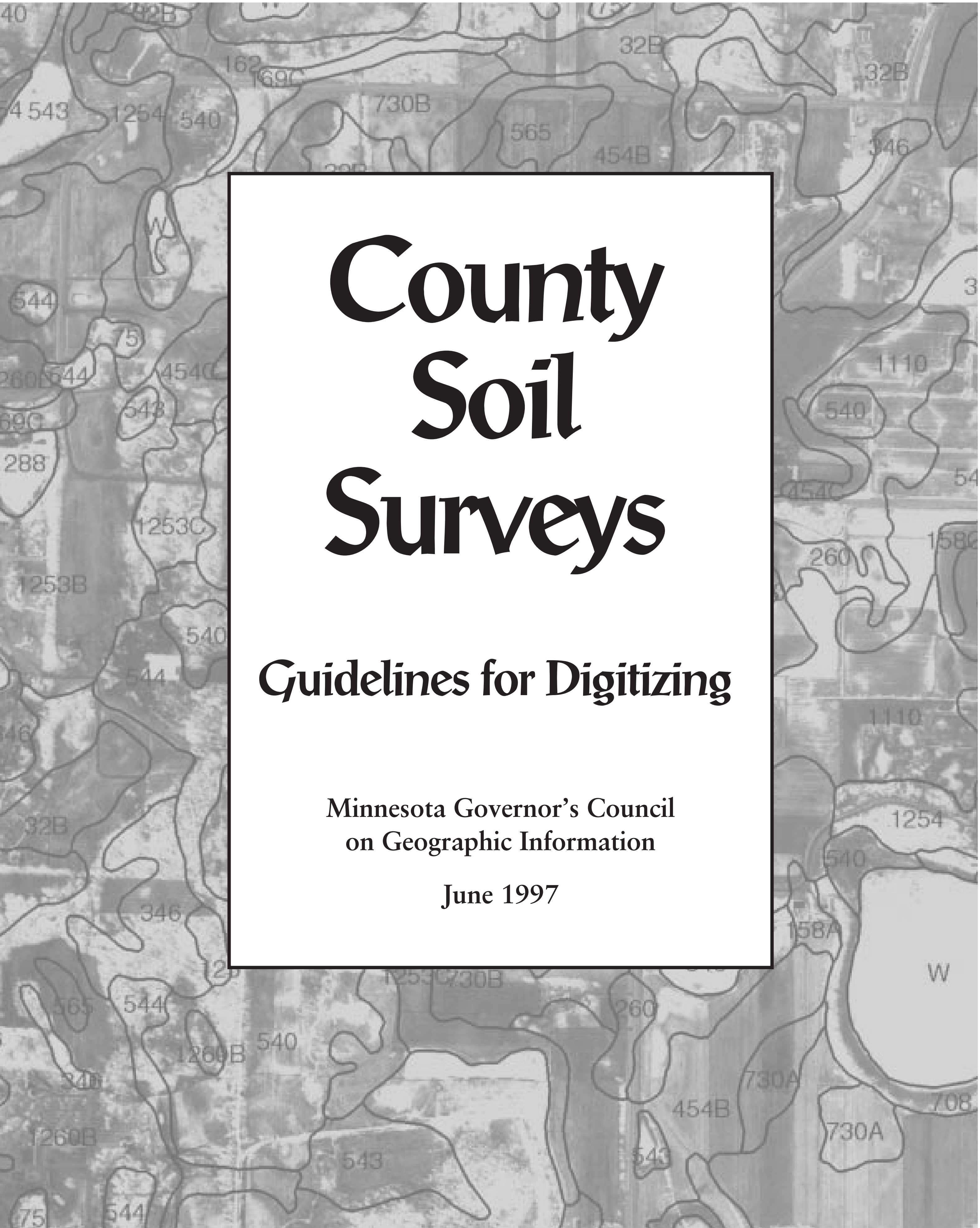

County Soil Surveys

Guidelines for Digitizing

Minnesota Governor's Council on Geographic Information

June 1997

The Governor's Council on Geographic Information was created in 1991 by Governor Arne H. Carlson to provide leadership in the development, management and use of geographic information and related technology. With assistance from Minnesota Planning, the council provides policy advice to all levels of government and makes recommendations regarding investments, management practices, institutional arrangements, education, stewardship and standards.

Minnesota Planning is charged with developing a long-range plan for the state, stimulating public participation in Minnesota's future and coordinating activities with state agencies, the Legislature and other units of government.

Upon request, *County Soil Surveys: Guidelines for Digitizing* will be made available in alternate format, such as Braille, large print or audio tape. For TTY, contact Minnesota Relay Service at (800) 627-3529 and ask for Minnesota Planning.

MN PLANNING

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June 1997

For additional information or copies of *County Soil Surveys,* contact the council staff coordinator at (612) 296-1208 or e-mail, gc@mnplan.state.mn.us. An electronic copy of this report can be found on the Governor's Council on Geographic Information's World Wide Web home page: www.lmic.state.mn.us/gc/gc.htm.

Cover map: Natural Resources Conservation Service, Minnesota State Office (map image shown in reverse).

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Summary

Creating a high-quality digital soil map and related database for geographic information systems is an expensive process. This report is intended to provide information and guidance to Minnesota organizations considering developing digital soil maps from county soil surveys.

Local and statewide demands for digital soil survey data are far outpacing the ability of federal and state soil mapping organizations to produce the data.

