PLATE B: CRUSHED-STONE RESOURCE POTENTIAL IN STEARNS COUNTY

Produced by the Aggregate Resource Mapping Program,
Division of Lands and Minerals,
Minnesota Department of Natural Resources

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SUMMARY

Regionally significant, crushed-stone potential exists in the eastern third of Stearns County, Minnesota. Surface exposures of granite, near the cities of St. Cloud, Rockville, Richmond, and Cold Spring, have been historical and are current sources for dimension stone (e.g. stone used for counter tops, building facades, and monuments). Only one quarry operation produces construction, crushed-stone aggregate. The quarry site is located just west of St. Cloud and is a Minnesota Department of Transportation (Mn/DOT) certified aggregate source for concrete (ASIS #73006). The quarry's proximity to both a major interstate highway and railroad corridors allow for the economical transport of crushed-stone aggregates to both local and distant markets, which include three regional growth centers - St. Cloud, the Twin Cities Metropolitan Area, and the Fargo/Moorhead Area.

In the western two-thirds of the county, crushed stone resources are sparsely distributed. Thick glacial sediment, up to 400+ feet in the southwest corner of the county, makes the bedrock surface difficult and economically unfeasible to access. Only three small surface exposures of granitic gneiss are known to exist within this region. Two of the three exposures are located within the cities of Sauk Rapids and Melrose. The third exposure is located near MN Highway 28 in Ashley Township, sections 17 and 18. It is speculated that this exposure may produce Class A aggregate, however quality testing is required to verify its competence.

PURPOSE

This plate displays the distribution of crushed-stone potential within 50 feet of the land surface. The purpose of this project is to map crushed-stone potential and is part of a larger project to identify construction aggregate resources in Stearns County, Minnesota. The Minnesota Department of Natural Resources (DNR), directed by *Minnesota Statutes*, section 84.94 "Aggregate Planning and Protection," provides counties with needed information to plan for the future availability of aggregate resources. Crushed stone is produced by mechanically crushing durable bedrock into desired-sized, angular particles that can meet the specifications for construction aggregate used in building roads, bridges, airport runways, etc. Crushed-stone resources are not evenly distributed across the state of Minnesota or within a single county. Therefore, determining where the crushed-stone potential exists within a county is an important tool for planning and land-use decisions.

The crushed-stone potential of any location within the county depends on the physical and compositional characteristics of the bedrock along with how deeply the bedrock is buried. For example, some of the granitic rocks exposed in Stearns County provide durable, high-quality, crushed stone that meets Mn/DOT specifications for a Class A aggregate source. Other rock types, like metamorphosed sedimentary rocks, can be soft, flaky, and not durable enough to be used for aggregate. Overburden refers to any material that must be removed to access the underlying bedrock resource. Overburden may include glacial sediment, weathered bedrock, and/or sedimentary rock units. The crushed-stone potential decreases as the overburden thickness increases. Any material removed to access bedrock is referred to as overburden. In Stearns County, overburden may include glacial sediment, sedimentary rocks, and highly weathered bedrock (Figure 1).

This reconnaissance-level assessment shows the distribution of crushed-stone potential within Stearns County. Geologic data, such as exposed bedrock locations, subsurface water well data, available drill core samples, geophysics, previous geologic studies, and verbal communication with local aggregate producers, provided the basis for the criteria that were used to define crushed-stone potential. Mapped crushed-stone potential defines an area where the geologic evidence was interpreted by the geologist to support a particular map designation. This map is not intended to provide the kind of site-specific information that would be required to determine the value or suitability of a potential crushed stone quarry at individual sites. Site-specific factors can include land ownership, the owner's preferences, environmental criteria, royalty rates, distances to the market, permitting requirements, and/or the cultural and historical significance of the location. Factors such as the economic feasibility of mining a given crushed stone resource may depend on transportation distances to a potential end user as well as the proximity of a permitted mining operation to existing transportation modes or corridors.

METHODOLOGY

Since aggregate resources are mined from the earth, geologic methods are required to determine the location, distribution, and quality of a potential aggregate source. At this reconnaissance-level (1:100,000) assessment, three geologic criteria are used to determine crushed stone potential: rock type, overburden thickness, and probability of occurrence based on the availability of data.

Different rock types have different physical properties (e.g. hardness, tenacity, chemical composition, and texture). To be suitable for use as a construction aggregate, a rock type or rock lithology must be hard, able to withstand pressure, and not fracture in a predominant direction. Previous work (Boerboom and others, 1995; Setterholm and Cleland, 1995) identified three major types of bedrock in Stearns County: Precambrian-aged crystalline rock, Precambrian-age crystalline rock that weathered into a saprolitic sediment, and Cretaceous-aged sedimentary bedrock. Because the sedimentary bedrock in Stearns County has no potential use as a crushed-stone resource, it is grouped with saprolite and glacial sediments and classified as overburden (Figure 1). Overburden thickness was assessed in areas where crystalline bedrock is less than 50 feet below the land surface (Figure 2). Finally, the quantity, quality, and distribution of the data determined the confidence level, or probability that crushed-stone potential designation is accurate.

