      - Datum conversion
  - Overlay
    - Graphic superimposition
    - Topological overlay
    - Automatic intersection and attribute merger
    - Manual feature creation
    - Cross-tabulation of area or number of mutual occurrences
    - Area weighted average of attribute values
    - Boolean overlay
      - Union (OR)
      - Intersection (AND)
      - Exclusive Union (XOR)
    - Topological overlay
      - Polygon on polygon
      - Line in polygon
      - Point in polygon
      - Line on line
      - Point on line
    - Sliver removal
  - Networks
    - Line and node attributes
    - Optimum path
    - Optimum distribution or collection route
    - Optimum allocation zones
  - Other geoprocessing
    - Buffering
    - Proximity search
    - Aggregate with line dissolve
    - Address matching
    - Nearest neighbor
    - Adjacency
    - Theissen polygons from points
- Data display and information product creation

Table 11-7: Software functionality checklist.

Function:		Application	Admin.	Planning	Mgmt.	Policy
Data Retrieval	Feature	by theme or layer				
		within window				
		by feature name				
		location				
		distance				
		direction				
		shape				
	Attribute	Boolean retrievals				
		attribute items				
		attribute values				
		frequency dist.				
		count				
		statistical summary				
Data Restructuring		raster/vector conv.				
		vector/ raster conv.				
		map tile appending				
		automatic edgematch				
		interactive edgematch				
		line thinning				
		line smoothing				
		feature generalization				
Data Transformation	planar	conformal and affine				
		least squares affine				
		projective				
	rubber	polynomial				
		inverse dist. weighted				
		tin-based				
		control-point look-up				
		projection conversion				
		datum conversion				
Overlay		graphic superimposition				
		sliver removal				
		area weighted average				
		cross-tabulation				
	overlay types	polygon on polygon				
		line in polygon				
		point in polygon				
		line on line				
		point on line				
	Boolean	Union (OR)				
		Intersection (AND)				
		Exclusive Union (XOR)				
	topol	intersect/attribute merger				
		manual feature creation				
Networks		line and node attributes				
		optimum path				
		optimum distrib/collect				
		optimum allocation zones				
Other		buffering				
		proximity search				
		aggregate/line dissolve				
		address matching				
		nearest neighbor				
		adjacency				
		Theissen polygons				

Figure 11-6: Functionality matrix.

are not only easily introduced, but also easily compounded, and very difficult to detect and correct. A discussion of errors, their sources, their impacts, and the methods of avoiding them is essential, therefore, to a discussion of spatial analytical functions.

The lack of data quality measures is a major obstacle to the effective utilization of GIS/LIS technology. Conventional wisdom suggests that the only long-term solution to the elimination and reduction of "errors" introduced by land information automation and spatial analysis is to collect all land data at the same level of validity (degree of accuracy) and reliability (precision), at the time it is needed to assure timeliness, and for the specific purpose intended to assure fitness for use. The economics of information currently preclude such an approach.

Administration, management, planning, and policy analysis of the land and its occupants "involves a balance between diverse factors of the natural environment and competing human interests ... "; as a result, these four land information functions of government "must integrate information from diverse sources" (Chrisman 1987). This integration of diverse sources of information "describes a process that goes on in our minds virtually all our waking lives as we sense, evaluate and store information about our environment" (Unwin 1981).

The overall validity and reliability of our decisions are based on this integrative process. For this process to be successful requires that we know what we are attempting to resolve, that we have the ability to translate data into information useful for the decisions before us, and that we have rules about the data to assure reproducible and valid outcomes. As we repeat this process again and again, we reduce the length and intensity of the overall process. Data become information and information is transformed into knowledge. GIS/LIS technology is simply a means to do more efficiently, effectively, and equitably what we do on an everyday basis.

Errors resulting from GIS/LIS use, then, can be classified into several sources: Errors in the data, error from natural variation and in original measurement, error caused by processing, errors from levels of measurement, and error from rules of combination (Table 11-8).

Error in Data

Until the recent need for automated data arising from the use of GIS/LIS analytical tools, issues of data quality have not tended to be a major concern of the non-mapping community. Issues of repeatable measures to known levels of measurement or to reality ("ground truth") have now become major automation issues. The

Error in data
Timeliness
Completeness
Map Scale
Reliability
Validity
Format
Cost
Error from natural variation and original measurements
Error from processing
Error from levels of measurements
Error from rules of combination

Table 11-8: Sources of errors.

ability to collect large volumes of digital data from aerial photography and orthophotography, satellites, and the global positioning system (GPS), in concert with expanded analytical functionality, requires users to consider the inherent quality of data.

Potential error sources are best understood by those who are responsible for collecting and building data bases -- manual or automated. Errors include age or timeliness of the data, completeness of the areal coverage, applicability of the map scale, reliability of the data from an areal and ground truth perspective, relevance of the data to the problem being addressed, numerical and spatial format of the data, accessibility of the data, and cost to access, collect, or convert data into a useful automated format (Burrough 1986; Larsen et al. 1978). Just as in manual methods, inappropriate use of data can result in arbitrary and capricious conclusions. Ultimately, the user or analyst must enlist professional integrity, experience, and judgment to determine the state and usefulness of the data for a particular task, application, or problem.

Timeliness of Data

Timeliness of natural resource data tends to decay at a slower rate than that of cultural data. However, as basic land information records are modernized through transactionally-based or on-line capture techniques in data collection systems, timeliness of the data as an error source will diminish. For example, as the register of deeds, the zoning administrator, and the building permit andinspection departments automate and integrate their daily activities with the property description department, a timely view of who owns the land, how is it zoned, and who plans to build will be possible. Environmental and positional data are now beginning to be captured by various on-line instruments such as weather satellites and global positioning systems (GPS) satellites. However, as one improves the timeliness of data collection, the ability to access data of exactly equal vintage becomes less realistic. Whatever the task or application, errors in the timeliness of data will remain an important factor to be considered in the use of those data.

Completeness of Data

Errors in completeness can arise if the data base does not completely cover the study area in question, or if the data are not of similar quality such as age. Studies have shown that a body of data of questionable quality that is geographically comprehensive and complete is more usable than accurate data of a scattered nature. For functioning and stable administrative political entities such as counties, municipalities, or school districts, completeness is important: each potential real estate taxpayer needs to be identified; each child must be accounted for school enrollment management. If the management or planning question requires natural boundary delineators such as watersheds or flood plain zones, all the water must be accounted for, as these units tend to cut across administrative and political units. Various levels of completeness can sometimes be solved by conducting additional surveys that fill data voids, by generalizing data to match less detailed data, or by conducting different levels of analysis to match existing data sets.

Map Scale

Map scale and the explicit collection of data depicted on a map have a direct relationship to the scale of the decision for which the map is useful and the type of analytical function chosen to manipulate the data. For example, to resolve a land administration question such as a trespass dispute over access to navigable waters by riparian owners using a criterion of "ordinary high water mark" requires, by legal precedent, on-site surveys (Zinn vs. Wisconsin 1983). In an automated world, for this land administration task, the analytical functions embedded in coordinate geometry (COGO) could be used to portray the surveyed property boundary locations. The depiction of the shoreline could be obtained from a large-scale base map (1:1,200 to 1:5,000). The analytical function of overlay could be used to spatially portray the high-water mark (shoreline) in comparison to the COGO-derived property boundary. This combination of functions could then depict the spatial extent of potential trespass, if any.

To resolve land management issues such as reduction of soil erosion from farmed land into waterways, smaller map scales (1:10,000 to 1:24,000) are appropriate given the nature of soil and the reliability and accuracy of soil erosion models such as the Universal Soil Loss Equation (USLE) (Wischmeier 1976). In this case, applicable analytical techniques might be the use of digital elevation models (DEMs)in combination with flow-routing models using automated data sources such as potential soil erosion, cropping practices, and rainfall, resulting in an estimate of soil amounts reaching the waterway. Map scale, the inherent scale of data collection, and the associated models used to manipulate the data directly limit the scale or unit of spatial analysis. Other analytical techniques might be the use of buffer analysis of a prescribed distance from the water's edge intersected with soil types, resulting in an index of potential erosion to the waterway.

Both approaches are measures of erosion depending upon the preciseness of the management question. However, the amount of analytical processing and complexity of the resultant data sets are much more complex in modeling with the USLE. Which approach is better is dependent upon the question being asked. If one wishes to regulate soil erosion, the modeling approach is most defensible. If one wishes to determine which erosive soils are spatially associated with navigable waters, the buffering approach is quite reasonable at a vastly reduced analysis cost.

Data Reliability

Reliability of the data tends be a derivative of how something was measured (precision), whereas validity of the data tends to be descriptive of how well the data reflect the question or issue being addressed (accuracy). Data might start out to be highly reliable or precise, but because of missing elements, inappropriate assumptions, or misuse of analytical techniques, the result can lead to invalid conclusions. For some automated data elements, such as surveyed property parcel boundaries, well defined collection and mapping standards are generally embedded in statutes and professional norms. Mapping reliability standards also exist for natural resources such as soils, but these natural resource reliability measures are driven more by professional and institutional convention than by legislation. This results in the need for considerably more "professional judgment" because of the spatial and transitional nature of soils as compared with a parcel boundary with a fixed and precise description. As this interest in data reliability has emerged, "truth in labeling" has been called for, whereby the source, density of observations, and ground truth employed become an explicit part of the automation product (Chrisman 1984).

For example, PLSS section corners are used over and over again to describe property as it changes ownership; these corners are relocated using the most reliable measures and valid evidence available. However, the actual location of the relocated monument may in fact not be in the correct or valid location because of an oversight of more conclusive evidence. Remonumentation law states that the valid location of a section corner monument can only be that which "retraces the original foot steps of the surveyor" who established the monument initially (Bauer 1984). This means that a monument can be reliably positioned over and over again using the best data available but, if more compelling evidence is obtained, the monument might be in an invalid location.

Data Validity

Validity is the bottom line of the overall data quality issue discussion. Validity (accuracy) is how well the measurement defines reality or a true value. Data can be up-to-date, complete, at the right scale, reliably collected, formulated in a useful way, accessible, and cost-effective, but if they are analyzed incorrectly or do not reflect the land issue being resolved, the extent of reliability will be deemed irrelevant or arbitrary and capricious.

The relevance of automated data to the administrative, management, planning, or policy issues being addressed is of major concern. The Wisconsin Department of Revenue (DOR), for example, must assess the value of land and its improvements to determine an equitable assessment for real estate tax purposes. One such measure of taxability is the inherent potential of the land to raise crops and gain economic income, irrespective of the actual farm income. To meet this constitutional requirement of equitable taxation, soil maps are used as surrogates to derive inherent production value. Soil types are classified on the basis of the ability to raise row crops such as corn, and these soils are grouped or ranked on a three-grade system (i.e., excellent, good, and poor) (Figure 11-7). Soil maps are used because the USDA Soil Conservation Service has over time developed a consistent and repeatable (reliable) set of measures of potential productivity from various soils. These measures or attributes of inherent productivity are considered valid expressions of potential land value for purpose of equitable taxation.

This eventual judgment is made by the individual or group being impacted by the decision, the decisionmaker being held responsible for the decision, or the courts being asked to mitigate the dispute. This tension between reliable but valid data remains a major dilemma for MPLIS implementors: which data will prove to be most useful for current and long-term users at a responsible cost?

Format

Burrough (1986) suggests there are three important data format issues. The first is technical. Assuming an automated environment, technical format comprises the way data are represented electronically on magnetic or disk media for storage, manipulation, analysis, and transfer between data base managers, analytical procedures, and graphical display devices.

The second issue is how the data are originally captured and structured. Data can be captured as primitives in a vector format such as points, lines, and areas or captured in raster formats. If data are in vector or polygonal form, the data structure can be graphical such as in CAD systems, topological as in many GIS platforms, or object-based as in some GIS platforms. If in raster form, the data can be represented by reflective values, presence/absence, predominant type, percents, value at centroids, or some combination of the above. The chosen data structure has a dramatic effect on how easily data can be shared and what spatial analytical functions can be employed.

The third format issue is concerned with scale of observation, conversion, storage; the type of projection utilized to transform the data; the errors of representation introduced; and the classification of the data into variables.

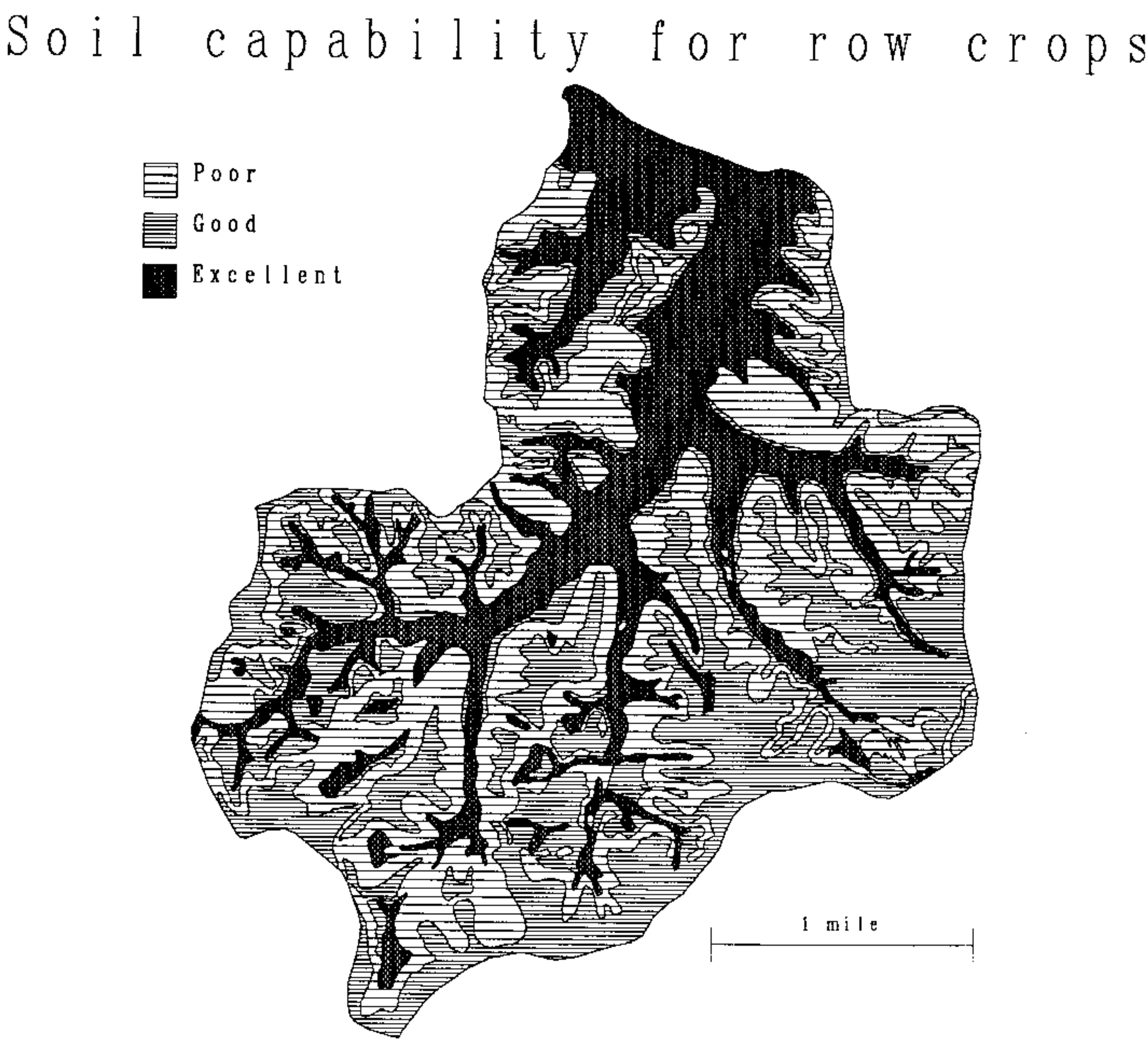


Figure 11-7: USDA SCS three-grade soils classification system.

Changing scales easily is an advantage of a modern information system. If a mathematical relationship exists between an existing scale and a proposed new scale, the change is primarily a technical procedure. Nevertheless, enlarging the scale of a data set that was originally collected at a smaller scale must be undertaken with thoughtfulness and considerable professional judgment. Transformations are of a similar nature. If there exists a mathematical relationship, the transformation is primarily technical. However, in the readjustment of the North American datum projection in 1927 to a more valid representation of the Earth's shape to the 1983 GRS datum, transformations between the two datums can be made only statistically and not mathematically. Spatial error in transferred coordinates will be generated as one moves back and forth between these two datums. The importance of these coordinate shifts depends upon the intended use of the land administration, planning, and management data.

Of particular problem is the use of existing classification schemes in a multipurpose use context. For example, how a tax assessor organizes certain data to determine the variable "swamp and waste" for real estate tax assessment purposes is probably quite different from how a botanist/ecologist organizes data to determine the variable "wetland" for regulatory protection purposes. The outcomes in terms of acres, taxes, regulations, and the property rights affected are quite different depending upon the underlying variable assumptions and associated data (Sullivan et al. 1985).

Historically, the reconciliation of classification systems was quite difficult; manual compilation and analysis limited flexibility. Automated systems offer much more flexibility by keeping the data as variable primitives and by being able to nest data sets for recompilation into other variables. Modern relational and object-oriented data structures also allow flexibility to create classification systems "on the fly" per application or issue. This ability to keep primitive views of the data is one of the real and measurable advantages of spatial information technology.

Cost

Collecting and converting data into digital form for spatial analysis remains the major impediment to the full employment and access to the benefit stream of GIS/LIS technology. Data conversion is reported to be easily 50-80% of system implementation cost (Antenucci 1990; Huxhold 1991). Over time, as systems move from manual collection and conversion methods to those that are automated and transactionally based, conversion costs will decline. Improved forms of data collection and conversion technology -- such as automated scanned digitizing, improved resolution of remote sensing and positioning systems, and new photogrammetric techniques such as orthophotography -- will also reduce data capture costs. Building and maintaining digitally structured data bases, however, will always remain as an economic restraint. Economic restraints appear in the form of relative societal importance of the problem being addressed, the associated mandates, the level of spatial and analytical uncertainty that can be tolerated, and the associated costs to collect, convert, and maintain the data in a digital form. Usually the outcome is some form of compromise between the best the technology can deliver and the ability to pay. (See Chapters 7 and 15 for more discussion about the economics of information.)

Error from Natural Variation or Original Measurements

Various state and Federal studies about land information conclude that the maps and documents that record the spatial interests and distribution about land found that "land records are not uniform nor are they related to a high quality geodetic reference system" (USDI 1990). These studies have also concluded that through the use of "a high quality" reference system, various layers or records of information can be "precisely aligned --- allowing the combination of information from multiple layers". These information layers include "parcels, roads, slopes, soils, zoning, sewer service, fire hydrants, flood plains, and land use (USDI 1990). Precision in this context refers to the ability to overlay or spatially integrate each layer and its data elements. This is similar to our definition of reliability --- the ability to repeat a measurement.

Some land features or boundaries are measured much less precisely (spatially reliably) than others, irrespective of the scale and the precision of the geodetic reference system. This is what is referred to as "natural variation" --- sometimes also referred to as that land information that tends to have "fuzzy boundaries" (Burrough 1986). More easily defined spatial objects are monumented and coordinated property boundaries and easements, pavement edges, fire hydrants, and political administrative land zoning boundaries based upon property boundaries such as the PLSS. More complex spatial objects are geographic spatial products of the natural world -- slopes, soils, and flood plains.

They constitute important records because in many parts of this nation they impact upon how land can be used and how it is regulated. Steep slopes resulting from excessive soil erosion limit use of agriculture lands; various soil types limit the location of residential development because of on-site sewage disposal requirements or flood-plain and flood-prone areas. Even the more culturally defined records of land-use zoning and land use are examples that can be characterized as having "natural variation or fuzzy boundaries." Zoning and land uses that can be attached as the sole attribute to a land ownership parcel boundary can be more precisely defined or at least defined to the same level of precision as the parcel boundary layer. Other, less well defined boundaries include shoreline zoning, which restricts building locations and on-site waste disposal location within the shoreline core. In Wisconsin, these restrictions are spatially defined and applied by such legal delineations as 1000 feet from the ordinary high-water mark of any existing lake and 300 feet from any navigable stream or river. Land use information also cuts across cultural delineations and boundaries. Large speculative single-owner land holdings adjacent to urban areas are an example. The owner might be utilizing the holdings in various ways -- some portion in a development stage, some maintained in a pre-development stage such as in agriculture use, and some in a natural or open space condition with the intent to provide public access or to include the open space for jointly owned private land such as in a condominium complex.

Some land information boundaries and attributes can be very precisely measured, and the error measured, mathematically described, and statistically reported. Other land information boundaries such as slope, soil, vegetation, and wetland "often reflect the judgment of the [resource expert] about where a dividing line, if any, should be placed" (Burrough 1986).

Natural processes and adaptation of biological phenomena such as soils and vegetation are a continuum; the boundary and attribute changes are areas of spatial transition between various soil characteristics, vegetation species, or, in the case of wetlands, the degree of "wetness." Attempting to spatially bound this natural variation is fraught with difficulty, but is legally necessary. Unless there are appropriate soils to accommodate on-site waste disposal, a building permit cannot be issued. Unless a homestead is outside the floodway, flood insurance will be required and types of land use will be restricted. Strict uniformity with respect to all land boundaries meeting the same level of precision is not technically or economically feasible or desirable. Levels of boundary and attribute "fuzziness" must be dealt with on the basis of the given mandate, the application intended, and economics of information management.

Error caused by inaccuracy of the data is a very different issue: it is a question of how well the boundary and attribute characterization of the representation reflect the object being measured. Error associated with accuracy could be as simple as mislabeling the attribute of a polygon; it could be as simple as an instrument that is poorly calibrated; it could be lack of knowledge or experience of the surveyor; it could also be the result of professional bias; or it could be the result of natural variation. Reliability (precision) is a function of how well the spatial object can be measured. Error can be introduced by mistakes, faulty instruments, lack of experience, and the natural variation that exists. Error in accuracy or validity of the data is impacted by the same factors, but statements about accuracy are dependent upon measurement interpretation and fitness for use rather than just the boundary measurement.

Error from Processing

Error from the processing of digital data is the least understood of the various potential sources of error sources. It begins with error being introduced in the capture or conversion process such as in digitizing, and can include the misuse of various spatial analytical functions such as overlay, the misuse of data given its level of original measurement, and assumptions about rules when data are used for land management and planning model conversion or are abstracted into a form that can be digested and manipulated. The error associated with this capture or conversion process impacts all subsequent use of the data -- for example, varying line widths when digitizing boundaries, particularly of spatial objects with transitional boundaries such as soils. Such errors can be managed by developing careful automation procedures and by including error and quality threshold checks.

Error introduced through the use of various spatial analytical functions is more subtle and perplexing. The use of topological overlay is a good example. The overlay function is used by a variety of disciplines for many purposes and applications. A good overlay operator remains a distinguishing feature between GIS/LIS and non-GIS/LIS products. The overlay process consists of combining two or more thematic maps and creating a third. It is conceptually straightforward, but fraught with unresolved error questions -- for example, errors created by natural variation within assumed homogeneous measures, the creation of sliver or spurious polygons along the edges of polygon intersections, and overlay with well defined boundaries such as property lines on transitional or overlapping boundaries such as soils, etc.

Nevertheless, the tool of overlay analysis remains one of the most used functions in modern GIS/LIS applications (Chrisman 1987). Professional expertise, a clear understanding of the inherent natural variation of the data being analyzed, and the spatial nature of the problem being addressed will continue, for the time being, to be the most efficient means to evaluate the reliability and validity of the analytical results.

Error from Levels of Measurement

The ease of transforming data into information, and integrating that diverse set of information into knowledge for making decisions, is related to how data were originally collected and measured. Various classification and measurement schemes have been devised. A particularly useful one for integrating and manipulating spatial data describes measurements in terms of four levels: nominal, ordinal, interval, and ratio (Table 11-9) (Unwin 1981).

Nominal measures involve no assumptions about values assigned to the data. Assignments of data are verbal or in name only ("nominal"). The data are inclusive and mutually exclusive. All spatial objects are assignable and no objects are assignable to more than one class. Examples are binary data (i.e., 0 or 1), presence/absence, and taxonomies. Nominal measures on U.S. Geological Survey (USGS) quadrangle maps at 1:24,000 include the various symbolized objects such as the presence or absence (geographically) of water, vegetation, and wetlands and labels such as city and township names.

Ordinal measures imply an ordered relationship between the objects, a consistent ranking on the application of some consistent criteria. The ranking is also verbal or in name (e.g., heavy, moderate, low). The break points between the measures are non-numerical. The break points are based on intended use, experience, and judgments. Ordinal measures on a USGS map could be the classification of roads, with the various roadway

Level	Basic operation	Example (USGS map at 1:24,000)
Nominal	Determination of equality of class; counting items	Forest, stream, water body, PLSS section lines.
Ordinal	Determination of more, less, or equality; counting items in a class	Road symbol as indication of capacity; stream order/number of branches
Interval	Determination of equality or difference of interval; addition, subtraction, multiplication, and division	Contour lines used to calculate difference in elevation and percent of slope
Ratio	Determination of equality or difference of ratio; addition, subtraction, multiplication, and division	Contour lines or spot elevations and a datum such as sea level to establish ratios between map elements

Table 11-9: Levels of measurement (from Unwin 1981).

symbols used to portray three levels of potential capability to handle vehicular traffic: two lane = heavy, paved = moderate, and non-paved = low. The order reflects potential to carry traffic using number of lanes and pavement type as the means to ordinate nominal measures.

Interval measures provide order and distance along a well defined scale. Objects can be described in meaningful units (the number of acres encompassed by Lake Michigan) and distances can be measured (the number of highway or air miles between Chicago, Illinois, and Madison, Wisconsin). Contour lines representing lines of equal elevation on USGS maps are also an example of interval measures; by subtracting one contour interval from another, the difference in elevation can be calculated.

Dividing the horizontal distance (in feet) between contour lines into the vertical difference (in feet) and multiplying the result by 100 to yield slope in percent.

Ratio measures have an inherent horizontal distance and meaningful zero point. If one assumes that mean sea level represents a vertical datum of zero, ratio measures can be made using USGS contour maps. The steps of the state capitol building in Denver, Colorado, are one mile above sea level (5,280 feet). The steps at the state capitol in Madison, Wisconsin, are 920 feet above sea level; therefore the capitol steps in Denver are 5.739 times higher than those in Madison.

Levels of measurement of spatially distributed data impact directly on the inherent long-term usefulness of the data, the method of analysis, and the certainty of the conclusions reached during the analysis. Automation allows for the manipulation of objects at all four levels of measurement depending upon the original level of measurement and the intended application. Point features such as domestic water well locations can be treated as nominal measures. By adding attribute data such as nitrate levels about the well, ordinal rankings of low, medium, and high can be created. Ratio calculations can also be conducted describing numerical differences between nitrate levels in each observed well. This can result in a ratio calculation in parts per billion, using no nitrate contamination as zero. Hydrologic units such as lakes, rivers, streams, and intermittent streams can be treated in a similar manner, given nominal measures as they exist, ordinated by ease of navigation, and ranked by interval measures by volume from attribute data.

Unwin (1981) pointed out an important limitation:

"... Although data may have been collected at one measurement level it is often possible and convenient to convert them into a lower level for mapping and analysis. Interval and ratio data can be converted into an ordinal or nominal scale... . What is generally not permitted is to collect data at one level and then attempt to map and analyze them as if they were at a higher level as, for example, by trying to add ordinal scales." To do so is a compelling desire given the flexibility of modern spatial analysis using GIS/LIS, but not to do so is an important principle."

Error from Rules of Combination

Use of GIS/LIS for determining land use and management suitabilities has become a very important use of information technology. The suitability analysis process consists of a series of analysis resulting in output that, according to Hopkins (1977), leads directly to two necessary components. The first is a procedure for identifying areas of land that are homogeneous in character and the second is a procedure for rating these areas with respect to suitability for a particular land use. This analytical process for identifying homogeneous areas and rating them also requires caution by the information technology user community, for certain rules of combination restrain the use of mathematical models.

Three major techniques by which to integrate and analyze land information to determine suitability for use have emerged over the past 30 years. They have evolved from "gestalt"-type methods in which homogeneity of resource or land-use patterns are determined by field observation, aerial photography, or topographic and thematic maps; gestalt implies that the whole cannot be derived from the parts. In the early 1970s the gestalt approach was replaced by the McHarg (1969) overlay method. This method of transparent overlays has been characterized by Hopkins (1977) as the "ordinal combination method." Nominal land resource measures are mapped as layers (e.g., soil, slope, vegetation) and overlaid using grey levels or numerical ranks (e.g., 1, 2, 3) to indicate importance or weight. The grey levels or numerical rank orders are meant to be ordinal in nature. In fact, they are often incorrectly assimilated or added and are treated as interval measures. These mistakes are fostered by the ease of data manipulation using modern information technology. Another method of analyzing information is called the "weightings and ratings game." This process consists of collecting layers of information such as soil type and assigning it a suitability weight for, say, sewerability on the basis of an agreed-upon scale of 1 to 100 and overlaying those layers with a land-use map and assigning a suitability weight for urbanization potential also based on a scale of 1 to 100. Those areas with the highest score (expressed in interval measures -- i.e., 1-100) would be the most suitable areas for new housing. Because of the measurement origins of the soil map, use of interval calculations might be responsible. However, since the land-use map was ordinal in origination, only ordinal results should be expected. The third and most acceptable type of suitability analysis consists of using explicit rules for combining layers, keeping in mind sources of data with respect to measurement levels, professional expertise, and application intent (Kiefer 1965).

Another rapidly emerging trend is to couple mathematical predictive models with the spatial analytical capability of GIS/LIS technology. These models can be of an empirical nature such as the Universal Soil Loss Equation (USLE). They can also be theoretical models based on established theory, such as viewshed and watershed representations using digital terrain algorithms. They can also be a mix of theoretical equations calibrated by field testing as in SLAMM (Wisconsin Source Loading and Management Model), which calculates potential urban pollutant loads to downstream water bodies. In the 1990s, we will see profound changes in the use of GIS/LIS technology, as these mathematical and statistical representations of spatial reality are incorporated into day-to-day land management, planning, and policy decisions. The problems of spatial error will be further exacerbated as these data-intensive models are implemented.

A Summary of Measures

What further confounds the issue of resultant error is that as part of the process of spatial analysis, we must often analyze attributes or address issues that are not readily measured outright or for which no exact measurement rules exist. Many land-use planning and management activities fall into this category: open space and residential planning, wetland protection management, and restoration and long-term ecological assessment, priority watershed management, etc. Depending upon the social and environmental values of those involved in developing and reviewing such plans, the time and money available for analysis and the societal importance of the issue, the data type collected will vary and its precision and accuracy will also vary. However, to wait until the data are perfect is not reflective of a society in need of decisions.

APPLICATIONS

Examples of the applications of land administration, planning, management, and policy analysis include town land-use administration and planning, soil erosion control planning, and water-quality policy evaluation in urbanizing regions. These applications were chosen to focus on various analytical capabilities found in GIS/LIS systems. Each application is compared with a master list of functions (Figure 11-8), and the functions used in the analysis are denoted for each application. However, a great deal of work is necessary to get the data bases into a useful form prior to analysis. Data collection, preparation, conversion, and automation are tedious, but essential.

TOWN LAND-USE ADMINISTRATION AND PLANNING

The first example, town planning, includes a brief discussion about the process of base map production and the development of other base data layers. A functionality matrix (Figure 11-8) for town planning illustrates the use of various functions associated with each of the four land-use plan components. This preparatory process eventually sets the stage for the more complex analytical phase.

Local units of government regularly develop and update land-use plans to provide a framework for future land-use policy decisions. This process often requires the assimilation of numerous local land records in both spatial and tabular format. This administration of land information is an essential first step in this type of local land-use planning effort. GIS/LIS layers automated to support this land-use plan formulation are noted in Table 11-10. MPLIS technology offers governments the opportunity to more effectively integrate, analyze, and incorporate these data into the land-use planning process. However, planners and policymakers must also understand how the technology best supports different phases of land-use plan development to realize its full potential.

Introducing GIS

LIS technology was recently put to use to support development of a land-use plan for the Township of Middleton, Dane County, Wisconsin. The Township Plan Commission (TPC) needed a plan that would help it address mounting development pressure from neighboring cities to convert rural lands to urban uses, to address potential changes in community character, and to address the impacts of development on natural resources. The TPC recognized the value of building a detailed digital data base of cultural and environmental resources to support their planning process. They felt that this information, when automated, could help facilitate plan development meetings and would allow them to communicate better with township citizens and city and county

Function:		Application	Town Land-Use Planning			
			Admin	Planning	Mgmt.	Policy
			Land Divisions	Land-Use Districts	Property Acquisitions	Agricultural Lands
Data Retrieval	Feature	by theme or layer	●	●	●	●
Data Retrieval	Feature	within window	●		●	
Data Retrieval	Feature	by feature name		●		●
Data Retrieval	Feature	location	●	●	●	●
Data Retrieval	Feature	distance				
Data Retrieval	Feature	direction				
Data Retrieval	Feature	shape				
Data Retrieval	Attribute	Boolean retrievals	●	●	●	●
Data Retrieval	Attribute	attribute items		●		●
Data Retrieval	Attribute	attribute values	●	●	●	●
Data Retrieval	Attribute	frequency dist.				
Data Retrieval	Attribute	count	●			●
Data Retrieval	Attribute	statistical summary	●	●		●
Data Restructuring		raster/vector conv.				
Data Restructuring		vector/ raster conv.				
Data Restructuring		map tile appending				
Data Restructuring		automatic edgematch				
Data Restructuring		interactive edgematch	●			
Data Restructuring		line thinning				
Data Restructuring		line smoothing				
Data Restructuring		feature generalization				
Data Transformation	planar	conformal and affine	●			
Data Transformation	planar	least squares affine				
Data Transformation	planar	projective				
Data Transformation	rubber	polynomial				
Data Transformation	rubber	inverse dist. weighted				
Data Transformation	rubber	tin-based				
Data Transformation		control-point look-up	●			
Data Transformation		projection conversion				
Data Transformation		datum conversion				
Overlay		graphic superimposition	●	●	●	●
Overlay		sliver removal				
Overlay		area weighted average			●	●
Overlay		cross-tabulation				
Overlay	overlay types	polygon on polygon		●	●	●
Overlay	overlay types	line in polygon				
Overlay	overlay types	point in polygon				
Overlay	overlay types	line on line				
Overlay	overlay types	point on line				
Overlay	Boolean	Union (OR)				
Overlay	Boolean	Intersection (AND)		●	●	●
Overlay	Boolean	Exclusive Union (XOR)				
Overlay	topol	intersect/attribute merger				
Overlay	topol	manual feature creation	●	●		
Networks		line and node attributes				
Networks		optimum path				
Networks		optimum distrib/collect				
Networks		optimum allocation zones				
Other		buffering			●	
Other		proximity search				
Other		aggregate/line dissolve		●	●	●
Other		address matching				
Other		nearest neighbor				
Other		adjacency			●	
Other		Theissen polygons				

Figure 11-8: Functionality matrix for town land-use planning.

Policy category	Existing land uses	Zoning	Soils	Sensitive sites	Environmental corridors
Residential	X			X	X
Business/commercial	X	X		X	
Agriculture	X		X		
Recreation	X	X		X	X
Environmental/open space	X			X	X

Table 11-10: LIS/GIS layers automated to support land-use plan formulation.

officials about the rationale for their decisions. They also believed that such a data base would assist with plan implementation and allow for flexible updates to reflect future changes in community values and land use priorities.

The Township of Middleton land-use planning process involved three major components: 1) the formulation of goals and policies, 2) description and delineation of Land Use Plan districts, and 3) identification of plan implementation strategies. Information collected to support the planning process included existing land use, land ownership, population and development trends, facilities and services, ecological resources, soil productivity, and hydrology. Each land record was maintained as a separate layer in the automated LIS. This resulted in the ability to produce maps that could depict any number of cultural and natural resource features relative to tax parcel ownership. In this application, most maps were reproduced by GIS software at the scale of 1:12,000 so individual landowners could clearly identify their own property. This scale was also compatible with orthophotos available for the Township. The orthophotos were used to support land-use delineations and natural resource delineations and provide a visual base for mapped LIS data.

The first step in development of the Township's land-use plan involved the formulation of goals and policies to provide future direction for local decision makers. The goals and policies were based on information generated by a citizen survey, public input from weekly plan commission meetings, responses to newsletters mailed to all landowners to keep them informed of progress on the plan, and the information collected and presented by the Land Information and Computer Graphics Facility at the University of Wisconsin-Madison (LICGF). Those LIS data layers automated and mapped to support goal and policy development are presented in Table 11-10.

The first step in the data automation and mapping process involved the production of a planning base map. This map provided a reference to which other layers in the LIS could be registered and viewed. Construction of the base map required automating a number of important and recognizable cultural features in the Township as separate layers in the LIS -- tax parcels, major sewer interceptors, electrical utility lines, perennial streams, the urban service area, and municipal and extra-territorial jurisdictional boundaries of the cities of Middleton and Madison. PLSS corner control, derived from USGS 1:24,000 digital line graphs, was used as the spatial reference framework to register individual layers in the LIS. Given the rural character of the Township, this control scale was deemed sufficient to support the project's mapping and spatial analysis needs (Figure 11-9).

Tax parcels, needed for the base map, were automated using 1:4,800 section-based linen maps maintained by the Dane County Land Regulation and Records Department (LRRD). Automated tax parcel boundaries were converted one PLSS section at a time, and later edgematched and joined into a single seamless layer in the LIS. A unique county tax parcel identifier was then assigned to each tax parcel in the layer, using a coding scheme established by LRRD. This identifier provides for the linking of data maintained on the County tax assessment rolls, such as assessed value and ownership, to the tax parcel layer. Farm tenure information was also coded to individual tax parcels by asking TPC members to identify agricultural landowners and their current farming status and long term land use intentions. When eventually remapped in relation to environmental resource layers, tenure information was useful to Township officials in identifying potential conflicts between TPC resource protection priorities and future landowner land-use intent.

