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

DATA SOURCES AND MAPPING METHODOLOGY
BENTON COUNTY, MINNESOTA

JONATHAN B. ELLINGSON

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INTRODUCTION

The purpose of this study is to identify and classify potentially valuable aggregate resources in Benton 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.

Due to urban sprawl and several other land use conflicts, aggregate resource development is becoming increasingly difficult. Why? Aggregate material consists of sand, gravel, and crushed stone. It is a high-bulk, but low-value commodity, which means that transportation costs can become significant. That is, generally the farther the aggregate must be hauled, the higher the price of the aggregate and the products derived from that aggregate. At the same time, land use conflicts between aggregate mining and urban development are becoming more common, with the result that the distance from the aggregate source to its potential users is increasing. Land use conflicts can include the following examples: cities expand into adjacent rural areas and aggregate resource deposits are covered by development; new residential development occurs adjacent to aggregate sources and causes opposition from nearby homeowners; and, in urban areas, the existing aggregate resources are becoming depleted due to high use or because the existing aggregate source may or may not meet the changing quality requirements for use in concrete or bituminous.

With these and other issues in mind, the 1984 Minnesota legislature passed a law (Minn.Stat., sec. 84.94, Aggregate Planning and Protection) that mandates the Minnesota Department of Natural Resources, in cooperation with the Minnesota Geological Survey and Department of Transportation, to conduct a program 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 recent geological history of the area. The geological history basically 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. For this study, this was accomplished by completing an aerial photograph interpretation of the entire county and confirming these interpretations with approximately 1350 water well logs and by observing over 1325 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 tell the geologic story. Finally, the aggregate bearing landforms were delineated and categorized 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 included aerial photographs, topographic maps, digital elevation models, shaded relief, subsurface data, gravel pit locations, 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 Benton 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, 2000) that contains basic information for over 300,000 wells drilled throughout Minnesota. Approximately 2400 of these wells are located in Benton County; the well data were obtained in mid 2000. Over half 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, interpret buried glacial 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 Benton 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 channels, alluvial fans, eskers, kames, 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 rodent holes, supplied additional exposures to the geological materials. Some of the already mined aggregate resources were exposed at 344 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).

To determine areas with a potential for crushed stone resources, a model was developed using Arcview and its Spatial Analyst extension. The data incorporated into the model included well locations with well log information indicating a depth to bedrock; outcrops from the soils information; outcrops observed in the field; and surface elevations, stored as a digital elevation model (DEM). To calculate the depth to bedrock in relation to the surface elevation, the point locations for depth to bedrock and outcrops (i.e., depth to bedrock equals 0) were subtracted from the surface elevations. A "top of bedrock" continuous surface for the county was then created by interpolating these points. These top of bedrock values were then subtracted from the surface elevations, resulting in approximate depth to crushed stone resource values for the county.

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 resources, 2) moderately desirable sand and gravel resources, 3) less desirable sand and gravel resources, 4) highly desirable crushed stone resources, 5) moderately desirable crushed stone resources, 6) less desirable crushed stone resources, and 7) limited potential for aggregate resources. 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 terrace 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.