General trends in the suitability, or quality, of bedrock as a source for crushed stone resources are interpreted from existing geologic information and Mn/DOT specifications. Bedrock maps used to interpret rock units suitable for crushed stone resources include: "Stearns County Atlas— Bedrock Geology of Stearns County" (1:100,000 and 1:200,000, Boerboom and others, 1998) and Minnesota Geologic Survey (MGS) Open File Report (OFR) 10-02 "Preliminary Bedrock Geologic Map of Minnesota" (1:500,000, Jirsa and others, 2010). Bedrock information within OFR 10-02 is a state-wide dataset that compiled existing bedrock maps, with scales varying from 1:500,000 to 1:24,000. In Stearns County, OFR 10-02 updates the bedrock geology of the Stearns County Atlas with newly acquired drilling and other geologic data. The MGS report "Pre-Penokean Igneous and Metamorphic Rocks, Benton and Stearns Counties, Central Minnesota" (Dacre and others, 1984) assessed the competency and the durability of related rock units. Physical characteristics like mineral composition, the degree of foliation and shear, and the degree of mineral alteration were indicators of the compositional quality of each rock unit.

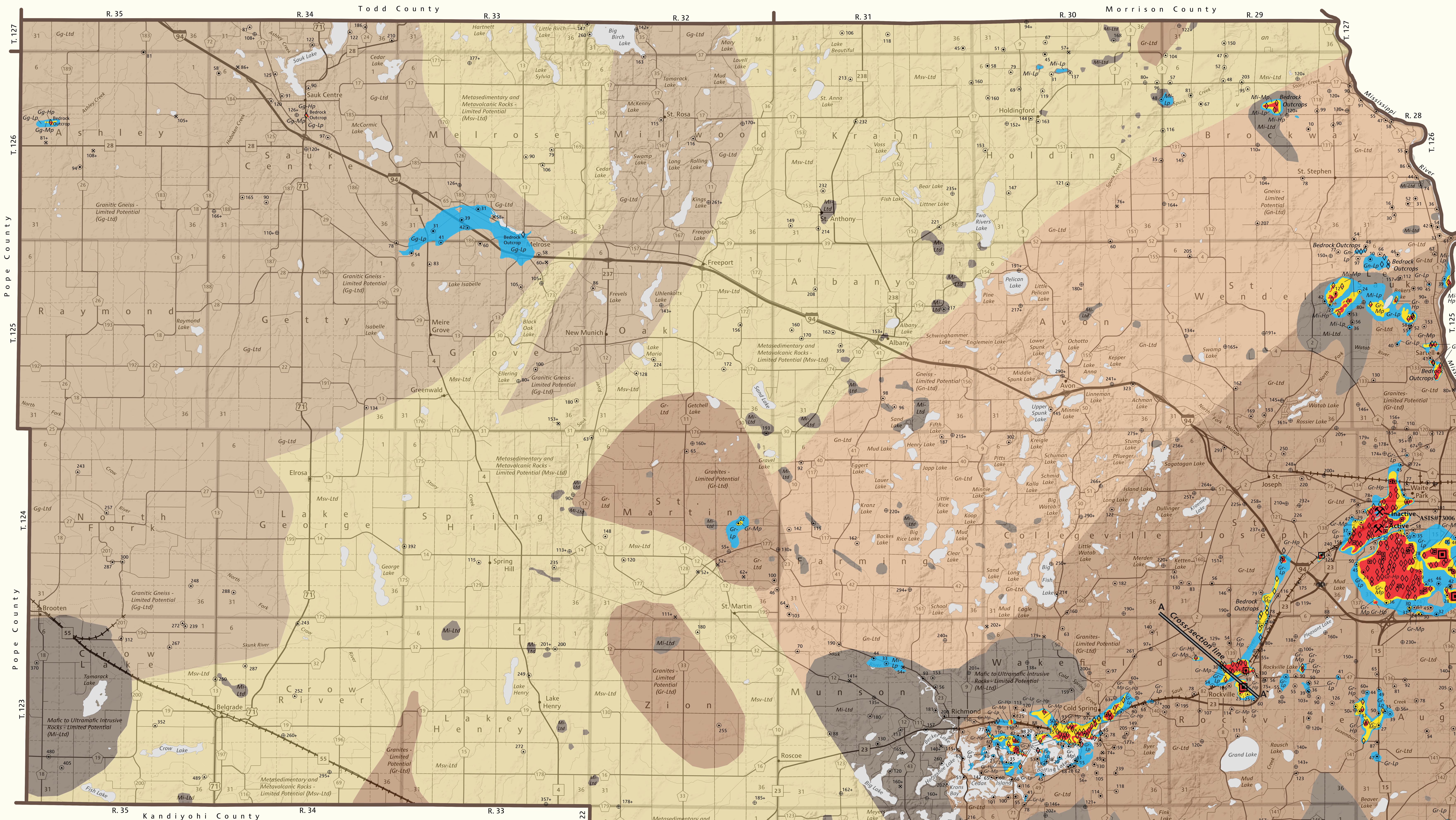
The sixteen Precambrian crystalline bedrock units mapped within the county a part of MGS OFR 10-20 were reclassified here into five generalized bedrock units that group bedrock of similar lithology and reflect rock types used in Mn/DOT's classification of crushed stone aggregates. Within the Mn/DOT classification system, Class A crushed stone ranks as the highest quality aggregate (Mn/DOT 3139.2 A2a) and is defined as crushed stone derived from listed rock types like basalt, diabase, gabbro, and granite. Class A aggregates are highly valued because they meet rigorous specifications for high performance mix designs required for Superpave and other applications. All other rock types, (e.g. schist, carbonate, and rhyolite) are classified as Class B aggregates. However, for a rock source at any given location to be qualified as a certified aggregate source for concrete, the material must undergo testing and meet Mn/DOT specifications (Mn/DOT Standard Specifications for Construction, 2005). This type of testing was not performed as part of this project. Therefore, the final determination of crushed stone quality was assessed on a relative scale from "very low" to "high" within the crushed stone potential classification system.