Modern soil surveys can be used for highway construction, agricultural planning, tax assessment, forest management and ecological research, among other activities. To provide information that local officials and others can use to make the best soil mapping decisions, the Governor's Council on Geographic Information Soils Data Committee has developed *County Soil Surveys: Guidelines for Digitizing*, which:

- Categorizes the nature and current status of all county soil surveys in Minnesota
- Describes common GIS data formats by which soil data can be stored
- Identifies methods and resources for converting soil surveys into digital map files and related databases

Techniques used by the federal Natural Resources Conservation Service to classify and map soils have changed significantly from early surveys, some of which were done in the 1930s. Minnesota's county soil surveys in general tend to fall into one of three categories:

- Outdated and in need of major resurvey before they are converted to digital form
- On unrectified base maps and in need of spatial corrections before digitizing
- On modern orthophoto base maps and ready for digitization

A hard look needs to be taken at the county soil survey before embarking on converting it to a digital product. Changing methods for producing county soil surveys over time have resulted in a lack of standardization. Loading an outdated survey into a GIS will not improve either the quality or the accuracy of the data. The process of bringing an outdated survey up to current NRCS specifications depends on the date and survey techniques used in the original mapping effort. This report describes the evolution of the National Cooperative Soil Survey in Minnesota and appropriate uses of soil surveys, as well as provides information to determine the status of all county soil surveys.

The report also describes the common GIS file types and considerations to be made in choosing which to use. While a discussion of file types can be somewhat technical, an understanding of the most common file types is important. File types affect the cost of the data conversion and the overall usefulness of a digital soil survey.

Finally, the report reviews issues that should be considered before converting paper soil survey maps into a digital GIS format.

County Soil Surveys

Contacts

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Glossary

Below are generally accepted definitions for terms used in this report.

Base map — Map containing geographic features used for orientation.

Digital soil data — Soil data stored in a digital, or computerized, format.

Edge matching — Ensuring that the features on adjacent map sheets fit together.

Geo-referencing — Translating the location of map features into real-world coordinates such as latitude and longitude.

Metadata — Detailed descriptions about data: geographic area covered, methods used to produce it, currency, accuracy, and so on.

Orthophoto — Computer-generated photograph that corrects for distortion caused by hills, valleys and other landscape features.

Raster format — Data structure where rows and columns are used to store images.

Rectified photography — Method used to minimize distortion caused by the camera angle.

Soil survey — Systematic inventory of soil types in a geographic area.

Terrain relief displacement — Distortion of features on an aerial photograph caused by hills, valleys and other landscape features.

Tic — Geographic control point or registration mark on a map, which represents a known location on the earth's surface.

Vector format — Data structure where all map features are stored as points, lines, and areas.

Introduction

Digital soil data was identified as the highest priority data need in a recent user survey conducted for the Governor's Council on Geographic Information. Since the early 1980s, several organized programs have produced digital soil map data. At the same time, data is being developed by various independent efforts in many inconsistent forms because of the lack of standards. Due to the cost of producing this data, it must be collected using high-quality processes that are structured and documented to common standards. Only in this way will digital soil data be obtained that can be used for any geographic area, such as county, watershed, ecoregion or farmstead.

This document is designed to help elected officials and others make informed decisions about creating digital soil data and dealing with vendors. It breaks up the decision-making process into three steps:

- **Determine the status of a county soil survey for digitizing.** County soil surveys vary greatly in quality and suitability of mapping for accurate digitizing. It is important to understand the implications of these differences before trying to create a digital soil map.
- **Review options for creating a digital soil product.** Each option has advantages and disadvantages, depending on the quality of the existing map.
- **Decide the technical specifications for the digital soil product.** Following the specifications presented in this document will help to ensure the greatest geographic compatibility of soil data with other digital data. These specifications can be used to guide vendors hired to do the digitizing work.

In this map from a modern soil survey, soil types are superimposed on a digital orthophoto base map. It shows about 1.5 square miles of Sherburne County just northeast of Elk River. Source: NRCS, Minnesota State Office

Soil Mapping in Minnesota

Minnesota soils have been mapped at scales and complexities ranging from page-sized state maps with general soil features to detailed site plots. Minnesota is part of the National Cooperative Soil Survey, which creates detailed soil maps at the county level. The county soil survey program was established in 1899 within the U.S. Department of Agriculture to help farmers determine the crops and management practices most suitable for the soils on their farm. As scientists learned more about soils, they investigated soil characteristics for other land uses. Modern soil surveys can be used for such diverse activities as highway construction, farm planning, tax assessment, forest management and ecological research.

Since the 1920s, aerial photography has been used as an aid for soil mapping and a presentation base for the final map. This has greatly increased the precision of soil surveys and permitted extensive mapping at detailed scales (1:24,000 or less). Participating in this effort have been federal and state agencies and the agricultural experiment stations of land grant universities, such as the University of Minnesota.

The NCSS adheres to a set of standards for soil map production, data collection and publication of soil surveys, making it one of the most historically consistent resource surveys. Consistency in methodology and final products, used with a common system of soil classification and interpretation, allows nearly seamless soil interpretations across political boundaries for watershed, ecoregion, state or national levels.

One of the first county soil surveys in Minnesota was produced in 1906 for Blue Earth County. Early soil maps were crude because no standard mapping procedures existed. County surveys were created at a fairly slow pace for the next 50 years. By the end of 1963, only one-third of the state had been mapped. In 1977, Minnesota embarked on a 16-year program to accelerate the rate of soil survey mapping. This acceleration was justified by the state's pressing need for knowledge of the soil resource base to assess agricultural and forest productivity and to evaluate the environmental impacts of land-use changes. The Legislative Commission on Minnesota Resources provided about one-third matching funding in partnership with counties and the federal government to complete or initiate mapping in all but three counties by the late 1990s.

