

AGGREGATE RESOURCE EVALUATION  
FOR A PORTION OF FELTON PRAIRIE  
CLAY COUNTY, MINNESOTA

BY

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PROJECT: 334-11

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## SUMMARY

This report summarizes the results of an aggregate resource evaluation conducted on 735 acres of public lands within Felton Prairie in Clay County, Minnesota. The evaluation was initiated by the Felton Prairie Stewardship Committee as part of a larger study on Felton Prairie. Funding for the project was from the Legislative Commission on Minnesota Resources. The evaluation was conducted by the Minnesota Department of Natural Resources, Division of Lands and Minerals.

The evaluation began in 1999 by examining earlier exploratory drilling and surrounding water well logs and by reviewing maps and aerial photographs. A geophysical study was then conducted in May 1999. In January 2000, a roto sonic drilling program was completed. Twenty seven holes were drilled for a total of 2059 linear feet ranging in depth from 25 to 145 feet. From this information, geologic interpretations were developed about the aggregate resource and volume estimates were calculated. The results are summarized below.

- Drilling confirmed the presences of two deposits of sand and gravel:
  - A deep, primary deposit (>100 feet thick)
  - A shallow, secondary deposit (discontinuous beach ridges)
- The primary deposit is north/south trending and located in the central portion of the study area. The secondary deposit is located in the western portion of the study area.
- The primary deposit thickness ranges from 0 to 100+ feet.
- The primary deposit is thick in the east and thins to the west.
- Average thickness of the primary deposit is approximately 60 feet.
- Not all of the sand and gravel is located on surface.
- Overburden thickness ranges from 0 to 50+ feet.
- Significant overburden was located in the southern and northern part of the study area.
- The volume of the primary deposit was estimated:
  - Above Water Table: 4,300,000 cubic yards
  - Below Water Table: 19,800,000 cubic yards
  - Total: 24,100,000 cubic yards
- Not included in the estimate are the discontinuous beach ridges, a portion of the study area with 30+ feet of overburden, and areas with no drill holes.
- This estimate is a statistical representation of the data gathered from the drill holes.
- The quality of the primary deposit is very good and the majority of the deposit meets Minnesota Department of Transportation specifications for concrete. Lower reaches of the deposit have a higher percentage of shale in the sand fraction.
- The gradations of the main deposit pass for Class 5 material. The secondary deposit does not pass for Class 5 material.



## INTRODUCTION

The purpose of this report is to describe the results of an aggregate resource evaluation conducted on 735 acres of public land in Clay County, Minnesota near the town of Felton. The study area is also located within the Felton Prairie Complex (Figure 1A). Felton Prairie covers approximately 10,500 acres of land of which 2,200 acres is publically owned (680 acres by Clay County, 1,370 acres by the State of Minnesota, and 150 acres by the United States Fish and Wildlife Service).

Within the Felton Prairie Complex are found remnants of native prairie plant communities, active gravel mining operations and a variety of other land uses.

The Felton Prairie Complex has areas of high aggregate potential (Figure 1B).

Aggregate potential refers to the probability that sand and gravel exists within the region. However, the local extent of the deposits within Felton Prairie is unknown. The objective of this study is to gather information about the sand and gravel on publically owned lands in the Felton Prairie Complex. Thus, the study area focuses upon those public lands with the highest aggregate potential.

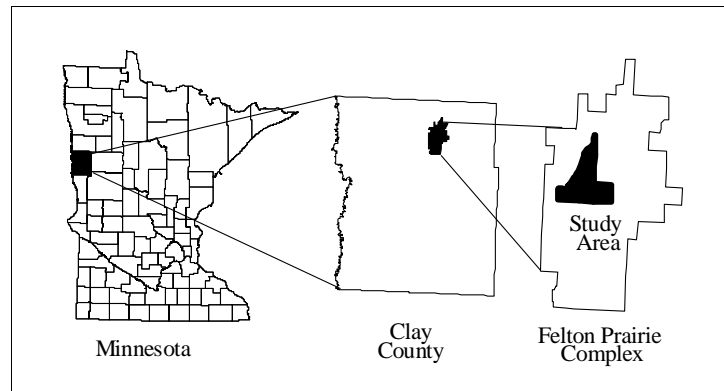


Figure 1A. Location of Felton Prairie Complex and study area.

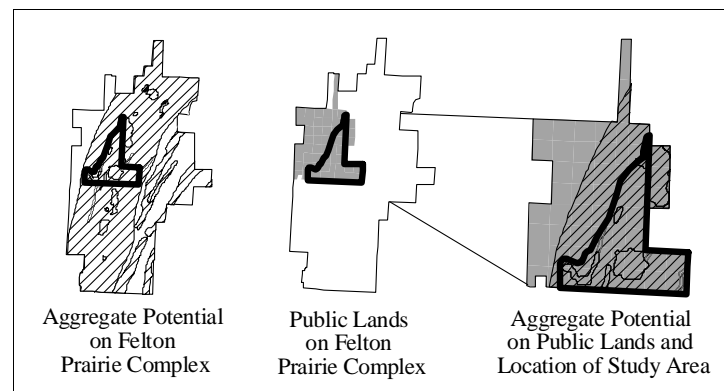


Figure 1B. The aggregate potential of Felton Prairie and study area.

The origin of this project was in 1998 when a local group, known as the Felton Prairie Stewardship Committee, submitted a proposal to the Legislative Commission on Minnesota Resources (LCMR) for funding consideration. Among other things, the proposal sought funds to provide aggregate information to the Committee so that a Felton Prairie Stewardship Plan for Public Lands could be prepared. The proposal was funded and the project was initiated in July of 1999. The Committee members included representatives from Clay County, Minnesota Department of Natural Resources (DNR), Minnesota Department of Transportation (MNDOT), The Nature Conservancy (TNC), United States Fish and Wildlife Service (USFWS), University of Minnesota (U of M), and the aggregate industry.

The aggregate resource evaluation began in 1999. The evaluation started by examining the work from earlier exploratory drilling and surrounding water well logs. Topographical maps, aerial photographs, and surficial geological maps were interpreted. A geophysical survey was conducted. In January of 2000, a rotosonic drilling program within the study area was completed. The entire length of the drill core was extracted and saved. The core was described, sampled, and analyzed. Information from the drilling program was used to compute a volume estimate for sand and gravel found above and below the water table. Volume estimates were calculated for the entire study area and then broken down into geographic areas.

The aggregate resource evaluation was conducted by the DNR- Division of Lands and Minerals for the Felton Prairie Stewardship Committee. The results of the resource evaluation are described in this report. Within the conclusion, the results are discussed and summarized by geographic areas. The data and conclusions are also summarized in two plates in the back of the report. Plate I contains data obtained from the rotosonic drilling and geophysical study. Plate II summarizes geologic observations and cross sections.

## GEOLOGIC SETTING

About 11,000 years ago, large glaciers occupied the Red River Valley (Clayton and Moran, 1981). These glaciers left behind many different types of sediment ranging from sand and gravel (outwash) to boulder rich-clay (glacial till). As the glaciers retreated to the north, large amounts of water were discharged. The meltwater carved deep (>100 foot) north/south trending channels into the landscape. Within the channel, sand and gravel was deposited. The sand and gravel is called outwash. Generally, when glacier



Figure 2. Glacial Lake Agassiz and the relative location of the study area.

margin is near the outwash channel, the sediments are coarse (rocks, gravel and some sand). As the glaciers retreated further north, the outwash became finer (mostly sand and silt with some gravel).

As the glaciers continued to melt, a large glacial lake filled the Red River valley. This lake is called Glacial Lake Agassiz and it existed for several thousand years (Figure 2). Many pre-existing landforms located within the basin were covered with silts and sands. However, landforms located near the lake's edge were modified by wave action. Over the course of time, the waves of the glacial lake washed existing sediments and redeposited them as beach ridges.

The study area is located on a waded-modified outwash channel. The sand and gravel was first deposited by an outwash channel and later modified by waves. Since the sand and gravel found in the study area is primarily outwash, the outwash is considered the “primary” deposit. On top of the outwash are Glacial Agassiz beach ridges. Compared to the primary deposit, the beach ridges are relatively smaller in size and volume. For this reason, the beach ridges are considered the “secondary” deposit.

## METHODOLOGY

Several different means of gathering information were used to conduct the aggregate resource evaluation. Information was gathered from several sources including; map interpretation, a geophysical survey, roto sonic drilling, sampling the drill core, geologic logging, analysis of the samples and computer modeling. Details on the various methods are described below.

### PREVIOUS WORK

Existing information within the study area was gathered and examined. The information included data from exploratory drilling and water well logs. Exploratory drilling was conducted in November of 1997 by MNDOT. The drill rig has a 10 inch diameter auger with a 20 foot continuous flight. Length was added to the drill flight with the addition of 5 foot augers. A total of 37 holes were drilled in the study area (Figure 3). Appendix A contains the geologic descriptions for each drill hole. One sample per hole was collected for drill holes that contained gravel. Sieve analysis was completed by the MNDOT Aggregate Materials Laboratory. The results of the exploratory drilling proved that the nature of the deposit was “rocky” and deeper than the maximum drilling extent of the auger (approximately 45 feet). The results also indicated that to fully understand the primary deposit, roto sonic drilling methods would be required. Samples taken from the primary deposit passed MNDOT specification for Class 5 aggregate.

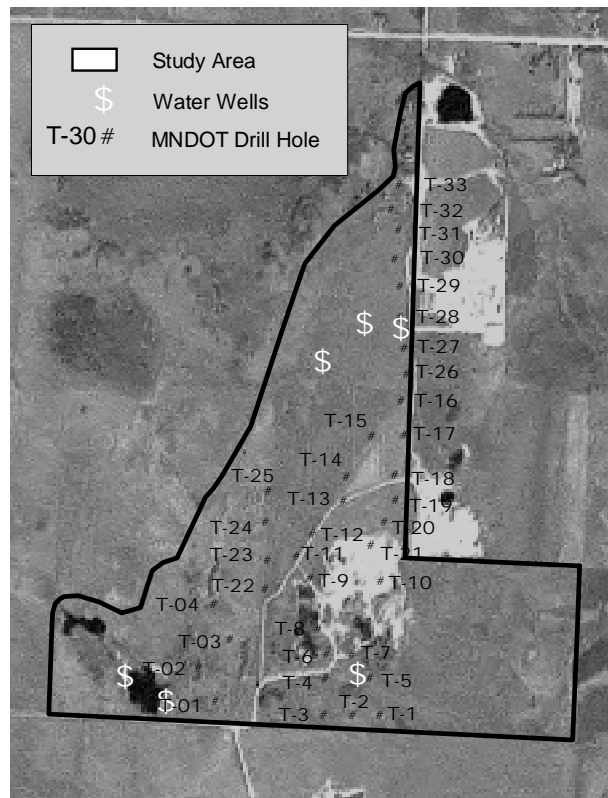


Figure 3. Exploratory drill hole and water well locations.

Data from several water wells located within the study area were used for the interpretation of the water table. The water well log also included brief geologic descriptions. Both the exploratory drilling and water well logs gave insight into the upper surface of the deposit.

#### MAP INTERPRETATION

Topographic maps and aerial photographs were analyzed for both regional and local geologic interpretations. Topographic maps were used to analyze and identify landforms such as beach ridges and other associated landforms. The following 7.5 minute U.S. Geological Survey topographic quadrangles were used: Syre, Twin Valley, Twin Valley SW, Ulen, Ulen NW, and Ulen SW. Color infrared aerial photographs (NAPP, 1991) as well as Landsat Satellite Images (1999) were analyzed to identify landforms and landmarks. Additional geologic information, specifically the surficial geology and sand and gravel trends, was obtained through the Clay County Aggregate Resources Map Series (DNR 1997).

#### GEOPHYSICAL STUDY

A geophysical study was conducted within the study area in May of 1999. The method used was a surficial electrical resistivity survey. The resistivity survey is a non-intrusive method of obtaining information about sediments below the ground surface (Plate I). The basic principle of electrical resistivity is to measure how well different sediments conduct electricity. For example, silts are more conductive/less resistive to electrical current when compared to gravel. The contrast between silt and gravel is measured at depth by a series of electrical transmitters and receivers placed at the surface. The purpose of the survey was to (1) refine the drill targets and (2) evaluate the applications of geophysics for this aggregate evaluation.

The survey was contracted to the Department of Geology and Geophysics, University of Minnesota in conjunction with the DNR- Division of Waters and DNR-Division of Lands and Minerals. A total of 12 transects were completed. Some transects were lined up consecutively to produce one longer line. For example, three transects make up line number 5 (Figure 4). In total, nine geophysical lines were completed.

#### ROTONSONIC DRILLING

A rotosonic drilling program was the next step in the aggregate evaluation. Rotosonic drilling is a specialized drilling service available from a few private contractors. Boart Longyear was selected as the drilling contractor. The Felton Prairie Stewardship Committee then determined drilling priorities and placement for approximately forty drill holes. The committee specified that whenever possible, the locations of the drill holes were to be placed in areas of disturbed vegetation (i.e. on old/new haul roads or within existing gravel pits).

Due to the increased cost in drilling, the number of holes was reduced from 40 to 27

holes. Based on the specified priorities and the number of drill holes, the study area was divided into four areas (Figure 4):

- Area 1: Consists of the Clay County gravel pit and the area to the north of the pit
- Area 2: Consists of the area south of the Clay County gravel pit
- Area 3: Consists of the Bicentennial Prairie
- Area 4: Consists of the State owned inactive gravel pits, the western edge and far northern portion of the study area

Overall, the final drill hole pattern had a scattered distribution with a greater density of holes in Area 1 (Figure 4). The location and elevation of the drill holes, gravel pit boundaries and the haul road were surveyed in November of 1999. The survey information generated surface elevations that were used in computer modeling.

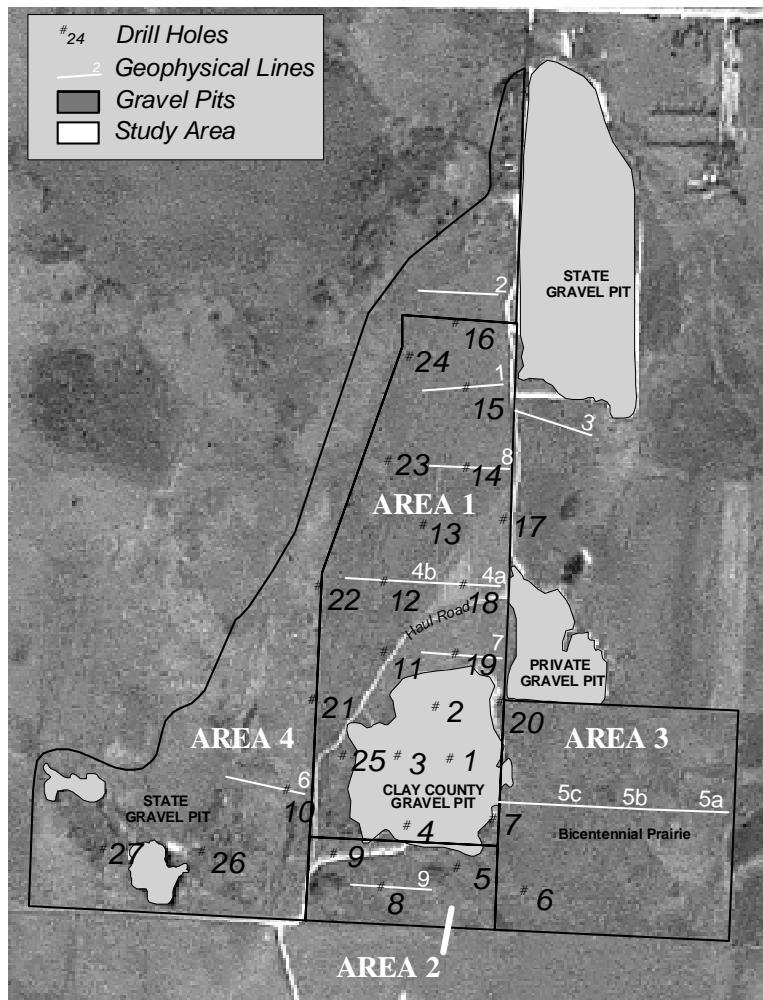


Figure 4. Location map of the drill holes, geophysical lines, and area designations. The gravel pits were defined by the top bank of the pit wall.