Incorporated boundaries and extra-territorial jurisdictions of the cities of Middleton and Madison were also included in the base map to provide TPC members with a visual understanding of municipal influence on town land-use authority. As the map in

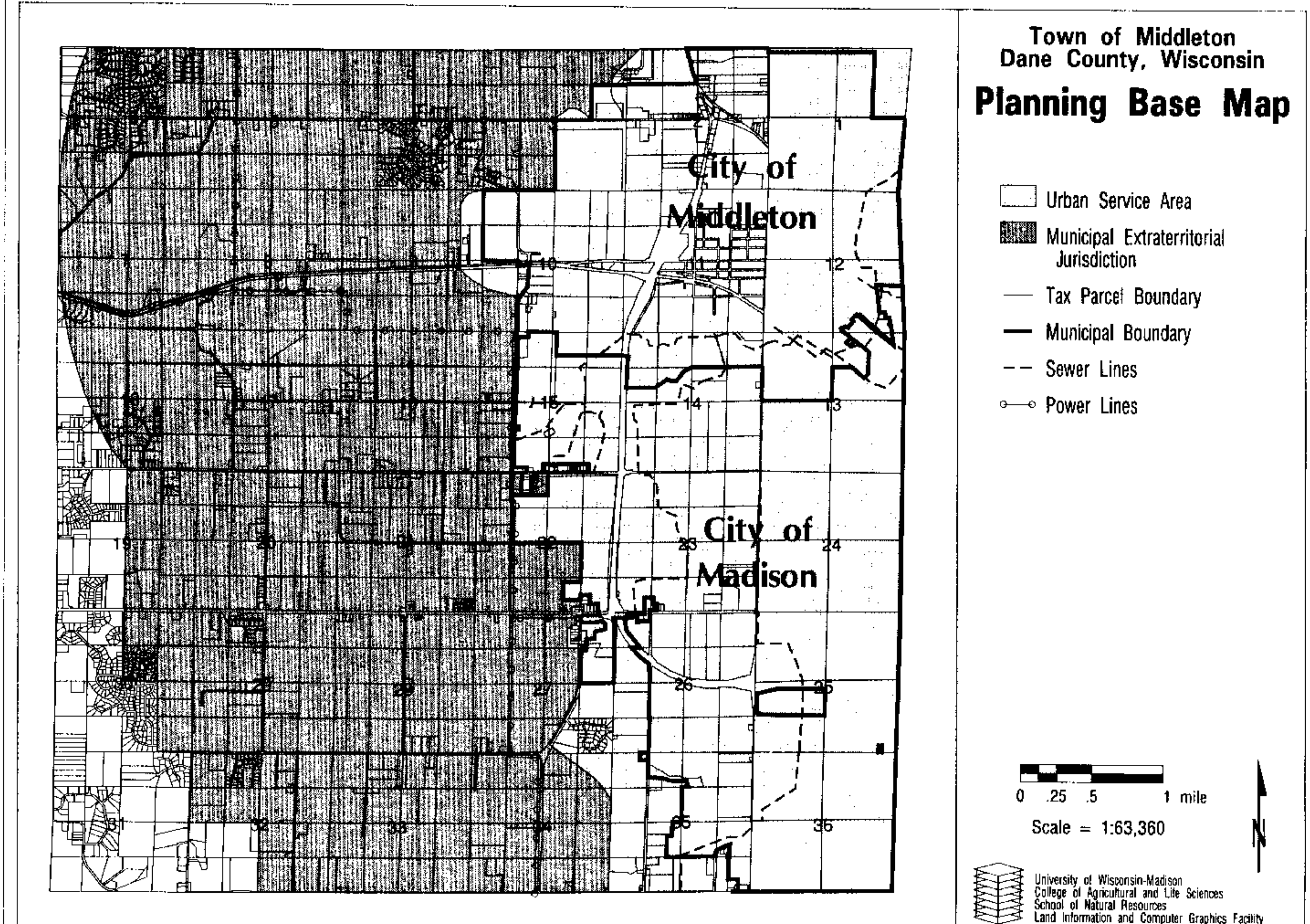


Figure 11-9: Middleton planning base map.

Figure 11-9 portrays, the two cities have collectively annexed the eastern one-third of the Township and they exert significant control over land divisions within their three-mile extra-territorial jurisdiction. The inclusion of the urban service area and major sewer and utility features in the base map enabled the TPC to identify those areas where urban development was planned and where urban services could be provided.

The second step in the plan preparation process was the creation of various layers of land information. Existing land use was the first layer constructed (Figure 11-10). To begin the process, a transparent base map was created and overlaid onto orthophotos so TPC members could identify 24 existing land uses in the town. Residential land uses were further divided into a number of separate categories on the basis of property size and type of land cover. Vacant, undeveloped residential lots were also flagged in the LIS and later remapped for guiding policies on "infill" and the creation of new property divisions in the Township. When land uses had been entered into the LIS, acreage for each land-use class were quickly available; they supplemented computer-generated maps displaying the spatial distribution of the land uses. In general, land-use information was used extensively in developing all five goal and policy categories.

The next layer that was automated was the land use zoning information (Figure 11-11). Zoning data for the two cities and for the Township were also automated and referenced to the digital base map. Because zoning information came from three different sources, it did not match along municipal boundaries and thereby required much editing. Since each unit of government maintained a unique zoning classification scheme, a standardized categorization was developed for mapping purposes. Eventually, when environmental resources and higher intensity zoning were automated and mapped, TPC members could more easily identify potential conflicts between them.

The first of two natural resource layers (Figure 11-12) identified productive farming soils in the Township. Soil mapping units for the Township of Middleton were extracted from an existing county-wide digital layer and assigned a crop productivity rating based upon the Wisconsin Department of Revenue's (DOR) three-tier soil grade classification scheme. Agricultural tax parcels were extracted from the tax parcel layer using the land-use code and overlaid with the soils layer to separate farmed from non-farmed soils.

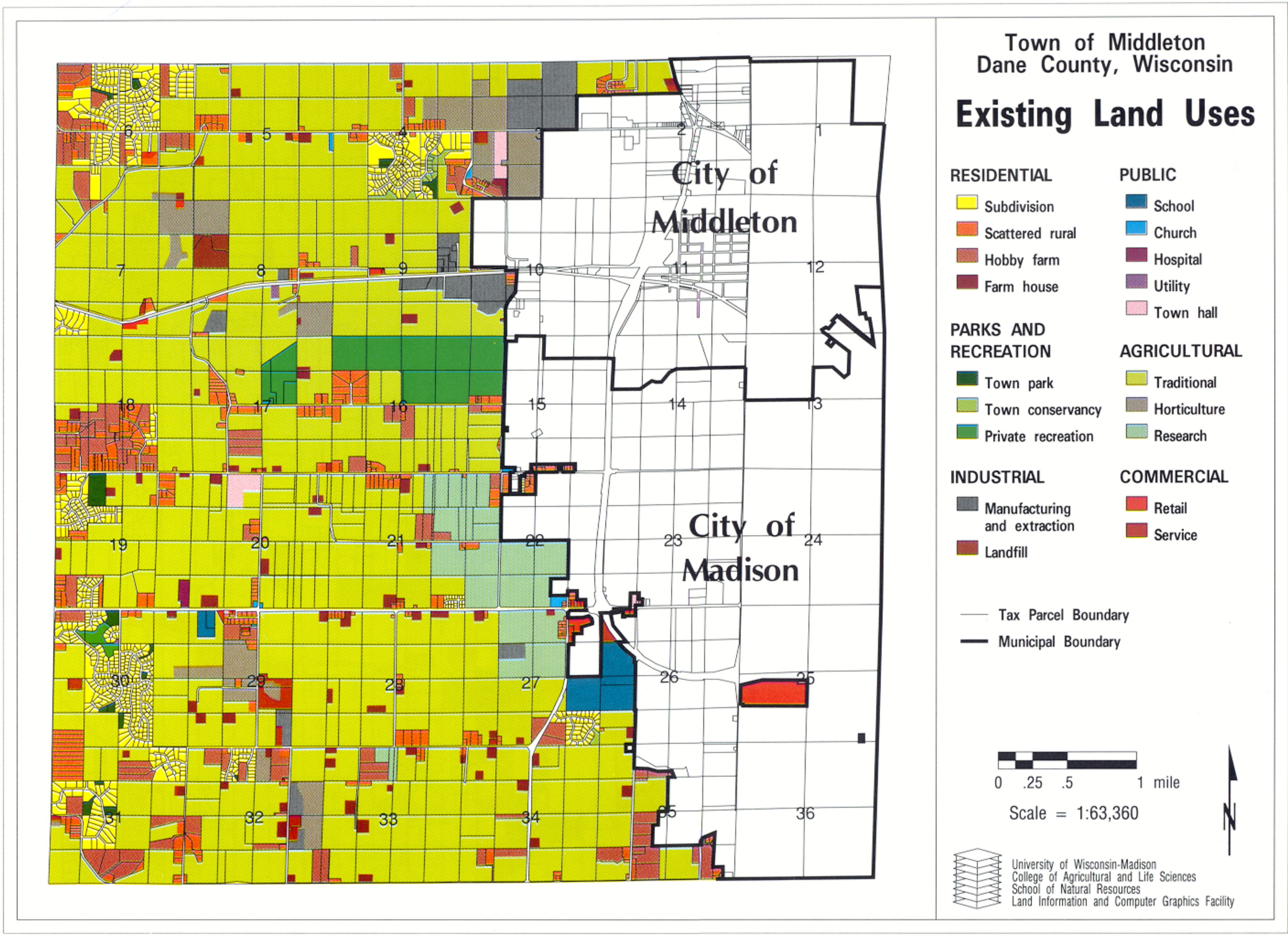


Figure 11-10: Existing land uses in Middleton.

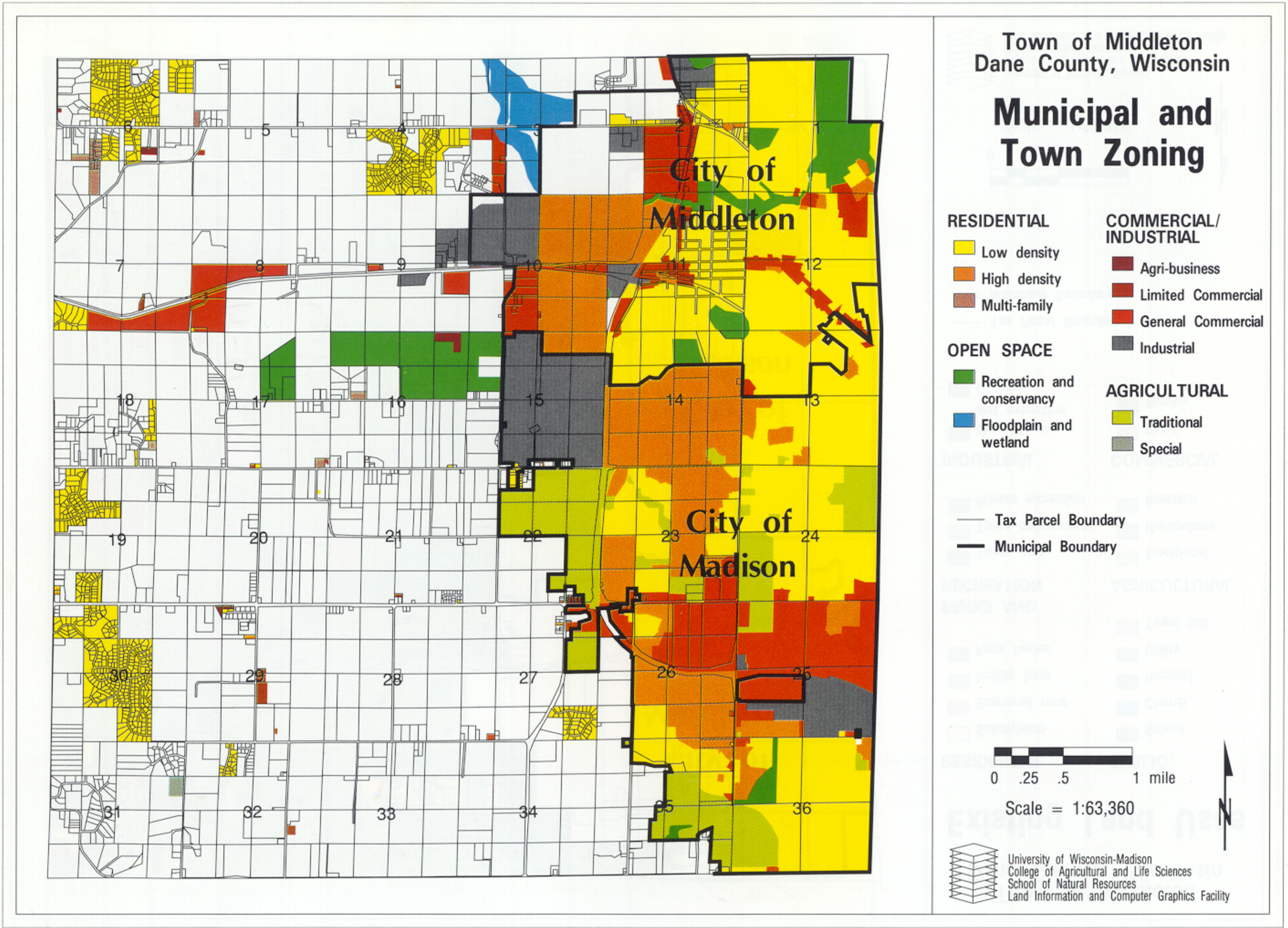


Figure 11-11: Town and municipal zoning in Middleton.

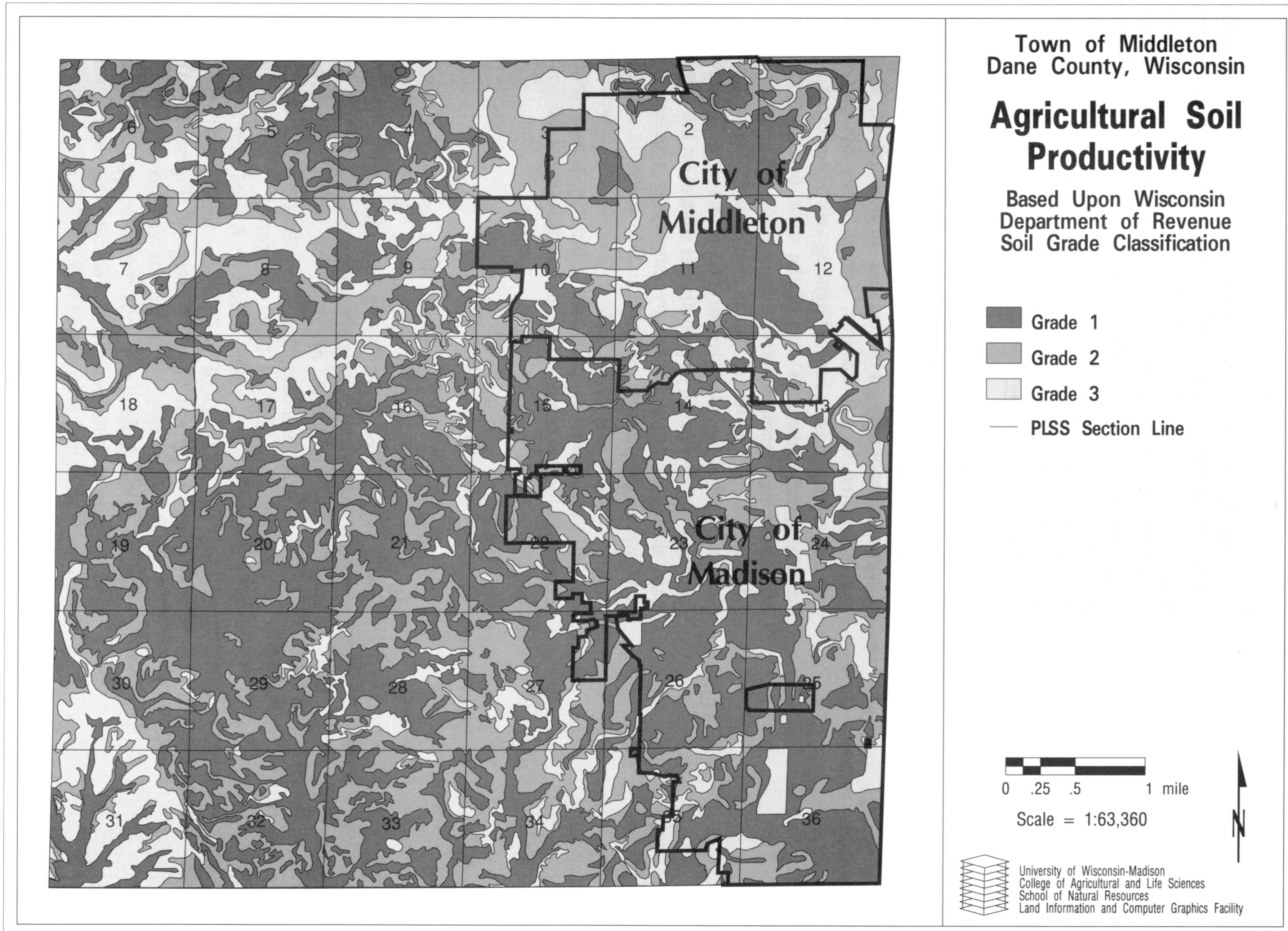


Figure 11-12: Agricultural soil productivity by DOR three-tier soil classification scheme.

The second layer of natural resources was automated from a number of sources. The TPC requested that detailed natural resource information provided by the Township's ecological consultants be incorporated into the LIS (Figure 11-13). They recognized that having this information in digital form would allow sensitive natural sites to be viewed in relationship to tax parcel, land use, zoning, and soils information already automated. This information was used to identify goals and policies specific to nine natural resource districts.

Several difficulties were encountered during the automation process. Many natural resource delineations do not have explicit boundaries because of the continuous gradient or natural variation of natural phenomena. For the sake of automation, boundaries were identified for all features, though many boundaries were coded as transition lines for highlighting and/or buffering. Despite the ecological consultants' use of the same orthophoto base for delineating their features, inexact registration of mylar overlays on the orthophotos introduced some spatial errors into the digital product. Spatial boundary registration errors were improved to a limited degree by identifying additional control on the consultants' maps during automation, and by employing special coordinate transformation functions available in GIS software. These types of problems and errors are often associated with maps prepared without automation in mind or without previous automation experience, or prepared before the establishment of conversion rules.

Agricultural Resource Goals (Policy)

Establishment of agricultural land use policy required the identification of currently productive farming soils in the Township. The coverage layers constituted by agricultural tax parcels + soil productivity were further divided by individual tax parcel. The total area of each soil grade for each highly productive parcel was computed. Parcels containing Grade 1 soils were assigned to one of three categories: >75% Grade 1; 50-75% Grade 1; and <50% Grade 1. A final map was produced showing the three DOR soil grade classes and tax parcels highlighted by percent Grade 1 category (Figure 11-14). This analysis and mapping effort would not have been possible without access to an available digital soils data base, again demonstrating the long-term multiple benefits that accrue when investments have been made in digital information in a MPLIS environment.

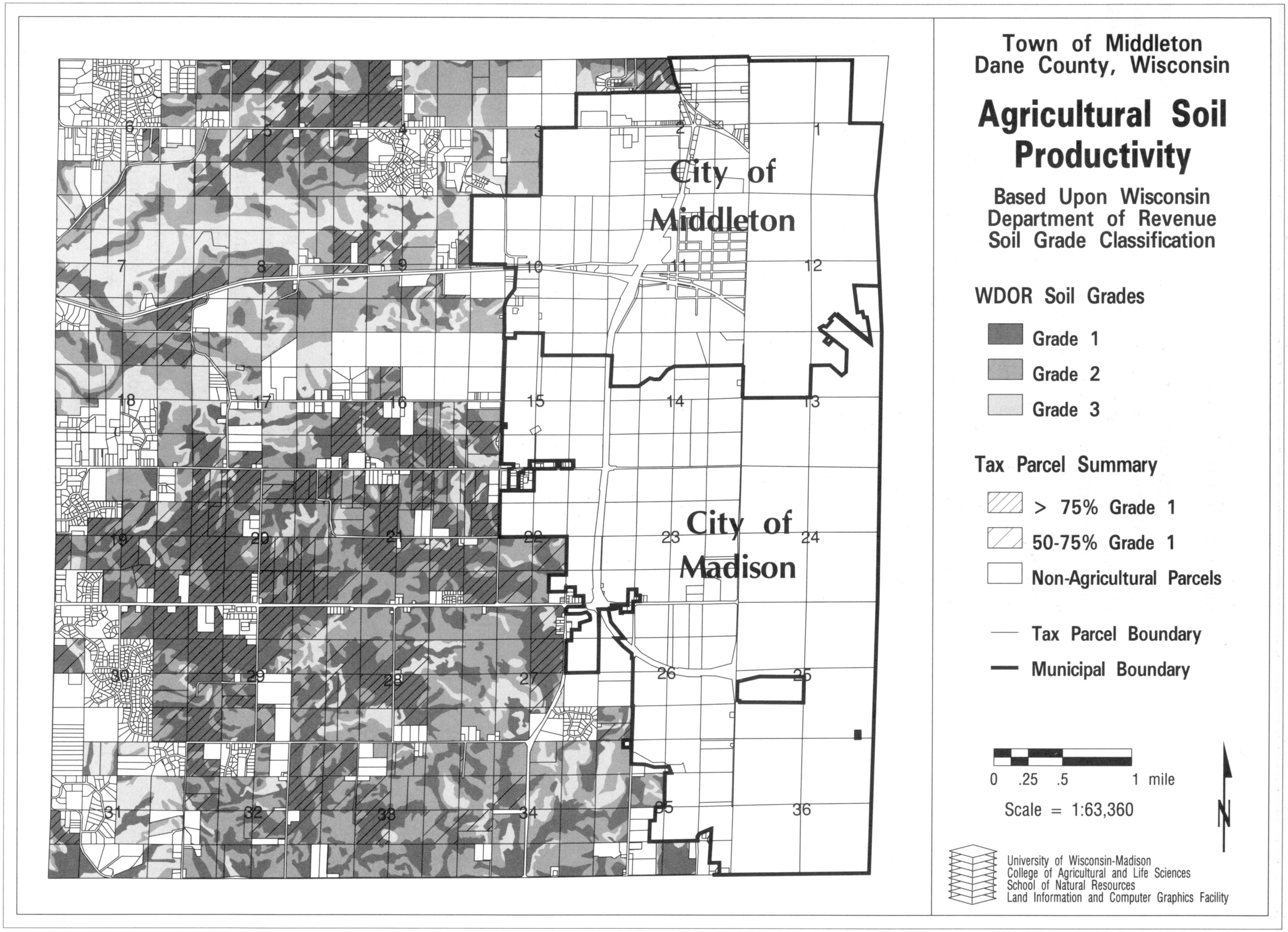


Figure 11-14: Soil productivity on agricultural lands in Middleton.

Land Use Districts (Planning)

The next step was the identification and delineation of land-use districts. The type and density of development permitted in each of the five districts was to reflect the Township's cultural and environmental patterns. Each commission member was given a set of five computer-generated maps -- a tax parcel base, existing land uses, zoning, soils, and sensitive natural sites -- along with plan goals and policies, and a personal vision of the Township, to delineate individual land-use district maps on a single overlay. These individual maps were then combined using the various overlay functions into a final, composite map of land use districts for the Township (Figure 11-15). The ability to provide scale match plots and to integrate information from various layers helped facilitate what initially appeared to be a bottleneck in the process.

The type and density of development allowed in each land-use district was a reflection, in part, of the information provided by the LIS. TPC members delineated districts, recognizing in advance that enforcement of district densities and protection of sensitive natural resources would be possible given the data layers, mapping, and overlay capabilities of their LIS. For example, the soils and agricultural land-use overlay that identifies Grade 1 soils by tax parcel could be used in reviewing development proposals that fall within the Agricultural Residential District. The conservancy land-use district was constructed by extracting selected sensitive sites from the natural resource layer and overlaying it on the other land use districts. The Conservancy/Open Space district would require 100% protection of select sensitive natural sites and institutional and recreational use parcels identified from the existing land-use layer.

Property Acquisition Program (Management)

The final step in the land use planning process was the development of a program for implementation of Township goals and policies and land use management techniques. The TPC considered many strategies to implement the Plan and discussed possible LIS products to support these strategies. Some of these strategies demonstrate the potential flexibility of a MPLIS. A property rights acquisition program was recommended to help the Township permanently protect its most valuable natural resource lands from development. Valuable lands could be ranked by integrating productive soils and sensitive natural sites and

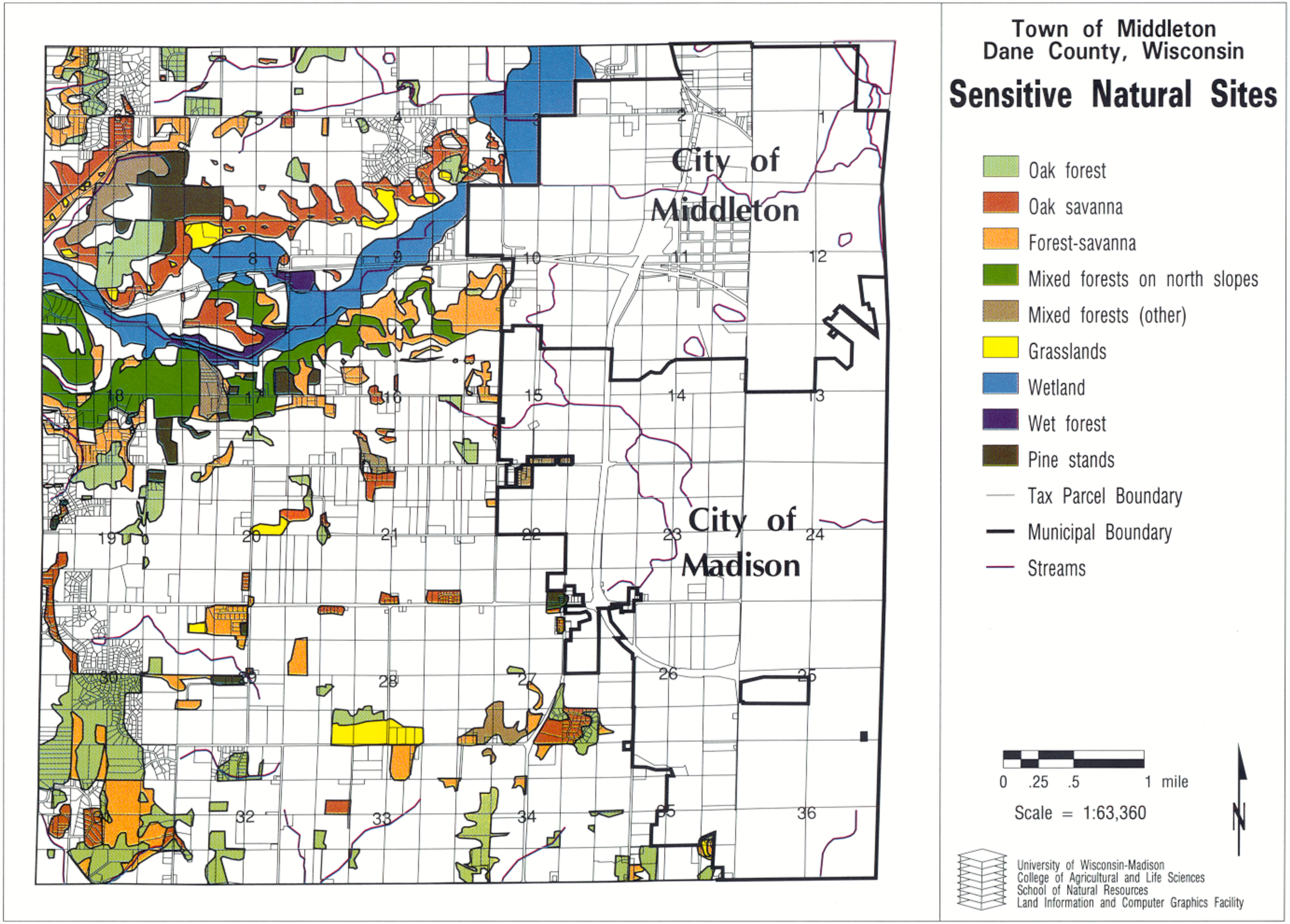


Figure 11-13: Sensitive natural areas in Middleton.

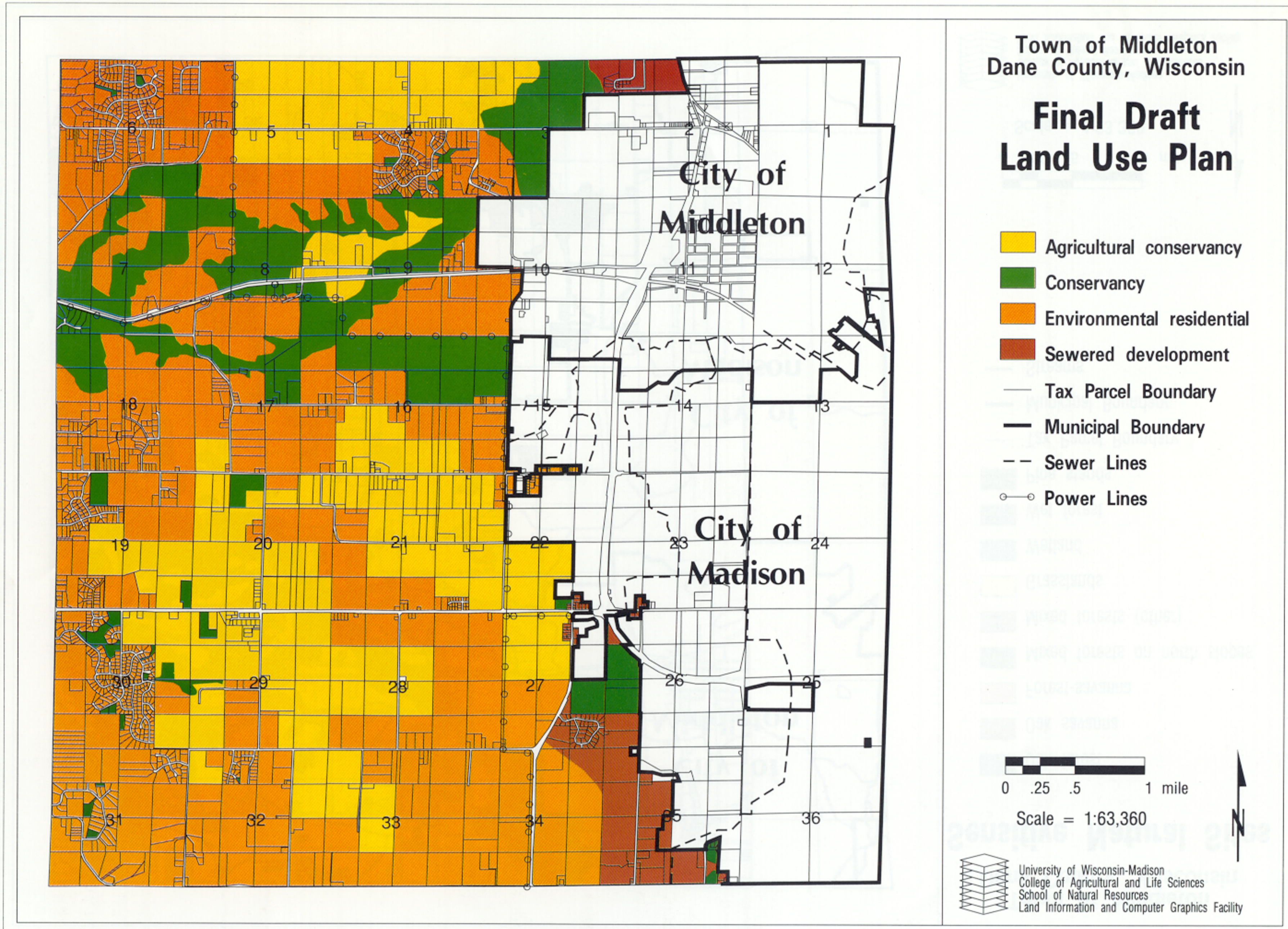


Figure 11-15: Final map for the land-use plan, created from the overlaying of five maps.

overlaying this information with the tax parcel layer. Farm tenure information, coded to individual tax parcels, could be useful in identifying potential conflicts between TPC resource protection priorities and future landowner land use intent.

Property acquisition program costs could be estimated using property tax and assessed value information derived from the County tax rolls. This information can be linked to individual tax parcels in the LIS through a unique tax parcel identifier. The purchase of land rights (i.e., development rights) or placement of conservation easements on properties in the Township could be monitored in the LIS including specific details of landowner contracts.

The technology could facilitate an educational program to promote stewardship of natural resources on sensitive lands. Site maps could be produced identifying natural resources to promote awareness of important natural resources on individual properties. Included with the maps would be recommendations for the preservation and/or management of the resources. The TPC could also use the landowner notification process as a mechanism for receiving feedback on the accuracy of natural resource delineations in the LIS.

Land Divisions (Administration)

Enforcement of land-use controls (i.e., zoning) could be aided by existence of various layers in the LIS. Spatial overlay and computer maps would help Township officials respond to development proposals or property subdivisions by quickly determining the presence of any restrictions to development as established by the land use district definitions. To promote infilling of developable land, the Plan proposed a cap on the number of vacant lots that can exist before restrictions are placed on the creation of new residential parcels. The LIS could be used to monitor the availability of vacant lots as they influence the number of new property divisions permitted.

Perceptions

Interviews with TPC members indicated that the most important perceived benefit of the technology was the ability to create and use a local data base rather than rely on more generalized information collected by state and county agencies and available at incompatible scales and resolutions. They found the software's capability to link tabular data to graphic output highly useful. The ability to map different combinations of LIS layers enhanced identification of resource patterns used as a basis for land use policy decisions. Integration of the tax parcel layer with other natural and cultural resource layers was especially important in helping the TPC treat landowners equitably when discussing land-use controls. Without the incorporation of modern GIS functionality, much of the analyses would have been too burdensome or too complex to conduct.

Soil Erosion Control Planning

Soil erosion control planning comprises both individual and composite responsibilities and so provides a focus for other analytical functionalities of the MPLIS (Figure 11-16). In soil erosion control, planning, management, and policy analyses have to respond to an existing set of mandates. The specific use and explanation of these tools to meet the requirements of Wisconsin laws and the 1985 Federal Farm Bill have been detailed for soil erosion control planning (Ventura 1988; Ventura et al. 1988a, 1988b). Congress has sustained this interest in rural land planning, management, and policy analysis by enacting the Food Security Act of 1985 and the Conservation Program Improvement Act (Title XIV) as part of the Food, Agricultural, Conservation, and Trade Act (FACTA) of 1990. More specifically, in 1990 Congress continued its interest in mitigating soil erosion by instituting cross-compliance mandates to farm managers to more effectively manage highly erodible soils.

Congress has also expanded its interest in land conservation, stewardship, and tenure by expanding the eligibility of existing and restored wetlands for inclusion in the Wetlands Reserve Program (Sec. 1237) and expanded its interest in more effective management of on-site farm chemicals in respect to surface and ground water resources.

In Dane County, Wisconsin, soil erosion control was monitored by MPLIS technology through a cooperative research project between the University of Wisconsin-Madison and the Dane County Land Conservation Department (LCD). Soil loss on agricultural parcels in the Township of Oregon was predicted by the USLE (Wischmeier and Smith 1978):

			Soil Conservation			
			Admin	Planning	Mgmt.	Policy
Function:		Application	Lands Exceeding Standards (HEL)	CRP Eligibility	Farm Conservation Plans	County-wide Erosion Plan
Data Retrieval	Feature	by theme or layer	●	●	●	●
Data Retrieval	Feature	within window	●	●	●	●
Data Retrieval	Feature	by feature name	●	●	●	●
Data Retrieval	Feature	location	●	●	●	
Data Retrieval	Feature	distance			●	
Data Retrieval		direction			●	
Data Retrieval		shape		●	●	
Data Retrieval	Attribute	Boolean retrievals	●	●	●	●
Data Retrieval	Attribute	attribute items	●	●	●	●
Data Retrieval	Attribute	attribute values	●	●	●	●
Data Retrieval	Attribute	frequency dist.				●
Data Retrieval	Attribute	count	●		●	●
Data Retrieval	Attribute	statistical summary		●		●
Data Restructuring		raster/vector conv.			●	●
Data Restructuring		vector/ raster conv.				
Data Restructuring		map tile appending	●	●	●	●
Data Restructuring		automatic edgematch			●	●
Data Restructuring		interactive edgematch	●	●		●
Data Restructuring		line thinning				●
Data Restructuring		line smoothing				●
Data Restructuring		feature generalization				●
Data Transformation	planar	conformal and affine			●	
Data Transformation	planar	least squares affine	●	●		●
Data Transformation	planar	projective				
Data Transformation	rubber	polynomial				
Data Transformation	rubber	inverse dist. weighted	●	●		●
Data Transformation	rubber	tin-based				
Data Transformation		control-point look-up	●	●	●	●
Data Transformation		projection conversion				●
Data Transformation		datum conversion				
Overlay		graphic superimposition			●	
Overlay		sliver removal	●	●	●	●
Overlay		area weighted average	●	●	●	●
Overlay		cross-tabulation		●	●	●
Overlay	overlay types	polygon on polygon	●	●	●	●
Overlay	overlay types	line in polygon				
Overlay	overlay types	point in polygon			●	
Overlay	overlay types	line on line				
Overlay	overlay types	point on line				
Overlay	Boolean	Union (OR)	●	●	●	●
Overlay	Boolean	Intersection (AND)				
Overlay	Boolean	Exclusive Union (XOR)				
Overlay	topol	intersect/attribute merger	●	●		●
Overlay	topol	manual feature creation				
Networks		line and node attributes			●	
Networks		optimum path				
Networks		optimum distrib/collect				
Networks		optimum allocation zones				
Other		buffering				
Other		proximity search				
Other		aggregate/line dissolve		●	●	●
Other		address matching				
Other		nearest neighbor				
Other		adjacency				
Other		Theissen polygons				

Figure 11-16: Functionality matrix for soil erosion control planning.

$A = R \cdot K \cdot LS \cdot C \cdot P$ where

A: Potential Soil Erosion (tons/acre/year)

R: Precipitation Factor

K: Soil Erodibility Factor

LS: Length and Steepness of Slope

C: Cropping Practices Factor

P: Management Practices Factor

The soil erosion potential on the property of each landowner in the Township (Chrisman et al. 1986) (Figure 11-17) was produced by a sequence of steps. The 36 tax parcel section maps maintained by the County Surveyor (1:4,800) scale, were manually digitized using a spaghetti method (Chrisman 1986a). Topological structuring was performed automatically using GIS functions. After editing and automated edgematching, each tax parcel polygon was assigned its unique identifier, as recorded on maps maintained by the LRRD. The identifier permitted access to the tax parcel assessment classification recorded in the automated tax rolls of the County Tax Lister.

As an example, the soils map (Figure 11-18) for Oregon Township was also produced using the same technology as Westport Township, by digitizing, editing, and edgematching six (1:15,840) sheets from the Dane County Soil Survey. Particular advantages were gained from using automated checks for topological consistency, which detected unlabeled polygons, missing linework, and edge misclassifications. After "zipping" together contiguous sheets, a topologically clean coverage was available for the entire township.

Several soil mapping unit attributes were essential to the soil erosion estimation process. The K factor (soil erodibility) is shown in Figure 11-19. The LS factor (combined slope length and steepness factor) is not shown. Tolerable soil loss, T, in tons/acre/year is compared to estimated annual soil erosion, A.