Uses of County Soil Surveys

Soil scientists produce a county soil survey by observing the terrain, drainage patterns, native vegetative cover and the parent material from which the modern soils were formed. Soils are classified and named based on nationwide uniform procedures. Areas with similar soil characteristics, delineated on aerial photographs in modern county soil surveys, are called map units. Published soil surveys contain maps with various map units delineated on base maps, plus a variety of tables that show how various soils will respond to different land-use applications.

The modern county soil survey is designed for basic land-use and related natural resource planning and management. The survey contains descriptions of the physical and chemical properties of soils and interprets the capabilities and limitations of soils for agricultural, forestry and urban uses. Agricultural land uses have been a traditional focus of soil survey applications. The surveys provide guidance on soil suitability for particular agriculture uses and techniques for overcoming soil and terrain limitations. Because agricultural productivity is so closely tied to soils, soil surveys have also formed a basis for rural land appraisal.

Soil surveys also are being used for diverse applications, such as community planning of residential and commercial development, transportation, recreation open space and natural areas, and in dealing with land-use conversions. For example, a soil survey can aid substantially in the search for suitable land for residential expansion by a community that wants to minimize losses of valuable agricultural land and retain highly erodible forest land in forest cover.

Natural resource applications of soil surveys arise out of the close connection between land-use management and natural resource conditions. Poor management of soil for a particular land use often results in an undesirable environmental situation. An example is the effects of accelerated soil erosion on lakes and streams caused by inappropriate land-use practices. Soil surveys are also an important consideration in prioritizing land for retention or changes in use to meet natural resource goals. To lessen the effects of erosion, for example, the identification of highly erodible lands through a soil survey, along with information on land use, can be used to help target lands for such programs as land set asides and conservation easements.

Soil surveys can play an important role in natural community restoration efforts because they provide a window to the past, showing conditions before the major human landscape modifications of the last two centuries. They can reveal original natural communities and features, thereby pointing to restoration opportunities.

Modern county soil surveys, however, are not intended for site-specific land-use determinations, such as the siting or approval of individual septic systems. Finding suitable sites for such land uses usually requires on-site investigation of soil characteristics by a professional soil scientist.

Soil Survey Quality

The quality of any county soil survey should be determined before any soil survey digitizing project is started. The County Soil Survey Status table on page 9 contains the status of soil surveys for each county. The characteristics of a particular survey can influence the selection of the method used to acquire the soil data and the usefulness of the final digital data product.

It is imperative to recognize that digitizing will not increase the quality of a soil survey. If a county's soil survey is outdated, digitizing the data will not increase its accuracy. The same can be said about existing digital soil surveys identified in the survey status table. The fact that these surveys were digitized does not improve their quality.

Two principal accuracy issues must be considered before digitizing a soil survey: spatial accuracy and attribute accuracy. Spatial data indicates where something occurs, while attribute data indicates the nature or characteristics of the spatial data. If soil boundary lines are to be digitized and overlaid with other geo-referenced data layers, they need to be consistent with the original published survey. The spatial accuracy of the line work in a soil survey is a function of three characteristics: scale, photographic base and topographic relief.

■ **Scale.** Generally the larger the scale, the higher the spatial accuracy.

■ **Photographic base.** The photographic base determines the types of spatial errors the survey will inherit from the base map. The NCSS has used three types of base maps in digitizing soils: rectified air photos, National High Altitude Photography orthophotos and National Aerial Photography Program orthophotos. Soil surveys for 63 Minnesota counties have been published on rectified aerial photography. In rectified air photos, tilt displacement (tilt of the aircraft) errors have been corrected, but spatial errors due to terrain relief displacement have not. Spatial errors are minimal in low-relief landscapes (less than 45 feet of vertical relief) but can be considerable in higher-relief landscapes. For both NHAP and NAPP orthophotography, tilt and terrain relief displacement errors have been removed. These orthophotos have the same qualities as a map, such as consistent scale. Soil surveys compiled on this base should be suitable for digitizing.

■ **Topographic relief.** With topographic relief, areas of low relief (flat areas with less than 45 feet of vertical topographic relief) are less likely to be distorted. Topographic distortions have been virtually eliminated in soil surveys based on orthophotos because they are corrected for both geometric and relief errors found in aerial photographs. Higher-relief areas will require some form of recompilation to a corrected map base before they are suitable for geographic information system applications.

Attribute accuracy is related to the vintage of the survey. Counties are divided into three categories based on soil survey vintage:

- **Modern survey based on the current classification standard.** These include counties where surveys have been published (35 counties); completed and awaiting publication, including those updated to modern standards (18 counties); and in progress, including updates (10 counties). These surveys are considered to be generally suitable for detailed land-use planning by the Natural Resources Conservation Service.
- **Outdated survey based on a classification standard no longer considered acceptable.** Recorrelation or extensive field work is needed to develop interpretations suitable for modern uses (21 counties).
- **No survey.** No soil survey is available or in progress (three counties).

Since soil scientists have learned more about soils since the first soil survey was conducted in Minnesota, both the soil mapping units for soils and their attributes have evolved. Outdated soil surveys have two principal shortcomings:

- They do not match up seamlessly with surveys from surrounding counties. The soil mapping units in modern surveys have been standardized nationally. Before the availability of standardized mapping units, soil scientists often labeled units with local monikers. As a result, identical soils in outdated surveys are often labeled differently from one county to the next. This makes direct comparisons from an outdated survey to any other soil survey difficult.
- They reflect the most current soil research at the time they were published. The many soil surveys in Minnesota reflect generations of soil science investigations. As a result, some soil mapping units from outdated surveys are not directly convertible to modern units. The quality of outdated map unit attributes will vary according to the year of interpretation.