Some holes were also placed on the geophysical lines. These holes were crucial in determining the accuracy of the electrical resistivity model compared to detailed geologic descriptions. A second geophysical method was performed at drill hole 8 of the rotosonic program. The second survey is a down hole electrical resistivity method. In the down hole survey, a single transmitter and receiver apparatus is placed down the hole and records information as it is pulled up the hole. To implement a down hole survey, industrial PVC piping was used to case the hole. The purpose of this study was to (1) determine the depth of different sediments and (2) to compare it to the drilling and other geophysical method. Out of the 27 holes, drill hole 8 was chosen because a significant quantity of overburden covered a potential sand and gravel deposit.

By means of rotosonic drilling, the deposit was sampled and described (Figure 5A). Rotosonic drilling uses steel carbide bits that can penetrate through both unconsolidated sediments and rock. Rotosonic drilling uses rotational and vibrational force to bore into the ground. There are two components to rotosonic drilling: (1) drilling with the core barrel and (2) drilling with the outer casing. The core barrel is drilled first to collect the sample. Before the core barrel is pulled up, the casing is drilled to prevent the hole from collapse. The drill produces segments of core with a 3.5 inch diameter (Figure 5B). The drill core represents a nearly continuous sample of the deposit. To minimize impact to the



Figure 5A (Above): The rotosonic drill rig.  
5B (Upper Right): Drill core being vibrated out of core barrel. 5C (Lower Right): Drill core getting labeled and boxed.



native vegetation, drilling was conducted in the winter after ground freeze. Because of winter conditions, the core was labeled, boxed and transported to the DNR Drill Core Library in Hibbing, MN for sampling (Figure 5C). The drilling resulted in a total of 2059 linear feet with a 95% recovery of the drill core.

#### GEOLOGIC LOGGING AND SAMPLING

The core was delivered to the DNR Drill Core Library in Hibbing, MN where it was described and sampled. To begin, the length of core collected from one hole was laid out in order from top to bottom (Figure 6A). The plastic bags containing the core were cut open. To observe a fresh face for the geologic descriptions, the core was split along its length (Figure 6B). A detailed geologic description, called a log, was written for each hole (Figure 6C). Within the descriptions, gravel is defined as a sediment size that is retained on a 2 millimeters (mm) sieve and up to 3 inches. This definition is consistent with the MNDOT Specifications Handbook for Construction (MNDOT, 1995). Distinct layers were identified and described and the following attributes were noted: the sediment type, color, mud (silt) content, sorting, percent gravel, upper contact, gradation, lithology, dominant gravel size, and maximum gravel size. Appendix B contains the detailed geologic logs. Constructed from the detailed logs, simplified logs were made for each hole. The simplified log noted the dominant sediment type, mud content, and color (Appendix C). Cross sections of the study area prepared from the simplified logs are found on Plate II.

The depth to the water table was also noted from the drill core. The water table was identified by a 1 to 2 inch black and rust layer. These layers are iron and manganese mineralization near the upper fringe of the water table. These water marks also correspond to both observations made out in the field and to the transition from moist to wet sediment within the core. Since the water table was difficult to determine while drilling, the water marks were an alternative method of obtaining this data.

After the descriptions were recorded, the core was sampled. Two types of samples were taken: samples for gradations and samples for quality analysis. The different tests required different sampling procedures:

#### Gradations

- Several samples were taken from each hole.
- The sample intervals were determined by changes in sediment size or every 10 to 15 feet.
- The length of the core was split in half and one of the halves was sampled (Figure 6D).
- Each sample weighed approximately 30 pounds.
- The sample was bagged, labeled and analyzed at the DNR- Hibbing Laboratory.

## Quality

- Approximately two samples were taken from each hole.
- The two sample intervals were determined at a distinct boundary.
- The boundary usually occurred at a consistent change in color (from brown to gray) or a change in sediment.
- One cubic centimeter of sediment was sampled along the length of the remaining half (Figure 6E).
- The sample was labeled and shipped to the MNDOT-Detroit Lakes Laboratory for analysis.



Figure 6A (Upper Left): Laying out the core.  
Figure 6B (Middle Left): Core split in half.  
Figure 6C (Lower Left): Describing sedimentary layers.  
Figure 6D (Upper Right): Sampling for gradations.  
Figure 6E (Lower Right): Sampling for quality.

The change in color from brown to gray represents a shift of the sediment from being oxidized to unoxidized. A list of the samples and the sample intervals can be found in Appendix D.

### LABORATORY ANALYSIS

As previously mentioned, quality analysis was performed at MNDOT- Detroit Lakes and gradational analysis was performed at the DNR- Hibbing laboratory. To determine the gradation of a sample, the different sediment sizes retained on sieves are measured by weight. Gradations can determine the percent gravel, sand and silt for a given sample. Quality analysis includes several different laboratory tests: shale float, lithology, magnesium sulfate, and Los Angeles Rattler (LAR). Shale and lithology tests look for the presence of deleterious rock, or substandard rock, for aggregate used in concrete and bituminous mixtures. LAR measures the durability during handling. Other quality tests include absorption and specific gravity. Absorption measures the amount of water retained in the small fractures of rocks. This procedure is used to determine the specific gravity. Specific gravity is used for the design of different bituminous and concrete mixtures. The quality tests is a reference to ascertain the relative value of a deposit.

### COMPUTER ANALYSIS

A computer model was generated to estimate the volume of the sand and gravel deposit found in Area 1. The model calculated volume estimates above the water table, below the water table, and the volume for the entire deposit. The estimate was based on information gathered from the rotosonic drilling program. Specifically, the volume estimate used gravel thickness and depth to water table in and around Area 1. The reduction of the number of drill holes from 40 to 27 increased the spacing between drill holes. Due to the larger spacing, this volume estimate should be regarded as an indicated resource evaluation. An indicated resource evaluation estimates the characteristics and grade of a deposit with a reasonable level of confidence. However, geologic continuity can not be assumed (Bulletin from the Society for Mining, Metallurgy and Exploration, Inc., 1999).

The spacing of the drill holes determined what method could be used to estimate volume. Due to the large spacing between drill holes (approximately 1000 feet) and the variability of a sand and gravel deposit, a polygon algorithm was used. The model determines a polygon around a drill hole based on the distance of the surrounding drill holes. If the drill holes are closely spaced, the polygons are smaller. If the drill holes are widely spaced, the polygons are larger. Once the polygons around the drill holes are established, the area of the polygon was calculated. The volume was then estimated by the area of a polygon around a drill hole times the gravel thickness found at that drill hole. Finally, all the volumes for the polygons

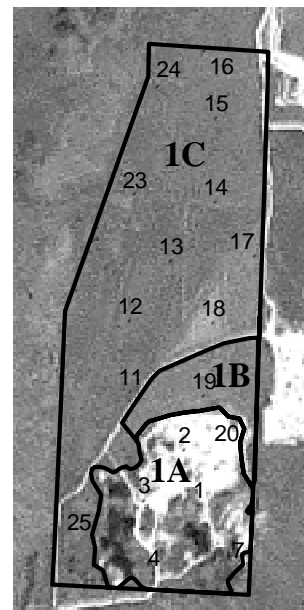


Figure 7. Subareas of Area 1.

were added together to produce an estimate for all of Area 1. Statistics were used to summarize the data. Within Area 1, three subdivisions were created. Volume estimates were also calculated for subareas in Area 1. The subareas are shown in Figure 7 and described below:

- 1A. The Clay County pit
- 1B. Area north of the county pit and south of the haul road.
- 1C. The remaining area within Area 1

**RESULTS**

ROTONSONIC DRILLING

Drilling provided insight into the characteristics of the deposit. The information obtained from drilling includes gravel thickness, the gravel interval, the amount of gravel above the water table, the amount of gravel below the water table, and the overburden thickness. Table 1 is a summary of the above mentioned data for each drill hole (Figure 8).

Drill Hole	Gravel Interval		Thickness	Water Table		Overburden	Depth to Water Table
	From	To		Above	Below		
1	0	55	55	3	52	0	3
2	0	54	54	3	51	0	3
3	0	65	65	3	62	0	3
4	2	65	63	4	59	2	6
5	29	86	57	5	52	29	34
6	0	0	0	0	0	55+	4
7	2	105	103	39	64	2	41
8	47	101	54	0	54	47	14
9	0	0	0	0	0	55+	11
10	7	16	9	1	8	7	8
11	2	70	68	17	51	2	19
12	15	76	61	0	61	15	15
13	2	85	83	12	71	2	14
14	1	78	77	19	58	1	20
15	19	91	72	6	66	19	25
16	20	65	45	6	39	20	26
17	19	83	64	5	59	19	24
18	2	84	82	23	59	2	25
19	2	79	77	24	53	2	26
20	2	95	93	41	52	2	43
21	1	17	16	5	11	1	6
22	2	13	11	5	6	2	7
23	10	52	42	1	41	10	11
24	0	0	0	0	0	65+	NA
25	1	6	5	5	0	1	10
26	9	15	6	1	5	9	10
27	0	0	0	0	0	40+	9

Table 1. Summary of information from rotonsonic drilling (all units are in feet).

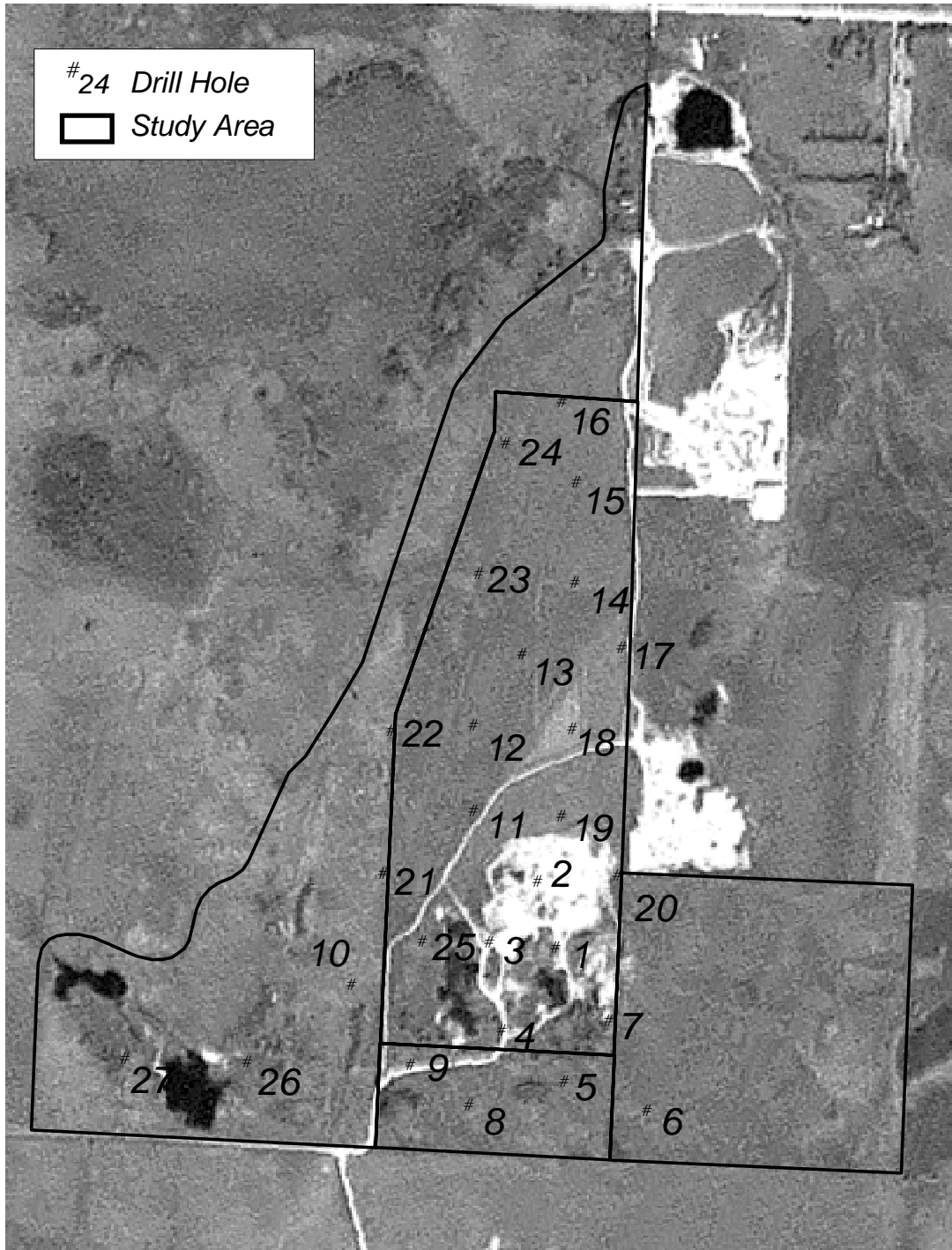


Figure 8. Location of the drill holes (1999 Landsat Satellite Image used as backdrop).

Based on the following drill hole information and survey information, general observations can be made about the deposit (Plate II).

- The deposit is thick to the east and thins to the west.
- Drilling confirms the presence of two gravel deposits:
  - A deep, primary deposit (>100 feet thick east of Area 1A).
  - A shallow, secondary deposit (discontinuous beach ridges).
- Most of the sand and gravel is located in Area 1.
- Not all of the sand and gravel is located at the surface.
- The sand and gravel found in the west is the surficial deposit.
- Significant overburden is found in the far south and far north of the study area.
- Overburden sediment ranges from medium sand to silts and clays.
- Within the County pit, the water table is found 0 to 4 feet below the surface.

The interpretations of the data are discussed in the conclusion.

VOLUME

The volume for the deposit found in Area 1 is estimated to contain approximately 24,000,000 cubic yards of sand and gravel (Table 2). Area 1 approximates the primary body of sand and gravel within the study area. Other areas were not modeled for different reasons. Area 2 had significant gravel resources below 30+ feet of sand and silt. Because the thick overburden appreciably limits the accessibility of the deposit, Area 2 was not included in the estimate. Area 3 contains one drill hole and three geophysical lines that span its width. This information is good for geologic observations, but it is difficult to model. Area 4 does not contain the primary deposit. The sand and gravel in this area is discontinuous and can not be modeled accurately.

(In cubic yards)	Subarea A	Subarea B	Subarea C	AREA 1
	County Pit	North of Pit	Remainder	Total
Above Water Table		900,000	3,400,000	<b>4,300,000</b>
Below Water Table	5,900,000*	2,000,000	11,900,000	<b>19,800,000</b>
<b>Total</b>	<b>5,900,000*</b>	<b>2,900,000</b>	<b>15,300,000</b>	<b>24,100,000</b>

Table 2. Best engineering estimate for Area 1.

\*NOTE: Because the water table is at or near the gravel pit floor, this estimate combines the gravel above and below the water table.