A land-cover map (Figure 11-20) was produced by digitizing, editing, and edgematching six sheets of land-cover maps prepared by the LCD. These sheets were prepared by photointerpretation of 35-mm color slides from the Agricultural Stabilization and Conservation Service (ASCS), and compiling the data on the same

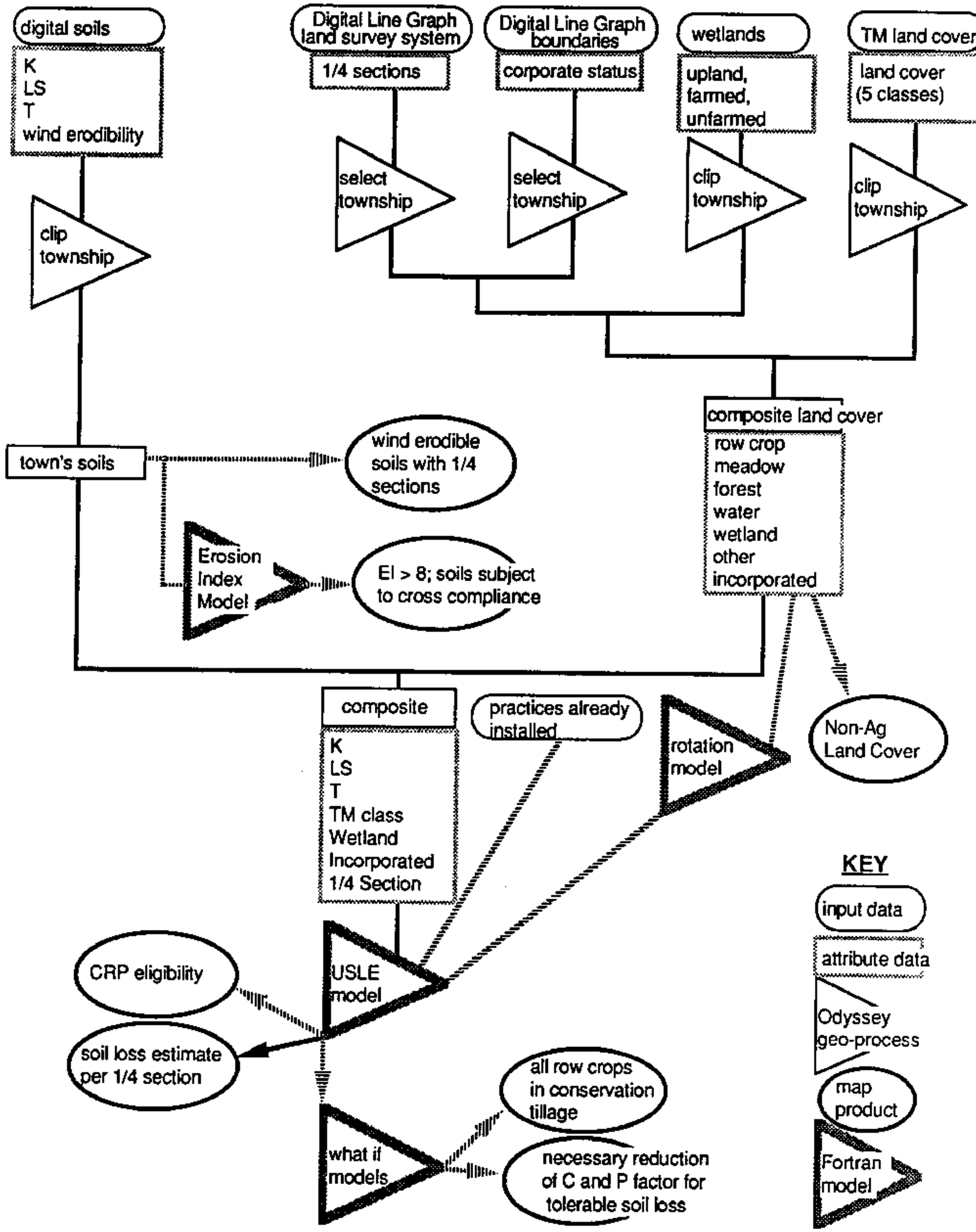
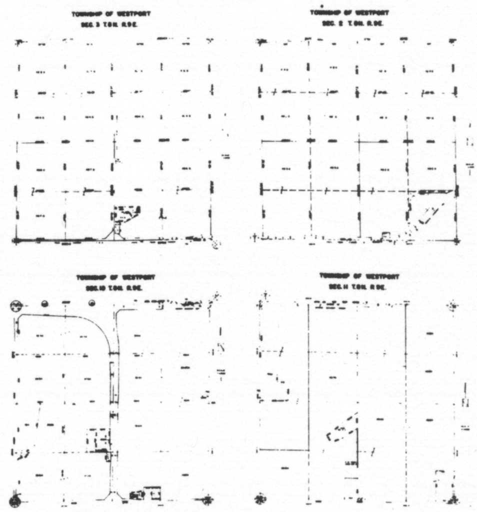


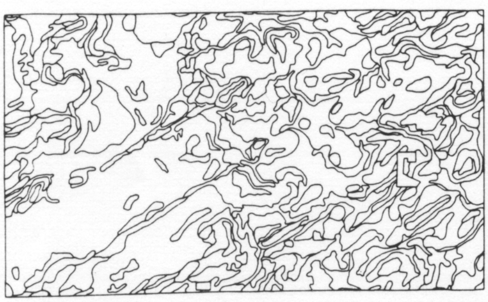
Figure 11-17: Soil erosion loss model and related processes.

Soils Record

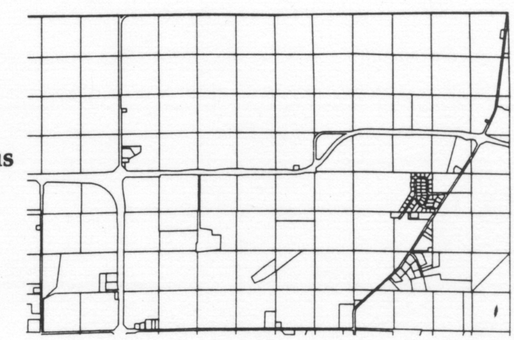
Parcel Record



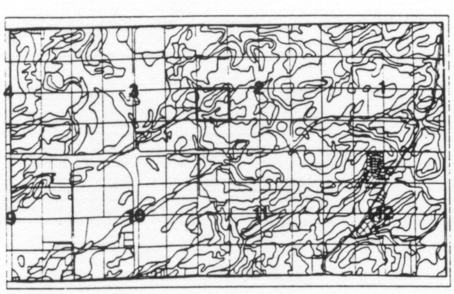
Conversion to Digital Format



Plus



Equals



Soils and Tax Parcels

SCS Soil Survey Sheet 42
Area: 3.5 x 2 miles, northeast corner of Westport Township
Dane County Land Records Project

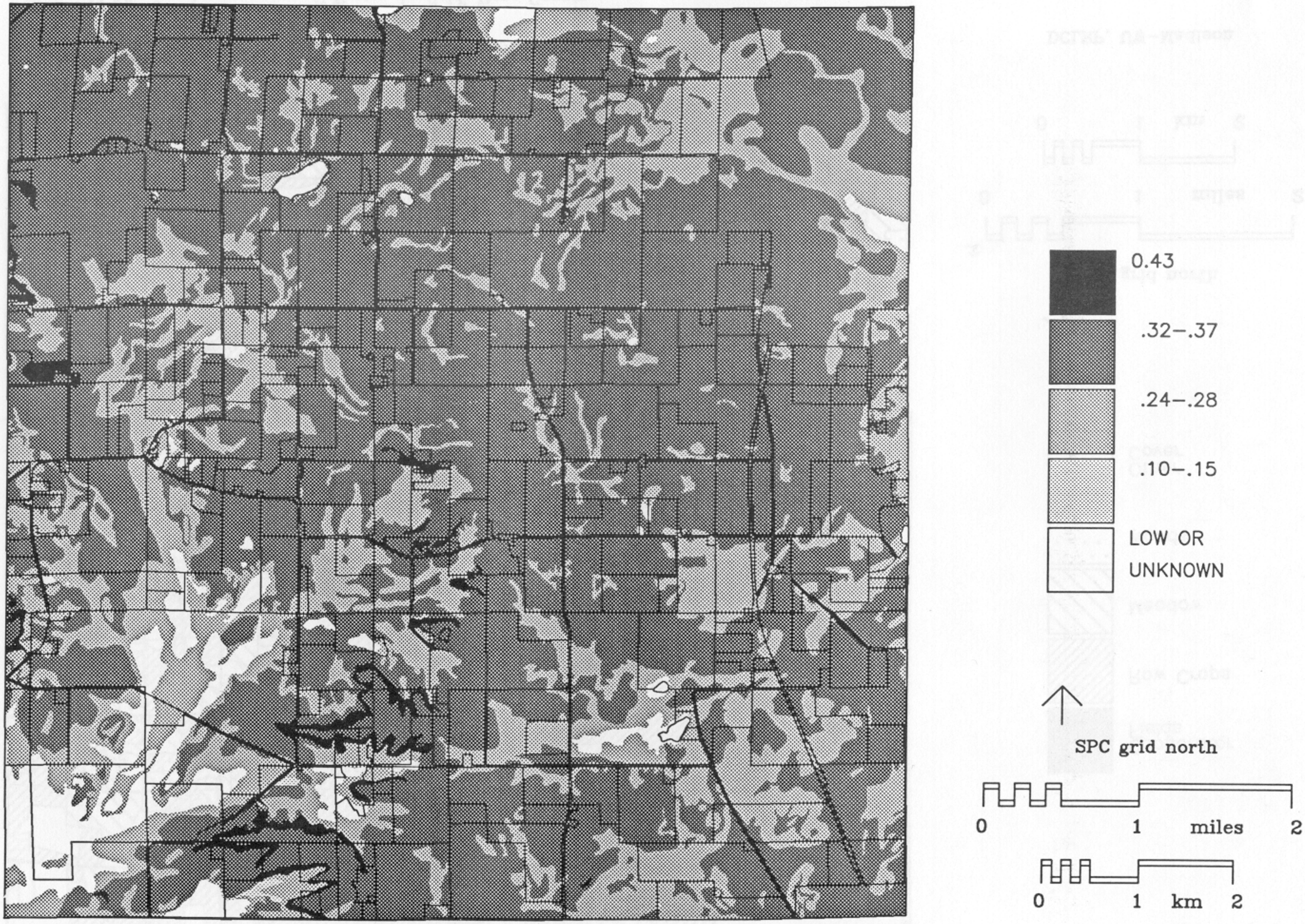
Breakdown of soil units in a specific parcel NW ¼ of SW ¼ of Section 2, T8N R9E

State Plane Coordinates of Parcel Boundary

60894.	36375.
59567.	36381.
59567.	36389.
59555.	37713.
60887.	37694.

			Soil Erodibility	Expected Crop Yields		
Soil Unit	**Acres**	**Polygons**	K-factor	Corn bu/ac	Silage tons/ac	Hay tons/ac
RnC2	22.0	4	0.28	105.0	14.0	5.0
PnB	6.1	2	0.32	130.0	18.0	5.5
SoE	0.5	1	0.32	0.0	0.0	0.0
ScB	0.7	1	0.37	125.0	19.0	5.0
GwD2	10.1	1	0.32	80.0	9.0	3.0
RnB	1.1	1	0.28	120.0	16.0	5.5
Totals	40.5	10				
Weighted Average Yields				102.0	13.3	4.5
Total Yield for Parcel				4133.0	540.0	183.0

Figure 11-18: Use of soils and parcel layers to create digital soil erodibility data.



Town of Oregon, Dane County, Wisconsin, T5N, R9E

Figure 11-19: Soil erodibility factor (K) in the Universal Soil Loss Equation

53

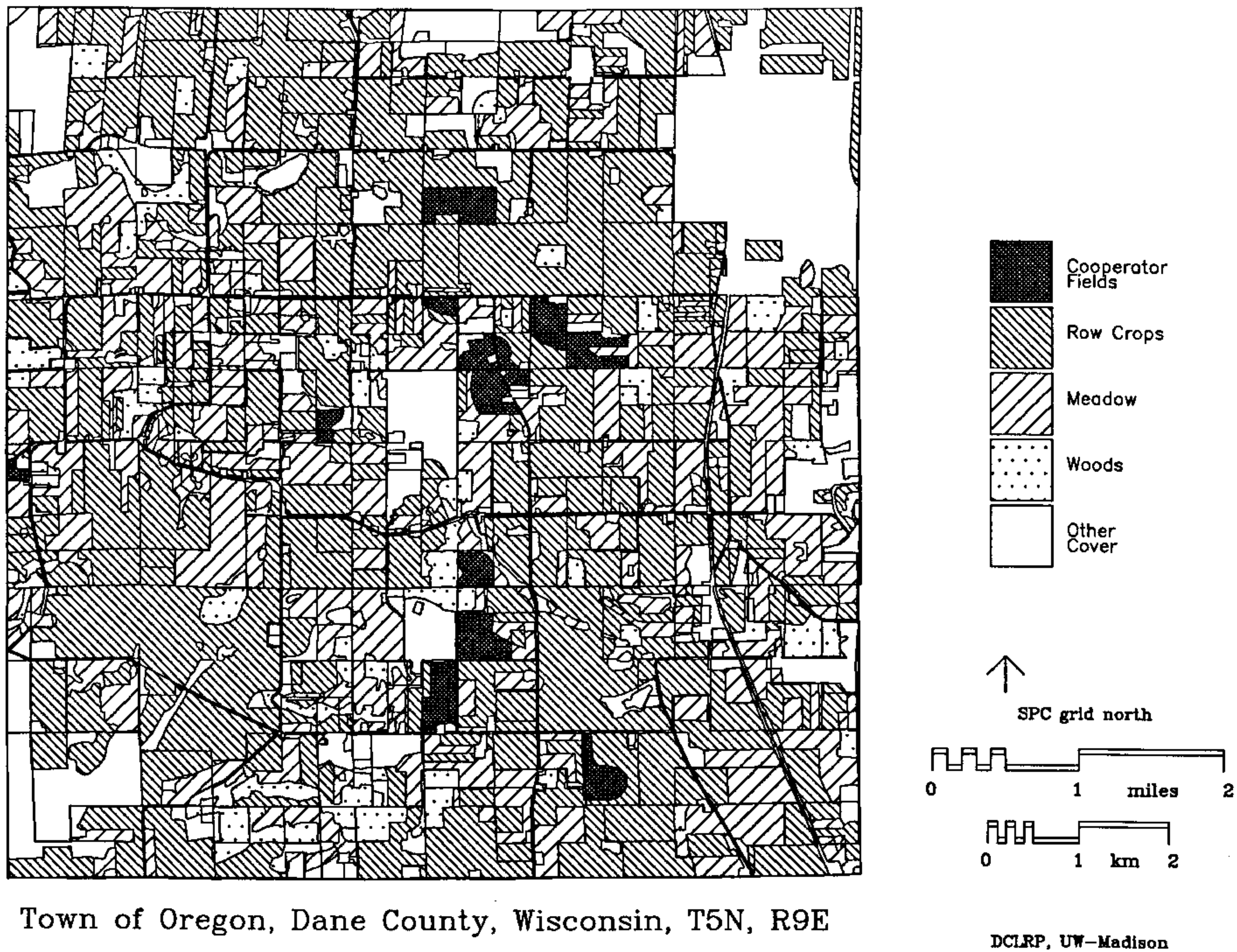


Figure 11-20: Land cover maps, C Factor, by field, Dane County.

photobase as the Soil Conservation Service (SCS) soil sheets. The cooperator fields are areas covered by agreements between the LCD and landowners. For each field, detailed USLE-related data were determined and used in the calculations. Row crops and meadows were assigned approximate C and P factors, because crop histories were not available. Areas of woods and other non-agricultural cover types were excluded from the analysis.

The rainfall factor, R, is a constant for this study area. The management practices factor, P, is known only in the few cooperator fields shown on the land-cover map. On a county-wide basis, the management practices factors were derived from remotely sensed imagery (C) and aerialphoto interpretation (P).

Figure 11-21 illustrates the result of overlaying erodibility (Figure 11-19), slope (not shown), and land-cover maps (Figure 11-20), excluding non-agricultural areas (Figure 11-17), and calculating A from the USLE. The A:T ratio is shown because legislation has specified thresholds for targeting specific areas of potential erosion on the basis of this ratio.

The uses of such analytical capabilities apply to all arenas of land administration. The planner will want to know which lands in Dane County require soil erosion control (Figure 11-22). An analysis shows that, of Dane County's 480,000 acres of farmland, about 236,000 acres will not meet tolerable soil loss standards ("T by 2000") as mandated by Ag 160 (Ventura 1988). The first column of Figure 11-16 shows the functions or operations employed. With the use of information technology, statistics are also easy to compute and aggregate (Table 11-11). The answer to the planner's question is that most of the steep and unglaciated western portions of Dane County's landscape (i.e., the Driftless Area) are susceptible to soil erosion. The drumlin fields to the east are also susceptible to erosion. It is not surprising to knowledgeable land planners that these two resource conditions are the most vulnerable to poor farm management activities.

To mitigate the impact of erosion on such sensitive land, Congress in 1985 instituted the concept of the Conservation Reserve Program (CRP). The program was set up to pay farmers over a 10-year period to keep such land fallowed in return for cash payments of about $60 to $80 per acre per year. MPLIS analysis determined which areas in the county were eligible for CRP payments (Figure 11-23). Because the Federal eligibility criteria changed after an initial assessment, another analysis was required.

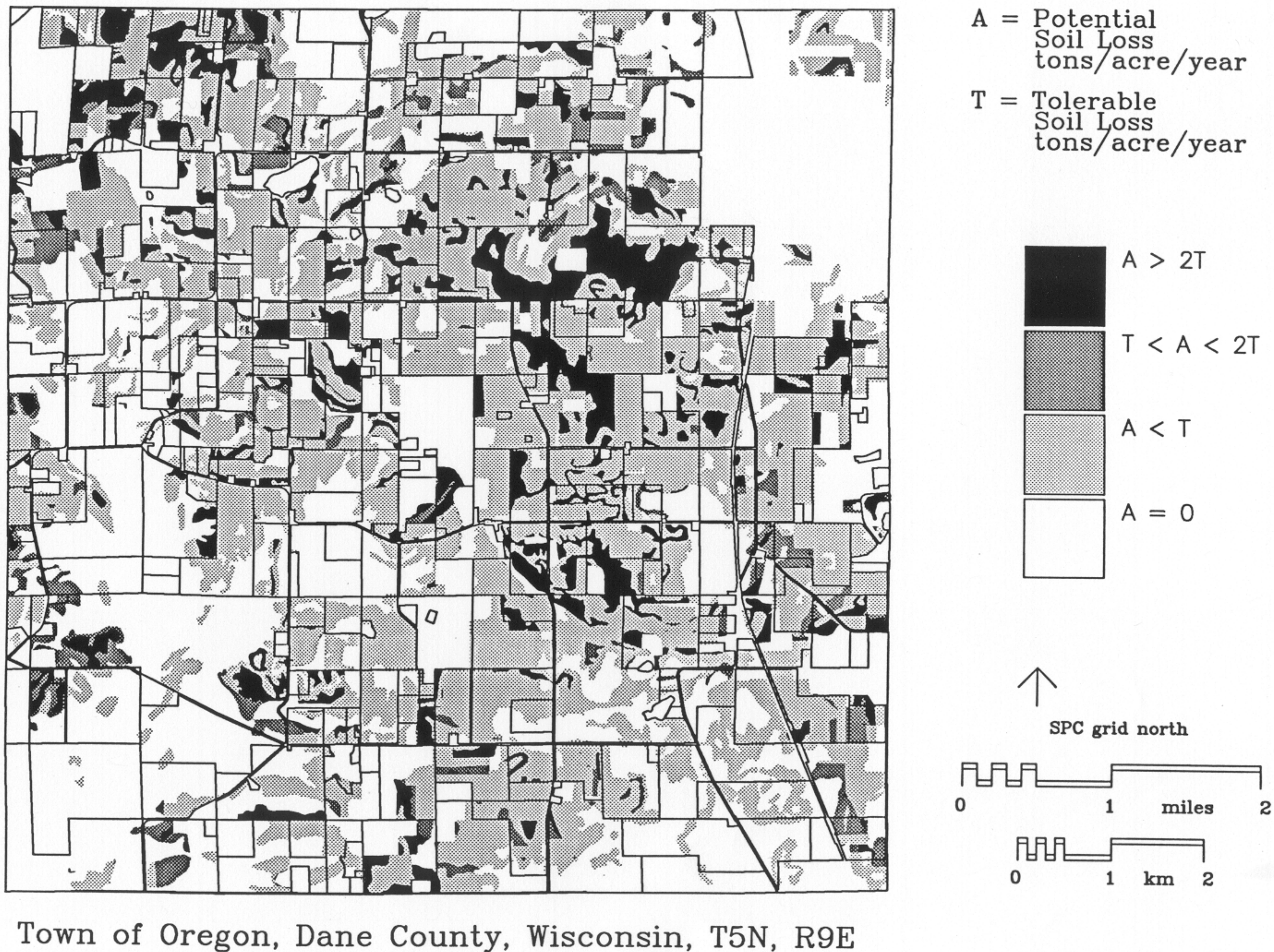


Figure 11-21: Ratio of potential soil erosion (A) to tolerable soil erosion (T)(A:T).

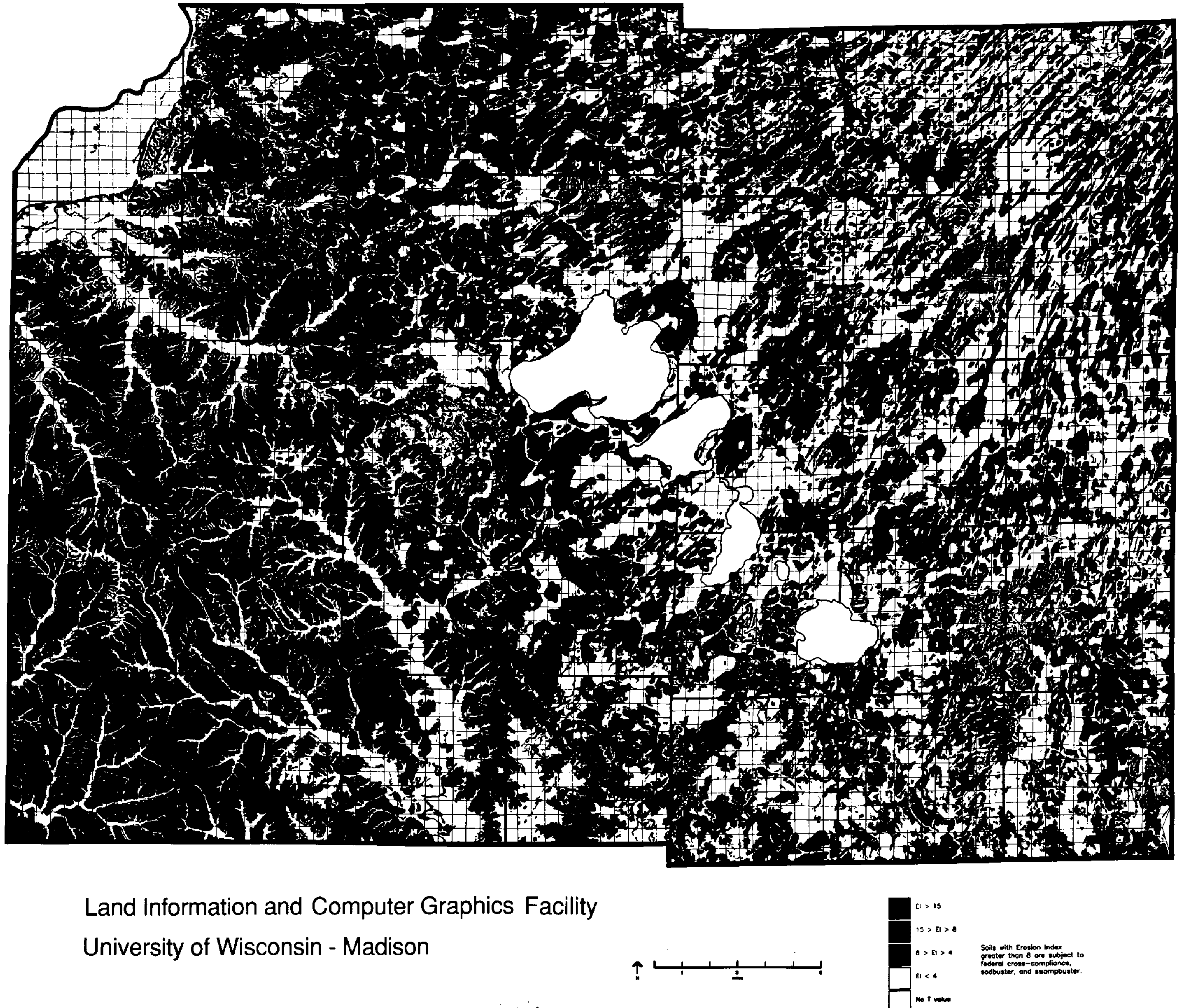
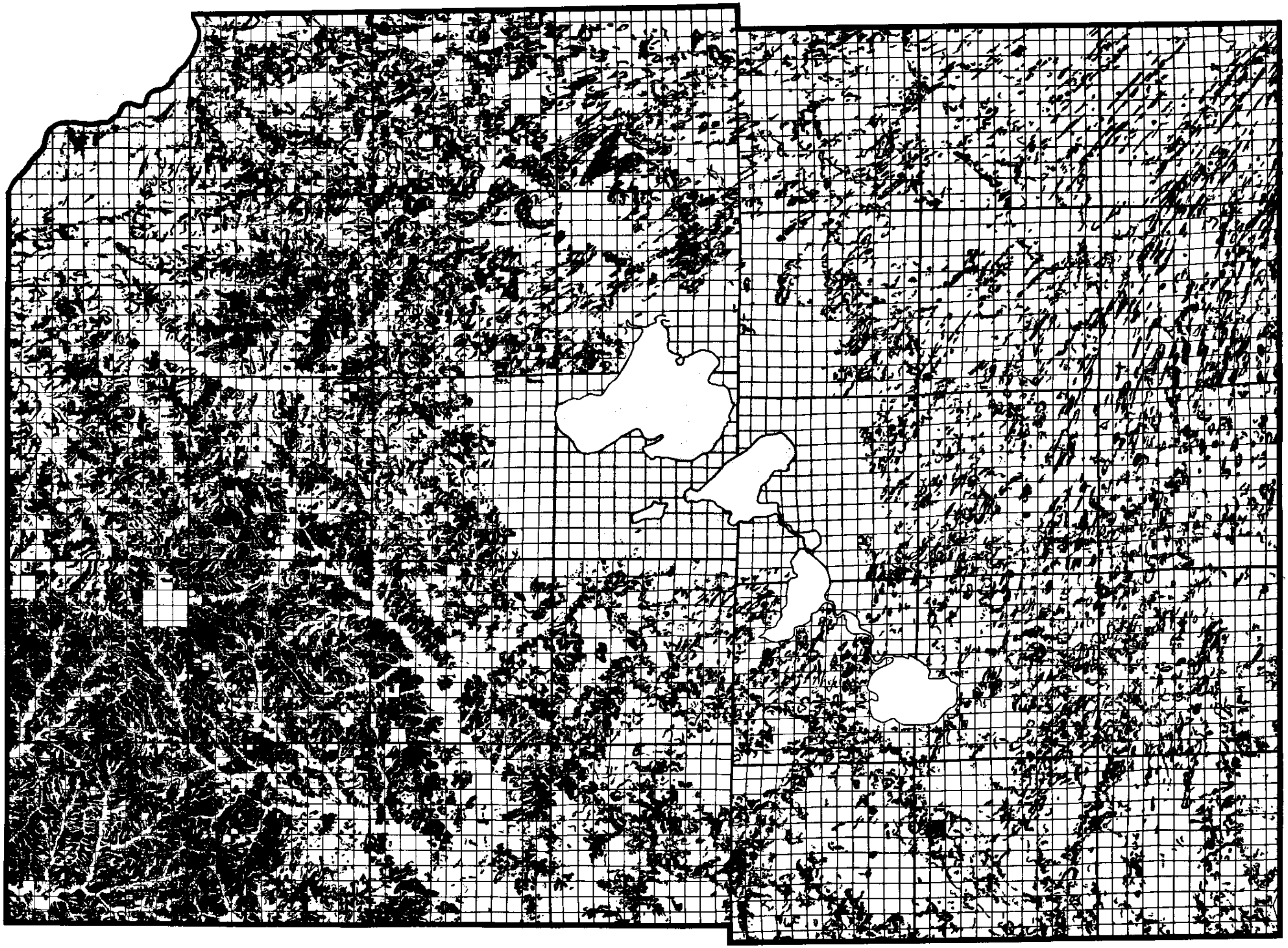


Figure 11-22: Soil erosion potential index.

CRP Eligibility

Conservation Reserve Program, 1985 Food Securities Act



Land Information and Computer Graphics Facility
University of Wisconsin - Madison

Figure 11-23: Areas eligible for enrollment in the Conservation Reserve Program.

Township	Town, Range	Ave.T Ag land	Ave. A Ag land	Ave. A Row	A/T Ag land	A/T Row	Erosion >3T	Erosion 3>T>1	Erosion <1 T
			-----(tons/acre/yr)-----				-------(acres)-------		
Mazomanie	T9R6	4.8	2.9	4.4	0.8	1.2	88	146	2357
Roxbury	T9R7	4.7	14.6	23.2	3.8	6.0	3748	2654	6765
Dane	T9R8	4.8	11.6	17.0	2.8	4.0	4182	4573	7732
Vienna	T9R9	4.9	8.3	11.0	1.9	2.6	2821	6609	9226
Windsor	T9R10	4.9	7.2	9.7	1.5	2.0	1734	6509	8251
Bristol	T9R11	5.0	5.0	8.6	1.4	1.8	1277	6824	8468
York	T9R12	5.0	8.3	10.4	1.7	2.1	1749	7854	7888
Black Earth	T8R6	4.5	9.7	15.8	3.0	5.0	1839	1142	8062
Berry	T8R7	4.6	15.2	25.6	4.0	6.7	4407	2055	7348
Springfield	T8R8	4.8	10.0	15.3	2.3	3.5	3664	4965	9633
Westport	T8R9	4.9	9.1	12.0	2.0	2.6	2037	4285	5320
Burke	T8R10	4.9	8.3	10.6	1.8	2.3	1423	4506	4375
Sun Prairie	T8R11	5.0	7.0	9.2	1.4	1.9	1199	6203	7276
Medina	T8R12	4.9	11.2	15.3	2.3	3.1	2626	4225	6925
Vermont	T7R6	3.3	21.1	32.7	8.2	12.7	5141	812	4792
Cross Plains	T7R7	3.9	13.0	20.1	4.8	7.4	5223	2053	7677
Middleton	T7R8	4.9	12.2	17.8	2.8	4.0	3054	2513	5527
Madison	T7R9	4.8	6.4	7.1	1.4	1.5	12	56	73
Blooming Gr.	T7R10	4.9	8.9	12.5	1.3	2.6	629	1634	2024
Cottage Gr.	T7R11	4.9	9.8	12.6	2.1	2.6	2380	5166	6351
Deerfield	T7R12	4.9	8.9	11.4	1.8	2.3	2080	3931	6947
Blue Mounds	T6R6	2.7	15.4	25.2	8.4	13.8	7098	2629	5529
Springdale	T6R7	3.4	15.5	23.4	6.1	9.3	8069	1301	7298
Verona	T6R8	4.2	11.7	16.6	3.3	4.7	4848	3059	7452
Fitchburg	T6R9	4.9	10.7	13.8	2.3	2.9	3353	5064	6676
Dunn	T6R10	4.8	12.2	15.0	2.6	3.1	2830	4117	4250
Pleasant Spr.	T6R11	4.7	9.0	11.6	2.0	2.6	2376	5422	6960
Christiana	T6R12	4.7	8.3	10.4	1.9	2.4	2373	6269	8553
Perry	T5R6	2.9	12.8	21.4	6.0	10.1	7471	1870	7651
Primrose	T5R7	3.3	11.6	18.3	5.2	8.2	5791	2473	8531
Montrose	T5R8	3.8	10.8	16.0	4.0	6.0	4246	2737	9115
Oregon	T5R9	4.7	9.8	13.5	2.2	3.1	2982	3647	8086
Rutland	T5R10	4.7	8.3	10.7	1.8	2.3	2365	5288	8609
Dunkirk	T5R11	4.7	8.8	0.6	1.9	2.3	2478	6177	7406
Albion	T5R12	4.8	8.1	10.3	1.7	2.2	1746	5718	7057
Area weighted average			10.5		3.0				
Total							109,337	134,486	236,190

A = potential soil loss; T = tolerable soil loss.

Table 11-11: Summaries of soil erosion estimates for Dane County.

According to the subsequent analysis, about 160,000 acres were deemed eligible for CRP, whereas initial Federal CRP eligibility estimates were only about 100,000 acres. The underestimate of about 60,000 acres was the result of an inability by Federal planners and policy analysts to utilize the detailed soil maps comprehensively and systematically across the county. Given the CRP payment levels, this underestimate of eligible acreage was not trivial. Their data came from the National Resource Inventory (NRI) sampling process, which proved insensitive to the resolution and grain of the drumlin landscape.

Because both state and Federal mandates impact site-management decisions (e.g., field by field), the macro- (or county-wide) analysis was not adequate for implementing the law. By law, soil erosion control planning takes place at the property/landowner/manager level. As described earlier in this chapter, the State of Wisconsin is an example of mandating individual land owner accountability. In 1981, it created a program to reduce soil loss (Chapter 92 of Wisconsin State Statutes).

A manager, then, might want to know which landowners require soil erosion control plans. Micro-analysis requires the manipulation of the MPLIS data base in a parcel-by-parcel manner. Such an analysis has been conducted for the Township of Oregon. Applying a modified version of the USLE for each farm landowner in Oregon Township yields an illustration of the distribution of non-compliance ($A > T$) by ownership units.

The average A:T ratio was computed for whole units of landownership by area-weighted average of cropland within a farm. Figure 11-24 illustrates which parcels and landowners will not be in compliance ($A > T$) unless they employ some additional conservation management procedures. Because the overall data base also includes the name and address of each landowner, those responsible for erosion control are explicitly identifiable. Column 2 of Figure 11-16 shows the functions employed.

When the lands and the people have been identified, the issue of actions to be taken arises. The policy analyst then will want to know which soil conservation control practice is most effective. Soil erosion control is possible by using various structural and non-structural methods. Non-structural methods tend to be the least costly to implement. One such non-structural technique is called "conservation tillage." This technique consists of leaving row-crop residue on the field as a means to reduce the impact of rain on the soil. The USLE can be re-run incorporating the policy analysis question of what would happen to compliance if conservation tillage were required of all farmers. Nearly all parcels would be brought up to the acceptable level ($A < T$) (Figure 11-25). Across Dane County, this would bring land in compliance

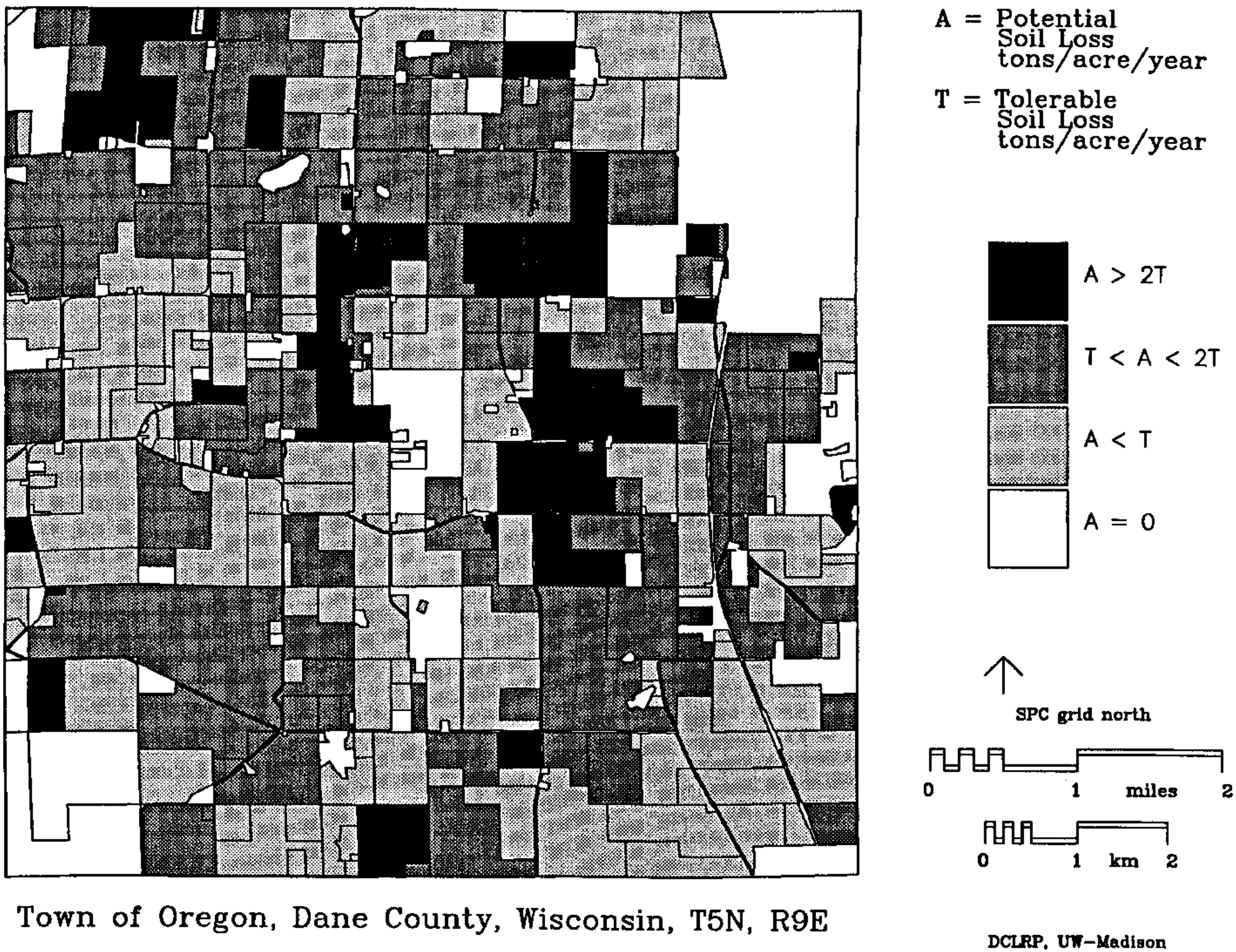


Figure 11-24: Landowners in non-compliance with soil erosion control mandates.