SUBSURFACE INFORMATION

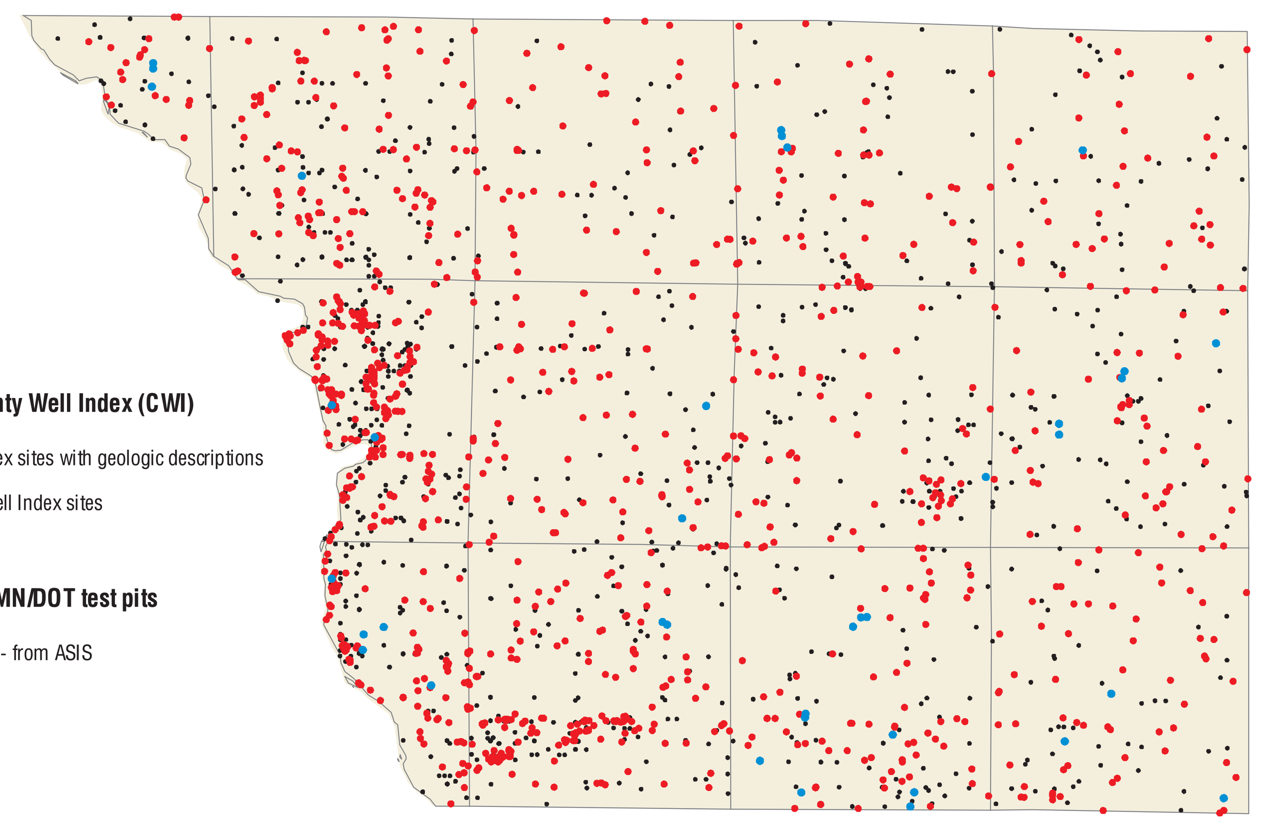

Figure 1. The County Well Index (CWI) is an online database of the Minnesota Geological Survey. CWI stores basic information for more than 300,000 wells that have been drilled in Minnesota. For Benton County, approximately 2400 wells were included in this database when the data were downloaded in 2000. Of these 2400 wells, approximately 1200 of the wells were found to contain geological descriptions that were used for this project. The 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 are from 1937 to 1995.

