Minnesota Department of Natural Resources
Division of Lands and Minerals
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PLATE A: SAND AND GRAVEL RESOURCE POTENTIAL IN STEARNS COUNTY

Produced by the Aggregate Resource Mapping Program,
Division of Lands and Minerals, Minnesota
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PURPOSE

The purpose of this project is to identify and classify potential construction aggregate resources (sand and gravel) in Stearns County, Minnesota for use by local governments to plan for future supplies. This information is intended to assist local planners and others in making comprehensive land use and zoning decisions regarding aggregate resources, introduce aggregate resource protection, spread the burden of development, and promote orderly and environmentally sound development of the resource. Having locally available, low-cost construction aggregates is fundamental to building and maintaining public infrastructure and private sector development. To accomplish these goals, two plates and a comprehensive data set on a CD-ROM were created. Plate A shows potential sand and gravel resources and Plate B shows potential crushed stone resources.

Aggregate materials are high-bulk, low-value commodities, which means transportation costs can account for a considerable amount of the delivered price. Lower construction costs for public and private projects can be achieved by using local aggregate supplies. In addition to transportation costs, land use conflicts can impact the availability, usability, and supply of aggregate. Land use conflicts, such as cities expanding into adjacent rural areas, aggregate resource deposits being covered by new developments, new development occurring adjacent to aggregate resources, and/or permanent conservation easements that exclude aggregate mining, are becoming more common in rural and urbanized areas. Specifications for the construction of roads and bridges require higher quality aggregate, which may be available only in limited and specific areas. At the same time, the need and increased use of aggregate material in and around cities are depleting permitted supplies. The end results are that aggregate resources are becoming less available and the transportation distances are increasing, which is passed on in costs to the consumer.

With these and other issues in mind, the 1984 Minnesota Legislature passed a law (*Minnesota Statutes*, section 84.94, Aggregate Planning and Protection) that directs the Minnesota Department of Natural Resources, in cooperation with the Minnesota Geological Survey (MGS) and Mn/DOT, to identify and classify potential aggregate resources. When the mapping is completed, the information is provided to local governments and the public. Since this is a reconnaissance-level survey of sand and gravel, site-specific evaluations are still necessary prior to any development of the resource, especially in regards to aggregate quality or environmental review. Factors such as ownership, zoning, protected waters and wetlands, environmental permitting, and other individual site characteristics are not part of the geological resource data summarized here.

METHODOLOGY

The method used for aggregate mapping integrates traditional geologic mapping techniques with the use of Geographic Information System (GIS). This allows multiple, discrete spatial data sets to be overlain and compared. Sand and gravel mapping is accomplished through three phases of work: 1) preliminary information gathering, 2) field work for verification, and 3) classifying aggregate resources.

Data Gathering: The first step in the mapping process is conducting literature and data searches to obtain a basic understanding of the regional geology. Some of the data gathered includes aerial photographs, topographic maps, digital elevation models, shaded relief maps, subsurface data, gravel pit and quarry data, existing maps of surficial and bedrock geology, published papers and reports, land use, as wells as several datasets of background information, including roads, railroads, PLS township, range, and section boundaries, and other data.

The County Well Index (CWI) database and the Aggregate Source Information System (ASIS) are important datasets used to interpret subsurface geology and for creating sand and gravel resource maps. CWI is an online database (www.health.state.mn.us/divs/eh/cwi) developed and maintained by MGS and the Minnesota Department of Health. These resources contain basic information for over 300,000 wells drilled throughout Minnesota. In Stearns County, there are 6785 wells with defined locations (Figure 2). An addition 13,618 unlocated wells are approximately placed within its corresponding section. The majority of CWI logs contain geologic descriptions. ASIS is a dataset compiled and maintained by Mn/DOT that consists of aggregate quality data, sand and gravel grain size analysis, and pit sheets displaying the descriptions of shallow test-hole logs with diagrams of test-hole locations. This information refers to specific sites that Mn/DOT evaluated from approximately 1930 to 2000.