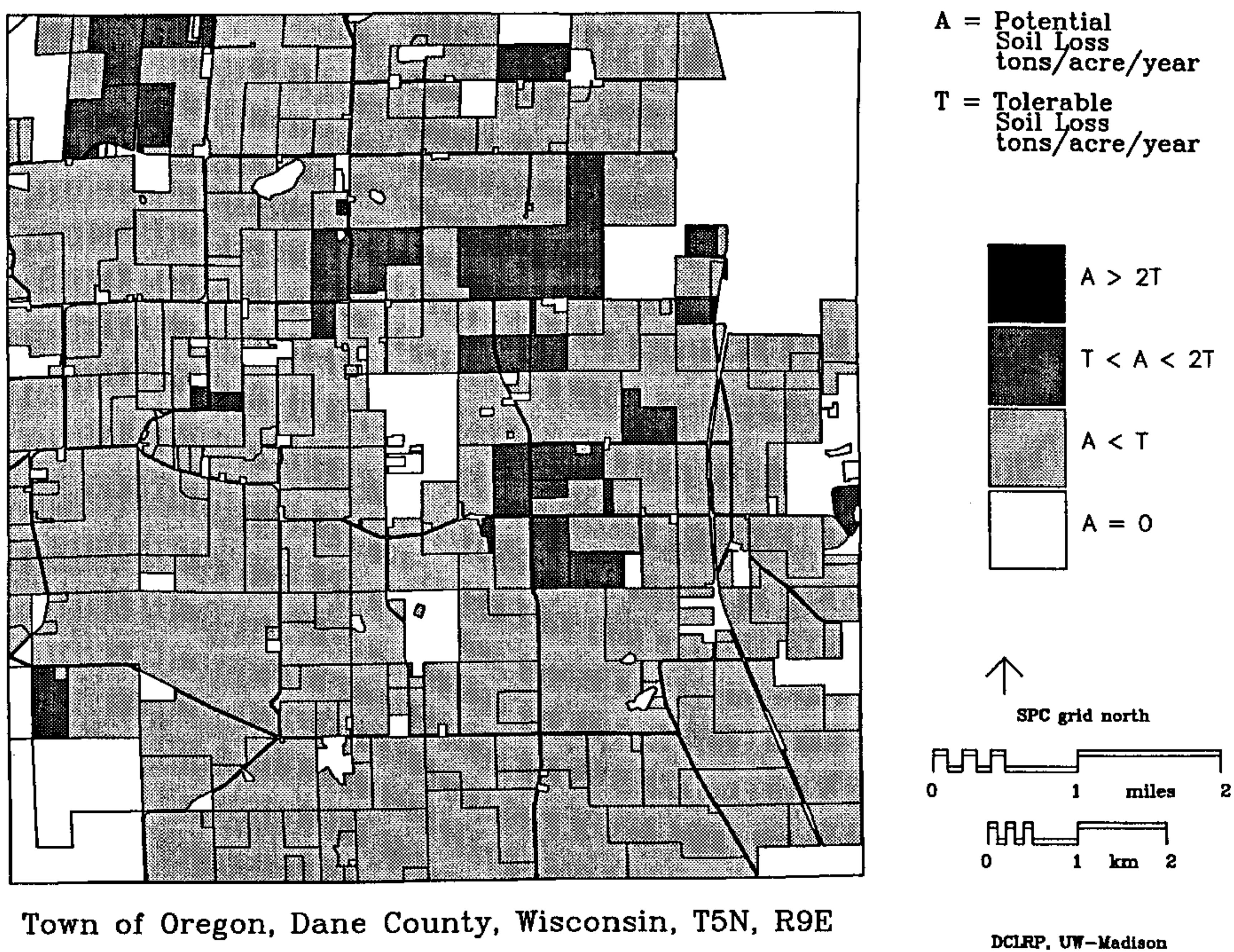


Figure 11-25: Effects of adopting conservation tillage on erosion control efforts.

to about 355,000 acres. Column 3 in Figure 11-16 enumerates the functions used for this analysis.

The ability to ask and answer these "What if" questions resulted in a major savings of time for conservation planning staff. It was also convincing to county officials who were required to endorse the final planning and management procedures for meeting compliance with the Federal and state mandates.

Other questions of policy relate to issues of land tenure. Planners and policy makers will want to know which landowners tend to be less conservation-minded (Figure 11-26). Comparing resident landowners with absentee landowners can show that lands owned by absentee landowners contribute more to soil erosion than do on-farm owners. Merging landowner names with tax mailing address ZIP codes revealed a loophole in Wisconsin's soil erosion control law: out-of-state owners do not qualify for farmland preservation income tax credit -- the incentive portion of the cross-compliance provisions.

WATER-QUALITY POLICY ANALYSIS

The use of an MPLIS in evaluating the potential soil sedimentation and pollutant impact on waterways from proposed land development plans illustrates how an MPLIS can be used to address -- a planning question: which land-use plans will result in the greatest contribution of sediment and pollutants to a waterway? -- , a management question: which sub-watersheds will require the most water-quality control measures and which landowners will be responsible for most of the soil erosion? -- , or a public policy question: what configuration of land-use types minimizes sedimentation impacts to waterways?

In the Township of Burke in Dane County, a proposed major new commercial development raised questions about its effects on water quality in the Yahara-Monona Watershed. Particular concern arose over the potential increase in sediment loadings into the waterways from fragile lands. At issue was the increased density of human activity from associated secondary development; a critical variable has been whether increased open space could ameliorate the effects on urban runoff on water quality in the area.

To assess the alternatives, six land-use scenarios were considered by local land planners and policy making officials: (1)

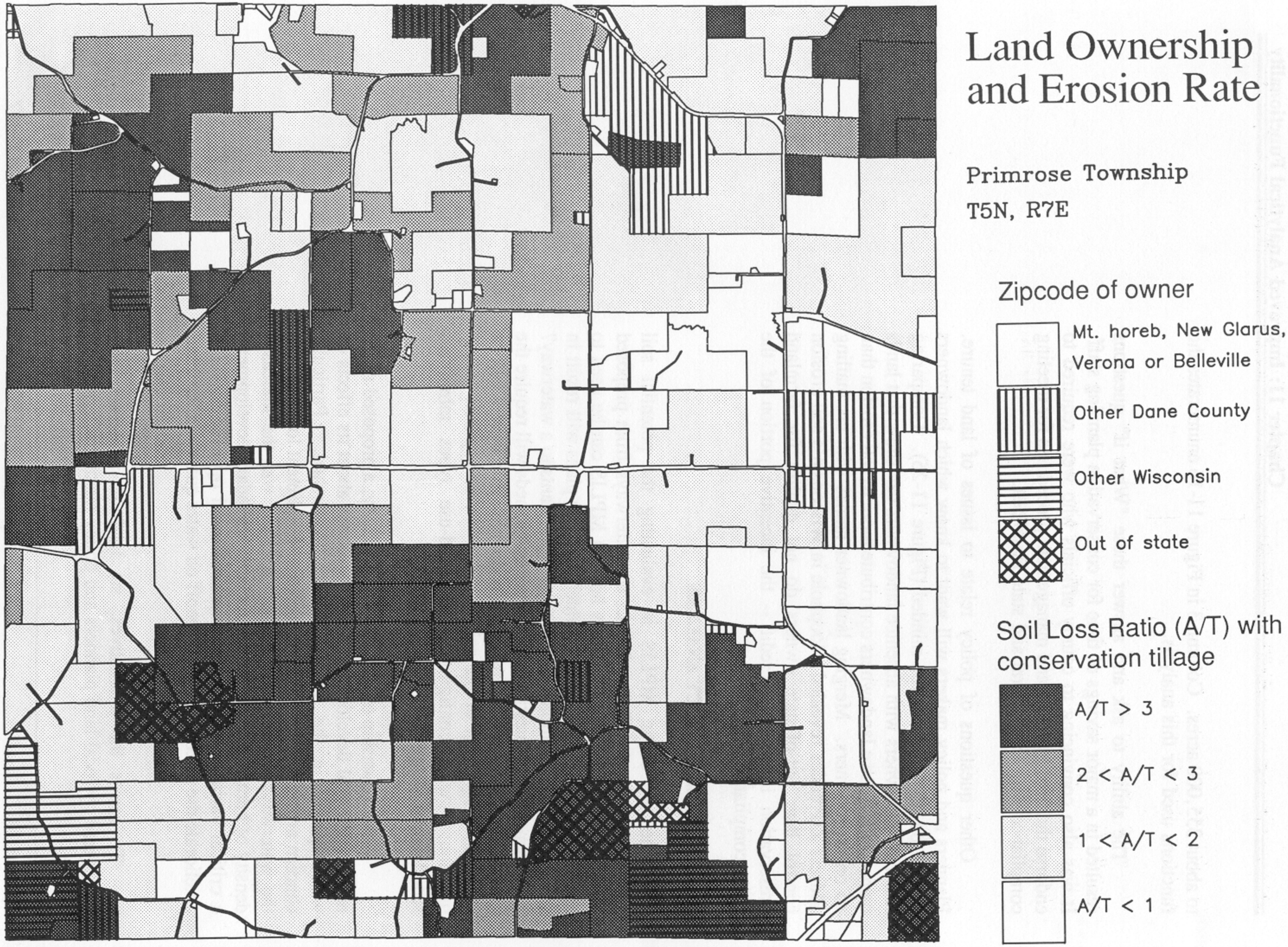


Figure 11-26: Land ownership and erosion rate.

the current land-use plan, (2) a modification of the plan, which would incorporate the protection of agricultural lands and environmental corridors, (3) plan buildout, which would incorporate zoning as an interpretation of land use where no planned land use exists, (4) zone buildout, which would assume all lands would be developed as zoned, where the planned land use would be less intensive than the zoned use, (5) modifications to the plan buildout, which would call for more open space in the final design, and (6) similar modifications to the zone buildout (Thum et al. 1990).

Analyses were made using various spatial analytical tools including overlay and buffering capabilities and digital terrain modeling functions (Figure 11-27). The sediment loading predictions were derived by connecting the LIS data base with the empirically derived water-quality model SLAMM (Pitt 1987a, 1987b). SLAMM was developed by the Wisconsin Department of Natural Resources (DNR) to predict nonpoint pollution runoff from urban development in critical watersheds around the state. Because SLAMM is basically a numerical and tabular model, interfacing it with the MPLIS provided additional analytical flexibility. More scenarios were possible and visual display made the outcomes potentially more understandable to policymakers. The reductions in nonpoint source sediment loadings between the plan buildout scenario and the modified plan buildout scenario have been mapped (Figure 11-28). The differences in sediment loadings are not trivial (Table 11-12).

Not only does the LIS illustrate which sub-watersheds will have reduced sediment loadings when more open space is incorporated into the plan, but it can ascertain which landowners will be affected by modifications to the existing land-use plan. It also clearly demonstrates which sub-watersheds are the most crucial for water-quality protection. The analysis numerically and graphically demonstrates the role that open space plays in water-quality protection.

Such analyses can give both planners and landowners the tools by which to forecast the results of their actions. That knowledge advances the opportunities for making optimum choices in safeguarding the land.

Function		Application:	Water Quality: Admin — NPDES Permits	Water Quality: Planning — Hydrologic Modelling	Water Quality: Mgmt. — Street Sweeping	Water Quality: Policy — Water Resource Inventory
Data Retrieval	Feature	by theme or layer	•	•	•	•
Data Retrieval	Feature	within window			•	
Data Retrieval	Feature	by feature name	•	•	•	•
Data Retrieval	Feature	location	•	•	•	
Data Retrieval	Feature	distance			•	
Data Retrieval	Feature	direction			•	
Data Retrieval	Feature	shape				
Data Retrieval	Attribute	Boolean retrievals	•	•	•	•
Data Retrieval	Attribute	attribute items		•		
Data Retrieval	Attribute	attribute values	•	•	•	
Data Retrieval	Attribute	frequency dist.		•		•
Data Retrieval	Attribute	count				
Data Retrieval	Attribute	statistical summary	•	•	•	•
Data Restructuring		raster/vector conv.		•		
Data Restructuring		vector/ raster conv.		•		
Data Restructuring		map tile appending				
Data Restructuring		automatic edgematch	•	•	•	•
Data Restructuring		interactive edgematch				
Data Restructuring		line thinning				
Data Restructuring		line smoothing				
Data Restructuring		feature generalization	•		•	
Data Transformation	planar	conformal and affine	•	•	•	•
Data Transformation	planar	least squares affine				
Data Transformation	planar	projective				
Data Transformation	rubber	polynomial				
Data Transformation	rubber	inverse dist. weighted		•		
Data Transformation	rubber	tin-based				
Data Transformation		control-point look-up	•	•	•	•
Data Transformation		projection conversion		•		
Data Transformation		datum conversion				
Overlay		graphic superimposition	•		•	
Overlay		sliver removal				
Overlay		area weighted average	•	•		•
Overlay		cross-tabulation		•		•
Overlay	overlay types	polygon on polygon		•		•
Overlay	overlay types	line in polygon	•	•	•	•
Overlay	overlay types	point in polygon	•	•	•	•
Overlay	overlay types	line on line				
Overlay	overlay types	point on line			•	
Overlay	Boolean	Union (OR)				
Overlay	Boolean	Intersection (AND)		•	•	•
Overlay	Boolean	Exclusive Union (XOR)				
Overlay	topol	intersect/attribute merger	•	•	•	•
Overlay	topol	manual feature creation				
Networks		line and node attributes	•	•	•	•
Networks		optimum path			•	
Networks		optimum distrib/collect	•	•	•	
Networks		optimum allocation zones				
Other		buffering		•	•	•
Other		proximity search				
Other		aggregate/line dissolve		•	•	
Other		address matching			•	
Other		nearest neighbor		•	•	
Other		adjacency		•		•
Other		Theissen polygons		•		

Figure 11-27: Functionality matrix for water-quality analysis.

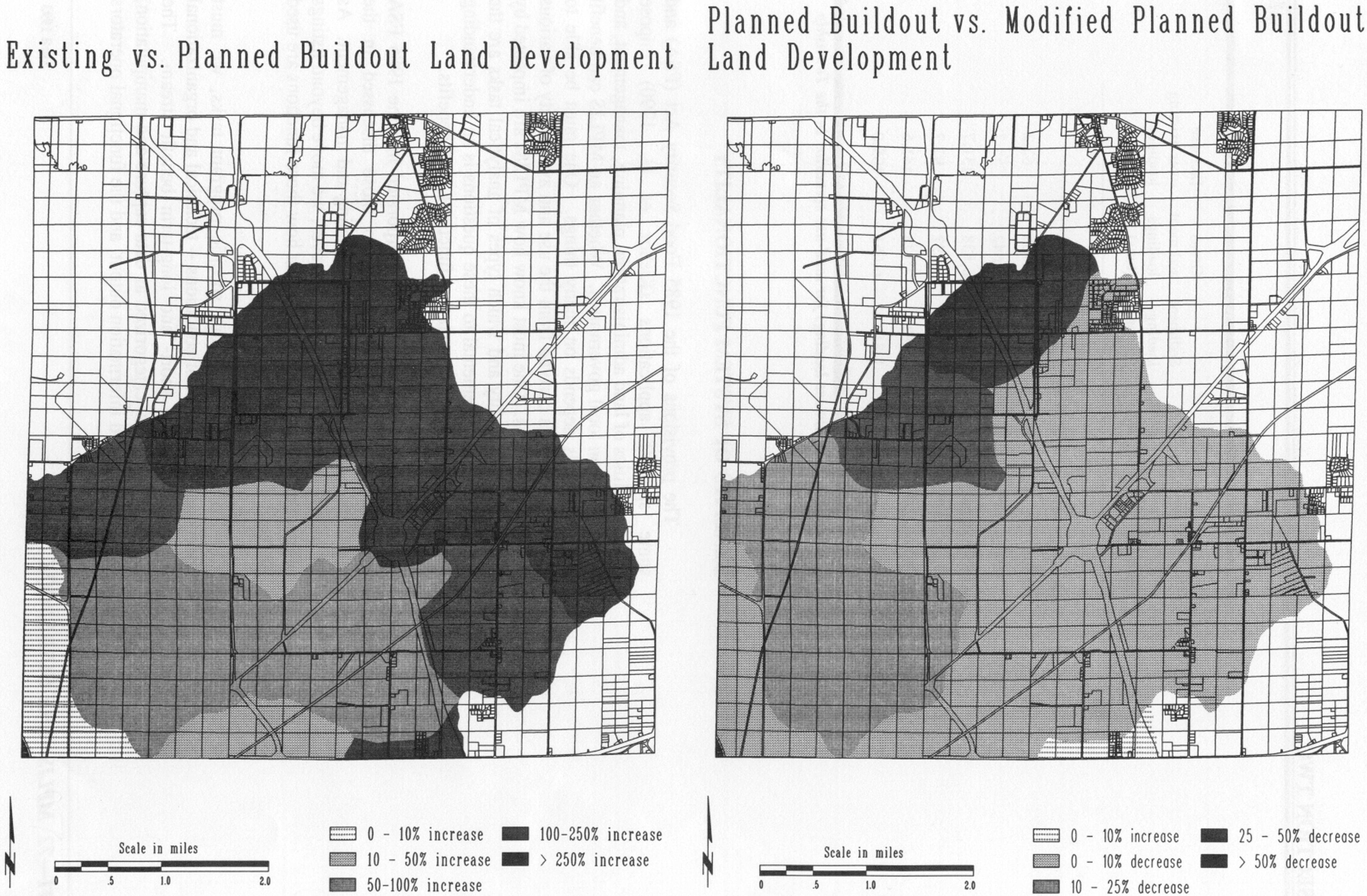


Figure 11-28: GIS approaches to nonpoint pollution assessment.

Scenario	Sediment loadings (lb/acre)	Gross sediment loadings (tons)	Increase over existing loadings (%)
Existing	1,513	2,951	
Planned	1,624	4,785	62.2
Modified Planned	1,671	4,642	57.7
Plan Buildout	1,846	6,838	131.7
Modified Plan Buildout	1,781	5,832	97.7
Zone Buildout	1,883	7,128	141.6
Modified Zone Buildout	1,816	6,051	105.0

Table 11-12: Annual sediment loadings for land-use scenarios in the Township of Burke.

BENEFITS OF SYSTEM FUNCTIONALITY

The provisions of the 1985 Food Security Act (FSA) and some spin-off applications (Kishor et al. 1990) impose responsibilities of land administration, planning, management, and policy tasks on local government. Whether an MPLIS can benefit these demands depends on many things. One must be able to assess the benefits derived from the use and availability of various GIS/LIS functions. One must know how MPLISs are impacted by GIS/LIS functionality and which types of analytical tasks are the most beneficial. Elemental to these questions is an understanding of the relationship between tasks, functions, and benefits.

The analytical applications incorporated into the 1985 FSA example are conceptually similar to those discussed in the application on soil erosion control planning and management. As we look at cost/benefit streams, however, we move beyond listings of functionalities and begin to look at how those functions are used for various tasks.

To address the various specific program tasks, we must understand the full set of conditions -- technical and organizational -- that impact the short- and long-term benefit stream. The technical functions, categorized as data capture and manipulation, data analysis, and information output, and the functional operators actually used must be considered. These technical functions must be regarded in conjunction with two institutional conditions critical to the full and successful exploitation of this vast set of GIS/LIS functions (Table 11-13). These institutional conditions consist of the organizational changes required in the work place to maximize the use of the various functions and the institutional arrangements needed to ensure that agencies establish effective communication channels. Organizational change and adaptation and institutional awareness are critical conditions to assure that the full stream of benefits is obtained.

The expanded matrix (Table 11-14) lists the technical and organizational functions in the first column for each task undertaken in Dane County and includes a description of each task in terms of the actual elements involved. The text describes the character of the benefit derived from incorporation of the various functions and lists the type of benefit derived from the set of functions utilized. For purposes of this discussion three categories of benefits are identified: efficiency, an overall measure of accomplishing the tasks faster; effectiveness, an increased capacity to perform tasks previously infeasible; and equity, an indication of overall fairness and impartiality through uniform treatment (Kishor et al. 1990).

Obviously, there is a correlation between the type of tasks involved and the functions utilized. It is therefore important to use this particular case study of the 1985 Food Security Act in the context under which there results were conducted. Important findings have been revealed.

- o Potential benefits are highly dependent upon the organization and institutional conditions in which the technology is employed. GIS/LIS functions make it possible to accrue benefits, but their full employment will eventually depend upon how quickly and effectively institutions adapt.

- o Most benefits would not be obtainable without the access to a variety of GIS/LIS functions, even though there is not necessarily a direct causal relationship between functions and benefits.

- o The technology *per se* cannot ensure equitable results, but because analyses can be conducted more efficiently it becomes possible to conduct an analytical operation

Table 11-13: List of GIS/LIS technical functions and institutional conditions.

Technical functions			Occurrences
1.	Data Capture and manipulation		
	1.1	Data capture through digitizing or scanning	6
	1.2	Data quality checks such as completeness and logical consistency	6
	1.3	Compact storage and flexibility through automation	5
	1.4	Data transformation from one coordinate system to another	4
	1.5	Data presentation at multiple scales	3
	1.6	Map Project changes	3
	1.7	Increased coding and classification efficiency	4
	1.8	Easy update of database	5
	1.9	Increased positional accuracy because of Global Positioning System	3
	1.10	Increased positional accuracy because of orthophoto quarter quadrangles	3
2.	Data analysis		
	2.1	Full relational data management capability	15
		2.1.1 Sorting and indexing	15
		2.1.2 Selective retrieval of data by logical or spatial criteria	17
		2.1.3 Full spreadsheet analysis	15
		2.1.4 Attribute merging by combining two or more database files	15
		2.1.5 Programming to expedite tedious operations	17
	2.2	Spatial data manipulation analysis	
		2.2.1 Buffering points, lines and polygons	9
		2.2.2 Combining two or more maps to create new maps--e.g., polygon overlay	10
		2.2.3 Accurately measuring occurrences, distances, and areas	7
	2.3	Data conversion for viewing/analysis purposes--e.g., contours to TIN 4	
	2.4	Modeling	6
	2.5	Performing "what if...?" analysis	3
3.	Information output		
	3.1	Immediate graphics display	5
	3.2	Customized hardcopy maps made quickly at varying scales	13
	3.3	Tabular display of attributed	14
	3.4	Easy generation of customized attribute reports	14
Institutional Conditions			
4.	Organizational changes		
	4.1	Encouraging use of new methods	2
	4.2	Hiring new, knowledgeable staff	1
	4.3	Training current staff	1
	4.4	Commitment of upper level management and elected officials	1
5.	Institutional arrangements		
	5.1	Data-sharing (multiple access of shared data by participating agencies)	5
	5.2	Data-custodianship	2
	5.3	Regular meetings for reporting and planning	2
	5.4	Cooperative agreements and memoranda of understanding	2

TABLE 11-14: CONSOIL PROGRAM BENEFITS OF GIS/LIS

User Interfaces

Command driven user interface
Pull-down or pop-up menu user interface
Icon-based user interface
Batch programs or command files for series of functions
Macro language or shell scripts for creating new commands
Source code or object code library for user program development
Tutorial or other method for self-instruction
An "undo' command to restore conditions prior to command
Recall of previous command(s) for re-execution
Logging of commands or operations
Soft error recovery
  user friendly error messages
  restore data files to original form
  remove scratch files

Data base management

Linkage of geographic data with attribute DBMS
Facility for entering data quality information
Facility for recording data lineage
Facility for tracking transactions or updates
Access to attribute data
  direct - by attribute identifier
  direct - by selected geographic feature
  through relational key
  by natural language or SQL instructions
Ability to create, view, and manipulate meta data
Database operations
  sort tabular or graphic files by attribute or location
  calculate new values by arithmetic or logical expressions
  relate data files by common unique identifiers
  define rules governing behavior of data elements
  create, store, retrieve, and generate standard reports
Provision for organizing files by project
Generation of status reports on content and status of data base
Capability to add data files without regard to size or scale
System security
  password access protection
  electable read only or read/write access for different users
Computer network operation
  access common data file from file server
  data check out/check in procedure

Geographic Data Automation

Manually digitize two-dimensional point, line, or polygon data
'Snap-to' previously digitized features
Photogrammetrically digitized data incorporation
Coordinate geometry: protract lines, angles, and curve, intersect lines (create nodes), bisect angles, locate tangents, least-squares traverse adjustment, store curve as radius, arc endpoints, or center point, arc endpoints, offset parallel lines
Manually encoded raster (cellular) data: raster editing, thresholding and line thinning, raster to vector conversion
  scanned map data - raster
  scanned photographic or satellite data
Topological structuring
  manual assembly

automatic (batch) assembly of polygons from lines
automated calculations of area, length, perimeter

Data Editing and Error Correction

Attribute data association
associate multiple attributes with geographic features
assign attributes
completeness check
attribute range or value checks
attribute format checks
Select features
by pointing
based on attribute value
Insertion or deletion of selected geographic features
Cut and paste' from update file
Interactive movement of individual points, lines, or areas
Interactive graphic annotation editing
Automated topological error reporting

Terrain and other 3-D Surface Representation

Contours
Regular gridded Z-values (digital elevation models)
Triangular irregular network (TIN)
Constrain contours by specifying barriers
Calculate cut or fill volume
Determine drainage networks or floodplains
Determine ridgelines or watershed boundaries
Determine viewsheds from user specified points
Compute slope and aspect values
Plot planar geographic features (terrain drape) over
2.5 D net, wireframe, or contours
Plot geographic features or perspective view
with shaded relief and hidden line removal

Import/Export

Arc/Info
AutoCad

DEM
DLG
ERDAS
ETAK
GIRAS
GRASS
Intergraph
MOSS
TIGER
Spatial Data Transfer Standard (SDTS)
etc.

Data display and analysis

Data Retrieval - select and display
by theme or layer
within window specified by coordinates or reference map
within window specified by on-screen digitizing -
by feature names or groups of names
by logical and Boolean retrievals on attributes

List attribute values of selected features
Report location of feature by pointing
Report straight-line distance or length by pointing
Report along-line-feature (network) distance by pointing

Data Restructuring
- raster to vector conversion
- vector to raster conversion
- map tile or sheet appending
- automatic edgematching
- line thinning or smoothing

Data Transformation
- planar transformations
- 'rubber-sheeting' planar transformations
- extract control point coordinates from master file
- incorporation of USGS/NOAA projection package
- incorporation of NOAA-NGS NadCon datum conversion

Overlay
Graphic superimposition
Topological overlay
Sliver removal
Cross-tabulation
Area weighted average

Networks
- Maintain line and node attributes
- Determine optimum path through network
- Determine optimum route for distribution through network
- Calculate optimum allocation or collection zones

Other Geoprocessing
- Buffer
- Proximity report
- Nearest neighbor
- Automated address matching
- Adjacency

<u>Data Display and Information Product Creation</u>

Data Display
- Generate graphic displays (on screens, plotters, etc.)
- Display vector data with raster (image) backdrop

Information Product Creation
- Compose products interactively
- Compose products with command files or map templates
- Store, retrieve, and re-display compositions
- User specified scale, orientation, map size, location on sheet
- Display point, line, and polygon data sets
- Display map features: neat lines, grid lines graticules
- Create and position: scale bar, legends or keys, north arrow, map titles, logos, single or multiple line text
- Interactively position map elements
- Ability to select point symbols, line types, and area fill patterns
- Ability to create, name, store, and select new point symbols, line type, and area fill pattern tables
- Ability to assign by attribute, selection or lookup table
- Automatically position text at pre-specified point location
- Ability to specify individually for any text string: font, case, size, spacing, color, angle, curvature

not previously economically possible. These functions empower the user to do analyses that had previously been manual and therefore technically impossible. This new empowerment provides the opportunity to implement policy in a more equitable manner than ever before.

- o Data analytical functions exist in the context of additional GIS/LIS functionality requirements. This includes the need to capture and convert data into a digital form prior to applying any analytical functionality.

- o Just as obvious is the need to portray the analytical and informational results graphically. The power and flexibility of GIS/LIS graphic functionality also expand the benefit stream. Being able to convert complex tabular data and calculations into graphic displays further increases the power of the tool and the resultant benefit stream.

- o In a multipurpose environment a full range of analytical functions is needed, even though some analytical functions dominate as a result of the variety of program tasks that require attention. In the Food Security Act case study, an excellent example is the "full relational data management capabilities."

Access to a robust array of functionality also expands the potential for an increased benefit stream; it therefore also increases the potential for successful and useful implementation of the overall technology and assists in the bringing about of institutional commitment.

SUMMARY

Computerized information technologies in the form of multipurpose land information systems coupled with relevant analytical functions offer land planners, managers, and policy analysts a very powerful method by which to plan, manage, and understand the natural resources of rural America. The technology has sufficiently matured; data bases are being developed by local, state, and Federal agencies that are useful to planners, managers, and policy analysts; and societal mandates such as the 1985 Food Security Act and the 1990 Food, Agriculture, Conservation, and Trade Act are requiring the full employment of analytical techniques. These mandates, MPLIS, and expanding analytical functionality are making Manning's dream -- the ability to connect people with place -- become a reality.

REFERENCES AND ADDITIONAL READINGS

Antenucci, John, 1990: "GIS Implementation: Getting Started," *Government Technology*, GT Publications, Inc., Sacramento, CA, August, pp. 20-22.

Arthur, J., 1989: "Results of OMB's Electronic Mapping Data Base Survey," *Proceedings of the National Conference on GIS*, Charting the Future of the Federal Government, U.S. Professional Development Institution, Silver Spring, MD.

Bauer, K.W., 1984: "Public Planning and Engineering: The Role of Maps and the Geodetic Base," Seminar on the Multipurpose Cadastre: Modernizing Land Information Systems in North American, IES Report 123, edited by B. J. Niemann, Jr., University of Wisconsin-Madison, pp. 130-139.

Brown, J.H., Philips, R.S., and Roberts, N.A., 1981: "Land Markets at the Urban Fringe," *Journal of the American Planning Association*, 47 (2), pp. 131-144.

Burrough, P.A., 1986: *Principles of Geographic Information Systems for Land Resource Assessment*, Clarendon Press, Oxford, England.

Chrisman, N., 1984: *Alternatives for Specifying Quality Standards for Digital Cartographic Data Quality*, Report 4, NCDCDS, edited by H. Moellering, Columbus, OH, pp. 43-71.

Chrisman, N., 1987: "The Accuracy of Map Overlays: a Reassessment," *Landscape and Urban Planning* 15, pp. 427-439.

Chrisman, N.R., Mezera, D.F., Moyer, D.D., Niemann, B.J., Jr., Sullivan, J.G., and Vonderohe, A.P., 1986: "Soil Erosion Planning in Wisconsin: Order of Magnitude Implications of Integrating New Technologies," *Proceedings of the Annual Conference of the Urban and Regional Information Systems Association (URISA)*, 1, pp.117-128.

Croswell, P.L., and Clark, S.R., 1988: "Trends in Automated Mapping and Geographic Information System Hardware," *Proceedings of the ACSM-ASPRS Annual Convention* [St. Louis, Missouri], pp. 69-78.

Dangermond, J. and Freedman, C., 1984: "Findings Regarding a Conceptual Model of a Municipal Database and Implications for Software Design," *Seminar on the Multipurpose Cadastre: Modernizing Land Information Systems in North America*, IES Report 123, University of Wisconsin-Madison, Institute for Environmental Studies, p.3.

Geddes, P., 1968: *Cities in Evolution: An Introduction to the Town Planning Movement and to the Study of Civics*, Harper & Row, New York.

GIS World, Inc. 1989: "GIS Now Official EPA Program," *GIS World* 2(3):12.

GIS World, Inc., 1990: "The 1990 GIS Software Survey," *The GIS Sourcebook 1990*, GIS World, Inc., Ft. Collins, CO, p. 18.

Goodchild, M. F., 1989: "Toward Enumeration and Classification of GIS Functions," *The GIS Sourcebook 1989*, GIS World, Inc., Fort Collins, CO, pp. 14-20.

Hopkins, L., 1987: "Methods for Generating Suitability Maps: a Comparative Evaluation," *AIP Journal*, October, pp. 386-400.

Huxhold, W.E., 1991: *An Introduction to Urban Geographic Information Systems*, Oxford University Press, New York.

Jacobs, H.M., 1989: "Implementing Local Multipurpose Land Information Systems," *Political-Economic Research Issues, Computers, Environments and Urban Systems* 13, pp. 3-13.

Kiefer, Ralph W., 1965: "Land Evaluation for Land Use Planning," *Building Sciences*, 1, pp. 105-126.

Kishor, P., Niemann, B.J.,Jr., Moyer, D.D., Ventura, S.J., Martin, R.W., and Thum, P.G. 1990: "Evaluation of GIS/LIS: Lessons from CONSOIL," *GIS/LIS 1990 Proceedings*, 2, pp.701-711.

Land Information and Computer Graphics Facility, 1983: "Concept for a Multipurpose Land Information System," (Diagram), University of Wisconsin-Madison, College of Agricultural and Life Sciences, School of Natural Resources, LICGF.

Larsen et al., 1978: "Land Records: The Cost to the Citizen to Maintain the Present Land Information Base," a Case Study of Wisconsin, Department of Administration, Office of Program and Management Analysis, 64pp, Madison, WI.

Liston, R.L., and TeSelle, G.W., 1988: "Implementing the GRASS GIS in the Soil Conservation Service," *Proceedings of GIS/LIS,* Accessing the World 2, pp. 759-765.

Manning, W., 1909: "For State-wide Survey," *The Bostonian*, 1(8), pp. 224-225 and 1(9), pp. 278-280.

Manning, W., 1913: "The Billerica Town Plan," *Landscape Architecture* 3(3), pp. 108-118.

McHarg, Ian L., 1969: *Design With Nature*, Natural History Press, New York.

Niemann, Bernard J., Jr., and McCarthy, M.M., 1979: "Spatial Data Analysis and Information Communication," *Planning the Uses and Management of the Land*, editors M.T. Beatty, C.W. Peterson and L.D. Swindle, American Society of Agronomy, Crop Science Society of America and Soil Science Society of America, Madison, Wisconsin.

Niemann, B.J., Jr., Sullivan, J.G., Ventura, S.J., Chrisman, N.R., Vonderohe, A.P., Mezera, D.F., and Moyer, D.D., 1987: "Results of the Dane County Land Records Project," *Photogrammetric Engineering and Remote Sensing*, 53(10), pp. 1371-1378.

Niemann, B.J., Jr., Merideth, R.W., Jr., Moyer, D.D., Clapp, J.L. 1990: "Land Information Systems Modernization In Wisconsin: Government-University-Professional Interactions," *Government Information Quarterly*, 7, pp. 269-283.

Openshaw, S., 1990: "Why Are We Still Waiting for Spatial Analysis Functionality?", *The GIS Sourcebook 1990*, GIS World, Inc., Ft. Collins, CO, p. 13.

Pitt, R.E., 1987a: "Small Storm Urban and Particulate Washoff Contributions to Outfall Discharges," PhD. Dissertation, University of Wisconsin-Madison.

Pitt, R.E., 1987b: "Manual of Practice for Stormwater Runoff Management, Section 27," National Park Service Manuscript.

Smith, J.M., 1992: "Forest Service Trims $1 Billion from Cost of GIS Buy," *Government Computer News*, p. 80.

Steiner, F., 1989: "The Food Security Act of 1985: Land Use Planning Implications for the United States," *Land Use Policy* (April), pp. 132-140.

Steiner, F., Young, G., and Zube, E., 1988: "Ecological Planning: Retrospect and Prospect," *Landscape Journal*, 7(1), pp. 31-39.

Steinitz, C., Parker, P., and Jordon, L., 1976: "Hand Drawn Overlays: Their History and Prospective Uses," *Landscape Architecture*, 66(5), pp. 444-455.

Sullivan, J.G., Chrisman, N.R., and Niemann, B.J., Jr., 1985: "Wastelands Versus Wetlands in Westport, Wisconsin: Landscape Planning and Tax Assessment Equalization," *Proceedings of the Annual Conference of the Urban and Regional Information Systems Association*, 1, pp. 73-85.

Thum, P.G., Pickett, S.R., Niemann, B.J. Jr., Ventura, S.J., 1990: "LIS/GIS - Integrating Nonpoint Pollution Assessment with Land Development Planning," *Wisconsin Land Information Newsletter*, Vol. 5, Number 2, pp. 1-11.

Unwin, D., 1981: *Introductory Spatial Analysis*, Methuen, London, 212 pp.

USDA Forest Service, 1988: "National GIS Plan: Geographic Information System," USDA Forest Service, Information Systems, Washington, DC, 15 pp.

USDI, 1990: "A Study of Land Information," Prepared in Accordance with Public Law 100-409, Section 8, U.S. Department of the Interior, Washington, DC.

USDI Bureau of Land Management, 1989: "Managing Our Land Information Resources," Land Information Management Study BLM-AA-AE-89-003-4540, U.S. Department of the Interior, BLM, Washington, DC.

Ventura, S.J., 1988: "Dane County Soil Erosion Control Plan," Dane County Land Conservation Department, Madison, WI, 108 pp.

Ventura, S.J., 1991: *Handbook for Land Information System Development in Local Government - Steps Toward Land Records Modernization in Wisconsin*, State Cartographers Office, Madison, WI, p. 62.

Ventura, S.J., Chrisman, N.R., Connors, K.F., Gurda, R.F., and Martin, R.W., 1988a: "A Land Information System for Soil Erosion Control Planning," *Journal of Soil and Water Conservation*, 43(3), pp. 230-233.

Ventura, S.J., Niemann, B.J., Jr., and Moyer, D.D., 1988b: "A Multipurpose Land Information System for Rural Resource Planning," *Journal of Soil and Water Conservation* 43(3), pp. 226-229.

Vonderohe, A.P., Gurda, R.F., Ventura, S.J., and Thum, P.G., 1991: "Introduction to Land Information Systems for Wisconsin's Future," State Cartographer's Office, Madison, WI, 81 pp.

Wisconsin Land Records Committee, 1987: "Final Report of the Wisconsin Land Records Committee," University of Wisconsin-Madison, Institute for Environmental Studies, p.3.

Wischmeier, W.H., 1976: "Use and Misuse of the Universal Soil Loss Equation," *Journal of Soil and Water Conservation*, 31(1), pp. 5-9.

Wischmeier, W.H. and Smith, 1978: "Predicting Rainfall Erosion Losses," *USDA Agriculture Handbook No. 537*, Government Printing Office, Washington, DC.

Wisconsin State Statute 92, 1981: Ag Rule 160.

Zinn vs. Wisconsin, 1983: 112 Wis 2d F17, 334 N.W. 2d 67.

12 THE BASE MAP

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INTRODUCTION

Earlier, in Chapter 2 of this Guidebook, an Introduction to Mapping Concepts was presented. In this chapter we focus on a particular aspect of mapping, base maps. In discussing base maps we consider the purposes for which base maps are developed and used, discuss the basic approaches that are used to construct base maps, examine digital mapping and the advantages it has for base mapping purposes, and suggest several factors to be considered when developing a base mapping program. Therefore, the primary focus in this chapter is on what a base map is, why a base map is needed, and how one can go about classifying base maps and their contents. Later, in Chapter 19, how a base map is constructed and maintained is discussed in some detail.