The observed water table within Area 1A ranges from 0 to 4 feet. Due to fluctuations in the water table, the volume calculation reflects the total amount of sand and gravel within the Area 1A. It is important to note that the estimates are based on a reconnaissance level drilling program. Therefore, very localized features such as existing stockpiles and varying slopes along the gravel pit wall are not figured in the estimation. The variability of the volume estimates are discussed in Appendix E.

GRADATIONS

The gradations were combined, or composited, into one representative sample from each area. To obtain a representative number for the various areas, the weighted average from each hole was calculated. Calculations weighted the gradations of each sample by thickness of that sample interval. Then, the area was calculated by averaging all the holes. Holes without sand and gravel were not included in the composites. For example, drill hole 24 did not contain significant gravel and was left out of Area 1C composite. For the same reason, drill hole 6 was excluded. Since this is the only drill hole in Area 3, there is no gradation to represent that area. The gradations are compared to MNDOT Class 5 standards. The comparison to Class 5 is used because it is a familiar product for comparative purposes. The gradations for each area initially were too coarse to meet specifications. A sample that is “too coarse” means that it contains material greater than 1 inch. Having coarse material in the deposit is a good characteristic. In fact, coarse material has a greater market value than Class 5.

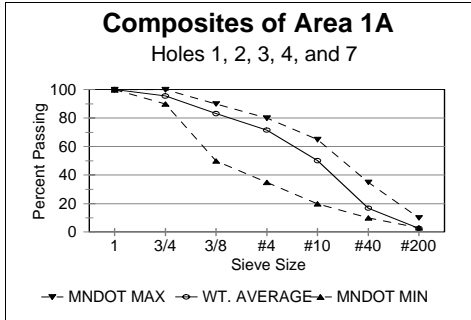
Screening of the deposit is necessary to sort the coarse material from the Class 5 material. In Figure 9, the gradations were adjusted to hypothetically reflect the sand and gravel after it has been through the screening process (Table 3). Under each chart, the approximate percent of material greater than 1 inch is noted. The results indicate that screening for rocks greater than one inch would produce Class 5 material. Exceptions can be seen in Areas 2 and 4. In Area 2, the deposit does not have enough 3/16 inch material. However, Area 2 is covered with 30+ feet of overburden. In Area 4, only material found in drill hole 22 passed Class 5 standards. Material in holes 10, 21, and 26 are too fine to pass Class 5.

	1 25mm	3/4 19mm	3/8 9.5mm	#4 4.75mm	#10 2.00mm	#40 425um	#200 75um
MNDOT MAX	100	100	90	80	65	35	10
MNDOT MIN	100	90	50	35	20	10	3
Area 1A	100	96	83	72	50	17	2.5
Area 1B	100	96	85	74	54	22	4
Area 1C	100	96	85	75	55	21	4
Area 2	100	93	79	67	46	13	2
Area 4- Hole 22	100	98	85	72	50	21	5
Area 4- Holes 10, 21, 26	100	99	94	90	79	37	5

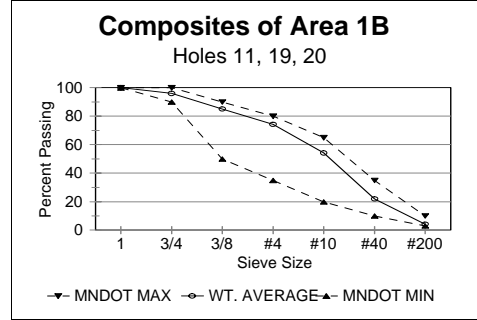
Table 3. MNDOT Class 5 specifications modified to represent deposit after screening of 1 inch material.

In Appendix F, the gradation results for each sample are listed. These results were modified in Appendix 2 to create gradations for every sedimentary layer within the simplified log.

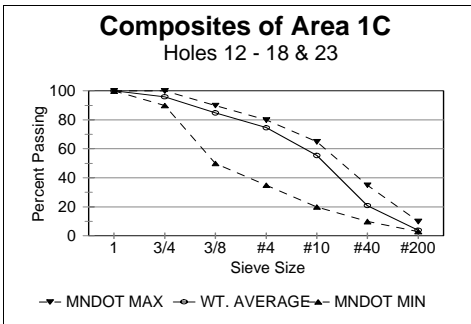
# MNDOT Class 5 Aggregate Composited Averages vs MNDOT Standard



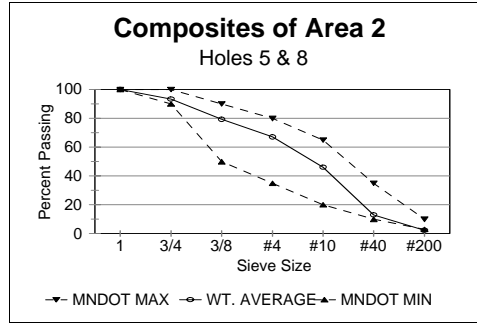
Above 1 inch: 18%



Above 1 inch: 15%



Above 1 inch: 14%



Above 1 inch: 20%

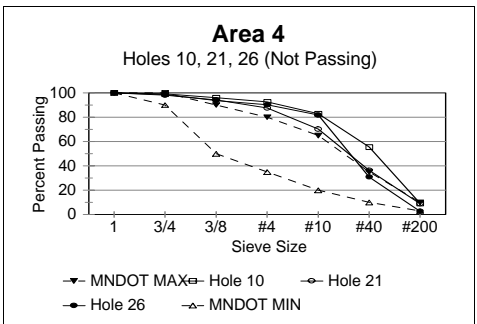
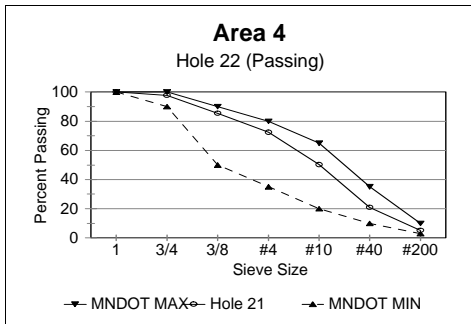


Figure 9. Area gradations.



QUALITY

The sand and gravel was tested to determine the soundness and durability of the deposit. To discover if there were any variances within the deposit, different portions of the sand and gravel were isolated. This was achieved by making a composite of the samples from a group of drill holes into one sample. For this project seven composites were created. Each composite represents a different portion of the sand and gravel. The drill holes were grouped based on two factors: the location of the holes and the depth of the sample. As previously described, the core changed color from brown to gray at depth. This change is a relatively consistent feature seen in all holes. Generally, two samples were taken for quality analysis per drill hole. One sample in the brown zone and one sample in the gray zone. The brown zone represents the upper portion of a hole. The gray zone represents the lower portion of the hole.

The quality results of the composited samples and MNDOT specifications for concrete are summarized in Table 4. Overall, the deposit is of very good quality and passes all MNDOT specifications for concrete. Some composites pass the specifications for concrete superstructures. The amount of spall (deleterious rock) is very low, there are little to no clay balls present, the total shale is very low and the amount lost in the LAR test is below 40 percent. However, portions of the deposit have a higher percent shale in the sand fraction. In composites 5 and 7, the percent shale in sand is 0.8% and 0.7% respectively. This is almost double the maximum amount specified for concrete (0.4%). This “hot spot” of shale is found in the north part of the study area and in the lower portion of the deposit (Figure 10). Blending the deposit with areas of low shale would probably decrease the shale percentage to meet specifications.

	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5	Comp 6	Comp 7	MNDOT Specifications	
	Upper	Lower	U & L	Upper	Lower	Upper	Lower	Concrete	Structures
% Shale in Sand	0.2	0.3	0.3	0.2	0.8	0.3	0.7	< 0.4	< 0.2
% Total Shale +4	0.0	0.0	0.1	0.1	0.0	0.0	0.0	< 0.7	< 0.3
% Other Rock	99.9	100	99.9	99.9	100	100	100		
% Total Spall +4	0.1	0.0	0.1	0.1	0.0	0.0	0.0	< 1.0	< 0.3
% Spall, SRock & Cball	0.1	0.0	0.1	0.1	0.0	0.0	0.0	< 3.5	< 3.0
% Absorption +4	0.74	0.69	0.97	0.87	0.68	0.89	0.84		
% Absorption -4	1.25	1.04	0.8	1.11	1.09	0.78	1.06		
Bulk Specific Gravity -4	2.62	2.62	2.62	2.62	2.64	2.64	2.63		
Bulk Specific Gravity +4	2.7	2.71	2.67	2.69	2.73	2.68	2.7		
% Loss (LAR)		19.7		20.0	19.6			< 40 %	

Table 4. Results of quality analysis. (+4) is the coarse fraction. (-4) is the fine fraction.

## Location Diagram of the Composited Areas

Composite 1: Upper portion  
Drill holes- 2, 3, 4, 5, 7

Composite 2: Lower portion  
Drill holes- 1, 2, 3, 4, 5, 7, 8

Composite 3: Both- (Sediment from beach ridges)  
Drill holes- 9, 10, 21, 22, 25, 26

Composite 4: Upper portion  
Drill holes- 11, 12, 13, 17, 18, 19, 20

Composite 5: Lower portion  
Drill holes- 11, 12, 13, 17, 18, 19, 20

Composite 6: Upper portion  
Drill holes- 14, 15, 16, 23, 24

Composite 7: Lower portion  
Drill holes- 14, 15, 16

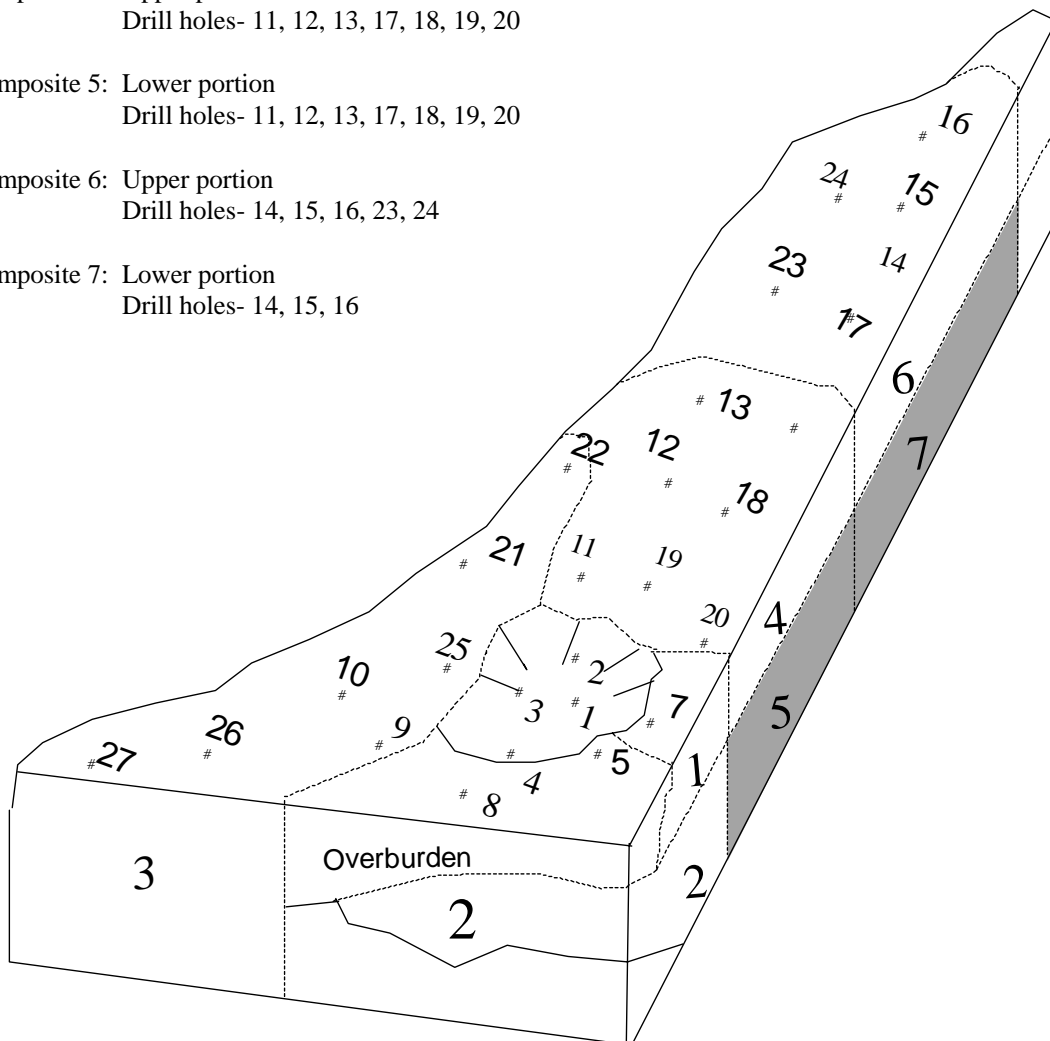


Figure 10. Composited portions of the study area.

## GEOPHYSICS

A comparison of the surficial resistivity study versus the rotosonic drilling was analyzed (Petersen, 2000). The comparison looked at what depth a sediment change occurred and if the geophysics registered the change. The results of the geophysics indicate sand and gravel register a higher resistivity than silt and clay. The relative scale is listed on Plate I.

The results from the down hole survey confirm observations from the surficial survey. Drill hole 8 had a change from silt to sand and gravel at 47 feet below surface. The down hole readings show a change occurring at approximately 50 feet below the surface.

Because of the notable difference in resistivity between silt/clay and sand/gravel, the bottom of this deposit can be mapped using the surface resistivity data. The geophysical readings of gravel compared to sand are not well differentiated. Therefore, changes from gravel to sand can not be mapped. Applying this to overburden, silty rich material can be consistently identified where sand over gravel can not.

## **CONCLUSIONS**

The rotosonic drilling program completed 27 holes. The depth of the drill holes range from 25 to 145 feet. Of 27 holes, 20 encountered gravel with a thicknesses greater than 10 feet. Significant gravel was not always present on the surface. Depending on the location within the study area, the results of the resource evaluation may vary. To address the different characteristics of the aggregate resource, the results are broken down into the four areas. Area 1 is further subdivided into 3 smaller areas. The areas will be described in the following order:

- Area 1
  - Area 1A
  - Area 1B
  - Area 1C
- Area 2
- Area 3
- Area 4

The observations about aggregate resources are interpretations of the data gathered from a reconnaissance level evaluation. It is not intended for mine planning purposes.

### AREA 1: 260 ACRES

- Represents the primary body of gravel within the study area.
- Volume (approximate)
  - Above Water Table: 4,300,000 cubic yards
  - Below Water Table: 19,800,000 cubic yards
  - Total: 24,100,000 cubic yards**
- Contains 18 holes- 16 holes have a gravel thickness >10 feet.

- Depth to water table (does not include Subarea 1A):  
     Ranges: 11 to 41 feet below surface  
     Averages: 24 feet below surface
- Gravel thickness:  
     Ranges: 0 to 103 feet  
     Averages: 62 feet
- Gravel trends: Thickens to the east (>100 feet), thins to the west (0 feet).
- Overburden: Approximately 0 to 20 feet, mostly found in the northern part of Area 1.
- Quality: Very good. The overall deposit passes MNDOT specifications (specs) for concrete. The lower portions of the deposit contain higher amount of shale in the sand fraction ( $\geq 0.7$  % by weight) which exceeds the specs (0.4%).
- Gradations: Very good. Contains a  $\geq 1$  inch fraction ranging from 15-18%. Passes MNDOT specs for Class 5 aggregate.
- Geologic observations: Drilling confirmed a north/south trend to the deposit. Scattered throughout the study area are large boulders. Although boulders were encountered at various depths within the deposit, they are difficult to quantify. The water table is approximately  $1000 \pm 5$  feet above sea level.