Field Work: Several weeks were spent driving accessible roads in the county looking for outcrops and exposures of geologic materials, as well as drilling test holes to further define aggregate deposits. Sediments exposed in artificial (e.g. road cuts, trails, foundation excavations, construction projects) and natural (e.g. stream cuts and animal burrows) exposures, offer sites where surface materials and glacial stratigraphy can be examined. A total of 2600 field observations were logged in Stearns County. Field work also included documenting sediment in existing gravel pits, which provided additional quality data and views of stratigraphic cross-sections. These larger views into the structure of the subsurface layers allowed the geologist to interpret the depositional setting and thereby better predict the extent of the deposit. A drilling program was completed with the collaboration of Mn/DOT Foundation Unit and the Maplewood Materials Laboratory. A total of 78 test holes were drilled to depths ranging from 7 to 24 feet, which helped define the areal extent and depth of selected deposits. Samples were taken from test holes for concrete aggregate lithologic examination by Mn/DOT. The drilling program was a reconnaissance-level evaluation and the quality results do not represent an entire deposit.

Sand and Gravel Data Compilation and Interpretation: Aggregate-bearing landforms are typically created by glacial meltwater and non-glacial streams and lakes. Sand-and-gravel-bearing features such as outwash channels, bars, terraces, and other more complex landforms that were created in contact with, or beneath the ice are distinguished on this map using a land-systems approach. This involves the identification of the processes by which glacial landscapes were created, thereby providing a context for individual landforms and making it possible to better predict the occurrence of a particular sediment type within a given feature. Other sediment characteristics such as color, texture, and grain shape, also help determine how the sediment was deposited. For example, a particular vegetation type might prefer well drained soils, such as sand and gravel. These substrates also have distinctive tones or patterns when viewed from aerial photographs.

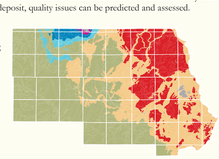
Using GIS software, aggregate resources were delineated by layering multiple datasets. Topographic maps (USGS 1:24,000), high resolution elevation data (LiDAR), shaded relief maps, aerial photographs, subsurface data, field observations, the location and distribution of existing pits, and soil surveys, were used to identify features containing sand and gravel resources. Aggregate resources were mapped at a scale of 1:50,000.

RESULTS

Overall, Stearns County has abundant sand and gravel resources; however, the resources are not evenly distributed throughout the county. Several large, areally extensive sand and gravel deposits were mapped within the county. The largest and most notable is an outwash feature (see Glossary of Terms) located in the southwest corner of the county and extends eastwards towards St. Cloud. The deposit grades from cobble-rich sand and gravel, observed in the western part of the deposit, to sandier textures observed in the eastern portion of Crow Wing Township. Thin to no overburden (sediment removed to access a resource) is associated with this landform. The deposit thickness varies from 10 to 60+ feet of sediment, and some areas may have a high water table. In general, quality data from test hole sample analysis (TH-120 and TH-121) and Mn/DOT ASIS data indicate high percentages of limestone, ranging between 44-51% by weight. Although this exceeds the Mn/DOT concrete specification for limestone (30% by weight, 3137.2D3c), the deposit has the potential for meeting bituminous quality specifications. The width of this outwash valley narrows as it continues eastward in the direction of St. Cloud. Also, higher potential exists in some portions of the outwash valley as it encounters and incorporates Superior lobe outwash deposits. Terrace and outwash features deposited adjacent to the Mississippi River are also large and areally extensive; however the texture is generally sandier and may lack >1-inch-sized rock particles. The thickness ranges from 10 to 70+ feet of sorted sediment consisting of layers of silt, sand and gravel. The predominant rock lithology encountered in limestone content from north to south-southeast. Similarly, an outwash deposit in the northwest corner of the county is listed as having moderate potential; however, portions of the deposit may be sandy and lack >1-inch-sized rock particles. Some deposits in northeastern Stearns County are not associated with typical sand and gravel landforms. These deposits tend to be exposed in gullies along dissected hillsides. Finally, high quality sand and gravel deposits in west-central Stearns County are scarce. Deposits in this region tend to be small, thin, and discontinuous.