DEFINITION

A base map can be defined in several ways, particularly given the advent of widespread computer mapping and other computer-generated graphics materials. For example, Robinson, et al., using a traditional cartographic view, suggest that a base map is "a map containing geographical reference information on which attribute data may be plotted for purposes of comparison or geographical correlation" (Robinson, et al., 1984, p. 517). Robinson notes that the view of the map maker and map user often vary and indicates that one observer has suggested that "Maps have many functions and many faces, and each of us sees them with different eyes" (Skelton 1972, p. 31).

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Another source defines base map as "a map on which information may be placed for comparison or geographical correlation" or as "a map from which other maps are prepared by the addition of information. In particular, a planimetric map used in the preparation of topographic maps" (NGS 1986, p. 142).

Yet another source defines a base map as the graphic representation at a specified scale of selected fundamental map information; used as a framework upon which additional data of a specialized nature may be compiled (American Society of Photogrammetry 1980, cited in NRC, 1983, p. 37). In local government, the term base map has been applied to a wide variety of maps, ranging from large scale parcel maps to small scale maps showing streets, railroads, rivers, and other geographic features. In order to more clearly understand exactly what a base map is, we first turn to the purpose for and uses of such base maps.

PURPOSE AND USES OF BASE MAPS

Earlier we have noted that to be able to process, manipulate, analyze, and display land (spatial) information, it is absolutely necessary that an accurate framework be in place as a frame of reference. As is noted throughout this Guidebook, a key, required component of such a frame of reference is a geodetic network. This component was also stressed by the National Research Council (NRC) in their studies on the multipurpose cadastre in the early 1980s.

However, while a geodetic reference system is a required component for an effective MPLIS, such a framework is not sufficient by itself. In order to facilitate system use (i.e., to ensure the "user-friendliness" of the MPLIS), it is also necessary that a "base map" be part of the system. Such base maps, whether in traditional hardcopy or digital form, are a key factor in being able to relate map (graphic) data and attribute data, the two major classes of data found in all MPLISs. In short, a base map should contain a minimum set of data that is useful to, and will be used by, a large set of MPLIS users. These data, like the geodetic layer, can be used to (1) relate objects on a single layer to other objects on that layer, (2) relate objects on two or more different layers, and (3) locate various data layers in space (i.e., based on a common geodetic reference system). In short, a base map should contain enough data to allow MPLIS users to orient themselves to the data in the base layer, as well as to integrate data from two or more layers that may be used for any particular analysis.

Huxhold articulates this purpose for base maps as follows: base maps "contain points, lines, polygons, symbols, and text in a spatial context that allows a visual understanding of how ... cartographic objects are related to each other" (Huxhold 1991, p. 186). In an MPLIS, "a base map contains the cartographic information that is common among all the different users of maps" (ibid.).

TWO TYPES OF BASE MAPS

There are several ways to classify base maps and one of the most useful ways is by their information content. "The base map consists of either cadastral information (the legal identification of features), or planimetric information (the physical identification of features), or it may consist of a combination of both cadastral and planimetric information" (ibid.).

Since there are major differences between cadastral and planimetric information, the decision about which type of information to use as the basis for a base map is a significant one. This decision will affect both the use of the MPLIS as well as the cost of building (and maintaining) the base map itself. The differences result because cadastral maps are based upon legal definition of land parcels and planimetric maps are based on physical features that can be seen on the land. Because of the differences in these two major feature classes, these two types of maps often disagree as to the location of a common feature.

PLANIMETRIC APPROACH TO BASE MAPPING

A planimetric base mapping approach has been the most common type of base mapping in many parts of the United States. This approach is based on the physical features that can be seen on the ground and recorded on maps. Therefore items that may be included on planimetric maps include "curb lines, roadways, sidewalks, street intersections, rivers, lakes, trees, manhole covers, fire hydrants, buildings, bridges ... fence lines" (Huxhold 1991, p. 186). The items included on planimetric maps "can be identified during field surveys or on photographs taken from airplanes" (ibid.).

The amount of detail collected from aerial photographs for inclusion in a planimetric (or line) map varies, depending on such factors as the uses the base map will serve, the financial resources of the agency building and maintaining the map, and other resources available. Therefore, one jurisdiction might include only roads, railroads, and major lakes and rivers. Other jurisdictions, with more resources and more planned uses for base map information, might include the entire list of information proposed by Huxhold in the list above.

Many base maps include information on elevation. For example, Chapter 19 describes the use of the stereo digitizing process, whereby ground elevations are obtained from aerial photographs to produce topographic maps. The resultant elevations are then displayed on a planimetric (base) map as elevation contour lines (i.e., lines connecting points of equal elevation).

One of the most common base maps in use in the United States is produced by the U.S. Geological Survey (USGS) in the U.S. Department of the Interior. These maps are produced in a variety of scales ranging from 1:24,000 to 1:2,000,000. However, jurisdictions desiring digital versions of USGS maps should be aware that, generally, only hardcopy versions are available for maps with scales greater than 1:100,000. Additionally, the USGS update cycle is relatively long, which means that jurisdictions wanting more frequent updates than USGS can provide will need to budget their own resources for such updates. For base map purposes, many jurisdictions rely on the 1:24,000, 7.5 minute USGS quadrangle maps that contain natural resource inventory, land use, and transportation layers. Larger scales (e.g., 1:500 or 1:600, up to 1:9,600 or 1:10,000) are required for many base map uses in urban areas.

Oneida County, Wisconsin, used the planimetric approach to base mapping. A description of the Oneida County base mapping program can be found in Appendix 12-1.

CADASTRAL APPROACH TO BASE MAPPING

The cadastral approach to base mapping focuses on the legal identification of features (as opposed to the physical identification of features in the planimetric approach). Because so much local government activity involves cadastral (parcel) data, many jurisdictions rely on the cadastral approach for base mapping.

Cadastral records contain data on ownership, taxation, and the delivery of a variety of public services ranging from utilities to health and public safety. The tax and ownership parcel are typically at the heart of a cadastral base map system.

Records on ownership and other legal interests in land parcels incorporate a wide variety of data. These records include ownership deeds, mortgages, liens, pending court actions, special assessments, zoning, rights-of-way, and easements (Huxhold 1991, p. 187).

To build and maintain an accurate cadastral base map requires data on the location and shape of each parcel, as well as the relationship of each parcel to other parcels. Further, as suggested above, many legal claims on the parcel are derived from local government powers of zoning, taxation, and similar legal authorities. This means that an accurate cadastral base map must draw on many records including deeds, tax descriptions, plat and subdivision maps, a variety of legal documents, indexes to legal documents in a variety of offices, and indexes to maps used for taxation, planning, etc. Because of these complexities, many jurisdictions build their initial cadastral base map by scanning existing tax parcel maps. A second, much more difficult, but much more accurate approach is to use computer driven coordinate geometry (COGO) programs that create digital records directly from legal descriptions recorded in the recorder or register of deeds office.

The 1980 NRC report on the "Need for a Multipurpose Cadastre" referred to base maps as "conventional photogrammetric line maps or orthophoto maps" (NRC 1980, p. 53). The NRC identified the base map, one of the five key components of the multipurpose cadastre, as consisting solely of the mapped data representing the physical features on the land. However, the NRC definition also included a cadastral overlay layer that links the base map, through the geodetic reference framework and coordinate system, to parcel maps, parcel descriptions, parcel indexes, location identifiers, and related land data files. Thus parcel (or cadastral) information, while not included on the recommended NRC base map, is closely linked to the planimetric base map through the reference framework.

The cadastral approach to base mapping has been used by Marion County, Oregon, in their Geographic Land and Data System (GLADS) (Kjerne 1984, p. 234). In GLADS, hardcopy maps are converted to a digital version and "stored on disk as a series of separate drawing files, each of which covers a section, quarter-section, or quarter-quarter-section at different scales. This information will eventually be merged together to form ... a 'continuous digital map' ..." (ibid.).

COMBINING THE PLANIMETRIC AND CADASTRAL APPROACHES

There are jurisdictions that use a combination of planimetric and cadastral information to build their base map. This combination approach is useful for jurisdictions that do not have a parcel map system, or where the existing maps are inaccurate, out-of-date, or otherwise unsuitable for digitizing or scanning (Huxhold, 1991, p. 192). "In these jurisdictions, planimetric maps are created from orthophotographs, and the parcel boundaries are added from the legal descriptions of the parcels, using reference points common to both sources. These references are usually physical features identified on the orthophotograph and also referenced in a parcel's legal description: the centerline of a street, a railroad, the shoreline of a river or lake, and other physical entities that, while too small to see on an aerial photograph, have been temporarily marked with a larger object (known as a target). Locating parcels in relation to these common reference points is often difficult and, in a densely populated area, very time-consuming because of the large number of parcels and the small number of reference points common to both map sources" (ibid.).

The process necessary to combine cadastral and planimetric data for a base map is not an easy one. North Carolina has a state program to assist counties in developing such a combination base map. Don Hollaway, then director of the North Carolina base mapping program, described the following steps needed in such an effort.

1. Create a planimetric base map from orthophotographs.

2. Conduct research in the Register of Deeds office, for every deed that is included in a particular map.

3. Input all boundary information from the deeds into an automated plotter.

4. Use the automated plotter to compute and generate a to-scale figure of each parcel.

5. Transfer these parcel drawings to a work copy of the base map.

6. Reconcile any gaps and overlaps of adjoining parcels. (These checks include such things as reference to use lines (fences, roads, streams) and field checks.)

This latter step is a most difficult one. Eunice Ayers, the former Register of Deeds in Forsyth County (one of the first counties in North Carolina to participate in the program), described the problem as follows.

"The most difficult single phase in the [MPLIS] project has been to complete the production of the graphic base (map)--identifying and resolving discrepancies between the graphic parcel descriptions digitized from tax maps and orthophotographic base maps. This process of rectification has been long, difficult, and frustrating. --- In compiling the land records, it is clear for the first time what mistakes and errors have existed in those records for years" (Ayers 1984, p. 298).

DIGITAL MAPPING

As we have noted throughout the Guidebook, it is not absolutely necessary for an MPLIS to be automated to function. Many improvements in land information systems can be made in a manual form. However, there are also many instances when major benefits of an MPLIS accrue primarily if the system is in an automated mode. Development of base maps is one of the areas where automated, digital methods are preferable.

One reason automated maps are preferable is that they provide an opportunity to shift our thinking away from hardcopy maps and to information arranged spatially in general. Any data that can be displayed spatially can be included in a digital data base. By storing these data in layers, it is also possible to select only those items necessary for any particular display, whether on a cathode ray tube (CRT) or as a plotted "map" on paper, mylar, or other print media.

A second major advantage of digital map data storage is the relative ease with which these data can be updated compared to hardcopy maps. Hardcopy maps are very often out-of-date as soon as they are produced. Also, to make corrections and updates requires reproducing copies for all users, or correcting each hardcopy map in existence that contains the data in question. On the other hand, a digitally based map can be updated as often as appropriate, even on a daily basis. Once the change is made to the digital data file, all subsequent users of the data base will have the latest information at their finger tips.

A third advantage of digital maps is the significant amount of digitally mapped data that already exist. Further, digitally mapped data resources are likely to continue to expand at a rapid rate. Examples of a few digital data bases that already exist provide an indication of the potential of this approach to mapping in general and base mapping in particular.

The USGS produces digital cartographic base data known as Digital Line Graphs (DLGs) and distributes them through the National Digital Cartographic Data Base. Large-scale DLG data are generally derived from USGS 1:20,000-, 1:24,000- and 1:25,000-scale topographic quadrangle maps. Intermediate-scale DLG data are derived from USGS 1:100,000-scale quadrangle maps. (Large-scale and intermediate-scale as stated here are as used by USGS. For most MPLIS developers and users, both of these scales (1:24,000 and 1:100,000) would be characterized as small-scale.) Large- and intermediate-scale DLG data are collected in nine separate categories: hypsography, including contours and supplementary spot elevations; hydrography, including flowing water, standing water, and wetlands; vegetative surface cover, including woods, scrub, orchards, vineyards, and vegetative features associated with marshes and swamps; non-vegetative features, including lava, sand, and gravel; boundaries, including state, county, city, and other national and State lands such as forests and parks; survey control and markers, including horizontal and vertical positions of third-order or better; transportation, including roads and trails, railroads, pipelines, transmission lines, and miscellaneous transportation features; manmade features, including cultural features such as buildings; and US Public Land Survey System (PLSS), including township, range, and section information. Although collection of all DLG categories for the entire nation is far from complete, significant numbers of DLGs are available. For 1:24,000 DLGs, USGS has focused its collection efforts on the PLSS, boundaries, transportation, and hydrography, although a thousand or more DLGs have been produced for every category. At the 1:100,000 scale, nationwide coverage is currently available for hydrography and transportation. Nationwide 1:100,000 coverage for PLSS, boundaries, and hydrography is scheduled to be completed by 1995.

The TIGER (Topologically Integrated Geographic Encoding and Referencing) system is an integrated data base containing all of the spatial data needed to administer the 1990 Census of Population and Housing. All statistical and reference maps for the 1990 Census were computer generated from the TIGER data base. The TIGER files contain data from three primary sources: (1) line segment produced maps from the USGS, (2) existing DIME files (DIME was the geographic base file created for the 1980 Census of Population and Housing), and (3) geographic area relationship files used for tabulating the 1980 Census. These three sources were merged into one integrated spatial data base. The TIGER data base is being used for reapportionment of election districts throughout the country. While it is not a LIS or GIS by itself, it does provide a data base that can be useful in many GIS/LIS applications.

Many of the existing digital data bases are of small scale. For example, the TIGER data base was built from the 1:100,000 USGS map base and is therefore not suitable for use in cadastral-type base maps. However, the TIGER line files are available for each of the 3,000 plus counties in the U.S. The TIGER file contains geographic features, such as roads, railroads, and rivers, as well as census block and tract numbers, address ranges, and latitude and longitude for each point. Therefore, these data are often adequate where small scale maps are relevant, such as for planning and resource management.

Digital base map data are sometimes available from other agencies or companies operating within a jurisdiction. Public to private base map sharing has been accomplished in Milwaukee, Wisconsin, with the city providing their cadastral base map to the utility, thus saving the utility the cost of initial compilation of such a map. In other cases, "private companies also provide digital base maps to local governments on a commercial basis. These files are usually byproducts of the primary service they provide: producing maps, providing GIS software and services, or converting maps to digital form for other organizations" (Huxhold 1991, p. 261). Whatever approach is used, the cost of developing a digital data base map depends upon: which features are converted (e.g., contour lines cost more than curb lines) and the accuracy of the placement of the features (i.e., the higher the accuracy, the greater the cost).

DEVELOPING A BASE MAPPING PROGRAM

In developing a base mapping program, there are a number of factors to consider. These include currently available spatial data, in both hardcopy and digital map form, financial and personnel resources that can be allocated to the process, the scale(s) of products that are to be produced, the accuracy requirements of the system users, the functions that the MPLIS, of which the base map is a part, are to address, and the subject matter of the various data layers that are to be included in the MPLIS. Several of these factors are introduced in Chapter 2. Others are addressed in Chapter 19. Chapter 19 also addresses specifics of base mapping programs, including development of plans and specifications, phases of the program, paneling and ties to the geodetic control framework, ground control surveys, stereo compilation, and producing a finished product. Alternative methods of producing base maps are discussed as well.

SUMMARY

Base maps are a critical component of an MPLIS because these maps record the geodetic, planimetric, and cadastral references to which the many users of the system will add their own special purpose data for display and analysis. Base maps are also important for the users because they can provide a continuously updated record of current geodetic, planimetric, and cadastral information as changes occur over time. Therefore, since the quality and use of data in the system rely heavily on the base map, these maps should be given major attention when constructing an MPLIS. Also, since the cost of mapping can be substantial, careful attention to the true needs of system users and alternative sources of data that can be used to construct and maintain base maps are equally important. As one of the key components of the MPLIS, planning and investments up front can be expected to yield major benefits in the future.

REFERENCES AND ADDITIONAL READINGS

Huxhold, William E., 1991: "An Introduction to Urban Geographic Information Systems," Oxford Press, New York.

Kjerne, Daniel, and Kenneth J. Dueker, 1984: "Two Approaches to Building the Base Map for a Computer-Aided Land Records System," Proceedings of Annual URISA Conference, Washington, DC.

National Geodetic Survey, 1986: *Geodetic Glossary*, National Geodetic Survey, Rockville, MD.

National Research Council, 1980: *Need for a Multipurpose Cadastre*, National Academy Press, Washington, DC.

National Research Council, 1983: *Procedures and Standards for a Multipurpose Cadastre*, National Academy Press, Washington, DC.

Robinson, Arthur H., Randall D. Sale, Joel L. Morrison, and Phillip C. Muehrcke, 1984: *Elements of Cartography*, fifth edition, John Wiley and Sons, New York.

Skelton, R.A., 1972: *Maps: A Historical Survey of Their Study and Collecting*, University of Chicago Press, Chicago.

APPENDIX 12-1
ONEIDA COUNTY CASE STUDY

INTRODUCTION

Oneida County, located in north-central Wisconsin and created in 1887, covers a total area of 779,000 acres of which 74,000 acres are water. There are 34 1/2 survey townships encompassing 1,242 Public Land Survey System (PLSS) sections of land. The County maintains a resident population of approximately 32,500, though it lists 52,200 parcels on the assessment role. This discrepancy is due to the large number of non-resident land and homeowners that visit the County for summer and winter recreational purposes.

Like many other counties in the State of Wisconsin, Oneida County is moving forward in the automation of its land records using GIS/LIS technology. A Land Records Committee was created in 1987 as a standing committee of the County Board to provide guidance on the development of a modern, computerized, parcel-based land information system. An early initiative of this process involved the creation of a base map to provide the foundation for consistent and accurate mapping of county records, including tax parcels, hydrography, soils, the transportation network, etc.

BASE MAP CHOICE

Oneida County considered a number of options to build a base map suitable for their mapping needs. They finally decided to build a digital planimetric base map, stereo digitized from aerial photography referenced to the state plane coordinate system that could be related to the PLSS. County officials felt that a photographic base map referenced to good ground control would allow them to accurately define the relative spatial location of landscape features and analyze the spatial relationships between real property boundaries and other land related data. Due to the County's dense forest cover, numerous lakes, streams, rivers, and irregular transportation network, aerial photography was the quickest and most economical means to construct the planimetric base map.

CONTROL FRAMEWORK

In 1989, the County acquired 1:20,000 photography to support the production of its digital planimetric base map. Leaf-off photography was obtained in order make detection of water boundaries, roads, and buildings easier. A 1:20,000 flight scale was chosen so that 1:2,400 and 1:4,800 scale map production that meets National Map Accuracy Standards could be supported. Prior to the flight, 55 ground stations were selected, monumented, witnessed, paneled, and observed using Global Positioning System (GPS) technology to provide horizontal control for the photography. The selected stations were spaced at approximately two-mile intervals along the County boundary and eleven-mile intervals in the interior. This spacing was dense enough to support the planned flight path and photo tiling strategy. The 55 GPS stations were observed with a 1:250,000 or better precision ratio and meet or exceed Federal Geodetic Control Committee (FGCC) second-order, class I standards. Elevation values (z) were also obtained during the GPS observations to provide vertical control, however these values do not meet FGCC standards. The 1990 total cost of the GPS surveys was $30,000 or approximately $545/station.

Nine hundred PLSS survey corners were also paneled prior to the flight in order to relate PLSS to the aerial photography and to derive approximate coordinate values for the corners during analytical processing of the photography. This was done in order to allow creation of a simple land net to support resource management and land planning purposes. On average, these photographically derived PLSS corner coordinates are correct to within 1.5 feet. To support future parcel mapping activities, survey-accurate coordinates will be determined for all the PLSS corners.

BASE MAP CONSTRUCTION

In order to construct a digital planimetric base map for the County, the 1:20,000 photography and GPS control could have been used to create mylar orthophotograph maps, from which the planimetric features could then be digitally derived. However, production of the hard copy orthophoto would have been an extra, costly step. The County decided to pursue stereo-digitizing instead, where base map features were digitized directly from film diapositives. The method of stereo-digitizing provided two benefits:

(1) planimetric base information, registered to a reference system, could be acquired for virtually the same cost as mylar orthophoto production;

(2) better positional accuracy of base features could be achieved (5-10') in comparison with orthophoto map digitizing (12'+).

Features derived from the diapositives included:

* geodetic reference system (paneled GPS stations)
* hydrography (i.e., lakes, rivers, streams, ponds, reservoirs)
* transportation (i.e., roads listed in the County Emergency Response Inventory, railroads, logging roads, airports, bridges)
* building footprints
* other cultural features (dams, major transmission lines, pipelines, sub stations, etc.)
* land net boundaries (PLSS) based on paneled corners
* annotation (textual information concerning map features)

As a special case, wetlands were not compiled from the photography due to the rigorous classification and delineation standards required by the Wisconsin Department of Natural Resources (WDNR). It was decided that wetlands would be automated at a later date in cooperation with WDNR, following their mapping and coding guidelines.

Oneida County entered into a contract with a private firm to complete the stereo-digitizing. Since the County had earlier selected ARC/INFO as its in-house Geographic Information System (GIS), it was important to find a contractor that was familiar with the software data model and that could deliver the appropriate format. During the bidding process, a number of contractors offered the capability to compile base features in one format that could be converted to the County GIS format. County staff chose to work with a vendor that could deliver in the ARC/INFO data format to avoid potential post-processing headaches that often accompany data conversion efforts.

Stereo-digitizing of base map features included not only the compilation of spatial information, but also coding of features following a predetermined tabular data base design strategy. Oneida County has been party to a multi-county Wisconsin consortium (LOCALIS Project) evaluating GIS data base design alternatives, specifically with regard to feature codes. Consortium discussions have been driven by the need for standardization among Wisconsin counties and compatibility with in-place federal and state data bases. For example, the U.S. Environmental Protection Agency and WDNR both maintain independent waterbody identification schemes for in-house purposes; however, coordination with County spatial data base development activities is also imperative. The LOCALIS Project County Consortium is attempting in part to meet that need.

BASE MAP MAINTENANCE

Natural features of the base map are not expected to change significantly over time and subsequently will need little revision. Natural features include lake shoreline boundaries, river banks, etc. Cultural features will be subject to more change and require a mechanism for update. Current subdivision regulations and zoning ordinances are a mechanism to track new or destroyed buildings and new road locations. Alterations of the administrative boundaries (i.e., municipal annexation), are usually filed in the Register of Deed's office. Other contributing parties will include town assessors, local fire departments, utilities, school districts, and city, state, and federal agencies. Many of these parties will likely be using the planimetric base map and other digital layers derived from the base (i.e., tax parcels) to meet their legal mandate and/or public service responsibilities. This common spatial and tabular data base will hopefully facilitate the inter-departmental and organizational communications needed for regular maintenance.

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13 THE PARCEL MAP

Earl F. Epstein and D. David Moyer

INTRODUCTION

This chapter is a discussion on parcel maps. In this discussion we consider:

- purposes for which parcel maps are created and maintained,

- the basic approaches that are used in the construction of parcel maps, and

- possible factors that are important in the design and implementation of a parcel mapping program.

Other chapters related to parcel mapping that are relevant to the discussion presented here include:

- Chapter 2 Introduction to Mapping Concepts
- Chapter 12 The Base Map
- Chapter 19 Mapping: Methods and Procedures

As in Chapter 12 on Base Mapping, the thrust of this chapter is on what a parcel map is, why a parcel map is needed, and how one goes about classifying parcel maps and their contents. Readers will find specifics on HOW to construct and maintain parcel maps in Chapter 19, where such matters are discussed in some detail.

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DEFINITION

A parcel map requires a fundamental unit - a parcel. This unit of land, the parcel, becomes the building block for information management, including information about land rights and interests. The parcel is also used in maps as the representation of the units themselves.

There are many land rights and interests, each right or interest representing a stick in the bundle of legal interests in a community. A parcel is an unambiguously defined unit of land within which a bundle of rights and interests are legally recognized in a community. A parcel encloses a contiguous area of land for which location and boundaries are known, described, and maintained, and for which there is a history of defined, legally recognized interests. The concept of a parcel has been defined as follows:

"A parcel is a continuous area of land described in a single description in a deed or as one of a number of lots on a plat, separately owned, either publicly or privately; and capable of being separately conveyed. For ease of indexing data, a segment of a street, highway, railway right of way, pipeline, or other utility easement may be treated as though it were a parcel" (Moyer and Fisher 1973). Determination of parcel boundaries on the ground defined in this way requires a sorting out of various other interests in land that are legally recognized. These parcels may or may not be coterminous. Generally, but not always, the primary interest is land ownership, as commonly understood, associated with those rights and interests that may be acquired and transferred.

Normally a parcel map represents the parcels from a specified area such as a region, county, township, Public Land Survey System (PLSS) section, municipality, subdivision, or some other defined area. The parcel map includes the boundaries of the land interests for these parcels. The parcel map may be called by a variety of names, including plat map, assessor's map, tax map, or cadastral map. Each map represents a compilation of land records specific to the particular map. However, the content, symbology, scale, accuracy, currency, completeness, and consistency vary widely among these common, specific parcel maps.

PURPOSES AND USES OF PARCEL MAPS

Parcel maps were developed and are used for a variety of purposes. These include:

1) an index to data and information about the parcel,

2) a representation of the boundaries of several related parcels, and

3) a basis for land-related decisions.

For example, tax assessor parcel maps are often used as indexes to assessment files, and as a means to visually display information to citizens about their particular lot. Surveyors prepare plat maps to denote the shape, relationship, and location of groups of parcels in a plat, as well as individual ownership parcels. Governments, particularly at the local level, use parcel maps to plan and manage the provision of a wide variety of services. Therefore, parcel maps are extremely useful, widely used, but still not universally available in all jurisdictions.

In its simplest form, a parcel map depicts in graphical form the boundaries of those particular sets of interests which are included in the bundle of rights for the land parcels.

For the common set of interests associated with land ownership, the boundaries are often described in terms of metes and bounds. However, existing parcel maps, compiled for a variety of purposes, and relying upon information whose sources are often not clear, make the compilation of parcel maps for an MPLIS a demanding task. The following are examples of the problems and decisions a parcel mapper typically faces as parcel maps are compiled, updated, and used.

1. Division and combination of parcels: One or more parcels that do not share a boundary line for one purpose are sometimes treated as a single parcel for other purposes. For example, two parcels which originated in separate ownership but are now owned by one person may be treated as one for purposes of tax billing.

Another example involves subdivision and re-subdivision of parcels. Parcel maps often show subdivided lots even when two or more must be combined to make a buildable lot, but some jurisdictions do not require a recorded re-subdivision for this combination. Alternatively, the map may show the re-subdivision as originally divided, with a tie bar indicating the association.

A third example involves lot combinations and splits. Owners may request the assessor to combine two lots, or split one lot into two, without any other action or survey recorded. In all of these examples, parcels which at one time were distinct are now combined or divided.

2. Easements: The treatment of easements on parcel maps varies widely. Some parcel maps show publicly held easements; some show any easement that affects assessed value; some show recorded easements only; and some do not show any easements at all.

For example, drainage easements and other areas that are dedicated to the local government as part of a subdivision may be indicated on the parcel map. Other interests from the "bundle of rights" such as zoning and tax districts are often treated as a separate map (or overlay), or separate attribute file. Many easements have never been recorded and even today, many jurisdictions do not always require their recordation.

3. Inconsistent descriptions: Some descriptions refer to land corners. Others refer to offsets from an engineering base line which are more likely to be tied to geodetic control monuments. Some refer to physical features, such as the midpoint between two

railroad rails, the removal of which make reestablishment of the right-of-way (ROW) boundary difficult and expensive.

4. Alleys, access roads, and private roads: These often appear on maps that are made from aerial photographs, but those that are not created by a recorded instrument, such as a subdivision or easement, often do not appear on parcel maps.

5. Subsurface and air rights: These sticks in the "bundle of rights" are sometimes sold separately. They may or may not be included on parcel maps. Cases of elevated freeways or viaducts that pass over surfaces that have other uses can be examined to determine whether such rights are included on the parcel map.

6. Condominiums and time-share units: Unlike two-dimensional parcel descriptions, these units often have height and time dimensions as well. These dimensions, that are critical to accurate parcel descriptions, are difficult to show on parcel maps. Areas of common ownership present similar difficulties for the parcel mapper.

7. Commercial, industrial, and institutional parcels: These parcels refer to the use of parcels, as opposed to parcels that are owned by individuals for purposes such as residential.

8. Publicly-owned lands: These parcels are sometimes not included in jurisdictions in which they do not generate property taxes. In other cases, assessors are required to assess and map them, even though taxes are not collected. For example, these parcels may be taxable if leased for certain purposes in some jurisdictions. Procedures to update the transfer of private-to-public and public-to-private transfers may not include map updates on a regular basis.

9. Ambulatory (movable) boundaries: Some parcel boundaries are determined by the position of natural features, typically water (e.g., rivers, streams, lakes). These boundaries are often determined in a manner and timeliness different from boundaries established by human action.

Mapping of parcels will often reveal inconsistencies among the description of the same and related parcels that are displayed on the map. Efforts to resolve these inconsistencies when constructing the map can result in a long, expensive process. A reasonable approach is to map the parcels, relying on those descriptions contained in the attribute files (such as deeds, mortgages, and tax descriptions), which are, in the judgement of the mapmaker, the best representation of the parcel boundary. Then a carefully designed procedure is followed to refine the map over time. This refinement may, in some cases, require the use of land surveys, legal agreements, and court proceedings. The final product, no matter what the process, is a representation of the parcels whose usefulness depends upon the quality of the mapmaker's judgement and that of the underlying descriptions.

The development of parcel maps involves a series of integrated operations that involve compiling land parcel information and preparation of a graphical representation of this information. Ideally, the geodetic framework and base map will be in place before development or revision of the parcel map layer. Chapter 19 provides guidance as to how to proceed when these ideal conditions cannot be met.

DESIGN FACTORS FOR A PARCEL MAPPING PROGRAM

The following is a checklist of factors that should be considered when designing a parcel mapping program. Discussion and agreement by as many system users as can be identified, hopefully by consensus, will help avert problems later.

1. Reach agreement on scale, format, accuracy, and content, in addition to parcel boundaries, parcel definition, timeliness, and specific features that are not to be included.

2. The expressed and implied needs of each office, agency, organization, and individual who will use the parcel map should be defined in terms of item 1. above.

3. Establish processes with information providers for the specific records and their attributes that will contribute to the parcel map, with particular attention to the definition of the quality of each record.

4. Determine which office or offices has the responsibility for design decisions and arrangements for execution of the parcel mapping plan.

5. Determine whether the parcel map will be built on a day-forward basis or whether maps will be available for all parcels on a specified target date.

6. Determine how the parcel map is related to the base map for the same area and the set of land records which it serves to integrate.

7. Determine how gaps and overlaps among the parcels will be resolved if they appear on the parcel map.

8. Determine how the final product will be represented and characterized for external and public users.

USES AND USERS

Parcel maps information is linked closely to the functions of local government since so many local government functions are related to parcels and their attributes. The primary uses of parcel maps among local government agencies are:

- property assessment
- planning and engineering activities
- management of title records
- management of public utility and service systems.

In addition, parcel maps are used by both public and private people in ways not intended by those who participate in their construction. This situation requires parcel mapmakers to anticipate as many uses as possible and to adopt practices that reflect appropriate diligence in map construction and maintenance, and the provision of as much data as possible about the attributes of parcel map data used.

SCALE

An appropriate scale for the paper product that represents parcels is the smallest scale that legibly shows all the information that is appropriate for that product. Different products may be prepared for different purposes. Parcel size and density of descriptive information that are to be included are the most important factors in selecting an appropriate map scale in this way. Since use and density of information usually vary, even within a jurisdiction, it is not uncommon for several map scales to be used. Parcel map scales typically range from 1"=50' (1:600) to 1"=800' (1:9,600). (See Table 13-1.) Comparable metric scales can also be used. Larger scales may be used in urban areas with high parcel density, with smaller scales used in rural and lesser developed areas with larger average parcel size.

CONTENT

Parcel maps generally include some or all of the items listed in Table 13-2. Due to the variation in scale and intended use, parcel maps may not contain information on all items or may contain incomplete information on some items. For example, parcel dimensions may not be shown because such information would crowd information on the map. Sometimes only street frontage dimensions are shown, since this item is often used as one of the factors in appraising value. In blocks where all the lots are of the same size, the dimensions may be shown only once. Other shorthand techniques may be used so that determination of parcel numbers and other information requires users have familiarity with the coding schema used. In some circumstances, specific information is not included because the data from which it is obtained are suspect.

Table 13-1: Typical parcel map scales

The following are commonly used mapping scales:

- o Urban areas: 1" = 50' (1:600) and 1" = 100' (1:1,200)
- o Suburban areas: 1" = 200' (1:2,400)
- o Rural areas: 1" = 400' (1:4,800) and 1" = 800' (1:9,600)

Taken from *Standard on Cadastral Maps and Parcel Identifiers*, IAAO, 1988, p. 7.

Automation of parcel maps often requires a change in procedures as to map content. For instance, in an automated system, dimensions of each parcel must be maintained in the data file, including provisions for dimension annotation on each parcel.

Table 13-2 also lists supplemental map information. This information may be on the parcel map, or it may be maintained separately. For instance, several of the items are often maintained on the Base Map that was discussed in Chapter 12.

MAP SHEET SIZE AND LAYOUT

Flexibility in scale and size of output information is one of the advantages of automated map data storage and manipulation. However, it is still a good idea to reach agreement on the common representations of parcel maps, including map sheet size, map name and numbering schemes, and similar attributes.

Multisheet map series typically use a grid of some sort to divide a large area into separate areas represented by separate paper products or map sheets. PLSS sections, quarter sections, or other comparable areas are often used. Provisions must still be made for odd sized areas along the west and north edges of PLSS townships for government lots and for land grants. The U.S. Geological Survey uses regular increments of latitude and

Table 13-2: Contents of the parcel map

Basic Information. Cadastral maps should contain the following:

- Boundaries of all parcels
- Parcel dimensions or areas
- Block and lot numbers and, if scale permits, names and boundaries of subdivisions and plats
- Boundaries of geographic subdivisions, for example, section, township, and range; government lot boundaries and numbers; land districts, land lots, and numbers
- Location and names of streets, highways, alleys, railroads, rivers, lakes, etc.
- Parcel identifiers
- Other basic map information including a map number, title block, revision block, legend, map key, north arrow, and keys to adjoining maps.

Supplemental Information. Supplemental parcel information should be recorded on overlays or a computerized data base. This allows access to as much or as little data as required without changing the original maps. It also facilitates use of the map data by other users.

Commonly collected supplemental information includes the following:

- Right-of-way and easement boundaries
- Names and addresses of parcel owners
- Assessed values
- Locations of improvements
- Street numbers
- Monumentation network coordinate listing
- Zoning information
- Special districts (e.g., voting)
- Sewer and water lines
- Waterways and county drains
- Topological and topographical information
- Soil types
- Sales data
- Deed and survey reference information.

Taken from *Standard on Cadastral Maps and Parcel Identifiers*, IAAO, 1988, p. 7.

longitude for map sheet boundaries. State Plane Coordinate System, arbitrary, or even irregular grids can be used. Whatever system is chosen, it should conform to a uniform standard map sheet style, an easy reference system for identifying individual map sheets, and be suitable for use with other map products in the jurisdiction, such as the base map. Figure 13-1 (a-d) contains several map identification schemes.

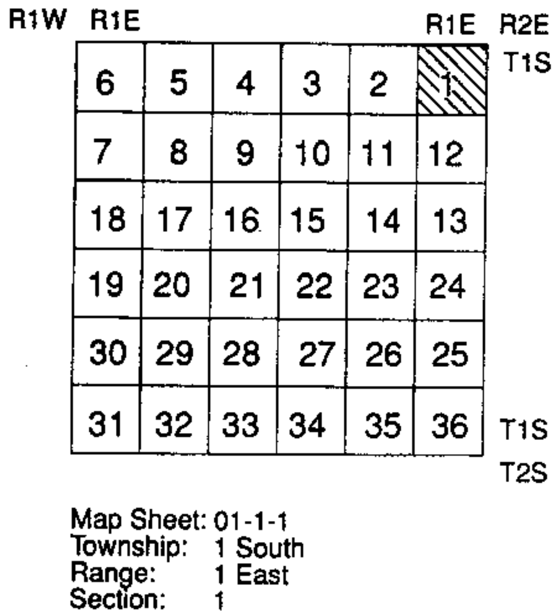


Figure 13-1a: PLSS Township, Range, and Section Map Designation

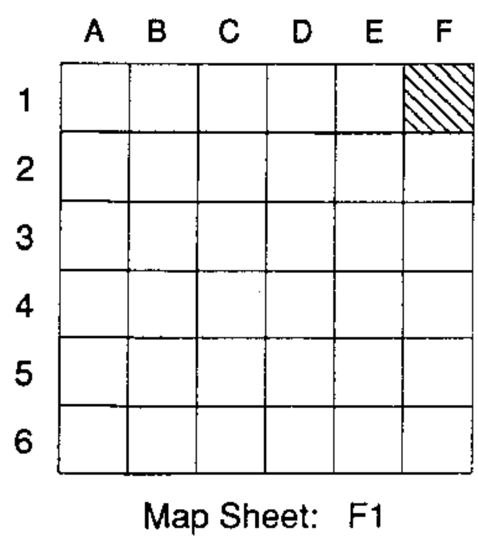
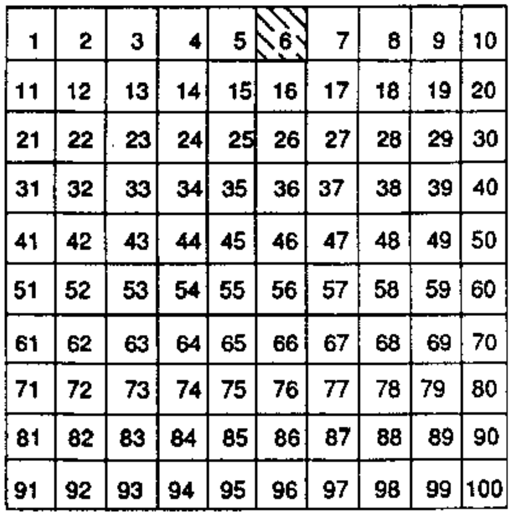
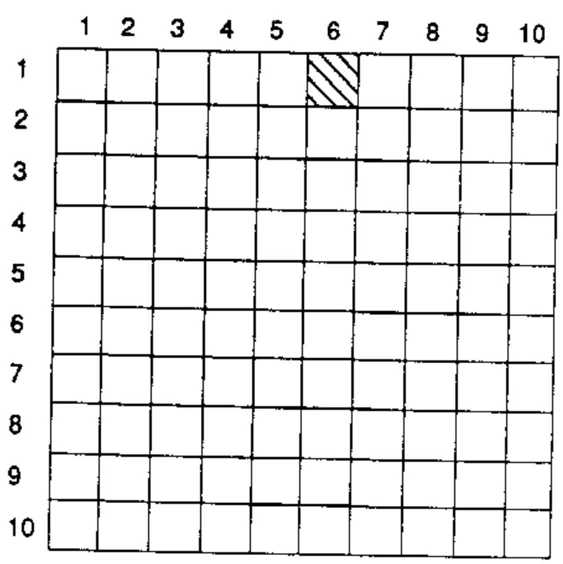


Figure 13-1b: Arbitrary Coordinate Map Designation for PLSS maps



Map Sheet 6

Figure 13-1c: Numbered Grid Map Designation



Map Sheet 1-6

Figure 13-1d: Arbitrary Coordinate Map Designation

MAP COMPILATION

Five major tasks need to be considered when actually developing a parcel map system. These tasks include:

1. Assembling and weighting the source data
2. Constructing a framework for the parcel maps
3. Compiling the boundaries of parcels
4. Adding notation as needed
5. Maintenance.