AREA 1A: 65 ACRES

- Represents the County gravel pit as of November of 1999.
- Volume (approximate):  
     **Total: 5,900,000 cubic yards\***  
     \*Does not account for sand and gravel in current stockpiles, waste piles, or along the banks of the pit.
- Contains 4 holes- all 4 holes have a gravel thickness >10 feet.
- Depth to water table: 0 to 4 feet below surface.
- Gravel thickness: 55 to 65 feet.
- Gravel trends: Pinches out to 5 feet just west of pit (Hole 25).
- Overburden: Already stripped in most of the pit area. Overburden was observed (silts and fine sands) at an exposure in the northwest corner of the gravel pit. Along the exposure, overburden pinched out to the east. To the west, overburden thickened to greater than 10 feet.
- Quality: Very Good. Passes specs for concrete.
- Gradations: Very good. Contains a  $\geq 1$  inch fraction averaging 18%. Passes MNDOT specs for Class 5 aggregate.
- Geologic observations: The overburden described in the northwest wall of the pit grades from fine sand (in the east) to silt (in the west). It also appears to thicken to the west.

AREA 1B: 23 ACRES

- Represents the area north of the County gravel pit and south of the haul road as of November of 1999.
- Volume (approximate):
  - Above water table: 900,000 cubic yards
  - Below water table: 2,000,000 cubic yards
  - Total: 2,900,000 cubic yards**
- Contains 3 holes- all 3 holes have a gravel thickness >10 feet.
- Depth to water table: 19 to 43 feet below surface.
- Gravel thickness: 68 to 93 feet.
- Gravel trends: Geophysics line 7 indicates a continuous deposit.
- Overburden: No overburden greater than 2 feet encountered in this area.
- Quality: The upper portion is very good, the lower portion is good but with higher shale in the sand fraction. Meets concrete specs.
- Gradations: Very good. Contains a  $\geq 1$  inch fraction averaging 15%. Passes MNDOT specs for Class 5 aggregate.
- Geologic observations: The wide range of the depth to water table is a result of the surficial topography.

AREA 1C: 172 ACRES

- Represents the area north of the haul road and west of the County gravel pit.
- Volume (approximate):
  - Above water table: 3,400,000 cubic yards
  - Below water table: 11,900,000 cubic yards
  - Total: 15,300,000 cubic yards**
- Contains 11 holes- 9 have holes have gravel with thickness >10 feet.
- Depth to water table: 11 to 25 feet below surface.
- Gravel thickness: 0 to 83 feet.
- Gravel trends: Thins to the west.
- Overburden: Encountered in holes 12, 15, 16, 17, and 23. Ranges from 10 to 20 feet.
- Quality: Upper portion is very good, the lower portion contains shale in the sand fraction.
- Gradations: Very good. Contains a  $\geq 1$  inch fraction averaging 14%. Passes MNDOT specs for Class 5 aggregate.
- Geologic observations: The western edge of the deposit is variable in gravel thickness and overburden. The northern portion has approximately 20 feet of overburden.

#### AREA 2: 50 ACRES

- Represents the area south of the County gravel pit.
- Volume: No estimates were created for this area due to the limited accessibility of the deposit (high overburden).
- Contains 3 holes- 2 holes have gravel with thickness >10 feet.
- Depth to water table: 11 to 34 feet below surface.
- Gravel thickness: 0 to 57 feet.
- Gravel trends: Geophysical line 9 show pockets of gravel with thick overburden.
- Overburden: 29 to 55+ feet.
- Quality: Good. The overall deposit passes MNDOT specs for concrete.
- Gradations: Very good. Contains a  $\geq 1$  inch fraction around 20%. Passes MNDOT specs for Class 5 aggregate.
- Geologic observations: Although the deposit is of good quality, the overburden/deposit ratio is around 1:1. In hole 5, approximately 5 feet of sand and gravel exists above water table.

#### AREA 3: 160 ACRES

- Represents the area the Bicentennial Prairie.
- Volume: Not calculated for this area.
- Contains 1 hole and no gravel was encountered.
- Depth to water table: In drill hole 6, the water table was encountered at 4 feet. As seen in the cross section 1 (Plate II), this water table is interpreted as being perched.
- Gravel thickness: 0 to 100+ feet.
- Gravel trends: Geophysical line 5a and 5b, indicate a thick resource on the western half of Area 3.
- Overburden: Most of geophysical line 5c shows little to no overburden where sand and gravel is indicated. Along a 40 foot exposure located on the west side of Area 3, no overburden was observed.
- Quality: No data.
- Gradations: No data.
- Geologic observations: Based from of the southern exposure of the private pit, the eastern exposure of the County pit, and geophysical line 5c, the thickest part of the entire deposit exists in the northwestern 40 acres of Area 3.

#### AREA 4: 265 ACRES

- Represents inactive DNR gravel pit, western part, and the northern most part of the study area.
- Volume: Not calculated for this area. The deposit is too discontinuous to be statistically represented. In addition, there is limited data with five drill holes and one geophysical line.
- Contains 5 holes- 2 holes have a gravel thickness >10 feet.
- Depth to water table: 6 to 10 feet below surface. The water table elevation starts to lower in this portion of the study area (990 to 970 feet above sea level). Surveyed depth of the inactive DNR gravel pit is 11 to 14 feet below water surface.
- Gravel thickness: Is variable, from 0 to 16 feet. May be thicker to the north.
- Gravel trends: Thin with some massive silt and sand units between gravel layers.
- Overburden: Where there are drill holes, 0 to 9 feet of overburden were encountered.
- Quality: Good. Passes MNDOT specs for concrete.
- Gradations: Poor. Four of the 5 holes sampled did not meet spec for Class 5. Sand and gravel found in this area contains too much sand and silt.
- Geologic observations: Within this area, a small beach ridge approximately runs along the western edge of the study area. The beach ridge is a shallow, surficial deposit. The deposit may contain some gravel sized particles, but gravel is not consistent throughout the deposit.

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## **APPENDICES**

**APPENDIX A**.....MNDOT Drilling Logs

**APPENDIX B**.....Detailed Rotosonic Drill Hole Log Description

**APPENDIX C**.....Simplified Rotosonic Drill Hole Log Description with Gradations

**APPENDIX D**.....Sample Intervals

**APPENDIX E**.....Volume Estimates

**APPENDIX F**.....Gradations (Sieve Analysis)

# APPENDIX A

## MNDOT DRILLING LOGS

Hole - Drill hole number (T = Test Hole).

From (ft) / To (ft) - Interval of sediment described (ex: from 1 to 3 feet).

Description - Dominant sediment type (ex: sand, gravel, silt, topsoil, till).

S & G - sand and gravel

w/ - with

Silt - Describes the relative amount of silt or mud found in the sediment

clean - contains no or very little silt (ex: clean sand or gravel with no or little fine material).

silty - contains moderate to high amounts of silt/mud (ex: dirty sand and gravel).

Color - Describes the dominant color encountered.

brn - brown

gry - gray

Significant Gravel - Describes whether the sediment contains a significant (>20%) amount of gravel.

Y - Yes there is a significant amount of gravel (ex: sand and gravel).

N - No there is not significant amounts of gravel (ex: silt, fine sand, clay, etc.)

Water Table (ft) - Depth to water table in feet.

Hole	From (ft)	To (ft)	Description	Silt	Color	Sig. Gravel	Water Table (ft)
T1	0 2	2 22	Topsoil Silt		brn	N	14.5
T2	0 1.5 9	1.5 9 18	Topsoil Sand Sandy Till	clean silty	brn gry	N	
T3	0 2 11	2 11 32	Topsoil Sand Sandy Till	clean silty	brn gry	N	18
T4	0 1.5 4 18	1.5 4 18 22	Topsoil Sand w/ grvl S&G Sand w/ grvl	clean clean clean	brn brn brn	Y	
T5	0 2	2 22	Topsoil S&G	silty	brn	Y	
T6	0 9	9 21	Topsoil Sand w/ grvl	silty	brn	Y	9
T7	0 0.5	0.5 17	Topsoil S&G	clean	brn	Y	3.5
T8	0 0.5	0.5 22	Topsoil S&G	clean	brn	Y	0.5
T9	0 20	20 22	S&G S&G	clean clean	brn gry	Y	1
T10	0 14	14 22	S&G Sand	clean clean	brn gry	Y	6
T11	0 1.5 13	1.5 13 22	Topsoil S&G Sand	clean clean	brn brn	Y	16
T12	0 1.5	1.5 22	Topsoil Silt		brn	N	
T13	0 1.5	1.5 22	Topsoil S&G	clean	brn	Y	20
T14	0 1	1 22	Topsoil S&G	clean	brn	Y	19
T15	0 1.5	1.5 22	Topsoil S&G	clean	brn	Y	18
T16	0 1 7	1 7 22	Topsoil Sand S&G	clean clean	brn brn	Y	
T17	0 1 18	1 18 22	Topsoil Sand S&G	clean clean	brn brn	Y	
T18	0 2 25	2 25 42	Topsoil Sand Sand w/ grvl	clean clean	brn brn	N	28

Hole	From (ft)	To (ft)	Description	Silt	Color	Sig. Gravel	Water Table (ft)
T19	0 2 8	2 8 15	Topsoil Silt S&G	 silty silty	 brn brn	 N	
T20	0 2 7 13	2 7 13 22	Topsoil Sand w/ grvl Silt S&G	 clean silty silty	 brn brn brn	 Y	 22
T21	0 1 8	1 8 21	Topsoil S&G Sand w/ grvl	 clean clean	 brn brn	 Y	 21
T22	0 1 2.5	1 2.5 22	Topsoil S&G Silt	 silty silty	 brn	 N	
T23	0 1	1 10	Topsoil S&G	 silty	 brn	 Y	
T24	0 1 12.5 16	1 12.5 16 22	Topsoil S&G Silt S&G	 clean silty silty	  brn brn	 N	 16.5
T25	0 0.5 20	0.5 20 22	Topsoil S&G S&G	 clean silty	 brn brn	 Y	 20
T26	0 2.5	2.5 22	Topsoil Silt	 silty	 brn	 N	
T27	0 1.5	1.5 18	Topsoil Silt	 silty	 brn	 N	
T28	0 1	1 22	Topsoil Sand	 silty	 brn	 N	
T29	0 1.5	1.5 22	Topsoil Sand	 silty	 brn	 N	
T30	0 1	1 22	Topsoil Sand	 silty	 brn	 N	
T31	0 1 5	1 5 9	Topsoil Sand w/ grvl S&G	 clean clean	 brn brn	 Y	
T32	0 13	13 21.5	S&G S&G	 clean silty	 brn gry	 Y	
T33	0 12	12 42	S&G S&G	 silty clean	 brn gry	 Y	
T01	0 1 11	1 11 21	Topsoil Silt Sand w/ grvl	 silty clean	 brn gry		
T02	0 1	1 22.5	Topsoil Silt				
T03	0 1	1 15	Topsoil Silt				
T04	0 1.5	1.5 22	Topsoil Silt				

## APPENDIX B

### DETAILED ROTOSONIC DRILL HOLE LOG DESCRIPTION

Drill Hole - Drill hole number (1-27).

From (ft) / To (ft) - Interval of sediment described (ex: from 1 to 2.5 feet).

Sediment Type - Describes the dominant sediment type (ex: sand, silt, clay, gravel).

N.S.	- not sampled (no recovery)	S & G	- sand and gravel
w/	- with	occ.	- occasional
cs.	- coarse		

Color - Describes the dominant color encountered.

dk.	- dark	lt.	- light	gry	- gray
brn	- brown	yel	- yellow	olv	- olive
org	- orange				

Silt Content - Describes the amount of silt or mud found in the sediment.

Ranges from : very silty - silt - silty - slightly silty - clean (no silt)

Gravel % - A visual estimate of the amount of gravel (rough approximation).

Sorting - A visual estimate of sorting.

VP	- very poorly sorted/unsorted	MW	- moderately to well sorted
P	- poorly sorted	W	- well sorted
MP	- moderately to poorly sorted	VW	- very well sorted
M	- moderately sorted		

Downward Gradations - Textural and sediment trends going downward.

Upper Contact - Described the contact with the overlying unit (sediment).

grad. - gradational contact

Lithology - Dominant rock type lithology (calcareous, granitic, mixed, non-calcareous).

Dominant Gravel Size - Describes the average gravel size in inches unless otherwise noted.

Example: .75 - .75 inches / 2-4 mm - 2-4 millimeters

Maximum Gravel Size - Describes the maximum gravel size encountered (inches).

Comments - General comments describing the sediment.

Drill Hole	From (ft)	To (ft)	Sediment Type	Color	Silt Content (%)	Gravel (%)	Sorting	Downward Gradation	Upper Contact	Lithology	Dominant Gravel Size	Gravel Size	Comments
1	0.0	0.5	graded sand w/medium gravel	dk brn	very silty	20	P	-	-	-	-	-	Occasional cobble
1	0.5	11.5	graded sand w/med-coarse gravel	brn/yel	very silty	0	P	-	grad.	-	1 1/2	3	Orange brown oxidation at 9 feet (2 inches wide), dark brown oxidation at 10-1.3 feet
1	11.5	11.8	sandy silt	gry	silt	3	P	-	grad. - sharp	-	-	1	Upper contact gradational to sharp, several clods, matrix supported pebble to one inch.
1	11.8	12.2	graded sand w/occ. gravel	brn-gry	very silty	15	P	-	-	-	-	1	-
1	12.2	12.5	sandy silt	gry	silt	3	P	-	grad. - sharp	-	-	-	Good gradation to 3/4 inch
1	12.5	15.0	graded sand w/fine gravel	gry-brn	very silty	30	P	-	-	-	-	-	Not uniform: few + 1.5 inches, 2 at 2.5 inches, boulder at 23 feet
1	15.0	24.5	graded sand/medium gravel	brn-gry	silty	45	P/M/P	-	-	-	-	-	2.5 inch thick silt clod, very sandy
1	24.5	25.0	graded sand w/fine gravel and silt	brn-gry	very silty	25	P	-	-	-	-	-	Slightly silty and coarser at base
1	25.0	26.5	fine-medium gravel	buff	clean	85	WM	coarsens	-	mixed	-	-	Siltier at top, mostly granules, more granules at top
1	26.5	30.0	graded sand w/occ. fine gravel	gry-brn	silty	10	M	-	sharp	-	-	-	Well graded
1	30.0	34.8	graded sand/medium-coarse gravel	gry	very silty	50	P	-	grad.	-	-	-	Probably matrix supported with granules and sand
1	34.8	35.0	sandy silt	gry	silt	5	P	-	sharp	-	-	-	Fines upward from medium-coarse sand at lower to fine-medium sand at top
1	35.0	36.5	medium sand	gry-brn	clean	2	WM	coarsens	-	-	-	-	Silty at lower 6 inches, sizes: 3 at 38 feet +1.5 inches, 2 boulders at 41.5 feet
1	36.5	41.5	graded to coarse sand w/medium-gravel	gry-brn	clean	40	P	-	grad.	-	-	-	-
1	41.5	42.0	graded sand w/occ. fine gravel	gry-brn	silty	8	M	-	-	-	-	-	-
1	42.0	45.0	N.S.	-	-	0	-	-	-	-	-	-	Upper 6 inches is fine-medium silty sand.
1	45.0	50.0	graded sand with rare fine gravel	brn	clean	2	MW	coarsens	-	-	-	-	Silty fine-medium gravel lag at 52.5-53 feet, sizes: 4 at 51-52 feet 2.5"
1	50.0	53.0	medium-coarse sand w/med-coarse gravel	gry-brn	silty	45	MP	-	-	-	-	2 1/2	3- 2 inch rocks found at 54-55 feet
1	53.0	55.0	graded sand w/ medium-coarse gravel	brn-gry	silty	40	P	-	-	-	-	2	Granules dominant and rare pebble in lower 6 inches; medium sand at top, coarse sand in middle
1	55.0	58.0	graded sand w/rare gravel	gry-brn	silty	2	WM	finer	-	-	-	-	Lower 6 inches is coarse sand and granules, outer sand is oxidizing to yellow-orange over 3.5 inches.
1	58.0	61.5	graded sand	gry-brn	clean	5	WM	-	sharp	-	-	-	Cored boulders at 61.75 and 65 feet, at 68-70 feet, till has fine white sand laminations
1	61.5	70.0	clayey silt to sandy silt till	dk gry	-	5	P	-	sharp	mixed	-	-	Abundant fine gravel, medium-coarse sand, coarser going down.
2	0.0	3.0	sand w/gravel	brn	clean	20	MW	matrix coarsens	-	non-calcareous	1/4	1 1/4	Mostly gravel will coarse sand, water table at 3 1/2 feet
2	3.0	8.0	s & g	brn	clean	55	MW	-	grad.	-	1/4-1/2	2 1/2	Coarse sand/fine gravel.
2	8.0	9.0	coarse sand w/gravel	brn	clean	20	W	-	sharp	mixed	2-4mm	1 1/4	Cobble rich sand and gravel with silty sand mix. Water table at 9.25 feet
2	9.0	10.0	s & g	brn	silty	35	M	-	sharp	mixed	1	2 1/2	Coarse sand and fine gravel.
2	10.0	11.0	fine gravel with sand	brn	clean	60	W	siltier going	sharp	mixed	1/4-3/8	1	Mostly medium-coarse gravel with some sand, pebble-supported matrix
2	11.0	12.0	s & g	brn	clean	80	M	-	sharp	mixed	1 1/4-1 1/2	2	-