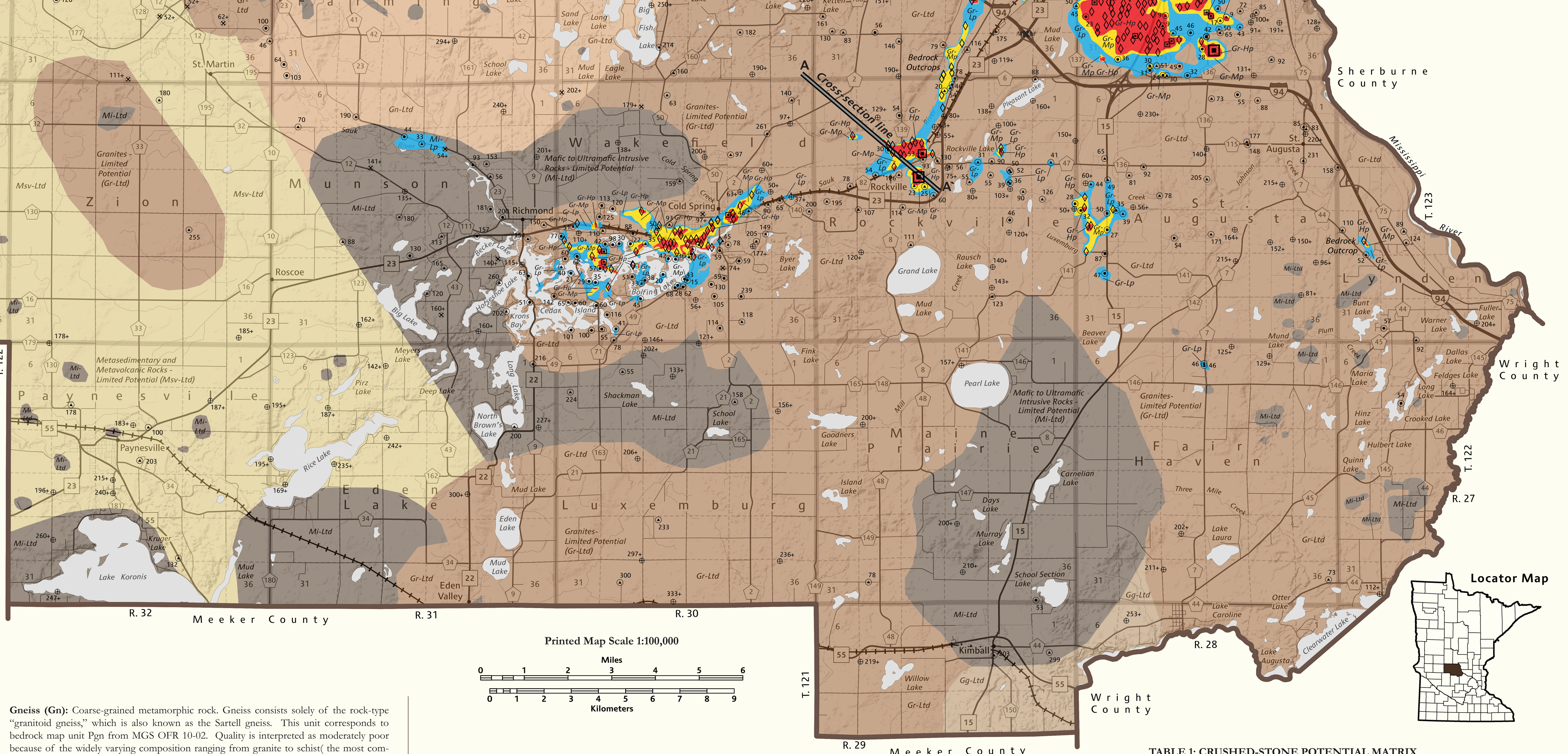
The overburden in Stearns County, as defined above for this project, includes glacial sediment as well as Cretaceous-aged rock, sediment and saprolite. Cretaceous rock and sediment are predominantly found the eastern and southeastern portions of the county. The DNR modeled overburden thickness datasets from various sources. Much of the subsurface information used for the model came from the County Well Index (CWI), an online database (www.health.state.mn.us/divs/eh/cwi) developed and maintained by the Minnesota Department of Health and MGS. CWI contains basic geologic and stratigraphic information for over 300,000 domestic and municipal water wells drilled throughout Minnesota. The CWI identifies wells as being either located or unlocated. Located CWI wells are field verified under the supervision of MGS. Unlocated CWI wells have not been field verified, but their records may contain information that can be used to associate a well with a given address or parcel of land. Unlocated wells are integrated into the DNR depth-to-bedrock model if the location of a well record is reasonably verified using parcel data from county tax records, address information, plat maps, air photographs, and road maps. When correlation has been established, the well is placed near a residential dwelling within the parcel. This method of locating wells is not as accurate as field checking using 7.5 Minute USGS Quadrangle maps and/or Global Positioning System (GPS). However, the level of accuracy is within an acceptable range for this reconnaissance-level assessment.

