Minnesota Department of Natural Resources
Division of Lands and Minerals
William C. Brice, Director

DATA SOURCES AND MAPPING METHODOLOGY
DODGE COUNTY, MINNESOTA

HEATHER E. ANDERSON

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INTRODUCTION

The purpose of this project is to identify and classify potential aggregate resources (sand, gravel, and crushed stone) in Dodge County, Minnesota. This information is intended to assist local planners in making land-use decisions regarding aggregate resources, introduce aggregate resource protection, spread the burden of development, and promote orderly and environmentally sound development of the resource. To accomplish this goal, four plates were constructed for this study: 1) A summary of the significant aggregate resource deposits (those most likely to be evaluated and explored for future commercial use), 2) a more detailed breakdown of all identified and potential aggregate resource deposits, including the geological characteristics of the deposits, 3) a description of the surficial geology, and 4) a discussion of the methodology and data sources used.

There are several factors related to aggregate resources that affect their availability, usability, and supply. These factors include transportation, quality, and land use conflicts. Aggregate materials are a high-bulk, low-value commodity, which means transportation costs can become significant. The farther the aggregate must be hauled, the higher the price of the aggregate and the products derived from that aggregate. Aggregate products, such as types of concrete or bituminous have specific quality requirements depending upon its end use. Therefore, aggregate deposits must be evaluated in relation to quality standards. At the same time, land use conflicts with aggregate mining and urban development are becoming more common. As a result, the distance from the aggregate source to its potential users is increasing. Land use conflicts can be caused by cities expanding into adjacent rural areas, aggregate resource deposits being covered by new development, or new residential development occurring adjacent to aggregate sources. In urban areas, the existing aggregate resources are becoming depleted due to high use.

With these and other issues in mind, the 1984 Minnesota legislature passed a law (Minn.Stat., sec. 84.94, Aggregate Planning and Protection) that directs the Minnesota Department of Natural Resources, in cooperation with the Minnesota Geological Survey and Minnesota Department of Transportation, to identify and classify potential aggregate resources where urbanization or other factors are resulting, or may result, in a loss of aggregate resources. When the study is completed, the information is provided to local governments and the public. Since this is a reconnaissance-level survey of these resources, it does not eliminate the need for a detailed site evaluation prior to a development proposal, especially in regard to aggregate quality or environmental review.

METHODOLOGY AND DATA SOURCES

The first step in determining the distribution of aggregate resources is to understand the surficial geology and the geological history of the area. The geological history tells us the story, or sequence of events, of when the aggregate and other sediments were deposited. By understanding this story, we can determine where the aggregate was deposited, as well as some of the general characteristics about the material. This was accomplished by interpreting aerial photographs of the entire county and then confirming these interpretations with approximately 1098 water well logs and by observing over 420 field sites. Several other data sets and techniques were also used and are described below. These interpretations and observations were then compiled to form a sequence of events to portray the geologic story. Finally, the aggregate bearing landforms were delineated and classified based on their geological characteristics.

A literature and data search was completed to get a basic understanding of the geology in the area and to compile a list of existing data. Much of this information was already available in a digital format or was incorporated into digital datasets. Some of the datasets used include aerial photographs, topographic maps, digital elevation models, shaded relief, subsurface data, gravel pit and quarry locations, geology, wetlands, streams, lakes, vegetation, soils, land-use, as well as several datasets of background information, including roads, railroads, township-range-section boundaries, and others. Once all this information was digital, a computer program by ESRI called Arcview, was used to help interpret, compile, and summarize the data. This information was then incorporated into the development of a working geologic model for Dodge County.

The subsurface data used for this study included the County Well Index (CWI) database and the Minnesota Department of Transportation's (MN/DOT) files (Figure 1). The CWI is an online database maintained by the Minnesota Geological Survey (MGS, 2001) that contains basic information for over 300,000 wells drilled throughout Minnesota. Approximately 1100 of these wells are located in Dodge County; the well data were obtained in 2001. Almost two-thirds of the wells contained geological descriptions that were found to be useful for this study. The MN/DOT gravel pit sheets consist of shallow test hole logs, textural (i.e., sieve or particle size) data, quality data, and a diagram of test hole locations (the associated data were summarized in a database). The subsurface information was used to look for buried sand and gravel deposits, determine the depth to bedrock, and identify the type of bedrock encountered.