Drill Hole (ft)	From (ft)	To (ft)	Sediment Type	Color	Silt Content (%)	Gravel (%)	Sorting	Downward Gradation	Upper Contact	Lithology	Dominant Gravel Size	Gravel Size	Comments
2	12.0	15.0	s & g	grn	silty	50	M	-	sharp	mixed	2-4mm	2 1/2	Color is distinctively green, mostly fine gravel and occasional cobbles
2	15.0	19.0	fine gravel w/sand	brn-gry	clean	65	W	coarsens	grad.	mixed	3/8	1	Mostly fine gravel with coarse sand.
2	19.0	24.5	s & g	gry	clean	60	M	-	grad.	mixed	1/2-3/4	2 1/2	Mixed with silt, no apparent layers
2	24.5	30.0	coarse sand w/fine gravel	gry	clean	20	MW	coarsens	grad.	mixed	2-4mm	1/2-3/4	A sequence of mixed sand, coarse sand, and fine gravel. 1 cobble-mostly pebble
2	30.0	32.0	fine sand w/cobbles	gry	clean	20	BM	-	sharp	non-calcareous	-	2	Two grain sizes, fine sand with 1-2 inch cobbles
2	32.0	35.0	N.R.	-	-	0	-	-	-	-	-	-	-
2	35.0	36.5	sand	gry	clean	0	W	coarsens	-	-	2	-	Fine sand grading to medium sand, no gravel
2	36.5	40.0	s & g	gry	clean	40	M	-	sharp	mixed	1/2	2	Mixed, no layering, some fine sand--matrix mostly medium-coarse sand.
2	40.0	42.5	sand w/gravel	gry	clean	15	MW	less gravel	grad.	non-calcareous	1/2	1 1/2	More sand going down, medium sand
2	42.5	52.0	s & g	gry	clean	25	MW	-	sharp	mixed	2-4mm	1	Mostly coarse sand with occasional pebble/cobble
2	52.0	54.0	silty s & g	gry	silty	35	M	-	sharp	mixed	1/4	2	Siltier than above, transition to below
2	54.0	59.0	silty s & g	gry	very silty	35	MP	-	grad.	mixed	-	-	Clay/silt balls, silt rich transition to fill
2	59.0	65.0	fill	dk gry	-	0	N	-	-	-	-	-	No sorting
3	0.0	2.0	silty s & g	brn-gry	very silty	20	P	silty	-	non-calcareous	3/8-1/2	1 1/2	Silt rich sand and gravel in the top two feet.
3	2.0	6.5	alternating s & g	brn	clean	45	WM	-	sharp	mixed	2-4mm	2	Alternating 6-8 inches of sand, then gravel
3	6.5	8.0	silty s & g	brn	very silty	30	MP	-	grad.	mixed	2-4mm	2	-
3	8.0	11.0	gravelly sand	brn	silty	60	WM	-	sharp	mixed	3/8	3	One 3" cobble
3	11.0	12.0	silty s & g	yel-brn	silt	35	MP	silty	-	mixed	3/8	4	Some cobbles, water table at 12', occasional gravel/silt layer, more silt at base
3	12.0	19.0	s & g	brn	clean	55	MW	-	sharp	mixed	3/8-1/2	3	Not in layers, gravel randomly scattered
3	19.0	19.5	sand w/gravel	yel-brn	clean	20	MW	fining	sharp	mixed	-	3/4	A sand layer with gravel, dominant gravel size is coarse sand.
3	19.5	26.0	gravel w/sand	gry-brn	very silty	60	M	-	grad.	mixed	1/2-1	2-3	One cobble, mixed, no defined layers, bt marks color change, unoxidized/oxidized
3	26.0	27.5	gravel w/sand	gry-brn	very silty	60	M	-	grad.	mixed	1/2-1	2-3	One cobble, mixed, no defined layers, less oxidized than above
3	27.5	31.5	coarse sand w/fine gravel	gry-brn	clean	30	MW	-	grad.	mixed	2-4mm	1	Homogenous except for occasional pebble
3	31.5	34.5	cobbles w/silt	gry	silt	80	BM	coarser & siltier	grad.	non-calcareous	1-1 1/2	2 1/2	Silt layer at base
3	34.5	37.0	gravelly sand	gry	very silty	70	M	-	sharp	non-calcareous	1/2-3/4	3	Well mixed, no layers.
3	37.0	44.0	coarse sand w/gravel	gry	clean	30	MW	fining	grad.	calcareous	2	1 1/2	One cobble, siltier on top, cleaner at base
3	44.0	47.5	s & g	gry	very silty	60	MP	cleaner	sharp	non-calcareous	1 1/4-1 1/2	4	Mixed, no layers
3	47.5	48.5	gravel w/sand	gry	silt	60	MP	-	sharp	non-calcareous	1 1/4-1 1/2	3 1/2	Similar to above with silt

Drill Hole	From (ft)	To (ft)	Sediment Type	Color	Silt Content (%)	Gravel (%)	Sorting	Downward Gradation	Upper Contact	Lithology	Dominant Gravel Size	Gravel Size	Comments
3	48.5	53.0	s & g	gry	silty	50	M	-	sharp	calcareous	3/8-1/2	2	Mixed sand and gravel
3	53.0	57.0	s & g	gry	clean	50	MW	siltier	sharp	calcareous	1/2	3	Mixed sand and gravel similar to above, except less silt, possible cobble layer at 54 feet.
3	57.0	59.0	cobbles w/fine sand	gry	very silty	60	BM	siltier	sharp	non-calcareous	1 1/2-3	2 1/2	Two sizes cobble and fine silty sand
3	59.0	64.5	s & g	gry	very silty	60	MP	-	grad.	calcareous	1 1/2-2	3	Similar to above, except less silt and more coarse sand
3	64.5	75.0	fill	dk gry	-	0	P	-	sharp	calcareous	-	-	Calcareous, silty clay/mud content
4	0.0	2.0	topsoil	blk	-	15	-	-	-	-	-	-	Gravelly loam, roots to 9 inches
4	2.0	5.0	N.S.	-	-	0	-	-	-	-	-	-	-
4	5.0	6.0	graded sand w/fine gravel	brn	very silty	25	P	-	-	-	-	-	Well graded to 3/8 inch, mostly granules with rare 1 inch pebble
4	6.0	11.5	coarse sand w/fine-medium gravel	yel-red-brn	silty	35	MP	-	grad.	-	-	3	Pebbles dominant, few 1.5 to 3 inches
4	11.5	14.8	coarse sand w/fine gravel	yel-red-brn	very silty	45	MP	-	grad.	-	-	3	3 rocks at 2-3 inches, granules to 6 inches; dark rusty brown at 13.75-14 feet
4	14.8	23.5	grades medium sand w/gravel	org-brn	clean	22	M	-	sharp	-	-	2 1/2	3 rocks are 1.5-2.5 inches, medium sand at top
4	23.5	24.5	graded sand and coarse gravel	brn-gry	very silty	50	P	-	-	-	-	2 1/2	All sizes, 4 rocks at 1.5-2.5 inches
4	24.5	26.8	medim-coarse sand w/rare gravel	gry-brn	clean	5	MW	coarsens	sharp	-	-	2 1/2	Fines up sequence, few granules and 3 pebbles, 1.5-2.5 inches
4	26.8	30.0	coarse sand w/medium gravel	brn-gry	very silty	45	P	coarsens	grad.	-	-	2	2-3 rocks 1.5-2 inches
4	30.0	32.5	graded sand	brn/buff	clean	3	MW	coarsens	sharp	-	-	2	Rare 2 inch pebbles (2), few granular
4	32.5	37.0	coarse sand and medium-coarse gravel	brn-gry	very silty	50	P	coarsens	grad.	-	-	2 1/2	Upper foot is less silty and has one pebble under 1 inch, the rest is 2.5 inches or less, very silty at 35-36 feet, cored boulder at 36 feet
4	37.0	40.0	N.S.	-	-	0	-	-	-	-	-	-	-
4	40.0	40.3	fine-medium sand	brn-gry	silty	0	MW	coarsens	-	-	-	-	Granules and pebble to 6 inches, very silty lower, slightly silty upper foot.
4	40.3	41.3	medium-coarse sand w/fine gravel	gry-brn	very silty	15	M	coarsens	sharp	-	-	-	Good gradation
4	41.3	45.3	medium gravel	gry	very silty	70	MP	coarsens	grad.	-	1 1/2	2 1/2	Mostly granules
4	45.3	46.0	graded sand w/fine gravel	gry/brn	silty	10	M	coarsens	-	-	-	-	Fine sand, silt, and gravel 2 inches or less
4	46.0	48.0	medium gravel	gry	very silty	75	BM	-	grad.	-	-	-	Cored boulder at 51 feet, middle foot is slightly silty and has less gravel
4	48.0	52.0	medium-coarse sand w/gravel	brn-gry	very silty	30	MP	-	sharp	-	-	-	Granules dominant, rare 1-2 inch pebble, some small pebbles
4	52.0	65.0	coarse sand w/fine gravel	gry-brn	clean	10	M	-	sharp	-	-	2	3 cored boulder in upper two feet, silt with pebbles
4	65.0	69.0	fill	olv-gry	-	5	P	-	-	calcareous	-	-	-
5	0.0	1.0	topsoil	blk	-	0	-	-	-	-	-	-	Very silty sand and gravel, darker layers
5	1.0	4.0	silty s & g	tan	very silty	10	MP	-	sharp	-	2	2	Silt with a small amount of gravel (lake sediments), dewatering clay strings
5	4.0	8.0	silt	tan	silt	2	MP	less sand	grad.	mixed	2	1/4	-



Drill Hole (ft)	To (ft)	Sediment Type	Color	Silt Content (%)	Gravel (%)	Sorting	Downward Gradation	Upper Contact	Lithology	Dominant Gravel Size	Gravel Size	Comments
5	8.0	10.0	silty s & g	tan	10	P	-	sharp	mixed	1/4	2	Fine sand, silty matrix supported, clay balls
5	10.0	14.0	silt w/gravel	brn	10	MP	-	grad.	mixed	1/4	1/2	Silty fine sand matrix, pebbles are matrix supported
5	14.0	17.0	sand w/gravel	brn	15	M	siltier	sharp	mixed	1/4	2 +	Mostly fine sand with gravel, greater mud content, upper part is dry
5	17.0	18.0	cobble layer	brn	90	M	-	grad.	non-calcareous	2	2 1/2	Cobble lag
5	18.0	29.0	sandy diamecton	dk brn	15	P	-	sharp	mixed	1/4	2 +	Overburden, water table at 29 feet, lower contact is marked by sandy lenses at base
5	29.0	31.0	silty s & g	org-brn	20	MP	sandier	sharp	mixed	2	1 1/2	Transition zone into clean sand
5	31.0	37.5	sand w/gravel	brn	20	MW	-	grad.	mixed	1/4	1/2	Mostly medium-coarse sand with abundant pea gravel. Dark horizon 34' x 6' wide
5	37.5	42.0	s & g	gry	60	M	better sorting	grad.	mixed	1/4	2 1/2	Sand and gravel is cobble-rich, pebble zones, but mostly mixed.
5	42.0	44.0	s & g	gry	60	MW	coarsens	sharp	mixed	1/4	1 3/4	Sequence: coarse sand to medium gravel.
5	44.0	46.0	pea gravel	gry	85	W	-	sharp	mixed	1/2	1 1/2	Mostly pea gravel and coarse sand with some small pebbles
5	46.0	48.0	s & g	gry	80	MW	coarsens	sharp	mixed	1/4	2	Sequence: coarse sand to pea gravel with some small cobbles
5	48.0	55.0	sand w/gravel	gry	20	W	coarsens	sharp	mixed	2	1	Sequence of medium sand to coarse sand with occasional pebble.
5	55.0	56.5	s & g	gry	35	M	-	grad.	mixed	2-4mm	1 1/2	Medium-coarse sand with fine-medium gravel
5	56.5	64.0	sand w/gravel	gry	30	MW	-	grad.	mixed	2-4mm	1/4	Mostly medium coarse sand with some fine gravel.
5	64.0	67.0	s & g	gry	50	M	-	sharp	mixed	1/2	2	Mixed sand and gravel (no layers), cobble-rich, good quality
5	67.0	68.5	s & g	gry	30	MW	-	grad.	mixed	1/2	1	similar to above, less cobbles.
5	68.5	69.5	s & g	gry	50	M	-	sharp	mixed	1/2	2	Mixed, cobble rich
5	69.5	70.0	fine sand	gry	5	W	-	grad.	mixed	2	1/4	Sand lens
5	70.0	75.0	coarse sand w/gravel	gry	20	MW	-	sharp	mixed	2	2	Coarse sand with some gravel, occasional small cobble
5	75.0	76.0	cobble zone	gry	80	W	-	grad.	non-calcareous	1	2 1/2	Partially washed from drilling
5	76.0	80.0	cobbly s & g	gry	50	M	-	grad.	non-calcareous	1/2	2 1/2	Mixed, more silt than previous cobbly sand and gravel.
5	80.0	83.0	s & g	gry	40	MW	-	grad.	-	1/2	1 1/2	Mixed, pebble rich.
5	83.0	85.0	N.R.	-	0	-	-	-	-	-	-	-
5	85.0	85.5	s & g	gry	40	MW	-	-	mixed	1/2	1 1/2	Mixed, pebble rich, similar to 80-83
5	85.5	90.0	fine sand	gry-tan	5	W	fining	sharp	-	2	4mm	Massive
5	90.0	94.5	sand w/gravel	gry	20	MW	-	sharp	mixed	2-4mm	1	Mostly medium-coarse sand, some fine sand layers, pebbles are scattered
5	94.5	95.0	sandy till	tan	0	N	-	sharp	-	-	-	-
5	95.0	103.5	N.R.	-	0	-	-	-	-	-	-	-