Stearns County has a complex glacial history. The surface deposits date to the most recent glaciation (>10,000 years ago) when three distinct lobes of ice transported and deposited sediments from discrete and far-off source areas, sometimes directly interacting with one another. The quality of sand and gravel deposited by these glacial lobes varies with the specific geology of the ice source area. The Superior lobe flowed from the northeast out of the basin of Lake Superior. The Wadena lobe, formally known as the Rainy lobe, flowed from the north and through the central part of the state. Finally, the Des Moines lobe flowed from the northwest. By understanding the glacial source of the deposit, quality issues can be predicted and assessed.

FIGURE 1: DISTRIBUTION OF SEDIMENT BY GLACIAL LOBE



Des Moines lobe sand and gravel is present in the western half of the county. Quality issues associated with Des Moines lobe sand and gravel include higher amounts of shale and limestone that can make it unsuitable for concrete applications. Sand and gravel originating from the Superior lobe generally contains more durable rock types like basalt and rhyolite from the North Shore Volcanic Group. Deposits observed in the central and southwestern portion of the county have higher percentages of a deleterious rock type called iron-oxide, which is interpreted as local incorporation of Cretaceous-aged bedrock. Iron-oxide content in this region ranges from 0.2 to 1.5 percent (Test holes 101-103, 106, 114-115, 139-140, 141-142, and 160) which exceeds 0.3 percent weight for Mn/DOT specification 3137.2D1b for iron-oxide in concrete. Wadena lobe sand and gravel deposits contain granite and limestone rock types and are generally considered to be higher in quality. Wadena lobe deposits are at the surface in northern Stearns County. Because the deposits of all three ice lobes are in close proximity and even overlap one another in places, sand and gravel in some areas can contain rock types from multiple glacial sources. The distribution of sediment by glacial lobe and dominant rock lithology was mapped in association with this assessment and shown in Figure 1.

SAND AND GRAVEL POTENTIAL

Sand and gravel potential is an assessment of the relative probability that a sand and gravel deposit exists within a given mapping unit. Almost all emphasis is placed upon geologic evidence, physical parameters such as areal extent, and interpretation at the reconnaissance level, rather than upon economic feasibility, site-specific level of evaluation, or other related parameters. This assessment does not imply that economic aggregate deposits exist everywhere within a given map unit designated as "Sand and Gravel Potential," but rather, that within such a map unit, geologic processes were active that could have created aggregate deposits within certain map units. Geologic measurements of sand and gravel deposits such as thickness or quality test data remain constant, but economic criteria and environmental permitting vary across time and at different locations. Important site-specific factors such as ownership, zoning, protected waters and wetlands, sensitive or protected environments, permitting, distance to markets, royalties, and individual site characteristics, such as access, all contribute to the feasibility of mining specific parcels; however, these factors are not considered in this reconnaissance-level study.

SIGNIFICANT SAND AND GRAVEL POTENTIAL: Geologic units that are inferred to contain sand and gravel resource potential. These units have data exhibiting geologic characteristics associated with sand and gravel-bearing landforms. Existing gravel pit and Mn/DOT aggregate sources within these units are considered to be identified, or known resources, that increase the level of confidence for that mapping unit.

Hp **High Sand and Gravel Potential:** Includes landforms such as outwash features, ice contact features, and end/thrust moraines. Predominant sediment typically consists of sand and gravel. The probability[2] that a potential sand and gravel resource exists within any map unit is moderately high to very high. Deposit thickness ranges from 10-60+ feet with less than 20 feet of overburden[3]. The sand and gravel resources occurring in this unit are moderate to very large in areal extent[4] and the textural characteristics[5] are moderate to very good. The quality[6] is moderate to very high relative to other sand and gravel resources within Stearns County.