The overburden thickness at any given location was estimated by creating a simple geologic model using a total of 2,212 depth-to-bedrock data points from the following sources: 315 DNR field observations, 122 soil survey bedrock outcrop locations, 700 MGS bedrock outcrop locations, and 1,075 water well interpretations in CWI. Using a 30 meter grid, the model calculates the bedrock-surface elevation and then subtracts it from the ground surface elevation to produce an approximation of overburden thickness. Crushed-stone potential was delineated where crystalline bedrock is within 0 to 15 feet, 16 to 30 feet, 31 to 50 feet, and 50+ feet of the surface. These intervals are intended to reflect current trends in mining (0 to 30 feet of stripping to access bedrock) and be relevant for future trends in mining (30 to 50 feet of stripping).

The accuracy of both the overburden-thickness model and the crushed-stone potential derived from this model rely upon the distribution and density of data points. The more data within an area, the greater the probability that crushed-stone resources exist at the depth described within the map unit. Some uncertainty is due to the variability of bedrock topography. In some areas, the bedrock surface is irregular and may have significant relief and be partially buried by glacial sediment. Also, the degree of weathering varies significantly from unweathered, very competent bedrock to bedrock that has completely decomposed into clay. Interpretations of water well records for crushed-stone potential categorized decomposed bedrock as overburden. Every effort was made to accurately capture trends in overburden thickness. The probability is a relative assessment that ranges from very low to high, based on the quantity, quality, and distribution of information associated with a map unit.

The assessment of crushed-stone potential integrates the three criteria of rock type, overburden thickness, and probability criteria into a classification system where areas within Stearns County are classified as having high, moderate, low or limited crushed stone potential. Areas designated as high or moderate potential are considered to be significant crushed stone resources, while areas classified as low or limited potential are considered to be nonsignificant crushed stone resources. This classification system is displayed in Table 1.





BASE MAP SYMBOLS

Symbols may appear in different shades due to the overlaid layers of crushed-stone resource potential (limited, low, moderate, or high).

Transportation Features
- Interstate Highway
- US Highway
- MN Highway
- County Highways and Roads
- Township and Other Roads
- Municipal Roads
- Railroad Tracks

Bounding Features
- Counties (Benton County)
- PLS Townships (Le Sauk)
- PLS Sections (1,6,31,36)

County Seat & Cities
- County Seat (St. Cloud)
- Cities (Cold Spring)

Physical Features
- Lakes (Bear Lake)
- Rivers & Streams (Stony Creek)
- Ditches

BASE MAP DATA SOURCES

Lakes, rivers, streams, and drainage ditches from NWI (National Wetland Inventory), Mn/DOT Base map, MN DNR 24K Streams, compiled at 1:24,000 from aerial photography (1979-1988) and USGS quadrangle maps (1980-1990); PLS (Public Land Survey) townships and sections layers extracted from PLS Project, 2001, MN DNR, Division of Lands and Minerals; Cities were derived from the GNIS (Geographic Name Information System) by pulling out the features that were coded as populated places. A selected subset of these was used for this map, 2003; County boundaries from MN DNR, derived from combination of 1:24,000 scale PLS lines, 1:100,000 scale TIGER, 1:100,000 scale DLG, and 1:24,000 hydrography lines, 1993; Hydrography labels derived from selected Mn/DOT County Highway Maps water feature annotations, 2002; Roads from Mn/DOT Base map, Fall of 2006; Railroad Tracks from Mn/DOT Base map, 2001.