ASSEMBLING AND WEIGHTING SOURCE DATA

The first task in the creation of a parcel map is to assemble relevant records from appropriate sources. These sources include:

1. Title records
2. Assessment records
3. Infrastructure records (highways, utilities, transmission lines, etc.)
4. Land use and zoning regulation records
5. Resource and environmental records
6. Court records
7. Survey records (plats, plans, and surveyor notes).

These records may include graphics (maps and sketches) as well as attribute data from nongraphic record files. (See Chapter 9.)

The location of property boundaries requires consideration of boundary evidence in two forms: documents and observations of the land. This written and physical evidence must be gathered, evaluated, and arranged in order to make a judgement of the status of the boundary. The judgment must be consistent with rules of law and practice. Application of these rules to evidence in a specific situation is not a mathematically precise activity.

Each significant land transaction between parties is an opportunity to observe, measure, mark, and describe the extent of rights in land. The resulting representation or description is specific to the transaction and can appear to be independent of earlier delineations. However, it must be properly related to previous descriptions which purportedly apply to the same property but which may or may not be the same in form or detail. The physical and documentary evidence must be evaluated, and priorities assigned to this evidence before a conclusion is made about the extent of property rights. The most recent description, or the one with the most precisely measured distance, may not properly represent the boundaries because it is the result of an incorrect or inappropriate conclusion about the evidence. Correct conclusions, measurements, demarcation, and description are the result of a proper application of the rules of law to the set of boundary records and observations.

The order of importance of boundary evidence, written and physical, is as follows:

a. *Right of Possession.* This is a right based on long possession irrespective of any intentions and actions expressed in writings. In circumstances defined by law, the extent of rights in land is established by long use. Descriptions and markers set according to these descriptions yield to considerations of long use, regardless of other considerations.

b. *Senior right.* This exists when current or recent boundary evidence for adjoining properties reveals an overlap, and the properties share a common history in the sense that they were created from the same larger property. For example, a grant of the southern half of a property establishes a senior right in the grantee who receives the southern half. This right prevails even if a mistake is made in delineating and demarcating the new parcel at the time of the grant or in subsequent surveys and descriptions. The points here are that (1) there may be no uncertainty when the law is applied to evidence of a boundary established at the time of the grant and (2) the overlap may be the result of an easily identified, incorrect conclusion whose effect has been perpetuated in a series of subsequent descriptions. Thus, the appearance of an overlap in the representation of independently described properties is not necessarily a legal problem.

> An overlap suggests, but does not establish, a senior right. Sometimes, reference to an adjoining property is suggestive of a senior right. However, because adjoining properties can be described independently in subsequent transactions, it is not uncommon to find reference to adjoining properties inserted in descriptions subsequent to property creation. These conditions highlight the rule that determination of the status of boundary requires an examination of the title and boundary history.

c. *Conflicting Elements*. The material above indicates that the intention of the parties who create a property are disclosed by documents prepared and actions taken at the time the property is first established. Subsequent observations and descriptions (i.e., surveys) are efforts to redetermine and reestablish the intentions and actions of the original parties. The documents and actions are evidence of these intentions and actions. Their appropriateness and weight is determined according to the rules of law.

A search of the title and boundary documents and an examination of the property can reveal an array of measurements, names, objects, land features, locations, addresses, and other items used to distinguish and demarcate one property from another. These elements may or may not represent the same location on the ground. To complicate the matter further, a single description in a transfer document may contain several elements which, when considered in the field, may or may not be in conflict. A single description may refer to an adjoining property, a natural monument, an artificial monument, a distance, an area, etc. For example, a description that reads "...300 feet to an iron pin at the road..." contains at least three points that may or may not be at the same place on the ground --- the terminus of the 300 feet, the iron pin, and the road. Whether these elements are in conflict is not ascertainable from the documents, but only from observation of the land. Therefore, it is premature to declare that a conflict exists before a full investigation of both the documents and the land.

A general priority among elements used to distinguish, delineate, and demarcate property can be described based on law and practice. The order is not absolute. It varies according to the law and practice in a particular jurisdiction. The date of the document and action is important. It applies where the parties reduce their intentions to documents, actions, and descriptions. The general priority is as follows:

(a) Monuments placed and referred to in the transaction document that creates the property and expressing the intention of the parties. The transaction document that creates the parcel may refer to monuments explicitly or implicitly as in the case of references to the "northwest quarter of section 10..." or to a subdivision plat which refers to monuments. Subsequent monuments must be defendable as a representation of the original intent and monumentation. Generally, natural monuments, such as rivers and geological features, prevail over artificial monuments such as pins set in the ground. Natural and artificial monuments generally prevail over what are called records monuments, which are references to such features as roads, mentioned in connection with artificial monuments in the example above.

(b) Distance

(c) Direction

(d) Area

(e) Coordinates.

It must be emphasized that this ranking is not absolute. Even in a state where an examination of statutes and cases reveals that this priority is appropriate, it is likely that the facts in a specific case may result in a variation. The facts and testimony of the observer give a weight to the evidence, which can, in some circumstances, alter the general priority. A well trained surveyor should be consulted to help resolve inconsistencies and conflicts.

The boundaries of parcels are established by documents and actions taken at the time a parcel is created and by subsequent effort to sustain the intentions and actions taken at that time. Subsequent activity is measurable against evidence which can be shown to be more consistent with the original efforts. Therefore, it is not proper to assume that a recent description with measurements by the most modern and precise instruments determines the boundary. The lesson here is that a parcel mapmaker must indicate what data are used to make the map. These data can range from a representation of the most recent description of a single parcel, to a depiction of the results of a complete title and boundary examination and judgment for all parcels in a jurisdiction, with every combination between these extremes. Full disclosure of the nature of material that contributes to the parcel map is essential.

CONSTRUCTING THE FRAMEWORK

As noted throughout this Guidebook, the geodetic reference system is the basic framework or layer on which all of the MPLIS rests. (See Figure 11-1). In addition, the base map, tied to the geodetic reference system, provides further orientation for parcel map information. Building on these two basic layers, parcel maps are compiled and maintained.

In PLSS states, section corners and quarter corners may be sufficient to establish a framework for the parcel map. This is true if corner locations are known to an accuracy consistent with the required needs for information derived from products based on those locations, such as the parcel map. The spatial relationship between each boundary and the monuments to which it is tied must be known. However, the spatial relationships among monuments and therefore among monuments, objects, and boundaries, are frequently unknown. Therefore, the distinction between local survey control, such as a well maintained PLSS, and the geodetic reference framework becomes important.

It is important to remember that parcel boundaries generally cannot be directly observed on the ground or on aerial photographs except where conspicuous objects or activity demarcate the boundary. To compile a parcel map, it is necessary to establish a link between the parcel map framework, such as the local reference network, and the geodetic reference framework, to ensure that relationships between parcels and geographic features that can be observed in the field, are accurately reflected on the map.

Unfortunately, it remains true that in many PLSS states, existing parcel maps were created with boundary data compiled under the assumption that the reference framework consists of perfectly square PLSS sections. Since sections are usually NOT square, such an assumption about the overall geometry of parcels in an area creates problems when monumented positions based on that assumption are used to relate locations of objects and boundaries found on aerial photographs and other geographical representations.

Further details on how to build and use the framework needed for a parcel map program can be found in Chapter 19.

COMPILING PARCEL BOUNDARIES: GAPS, OVERLAPS, AND COMPLETENESS

Once relations between locations that constitute the framework are determined, the process of placing parcels within the framework begins. This process depends upon a prioritization of the parcel records and data as suggested above.

Standards and procedures for compilation and maintenance of maps must be documented and consistently followed in order to reduce liability for their use. Use of such standards is particularly important as an MPLIS is automated, whether or not the compilation is handled by a contractor outside the government agency itself (Epstein and Roitman 1987).

While all aspects of parcel mapping are important, particular attention should be focused on ensuring that all parcels are accounted for. Usually, the best available tool for such a check is the current assessment record. However, many jurisdictions do not include tax exempt parcels in their assessment files. Also, there are examples where as many as 20 percent of parcels in a jurisdiction are not in the current assessment record. A variety of procedures can be used for resolving such errors of omission, including field surveys. (Chapter 19 contains additional details on this process.)

ADDING ANNOTATIONS

Annotation is often one of the most time-consuming tasks in constructing parcel maps. Cartographic skills are required to place dimensions, parcel identifiers, subdivision names or references, block numbers, and other information on the map so it can be read and interpreted easily. Consistent lettering styles for each class of information contributes to legibility, as do general rules to govern the placement, angle, and orientation of text. In a computer mapping environment, the annotation rules are important in realizing the potential for flexible display of the data. Figure 13-2 shows the variety of information and the potential density of annotation. Placement of annotation on a separate layer increases the flexibility of mapping. However, caution in using this approach is necessary in automated mapping, especially when map output is often produced in a variety of scales which affects the density and placement of annotation. Good annotation is also crucial for the reduction of liability for use of the map products.

MAINTENANCE OF THE PARCEL MAP

Maintenance of the accuracy and timeliness of the parcel map is crucial if it is to serve its role as the basis for integrating a variety of parcel-related records and information. This point cannot be overemphasized. Parcel maps already exist in many jurisdictions. Development of a parcel map program does not automatically produce an MPLIS. The parcel map remains an historical document when it is produced if no provision is made for maintenance. The parcel map becomes part of the process labeled an MPLIS when it remains timely and accurate and the basis for

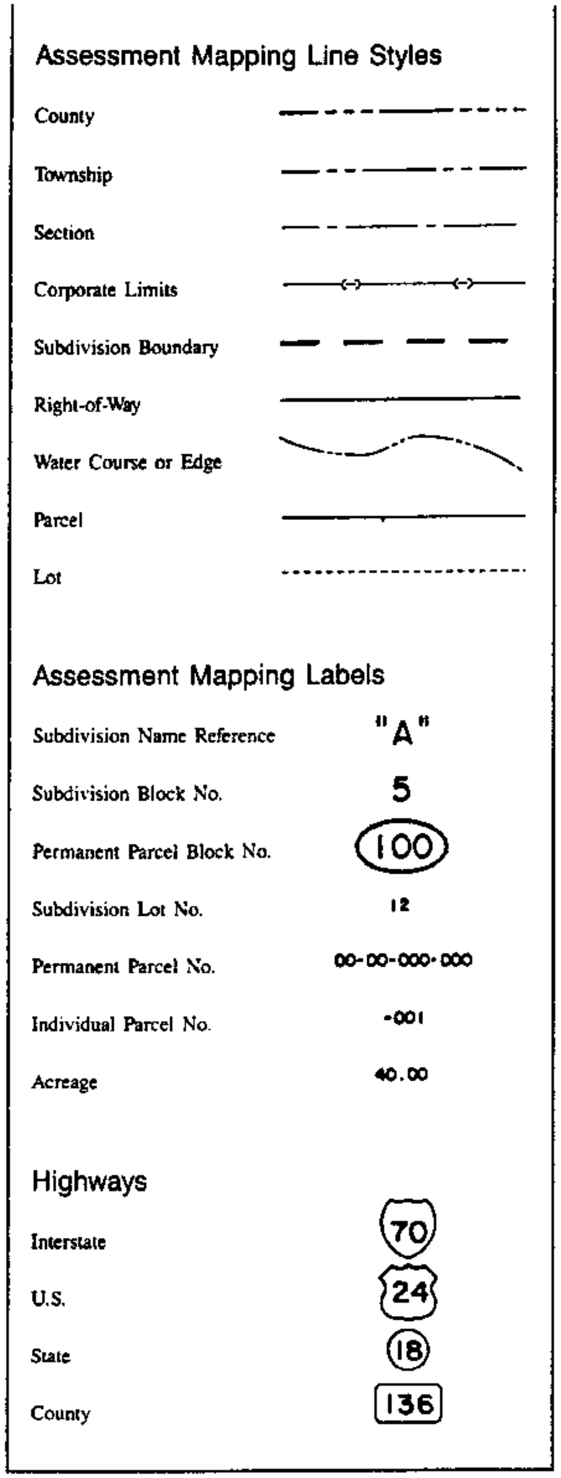


Figure 13-2: Typical Map Symbols (IAAO, 1988, p.8)

unique parcel identifiers that are attached to all parcel-related documents and for the general process of indexing parcel-related data and information.

The National Research Council (NRC) recommends that "the updating of [parcel maps] be scheduled so as to assure that they will reliably show any new or changed land parcels that have been in existence for two weeks or more. Where overlays are used by the recorder of deeds to display the parcel numbers used for indexing land-title records, this updating should occur within one week" (NRC 1983, p. 56). Achievement of goals such as this requires mechanisms exist for the unfettered flow of data between data gatherers and mapmakers.

Those agencies whose mandated activities rely on timely, accurate, and complete parcel boundary information are the logical ones to initiate and maintain the parcel map. Individual transactions that affect one or a few parcel boundaries, and result in boundary descriptions, are handled by subdivision review, planning, engineering, surveying, probate court, clerk, highway, register of deeds, building code inspection, and other offices. The assessment office is regularly concerned with all parcels in a jurisdiction. The important point is to assure that timely, complete information of known accuracy flows to the parcel mapmaker.

SUMMARY

Development of parcel maps is a crucial step in the development of an MPLIS. The parcel is a concept associated with rights and the relations between people in regard to land and its product. These relations are complex and basic in a community. Thus, a parcel is a complex concept and entity. Parcel maps found in local government offices reflect this complexity. The parcel map is a spatial representation of interests in land that were described in Chapter 4.

Parcel maps build on the base map layer, using a geographic framework to relate the locations of parcels within the parcel layer and to other MPLIS layers. A variety of records that delineate parcel boundaries are used to fit parcels together in a geographic representation. In order to create and maintain a parcel map of known and described quality, it is necessary to establish and supervise a process that ensures the unfettered flow of these records and their use according to appropriate standards.

REFERENCES AND ADDITIONAL READINGS

Brown, C.M., W.G. Robillard, and D.A. Wilson, 1986: *Boundary Control and Legal Issues*, Chapter 5, "Locating Sequential Conveyances," 3rd edition, John Wiley and Sons, New York.

Epstein, Earl F. and Howard Roitman, 1987: "Liability for Information: Speculation and Theory," Proceedings of Annual URISA Conference, Ft. Lauderdale, Florida, Vol. IV, pp. 115-125.

Huxhold, William E., 1991: *Urban Geographic Information Systems*, Oxford University Press, Oxford, England.

International Association of Assessing Officers, 1988: *Standard on Cadastral Maps and Parcel Identifiers*, International Association of Assessing Officers, Chicago, Illinois, 41 pp.

Moyer, D. David, and Kenneth P. Fisher, 1973: Land Parcel Identifiers for Information Systems, American Bar Foundation, Chicago, Illinois, 600 pp.

National Research Council, 1983: *Procedures and Standards for a Multipurpose Cadastre*, National Academy of Science, Washington, DC, 173 pp.

14 GETTING STARTED: HOW TO ORGANIZE YOUR IMPROVEMENT EFFORTS

Stephen J. Ventura

GIS-RELATED TECHNOLOGY IN LAND RECORDS MODERNIZATION

Hardware and software for automated land information systems (LIS) have become affordable and accessible at every level of government. Computers now offer data storage and instruction processing capacities rivaling computers costing many times as much a decade ago. Commercial software for both geoprocessing and database management has also become available, affordable, and understandable.

The commercialization of technology-based solutions for land records has set in motion a process that will have far-reaching effects on decision making in local government. Many departments and agencies are interested in implementing land information systems. It has been suggested that most decisions made by local government require some kind of information related to spatial reference. Many offices of planning, transportation, public works, emergency services, assessment, land conservation, and real property listing clearly can benefit from automated, integrated land records systems. Many other county and municipal departments and private companies such as utilities and real estate interests that use maps or other spatial data can benefit as well. Land records reform through automation has become a major goal of local governments across the United States.

But an LIS cannot be implemented simply by buying hardware and software. These and other components of a system must all be carefully matched to an organization's needs and characteristics.

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When computer-based technologies have been determined to be appropriate for a jurisdiction's land records modernization process, it is important to begin an implementation carefully. Many of the initial decisions made before and during implementation can have profound effects on the long-term efficiency and effectiveness of a system. These initial decisions include how people learn about the system, how needs assessment, requirements analysis, and system design are conducted, and who is involved in these processes.

Other chapters of this GUIDEBOOK offer information on specific problems. Technical issues, such as user needs assessment and functional requirements analysis, discussed in Chapter 16, should help an organization determine the scope of a project, which departments and applications to include in a system, what kinds of data to automate, and which preliminary decisions about system design must be made to write effective requests-for-proposal (RFPs) for hardware and software. Institutional issues, such as funding and benefit/cost analysis (Chapter 15), organizational and administrative changes (Chapter 8), and institutional arrangements and cooperative agreements (Chapter 17) need to be considered during implementation as well. Chapters on automation (Chapters 21-24) detail hardware, software, systems design, and particularly data-related issues such as sources, conversion strategies, integrity, compatibility, and management. Addressing technical and institutional issues provides a sound foundation for the negotiation, persuasion, compromise, insight, and risk-taking necessary to implement an LIS.

The purpose of this chapter is to instruct the reader on the very first steps in implementing an automated LIS -- selling the vision, laying the groundwork for understanding technical and institutional issues, assessing methods for learning about LIS, and determining the initial scope of a project. This latter decision, early in the implementation process, can be critical. An organization must find a balance between including enough participants to achieve the benefits of an MPLIS and keeping the project small enough to be manageable and affordable.

Much of this chapter is based on the assumption that the group or individual responsible for local land records modernization will "cast its net" broadly to involve many departments and agencies in a land information system that provides benefits for a broad group of public and private users. Whereas it is possible to automate the function of a single office or limited group of offices, positive benefit/cost ratios are most often found when many users can share data, technical expertise, equipment, and costs. Although it might require more effort to start a system that meets the needs of many users, long-term benefits are more likely to result, and the benefits are likely to be larger.

Including others requires commitment to and agreement on data handling. One model for an MPLIS (Chapter 7, Figure 7.5) includes data custodians -- agencies or offices with statutory responsibility to maintain land records who have agreed to maintain automated land information in a form and format such that it can be shared with other groups as needed. To be successful, this requires institutional agreements on issues such as a common geodetic reference framework, data exchange, and quality standards. As a consequence, the initial contact with and education of potential participants is an important part of "getting started."

OVERVIEW OF LIS IMPLEMENTATION

LIS implementation typically follows a sequence of about six distinct steps or stages. This chapter provides detailed information on the first step -- the introduction of the technology. Other steps are discussed in depth elsewhere in the GUIDEBOOK, but this section provides a brief overview of those other steps to help the reader begin to construct a picture of how to organize implementation efforts.

An organization must first be introduced to new ideas and methods -- the technology introduction -- both to convince people in an organization to give the new methods a chance and to explain the implementation process, particularly the next step, which requires their direct participation. This next step, commonly called a "user needs assessment," examines current and prospective land records activities, considering people and how they use the data.

After the "people" side of record keeping and use has been examined, the next step, "system requirements analysis," is to determine what will be needed to automate the procedures and analyses. This must include the hardware, software, and personnel resources needed to automate, maintain, update, and access the data in an automated, integrated system.

A system design can be developed after requirements in terms of information, software, hardware, institutional arrangements, and other system components are determined. This should be accompanied by an implementation plan, which specifies how to get from current methods to the envisioned system. When the system is finally ready to run, pilot projects can be undertaken to gain experience and support for the new system before major changes are made in operating procedures.

TECHNOLOGY INTRODUCTION

A technology introduction includes exposure to GIS concepts, hardware, and software prior to adoption by an organization. Vendor seminars, workshops, conferences, booklets, and demonstrations are all suggested means for this preliminary preparation and education. In many cases, technology introduction is also part of the process of convincing decision-makers to invest in the technology. It is also helpful to present the process and expectations of the needs assessment and requirements analysis to potential users, so they are prepared to explain their use of spatial information in their day-to-day operations.

USER NEEDS ASSESSMENT

The purpose of a needs assessment is primarily to identify potential LIS users, determine what users do, how they do it, with what data and analytic techniques, and how they might be able to take advantage of LIS technology. The needs assessment typically covers:

- who uses an organization's land records?
- what kinds and forms of data are managed?
- how are data used: what analyses are done; what decisions are made; what information products are generated?
- how often are the various types of records accessed and updated?
- who has the responsibility for data maintenance?
- what improvements might be possible through automation: what can users do more effectively or efficiently; what is possible that wasn't possible with manual methods?

The needs assessment almost always consists of surveys and interviews with potential users of LIS, and might be supplemented by examining existing studies, documents, and legislation. Needs assessment can identify the goals and objectives of the LIS, the bounds of the project, and the connection of the LIS within and beyond an agency, as well as additional detail about specific applications.

The expectations from needs assessment vary widely. Results of an assessment can range from being the entire basis for system design to being completely data oriented. In addition to exploring the data needs and types of applications of spatial data users, areas of inquiry include frequency of transactions, the rates of information flow, the accuracy and currency required for various uses of data, the frequency and types of requests, and the required speed of delivery. In many cases, a user needs analysis can provide an assessment of the level of knowledge of users, as well as some indication of how much time and effort must be expended on training, application software, and user interfaces.

A user needs assessment can play a fundamental role in facilitating system design. This is especially helpful if an organization starts without strong preconceived notions of which particular LIS software and system design are most appropriate. Software vendors who also implement systems might be interested in adapting their products and services to users' needs, and so concentrate primarily on tasks and data and how their proposed solution can manage them, without dealing with organizational and institutional aspects of design.

Some user needs analyses have been criticized for missing opportunities that LIS offers. Users unfamiliar with the capabilities of the technology might not be able to adequately verbalize their spatial data problems and might not be able to conceptualize what can be done with LIS. In the user needs process, users must have a sufficiently adequate understanding of LIS to "dream big" -- to be able to envision what they might do with an automated approach, things that were too costly or complicated to do with manual methods. In most cases, LIS can do much more than simply automate existing procedures.

SYSTEM REQUIREMENTS ANALYSIS

This analysis is the process whereby user needs are translated into the technical requirements of a system, including hardware and software configurations, data sources, and data management procedures, data accuracy requirements, and the kind of information products that need to come from the system. A requirements analysis determines what will be needed in terms of:

- software functionality;
- computer hardware and peripherals, including input and output devices;
- data storage volume and data access speed requirements;
- data standards, including data quality and data exchange;
- technical expertise, staffing, training;
- system startup and maintenance costs.

This analysis can be done in combination with either user needs assessment or systems design in step-by-step implementation procedures. If the objective of this process is to develop an RFP, requirements analysis should include specifications for needed LIS software functions as well as hardware requirements. A requirements analysis might include a technology assessment to make sure that expectations of the system are reasonable. Requirements analysis might consider additional factors such as staffing, physical workspace needs, support personnel (especially programming support), security considerations (for data and equipment), and cost accounting and efficiency measures.

Of primary concern in requirements analysis is determining software functionality -- its capability and capacity for LIS applications. The elements of functionality -- for example, data automation, management, analysis, and display functions that LIS software is capable of -- can be used to determine what will be required in an RFP, given present and future applications. Hardware represents a substantial part of an initial investment in LIS, but the considerations are straightforward and secondary in importance. Basic advice is to "buy the fastest machine with the most memory that is within your budget." In general, software should be selected first (or simultaneously); the "platform" must support the software that is chosen. Some additional requirements concerning data models, system design, and integration of new technologies into an organization should be considered before making a commitment to a particular hardware and software solution. It is appropriate to develop RFPs only after an organization has a strategy for evaluating software and hardware needs (benchmarking) and for effectively organizing and using these new tools.

The Federal Interagency Coordinating Committee on Digital Cartography (FICCDC 1988) provided a good list of generic GIS functionalities that can be used to guide the selection of software requirements for specific applications. Table 14-1 is a list of generic GIS functionalities, modified and enhanced from the FICCDC list. The FICCDC report also includes a list of hardware components and some evaluation criteria.

SYSTEM DESIGN

System design efforts range from models for the institutional arrangements needed for a multipurpose system to data models to the configurations of hardware and software. A leading vendor suggests that a conceptual design includes application module designs, a data base model, hardware and software specifications, and an administrative framework. The "data model" can consist of many components including data flows, data structure and format, entity relationships, query processing, user interface methods, and data indexing and archiving procedures.

Many choices must be made in designing an LIS, often involving tradeoffs. For example, a highly customized system might be easy to operate, but have limited flexibility, or a detailed database might have all the information "on-line" for any possible query, but might be slow to respond because of large data volumes.

An organization is best served if choices in system design arise from the results of user needs assessment and requirements analysis. The system can also build on currently successful applications, rather than assuming they must be replaced. Evidence suggests, however, that software selection and/or data sources are too often the most important factors in system design. This is often the result, for example, of consultants being familiar with only one software package and invariably recommending that package as the solution. Knowledge about available options is the best way for an organization to avoid getting boxed into a particular solution that might not be optimal.

IMPLEMENTATION PLAN

An implementation plan is generally an incremental work plan. These plans might detail who is responsible for which tasks, when they will be started and finished, and what resources (funds, data, and staff) will be needed. The plan can specify individual responsibilities in data management, data base and equipment maintenance, and vendor and agency liaison. The plan can also be simply for general work flow and staffing. In many implementation plans, preparation of staff in the use of new equipment and procedures is absent or not well developed; such activities should be included. Table 14-2 lists some activities typically included in the planning necessary to integrate new computer-based technologies into an organization.

PILOT PROJECTS

Pilot projects, demonstrations, and benchmark evaluations provide experience on a small scale before full commitment to new methods. Most LIS implementors indicate that projects in a limited geographic area or for a single application are essential for success. They introduce users to hardware and software, help identify problems or bugs in the system before full commitment, allow comparison of various solutions and approaches, and facilitate preparation of attractive hard-copy information products for decision-makers who must be convinced of the system's viability.

The pilot project also provides a way of testing new applications before an agency makes a full commitment to automated methods. The methods and procedures can be fine-tuned by skilled problem-solvers before everyone is expected to use them. Personnel can be gradually trained in more automated individual applications, easing the transition rather than radically changing all daily routines at one time.

INTRODUCING LIS TECHNOLOGY TO AN ORGANIZATION

The purpose of a technology introduction is two-fold. First, it exposes an organization to the new concepts and methods: what are the new techniques, equipment, and methods; how might they change operations; how will products or services change; and what are the potential costs, benefits, and other implications of the new technology? Second, it introduces prospective users to the implementation process: how will the organization make a transition to the new methods; why and how will they participate in the user needs assessment; and what is their likely role in the long-term use and maintenance of the system?

An LIS plan and its implementation are, in essence, a technology transfer process. Technology transfer cannot take place without someone taking a leadership role. That someone must be able to sell a vision of what LIS can accomplish in an organization, both to personnel who will ultimately use the system and to decision-makers who must commit funding for it. Change is resisted in many organizations; persuasive arguments about the benefits of a technology might be a necessary part of the implementation process. Without an effective introduction to benefits, costs, and consequences of a new approach, neither users nor decision makers are likely to embrace the ideas.

SELLING THE VISION

"Selling the vision" is best done by a champion (or champions) of the technology within an organization. The champion must be an effective spokesperson and organizer, able to see the bigger picture and to involve others. Hired consultants can be effective in persuading and educating, but initially there must be someone who has a vision of the organization, who is willing to promote the technology, to explain the concepts (or bring in experts who can), to make at least the initial choices about the scope of the project, to decide who to include in planning and design sessions, and generally to foster and facilitate change. This facilitator must put in place a mechanism to deal with difficult institutional issues such as long-term funding commitments, restructuring of an organization, new relations with other organizations, data security and access, etc. Without this facilitator, an LIS implementation might be impaired and the benefits limited.

To some extent, the champion must be a risk-taker. When technical shortcomings or institutional roadblocks impair a project, a champion might be exposed to unflattering professional scrutiny. When people's work activities are altered by LIS implementation or "skeletons in the closet" are revealed during the process, the champion might be personally impugned. Indeed, inspirational stories surround some of the early LIS implementors, such as

Eunice Ayers (Forsythe County, North Carolina), Murray Rhodes (Wyandotte County, Kansas), Dale Friedley (Florida), and Bob Cook (Cincinnati, Ohio), and how they overcame many odds.

The champion must have technical expertise, or must work with someone else who will be responsible for technical aspects of implementation. For example, in the early 1980s, Murray Rhodes worked closely with Ed Crane: Rhodes fought the political and economic battles, while Crane solved the difficult technical problems in Wyandotte County, Kansas. Having simply an "LIS implementor" might not be sufficient to provide the leadership needed to overcome the institutional and technical hurdles.

The champion should be able to transform technical jargon into decision makers' own frames of reference. The champion's approach during an introduction to LIS must emphasize the efficiency or effectiveness of new methods, rather than presenting information that might sound like abstract or arcane technical concepts. Once a commitment to implementation has been made, technical experts can introduce specific concepts and terms in a formal or informal training process.

The champion must ultimately be able to "let go" of the process after successful implementation. Given the goals of LIS capabilities distributed broadly through an organization and end-user involvement in system design, the technology should permeate the organization and users assume responsibilities. Ideally, the champion initiates the interest in the new ideas for an organization and then provides enough guidance and standards that the technology doesn't run out of control, a situation that could result in merely automating existing problems.

The best champion might well be one who is self-selected, the true believer willing to take on the inertia because the belief is so great. A designated champion seldom fills the role with the same degree of enthusiasm.

LAYING THE GROUNDWORK

Technology introduction has a direct impact on subsequent steps in an LIS implementation process. In addition to wanting to understand the technology in general, potential users want to know specific details about the implementation process and expectations of the needs assessment and requirements analysis. They want to know why the needs assessment interviewers are asking so many questions about how they do their job! To answer the assessment questions effectively, users need at least a basic understanding of spatial data and LIS so they can explain their use of spatially-related information, how data could be used in an automated form, and how work products (services, decisions, etc.) could benefit.

A successful LIS implementation requires interaction and feedback between the end users and the technical experts helping to design a system and build applications. Continual feedback throughout the entire implementation process is helpful. It provides immediate evaluation of the utility of the experts' efforts, and gives end users a voice in the process. It is appropriate to initiate this feedback upon first exposure -- during technology introduction. This can open communication channels and build confidence in the experts who are guiding the implementation.

LEARNING ABOUT LIS

Adoption of geographic information systems and related technologies has accelerated dramatically in the last few years. At the same time, there has been an explosion in information about LIS. This means there might be too much information available, too much to sort through to determine what is valid, unbiased, and applicable to particular local circumstances.

Finding objective and reliable advice can be one of the most challenging aspects of LIS implementation. Information that purports to explain LIS is available from a variety of sources. It isn't possible to say which might be misleading or biased, but one piece of advice is always valid: an organization buying into LIS must get more than one opinion and must refer to more than one source. It must be an informed consumer.

CONSULTANTS

Expertise for designing and implementing an LIS obviously can be obtained by hiring the right people, but finding the right consultant for a situation will require some effort. A few precautions are in order before an organization begins to search for that service.

Consultants might be vendor-allegiant or vendor-neutral. Vendor-allegiant consultants consistently recommend the software packages and/or computer hardware that they represent. If the hardware or software is not appropriate for a particular situation, the consultants might go to great lengths to try to adapt it anyway. Nonetheless, many vendor-allegiant consultants are reliable and can address specific problems and issues. On the other hand, vendor-neutral consultants generally concentrate on specific needs of a situation and try to find the best solution, though they too can be limited in experience or range of knowledge.

Consultants can have a wide range of LIS experience. LIS is considered to be a growth area and many people have only recently begun to work in this arena. Many companies that specialize in related fields such as surveying or photogrammetry now offer LIS services. Such companies might offer excellent help, but they might also be narrowly focused on particular aspects of a larger implementation process such as data automation. No formal certification of LIS consultants exists, but reputable vendors will respond to "requests for qualifications" -- descriptions of the kinds of projects they have been involved with and the training of their personnel. Prospective consultants should be able to provide names of former clients.

Consultants might try to simply "please the client." They might avoid controversial or expensive recommendations, even if evidence suggests that those might be good ways of accomplishing goals. Before working with a consultant, an organization should have clear ideas about its long-range goals. It must communicate these goals, then ask the consultant to work on more than one alternative for achieving these. This allows the client to evaluate trade-offs between various approaches.

Consultants might try to make themselves indispensable in the long-term functioning of an LIS. To avoid this, there must be a clearly detailed process for transferring knowledge about system design and operation to permanent personnel. Staff should also be trained in the development of new applications, so a client doesn't have to retain consultants every time a new need occurs.

An important consideration in selecting a consultant is finding someone who has a thorough understanding of GIS technology and either knows or has a well-defined process for learning the operations of an organization. Finding a consultant can be as easy as looking in a local community or as complicated as developing and circulating a formal RFP nationwide for consulting services. The advantage of finding a local consultant is the likelihood that the firm's personnel will already be familiar with the local situation. It is desirable to make sure that the local firm's personnel keep in touch with new trends in the technology; LIS is a complex and rapidly evolving field, and hardware and software in particular can become dated rapidly.

If there is no one locally available who is appropriate for the task, an office can turn to the many companies specializing in LIS implementation. Professional associations are a good place to find out about such companies. Several professional organizations (Table 14-3) are partially supported by the vendor community, including LIS consultants. These associations produce journals, newsletters, and pamphlets that contain descriptions of corporate sponsors including consultants, along with their advertisements. A number of newsletters and magazines about GIS also contain advertisements from and articles by consultants.

In most cases, consultants and vendors are willing to demonstrate their services or products without obligation. This can be done on site, at another implementation site, or at a trade show or conference. If an organization has sufficient confidence in its own knowledge of the technology, this is an excellent way to become familiar with the consultants' approaches and the ranges of their expertise. However, such a demonstration can also be a "hard sell," so one must be prepared to ask questions and visit more than one display or site. Demonstrations are generally focused on hardware and software, whereas a new system must also account for personnel, training, financing, institutional and inter-departmental arrangements, and so forth.

Site Visits

Most public employees are willing, if not eager, to show off innovations that have helped them do a better job. Visiting such sites removes the slant of consultants' interpretations. One can get more open answers about system implementation, operation, and cost. There are lessons to be learned from both successes and failures. The adjustments and adaptations to make commercial products work in a particular situation are important lessons. In addition to other local government systems, there are LIS facilities at utility companies, state agencies, and universities that can provide ideas and information.

The most useful information is likely to come from sites that are similar to one's own - in size, project scope, applications, budget, staff technical expertise, and so forth. This doesn't mean, however, to exclude all the "Cadillacs." For example, a rural county's budget or experience might not be similar to a large city's, but the latter operation might have many methods and procedures that could be cost-effective or efficient in the rural situation. Moreover, the steadily decreasing cost of computing might mean that some of those advanced features in equipment and software will be available in the near future on less expensive systems.

Books, Professional and Trade Journals, and Videos

The rapid diffusion of LIS technology has been accompanied by a phenomenal growth in published material. The first general textbook on geographic information systems was published in 1987. In 1991 there were over half a dozen to choose from and several others in the works (Table 14-4). The first video on land records modernization was produced at the University of Wisconsin-Madison in 1986. URISA, ACSM, AM/FM, and other professional associations have produced new videos, as have many vendors and consultants.

For the novice, the amount of written and video material available can be overwhelming. It can be difficult to ferret out what is important, relevant, or, even, true. Implementors of an LIS should ask counterparts and peers what has been useful to them.

Several professional journals and conference proceedings concentrate primarily on LIS and related technologies. Each of the professional societies listed in Table 14-3 publishes at least one journal and sponsors at least one annual conference with published proceedings. Each professional society has a slightly different focus. URISA, ACSM, and AM/FM are most likely to have articles of interest to local government, but all the others occasionally have applicable information. Other professional associations occasionally have journal articles or conference proceedings of interest.

Trade newsletters and magazines come and go too quickly to list them all. A recent report listed 92 newsletters and publications devoted to GIS and remote sensing. When an organization begins investigating LIS hardware and software, it will undoubtedly get on the mailing lists of many of these. Two in particular are worth noting: *GIS World* (bi-monthly; by subscription; see Table 14-4, the address for *The GIS Sourcebook*) is a good source of information about GIS activities of the federal government, states, larger cities, counties, and utilities, and of the nationwide vendors. *Government Technology* (monthly; free; 1831 V Street, Sacramento, CA 95818) often has good articles about implementation of LIS systems in a variety of public offices.

For those who need a quick introduction, videos present an easy, non-intimidating means to become familiar with LIS. Prospective users can absorb the information in comfortable surroundings without the accompanying high-pressure sales pitch. Although only a limited amount of material can be conveyed in a 20- or 30-minute video, it can be enough to draw people into the process so they want to find out more. URISA recently released a video about land information systems targeted at elected officials and upper-level management in local government. A video produced by the University of Wisconsin specifically addresses the concept of the MPLIS in local government. Software vendors are another source of videos, though they often carry a strong sales message.

Conferences, Seminars, and Workshops

Just as there is an explosion of written material on LIS, there is a corresponding explosion in meetings about it. Conferences provide opportunities to hear different viewpoints -- from those involved in day-to-day implementation and management, from vendors and consultants, and from academics studying the whole process. Seminars and workshops can provide an opportunity for in-depth information about particular aspects of LIS. Many newsletters have listings of upcoming meetings, conferences, and workshops.

Again, the wise consumer would learn something about the various meetings before committing time and money. It helps to know who is sponsoring the event; is it only one vendor? Is the main purpose to educate and disseminate information, or is it to make sales for the sponsors? What are the affiliations and reputations of the speakers? If it is a seminar or workshop, is there a "hands-on" component? This could be most informative. Learning, especially learning software, is much easier by doing.