Color infrared and black-and-white aerial photographs were used in conjunction with geological modelling to delineate geological landforms and aggregate resources. Stereoscopic pairs of color infrared aerial photographs (NAPP, 9"x9" at 1:40,000 scale, April 1991 and 1992) were used along with reconnaissance-level, high-altitude, black-and-white photographs (1:80,000 scale). Aerial photographs (DOQs) were also available digitally and used within Arcview (1:12,000 scale; Figure 2). Aerial photographic interpretation was completed with a glacial mapping technique known as the landsystems approach (Eyles, 1983). This technique relies on the principle that depositional glacial landforms are composed of a predictable range of sediments, some consisting of sorted sand and gravel and others consisting of silts, clays, or unsorted materials. In addition to the landsystems approach, several other general characteristics helped determine the nature of the material, such as tonal contrasts, texture, context, shape, size, trend, association, and patterns. These characteristics can help determine the properties of the surface material (e.g., certain vegetation grows on well drained soils, such as sand and gravel, which on an aerial photograph has a distinctive texture, tone, pattern, etc.).

The landform recognition approach (part of the landsystems approach) was also used when interpreting the topography within Dodge County; glacial landforms have distinct and unique shapes and patterns that can be observed in their topographic expression. Topographic maps (USGS 1:24,000), digital elevation models, and shaded relief maps (Figure 3) were all used to help delineate these sand and gravel bearing features. The topographic expression of a feature can also be observed by looking at the distribution of lakes and wetlands. For example, a string of lakes and/or wetlands may be the signature of a glacial outwash channel or collapsed channel, which may host sand or gravel deposits. Several aggregate bearing features (outwash channels, collapsed outwash, alluvial fans, and terraces) were located using this technique.

The aerial photographs, subsurface data, topographic expressions, and soils were all compiled and the inferred geologic and aggregate resource contacts were digitized on-screen, using Arcview, generally with a digital version of the 7.5 minute topographic maps (1:24,000) or the aerial photography (DOQs at 1:12,000) used as a backdrop. The mapping units were then ready to be field checked. Field work consisted of confirming landform recognition, looking for natural exposures of the surficial material, and drilling test holes where aggregate had been mapped. Landform recognition was accomplished by driving every accessible road in the county, checking interpretations made with aerial photographs and topographic models. Streams and road cuts offered several places where the surficial materials, glacial stratigraphy, and bedrock formations were exposed. Excavations, such as basements, trenches (cables, pipes, foundations), judicial ditches, construction projects, and even animal holes, supplied additional exposures to the geological materials. Some of the already mined aggregate resources were exposed at 169 gravel mines and quarries found in the county. These locations supplied additional quality data and good stratigraphic cross-sections to help interpret the modes of deposition. Additional test holes were drilled, with the permission of the landowner, where data was needed to confirm the presence of sand and gravel (Figure 4). The overall result is that the aggregate resources are mapped at a scale of 1:50,000.

To determine areas with potential for crushed stone, significant thickness of limestone was mapped in relationship to the depth of bedrock. The limestone units were further differentiated by quality by noting the frequency of shale partings (massiveness) and other sedimentary features. Three limestone units of sedimentary Paleozoic rocks found within Dodge County were identified as having crushed stone potential: the Stewartville, Prosser, and the Cummingsville. All three are members of the Galena group. Other limestone units do exist in the County, like the Platteville; however, they are either thin or buried beneath significant overburden. A stratigraphic column defining the units of bedrock exposed in Dodge County can be seen in Figure 5. This column is modified from Mossler (1985) and describes the different types of bedrock, formation names, relative thickness of units, and chronostratigraphic age. To calculate the depth to crushed-stone resources, the depth to bedrock was interpreted using data from well log information that indicated a depth to bedrock, outcrops from soils information, and outcrop exposures observed in the field. Combining the information using GIS software, contours were drawn in intervals of 20, 30, and 40 feet to designate thickness of overburden.