GIS support and cartography by Kevin J. Hanson, MN DNR, Division of Lands and Minerals.

CRUSHED-STONE POTENTIAL

Crushed-stone potential is based upon interpreting existing geologic data, Mn/DOT Specification for Class A Aggregate (Mn/DOT 3139.2 A2a), and geologic observations of bedrock made in the field. This reconnaissance-level assessment does not imply that crushed-stone resources exist everywhere within a given map unit designated as "Potential Crushed Stone Resources." Rather, that geologic conditions exist at the map scale such that crushed stone resources are reasonably expected to occur somewhere within the map unit. Since this is a reconnaissance-level survey, site specific evaluations are still necessary prior to any development of this resource, especially in regards to aggregate quality or environmental review. Factors such as ownership, zoning, protected waters, wetlands, and other individual site characteristics are not part of the geological resource data summarized here.

SIGNIFICANT CRUSHED-STONE POTENTIAL: Includes high and moderate potential map units. The following bedrock lithologic types are interpreted to have significant potential for crushed stone: granite rock, granitic gneiss, and mafic to ultramafic intrusive rock. These bedrock types generally have physical characteristics suitable for producing Class A aggregates, inferred to be thick (greater than 200 feet), and covered by less than 30 feet of overburden. Most of the quarries located within the county are active or inactive dimension-stone quarries. Dimension-stone quarries are located within rock types that are also suitable for crushed stone aggregate and, for the purpose of this project, are considered as identified crushed-stone resources.

Gr-Hp Gg-Hp Mi-Hp **High Crushed-Stone Potential:** Includes granites (Gr-Hp), granitic gneiss (Gg-Hp), and mafic to ultramafic intrusive rock (Mi-Hp) exposed at the land surface or buried by less than 15 feet of overburden. Depending on the rock type, the interpreted quality is either moderate or very high. The probability of crushed stone existing within a map unit ranges from moderate to very high.

Gr-Mp Gg-Mp Mi-Mp **Moderate Crushed-Stone Potential:** Includes granites (Gr-Mp), granitic gneiss (Gg-Mp), and mafic to ultramafic intrusive rock (Mi-Mp) buried beneath 16 to 30 feet of overburden. Depending on the rock type, the interpreted quality of these units is either very good or moderate. The probability of crushed stone resource existing within a map unit ranges from moderate to moderately high.

NONSIGNIFICANT CRUSHED-STONE POTENTIAL: Includes low and limited potential map units. Nonsignificant is a term used in this assessment to define mapped areas that contain any of the following conditions: lower quality bedrock units, high quality bedrock units with thick overburden (>30 feet), or areas where higher potential may exist but cannot be verified due to a lack of substantiating data which facilitate a lower probability rating. Lower quality bedrock units include gneiss as well as metasedimentary and metavolcanic rocks. These rock types do not have physical characteristics suitable for producing Class A aggregates. No quarries exist within these rock types.

Gr-Lp Gg-Lp Mi-Lp Gn-Lp **Low Crushed-Stone Potential:** Includes granites (Gr-Lp), granitic gneiss (Gg-Lp), and mafic to ultramafic intrusive rock (Mi-Lp) buried by 31 to 50 feet of overburden or gneiss (Gn-Lp) buried by 0 to 15 feet of overburden. Low potential also includes areas with little supporting data to substantiate a higher potential classification. The interpreted rock quality for granites, granitic gneiss and mafic to ultramafic rock units ranges from moderate to very high. The interpreted rock quality for gneiss is low. The probability that these rock types occur within the map unit ranges from low to high depending on rock type and overburden thickness.

Limited Crushed-Stone Potential: Includes all rock types listed below with varying thickness of overburden (15 to >50 feet). The interpreted quality ranges from very low to very high. The probability of crushed stone existing within a mapping unit ranges from low to moderately low. Limited potential includes any of the following conditions and is symbolized as:

- Gr-Ltd **Granites** with >50 feet of overburden
- Gg-Ltd **Granitic Gneiss** with >50 feet of overburden
- Gn-Ltd **Gneiss** with >15 feet overburden
- Mi-Ltd **Mafic to Ultramafic Intrusive Rocks** with >50 feet of overburden
- Msv-Ltd **Metasedimentary and Metavolcanic Rocks** with varying thickness of overburden (~30 to >50 feet)

IDENTIFIED CRUSHED-STONE RESOURCES

Locations where crushed-stone resources or dimension-stone resources have been or are currently being mined. The 32 quarry locations were compiled from topographic maps, aerial photographs, and fieldwork. Size of symbol indicates the relative areal extent of the pit in acres.