Mp **Moderate Sand and Gravel Potential:** Includes landforms such as outwash features, ice contact features, and end/thrust moraines and palimpsest topography (see Glossary of Terms). Predominant sediment ranges from sand with gravel to sand and gravel. The probability that a potential sand and gravel resource exists within any map unit is moderate to very high. Deposit thickness is typically greater than 10 feet, but in some landforms can range from 0-50+ feet with 0-20+ feet of overburden. The sand and gravel resources occurring in this unit are moderate to moderately large in areal extent and the textural characteristics are moderate to good. The quality is typically moderate to high relative to other sand and gravel resources within Stearns County.

NONSIGNIFICANT[1] SAND AND GRAVEL POTENTIAL: Units that generally have little or no potential for significant aggregate resources or lack sufficient data to support a classification of significant aggregate resources. These units typically contain clay, silt, fine sand, unsorted sediments (till), or very thin layers of sand and gravel. Units may include aggregate resources that are too small to map or with significant overburden.

Lp **Low Sand and Gravel Potential:** Includes landforms such as alluvial features, outwash features, ice contact features, moraines, and collapsed channels. Predominant sediment varies and can include silty sand, sand, sand with gravel, silty sand and gravel, and sand and gravel. The probability that a potential sand and gravel resource exists within any map unit is low to moderately low. Deposit thickness typically is less than 10 feet, but can range from 0-70+ feet with overburden thickness ranging from 0-45+ feet. The sand and gravel resources occurring in this unit are very small to moderate in areal extent and the textural characteristics are poor to good. The quality ranges from low to high relative to other sand and gravel resources within Stearns County.

Ltd **Limited Sand and Gravel Potential:** Includes landforms such as alluvial features, moraines, collapsed channels, and bedrock. The deposits of this unit contain all or one of the following: clay with boulders (till), bedrock, clay, silt, sand, and/or gravel. The probability that a significant sand and gravel resource exists within this unit is very low to moderately low. The thickness of the deposits is typically less than 5 feet but can range from 0-60+ feet with overburden thickness ranging from 0-100+ feet. The sand and gravel resources occurring in this unit are very small to small in areal extent and textural characteristics are very poor to moderately poor. The quality ranges from very low to moderately low relative to other sand and gravel resources within Stearns County. A limited potential rating includes the circumstance where characteristics are unknown; there was insufficient data to give a higher ranking; limited access to an area for further investigation; and/or no obvious landform-sediment association.

IDENTIFIED SAND AND GRAVEL RESOURCES

Several sources of information were used to identify gravel mine locations including: topographic maps, aerial photographs, soil surveys, Mn/DOT files, fieldwork, gravel operators, and other sources. Gravel mines range in size from less than 1 acre to greater than 50 acres and may be active, inactive, depleted, or reclaimed. The sand and gravel quality of the mines varies. Size of point indicates the relative areal extent of the pit as of 2010.

Small <5 acres	Medium 5-15 acres	Large >15 acres
n = 685	n = 73	n = 37
n = 54	n = 31	n = 27
n = 9	n = 1	
n = 8		

OTHER FEATURES

n = 36	
n = 28	

Gravel Pits: Includes sites that have been or are currently being mined.

Gravel Pits - Mn/DOT ASIS: Sites were identified by Mn/DOT as part of the Aggregate Source Information System (ASIS). Although identified as a potential resource location, sites have not necessarily been mined or geologically evaluated. Some locations were modified to better correlate to present gravel pit boundaries.

Sand Pits: Contain significant amount of sand with little to no gravel. Includes sites that have been or are currently being mined.

Sand Pits – Mn/DOT ASIS: Sites were identified by Mn/DOT as part of ASIS. Although identified as a potential resource location, sites have not necessarily been mined or geologically evaluated. Some locations were modified to better correlate to present sand pit boundaries.