SUBSURFACE INFORMATION

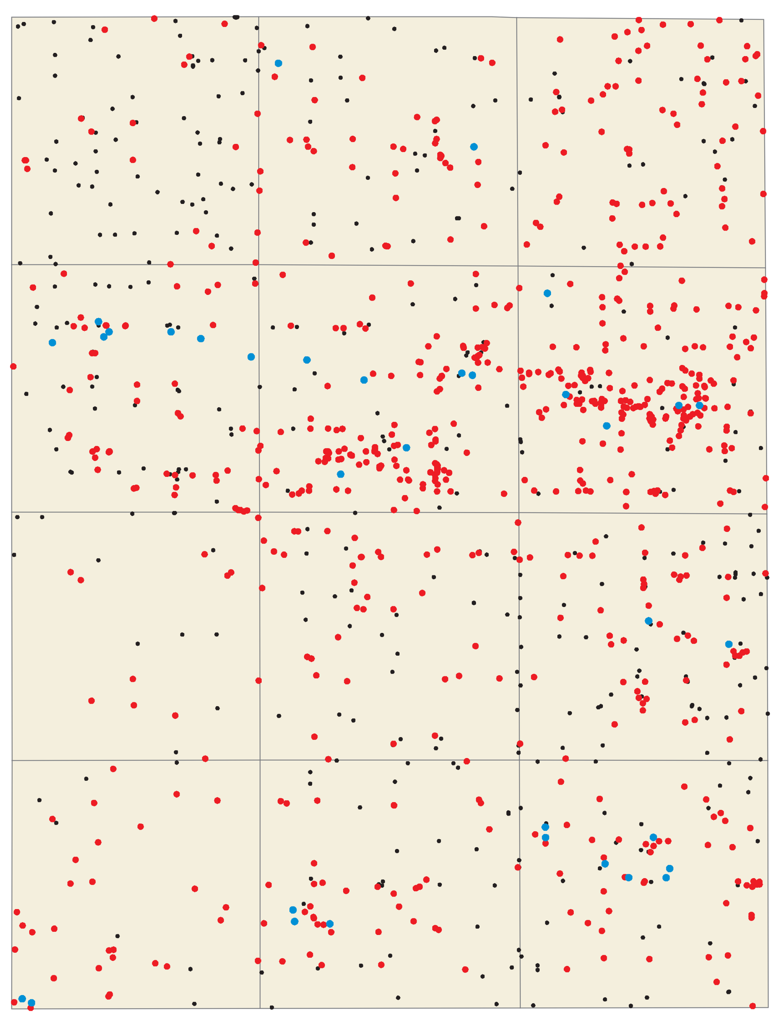


Figure 1. The County Well Index (CWI) is an online database of the Minnesota Geological Survey. CWI stores basic information for more than 300,000 wells that have been drilled in Minnesota. For Dodge County, approximately 1100 wells were included in this database when the data were downloaded in 2001. Of these 1100 wells, approximately 700 of the wells were found to have geological descriptions that were used for this project. The Minnesota Department of Transportation (MN/DOT) test pit data consist of a series of auger drill holes with both textural (sieve analysis) and quality (soundness and durability) data. The test pits data sheets were collected and created during the period from 1937 to 1995.