	Small <5 Acres	Medium 5-15 Acres	Large >15 Acres
Crushed-Stone Quarry			n = 2
Dimension Stone Quarry	n = 25	n = 2	n = 3

DEPTH TO PRECAMBRIAN CRYSTALLINE BEDROCK DATA POINTS

Several data sets are used to model the depth to crystalline bedrock in Stearns County: County Well Index (CWI), MGS bedrock outcrops, DNR field observations of bedrock outcrops, & NRCS-USDA SSURGO bedrock outcrops soil survey data. Located CWI is a published dataset by the Minnesota Department of Health where the location of the well has been verified. Unlocated CWI is obtained by the DNR and approximately placed to a corresponding address. Located and Unlocated CWI displays those water wells that encountered crystalline bedrock. "Minima" are wells that do not hit crystalline bedrock, but are used to identify areas that have irregular bedrock elevations and refine the depth-to-bedrock model. Depth-to-bedrock and minima labels are in feet. *Not all the data points described above were placed on this map due to overlap of data points at this map scale (1:100,000).

- 32 CWI-Located: Depth-to-Bedrock Labeled (n=*355)
- 115+ CWI-Located Minima: Well Depth Labeled (n=*189)
- 65 CWI-DNR Located: Depth-to-Bedrock Labeled (n=*172)
- 80+ CWI-DNR Located Minima: Well Depth Labeled (n=*28)
- Bedrock Outcrops (n=*677)

GEOLOGIC CROSS-SECTION LINE SYMBOL

Figure 2 shows a geologic cross-section for a small portion of Stearns County located within Township 129 N., Range 29 W. See Figure 2 for more information.

A — A` Cross-section line symbol shown on map

PRECAMBRIAN CRYSTALLINE BEDROCK DESCRIPTIONS

Five generalized bedrock types are described in this section. These bedrock types combine sixteen Precambrian crystalline bedrock units mapped within Stearns County (MGS, OFR 10-02). The descriptions below include general rock lithology; associated bedrock map units from MGS, OFR 10-02; the interpreted quality and physical characteristics that may affect quality; size of outcrop exposure(s); distribution of outcrops within the county; if the rock type is a known source for Mn/DOT classification for Class A aggregates; if the rock type has been quarried; crushed stone potential; and specific gravity, which is useful information for designing concrete and bituminous mixes. For more detailed geologic descriptions of bedrock units, please refer to the original MGS bedrock datasets (MGS-OFR 10-02).

Granites (Gr): Coarse-grained crystalline rock. This bedrock type combines three MGS OFR 10-02 rock descriptions: "undifferentiated granites" (also known as St. Cloud, Richmond, and Rockville granites), "massive granites," and a "granodioritic intrusion" (also known as Reformatory granodiorite) which correspond to bedrock map units Pgu, Pgr, and Pgd, respectively. Quality is interpreted within this assessment as very good. Local occurrences of preferred orientation of larger minerals, foliation (caused by metamorphism), mineral elongation, or various degrees of bedrock weathering may lower the quality in some areas. Granites, which are located in south-central and southeastern Stearns County, are exposed as small to large clusters of outcrops that can range from <1 to 1,500 acres and are a known source for dimension stone and Class A aggregate for bituminous and concrete. Depending on thickness of overburden, crushed stone potential can range from high to limited. Specific gravity typically ranges from 2.5 to 2.7.

Granitic Gneiss (Gg): Coarse-grained crystalline and metamorphic rock. This bedrock unit combines "gneissic, granodiorites to tonalites", "granitic orthogneiss and migmatites", and "granitic to granodioritic orthogneiss" and corresponds with bedrock map units Amt, Amg and Agn, respectively, from MGS OFR 10-02. Crushed stone within 30 feet of the surface only occurs within the "gneissic, granodiorites to tonalites" rock types, MGS map unit Amt. The quality is interpreted within this assessment as moderate due to varying degrees of metamorphism producing weak to strong foliation, mineral elongation, and preferred orientation of larger minerals. Also, the "gneissic, granodiorites to tonalites" rock unit may have been variably weathered. These factors may also lower the quality of this unit in some areas. Exposures of granitic gneiss, located in the northwestern portion of the county occur as small, isolated outcrops that are less than 5 acres. These outcrops represent the only near surface bedrock exposures in a large geographic area dominated by thick overburden (>100 feet). One quarry existed in this rock unit, which was used to make blocks for local basements and foundations. Based on its physical characteristics, this rock type may classify as Class A aggregate for bituminous and concrete. Depending on thickness of overburden, crushed-stone potential can range from high to limited. Specific gravity typically ranges from 2.5 to 2.7.