Borrow Pits: Contains other unconsolidated sediment like clay, silt, and clay with boulders and do not contain significant amounts of sand and/or gravel. Include sites that have been or are currently being mined.

Prospects: Indicates a site that has been prospected and/or leased by Mn/DOT. A prospected classification does not necessarily imply that the source is actually producing aggregate at the present time. In fact, it may only indicate an aggregate deposit that was at one time leased by Mn/DOT and whose aggregate quality has been tested, but from which no material has ever been excavated.

GEOLOGIC DATA SOURCES FOR MAP UNIT INTERPRETATION

Field observations, County Well Index (CWI) database, and test-holes were data sources used in the interpretation of sand and gravel potential.

Field Observations: A total of 2600 field observations were logged throughout the course of the project. Pits were also inventoried and include 932 gravel pits, 16 sand pits, and 28 borrow and clay pits. Surficial geologic sediment, glacial stratigraphy, and bedrock formations were observed in road cuts; stream exposures; excavations, such as basements, judicial ditches, construction projects, and (cable, pipe, tiling); and animal holes. Field observations of gravel pits and sand pits are shown on the map as Gravel Pits and Sand Pits (See Identified Sand and Gravel Resources).

Field observations are symbolized by primary material type observed. Note, the following symbols may appear in different shades due to the overlayering of sand and gravel potential map layers.

▪ Sand and Gravel ▲ Sand • Till × Silt/Clay ♦ Bedrock Outcrop

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FOOTNOTES ASSOCIATED WITH SAND AND GRAVEL POTENTIAL

[1]Nonsignificant: Aggregate resources that do not meet the criteria for high or moderate aggregate potential according to the characteristics listed in Table 1. This is a relative classification that changes from one mapping region to another.

[2]Probability: The degree of certainty that aggregate exists within a mapping unit largely defined by the amount of available information. Many gravel pits verify the certainty for many map units classified as high potential.

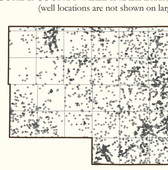
[3]Overburden: The material that lies above the sand and gravel that must be removed to access a deposit.

[4]Areal Extent: The size, horizontal extent, or distribution of a unit (e.g., area in acres). This attribute does not necessarily reflect the size of an individual polygon but the size of a deposit found within that polygon.

[5]Textural Characteristics: Particle size distribution, defined as the percentage of gravel or sand vs. silt or clay (e.g., sieve analysis).

[6]Quality: The physical characteristics of the material, such as soundness (e.g., magnesium sulfate test), durability (Los Angeles Rattler test), and percent of deleterious rock types such as iron oxide, disintegrating rock, or unsound chert. Field observations supplement historic data.

FIGURE 2: COUNTY WELL INDEX DATABASE—LOCATED WELLS
(well locations are not shown on larger resource map)



County Well Index Database-Located Wells: The CWI is an online database maintained by the Minnesota Geological Survey and the Minnesota Department of Health. Figure 2 displays the 6785 wells (as of 06/07) located within Stearns County that were referenced to create this map. There are an additional 13,618 unlocated wells also referenced for this map that are not shown here. Unlocated wells have not been field verified by the MGS for location accuracy.

Sand and Gravel **Test Holes:** Test holes were completed during a cooperative drilling program between DNR and Mn/DOT. A total of 78 test holes were drilled to verify the presence or absence of sand and gravel. Each test hole is labeled with significant material(s) extracted from the holes. Selected samples from test holes were analyzed for quality at a Mn/DOT material laboratory. Sampled test holes are shown on the map as TH-### and the corresponding results can be found in Table 2.

TH-106 **Test Hole Sampling by Mn/DOT for Construction Aggregate Quality:** Sample quality has been characterized at the reconnaissance level by 23 samples and more than 2600 visual field observations. The Mn/DOT concrete lithlogical exam identifies certain deleterious rock types present within a sample and calculated as a weight percent.

BASE MAP SYMBOLS
Symbols may appear in different shades due to the overlaid layers of sand and gravel resource potential (limited, low, moderate, or high).