Digitizing Status Categories

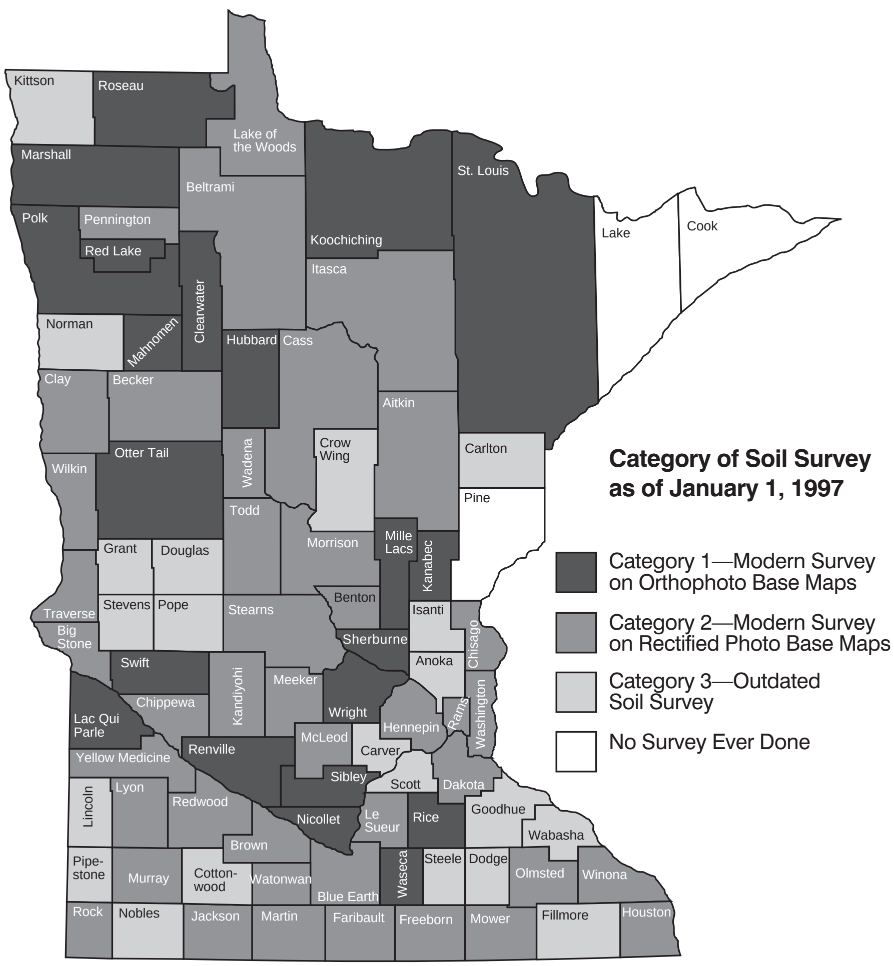
The Governor's Council on Geographic Information has developed four categories of county soil surveys (see the County Soil Survey map on page 7). These classes are based on the vintage of the survey and the type of photography used for the survey map base. They are designed to help users determine the best path to creating a digital soil database. Categories 1 through 3 are outlined below; Category 4 recognizes where no soil survey exists because the county has not been surveyed (this includes three counties).

- **Category 1: Modern soil survey on an orthophoto base.** These soil surveys have both accurate spatial and attribute information and represent the highest-quality soil survey data. They should be carefully digitized to retain the quality of the data. This category has three subgroups based on mapping status: 1A, soil survey published (one county); 1B, soil survey awaiting publication (10 counties); and 1C, soil survey being mapped (10 counties).

- **Category 2: Modern soil survey on rectified photography.** These soil surveys have accurate attribute information, but spatial accuracy varies with topography — generally high in areas with little relief but markedly less so in those of high relief. This means that the soil layer in the GIS will not consistently line up with other layers. The lack of spatial accuracy often will result in gaps and overlaps when the soil survey data sheets are assembled for a county. Digitizing a soil survey will not improve its spatial accuracy. Digitizing firms often "edge-match" the soil survey, but this improves only the visual appeal of the map, not the spatial accuracy. Category 2 soil surveys that are digitized will have variable spatial accuracy. Digitizing these surveys may not be a wise investment of public funds. They can, however, be recompiled on orthophoto base maps to correct spatial accuracy problems. The recompiled survey would then be considered to be a Category 1 soil survey. Recompilation is a difficult and expensive task that must be supervised by a qualified soil scientist. The NRCS should be involved before any recompilation discussion or work is attempted. For more information, contact the state NRCS office at (612) 290-3679.

Category 2 surveys fall into three groups based on relief classes. These classes were determined by calculating elevation diversity from 3-arc second digital elevation model data and provide, at best, rough guidelines of relative terrain relief. The groups are: 2L, lowest relief (18 counties); 2M, moderate relief (18 counties); and 2H, highest relief (six counties).

Only About One-Fourth of Counties Have Surveys Ready for Digitizing to Modern Standards



Source: Soils Data Committee, Minnesota Governor's Council on Geographic Information

■ **Category 3: Outdated soil survey requiring updating of map or attribute data before digitizing.** These soil surveys have all the shortcomings of Category 2 surveys, plus they represent an outdated understanding of soils. This means that their soil mapping units and attributes are not current. Mapping units in Category 3 surveys are often unique to the county and end abruptly at the county boundary. In addition, the attributes associated with a soil mapping unit, such as productivity, may have changed since the survey was published.