STEPPING STONES FOR INTRODUCING LIS

Of course, there is no one right way to introduce innovation to an organization. Many different circumstances (organizational structure, financing, technical expertise, etc.) and presumptions about LIS (ranging from fear and rejection to blind, dogmatic faith) abound. One possible pathway to begin an LIS implementation involves five kinds of activities.

IDENTIFYING RESPONSIBLE PARTIES

A wide range of skills, both technical (data management, hardware and software, and training) and institutional (financing, political support, and intra- and inter-agency relations), is needed to lead system implementation. As a result, leadership might come from an individual or a small committee of those responsible for leading various efforts. Eventually, it might be desirable to have a much broader "steering committee" that represents interests of many users of a system. But in these early stages, effective leadership is generally provided by a small group responsible for learning and addressing a range of issues.

EDUCATING IMPLEMENTATION LEADERS

Implementation leaders don't have to know everything -- just enough about the aspects of LIS to effectively deal with others involved in the process. To convince decision-makers to support a new approach, implementation leaders must be able to convey efficiency and cost arguments. To work with consultants, they must be assertive, effective communicators and be able to detect misleading claims. To work directly with potential users, they must also have a good technical grasp. Implementation leaders might need intensive training best acquired at workshops and short courses. They could benefit from site visits and should become familiar with a variety of printed material.

CONVINCING DECISION MAKERS

Upper level management and elected officials need to know that changes are necessary. In most LIS implementations, up-front costs are large and paybacks are gradual. Unless decision makers give their long-term support, the system could be derailed before it is fully operational. Technology introduction for this group is oriented toward the costs and benefits of LIS. This group doesn't need technical details, but description of the tasks ahead should not be oversimplified. It is most important that what can be reasonably delivered is not oversold or over-promised. Videos might be an effective way to reach these people, along with personal visits and briefings. If used at all, written material and presentations should be short and concise.

CONDUCTING A PRELIMINARY CENSUS

A census should be made of prospective spatial data users. A preliminary questionnaire (see Appendix 1 for samples) can serve two purposes. One is to select initial project participants from the broader group of all users of spatial data in local agencies, locally active state and federal agencies, utilities, and companies. The second is to identify basic data resources and custodians. When questionnaires are tabulated, it might be helpful to hold a general public forum to explain the results and outline the project scope and goals.

INTRODUCING USERS TO THE TECHNOLOGY

When a commitment has been made, the training and education of potential users can begin. In-house demonstrations and seminars are the most effective way to reach a large audience. For example, a consultant could present a lecture for an hour or two, and then provide live demonstrations for smaller groups through the remainder of the time. Prospective users should get an introduction to the basic concepts of LIS, including data automation, management and analysis, and information products. Written material such as newsletters and memos can be used to explain the goals of the implementation process and how users will be involved in needs assessment. Users who will be most affected need to become prepared for a change. Some people should be warned that automation might profoundly change their responsibilities and day-to-day tasks. These should be regarded as positive changes, helping them do their job more efficiently and effectively. It is essential, however, that the tasks ahead are not oversimplified and that it is understood that the new methods will not solve all their problems.

SCOPE OF THE PROJECT

LIS implementation begins by decision makers making a commitment, system implementors learning the technology and the implementation process, and users understanding the concepts of LIS. But who are all these users and which decision makers must make a commitment? Which departments, individuals, and applications will be included in the initial detailed needs assessment? Which might be added sometime later? Which are probably not amenable to incorporation into an LIS? Before beginning the next steps in the implementation process -- user needs assessment and system requirements analysis -- it is necessary to make some decisions about the initial scope of the project.

The scope of the project should not be limited until a preliminary census of spatial data users has been conducted. There is a risk of losing contributing participants, data sources, or other resources if preconceived constraints or hasty benefit/cost analyses limit the scope. When agencies' interests, data, resources, etc., have been sketched out, the scope of a project can begin to take shape.

LIMITING OR EXPANDING AN LIS

The appropriate scope of an LIS implementation depends on the situation -- available funding, available expertise, status and interest of prospective participants, mandates governing their responsibilities, types of applications and data, personal or professional conflicts, existing agreements, and so forth. Many of these factors will become clearer during the needs assessment and requirements analysis, and as a result will be reflected in a system design or RFP. But, it is necessary to make some initial decisions about whom to include in the technology introduction and needs assessment processes. This amounts to making a number of trade-offs.

The benefits of an MPLIS will accrue more rapidly in systems that incorporate many applications and departments. Many users will be able to work from common databases, i.e., from the same set of facts and information. As a result, duplication of effort and redundant data sets can be eliminated and more accurate, complete, up-to-date information should be accessible from each custodian -- that is, the departments or agencies agreeing to maintain part of the system or its data.

These benefits will be countered by increased complexity of the project as more participants are added. It will be more difficult to set priorities. Every step will have a longer lead time and it will be more difficult to develop and adhere to timelines. More decision makers -- upper-level management and elected officials -- must be involved. The system and database design will be more complex, quite probably involving more formal methods such as on-line data dictionaries and structured systems analysis.

If the costs of a more inclusive system are shared equitably, everyone should benefit. Though there are likely to be larger start-up costs, these and maintenance costs will be spread among a larger group. Duplication and redundancy in data collection and management and in technical expertise should be reduced. Not every department will need several trained LIS experts. The entire array of hardware, software, and, in particular, peripherals that are only used occasionally won't have to be purchased by each participant. Widely used equipment such as terminals or workstations might be purchased at volume discounts. The net result can be substantial cost savings.

The equitable distribution of costs can be a difficult issue though, particularly when groups have very different data quality standards. If one group requires very accurate and/or very current (therefore expensive) data, there is the question of whether that group should bear the entire cost increment of the additional accuracy or if the cost should be spread among all users. If agreement can be reached on these tradeoffs, the benefits of an automated LIS will be spread over a larger group of participants. As spelled out in some detail in the next chapter, accounting for costs and benefits in an LIS is not always a simple task. In light of this uncertainty, an incremental implementation should provide a few immediate returns, which should engender sufficient support for the system to realize longer-term benefits.

In situations where there is little experience with GIS technology, it might be appropriate to start small, with only a few participating departments. The reasons are similar to those for doing pilot projects. On the technical side, it provides experience in the use of hardware and software and allows comparison of various approaches and solutions before too much is dependent on the system. On the institutional side, it provides cost/benefit information and products that are visible demonstrations of the system's benefits. This approach of building from limited participation will allow negotiation of cooperative agreements among departments or agencies, to grow as needed, rather than to force linkages in response to overt pressure or crises.

In a general sense, systems can be designed with the capacity to expand and incorporate new users. As the institutional and financial details are worked out, new users can be accommodated. Some efforts, however, might have to be redone at a later date, when greater accuracy or capacity is needed. For example, digitizing existing tax parcel maps creates a land ownership "layer" quite adequate for many applications such as resource management and planning. More accurate "coordinate geometry"-based mapping is needed to support tax assessment or conveyancing, but this might not happen for some time. These accuracy/speed/cost/scope-of-applications trade-offs are especially critical in the creation of base maps and geodetic reference frameworks.

IDENTIFYING PARTICIPANTS

Almost everything done in local government can be tied to a spatial location in some way. Even legal and judicial systems or social service departments must maintain addresses of clients and facilities, and might want to plot incidents such as crime or accident locations to relate them to other spatial variables. To keep a land information plan manageable, however, it is necessary to identify those departments central to land records modernization. These are primarily those departments that record or produce basic spatial data or are large-volume users. After the system develops, other users can be added. When the system is technically mature, additional users will add detail and richness to the system, and enhance the utility for all.

Several types of data, such as land-ownership-related data, are clearly important to an LIS. In most cases, the departments or agencies likely to be custodians of these data are obvious. It is important to include these entities in the initial decisions about system scope, design, and implementation, though they need not all be full users of the system from the start.

Table 14-5 is a generic list of many county, municipal, and town functions or offices that might be interested in participating in an LIS. It also includes state, federal, and private agencies that operate at the local level. A two-tier user needs assessment might be useful for screening the interest and commitment of these groups. A questionnaire (Appendix 1) can be used to find out who has what data and whether they are interested in working together on a multipurpose system. Such a questionnaire, with a simple memo explaining its purpose, can be distributed broadly within and beyond an organization with little effort. Response might be better if the questionnaire goes out under the signature of a prominent official such as a mayor or county executive.

On the basis of responses to the questionnaire, groups that have important data and/or have applications that readily fit within the scope of the system can be included in a more detailed needs assessment and system requirements analysis as outlined in the other chapters.

ENSURING FULL PARTICIPATION

Responses to the initial questionnaire might show that some departments or individuals who control important data sets are reluctant to participate in LIS implementation. Even some of these who appear to be responsible for data sets critical to the LIS might not be willing to participate in the process. This can impair the effective design and functioning of a system. Fortunately, there is a variety of ways to overcome these barriers.

Education is a valuable tool for overcoming the fear of change. Some people dislike or distrust computers in general; some might fear that their positions will be eliminated or that their authority will be reduced. Such fears generally arise from misunderstanding. If people are willing to listen with an open mind, they can generally be persuaded to at least give new ideas a try. These people might need personal attention in technology introduction, specifically using examples from their type of operation and addressing their concerns directly.

Sometimes individuals within a department are particularly willing to make a commitment to the new approach. Those contacts should be carefully nurtured. It is, after all, people who make these systems work. If a few people take the risk and begin using new methods, others will look over their shoulders to see if and how things work. In this way, more participants might be drawn into the process as they see for themselves that new methods are in some ways an improvement. The more people who become interested in the process, the more supporters the LIS will have.

Individuals or departments might also be reluctant to change because of "institutional inertia." They might already have considerable investment in existing methods such as manual cartography or drafting. They might feel that they are adequately fulfilling the requirements of their mandates. They might have "skeletons in their closets" -- inadequate or undocumented record keeping that they don't wish to expose to the scrutiny of a needs assessment.

It is possible to overcome institutional inertia through education, convincing individuals or departments to look at the overall good of an entire organization rather than more narrowly at their own responsibilities and budgets. Individuals or departments must be convinced that they won't be punished for past inadequacies, and that the LIS implementation is an opportunity to make reforms.

It might be necessary, in some cases, to promote change from higher levels in an organization with recalcitrant departments or individuals. This means first convincing upper-level management or elected officials of the importance of the new approach. They in turn can use their influence and directives. It is, however, the educational aspect that will provide the most lasting commitments, for no one likes to be forced to do something.

In the worst case, it might be necessary to design a system to work around non-participants. For example, because of open records laws, the non-participants must at least provide data in the form in which it is routinely used. This might make it possible to work around the reluctant individuals and still incorporate the necessary data, though not necessarily in the form that is most useful. This is not an ideal solution, but it can serve as a temporary measure until attrition and public or peer pressure alter the situation.

If upper-level management or elected officials are the reluctant parties, the best arguments are likely to be those centered around costs and benefits. Suggestions and details on benefit/cost study methods can be found in Chapter 15. It remains true, however, that much of the cost of an LIS is up front, in initial outlay for data automation or conversion, system design, hardware and software, and so forth. Many of the benefits, on the other hand, occur over longer periods of time and might not be easily measured. For example, what is the value of better, more informed decisions?

One possible strategy for allaying the fears of major budgetary impacts of an LIS and at least beginning the implementation process is a simple argument: "Growing evidence from other jurisdictions indicates that LIS is a cost-effective approach for land records management; the only way to know if this is true in this jurisdiction is to undertake a user needs assessment and a system requirements analysis."

Approval to conduct a needs assessment will likely result in the prediction of a positive benefit/cost ratio over the long term, which can be used to convince decision makers. There is always a chance, though, that a major step into automation might not be right at the present time. That is not necessarily a bad outcome of the needs assessment; it is still a contribution toward land records modernization. Through the critical examination of data sources and data management methods and the mandates surrounding spatial data use, a needs assessment will help offices manage spatial data more efficiently and effectively with manual methods too. Overall, it will have contributed to more thoughtful and rational use of information resources and, ultimately, to good government.

SUMMARY

There are many ways in which GIS hardware and software can enhance the efficiency and effectiveness of a modern multipurpose land information system. Automation can be an important component of an MPLIS, but technology alone is not a sufficient solution; institutional, organizational, and economic issues must also be addressed. In implementing an automated land information system in local government, several types of activities are typically found: for example, technology introduction, user needs assessment, system requirements analysis, implementation planning, and pilot projects.

In many situations, a "champion" is needed to initiate a land records modernization project and the technology introduction. That champion must educate two immediate groups: decision makers, who provide political and financial support, and technical staff, who will operate a system. The champion must ultimately reach a broader group of agencies and organizations, who will eventually use the system or share data. Careful choices must be made in the early stages of an LIS implementation about whom to include, how to organize them, and how to find out about their needs and resources.

The MPLIS concept requires significant institutional commitment and involvement. It involves much more than buying hardware and software and automating data. Perhaps the most critical aspects are people and organizations that must evolve and adapt to new methods. User needs assessment and system requirements analysis (see Chapter 16), later steps in the implementation process, are intended to probe deeply into how and why organizations manage and use land records. This in-depth examination could have other results, including recommendations for major changes in operating procedures and service delivery, in addition to the changes inherent in automation. An extensive and deep interest in and commitment to modernizing land records systems -- making them more efficient, effective, and accessible -- is necessary to successfully embark on this course of change.

REFERENCES AND ADDITIONAL READINGS

ACSM Committee on Geographic Information Management Systems, 1988: "Multi-Purpose Geographic Database Guidelines for Local Governments." *ACSM Bulletin*, 114(June), 19-30.

Bauer, K. W., 1982: "Problems of Political Support at the Local Level for Development of Technically Sophisticated Land Information Systems." *Proceedings of the International Symposium on Land Information at the Local Level*, University of Maine at Orono, 11-22.

Chrisman, N. R., and Niemann, B. J., Jr., 1985: "Alternative Routes to a Multipurpose Cadastre: Merging Institutional and Technical Reasoning." *Proceedings, Auto-Carto 7*, Washington DC, March 11-15, 1985, 84-95.

Dangermond, J., 1988: "A GIS is a Computer Based System to Capture, Store, Edit, Manipulate, and Display Geographically Referenced Information." University of Wisconsin-Madison Engineering Professional Development short course *Developing Geographic Mapping and Analysis Systems*, Madison, WI, April 16-18, 1988.

Dickinson, H. J., and Calkins, H. W., 1988: "The Economic Evaluation of Implementing a GIS." *International Journal of Geographical Information Systems*, 2(4), 307-327.

Federal Interagency Coordinating Committee on Digital Cartography, 1988: *A Process for Evaluating Geographic Information Systems*, S. C. Guptill, ed., U.S. Geological Survey Open-File Report 88-105, 136 pp.

Gurda, R. F, Niemann, B. J., Jr., Ventura, S. J., Moyer, D. D.,Amundson, J., and Braunschweig, H., 1988: "Developing Data Models for Multi-Agency Land Information Systems." *Technical Papers, 1988 ACSM-ASPRS Annual Convention*, St. Louis, Missouri, March 13-18, 1988, 2, 39-46.

Smith, T. R., Menon, S., Star, J. L., and Estes, J. E., 1987: "Requirements and Principles for the Implementation and Construction of Large-scale Geographic Information Systems." *International Journal of Geographical Information Systems*, 1(1), 13-31.

See Tables 14-3 and 14-4 for professional organizations and textbooks providing more information about automated land information systems.

Table 14-1: GIS SOFTWARE FUNCTIONALITY

User Interfaces

Command driven user interface
Pull-down or pop-up menu user interface
Icon-based user interface
Batch programs or command files for series of functions
Macro language or shell scripts for creating new commands
Source code or object code library for user program development
Tutorial or other method for self-instruction
An "undo' command to restore conditions prior to command
Recall of previous command(s) for re-execution
Logging of commands or operations
Soft error recovery
- user friendly error messages
- restore data files to original form
- remove scratch files

Data base management

Linkage of geographic data with attribute dbms
Facility for entering data quality information
Facility for recording data lineage
Facility for tracking transactions or updates
Access to attribute data
- direct - by attribute identifier
- direct - by selected geographic feature
- through relational key
- by natural language or SQL instructions

Ability to create, view, and manipulate meta data
Database operations
- sort tabular or graphic files by attribute or location
- calculate new values by arithmetic or logical expressions
- relate data files by common unique identifiers
- define rules governing behavior of data elements
- create, store, retrieve, and generate standard reports

Provision for organizing files by project
Generation of status reports on content and status of data base
Capability to add data files without regard to size or scale
System security
- password access protection
- electable read only or read/write access for different users

(Table 14-1 continued)

Computer network operation
  access common data file from file server
  data check out/check in procedure

Geographic Data Automation

Manually digitize two-dimensional point, line, or polygon data
"Snap-to" previously digitized features
Photogrammetrically digitized data incorporation
Coordinate geometry: protract lines, angles, and curve, intersect lines (create nodes), bisect angles, locate tangents, least-squares traverse adjustment, store curve as radius, arc endpoints, or center point, arc endpoints, offset parallel lines
Manually encoded raster (cellular) data: raster editing, thresholding and line thinning, raster to vector conversion
  scanned map data - raster
  scanned photographic or satellite data
Topological structuring
  manual assembly
  automatic (batch) assembly of polygons from lines
  automated calculations of area, length, perimeter

Data Editing and Error Correction

Attribute data association
  associate multiple attributes with geographic features
  assign attributes
  completeness check
  attribute range or value checks
  attribute format checks
Select features:
  by pointing
  based on attribute value
Insertion or deletion of selected geographic features
Cut and paste from update file
Interactive movement of individual points, lines, or areas
Interactive graphic annotation editing
Automated topological error reporting

Terrain and other 3-D Surface Representation

Contours
Regular gridded Z-values (digital elevation models)
Triangular irregular network (TIN)

(Table 14-1 continued)

Constrain contours by specifying barriers
Calculate cut or fill volume
Determine drainage networks or floodplains
Determine ridgelines or watershed boundaries
Determine viewsheds from user specified points
Compute slope and aspect values
Plot planar geographic features (terrain drape) over
  2.5 D net, wireframe, or contours
Plot geographic features or perspective view
  with shaded relief and hidden line removal

Import/Export

Arc/Info
AutoCad
DEM
DLG
ERDAS
ETAK
GIRAS
GRASS
Intergraph
MOSS
TIGER
Spatial Data Transfer Standard (SDTS)

Data display and analysis

Data Retrieval - select and display:
  by theme or layer
  within window specified by coordinates or reference map
  within window specified by on-screen digitizing -
  by feature names or groups of names
  by logical and Boolean retrievals on attributes
List attribute values of selected features
Report location of feature by pointing
Report straight-line distance or length by pointing
Report along-line-feature (network) distance by pointing

Data Restructuring
  raster to vector conversion
  vector to raster conversion
  map tile or sheet appending

(Table 14-1 continued)

automatic edgematching
line thinning or smoothing

Data Transformation
planar transformations
"rubber-sheeting" planar transformations
extract control point coordinates from master file
incorporation of USGS/NOAA projection package
incorporation of NOAA-NGS NADCON (or CORPSCON) datum conversion

Overlay
graphic superimposition
topological overlay
sliver removal
cross-tabulation
area weighted average

Networks
maintain line and node attributes
determine optimum path through network
determine optimum route for distribution through network
calculate optimum allocation or collection zones

Other Geoprocessing
buffer
proximity report
nearest neighbor
dissolve
automated address matching
adjacency

Data Display and Information Product Creation

Data Display:
generate graphic displays (on screens, plotters, etc.)
display vector data with raster (image) backdrop
generate hardcopy output to plotters, printers, filmwriters, etc.

Information Product Creation:
compose products interactively
compose products with command files or map templates
store, retrieve, and re-display compositions
user specified scale, orientation, map size, and location on sheet

(Table 14-1 continued)

display point, line, and polygon data sets
display map features: neat lines and grid lines graticules
create and position: scale bar, legends or keys, north arrow,
map titles, logos, and single or multiple line text
interactively position map elements
ability to select point symbols, line types, and area fill patterns
ability to create, name, store, and select new point symbols,
line type, and area fill pattern tables
ability to assign by attribute, selection, or lookup table
automatically position text at pre-specified point location
ability to specify individually for any text string: font, case, size, spacing, color, angle, and curvature

Source: Modification and Enhancement of FICCDC, 1988.

Table 14-2: ELEMENTS OF AN LIS IMPLEMENTATION PLAN

Work plans:	Which tasks are necessary for system operation? Which optional tasks will most enhance system capabilities?
Timelines:	By when should designs and plans be completed and approved? When should tasks be completed? When is equipment and outside data expected to arrive?
Staff responsibilities:	Who is responsible for carrying out tasks, project management, system maintenance and backup, security, vendor liaison, consultant liaison, budget liaison, training, etc.?
Training:	Who will receive initial training in various aspects of the system, including hardware maintenance, system management, and software programming? How will new users be trained?
Data automation:	What sequence of automation will yield system benefits in a reasonable time frame? Which data automation methods (e.g., digitizing, scanning, and COGO) are appropriate for which source materials? What data are already automated? Who has the data and what will have to be done to convert them?
Application development:	Which applications have a high likelihood of early success? Which application priorities will be impacted by events outside the control of the implementor?
Workspace arrangements:	Where will equipment go? Are there special requirements in terms of environmental conditions, air-conditioning, or power sources?
Collection and handling:	What kind of document control procedure is needed of source materials?
Quality control procedures:	What consistency checks should be established? What are the standards for various processing steps?
Equipment and software:	Does equipment and software do all that is claimed? Does it fulfill the needs for testing and evaluating our applications? If the software is being added to an existing platform, what will the effect on existing operations be?
Backups:	How often should they be done? On what media? Using what procedure?

(Table 14-2 continued)

Database maintenance:	What procedures and sources will be used to update the data base with new information? How will files be organized and accessed?
System and equipment:	Are measures required such as passwords, read-only protection, locks, and security clearances? Have all types of security been considered: physical security (theft, vandalism, power problems, "acts of God", etc.), data base security (access), and data element security (authorization)?
Cost and time audits:	How do we account for time and effort in system construction and maintenance?
Alternative and fall back:	What are the contingency plans if tasks cannot be completed?
Continued interaction:	How will we respond to new application developments? How can we assure with technical experts that system capabilities remain dynamic?
System review:	How often should we audit the performance of the system? Which aspects should be reviewed? What outside reviews are expected? Are there regulatory approvals needed?
Modification procedures:	How can we incorporate the results of performance evaluations into system and feedback loops evolution?

Table 14-3: NATIONAL PROFESSIONAL ORGANIZATIONS WITH LIS ACTIVITIES

American Congress on Surveying and Mapping (ACSM)
5410 Grosvenor Lane, Suite 100
Bethesda, MD 20814-2122
phone: (301)493-0200; fax: (301)493-8245

American Society for Photogrammetry and Remote Sensing (ASPRS)
5410 Grosvenor Lane, Suite 210
Bethesda, MD 20814-2160
phone: (301)493-0290; fax: (301)493-0208

AM/FM International
14456 East Evans Avenue
Aurora, CO 80014-1409
phone: (303)337-0513; fax: (303)337-1001

Association of American Geographers (AAG)
1710 16th Street, N.W.
Washington, DC 20009-3198
phone: (202) 234-1450; fax: (202) 234-2744

International Association of Assessing Officers (IAAO)
1313 E. 60th Street
Chicago, IL 60637
phone: (312) 947-2064

National Computer Graphics Association (NCGA)
2722 Merrilee Drive, Suite 200
Fairfax, VA 22031
phone: (800)225-NCGA or (703)698-9600; fax: (703)560-2752

Urban and Regional Information Systems Association (URISA)
900 2nd Street, N.E., Suite 304
Washington, DC 20002
phone: (202)289-1685; fax: (202)842-1850

Other organizations that occasionally offer materials of interest:

American Planning Association
1776 Massachusetts Avenue, N.W.
Suite 704
Washington, DC
phone: (202)872-0611

(Table 14-3 continued)

American Public Works Associations
1313 E. 60th Street
Chicago, IL 60637
phone: (312)667-2200

National Association of Counties
440 First Street, N.W.
Washington, DC 20001
phone: (202)393-6226

Soil and Water Conservation Society
7515 N.E. Ankeny Road
Ankeny, IA 50021
phone: (515) 289-2331

North American Cartographic Information Society
6010 Executive Boulevard, Suite 100
Rockville, MD 20853
phone: (301)443-8075

Table 14-4: BOOKS ON LAND AND GEOGRAPHIC INFORMATION SYSTEMS

Aaronoff, Stan, 1990: Geographic Information Systems: A Management Perspective, WDL Publications, Ottawa, Ontario.

All, Kathleen, Green, Stanton, and Zubrow, Exra, editors, 1990: Interpreting Space: GIS and Archaeology, Taylor and Francis, New York, NY.

Antenucci, John, et. al., 1991: Geographic Information Systems: A Guide to the Technology, Van Nostrand Reinhold, New York, NY.

Burrough, P., 1987: Principles of Geographic Information Systems, Addison-Wesley Press, New York, NY.

Dale, P., and McLaughlin, J. D., 1988: Land Information Management, Oxford University Press, New York, NY.

GIS World, 1989 and 1990: "The GIS Sourcebook," GIS World, Inc., P.O. Box 8090, Ft. Collins, CO 80526.

Guptill, Stephen, editor, 1988: "A Process for Evaluating Geographic Information Systems," USGS Open File Report 88-105, U.S. Geological Survey, Reston, VA 22092.

Huxhold, William E., 1991: An Introdiction to Urban Geographic Information Systems, Oxford University Press, New York, NY.

Langran, Gail, editor, 1992: Time and the Geographic Information System, Taylor and Francis, New York, NY.

Onsrud, Harlan, and Cook, David, editors, 1990: Geographic and Land Information Systems for Practicing Surveyors: A Compendium, American Congress on Surveying and Mapping, Bethesda, MD.

Ventura, Stephen J., 1991: Implementation of Land Information Systems in Local Government - Steps Toward Land Records Modernization in Wisconsin, Wisconsin Geological and Natural History Survey, 3817 Mineral Point Rd., Madison, WI 53705.

Vonderohe, Al P., Gurda, Robert F., Ventura, Stephen J., and Thum, Peter G., 1991: "Introduction to Land Information Systems for Wisconsin's Future," State Cartographers Office, Wisconsin Geological and Natural History Survey, 3817 Mineral Point Rd., Madison, WI 53705

Table 14-5: LOCAL LAND RECORDS USERS

County and municipal offices or functions

- Taxation/Assessment
  - Real property lister
  - Abstractor
  - Assessor
  - Clerk
- Register of deeds
- Landmarks Commission / Historical Society
- Surveyor
- Zoning administrator / Zoning inspector
- Public works
  - Water and sewer
  - Gas and electric
  - Transportation
  - Storm drainage
  - Engineering
  - Waste management
- Conservation
  - Agricultural Extension Services
  - County Forest Manager
  - Soil and Water Conservation District
- Planning
- Community development
- Recreation / Parks
- Building inspection / Permits and licenses
- Public safety (emergency services, fire, police, rescue)
- Data processing
- Sanitarian / Health officer

State Departments (including regional offices)

- Natural Resources/Environmental Protection
- Transportation
- Revenue
- Administration
- Agriculture, Trade, and Consumer Protection
- Justice
- Development
- Labor
- State Cartographer/State Surveyor or other NCIC affiliate
- Geological or Natural History Survey

(Table 14-5 continued)

Planning
Universities (e.g., departments of Geography, Civil Engineering, Computer Science, Forestry, Landscape Architecture, and Planning)

Regional and special districts

Registrar of voters
School districts
Sewerage districts
Regional planning commissions
Watershed associations

Federal

Environmental Protection Agency
Federal Emergency Management Agency
USDA Soil Conservation Service
USDA Agricultural Stabilization and Conservation Service
USDA National Forest Service
USDI United States Geological Survey
USDI Fish and Wildlife Service
USDI Bureau of Land Management
USDC Bureau of Census
USDC NOAA National Geodetic Survey

Private

Board of Realtors
Title insurance companies
Timber corporations and other land holders
Consulting engineering firms - surveying, photogrammetry, mapping, GIS
Appraisers
Land-holding conservation organizations (e.g., Nature Conservancy)

Utilities
Gas
Electric
Water
Cable television
Telephone
Digger's Hotline services

APPENDIX 14-1
PRELIMINARY DATA INVENTORY AND POTENTIAL USER SURVEY FORMS

The preliminary questionnaire (example shown on page 14-39) is one of the two types of user needs assessments. It is usually a brief mail survey broadly cast to all potential system participants. Its purpose is to get:

- an initial assessment of who might be interested in participating in a multi-agency information system

- a general idea of what kinds of data they use and information needs they have

- what they might be able to contribute in terms of resources such as staff time, expertise, equipment, etc.

A cover letter from a prominent official can enhance response rates. Many jurisdictions have followed the survey with a general meeting to explain results and outline in a general way what they hope to accomplish.

(Appendix 14-1: Form 1)

Multipurpose Land Information System
Prospective User Survey

Name ______________________ **Position** ______________________
Department ______________________ **Phone** (______)______________________
Company or Community ____

Land Related Data Production

1) Does your agency create any new maps (e.g., parcel maps)? Y N

If yes, briefly describe_________________________________

2) Does your agency compile data on existing maps (e.g., zoning maps)? Y N

If yes, briefly describe_________________________________

3) Is your agency responsible for assigning spatial identifiers - *geocodes* (e.g., parcel identification numbers, well identification numbers) Y N

If yes, briefly describe_________________________________

4) Does your agency create or compile data directly tied to maps or geocodes (e.g., farm conservation plan, assessed value)

If yes, briefly describe_________________________________

5) Are any of the above land related data automated (in digital form)? Y N

If yes, briefly describe_________________________________

6) Which of the above activities are required by legal mandates?

7) Which are done primarily for internal information needs and client services?

8) List (or attach) any available written reports that describe your data production methods, data quality evaluation, or data access policies.

9) List other organizations that access or obtain the data you produce.

(Appendix 14-1: Form 2)

Multipurpose Land Information System
Prospective User Survey

Land Related Data Use

1) What land related data does your agency access and use on a regular basis (for example, assessed value, soil type, easements)? In what form do you generally get the data (e.g., maps, tables, printouts, digital)? Who produces the data?

DATA	FORM	SOURCE

2) Which of these data forms must be further processed to be useful for your agency or its clients? List any sources from which data are substantially changed or enhanced and the final form of the information product that your agency uses.

DATA	INFORMATION PRODUCT

3) What land-related data does your agency access and use occasionally? In what form do you generally get the data (e.g., maps, tables, printouts, digital)?

DATA	FORM	SOURCE

4) List any of the above data sources that you are not satisfied with and why (e.g., not accurate enough, not readily available, not current)

DATA	PROBLEM

(Appendix 14-1: Form 3)

Multipurpose Land Information System
Prospective User Survey

Automation of Land Records

1) Which of these terms are you familiar with?

- __ geographic information systems (GIS)
- __ computer aided drafting (CAD)
- __ automated mapping and facilities management (AM/FM) systems
- __ national geodetic reference system
- __ global positioning system
- __ data "custodians"

2) Does your agency have any automated land information?

- __ tabular data software:________________________
- __ CAD software:________________________
- __ GIS or AM/FM software:________________________

(If you checked any of these, skip to question 6)

3) Is your agency considering an automated land information system in the future? Y N

4) Do you think an automated land information system could help your agency better manage the land-related information that it uses? Y N

5) Would you like someone to contact you and provide more information about automated land information systems? Y N

6) Would your agency be interested in participating in a county-wide multipurpose land information system? Y N

7) Which of the following resources might you be able to contribute to a system (<u>this is not a commitment</u>; it is for general information only):

__ funding	__ equipment or software
__ technical expertise	__ training
__ data sharing	__ staff time (for automation or operations)
__ policy committee	__ design and implementation committee
	__ other (please specify)

THANK YOU FOR TAKING THE TIME TO COMPLETE THIS SURVEY

15 ECONOMICS OF MPLIS: CONCEPTS AND TOOLS

D. David Moyer

INTRODUCTION

Economics is a social science that permeates many aspects of our daily lives. Economics impacts our individual households, the agencies or companies for which we work, our nation, and more recently, the entire world. Thus, economics affects each one of us in many ways.

Economics also provides us with tools and a framework for use in evaluating many alternatives about which we must make decisions. This chapter focuses on the use of economic tools that are relevant to the evaluation of various aspects of MPLIS systems. Thus we can use economics to:

- examine land information and land information systems in general,
- evaluate a new MPLIS that is being considered for implementation,
- compare two or more MPLIS alternatives,
- compare current modes of operation with the MPLIS approach, and
- evaluate individual projects involving the use of MPLIS, whether manual or automated.

This chapter is divided into three sections. The first section considers the general field of land information system economics. This section attempts to provide a broad economic framework for the later sections. Therefore, a number of concepts are examined, including supply and demand of information, production functions, marginal cost functions, impact of technology, supply and demand, and joint products.

D. David Moyer is Wisconsin State Advisor for Land Information and Geodetic Systems with the National Geodetic Survey.

The second section turns to a specific tool, benefit/cost analysis (BCA), that is widely used in the evaluation of government projects of all sorts, including MPLIS systems. The section defines BCA, discusses how it is used and the kinds of results (help) it can bring to the decision maker, and finally, outlines a number of caveats with which the user of BCA should be aware.

Section three presents a number of examples from the literature of economic evaluations of LIS/GIS. The section provides information on approaches used, as well as results obtained.

ECONOMICS OF LAND INFORMATION SYSTEMS

The purpose of this section is to provide a broad framework for the discussion of the economics of MPLIS systems. Therefore, we begin with a number of concepts and terms that are relevant to our later discussion.

There are at least two basic uses for information economics in the discussion of MPLIS systems:

1. Information economics helps provide an understanding of the development, maintenance, and use of MPLIS. That is, the successful design of an MPLIS depends on an understanding of the value and cost of land information and LIS.

2. It also provides ideas on concepts and approaches that can be used in justifying an MPLIS and selling it to the administrators and other decision makers in your organization. For instance, information economics is not only about the cost of building a MPLIS system, or the savings that such a system will provide, compared to current manual methods. Rather, while information economics is useful for the above uses, it is also important in understanding and evaluating the impact of changes in the way the organization does business, since this is really the long-term impact of the effective introduction of an MPLIS system into an organization.

DEFINITIONS AND CONCEPTS

Before turning to details on information economics, we should note several definitions and concepts that are important to this discussion.

An MPLIS was defined earlier as the hardware, software, data, people, and institutional and organizational structure needed to collect, edit, store, analyze, retrieve, and output land information. Data in the system are arranged systematically in order to facilitate accessibility by users, as well as consistency of the data base and outputs created from it. Other features of an MPLIS include precision, accuracy, refinement of definitions (e.g., what is a parcel?), completeness, currency, frequency, and flexibility. Each of these features or characteristics influences the design, operation, and resultant economics of the MPLIS. For example, greater accuracy of data will usually increase the cost of the MPLIS, but it will also often increase the use of the system as well. This increased use can produce new benefits for existing system users, as well as generate new users of the system. Since system costs will then be spread over a wider user base, thus producing greater benefits, the additional costs for improved accuracy are often more than offset by increased benefits to users of the system.

Decision Framework

Decisions regarding MPLIS made by local and state governments are related, by and large, to existing information functions. The governmental agencies involved already have legally defined responsibilities related to land information. They also have the means to fulfill these responsibilities. (They may not be able to do the job as quickly as they or their customers would like, and the resulting output may not be as refined as would ideally be the case, but required results are generally produced.) Government workers rely on standard forms, statutory, administrative rule, or historical precedent, files that have been created for convenience, and numerous "make do" adaptations that have been created to get the job done. This means that the implementation of an MPLIS almost always means changing or replacing an already existing system. We seldom have the luxury of starting a city, county, or state LIS system from scratch (Wunderlich and Moyer, 1986).

Data and Information Distinguished

Information is data that has been put in context. That is, information is data that has been processed or transformed in order to meet a particular need. Economics tends to narrow the definition of information still further, defining information as the reciprocal of uncertainty. Thus, the more relevant information we have about a particular situation or item, the less uncertainty (more reliability) that exists. Therefore, it is possible to treat information as a goods or service that has value because of the ability of additional units of information to reduce uncertainty. Figure 15-1 illustrates this relationship between information and uncertainty.

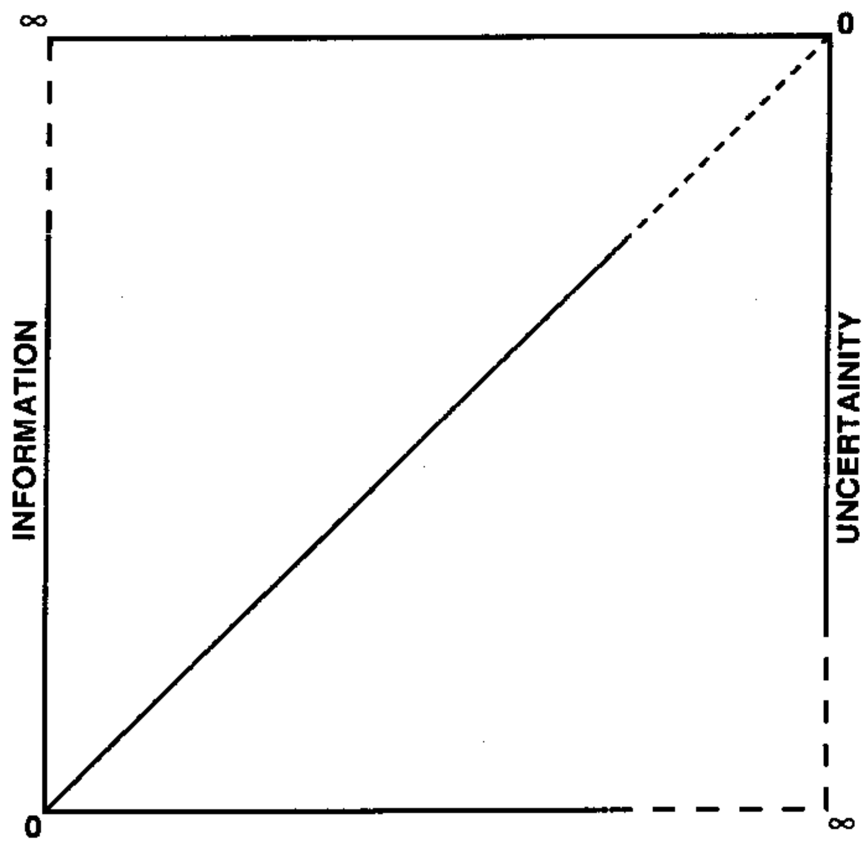

Figure 15-1: Information Vis-a-Vis Uncertainty

As an example, consider the information/uncertainty involved in defining the size, shape, and location of a parcel of land. A surveyor prepares a description of the parcel by using various equipment, field techniques, previous records, training, and traditions in the geographic area of interest. Depending on the client's needs and resources to pay for the service, the surveyor may prepare a simple sketch for a mortgage survey, use a theodolite or even GPS to determine coordinates of property corners, angles, and distances, and tie the parcel description to a plat, city plan, or even a statewide, nationwide, or worldwide coordinate system. Each additional relevant piece of information will decrease the uncertainty about the parcel description. The level of accuracy will also affect the information content (and cost) of the survey (for example, a survey with a closure accuracy of 1:3,000 will contain less information and be less costly than a 1:50,000 or 1:100,000 closure survey).