Transportation Features
- 94 Interstate Highway
- 71 US Highway
- 238 MN Highway
- 17 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

Topographic Relief
- Hillshade (Azimuth = 315 Altitude = 345)

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.

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Printed Map Scale 1:100,000
Based on a 1:50,000 scale resource assessment

Miles 0 1 2 3 4 5 6
Kilometers 0 1 2 3 4 5 6 7 8 9

Locator Map

TABLE 1: CLASSIFICATION OF SAND AND GRAVEL POTENTIAL

Characteristics	SIGNIFICANT RESOURCES		NONSIGNIFICANT[1] RESOURCES	
	High Potential	Moderate Potential	Low Potential	Limited Potential
Surficial Geology Landforms	Outwash features; ice contact features; and end/thrust moraines	Outwash features; ice contact features; end/thrust moraines, and palimpsest topography	Alluvial features; outwash features; ice contact features; moraines; collapsed channels	Alluvial features, moraines, collapsed channels; and bedrock
Predominant Sediment Description	Sand and gravel	Sand with gravel to sand and gravel	Silt, sand and gravel	Till, clay, silt, sand, gravel, and bedrock
Probability[2]	Moderately high to very high	Moderate to very high	Low to moderately low	Very low to moderately low
Sand and Gravel Thickness (in feet)	10-60+	0-50+	0-70+	0-60+
Overburden[3] Thickness (in feet)	0-20	0-20+	0-45+	0-100+
Sand and Gravel Deposit Size (areal extent[4])	Moderate to very large (10-30+ acres)	Moderate to moderately large (5-15+ acres)	Very small to moderate (3-10+ acres)	Very small to small (<1-5+ acres)
Sand and Gravel Textural Characteristics[5]	Moderate to very good	Moderate to good	Poor to good	Very poor to moderately poor
Sand and Gravel Quality[6]	Moderate to very high	Moderate to high	Low to high	Very low to moderately low

Classifying Sand and Gravel Potential: Sand and gravel resources were divided into four categories based on the type of geologic feature, probability (certainty), sand and gravel thickness, overburden thickness, deposit size (areal extent), textural characteristics (grain size distribution), quality (soundness and durability), and the sediment description as observed in the field (Table 1- see definitions of terms in Footnotes at left). For example, a classified landform, such as an ice contact feature, typically contains sand and gravel. The resource has a high probability of containing aggregate when the landform has gravel pits located within its boundaries, sand and gravel is observed at or near the surface, and sand and gravel is encountered in surrounding water wells. Historical laboratory test results of aggregate quality are compiled, interpreted, and extrapolated from Mn/DOT pit sheets. In addition to Mn/DOT quality data, observations of quality characteristics can be assessed during field work. Thickness of overburden and sand and gravel were determined from observations and water well information. For example, if a deposit has areal extent greater than 20 acres, has thickness greater than 15 feet, has overburden thickness of 5 feet or less, has high quality, good texture, and an existing gravel pit, then the resource is classified as having high potential (Table 1).

The areas classified as nonsignificant sand and gravel resource potential (low and limited potential) meet the criteria listed in Table 1. Deposits that are too small in areal extent, are too thin, have too thick of overburden, contain significantly more sand than gravel, lack identified resources, or do not meet quality specifications are in these categories.