Digitizing a Category 3 soil survey will not improve the survey's accuracy and is not recommended. A digitized Category 3 soil survey will contain the limitations outlined in Category 2 as well as unreliable attribute information. If such a survey is digitized, the process used to digitize it, along with the shortcomings inherent in it, should be documented for others who may wish to use the data.

An updated soil survey is required to raise Category 3 surveys to a Category 1 status. An NRCS evaluation of the soil survey should be completed before any recompilation work is initiated.

Category 3 soil surveys fall into three groups based on relief: 3L, low relief (six counties); 3M, moderate relief (10 counties); and 3H, high relief (five counties).

Technical Options

Some parts of the state may have some form of digitized soil data available (see the County Soil Survey Status table on page 9), but with the potential limitations previously discussed. Existing products include the Soil Survey Information System, raster files in other formats such as EPPL7 and vector files in various file formats, such as ARC/INFO, DLG and MAPINFO. Depending on the survey area's situation, the availability of an existing digital product may facilitate the production of an accurate, geo-referenced soil survey.

Digital Formats

A GIS manages and manipulates two types of data produced by a modern soil survey: attribute and spatial. Attribute data describes the characteristics of each soil mapping unit, such as predominant soil series, soil drainage class and texture of the surface horizon. Spatial data is represented by points, (e.g., wet spots, sinkholes), lines (e.g., stream and drainage systems) and polygons (e.g., soil mapping units). This spatial information must be referenced to a geographic coordinate system and is usually stored as either raster (grid-cell) or vector (arc-node) digital format.

In raster formats, an area is divided into rows and columns of cells (rasters), and each raster is assigned an attribute value representing the feature for that location. Rasters of various sizes can be used, depending on the scale of the map being digitized. Grid cell sizes of 10 to 30 meters square typically are used for county-level surveys. With raster data, the value of a cell represents the predominant mapping unit if more than one mapping unit occurs in that grid-cell location.

Vector formats are based on the explicit definition of coordinates that define the location of a point, line or polygon feature. For example, a soil mapping unit consists of a series of points defining vectors that outline the unit boundaries. Each vector is assigned two identifiers, one for each side of the vector. Each identifier defines the attribute for the polygon.

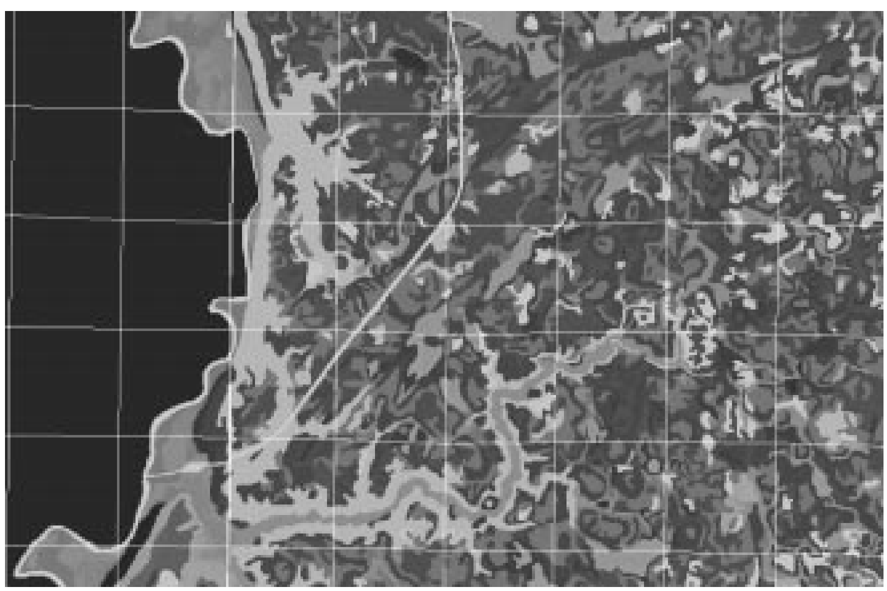
Digital Soil Data Formats Common in Minnesota

Raster Soil Data

Raster soil data in Minnesota is generally available through the University of Minnesota Soil Survey Information System and the Environmental Planning and Programming Language, version 7.0. The majority of modern soil surveys have been captured and converted to raster files for use in one or both of these two programs. These specific formats and their inherent limitations are highlighted below.

- **SSIS.** This polygon-based product displays soil on a section-by-section basis, along with associated attributes such as acidity or alkalinity and hydrologic group. SSIS calculates acreage of selected polygons and attributes, and displays and calculates small area coverage within a section to show soil variability within fields.

In early versions of this system, each section file represented one square mile whether or not it was a full section. The sections on the north and west side of most townships are either less or more than one square mile because of



This gray-tone map displays soil types using EPPL7 raster-format software. It shows the northwestern corner of Le Sueur County. The straight white lines represent section lines from the Public Land Survey. Source: Land Management Information Center