AERIAL PHOTOGRAPHY

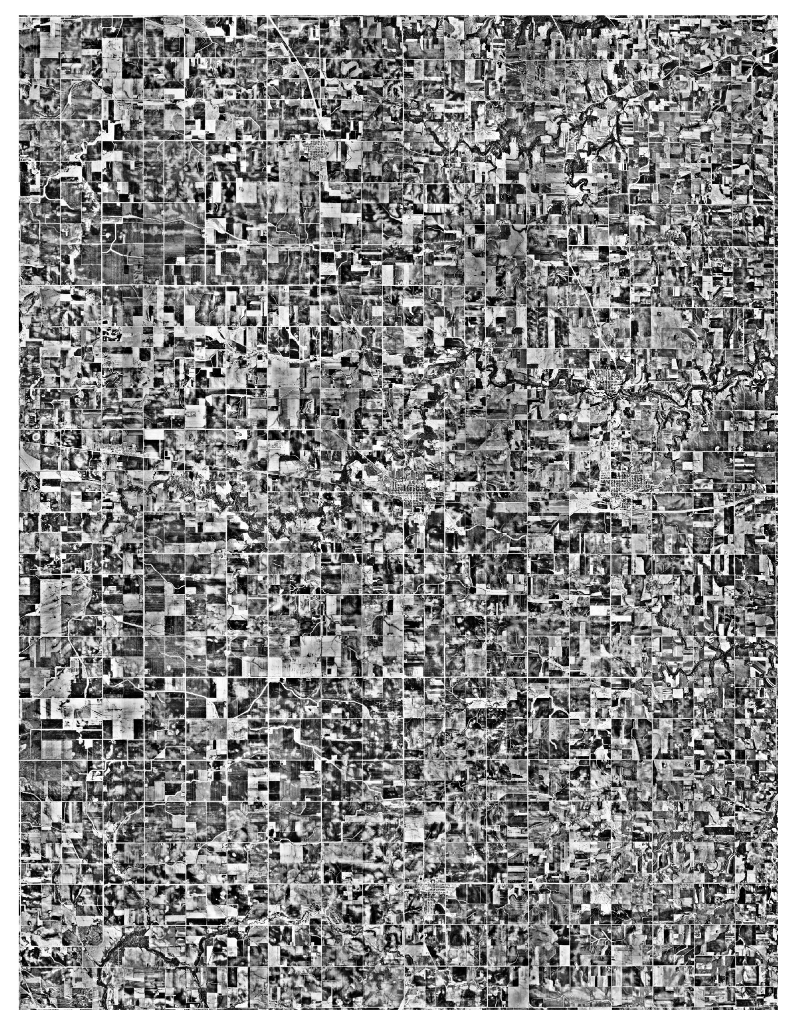


Figure 2. This aerial photography mosaic is composed of Digital Orthophotoquads (DOQs), that is, computer-readable images of aerial photography, that are available from the U.S. Geological Survey (USGS). The aerial photographs were taken in April 1991 and April 1992, from an airplane that was at 20,000' above the land surface using film that was 10" wide. The photographs were then scanned at a 1-meter resolution to create the 1:12,000 quarter-quad DOQ products. For this mosaic, the scanned photographs were resampled at a 10-meter resolution and combined into a county-wide image.

SHADED RELIEF

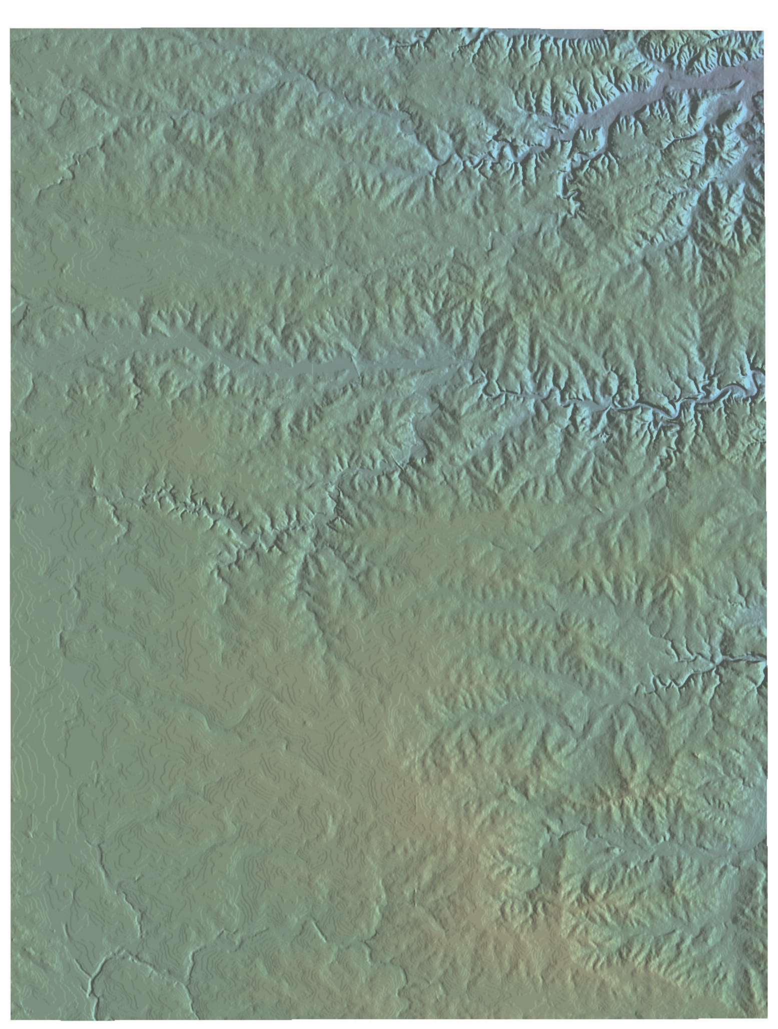


Figure 3. The shaded relief plot of Dodge County was derived from Digital Elevation Model data and the use of a hillshading command to make the elevations appear 3-dimensional, by adding bright spots and shadows as they might be cast by the sun. Digital Elevation Models (DEMs) are digital files storing terrain elevation at regularly spaced, horizontal intervals derived from U.S. Geological Survey (USGS) 7.5-minute quadrangles. The DEM data used in this case are available at 30-meter spacing from the USGS.