Drill Hole (ft)	To (ft)	Sediment Type	Color	Silt Content (%)	Gravel (%)	Sorting	Downward Gradation	Upper Contact	Lithology	Dominant Gravel Size	Gravel Size	Comments
5	103.5	clay/silt	blk	-	0	-	-	-	-	-	-	-
6	0.0	sand w/gravel	blk	-	5	-	-	-	non-calcareous	-	-	Loamy sand, dominant gravel size is granule
6	1.3	graded sand w/occ. medium gravel	blk-brn/lt-brn	very silty	10	P	-	grad.	calcareous	-	1 1/2	Dark orange-brown-rust staining layer at 4" above silt. Dominant gravel size is granule, mod. calcareous below 3", dark brown up, light brown lower
6	4.0	diamict	olv-brn	silt	5	P	-	sharp	calcareous	3/8-3/4	-	Silt with pebbles and sand, occasional sandy silt zones, occasional rust granules, horizons of rust laminations at 8-9 feet, mod-very calcareous.
6	11.0	sand w/fine gravel	brn	very silty	35	P	-	sharp	calcareous	3/8-3/4	3/4	Upper half is black with plant fibers (roots?), 50% carb., subround to rounded
6	11.5	diamict	olv-brn	silt	5	P	-	sharp	calcareous	-	1/2	Silt with sand and granules
6	12.0	diamict	gry	very silty	5	P	-	-	calcareous	-	6	Very fine sand and silt, 6 inch boulder cord at 13.5 feet, color change from 11.5, lower foot has occasional 1 inch thick fine-medium sand layers
6	15.0	fine sand	gry	very silty	0	MW	-	sharp	calcareous	-	3/8	Occasional medium sand pocket in lower part, trace of gravel, moderately calcareous
6	17.5	clay silt	gry	-	0	W	-	sharp	calcareous	-	1/2	Conchoidal ped flow, very sharp upper contact.
6	18.0	fine-medium sand	brn-gry	very silty	5	MW	-	sharp	calcareous	1/2	-	Cored one 5 inch rock at 19 feet, gravel in middle by rock, under 1/2 inch dominant gravel size.
6	20.0	clay silt	dk gry	-	0	W	-	sharp	-	-	-	Conchoidal breakage in upper-lower, had 3 inch diameter (silt) with granules w/ horizon iron stain line.
6	21.0	sandy silt diamict	org-brn	silt	7	P	-	sharp	calcareous	-	2 1/2	Visible vugs, looks like mix of till, silt, and silty sand/gravel, mottled
6	23.0	sand w/medium gravel	org-brn	very silty	45	MP	-	sharp	calcareous	1/2-3/4	1	2-3 inch zones of silty diamict.
6	24.5	fine sand	dk olv-brn	silty	0	W	finer	sharp	-	-	-	Moderately calcareous
6	27.5	sandy silt diamict	dk olv-brn	silt	8	P	-	-	calcareous	1	2	Visible under 1 mm vugs Throughout, moderately calcareous, one inch or less dominant size.
6	34.0	fine-medium sand	org-brn	silty	0	MW	-	sharp	calcareous	-	1 1/2	Occasional 1 inch pebble throughout, coarser at base and top, moderately calcareous
6	38.0	silt diamict	dk-gry	-	0	P	-	sharp	-	-	1 1/2	Upper 1/2 is orange-brown, occasional iron mottle down to 41 feet, moderately calcareous
6	43.0	fine-medium sand	gry	very silty	5	MW	-	-	calcareous	1/4-1/2	1/2	Coarser at top and bottom, medium-calcareous
6	45.5	medium sand	lt gry	silty	0	W	-	grad.	-	-	-	Rare gravel in upper foot, 4- 3 inch silty fine sand layers in lower 3 feet, slightly calcareous
7	0.0	sandy loam/silty medium-coarse sand	blk/brn	very silty	0	P	coarsens	-	-	-	-	Lower grades to brown, organics
7	1.5	medium-coarse sand w/occ. granules	brn	clean	0	WM	-	-	-	-	3/4	Rare pebble to 3/4 inch
7	1.9	fine sand w/fine gravel	blk/lt brn	silty	0	P	-	-	-	1/2	-	Dominant gravel under 1/2 inch
7	2.5	fine-medium sand w/fine gravel	brn	silty	0	PM	-	-	-	-	1	1/2 to 1 inch pebble
7	3.0	graded sand with gravel	brn	clean	0	MP	-	-	-	-	1 1/2	Good gradation from granule to 1 1/2 inch, slightly silty
7	3.5	cleaned graded sand and fine gravel	brn	clean	0	PM	-	-	-	-	2	Mostly granule and under 1/2 inch, rare 2 inch.
7	4.9	gravelly silt	blk	silty	0	P	-	-	-	-	-	Clod former
7	5.0	fine sand w/occ. coarse gravel	gry-brn	very silty	0	MP	-	-	-	-	1 3/4	3/4-1 3/4 inch pebbles, black organic 3/4 inch clods in upper
7	5.8	graded sand and fine gravel	lt brn	very silty	0	-	-	-	-	1/2-2	-	Occasional cobble, upper is gradational with less gravel

Drill Hole	From (ft)	To (ft)	Sediment Type	Color	Silt Content (%)	Gravel (%)	Sorting	Downward Gradation	Upper Contact	Lithology	Dominant Gravel Size	Gravel Size	Comments
7	8.0	8.5	graded sand and fine gravel	brn	silty	50	MP	-	-	-	-	-	All under 3/4 inch, bimodal sizes
7	8.5	8.9	fine-medium sand with fine gravel	brn	clean	0	MP	-	-	-	3/4	-	All under 3/4 inch, bimodal sizes.
7	9.0	9.1	fine sand	brn-wht	clean	0	W	-	-	-	-	-	Beach 2
7	9.1	10.5	graded sand with fine gravel	lt brn	clean	0	M	-	-	-	1	-	Mostly 1 inch or less, some zones of fine sand
7	10.5	10.8	fine sand w/occ. pebble	lt brn	clean	0	-	-	-	-	3/4-1	-	-
7	10.8	11.0	silt	lt gry	silt	0	W	-	-	-	-	-	No clay
7	11.0	12.5	graded sand w/occ. fine gravel	brn	silty	0	M	-	-	-	-	-	Mostly pea
7	12.5	14.0	graded sand w/fine gravel	lt brn	clean	0	PM	-	-	-	-	-	Good gradation to 1/2 inch
7	14.0	16.0	fine sand	tan	clean	0	W	grades	-	-	-	-	Some gray color, occasional pebble, dry in lower
7	16.0	16.5	fine sand w/occ. fine gravel	tan	clean	0	M	-	-	-	1/2	-	Dominant gravel size 1/2 inch or less.
7	16.5	17.0	graded sand w/fine gravel	brn	clean	0	P	-	-	-	-	-	1/2 inch or less, match/pea dominant
7	17.0	17.5	fine-medium sand w/fine gravel	lt brn	clean	0	MP	-	-	-	-	-	A "A"
7	17.5	20.5	fine-medium sand	wht-brn	clean	0	WM	-	sharp	-	-	-	Rare granules 4 mm or less
7	20.5	21.5	graded sand and gravel	brn	silty	45	P	finer	grad.	-	-	-	Pebbles to 2 1/2 inch, good gradation
7	21.5	21.7	granite boulder	wht	-	0	-	-	-	-	-	-	No k-feldspar
7	21.7	24.7	coarse sand	brn	clean	0	WM	-	-	-	-	3/4	Rare 3/4 inch pebble and pea
7	24.7	25.0	graded sand	lt brn	silty	0	MP	-	grad.	-	-	-	gradational up and down
7	25.0	28.5	fine-medium sand	brn	clean	0	W	-	-	-	-	-	-
7	28.5	30.0	fine sand w/fine gravel	lt brn	very silty	0	MP	-	grad.	-	-	1	Some zones with coarse sand and fine gravel, dry, pebble to 1 inch, good gradation
7	30.0	31.0	graded sand w/occ. fine gravel	tan	very silty	0	P	-	-	-	-	-	Occasional silt clods, dominant fine sand, pebble 3/4 inch or less
7	31.0	34.0	medium sand	brn	clean	0	WM	-	-	-	-	-	Occasional pea
7	34.0	35.0	silty fine sand w/occ. fine gravel	wht-tan	very silty	0	MP	-	-	-	-	-	Dry, powdery
7	35.0	35.7	fine sand	brn	clean	0	W	-	-	-	-	-	Match and pea washed on outside
7	35.7	36.3	graded sand and coarse gravel	brn	clean	35	MP	-	-	-	-	-	3-3 inch pebbles, bimodal sand and pebble
7	36.3	42.5	graded sand w/fine gravel	brn	silty	20	MP	-	-	-	3/8	2	Random pebble and 2 inch, 3/8 inch or less dominant, dark brown iron stain at 41 feet (1 1/2 inch wide), minor 1/2 inch at 40.5 feet, fairly dry
7	42.5	44.0	fine-medium sand	gry-brn	clean	0	M	-	-	-	-	1 1/2	Rare pebble 1 1/2 inch
7	44.0	47.0	graded sand w/fine gravel	brn	clean	20	PM	-	grad.	-	-	2	Pebble to 2" rare
7	47.0	54.5	graded sand w/occ. fine gravel	lt brn	clean	10	PM	-	-	-	-	3/4	Layered zones of medium, moderate sorted sand with rare gravel and coarse sand with gravel, mostly granule (match and pea)

Drill Hole	From (ft)	To (ft)	Sediment Type	Color	Silt Content	Gravel (%)	Sorting	Downward Gradation	Upper Contact	Lithology	Dominant Gravel Size	Gravel Size	Comments
7	54.5	55.0	graded sand w/ fine gravel	dk brn	very silty	50	P	-	grad.	-	-	3/4	Granule dominated, rare 3/4 inch
7	55.0	60.5	graded sand w/fine gravel	dk brn	silty	30	PM	-	-	-	-	1/2	Possible iron stain at 58", silt clods at 56-59", gravel 1/2" or less, rare 1/2" to 1" pebble, layered med-sand w/gravel to coarse sand with gravel
7	60.5	63.0	fine-medium sand	gry-lt-brn	clean	0	W	-	grad.	-	-	2	Rare pebbles 1/4 - 2 inches, iron stain (1/2 inch wide) is bright orange at 62.5 feet
7	63.0	64.5	coarse sand and fine gravel	brn	clean	50	WM	-	sharp	-	-	-	Dark brown slight iron stain at 63.75 to 64 feet, 95% granite, rare 1/2 inch, slightly silty at base
7	64.5	65.0	graded sand w/fine gravel	gry-brn	silty	30	P	-	grad.	-	-	1.75	Good gradation to 3/4 inch pebble
7	65.0	67.5	coarse sand and fine gravel	gry-brn	clean	50	WM	-	-	-	3/8	-	3/8 inch or less granule dominant
7	67.5	71.0	graded sand and medium gravel	gry-brn	silty	50	PM	-	-	-	-	2	40-60 percent gravel, muddier downward over 2-3 foot intervals, four 2 inch rocks found at 68-69 feet, rare 1 1/2 inch found 69-71 feet
7	71.0	72.0	fine-medium sand w/medium gravel	gry-brn	clean	30	PM	-	-	-	1/2-1 1/4	-	Pebbles in fine sand matrix, bimodal
7	72.0	73.0	coarse sand and fine gravel	gry-brn	silty	35	M	-	-	-	1/2	1.5	Granules to 1/2 inch dominant
7	73.0	75.5	fine-medium gravel	gry	very silty	90	WM	-	-	-	-	1.5	Larger pebbles at lower, more gray silt in lower
7	75.5	76.0	gravely silt	gry	very silty	5	P	-	-	-	-	-	Granite pebble blocked core at 76 feet, slightly less calcareous than till (but may be till), less granules, clod former
7	76.0	80.0	NS	-	-	0	-	-	-	-	-	-	-
7	80.0	84.0	fine-medium sand	gry-brn	clean	0	W	-	-	-	-	-	Upper 6" has gray gravely silt clods, may be contaminated with granules in sand, 3" zone of laminated light gray sandy silt w/sand, siltate at 82'
7	84.0	84.8	graded sand and coarse gravel	gry-brn	clean	40	P	-	sharp	-	-	2	-
7	84.8	89.0	coarse sand w/fine gravel	gry-brn	clean	0	MW	-	grad.	-	-	-	Small granules only, grades up (6 inches)
7	89.0	102.0	coarse and and gravel	gry	very silty	50	MP	-	grad.	mixed	-	1 1/2	50% dark, nice gradation, lots of 2 inch in 100-102 feet, 1 or 2- 4 inch rocks, occasional 1 1/2 throughout
7	102.0	105.0	fine-medium sand	gry-brn	silty	0	WM	-	-	-	-	-	Rare granule, only 2 inch recovered, top bag says 102 feet, upper is graded sand
7	105.0	110.0	gravely, sandy, clayey silt	gry/olv-gry	-	10	P	-	-	calcareous	-	-	Till is calcareous, not much clay, two 4-6 inch rocks at 105-106 feet, 1-3 rocks at 109 feet, most of it pulverized, limestone and granite basalts
8	0.0	1.0	topsoil	blk	-	0	-	-	-	-	-	-	Sandy loam, 3 inch thick sod
8	1.0	5.0	loamy graded sand	dk gry-brn	very silty	0	-	-	grad.	-	-	-	Only one foot of sample for 4 foot of hole, rare granules, trace of gravel
8	5.0	6.8	sandy till	yel or brn	very silty	5	P	-	-	calcareous	-	3/4	Moderately calcareous, some iron stained streaks, clod former, schist grains
8	6.8	7.0	graded sand w/rare gravel	brn	very silty	5	P	-	sharp	-	-	1/4	Well graded gravel, granule gravel size dominant
8	7.0	9.0	fine sand	lt brn	silty	0	MW	-	-	-	-	-	Lower 6 inches is siltier and less sorted with a 1 inch dark brown graded sand at base
8	9.0	12.0	very sandy till	gry/yel-br	very silty	7	s	-	-	-	-	-	Schist grains, iron mottles and streaks
8	12.0	16.5	fine-medium sand	red-brn	silty	0	MW	finer	sharp	-	-	3/4	Crossbedding indic at 13-15' (20-45 degrees), fine sand: 14.5-16.5', med sand: 12-14.5', few out of place?, 1/4-3/4" pebbles at 15-16'
8	16.5	17.5	till	dk gry/red-b	-	8	P	-	sharp	-	-	-	Top .4 feet is weathered, silt
8	17.5	21.5	graded sand w/occ. fine gravel	red-brn	silty	10	MP	finer	sharp	-	-	-	Fine-med. sand in low grades to graded sand w/fine grades (20%), possibly 2 coarse up seq. at 21.5-20 & 20-17.5, 17.5-19 silt outer 1/2-1" over s & g
8	21.5	22.5	fine-medium sand	gry	silty	0	M	-	sharp	-	-	3	1-3 inch diameter till balls in upper