AERIAL PHOTOGRAPHY

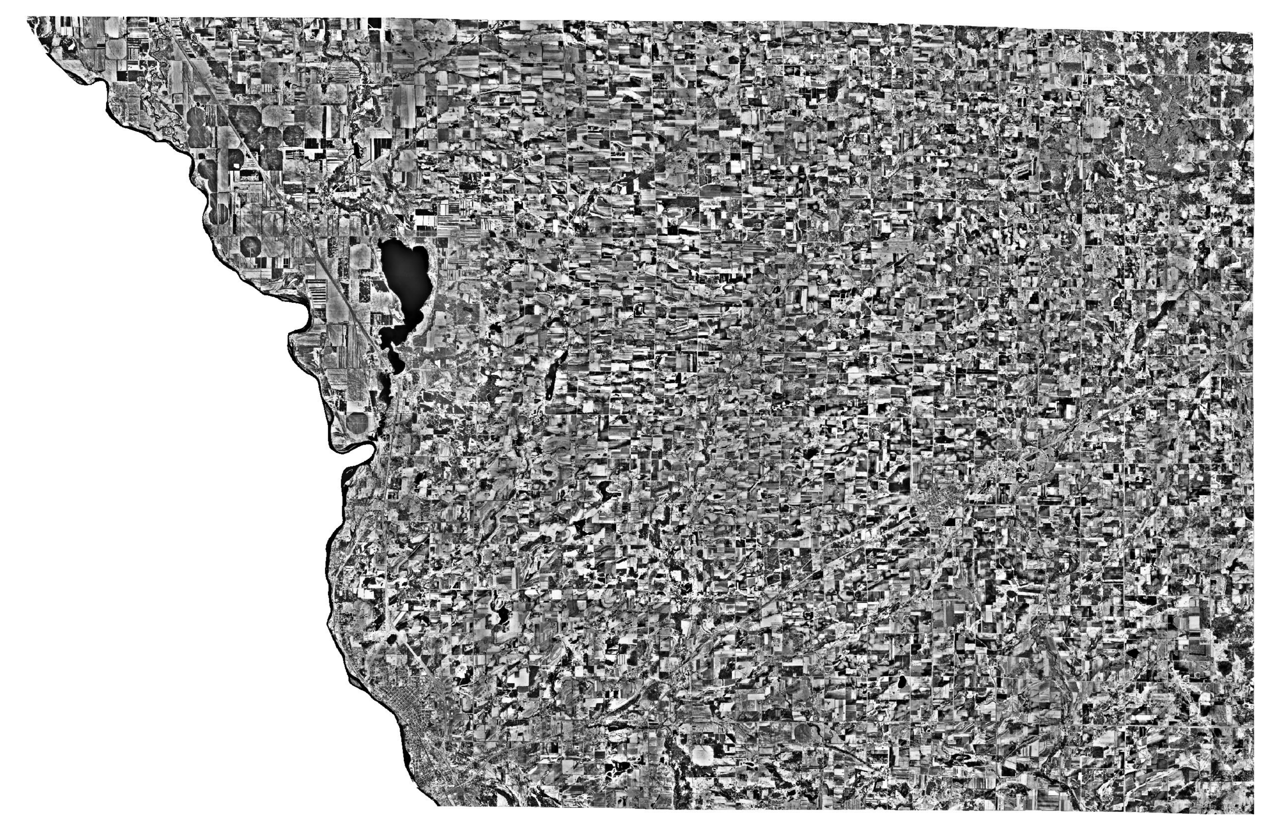

Figure 2. This aerial photography mosaic is composed of Digital Orthophotoquads (DOQs), that is, computer-readable images of aerial photography, that are available from the U.S. Geological Survey (USGS). The aerial photographs were taken in April 1991 and April 1992, from an airplane that was at 20,000' 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