TABLE 2: TEST HOLE SAMPLES TESTED BY MN/DOT FOR CONSTRUCTION AGGREGATE QUALITY

Test Hole ID *TH-#/-# = quadrule samples*	Map Location *T=Township, R=Range, and S=Section*	% Gravel	% Silt/Clay	% Shale in Sand	% Total Shale +4	% Total Sample Shale	% Carbonate	% Iron Oxide	% Unsound Chert	% Total Sample Spall	% BA Spall +4
TH-100/105	T 123 N, R 30, S 11	20	3.0	0.0	0.0	0.0	30.1	0.3	0.03	0.1	0.4
TH-101/102/103	T 123 N, R 29, S 5/6	31	5.5	0.2	0.1	0.2	36.2	0.6	0.1	0.4	0.8
TH-106	T 123 N, R 30, S 5	21	6.0	0.0			11.9	0.7	0.1	0.2	0.8
TH-112/113	T 122 N, R 30, S 13	31	4.7	0.7	0.5	0.6	18.1	1.1		1.1	2.1
TH-114/115	T 124 N, R 29, S 29	17	3.9	0.0	0.1	0.0	26.4	0.6	0.2	0.2	1.2
TH-120	T 123 N, R 35, S 33	28	2.3	0.7	0.1	0.6	48.5	0.1	0.03	0.6	0.2
TH-121	T 123 N, R 35, S 29	37	4.9	0.5	0.1	0.4	50.6	0.5	0.2	0.6	0.8
TH-126/134	T 126 N, R 33, S 6	36	4.4	0.0			25.5	0.4	0.3	0.2	0.7
TH-130/131	T 126 N, R 32, S 30	12	4.2	0.0	0.1	0.0	29.2	0.2	0.5	0.1	1.2
TH-139/140	T 122 N, R 28, S 17	19	2.5	0.3	0.1	0.2	33.4	0.7	0.5	0.5	1.3
TH-141/142	T 122 N, R 28, S 19	14	4.6	0.0	0.0	0.0	39.7	0.2	0.03	0.0	0.3
TH-143	T 122 N, R 28, S 31	16	3.5	0.0			37.8	1.5	0.4	0.3	1.9
TH-146	T 126 N, R 28, S 29	34	2.5	0.0			3.9		0.2	0.2	0.5
TH-161	T 123 N, R 30, S 5	44	6.8	0.0			14.1	0.5	0.1	0.3	0.6

Test Hole Sampling: A total of 23 holes were sampled. Samples from the same deposit were combined into a single composited sample. As a result, 14 samples were submitted to the Mn/DOT Maplewood Materials Laboratory for concrete aggregate lithological examination. The table above lists the results from this test in weight-percent and includes the following: gravel (#4 sieve), silt/clay (<200 sieve), shale in sand, shale in gravel, total shale, carbonate, iron oxide, unsound chert, total sample spall, and bulk aggregate (BA) spall for greater than 4.75mm. Sample locations are labeled by Test Hole ID and the primary material extracted.

The bituminous specification (Mn/DOT 3139.2), for allowable total sample spall by weight is 5%. All other listed attributes are calculated within the total sample spall%. The shale content is low for samples tested (<2.5% in sand and <0.7% in gravel); however, high amounts of carbonate (>30%) and iron oxides (>0.3%) are present in many samples. Overall, sample results indicate that tested deposits meet specifications for bituminous, but not for concrete (3126 and 3137.2 Mn/DOT Standard Specifications for Construction, 2005).

Blank values represent test parameters that were not completed for that parameter. These results are only general guidelines that are useful for planning. Additional testing should be completed to statistically characterize any deposit.

GLOSSARY OF TERMS

Collapsed Channel: A channel formed beneath glacial ice that subsequently collapsed and filled in by glacial sediment.
Ice Contact Feature: Used to describe landforms that were deposited in contact with glacial ice.
Moraines: A glacial landform that describes an accumulation and deposition of unconsolidated glacial sediment.
Palimpsest Topography: A term used to describe a pre-existing landform or landscape that is still observable despite being overridden by the most recent glacial advance.
Outwash: A type of sand and gravel bearing landform that was deposited by glacial meltwater.
Sand and Gravel: For the purpose of this assessment, sand and gravel is a term used to describe sediment with an estimated gravel content greater than 30 percent.
Sand with Gravel: For the purpose of this assessment, sand with gravel is a term used to describe sorted sediment with an estimated gravel content between 10 and 30 percent.
Till: Unconsolidated sediment containing all sizes of sediment from clay to boulders directly deposited by glacial ice.

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