Drill Hole	From (ft)	To (ft)	Sediment Type	Color	Silt Content (%)	Gravel (%)	Sorting	Downward Gradation	Upper Contact	Lithology	Dominant Gravel Size	Gravel Size	Comments
8	22.5	24.5	fine-medium sand	gry	silty	0	M	-	sharp	-	-	1	Forms molds (sand castle sand), some medium-coarse sand zones with indication of crossload. One zone has numerous 1/2-1 inch pebbles
8	24.5	38.5	fine sand and silt	gry	very silty	0	W	-	grad./sharp	-	-	-	Uniform fine sand, upon drying deformed beds of whitish gray fine-medium sand within gray silt/very fine sand, lower foot has more fine-medium sand
8	38.5	43.0	sandy silt w/ medium-coarse gravel	gry	very silty	20	P	-	grad.	-	1-2	3 1/2	Cored boulder at 38.5 and 41.5, clod former, grades over .2 feet
8	43.0	44.0	coarse sand w/fine gravel	gry-brn	very silty	10	P	-	sharp	-	-	-	Dominant gravel size and maximum gravel sizes are both granular
8	44.0	46.5	medium sand	gry-brn	silty	0	M	-	-	-	-	-	Siltier in upper
8	46.5	47.0	granite	red	-	0	-	-	-	-	-	-	At least 6 inch diameter, broke in 4 layers
8	47.0	48.5	silt, sand, medium-coarse gravel	gry	very silty	25	P	-	-	-	1 1/5	3 1/2	Muddy
8	48.5	51.0	coarse sand and medium-gravel	brn-gry	very silty	40	P	coarsens	-	-	-	-	Dominant gravel size is a mix, relatively clean coarse sand in upper 6 inches w/rate gravel
8	51.0	54.0	coarse sand and fine-medium gravel	brn-gry	very silty	50	MP	coarsens	sharp	-	3/4	3	Lower 6 inches is almost all gravel to 1 1/2 inches, One 3 inch rock at 52 feet, upper is granule gown
8	54.0	57.0	coarse sand and coarse gravel	gry-brn	silty	60	M	coarsens	sharp	-	1/2-3	3 1/2	Muddy at base
8	57.0	61.0	coarse sand and medium-coarse gravel	brn-gry	silty	45	M	coarsens	sharp	-	1 1/2	3	Upper is less silty
8	61.0	65.0	medium-coarse sand w/rare medium-gravel	gry-brn	silty	8	WM	-	grad.	-	1/2-2	2	Siltier at top, Almost bimodal with gravel, Clay ball 1 1/2-2 inches at 64.75 feet
8	65.0	69.0	medium-coarse sand	brn	clean	0	MW	coarsens	grad.	mixed	-	-	Rare granules in lower, 20% yellow-white, 20% black-red, 60% quartz
8	69.0	75.0	medium-coarse sand w/medium gravel	brn	silty	20	M	coarsens	grad.	-	2	3	Lower foot is very silty, most gravel is in lower three feet with rare pebble above.
8	75.0	78.0	coarse sand and medium gravel	brn-gry	very silty	50	MP	-	-	-	1-2 1/2	2 1/2	Muddy in center where there are mostly pebbles and minor sand
8	78.0	80.0	NS	-	-	0	-	-	-	-	-	-	-
8	80.0	82.0	medium-coarse sand w/fine gravel	gry-brn	silty	20	WM	coarsens	-	-	-	1/2	Fines up from pea gravel to medium sand, dominant gravel size is granular
8	82.0	87.0	medium-coarse gravel	buff	silty	95	WM	-	sharp	-	-	-	Smallest gravel is about 3/8 inch, 75% gravel, 15% limestone, 10% metamorphic rock
8	87.0	90.0	NS	-	-	0	-	-	-	mixed	1-2 1/2	3	Siltier in lower
8	90.0	92.0	Medium gravel	gry	very silty	90	-	-	-	-	3/4-1 1/2	2 1/2	Granule to 1/2 inch dominant gravel size, siltier in lower.
8	92.0	95.0	fine-medium sand	brn-gry	very silty	70	P	-	sharp	-	1/2	2.5	Occasional pea gravel clod near base (silt matrix), possibly 3 fine up sequences
8	95.0	100.5	fine-medium gravel	brn-gry	very silty	70	MP	coarsens	-	-	1/2	2	Form clod
8	100.5	101.0	silt w/fine-medium gravel	brn-gry	very silty	15	P	-	sharp	-	-	-	Trace percentage of gravel
8	101.0	102.0	graded sand	brn-gry	very silty	0	MP	-	grad.	-	-	3/8	Maximum gravel size is granule, cleaner at base, trace percentage of gravel
8	102.0	105.0	medium sand	gry-brn	clean	0	M	coarsens	sharp	-	-	-	Dominant gravel size is granular, medium-fine sand at base alternates with medium-coarse sand, upper fit has most gravel that is the most coarse
8	105.0	109.5	medium-coarse sand	brn	clean	0	MP	finer	-	-	-	1/2	Granular dominant, pea max size, sandy silt balls at 112, 114, and 115, fines down.
8	109.5	115.0	coarse sand	buff	clean	0	M	coarsens	sharp	-	-	-	114' med-coarse sand, coarse sand subangular, trace % gravel
8	115.0	117.0	medium sand	yel-brn	clean	0	M	-	-	-	-	-	Granular dominant gravel size, trace percentage of gravel, iron stained.

Drill Hole (ft)	To (ft)	Sediment Type	Color	Silt Content (%)	Gravel (%)	Sorting	Downward Gradation	Upper Contact	Lithology	Dominant Gravel Size	Gravel Size	Comments
8	117.0	medium sand	gry-brn	clean	0	M	-	grad.	-	-	-	Maximum gravel size is pea, rare granule, trace percentage of gravel
8	122.0	fine-medium sand	wht-gry	clean	0	WM	finer	grad.	non-calcareous	-	-	Quartz
8	124.5	silt and fine sand	lt gry	silty	0	WM	varies	sharp	-	-	-	Trace gravel %, 1/2" silt with med. sand layer near top, 1-2" med. sand above it, silt appears?, one 1" band of coarse sand at 127", grades up & down
8	125.0	medium-coarse sand	gry-brn	clean	0	WM	finer	sharp	-	-	-	Maximum gravel size is a rare granule, trace percentage of gravel
8	127.5	very fine sand and silt	lt gry	clean	0	WM	finer	grad.	-	-	-	Solid core, maximum gravel size is granule
8	127.8	medium sand	lt gry	clean	0	M	-	grad.	-	-	-	Trace percentage of gravel
8	128.0	fine sand w/occ. fine gravel	gry	silty	5	MP	-	-	-	-	-	Trace percentage of gravel, 2 possible fining up sequences, 3/8" gravel in lower 3"
8	128.5	fine-medium coarse sand	brn-wht	clean	0	M	finer	sharp	-	-	-	Sandy silt in upper inch
8	128.8	fine sand and silt	lt gry	clean	0	W	-	sharp	-	-	-	Trace percentage of gravel, clay balls at 134', not till, upper foot is medium-coarse sand with occasional granule
8	129.1	fine-medium sand	lt gry	clean	0	W	coarsens	sharp	-	-	-	Trace percentage of gravel, 2 possible fining up sequences, 3/8" gravel in lower 3"
8	133.0	medium sand	lt brn	clean	0	M	-	grad.	-	-	-	Sandy silt in upper inch
8	135.0	medium-coarse sand	buff	clean	0	M	coarsens	grad.	-	-	-	On gravel road, road material
8	143.5	medium sand	brn	clean	0	M	coarsens	sharp	-	-	-	Cobbles and silt, organically rich on top
9	0.0	silty s & g	buff	very silty	20	MP	-	-	mixed	1/2-3/4	1 1/2	Some sandy till layers, very washed till above clay balls
9	1.0	cobbly silt	blk	very silty	30	MP	black to gray	grad.	non-calcareous	2	3+	Oxidized rust mottles to 11 feet, starts to turn compact gray at 13.5, becomes very sandy at base
9	5.0	silty s & g	org-brn	very silty	25	MP	-	sharp	mixed	1/4	1	Massive, some thick alternating layers of fine and very fine sand/silt.
9	6.5	till	brn-gry	-	0	N	-	grad.	mixed	-	-	Sandy, limestone rich
9	15.0	fine sand	gry	very silty	2	W	-	grad.	-	9	4mm	Massive, similar to above, fine sand, some sections are silty.
9	31.0	sandy till	gry	-	0	N	-	sharp	mixed	-	-	Massive, similar to above, fine sand, some sections are silty.
9	32.0	fine sand	gry	very silty	2	W	coarsens	sharp	-	2	4mm	Sandy loam
10	0.0	topsoil	blk	very silty	0	-	-	-	-	-	-	Color is darker towards top, upper .4 has no gravel
10	1.0	medium sand w/coarse gravel	dk brn	very silty	30	P	finer	sharp	non-calcareous	1	2	Some subangular and glassy, 95% quartz, slightly calcareous.
10	2.5	N.S.	-	-	0	-	-	-	-	-	-	Very sharp upper contact, slightly calcareous
10	5.0	fine-medium sand	lt gry-brn	silty	0	W	finer	-	non-calcareous	-	-	Lower 2' olive-brown color to dark green, dark rusty color at 12.5 J(1" wide), dark brown/black stain 2' above iron stain, granular dominant size
10	7.0	graded sand w/coarse gravel	red-brn	very silty	30	MP	-	sharp	calcareous	1/2	2	4" pink granite near base, muddy in lower half, dominant gravel size is granular
10	9.0	coarse sand	brn-olv	silty	0	W	-	sharp	calcareous	-	-	Cored granite in lower, mixed layers of sand and gravel vs. silt, dominant gravel size is granular
10	14.5	fine gravel	gry-brn	very silty	70	MP	coarsens	grad.	calcareous	-	4	
10	15.5	silt w/occ. fine gravel	gry	very silty	15	P	-	sharp	calcareous	-	6	

Drill Hole	From (ft)	To (ft)	Sediment Type	Color	Silt Content (%)	Gravel (%)	Sorting	Downward Gradation	Upper Contact	Lithology	Dominant Gravel Size	Gravel Size	Comments
10	16.5	17.5	very fine sand	brn-gry	very silty	0	W	-	sharp	calcareous	-	3/4	No bedding obstructions, diamictic clast in lower 2"; moderately calcareous
10	17.5	18.0	clay silt	gry	-	0	W	-	sharp	calcareous	-	-	Occasional pebbles, moderately calcareous
10	18.0	18.5	graded sand w/fine gravel	brn-gry	very silty	35	MP	-	-	calcareous	-	-	Moderately calcareous
10	18.5	39.0	diamictic sandy silt w/pebbles	olv-brn/gry	silt	0	P	-	sharp	calcareous	-	-	Random gravel size, think silty fine gravel at 21", thin fine sand laminated at 39"
10	39.0	41.5	sandy gravelly silt	lt brn-gry	very silty	25	P	-	sharp	calcareous	1/2	3/4	Center has a clast? Of fine-medium gray and brown sand, lower 3" is firm fine gravel with silt matrix
10	41.5	43.0	clay silt	dk gry	-	0	W	-	sharp	calcareous	-	-	Trace percentage of gravel, common pebbles throughout, petroleum odor
10	43.0	44.0	fine gravel and silt	lt gry	very silty	30	P	-	sharp	calcareous	-	-	retains shape of core mostly, petroleum odor
10	44.0	52.0	clay silt	dk brn-gry	-	0	-	-	-	calcareous	-	-	Small snail at 45.5'; laminated, petroleum odor, wood (roots?) at 51.5-52 with some fine sand layers in this zone
10	52.0	53.0	medium-coarse sand w/fine gravel	brn-gry	silty	25	MP	coarsens	-	calcareous	1/2	1	Dominant gravel size is under 1/2 inch
10	53.0	54.0	very fine sand and silt	gry	very silty	0	-	-	sharp	calcareous	-	-	Graphite gray, occasional granules and pebbles (some deformed bedding possible), petroleum odor
10	54.0	59.0	diamictic	lt brn-gry	silt	5	P	-	sharp	calcareous	-	-	Upper contact has two inches of relief, silt with sand and pebble, moderately to very calcareous
10	59.0	59.5	medium sand	brn-gry	very silty	0	M	-	-	calcareous	-	1/4	Most retains cove shape, granule is dominant gravel size, moderately calcareous, trace percentage of gravel
10	59.5	65.0	fill	gry	-	10	P	-	sharp	calcareous	-	2	Upper foot has light orange mottles, hard, moderately calcareous on top, very calcareous bottom 2 feet
11	0.0	1.5	topsoil	blk	-	0	-	-	-	-	-	-	Mixed humus
11	1.5	6.5	s & g	tan	silty	35	M	-	grad.	mixed	1/4	2	Mixed, less gravel, less sand
11	6.5	7.0	s & g	tan	silty	25	M	-	grad.	mixed	1/4	2	Medium sand with some gravel
11	7.0	8.0	sand w/gravel	brn	clean	20	M	-	sharp	mixed	2-4mm	1/2	Silty sand and gravel
11	8.0	10.0	silty s & g	tan	very silty	25	MP	-	grad.	mixed	1/4	2	Clean, mixed
11	10.0	12.5	s & g	brn	clean	30	M	grades	sharp	mixed	1/4-1/2	1/4	Several 2" layers of sand and gravel
11	12.5	15.0	silty s & g	tan	silty	35	M	-	grad.	mixed	3/4	2	Very dirty and gravel (mostly 2-4mm), different color horizon
11	15.0	16.0	silt w/gravel	olv-tan	very silty	25	MP	-	sharp	mixed	2-4mm	2	Less silt than above, water table at 19, mostly 24 mm
11	16.0	20.0	silty s & g	brn	silty	50	M	-	grad.	mixed	2-4mm	2 1/2	Sand with some gravel, grades into next unit with some silt
11	20.0	21.0	sand w/gravel	brn	clean	15	MW	-	sharp	mixed	2	3/4	Mixed (no layers), coarse sand matrix
11	21.0	30.0	s & g	brn	clean	40	M	-	grad.	mixed	1/4	2	Medium coarse sand with occasional pebble
11	30.0	36.0	sand w/gravel	brn	clean	20	MW	-	sharp	mixed	2-4mm	3/4	Mostly pea gravel with some sand
11	36.0	40.0	pea gravel	brn	clean	80	W	coarsens slightly	grad.	mixed	1/4	2	Mostly coarse sand with some pebbles--granular
11	40.0	43.0	sand w/gravel	brn	clean	20	MW	coarsens	grad.	mixed	2-4mm	3/4	Cobble transitions into gray
11	43.0	44.0	cobble layer	gry-brn	silty	65	M	-	grad.	mixed	1 1/4	2 1/2	