National Cooperative Soil Survey
County Soil Survey Status, January 1, 1997

County	Category	Vintage	Base Map	Relief	Digitized Product*	County	Category	Vintage	Base Map	Relief	Digitized Product*
Aitkin	2L	Modern	Rectified	L	No	Marshall	1B	Modern	NHAP Ortho	L	No
Anoka	3L	Outdated	Rectified	L	Vector (in progress)	Martin	2L	Modern	Rectified	L	SSIS, Vector
Becker	2M	Modern	Rectified	M	No	McLeod	2L	Modern	Rectified	L	SSIS, EPPL7
Beltrami	2L	Modern	Rectified	L	SSIS (partial), EPPL7 (partial)	Meeker	2M	Modern	Rectified	M	No
						Mille Lacs	1C	Modern	NAPP Ortho	M	No
Benton	2M	Modern	Rectified	M	SSIS	Morrison	2M	Modern	Rectified	M	No
Big Stone	2L	Modern	Rectified	L	SSIS, EPPL7	Mower	2M	Modern	Rectified	M	SSIS, EPPL7 (partial)
Blue Earth	2M	Modern	Rectified	M	SSIS, EPPL7	Murray	2M	Modern	Rectified	M	SSIS, EPPL7
Brown	2M	Modern	Rectified	M	SSIS, EPPL7	Nicollet	1A	Modern	NHAP Ortho	L	SSIS, EPPL7
Carlton	3M	Outdated	Rectified	M	Vector	Nobles	3M	Outdated	Rectified	M	No
Carver	3H	Outdated	NHAP Ortho	H	SSIS, Vector (in progress), EPPL7	Norman	3L	Outdated	Rectified	L	SSIS
						Olmsted	2H	Modern	Rectified	H	SSIS, Vector
Cass	2M	Modern	Rectified	M	No	Otter Tail	1B	Modern	NHAP Ortho	M	No
Chippewa	2L	Modern	Rectified	L	SSIS, EPPL7	Pennington	2L	Modern	Rectified	L	SSIS, EPPL7
Chisago	2M	Modern	Rectified	M	SSIS, EPPL7	Pine	4	No survey	N/A	M	N/A
Clay	2L	Modern	Rectified	L	Vector	Pipestone	3M	Outdated	Rectified	M	SSIS, EPPL7
Clearwater	1B	Modern	NHAP Ortho	M	No	Polk	1B	Modern	NHAP Ortho	M	No
Cook	4	No survey	N/A	H	N/A	Pope	3M	Outdated	Rectified	M	No
Cottonwood	3M	Outdated	Rectified	M	SSIS, EPPL7	Ramsey	2H	Modern	Rectified	H	SSIS, Vector (in progress), EPPL7
Crow Wing	3M	Outdated	Rectified	M	No						
Dakota	2M	Modern	Rectified	M	Vector	Red Lake	1C	Modern	NAPP Ortho	L	No
Dodge	3M	Outdated	Rectified	M	SSIS, EPPL7	Redwood	2L	Modern	Rectified	L	SSIS, EPPL7
Douglas	3M	Outdated	Rectified	M	SSIS	Renville	1B	Modern	NHAP Ortho	H	No
Faribault	2M	Modern	Rectified	M	SSIS, EPPL7	Rice	1B	Modern	NAPP Ortho	H	No
Fillmore	3H	Outdated	Rectified	H	No	Rock	2M	Modern	Rectified	M	SSIS, EPPL7
Freeborn	2L	Modern	Rectified	L	No	Roseau	1C	Modern	NHAP Ortho	L	No
Goodhue	3H	Outdated	Rectified	H	SSIS, EPPL7	Scott	3H	Outdated	Rectified	H	Vector (in progress)
Grant	3L	Outdated	Rectified	L	No	Sherburne	1B	Modern	NAPP Ortho	L	No
Hennepin	2M	Modern	Rectified	M	SSIS, Vector (partial)	Sibley	1B	Modern	NHAP Ortho	L	SSIS
Houston	2H	Modern	Rectified	H	SSIS, EPPL7	St Louis	1C	Modern	NAPP Ortho	M	Vector (in progress)
Hubbard	1C	Modern	NAPP Ortho	M	No	Stearns	2M	Modern	Rectified	M	SSIS, Vector, EPPL7
Isanti	3L	Outdated	Rectified	L	No	Steele	3M	Outdated	Rectified	M	SSIS, EPPL7
Itasca	2M	Modern	Rectified	M	Vector	Stevens	3L	Outdated	Rectified	L	SSIS, EPPL7
Jackson	2L	Modern	Rectified	L	SSIS, Vector	Swift	1C	Modern	NAPP Ortho	L	SSIS, EPPL7
Kanabec	1C	Modern	NHAP Ortho	M	No	Todd	2M	Modern	Rectified	M	No
Kandiyohi	2L	Modern	Rectified	L	SSIS, EPPL7	Traverse	2L	Modern	Rectified	L	SSIS, EPPL7
Kittson	3L	Outdated	Rectified	L	SSIS	Wabasha	3H	Outdated	Rectified	H	No
Koochiching	1C	Modern	NAPP Ortho	L	No	Wadena	2L	Modern	Rectified	L	SSIS, Vector
Lac Qui Parle	1B	Modern	NHAP Ortho	L	No	Waseca	1C	Modern	NAPP Ortho	M	No
Lake	4	No survey	N/A	H	N/A	Washington	2H	Modern	Rectified	H	SSIS, Vector
Lake of the Woods	2L	Modern	Rectified	L	No	Watonwan	2L	Modern	Rectified	L	SSIS, EPPL7
Le Sueur	2H	Modern	Rectified	H	SSIS, EPPL7	Wilkin	2L	Modern	Rectified	L	SSIS, EPPL7
Lincoln	3M	Outdated	Rectified	M	No	Winona	2H	Modern	Rectified	H	SSIS, EPPL7
Lyon	2M	Modern	Rectified	M	SSIS, EPPL7	Wright	1C	Modern	NAPP Ortho	M	No
Mahnomen	1B	Modern	NHAP Ortho	L	SSIS	Yellow Medicine	2L	Modern	Rectified	L	SSIS, EPPL7

*Digitized products are described in more detail in the next section.