PRODUCTION FUNCTIONS

A conventional production function is displayed in Figure 15-2. This curve indicates that as inputs (e.g., time, money, effort) are increased, we obtain less and less increase in output. This is often referred to as the law of diminishing return, since each additional unit of input produces a smaller and smaller increase in output. Also, this figure suggests that it is possible to approach, but never actually reach, the state of complete information.

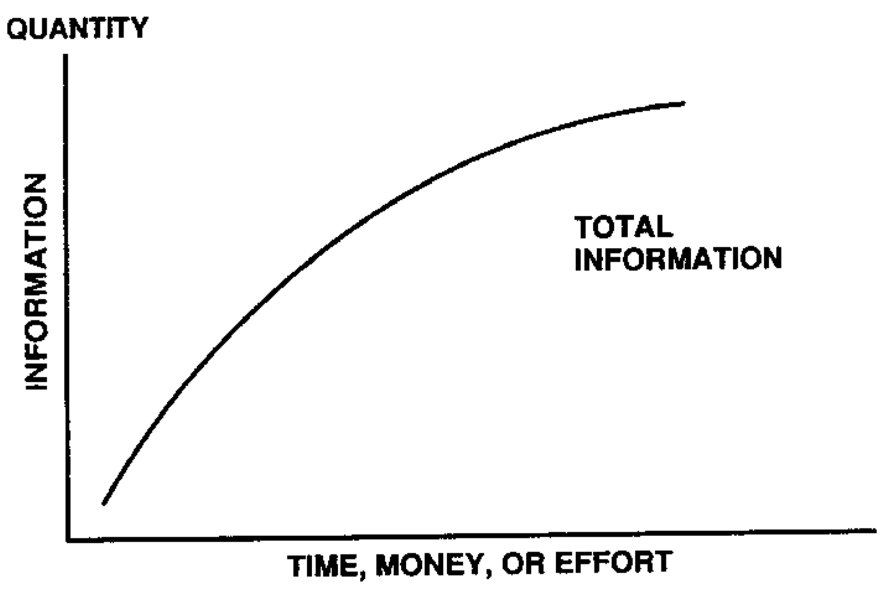

Figure 15-2: Information Production Function

The process we use in the United States for the evaluation of quality of title exemplifies the process of approaching, but never reaching, a point equal to full information. The U.S. title system depends on the recording of evidences of title, not the title itself. Therefore, the title evaluation process requires that we collect as much of this evidence as we want or are willing to pay for. In this title examination process, the reduction of uncertainty almost never reaches the zero point (e.g., see Figure 15-1). In economic terms, the best title is not necessarily the one with all uncertainty removed, but rather the one about which all uncertainty worth searching for has been removed. For example, it makes "economic sense" to search for information until the savings from the last unit of information obtained just exceeds the cost of obtaining the information.

Similar illustrations can be made for survey maps, assessment records, or as-built highway or building drawings. In each case, more effort, time, or money will likely produce more accuracy, more detail, or more timely information. The economic issue that must be faced is what cost, in terms of dollars, time, or effort, is the user willing to pay for these marginal increases in inputs in order to obtain more, or higher quality, output. Also, in MPLIS, it must be kept in mind that different users and different purposes are likely to have different requirements. Economics can help in these instances by helping to determine what the additional costs are and suggest how these costs might be allocated to users.

MARGINAL COST FUNCTIONS

Another way to consider (and plot) these changes in production due to increased inputs is to examine only the marginal changes in cost and production. Thus in Figure 15-3, the first

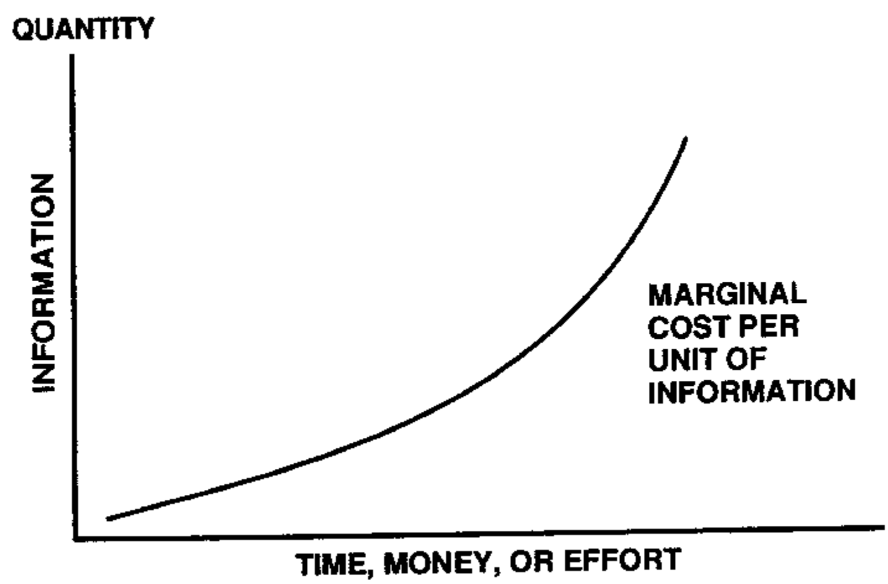

Figure 15-3: Marginal Cost Function for Information

additional units of output cost relatively little (i.e., the curve rises only slightly at the beginning as we move to the right). Subsequently, as we move further to the right, each additional unit of output costs more and more (in time, dollars, etc.), and the curve soon is nearly vertical.

Understanding and use of production functions can be useful to both designers and users of MPLIS systems. However, it must be noted that to create such functions, it is necessary to specify (or find proxies for) output units of information, measures for inputs such as effort and time, and make comparisons between alternative production functions.

IMPACT OF TECHNOLOGY

Comparison of alternative production functions arises, for instance, due to the development of new technology. New technologies for handling land information can revolutionize access to data, producing large increases in both the number of users and the uses to which the information is put.

Computerization of property assessment records permits the use of computer assisted mass appraisal (CAMA), which radically changes our ability to aggregate assessment data, manipulate these data for assessment and other uses, and makes possible the access of these data by a much larger group of users.

Changes resulting from new technology are represented graphically in Figure 15-4. Status quo is represented by the solid curve, while introduction of new technology causes a shift to the "dashed" curve. Two types of shifts are illustrated: increases in output and savings in inputs. The creation of digitized information on physical features of land has greatly enhanced the opportunities for planners to create and consider optional designs for land development (WLIN, 1983). Computer assisted appraisal now allows annual reassessment of parcels, many of which were only changed at 5-, 8-, or 10-year intervals when manual assessment was used. CAMA systems have greatly reduced manual labor of repetitive entries into record files and indexes. Microfilming, digitizing, and image processing have reduced the physical space needed for record storage, as well as making these records more easily accessible to a much larger audience. The net result is major shifts in the production, cost, and use of many kinds of land information.

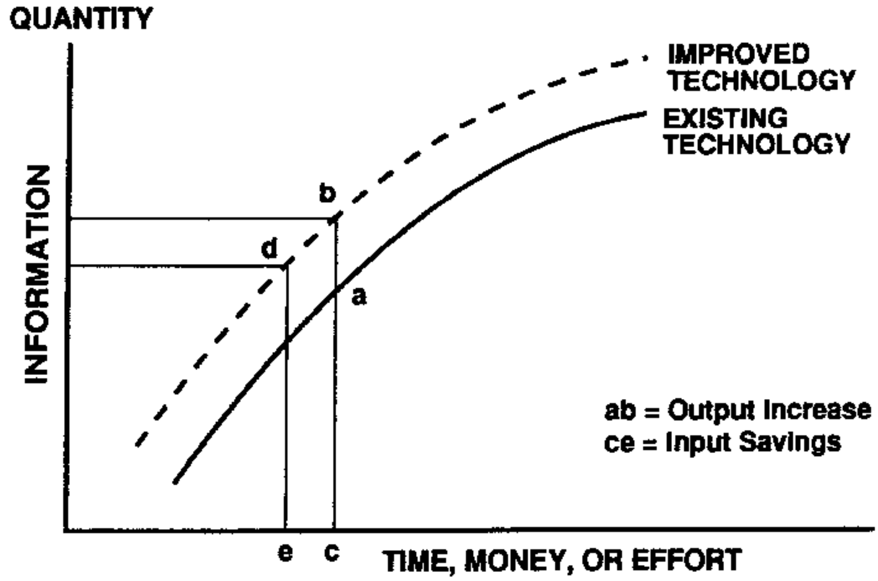

Figure 15-4: Impact of Technology on Information Production Function

SUPPLY AND DEMAND

Four concepts or assumptions provide the foundation for the discussion of supply and demand of land information:

1. Information has value.
2. People want information.
3. Information is limited in amount.
4. Information is made available at a cost.

These concepts are useful in the general examination of MPLIS.

The "market" for land information is a far cry from the classical free market mode. Problems such as poorly defined units of information, lack of precise terms of exchange, and the impact of regulations and fee structures all tend to make it difficult to determine the slope and shape of demand and supply curves for land information. Nevertheless, supply and demand concepts help provide a framework for a discussion of the various costs and benefits of land information and land information systems.

Figure 15-5 contains several examples of typical demand curves (functions) that exist as to land information. Note that as the price, P, of land information (on the vertical axis) drops, we can expect the quantity of land information demanded to increase.

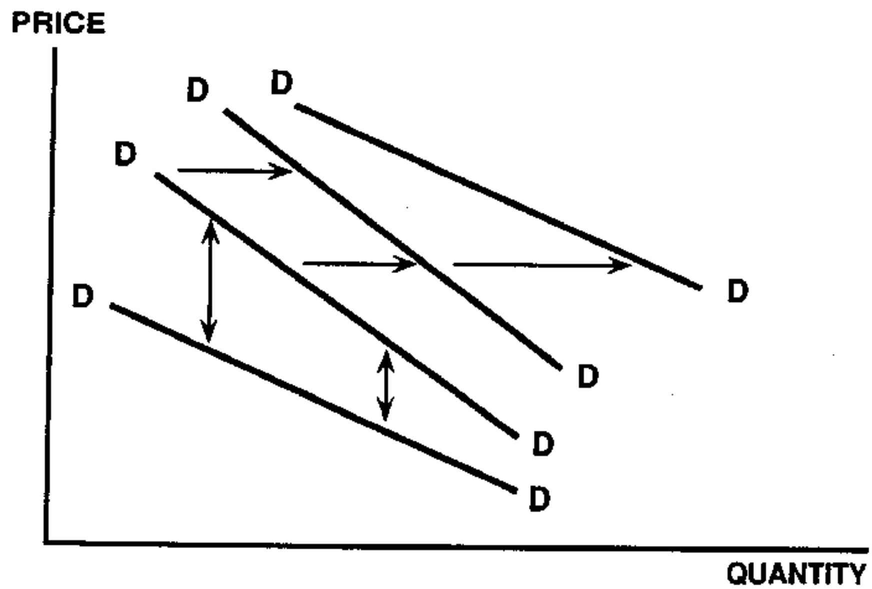

Figure 15-5: Information Demand Functions

Similarly, the supply curve in Figure 15-6 suggests that more information will be provided when more dollars are made available to pay for it (i.e., when the price increases). These concepts thus can be used to help users determine what land information they really want to request, and also, to help providers decide what land information they will provide, given the price they can realistically expect to receive for it. Therefore, economic analysis can be useful if it can provide even rough estimates to guide users and producers in this decision making process. For

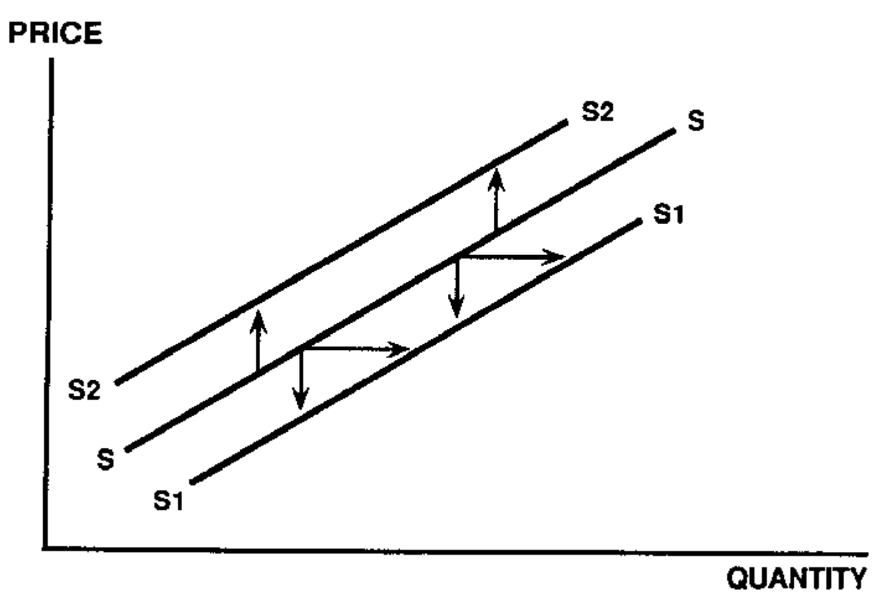

Figure 15-6: Information Supply Functions

example, how much more assessment information will be used if we can cut the access time (an important cost) by 25 or 50 percent? Similarly, how many new tables or new maps would be produced if demand, as evidenced by willingness to double the expenditures for such products, became apparent?

Thus far, we have considered the shape and slope of supply and demand curves as related to information. In many cases, the shifts and changes affect relationships between supply and demand. For example, new uses of title or tax record information may shift the demand for information to the right (Figure 15-5). New technology, in the form of LIS software or computer hardware, may increase capital costs, but also lower the time and effort for public officials and other users. The net result is a downward shift in the supply curve (Figure 15-6). If automation results in the capability to produce more information at a given cost, the supply curve can shift to the right (Figure 15-6). The use of scanning technology to capture certain types of graphic data for use in an MPLIS is one example of the supply curve shifting to the right. Use of scanners has been found to produce a three-fold increase in output of soils data for a given level of inputs (time and cost) (Moyer and Niemann 1990). Comparable shifts have been documented through the use of Global Positioning System (GPS) technology for determination of coordinate locations for survey monuments (ibid.).

Industry-wide demand and supply relationships can provide important insights into the land information "business." For example, the demand for GIS/LIS products in the United States over the 8 years from 1992-1999 is estimated to total $100 billion (*The Economist*, 1992). A demand of this magnitude will have major impacts on the equilibrium quantity supplied, as well as the shapes of the supply and demand curves. Similarly, new technology has, and will continue to have, a major impact on the information "market." For instance, $10,000 workstations of today have the capabilities of $250,000 mainframe computers of the mid-1980s, a 96 percent reduction in cost. Comparable improvements in technology appear likely to continue to occur.

Probably even more important in planning and evaluating an MPLIS for a specific jurisdiction is to focus on the demands and supplies that are likely to result from specific classes of users. The needs (demands) of planners, assessors, and title conveyancers, compared to the output (supplies) provided by recorders and title insurers is more manageable and probably more useful when evaluating a jurisdiction-specific MPLIS.

It is also important to consider demand and supply of information at each stage of production. For example, an assessor is a user (demander) of information from other local officials for some parts of the assessment process. The assessor is also a supplier of information to other officials, such as treasurers, private appraisers, and taxpayers, at other times. By setting up the analysis in this way, it is easier to carry out the evaluation, and it usually produces a result that is more pertinent to the local situation.

JOINT PRODUCTS

Two or more offices, agencies, or other user groups sometimes work together to produce a product that is needed by all members of the producing group. The economies resulting from the production of these products jointly can be credited as benefits of an MPLIS. Caution should be used when valuing joint products, since such economies are typically more often claimed than actually demonstrated (Wunderlich and Moyer 1984). However, there are a number of examples of economies resulting from such joint product efforts.

1. Reduction in duplicate map sets: Albuquerque reduced the number of map sets maintained by the city from seven to one.

2. Specialization of knowledge: Title insurers have specialized in the compiling of data and production of information about the quality of land titles. This specialization produces information that now produces income for such companies of several billion dollars annually. This information is generally of higher quality, cheaper, and more accessible to the user public than data in the public record system maintained by counties.

3. Added value resulting from the combination of separate data elements: By combining ownership data and soils data, the resulting information is more useful for value assessment and for producing soil erosion reduction plans [in Wisconsin].

4. Efficiency in data processing: As computers (hardware) become faster, less time is needed to access programs (software) and load data bases, which saves time for the operator as well as saving computer time.

5. Coordinated outlets for information products and services: Users of MPLIS systems save time, frustration, and error by having access to a one-stop system for access to land information (e.g., building permits).

One final aspect on joint products should be noted -- some tradeoffs may be necessary to produce these products. For example, compromises may be necessary as to levels of precision, ease of access, currency of data, and frequency of updates. Any losses (costs) as to these items, for specific offices or for specific functions, must be measured against overall gains (benefits) that accrue to the MPLIS in general.

BENEFIT/COST ANALYSIS

One of the tools that is widely used in the economic evaluation of public sector projects and systems is BCA. This section examines the economic nature of information, what BCA is and how it is used, the complexities of BCA, the kind of help it can provide to decision makers, and outlines several caveats that should be kept in mind when applying BCA to specific information system situations.

ECONOMIC NATURE OF INFORMATION

In any sector of our economy, we can point to scarcity -- of dollars, people, or time -- that affects the output of goods and services. In order to make decisions regarding the economy, (e.g., how to carry out a job most effectively or whether to do one task as opposed to another), we need to collect and organize information to help make these decisions. This is true whether our role is policy maker, bureaucrat, or private consumer.

Economic evaluation techniques can provide a number of answers to questions that are often raised when MPLIS systems are competing for resources. Questions include:

- How much will the new system cost to implement?
- How much will the new system cost to maintain?

- What cost savings will it produce (e.g., what current tasks will it replace)?
- What additional benefits, besides cost savings will the MPLIS produce (e.g., what new products will it produce and what is their value)?
- How does the MPLIS compare with other systems and projects that are competing for dollars in this budget framework?

A number of techniques, including BCA provide a rational framework for providing the answers to such questions in a dollars and cents context that is relatively easy to understand.

For products in the private sector, "markets serve as the decision making mechanism for deciding <u>what</u> will and will not be produced" (Epstein and Duchesneau 1984). Also, these markets help determine the <u>amount</u> that will be produced (and demanded) and the <u>price</u> at which products will be bought and sold.

In this private market situation, benefits are reflected by the willingness of consumers to make expenditures in order to buy and consume various amounts of a product or service. Similarly, expenditures "are reflected by the schedule [production function curve] of costs incurred at various levels of output" (ibid.). The interaction of these benefits and costs in the market establishes the price or value of the product in question. Resources are then allocated by supply and demand forces, as discussed above. Markets, and the prices that operate within them, thus provide a mechanism for determining the benefits and costs of alternative users for scarce resources. Both the producer and the consumer are thereby guided in their decision making by the information they receive from the market.

Unfortunately, traditional markets do not provide much help when it comes to valuing information and information systems. The market is not directly applicable to most situations that involve government (and other public sector) products and services. This conclusion is based on several assumptions, all of which are related to the economic nature of information:

1. Public goods are consumed collectively. Governmental products (public goods) are consumed collectively by society as a group, while private goods are usually consumed by individuals. This consumption "pattern" for public goods results because no one can be excluded

from consuming a public product, once it is produced. (Items such as national defense, the Interstate Highway system, and survey monuments are typical examples of public goods that are "available to all consumers.")

2. Public information is a public good.

3. Public information is not sold in a traditional market.

4. Value of information is determined by its contribution to decisions.

5. People will pay for information that reduces risks associated with decisions that they must make.

6. The search is not necessarily for the best information, but for the best information worth searching for.

This last point is obvious when considering the evaluation of the quality of a land title or collecting information about the value of a land parcel. The cost of collecting all information about a land title would be very expensive. In many cases, the acquisition of all information is not possible, even if resources to do so are unlimited. Therefore, the tradeoffs of greater certainty about title quality are almost always compared with the cost of acquiring more information about the title.

What all this means is that some alternative, non-market method of resource allocation is needed in regard to public goods, such as land information or MPLIS systems. BCA is one approach that is often used to help in decision making in the public sector. That is, BCA in the public sector replaces the function served by the market in the private sector.

DEFINITION OF BENEFIT/COST ANALYSIS

Important points about BCA include the following.

1. BCA is a means to organize ideas and structure the decision process.

2. BCA forces a consideration of both quantifiable and non-quantifiable factors in public expenditure decisions.

3. BCA is not a substitute for making decisions, rather it is a tool to provide help in this process.

The basic idea in a BCA is to determine if benefits exceed costs. This involves adding up all costs and all benefits and comparing them. This comparison is typically carried by determining the benefit/cost ratio, i.e.,

$$\frac{\text{Sum of all Benefits}}{\text{Sum of All Costs}} = \text{B/C ratio}$$

If the ratio is greater than 1 (i.e., if $B > C$), the project, system, or service is considered to be cost effective.

While BCA is simple in concept, it becomes much more complex when actually applied to a specific situation. Identifying all impacts that result in costs and benefits, placing a value (or weight) on each item identified, and comparing the sum of benefits with the sum of costs is almost never a simple procedure.

COMPLEXITIES OF BCA

Identifying the Impacts

There are a number of reasons for the operational complexity of BCA. First, all of the benefits and costs of the activity must be identified. It is usually relatively easy to identify direct impacts, such as income from products, costs of new hardware, labor to operate the system, and cost-savings from termination of the activity replaced. However, the indirect impacts are, by definition, much harder to identify. Indeed, the decision-making process often becomes more difficult due to this aspect of BCA, since a larger number of relevant factors are identified for consideration than would otherwise be the case.

A classical BCA should include all impacts that apply, regardless of where in society they occur. However, in actuality, many impacts are not included. These excluded impacts are outside the framework within which the decision maker is operating. These excluded impacts are often termed externalities. The following examples are illustrative of the restrictions that are sometimes applied to BCA.

a. A soft drink bottler evaluates the benefits and costs of switching from returnable to non-returnable bottles. The bottler compares the cost of producing new, non-returnable bottles each time, versus the cost of collecting and cleaning the returnable bottles. Based on a lower cost for producing new bottles each time, the bottler chooses the non-returnable option. The shortcoming in this analysis is that the benefit/cost equation was not complete, since the external effects of the societal costs of disposing of the bottles (in landfills or recycling), are not included in the decision-making process.

b. A government agency evaluates the benefits and costs, within their agency, of using GPS (Global Positioning System) to develop a geodetic survey network to support engineering work in their agency. Since the benefits exceed costs, the agency approves and implements the system. The shortcoming here is that if other agencies and the private sector had been included (i.e., if "the net had been cast wider"), an even more favorable benefit/cost ratio would have been obtained. (While costs of including others would have increased the costs, the benefits of such a multi-agency effort would have increased even faster.)

Valuing the Impacts

A second operational complexity of BCA arises due to the need to assign a weight (or value), to each impact identified. Some effects, such as increased output, decreased costs, less space, fewer employees, more hardware, and new software, are relatively easy to weigh. Other impacts are more difficult when their impact is secondary or tertiary, being relatively far removed from the decision that is being made. For example, how do you weight the impact on the national mortgage market due to the reduced title transfer costs that result from title insurance or automated title record systems in county government?

Other approaches have been suggested for valuing the impacts of GIS use. One such approach involves a three-step process (Gillespie, 1991):

1. Identify how outputs have changed.

2. Identify how each change in the output affects the users.

3. Determine the value of each effect on the users.

This technique is suggested to be especially useful in valuing benefits that occur as a result of being able to do tasks with the MPLIS that were not possible using manual methods.

Accounting for Temporal Differences

A third difficulty in carrying out a BCA is that costs and benefits do not occur all at one time. More often costs and benefits, especially the latter, tend to occur as a stream over a period of time. This is particularly true for benefits, which often accrue over 5, 10, or 20 or more years. Costs, on the other hand, tend to be "front end loaded," occurring early in the project (see Figure 15-7).

The "total cost" curve in Figure 15-7 shows that there are substantial costs at the very beginning of LIS development. Also, benefits do not start occurring immediately; rather they are delayed until the system has been in operation for several months, a year, or longer. By tabulating total costs and total benefits, a breakeven point, where total project costs are equal to total project benefits, can be obtained. In many LIS projects, this breakeven point occurs about 5 to 7 years after initiation of the project.

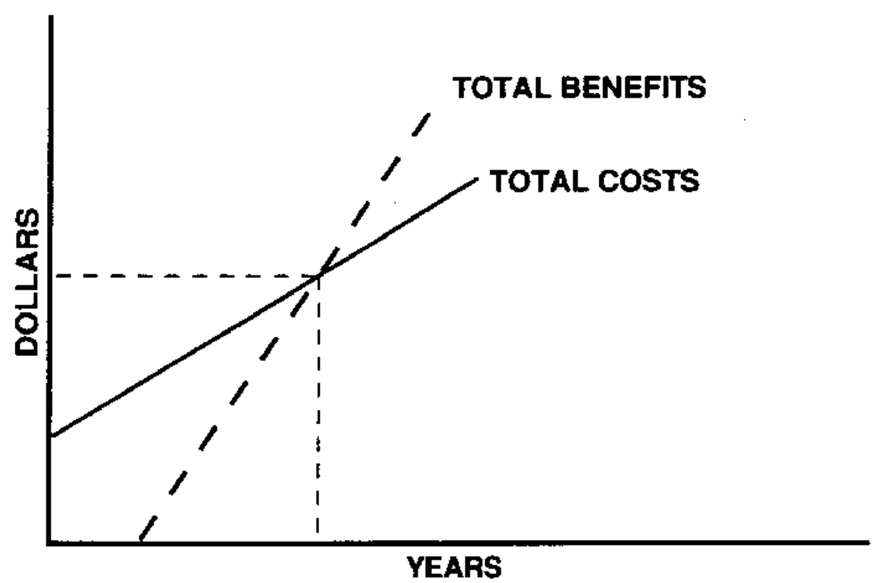

Figure 15-7: Breakeven Point, as Determined by Benefit and Costs Functions

The complexity that must be addressed is that these streams of benefits and costs must all be converted to a single point in time (i.e., present value), in order to make a valid comparison. Such a comparison is usually done by converting all benefits and costs to a present value, as of a specific date.

Interest Rate

A fourth complexity, related to the third, is what interest rate should be used to convert all values to the present. Care should be exercised to ensure that the selected interest rate does not have an unintended (or unknown) impact on the final outcome of the BCA. Conversely, the interest rate should not be selected to produce an intended impact. That is, the discount rate should be objectively selected, not subjectively selected so as to yield the desired result.

Analysis of System Output

Benefits are often measured in terms of reduction in costs. This approach to benefit determination usually assumes the continuation of the current output of goods or services. This assumption can lead to two kinds of problems, first, the continued production of output that is no longer needed or worthwhile and second, the failure to recognize new or future needs of systems users. Both of these assumptions should be carefully examined when carrying out an evaluation of an MPLIS. It is sometimes possible to delete or modify products or processes that exist only because "we have always done it that way." Also, remember that early implementers of MPLIS systems have found that the majority of benefits that have accrued to their new system have been unexpected. Therefore, you can safely assume that several benefits will probably accrue, even though you are unable to identify them when the project is first undertaken.

The bottom line is to keep in mind that BCA, while it is a valuable tool, is not a substitute for the need to make decisions. Many factors, including those outlined above, should be considered when carrying out BCA.

EXAMPLES OF ECONOMIC EVALUATION TECHNIQUES

This section provides a brief overview of several economic evaluations that have been conducted for GIS, LIS, and MPLIS systems. While the emphasis is on benefit/cost analysis, other techniques are included as well. Additional studies cited in the literature are included in the References and Additional Readings section of this chapter.

The list of citations here is not exhaustive. Rather it is illustrative of the kinds of economic evaluations that have been conducted by others and found to be useful. In the discussion here, we will point out strengths and weaknesses of these studies, which is intended to help others who need to conduct an economic evaluation of a land information system or project.

1. "Final Report of the Subcommittee on Benefits and Costs," Wisconsin Land Records Committee, 1987. Available from the Institute for Environmental Studies, University of Wisconsin, 70 Science Hall, Madison, WI 53706. Cost: $ 2.00.

This report provides some guidance as to how to go about conducting a BCA. A brief introduction on BCA is followed by several examples. The examples range from elementary studies to very complex, giving an indication of the scope of analyses for which BCA may be appropriate. A bibliography of articles prepared since 1981 on the application of BCA to LIS and related systems is also included. As is typical, the articles cited generally deal with costs more extensively than benefits.

2. "Land Records: The Cost to the Citizen to Maintain the Present Land Information Base, A Case Study of Wisconsin," prepared by Barbara Larsen, et al., 1978. Published by the Wisconsin Department of Administration, 101 South Webster Street, Madison, WI 53703.

This study is a landmark in the field. While it focuses largely on costs, it was the first, and as yet unreplicated, study that provided an innovative approach to documenting costs of maintaining current, manual systems of land records. It has been widely cited, noting that the costs documented amounted to over $35 per parcel per year, in 1978. Recent updates have projected current costs at over $70 per parcel per year. The study was also effective in focusing attention of policymakers (in the legislature and in state agencies) to LIS issues in general and on economics of LIS in particular.

3. "The Use and Value of a Geodetic Reference System," by Earl F. Epstein and Thomas D. Duchesneau, 1984. Published by the Federal Geodetic Control Committee and available from the National Geodetic Survey Information Branch, 11400 Rockville Pike, Room 26, Rockville, MD 20852, for $5.00.

The Epstein/Duchesneau report is one of the best available examples of classical BCA applied to land information systems. The analysis focuses on four case studies in the application of highway construction, local and regional planning, and private land development.

Several aspects of the report are worthy of note.

a. Value (benefit) determination is examined in terms of the demand for the output of the system, measured in terms of the price consumers are willing to pay for the output.

b. Benefits are measured in terms of costs that government avoids as a result of the operation of the LIS system.

c. The geodetic reference system yielded a large stream of benefits, with a benefit/cost ratio of between 1.7 and 4.5 in the four geographic areas studied.

d. The majority of the benefits were the result of secondary and tertiary uses of spatial information that was based on the geodetic system.

e. The authors argue that benefits of the geodetic system accrue since it provides universal compatibility of information in the LIS that allows many persons other than the initial producers to make use of the data.

The report provides good documentation of the benefits that accrue due to careful planning and development of LIS that use geodetic control networks. These networks provide the basis for coordination and linkage of land information from a variety of files for a variety of functions. These linkages, in turn, permit many users to rely on a common, coordinated data base for a wide variety of uses.

4. "The Development of an Automated Mapping and Land Information System: A Demonstration Project for the Town[ship] of Randall, Kenosha County [Wisconsin]," prepared by the Southeastern Wisconsin Regional Planning Commission, 1985. Available from SEWRPC, P.O. Box 769, 916 N. East Ave., Waukesha, WI 53187-1607 for $10.

This report concentrates on the cost side of the equation. The cost approach is extremely detailed, resulting in a comprehensive look at costs for this pilot study area. Costs are included for all aspects of each function for the mapping and survey control process. Therefore, they appear to be overstated in some cases, since a significant proportion of the work had been completed. This is similar to the situation that exists in many jurisdictions. Therefore, while undue reliance on the specific data in the report is not warranted, the framework and procedures used are noteworthy.

5. "Comparing the Costs: Manual Versus Automated Procedures for Handling Land Records," by D. David Moyer, et, al., 1988, *Proceedings of the American Congress of Surveying and Mapping*, Volume 5, pp. 198-206.

This paper provides cost data on converting four layers of land data to digital form and producing a countywide plan for soil erosion control for Dane County, Wisconsin (see Table 15-1). The Dane County data were extrapolated to produce an estimate of the cost necessary to produce these four automated layers for 54 additional counties in Wisconsin. These other counties actually developed erosion control plans using manual methods and produced hard copy reports, rather that automated systems. Since the State provided nearly $800,000 to the counties to produce the reports in a manual mode, the authors concluded that automated techniques were comparable in cost to manual methods. They also note that by using the automated techniques, Dane County also had available an automated data base that was suitable for many additional uses.

6. "Economic Impacts of LIS Technology upon Sustainable Natural Resource and Agricultural Management," by D. David Moyer and Bernard J. Niemann, Jr., 1991, *Surveying and Land Information Systems*, Vol. 51, No. 1, pp. 17-21.

This paper suggests a method for dealing with the complex analyses that are necessary to evaluate MPLIS systems. Five categories of benefits are suggested and documented: improved efficiency, responsiveness, integration, fairness and equity, and effectiveness. Among the specific analyses are a cost comparison of manual versus scanner data digitization and conventional versus GPS land surveying techniques. The authors conclude that automated LIS systems are necessary to deal effectively with complex government programs being mandated to conserve natural resources.

Table 15-1: Costs to produce automated data layers for soil erosion control planning in Dane County, Wisconsin.

LAYER	COST (1)		
	Per Sq. Mile	Per Twp.	Statewide(2)
Soils(3)	$12.00	$432.00	$480,000
Land Cover (4)	1.50	54.00	60,000
Wetlands (5)	.05	1.80	2,000
PLSS (6)	3.75	135.00	150,000
Production (7)	3.00	108.00	120,000
Total	$20.30	$730.80	$812,000

(1). Based on personnel charges of $12.00 per hour, computing costs of $1.50 per CPU minute and $1.00 per connect hour on VAX 8600 computer.
(2). Extrapolated costs for the approximately 40,000 square miles for which an erosion control plan is required in Wisconsin.
(3). Conversion to digital record, based on scanning technology.
(4). Using LANDSAT Thematic Mapper data.
(5). Data format conversion only (already automated).
(6). PLSS - public land survey section corner information from 1:24,000 USGS Digital Line Graphs (assumes 50% cost share with USGS).
(7). Production costs include analyses, computing, and plotting of seven maps for each township.

SUMMARY

There has been a rapid increase in the implementation and use of land information systems in the past five years. Government agencies and private companies have both contributed to this trend. Based on the systems in place and efforts underway, it appears likely that this trend will continue for the foreseeable future. But in spite of this increasingly acceptable way of handling spatial data, nearly all systems must be justified to decision makers, and generally this justification must be conducted in an economic framework.

Decision makers, whether at the policy or administrative level, must make many choices among competing demands for resources. It is important therefore, that justifications be carried out in a manner that will make the case for MPLIS systems as clearly and convincingly as possible.

Economic evaluations are one approach that has been widely used to justify many publicly funded systems and projects. This chapter suggests that such techniques are generally applicable to LIS evaluation, and provides a number of examples where they have been successfully used. BCA is especially important since it is widely used and generally understood.

However, techniques like BCA may bring additional complexity into the decision making process, since a larger number of relevant impacts may be identified for consideration.

In making economic evaluations of MPLIS systems, new tasks that need to be done, as well as old tasks that are no longer needed, should be documented. Benefits in terms of cost savings and new, improved outputs can often be documented through this process.

While benefit cost analysis is not an easy task, it is a powerful tool that can often provide valuable assistance to decision makers.

Finally, economic evaluation of an MPLIS is an on-going process. Documentation of costs and benefits are just as important for modifying and improving an MPLIS as in supporting initial implementation.

REFERENCES AND ADDITIONAL READINGS

The Economist, 1992, p. 73.

Epstein, Earl F. and Thomas D. Duchesneau, 1984: *The Use and Value of a Geodetic Reference System*, University of Maine at Orono, Federal Geodetic Control Committee, Rockville, MD.

Gillespie, Stephen R., 1991: "Measuring the Benefits of GIS Use," *Proccedings of ACSM/ASPRS Fall Convention*, Atlanta, Georgia, pp. A-82 to A-94.

Gurda, Robert F., Bernard J. Niemann, Jr., D. David Moyer, and Stephen J. Ventura, 1987: "Costs of Benefits of GIS: Problems of Comparison," *Proceedings of the AAG International Geographic Information Systems Symposium*, Crystal City, VA, Vol. 3, pp. 215-224.

Kishor, Puneet, Bernard J. Niemann, Jr., D. David Moyer, Stephen J. Ventura, Robert W. Martin, and Peter G. Thum, 1990: "Evaluation of GIS/LIS: Lessons From CONSOIL," *GIS/LIS '90 Proceedings*, November, Anaheim, CA, Vol. 2, pp. 701-711.

Larsen, Barbara J., James L. Clapp, Alan H. Miller, Bernard J. Niemann, Jr., and Arthur L. Ziegler, 1978: "Land Records: The Cost to the Citizen to Maintain the Present Land Information Base, A Case Study of Wisconsin," Wisconsin Department of Administration, Office of Program and Management Analysis, Madison, WI 64 pp.

Mishan, E. J., 1971: *Cost-Benefit Analysis, An Introduction*, Praeger Publishers, Inc., New York.

Moyer, D. David, 1980: "Property, Economics, and Information: A Foundation for Land Information System Evaluation," *Geoprocessing Journal*, [Amsterdam] Vol. 1, pp. 275-295.

Moyer, D. David and Bernard J. Niemann, Jr., 1991: "Economic Impacts of LIS Technology Upon Sustainable Natural Resource and Agricultural Management," *Surveying and Land Information Systems*, Vol. 51, No. 1, pp. 17-21.

Moyer, D. David, Bernard J. Niemann, Jr., Robert F. Gurda, and Stephen J. Ventura, 1988: "Comparing the Costs: Manual Versus Automated Procedures for Handling Land Records," *Proceedings of ACSM/ASPRS*, St. Louis, MO, Vol. 5, pp. 198-206.

Prest, A. R. and Ralph Turvey, 1965: "Cost Benefit Analysis: A Survey," *The Economic Journal*, Vol. 75, December, pp. 683-735.

Southeastern Wisconsin Regional Planning Commission, 1985: "The Development of an Automated Mapping and Land Information System: A Demonstration Project for the Town of Randall, Kenosha County, Wisconsin," Waukesha, WI.

Ventura, Stephen J., Nicholas R. Chrisman, Kevin F. Connors, Robert F. Gurda, and Robert W. Martin, 1988: "A Land Information System for Soil Erosion Planning," *Journal of Soil and Water Conservation, Vol. 43, No. 3, pp. 230-233.*

Wisconsin Land Records Committee, Subcommittee on Benefits and Costs, 1986: "Benefit Cost Applied to Land Records," Center for Land Information Studies, University of Wisconsin-Madison, 40 pp.

Wunderlich, Gene, and D. David Moyer, 1984: "Economic Features of Land Information Systems," *Proceedings of Seminar on the Multipurpose Cadastre: Modernizing Land Information Systems in North America*, edited by Bernard J. Niemann, Jr., IES Report 123, University of Wisconsin, Madison, pp. 41-60.