Mafic to Ultramafic Intrusive Rocks (Mi): Includes a variety of rock types, typically serpentinized peridotite, pyroxenite, hornblendite, gabbro (also known as St. Wendel gabbro), and diorite (also known as Watab diorite), and gabbroic to dioritic intrusions and correspond to MGS OFR 10-02 bedrock map units Pmi, Pgp, Pga, and Pm, respectively. Quality of this rock is variable depending on dominant lithology; however, quality is broadly interpreted as moderate. Quality may improve with larger areal extent of an intrusion, greater distance from contacts with other rock units, and less fracturing within the rock. This unit is exposed in clusters of small outcrops that range in size from <1 to 15 acres. Exposures are located in far eastern Stearns County and no quarries have been observed within this bedrock type. Based on its physical characteristics, this bedrock type may classify as Class A aggregate for bituminous and concrete. Depending on overburden thickness, crushed-stone potential can range from high to limited. Specific gravity typically ranges from 2.6 to 3.0.

Gneiss (Gn): Coarse-grained metamorphic rock. Gneiss consists solely of the rock-type "granitoid gneiss," which is also known as the Sartell gneiss. This unit corresponds to bedrock map unit Pgn from MGS OFR 10-02. Quality is interpreted as moderately poor because of the widely varying composition ranging from granite to schist(the most commonly encountered lithology consisting of biotite-cordierite-garnet mineral assemblages) and a varying degree of layering and foliation (Dacre and others 1984). Exposed as small, individual outcrops (< 0.1 acres) to clusters of small outcrops (1 to 12 acres), this unit is located in far eastern to northeastern Stearns County. No known quarries have existed in this bedrock unit. Even though this unit is categorized as gneiss, and by definition could grade as a Class A aggregate, the variable lithology of this unit generally precludes its use as a durable source of bedrock and for use in bituminous and concrete products. Because of the poor quality of this bedrock unit, crushed-stone potential is only delineated where overburden thickness is 15 feet or less and these near surface exposures are designated as having low potential. The specific gravity typically ranges from 2.6 to 3.0.

Metasedimentary and Metavolcanic Rocks (Msv): Sedimentary and volcanic rocks that have experienced varying degrees of metamorphism. Metasedimentary and metavolcanic rocks consist of the following rock types or formations: Animikie Group, Little Falls Formation, Iron Formation, and metavolcanic rocks. Listed in order of introduction, the unit consists of MGS OFR 10-02 bedrock map units Pas, Pls, Pit, and Pmv. The quality of this unit is interpreted as poor. There are no surface exposures of this bedrock unit and the shallowest encounter within well records is ~30 feet. No known quarries exist in this rock type and it does not classify as a Class A aggregate. No crushed stone-potential is designated within this rock unit because of the interpreted poor quality of this unit and thicker overburden. The specific gravity can range from 2.0 to 3.0.

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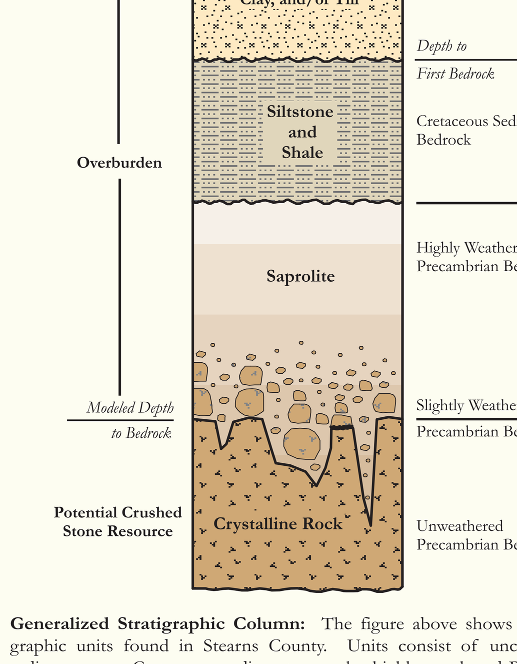
FIGURE 1: GENERALIZED STRATIGRAPHIC COLUMN



Generalized Stratigraphic Column: The figure above shows four stratigraphic units found in Stearns County. Units consist of unconsolidated sediments over Cretaceous sedimentary rocks, highly weathered Precambrian bedrock called saprolite, and Precambrian crystalline bedrock. Of these various units, only Precambrian crystalline bedrock has crushed-stone potential. Therefore, the modeled depth-to-bedrock, determined from interpreting CWI data, is the depth to the surface of slightly weathered crystalline bedrock. Saprolite and sedimentary rocks were grouped together with unconsolidated sediments and classified as overburden. The amount of overburden at any given site is dependent on the degree of erosion and chemical weathering. As a result, the depth to crystalline bedrock can range from surface exposures to deeply buried (>300+ feet) by one or more types of overburden.