Note: This inventory of digitized products is still being compiled. People who have information on digital soil products not listed here are asked to contact Jay Bell, Department of Soil, Water and Climate, University of Minnesota, 439 Borlaug Hall, St. Paul MN 55108; telephone, (612) 625-6703; e-mail, jay.bell@soils.umn.edu . For information on the Soil Survey Information System, contact Pierre Robert, Department of Soil, Water and Climate, University of Minnesota, 439 Borlaug Hall, St. Paul, MN 55108; telephone, (612) 625-3125; fax (612) 624-4223. For information on the Environmental Planning and Programming Language, version 7.0, contact the Land Management Information Center, 658 Cedar St., St. Paul, MN 55155; telephone (612) 296-1211; fax (612) 296-1212.

survey corrections. Since 1992, however, the section files in SSIS have been geo-referenced and are much better referenced to the Public Land Survey.

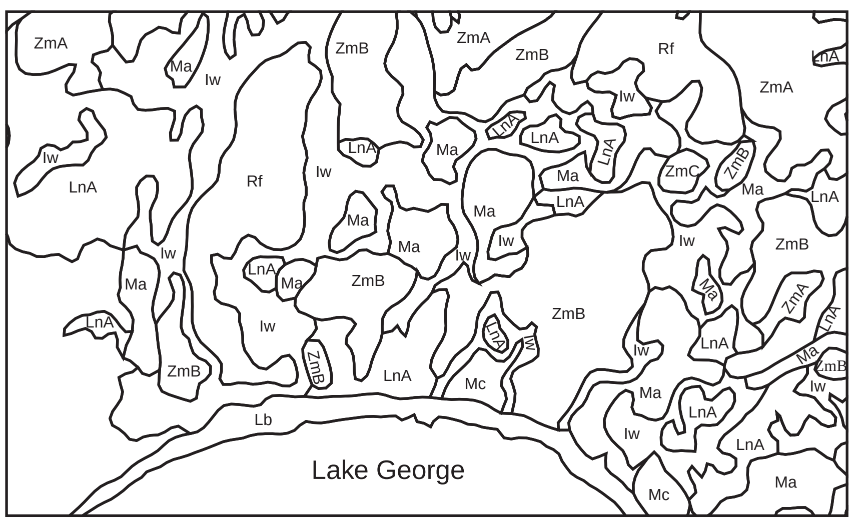
SSIS is not a GIS. Early versions are not spatially oriented, nor can the system combine map themes, create new themes or coverages or display soil maps for more than a section, such as a township or county. By themselves, SSIS section files are not well suited to conversion to a GIS. They can be converted to other GIS formats such as raster and vector; however, spatial errors introduced through the addition of geo-referencing will remain and can be significant in Category 2 and 3 counties.

■ **EPPL7.** This raster-based GIS is made up of four major programs: EPPL, DOTPLOT, DISPLAY and DIGITIZE. Most EPPL7 soil coverages have been created through the conversion of SSIS files. The final product is digital in a raster format with vector overlay capability. EPPL7 soil coverages can be used in most raster-based GIS software programs. They can also be converted to a vector-based GIS through the use of common file conversion routines.

The main consideration when using an EPPL7 soil layer is one of spatial accuracy. Because the most likely source for this layer was SSIS data from Category 2 or 3 surveys, the spatial errors introduced are carried forward to the EPPL7 database. Additional spatial error may be introduced in the conversion routine because of the need to "rubber sheet" (that is, adjust to better fit a more accurate base map) the sections to real coordinates and the required edge-matching. Although spatial error in the data may exist, EPPL7 soil layers are well suited for raster-based systems and for natural resource analyses at the township and county levels.

Vector Soil Coverages
While vector soil coverages are not as common in Minnesota as raster coverages, almost all recent efforts to digitize soil surveys have resulted in vector coverages. Current vector coverages are limited to just a few counties.

A number of commercial vector-based GIS software packages are available. They are characterized by a data format that is commonly referred to as vectors or polygons. Because these systems use lines, points and polygons to characterize data, they provide for a high degree of spatial accuracy. In using a vector-based soil layer, the user needs to understand how the layer was created. In general, vector-based soil layers are generated in a two-step process. The first step involves scanning or hand-digitizing the hard-copy soil map sheets. The second step is "rubber sheeting" the digital file to real-world coordinates. The rubber-sheeting process, however, will not remove terrain displacement errors. The same spatial errors that occur in SSIS and EPPL7 are likely to occur in this process unless the soil survey was done with and compiled onto orthophotographs. Vector soil layers can also be created by converting raster coverages. Most GIS packages allow for the creation of DLG- or DXF-formatted line files, which can be exported and imported between GIS packages and converted into a data layer. As with the EPPL7 soil layer, as long as the end user of the data is aware of the potential for spatial error and uses the data within its limitations, soil information is a useful and powerful layer in a vector-based GIS system.



In this vector line map, soil types are indicated by letter codes. Note the detail captured in this example of a one-half square mile area from the Anoka County Soil Survey. Source: Land Management Information Center

Advice on Producing Digital Soil Data

NRCS is producing digital soil data to national standards from county soil surveys, although present funding and staffing levels allow this work to proceed at only a slow pace. Many counties are choosing to produce digital data before the NRCS schedule would allow. Most will contract this production work out.

Contracting for the production of digital soil data can be complicated. This section offers guidance on various aspects of the contracting process. Digital soil data resulting from contracts that include the following provisions will ensure the greatest compatibility with other digital data and will best meet the needs of local governments and contribute to the state's goal of achieving a seamless digital soil database.