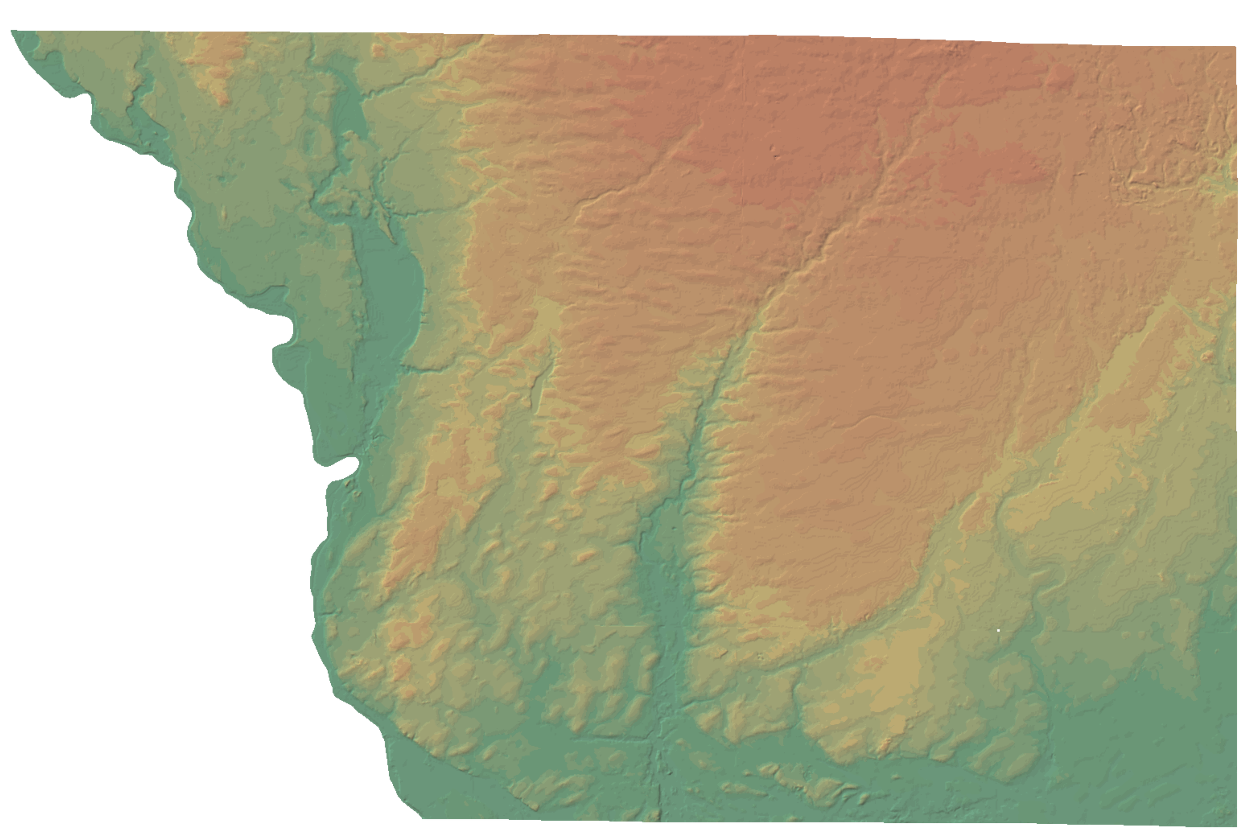

Figure 3. The shaded relief plot of Benton County was derived from Digital Elevation Model data and the use of a hillshading command to make the elevations appear 3-dimensional, by adding bright spots and shadows as they might be cast by the sun. Digital Elevation Models (DEMs) are digital files storing 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. In general, the green colors are lower elevations and the brown colors are higher elevations. Darker shades of the colors are those in shadow, due to hillshading.