TABLE 1: CRUSHED-STONE POTENTIAL MATRIX

Bedrock Geology	Quality[1]	Probability[2]	Overburden	Crushed-Stone Potential
Granites (Gr)	Very Good	Moderate to Very High	0-15 Feet	High Potential (Gr-Hp)
		Moderate to High	16-30 Feet	Moderate Potential (Gr-Mp)
		Low to Moderate	31-50 Feet	Low Potential (Gr-Lp)
		N/A	50+ Feet	Limited Potential (Gr-Ltd)
Granitic Gneiss (Gg)	Moderate	Moderate to Very High	0-15 Feet	High Potential (Gg-Hp)
		Moderate to High	16-30 Feet	Moderate Potential (Gg-Mp)
		Low to Moderate	31-50 Feet	Low Potential (Gg-Lp)
		N/A	50+ Feet	Limited Potential (Gg-Ltd)
Gneiss (Gn)	Moderately Poor	Moderate to High	0-15 Feet	Low Potential (Gn-Lp)
		N/A	16-50+ Feet	Limited Potential (Gn-Ltd)
Mafic to Ultramafic Intrusive Rocks (Mi)	Moderate	High to Very High	0-15 Feet	High Potential (Mi-Hp)
		Moderate	16-30 Feet	Moderate Potential (Mi-Mp)
		Low to Moderate	31-50 Feet	Low Potential (Mi-Lp)
		N/A	50+ Feet	Limited Potential (Mi-Ltd)
Metasedimentary & Metavolcanic Rocks (Msv)	Poor	N/A	31-50+ Feet	Limited Potential (Msv-Ltd)

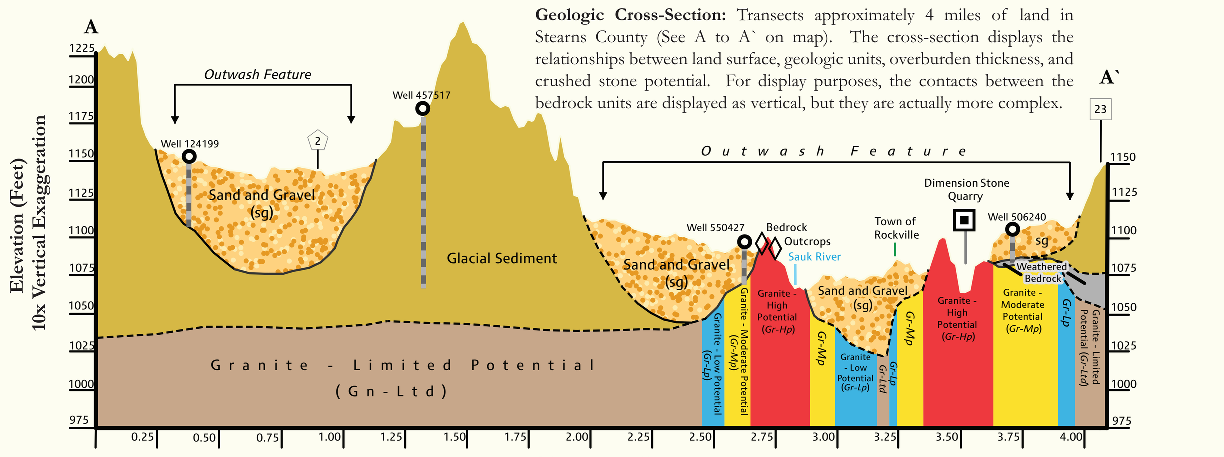
Classifying Crushed-Stone Potential: The matrix in Table 1 lists five generalized, crystalline types that are found at or near the land surface in Stearns County. The determination of crushed-stone potential is a function of the interpreted quality of the bedrock as a crushed-stone source, the overburden thickness, and the probability, or certainty, that crushed-stone resources exists within a map unit. Near-surface bedrock exposures and outcrops are reliable and abundant. As a result, areas of high potential tend to have greater probability than areas of low potential.

On the map and in the matrix high potential is symbolized in red, moderate potential is symbolized in yellow, low potential is symbolized in blue, and limited potential is symbolized by bedrock type of the Precambrian crystalline bedrock found within Stearns County.

[1] *Quality:* The physical characteristics of the material.
[2] *Probability:* The degree of certainty that aggregate exists within a map unit.

FIGURE 2: CROSS-SECTION OF BEDROCK GEOLOGY AND CRUSHED-STONE POTENTIAL

Geologic Cross-Section: Transects approximately 4 miles of land in Stearns County (See A to A' on map). The cross-section displays the relationships between land surface, geologic units, overburden thickness, and crushed stone potential. For display purposes, the contacts between the bedrock units are displayed as vertical, but they are actually more complex.



A — A` Cross-section line symbol seen on map

Products of this project include a CD/ROM with two digital maps (Plate A and Plate B), GIS data, and metadata