Determining the Cost

The cost of acquiring a digital soil survey will depend on the condition of a county's current soil survey. For Category 2 or 3 surveys, digitizing the map sheets (scanning and labeling) may represent only a small portion of the total cost of creating a digital layer. This is because of the relatively high costs of recompilation and correlation.

Starting the Process

Once the decision is made to digitize a soil survey, the NRCS field representative should be contacted. This person can provide a list of resources and information on other soil digitizing projects in the area (e.g., *A Quality Matrix for Digital Soil Surveys*). NRCS digitizing specifications were designed to ensure the greatest compatibility of soil data with other digital data. If modern NRCS soil classification specifications are not met, the data will probably need to be digitized again to make it compatible with other data sets.

Common Considerations

Some of the more common conventions found in soil survey contracts are noted below. While this list is not comprehensive and the language cited is not intended to be used verbatim, the list does address many issues that are easily overlooked. Misunderstandings, costly contract amendments and unmet expectations can be avoided by discussing these issues with the digitizing vendor before data is collected.

File Naming Convention

A standardized file naming scheme, with up to an 8-character file name and a 3-character extension, allows easy implementation of batch processing. A common method is a four-character county abbreviation and an NRCS sheet number (1-99) (e.g., anok001.e00). Map sheets with insets will require separate files for each inset. These inset files should be named with the four-character county abbreviation, a one-digit alpha code starting with "a," and an NRCS sheet number (e.g., anok001a.e00).

Map Projection

The map projection should match the organization's standard. Specifying a map projection is important; if this is not done, all of the data file may have to be processed to match the projection after it is done. The necessary specifications are: projection, such as UTM or State Plane; zone, if applicable; units, such as meters or feet; datum, either NAD27 or NAD83; and spheroid, such as Clark 1866 and so on.

Map Registration

Each soil survey map sheet must be registered with a minimum of four tics. The data should ideally be within a polygon defined by the tics. Data outside the tics will have significantly deteriorated spatial accuracy. Most modern soil surveys have State Plane coordinate tic marks on each sheet (and on insets). These coordinates should be used for registration and conversion to other projections.

Data Model

All files for the entire project area should be submitted using the following criteria (the terminology used here is for the ARC/INFO GIS system; these terms and processes can be found in most other GIS packages):

- All features recorded in the data files will be captured as areas (not just linear or point features). When plotted and registered to its corresponding manuscript, no plotted line will deviate from the original line work by more than 0.010 inch.
- Each coverage will have polygon topology. All features recorded in the data files will be captured as areas (not just linear or point features). When plotted and registered to its corresponding manuscript, no plotted line will deviate from the original line work by more than 0.010 inch.

- Point soil features will be captured on a separate coverage with point topology. When plotted and registered to its corresponding manuscript, no plotted point will deviate from the original line work by more than 0.010 inch.
- Every polygon will be assigned one and only one label. Each label point will be located away from the polygon edges and as near the center of the polygon as is practical.
- Only soil information will be captured; no digital representation of internal tics or administrative boundaries, such as section lines, is recommended. Within the same sheet, adjacent polygons of the same soil type are not permitted (run the dissolve function to check).
- The coverage will contain no node errors. Connectivity between line segments will be complete.
- The use of pseudo-nodes will be kept to a minimum and used only when necessary.
- Extraneous marks that may exist on the manuscript will not be collected in digital files.

Graphic Data Accuracy
Graphic plots should be produced by the vendor and delivered with the data to test positional accuracy of the digital line work. When each plot is registered to its corresponding manuscript, no plotted line should deviate from the original line work by more than 0.010 inch.

Output Format
Final digital products should be provided in vector format. One commonly used format is uncompressed ARC/INFO export files, which is preferred. This industry standard format is widely used in Minnesota and easily converted to most other geographic data formats. A convenient way to transfer data is via a CD-ROM written using the ISO 9660 CD-ROM archive standard. A printed list of data files should be included with each CD.

Documentation
The digitizing vendor must submit a final report documenting the data as a condition of acceptance. It is recommended that vendors fill out the standard state metadata file developed by the Governor's Council on Geographic Information. Substantially more concise than the federal standard, this file can be requested from the council's Internet home page at www.lmic.state.mn.us/gc/gc.htm. The vendor's final report must include the following information at a minimum:

- **Process.** Detailed information about the procedures used to produce the final data products should include descriptions of data capture, processing and quality-control techniques and identification of the specific hardware and software used.
- **File information.** Detailed information about each completed data file should include the following: data file name, as discussed above under "File Naming Conventions"; data file area of coverage (descriptive or graphic); and source information, including source citation and scale or resolution, type of source (photography, orthophotography, satellite image, etc.), type of source media (polyester-based product, stable paper, paper, etc.) and date of source material.
- **Final production date and production manager's name.**

Acceptance Testing
All submitted data must pass a quality assurance test to confirm compliance with data compatibility requirements outlined in the contract. Submitted data must be independently tested and reviewed. Acceptable error rates and a remedy for failure to meet standards should be established; a common remedy is to return the data to the vendor for free repair. The acceptance testing recommended by the NRCS varies with the quality of the soil survey. The local NRCS representative should be consulted before criteria are set.

Delivery Schedule and Media
A schedule for the orderly delivery and acceptance testing of all data sets should be established and the vendor required to submit in writing for approval any change to the schedule or delivery method.

Township Tic Labeling
Section corners used to register the soil survey should adhere to the numbering conventions maintained by the Land Management Information Center. A layer of statewide section corners is available from the Land Management Information Center at a scale of 1:24,000 (SECTIC24K). More accurate section corner data may be used where it exists, and State Plane tics on the soil sheet, especially for insets, can be used, since four-section sections are rarely available.