FIELD OBSERVATION SITES

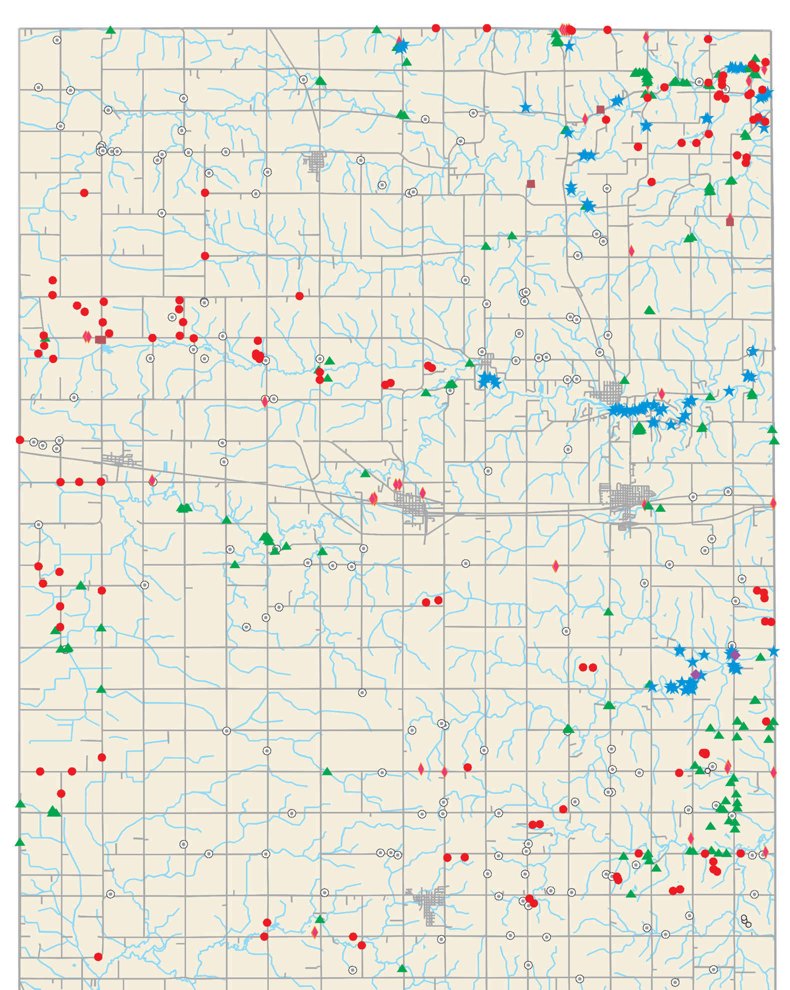
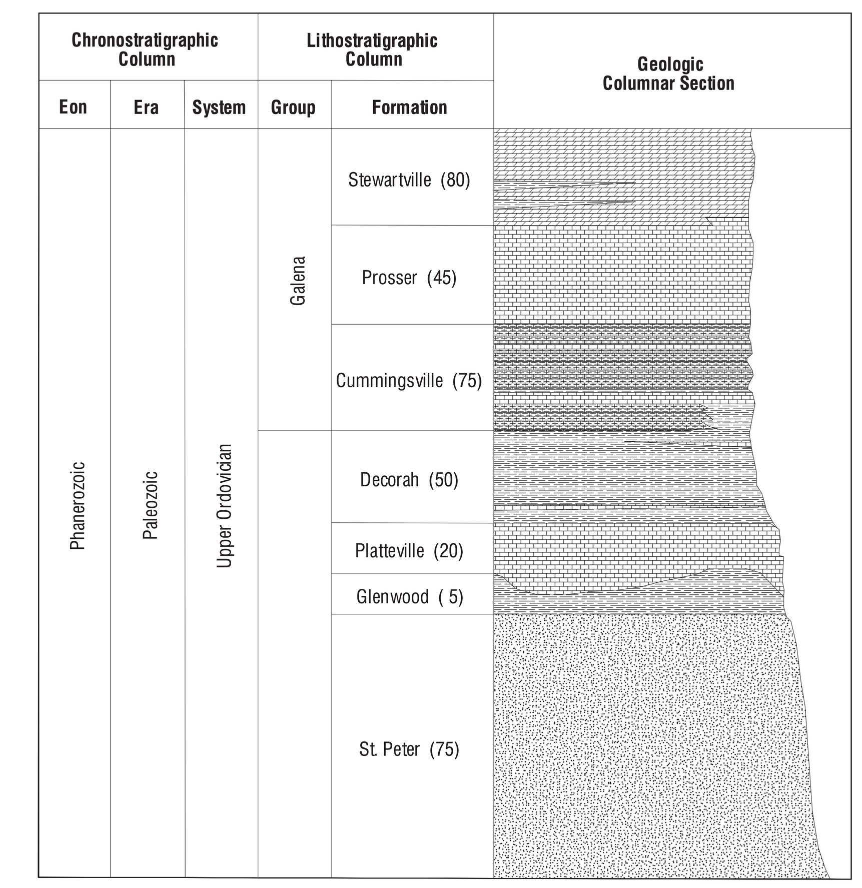