FIELD OBSERVATION SITES

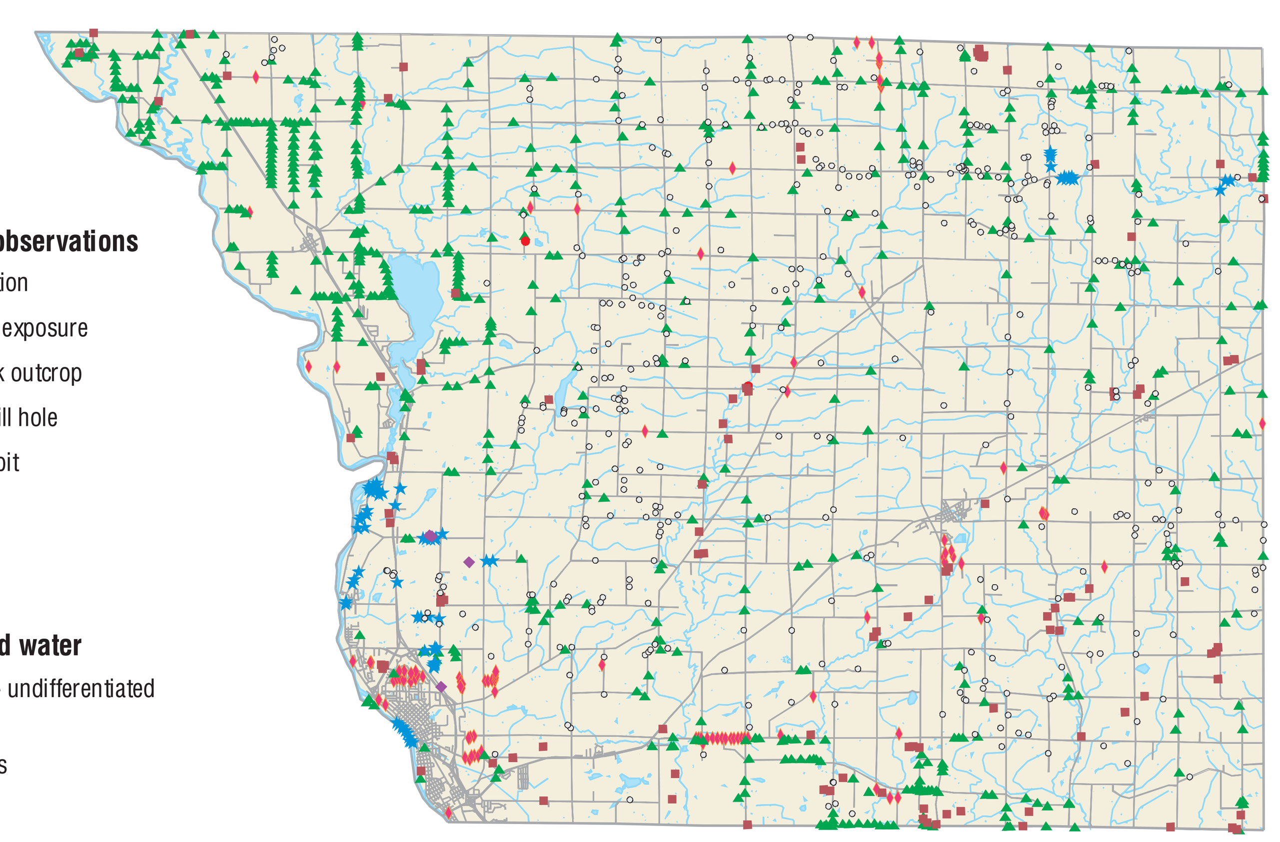

Figure 4. Field work was completed during the summer and fall (July to November) of 2001. Field observation sites consisted of bedrock outcrops, natural exposures, excavations, 8" diameter auger drill holes, gravel pits, and quarries. Every accessible road in the county was traveled looking for these sites to help determine the landform expressions. Field observations were recorded at approximately 1325 sites throughout the county.

Table 1. SAND AND GRAVEL POTENTIAL

Characteristic	Desirability Ranking: High	Moderate	Less	Limited
Surficial Geology Features	Outwash channel, terrace, fan; esker; kame	Alluvial flood plain, terrace, fan; outwash channel, terrace, fan; esker; kame	Alluvial flood plain; beach; delta; sandbars; sand dunes; outwash	Moraines; collapsed channel flood plain; 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	Good	Moderately good to good	Moderately poor 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 mineral make-up.

Note: Colors associated with rankings (High, Moderate, Less, Limited)

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, deposit size, probability, quality, and bedrock description. The crushed stone resources within Benton County consist of pink and gray granites, which are recognized as some of the highest quality bedrock resources in the state of Minnesota. Because all of the crushed stone resources are considered to be of very high quality, have a large deposit size, and are very thick (>100 feet), the overburden thickness was the primary criterion used for classifying the crushed stone resources into three categories. First of all, any unit was considered accessible if the overburden thickness was less than 50 feet. To further subdivide the resource potential, the overburden thicknesses less than 50 feet were considered: if the overburden thickness was less than 20 feet (i.e., 0-20 feet), the unit was considered highly desirable; if the overburden thickness was between 20-30 feet, the unit was considered moderately desirable; and if the overburden thickness was 30-50 feet, the unit was considered less desirable. The probability for a given unit was based on the number of occurrences of outcrops and CWI wells confirming the depth to granite - the higher the number of occurrences, the higher the probability ranking.

The areas identified as limited aggregate potential did not meet the above mentioned criteria. The deposits may have been too small, not thick enough, had 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

Eyles, N., 1983, Glacial Geology: A Landsystems Approach, Glacial Geology: An Introduction for Engineers and Earth Scientists, Pergamon Press, Oxford, p. 1-18.

Minnesota Geological Survey, 2001, County Well Index for Benton County, Minnesota, 2385 records.

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 from State of MN/DOT Basemap 2001 - Roads, Minnesota Department of Transportation, BaseMap Development Group, Surveying and Mapping Section.
Civil Townships and Municipal Boundaries from MN/DOT Basemap 2001 - 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 356, Significant Aggregate Resource Deposits.
Plate II, Report 356, Aggregate Resources.
Plate III, Report 356, Surficial Geology.
Plate IV, Report 356, Data Sources and Mapping Methodology