Figure 4. Field work was completed during the summer and fall (July to November) of 2001. Field observation sites consisted of bedrock outcrops, natural exposures, excavations, 8" diameter auger drill holes, gravel pits, and quarries. Every accessible road in the county was traveled looking for these sites to help determine the landform expressions. Field observations were recorded at approximately 420 sites throughout the county.



Stewartville Formation: Fine crystalline, dolomitic limestone that is yellow to gray in color. There may be thin beds of shale within the unit. This limestone has a *high crushed stone potential*; however, the magnesium content is too high for Portland cement.

Prosser Limestone: Massive, fossiliferous limestone that is yellow to gray in color. There are infrequent shale partings within the unit. The limestone has a *high crushed stone potential* and may be suitable for Portland cement.

Cummingsville Formation: Shaly limestone that is yellow in color. Shale can have gray-green color and is calcareous. There are many shale partings in this unit; therefore, the limestone has a *low crushed stone potential*.

Decorah Shale: Fossiliferous shale that is green-gray in color. The unit contains thin beds of limestone. The shale has *limited aggregate potential*.

Platteville Formation: Pitted, fossiliferous limestone that is yellow-gray in color. Only thin sections of the unit have been observed. The limestone has a *limited aggregate potential*.

Glenwood Formation: Shale that is green-gray in color. It is a very thin unit and has a *limited aggregate potential*.

St. Peter Sandstone: Poorly cemented, quartzose sandstone that is white to light gray in color. The unit contains very fine to medium grained sand. This unit has a *limited aggregate potential*.

Note: Under the "Formation" column, the number in parentheses (e.g., (75)) represents the approximate thickness of the formation in feet.

Figure 5. Stratigraphic column of bedrock units exposed in Dodge County (Adapted from Mossler, 1987, and Minnesota Geological Survey, 2001)

After completing the field work and developing the model for looking at crushed stone resources, a very detailed interpretation of the aerial photographs was done to finalize the geologic map units, incorporate the field data, and separate out the areas with potential aggregate resources. The aggregate resources were divided into seven categories (see Plate 2): 1) highly desirable sand and gravel deposits, 2) moderately desirable sand and gravel deposits, 3) less desirable sand and gravel deposits, 4) highly desirable crushed stone deposits, 5) moderately desirable crushed stone deposits, 6) less desirable crushed stone deposits, and 7) limited potential for aggregate deposits. The sand and gravel resources were divided into these categories based on the host geological feature, probability, sand and gravel thickness, overburden thickness, deposit size (areal extent), textural characteristics (sieve analysis), quality (soundness and durability), and the sediment description as observed in the field (Table 1). For example, a flood plain deposit typically hosts sand and gravel, thus the feature may have potential. If the deposit has a gravel pit located on or adjacent to it and sand and gravel were encountered during drilling while doing field work, it has a very high probability. If that deposit is 30 feet thick with 2 feet of overburden and covers 40 acres in areal extent, the aggregate thickness, overburden thickness, and deposit size are all in the high to very high category. If the texture indicates a high percentage of gravel and the quality meets MN/DOT specifications, then this terrace deposit is categorized as a highly desirable sand and gravel deposit (Table 1). Even if a deposit has good geologic characteristics for sand and gravel, one economic factor, such as haul distance costs, could make a deposit less desirable, but this was not considered in Table 1.

Table 1. SAND AND GRAVEL POTENTIAL

Characteristic	Desirability Ranking			
	High	Moderate	Less	Limited
Surficial Geology Features	Alluvial flood plain terrace; outwash channel; terrace	Alluvial flood plain, terrace; outwash channel; terrace; collapsed outwash	Alluvial flood plain; outwash plain; delta; terrace; kame; esker	Moraines; till plains; glacial lake bed
Probability[1]	High to very high	Moderately high to very high	Moderate to high	Low to moderately high
Sand and Gravel Thickness (in feet)	20-50	10-50	0-50	0-20
Overburden Thickness (in feet)	0-5	0-10	0-20	0-100
Sand and Gravel Deposit Size (as areal extent)	Moderately large to very large	Moderate to moderately large	Small to large	Small to large
Sand and Gravel Textural Characteristics	Moderately good to good	Moderate to moderately good	Moderately good to good	Poor to good
Sand and Gravel Quality[2]	Moderately high to very high	Moderately high to high	Moderate to high	Low to moderately high
Sediment Description	Sand and gravel	Sand and gravel	Sand with occasional sand and gravel	Clay/silt/sand with occasional sand and gravel

[1]Probability is the degree of certainty that aggregate exists within a unit.

[2]Quality is defined in terms of soundness, durability, and content of deleterious material.

Note: Colors associated with rankings (High, Moderate, Less, Limited) used on Plate II.

Crushed stone resources were divided into three categories: highly desirable, moderately desirable, and less desirable. These resources were divided into their respective categories based on overburden thickness, deposit thickness, and quality. Highly desirable crushed stone consists of Stewartville/Prosser limestone with overburden thickness no greater than 20 feet. Moderately desirable crushed stone consists of Stewartville/Prosser limestone with overburden thickness between 20 to 30 feet. Less desirable consists of Stewartville/Prosser limestone with overburden between 30 to 40 feet and Cummingsville with overburden no greater than 20 feet. A distinction in quality was made between Stewartville/Prosser and Cummingsville based on the thickness and frequency of shale partings. The limestone of the Stewartville/Prosser is more massive with less shale partings; whereas the limestone of the Cummingsville contains shale beds that occur in regular intervals. Therefore, the Stewartville/Prosser is more desirable for crushed stone.

The areas identified as limited aggregate potential did not meet the above mentioned criteria. The deposits may have been too small in areal extent, not thick enough, have too much overburden, may not have met the quality specifications, or contained material too fine in size. Along with aggregate potential, all known identified sources of aggregate were mapped. This included gravel pits and quarries ranging in size from less than an acre to more than 50 acres. These gravel pits and quarries may be active, inactive, depleted, or reclaimed, but represent an area where aggregate is or has been mined.

REFERENCES

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Mossler, John H., 1987, Paleozoic Stratigraphic Nomenclature for Minnesota, Minnesota Geological Survey, Report of Investigations 36, Plate 1.

Zanner, Carl W., 1998, Late-Quaternary Landscape Evolution in Southeastern Minnesota: Loess, Eolian Sand, and the Periglacial Environment. University of Minnesota, PhD Thesis.

Base map data sources:
Lakes, wetlands, and rivers from National Wetland Inventory, U.S. Fish and Wildlife Service, compiled at 1:24,000 from aerial photography (1979-1988) and spot field checked.
Public Land Survey - PLS Project, 2001, Minnesota Department of Natural Resources, Division of Lands and Minerals.
Roads were obtained from Dodge County in September of 2002.
Civil Townships and Municipal Boundaries from MN/DOT Basemap 2001 - Data layers Civiltwp and Muni, Minnesota Department of Transportation, BaseMap Development Group, Surveying and Mapping Section.

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Projects are determined by a committee composed of Governor-appointed members from the public and private sectors.

This project includes a CD/ROM of maps, data, and metadata in a digital format and the following plates:
Plate I, Report 357, Significant Aggregate Resource Deposits.
Plate II, Report 357, Aggregate Resources.
Plate III, Report 357, Surficial Geology.
Plate IV, Report 357, Data Sources and Mapping Methodology