Drill Hole (ft)	To (ft)	Sediment Type	Color	Silt Content (%)	Gravel (%)	Sorting	Downward Gradation	Upper Contact	Lithology	Dominant Gravel Size	Gravel Size	Comments
11	44.0	45.0	cobbly s & g	gry	55	M	-	sharp	mixed	1 1/2	3 +	Gray, cobble-rich sand and gravel, more sand than above
11	45.0	57.5	cobbly s & g	gry	65	M	-	grad.	mixed	3/4-1 1/2	3 +	Mixed, some layers of siltier sand and gravel, mostly homogeneous
11	57.5	70.0	cobbly s & g	gry	45	M	-	grad.	mixed	1/4	2 1/2	Coarse sand and fine gravel with cobbles
11	70.0	75.0	fill	dkf gry	0	Non	-	sharp	calcareous	-	-	-
12	0.0	1.5	sand	blk	0	-	-	-	-	-	-	Loamy
12	1.5	4.5	graded sand w/rare gravel	yel/brn	5	-	-	sharp	-	-	1/2	Upper foot is darker getting lighter with depth, "A" horizon contact is sharp, dominant gravel size is granule
12	4.5	14.5	fine-medium sand	lt org-brn	0	W	-	sharp	-	-	1/2	Dark red-brown iron horizon streaks throughout, but common at 5'-10', 90% quartz, dominant gravel size is granule, trace percentage of gravel
12	14.5	35.0	medium-coarse sand w/gravel	brg-brn/brn	35	MP	-	sharp	mixed	1	3	Upper foot at 15' is slough, occasional +2" rocks throughout, occasional silty zones
12	35.0	39.0	coarse sand w/coarse gravel	brn	35	M	coarsens	grad.	-	1/2	4	Silty foot of coarse gravel at base, partly cored 4" granite at base
12	41.0	45.0	N.R.	-	0	-	-	-	-	-	-	-
12	45.0	49.0	coarse sand and fine gravel	org-brn	50	M	-	-	-	-	3	Reefill, siltier at base, dominant gravel size is granule
12	49.0	50.0	sandy coarse gravel	brn-gry	70	-	coarsens	sharp	-	2	2 1/2	Muddy at base
12	50.0	54.0	medium-coarse sand w/fine gravel	gry-brn	30	MP	coarsens	-	-	-	3/4	Siltier at base
12	54.0	58.0	graded sand and coarse gravel	brn-gry	60	P	-	grad.	-	1/2-1 1/2	4	Recovery lower than normal, partly cored 3 1/2" rock at 59', alternating zones of muddy and less muddy
12	58.0	61.0	N.R.	-	0	-	-	-	-	-	-	-
12	61.0	62.0	graded sand	brn-gry	0	M	coarsens	-	-	-	-	-
12	62.0	63.0	graded coarse sand w/fine gravel	brn-gry	40	MP	coarsens	grad.	-	-	3/8	Dominant gravel size is granule.
12	63.0	65.0	graded gravel	gry	60	P	coarsens	grad.	-	-	3 1/2	Muddy, dominant gravel size is all
12	65.0	70.0	coarse sand	gry-brn	20	M	coarsens	sharp	-	1/2	1 1/2	Muddy at base 6 inches, dominant gravel size is less than 1/2 inch
12	70.0	72.0	medium-coarse sand w/occ. fine gravel	brn-gry	15	M	coarsens	sharp	-	-	3/8	Siltier in lower, dominant gravel size is granule
12	72.0	75.5	graded sand and fine gravel	brn-gry	45	P	-	grad.	-	1	1 1/2	Gravelly-sandy silt, minor clay
12	75.5	82.5	diamicton	gry	5	P	-	sharp	-	-	-	Minor clay
12	82.5	83.5	fine sand	brn-gry	0	MW	-	sharp	-	-	-	Minor clay
12	83.5	85.0	diamicton	gry	0	P	-	sharp	-	-	-	Loamy
13	0.0	2.0	topsoil	blk	0	-	-	-	-	-	-	-
13	2.0	5.0	N.R.	-	0	-	-	-	-	-	-	-
13	5.0	7.0	medium sand w/gravel	tan	20	M	coarsens	-	calcareous	1/4	1	Sand grades from medium to sandy silt
13	7.0	9.0	sand w/gravel	tan	5	W	fining	sharp	calcareous	2	1/2	-



Drill Hole (ft)	To (ft)	Sediment Type	Color	Silt Content (%)	Gravel (%)	Sorting	Downward Gradation	Upper Contact	Lithology	Dominant Gravel Size	Gravel Size	Comments
13	9.0	11.5 gravely silt	buff	silt	25	MP	coarsens	grad.	calcareous	1/4-1/2	2	Mostly silt with gravel, some sand
13	11.5	16.0 silty gravel	buff	silty	35	MP	mix	sharp	calcareous	1/4-1/2	2	More gravel, similar to above
13	16.0	19.0 s & g	brn	silty	45	M	coarsens	sharp	calcareous	1/4	2 1/2	Segment coarsens down from medium sand to small cobbles
13	19.0	21.0 s & g	brn	clean	50	MW	coarsens	sharp	mixed	2-4mm	1/2	Sequence coarsens down
13	21.0	23.0 sand w/fine gravel	tan	clean	15	W	-	sharp	mixed	2-4mm	1/2	Similar to above with less gravel, medium-coarse sand
13	23.0	24.5 s & g	brn	clean	50	MW	coarsens	grad.	mixed	1/4-1/2	2	Grades from coarse sand and ends in small cobble layer
13	24.5	34.0 coarse sand with gravel	brn	clean	15	W	coarsens	sharp	mixed	2-4mm	1 1/2	Coarsens down from coarse sand to fine gravel and cobbles
13	34.0	34.5 cobbles w/silt	brn	silt	45	MP	-	sharp	mixed	3/4	3	Cobble layer with silt and gravel matrix
13	34.5	45.5 sand	brn	clean	10	W	-	sharp	mixed	2	3/4	Massive coarse sand
13	45.5	50.0 s & g	gry-brn	silty	65	M	-	sharp	mixed	3/4	3+	47.5 water table, mixed sand fine-medium with silt matrix
13	50.0	58.5 sand w/gravel	brn	clean	20	W	-	sharp	mixed	1/4-3/8	1	Massive, coarse sand
13	58.5	60.0 cobbly s & g	gry-brn	silty	50	MP	-	sharp	mixed	2	2 1/2	Very coarse gravel in medium-coarse sand, some silt
13	60.0	63.5 sand w/gravel	gry-brn	clean	20	MW	coarsens	sharp	mixed	2-4mm	1 1/2	Coarsens down with increased gravel, coarse sand to sand and gravel
13	63.5	68.5 s & g	brn-gry	silty	55	M	-	sharp	mixed	1/4-1/2	2 1/2	Mixed massive, no layers, homogeneous
13	68.5	69.5 sand w/gravel	gry-brn	clean	15	MW	coarsens	sharp	mixed	2-4mm	1	Medium-coarse sand with occasional pebble
13	69.5	74.5 s & g	gry-brn	clean	50	M	-	sharp	mixed	1/4-1/2	2	Mixed, no layers, fine-medium gravel with medium-coarse sand
13	74.5	75.0 cobble layer	-	clean	90	W	-	sharp	non-calcareous	1 1/2	2	Cobble layer
13	75.0	77.0 diamicton	med-gry	silt	0	P	-	-	calcareous	-	-	Washed till?
13	77.0	79.0 s & g	brn-gry	clean	50	M	-	grad.	mixed	1/4-1/2	1 1/2	Coarse sand matrix with fine-medium gravel
13	79.0	84.5 sand	gry	clean	5	W	-	grad.	mixed	2-4mm	1/2	Medium sand with few small pebbles
13	84.5	90.0 till	dk-gry	-	0	P	-	-	-	-	-	Very silty clay, till
14	0.0	1.5 topsoil	blk	-	0	-	-	-	-	-	-	Loamy
14	1.5	16.0 s & g	buff	silty	35	M	-	grad.	mixed	3/8-3/4	2	9, 10.5, 11.5, water marks from sand matrix, cobbles matrix supported
14	16.0	16.5 s & g	brn	clean	50	MW	-	sharp	non-calcareous	3/8-1/2	1	Mixed heterogeneous, no layers
14	16.5	18.5 silty s & g	gry-brn	very silty	30	MP	leaner, coarse	sharp	mixed	1/2	3	Dirty sand and gravel, potential cobble layer at base
14	18.5	19.5 medium sand	brn	silty	5	MW	cleaner	sharp	-	-	1/2	Mostly sand with a few granules
14	19.5	22.0 silty s & g	gry-brn	very silty	40	MP	coarsens	sharp	non-calcareous	1/2-3/4	3	Silty
14	22.0	23.0 sand w/gravel	rust-brn	clean	20	MW	-	sharp	mixed	1	2	Sand with a few large pebble/cobbles

Drill Hole	From (ft)	To (ft)	Sediment Type	Color	Silt Content (%)	Gravel (%)	Sorting	Downward Gradation	Upper Contact	Lithology	Dominant Gravel Size	Gravel Size	Comments
14	23.0	24.0	silty s & g	gry-brn	very silty	40	MP	cleaner	grad.	non-calcareous	1/2	2	Mixed
14	24.0	25.0	s & g	rust-brn	clean	35	M	-	grad.	non-calcareous	1/2	1 1/4	Mixed
14	25.0	31.0	gravel w/sand	gry	clean	75	MW	-	sharp	mixed	1/2-3/4	1 1/2	Mixed, mostly gravel, low recovery 26-29
14	31.0	35.0	s & g	gry-brn	very silty	60	MP	-	grad.	mixed	1/2-3/4	1 1/2	Low recovery 31-34, more gravel, less silt than above.
14	35.0	37.5	sand w/gravel	gry-brn	clean	20	MW	-	sharp	mixed	1/4-1/2	1 1/2	Homogeneous, clean sand, no layers
14	37.5	38.5	silty s & g	gry	very silty	35	MP	-	sharp	mixed	1	2	Very silty, no layering
14	38.5	46.0	s & g	gry	clean	30	M	slightly silty	sharp	mixed	1/4-1/2	2	Mixed, low recovery
14	46.0	50.0	s & g, w/cobble layer	brn-gry	silty	50	M	alternating layer	sharp	mixed	3/4	3+	Alternating cobble and sand layers, low recovery, 46-49
14	50.0	61.0	s & g	gry-brn	clean	40	M	-	sharp	mixed	1/4	2	Mixed with one silty sand and gravel at 53
14	61.0	65.0	coarse gravel w/sand	gry-brn	silty	70	M	-	sharp	mixed	1 1/4	3	Mixed, cobble support sand matrix, medium coarse
14	65.0	67.0	sand	brn	clean	5	W	massive	sharp	calcareous	2-4mm	1/2	Massive, medium-coarse sand
14	67.0	73.0	silty s & g	brn-gry	very silty	50	MP	-	sharp	mixed	1 1/4	3	Mixed (no layers), matrix sand with silt medium coarse
14	73.0	75.0	silty s & g	brn-gry	very silty	50	MP	-	grad.	mixed	1 1/2	3+	More silt than above
14	75.0	76.0	s & g	brn	clean	25	M	coarsens	grad.	mixed	1/2	3+	Cleaner than above, matrix supported cobbles
14	76.0	78.0	silty s & g	gry	silt	40	MP	-	sharp	mixed	1/2	3	Very dirty, mostly silt matrix
14	78.0	88.5	sand diamict	dk gry	very silty	0	P	-	-	-	-	-	-
14	88.5	95.0	fill	dk gry	-	0	-	-	-	-	-	-	Washed till, transition
15	0.0	1.0	topsoil	blk	-	0	-	-	-	-	-	-	Leamy/silty
15	1.0	6.5	sandy silt	tan	silt	1	W	-	grad.	very calcareous	-	-	Homogeneous layer of silt
15	6.5	7.5	diamict	tan	silt	0	P	-	sharp	very calcareous	-	-	Turbidity/dump, oxidized
15	7.5	11.5	silty fine sand	tan	silt	1	W	-	sharp	calcareous	-	-	Homogeneous with some silt layers, some bedding preserved
15	11.5	13.0	sand silt	tan	silt	1	W	siltier	grad.	calcareous	-	-	Transition zone between upper and lower layers
15	13.0	17.5	silt w/fine s & c layers	tan	silt	1	W	coarsens	grad.	very calcareous	-	-	Zones are fine sand and clay
15	17.5	19.0	silt w/fine s & c layers	tan	silt	1	M	coarsens	sharp	calcareous	-	-	Transition zone between upper and lower layers
15	19.0	22.0	sand	tan	clean	5	MW	coarsens	grad.	-	3/8-1/2	1/2	Fine sand grading to medium with some pebbles
15	22.0	25.0	s & g	tan	clean	40	MW	-	sharp	mixed	1/2-3/4	1	Fines: calcareous, coarse: non-calcareous, mixed with some large pebbles
15	25.0	26.5	cobbles w/sand	tan	clean	90	W	-	sharp	-	1	3	Cobbles with medium-coarse sand
15	25.0	28.0	coarse sand w/gravel	tan	silty	20	MW	-	grad.	calcareous	2-4mm	11	Transition zone between layer above and below

Drill Hole	From (ft)	To (ft)	Sediment Type	Color	Silt Content (%)	Gravel (%)	Sorting	Downward Gradation	Upper Contact	Lithology	Dominant Gravel Size	Gravel Size	Comments
15	28.0	30.0	NR/NC	-	0	0	-	-	-	-	-	-	-
15	30.0	33.0	sand w/fine gravel	tan	clean	15	W	coarsens	sharp	mixed	2-4mm	1/2	Top part of sequence, one cobble, grades from medium-sand to coarse sand and fine gravel.
15	33.0	35.0	silty s & g	tan	very silty	45	M	litter & coarsens	grad.	mixed	1/2-1	2 1/2	Bottom part of sequence, cobble rich, grades siltier, coarse sand matrix
15	35.0	36.0	silty fine sand	tan	silty	20	MP	-	sharp	mixed	2-4mm	1/2	Very silty material or sandy diamicton
15	36.0	42.0	sand w/fine gravel	tan	clean	20	W	coarsens	sharp	calcareous	2-4mm	1/2	Slight coarsening down (more gravel)
15	42.0	45.0	s & g	tan	clean	35	M	-	sharp	mixed	1/2-3/4	2	Mixed, potential cobble at base, matrix supported
15	45.0	49.5	fine gravel	tan	clean	50	MW	coarsens	sharp	calcareous	2-4mm	1 1/2	Top part of sequence coarsening down from the sand to fine gravel with occasional pebble.
15	49.5	51.0	s & g	tan	silty	80	M	coarsens	grad.	granitic	1/2-3/4	2	Bottom part of sequence, coarsens down, more silt, possibly ends in cobble layer
15	51.0	55.0	s & g	tan	clean	40	M	-	sharp	granitic	3/4	2/2	Mixed, medium sand matrix.
15	55.0	60.0	sand	tan	clean	20	W	coarsens	sharp	granitic	2-4mm	1/4	Top part of sequence, fine sand to coarse sand with fine gravel
15	60.0	65.0	s & g	tan-gry	silty	35	M	coarsens	grad.	mixed	1/2	2 1/2	Homogeneous sand with occasional 2" rocks
15	65.0	78.0	medium-coarse sand	gry	clean	15	W	-	sharp	granitic	2	2	Mixed, cobbles are matrix supported
15	78.0	84.0	s & g	gry	silty	30	MW	-	sharp	mixed	1/2-1/4	2 1/2	Very dirty sand and gravel, better part washed due to chilling
15	84.0	86.0	silty s & g	gry	very silty	60	MP	-	sharp	mixed	1/2	1 1/2	Less silt than above, similar sizes
15	86.0	87.0	s & g	gry	silty	60	M	-	-	mixed	1/2	1 1/2	Cobble supported matrix with firm sand and silt
15	87.0	90.0	silty s & g	gry	very silty	75	MR	-	sharp	mixed	1/2-1	3	Two inch layer of fine sand, mixed.
15	90.0	91.0	sandy s & g	gry	silty	35	M	grades finer	grad.	calcareous	3/8-1/2	1 1/2	Very homogeneous, some sections of more silt, massive
15	91.0	105.0	fine sand	gry	clean	1	W	-	sharp	calcareous	-	-	-
16	0.0	2.5	topsoil	blk	-	0	-	-	-	-	-	-	-
16	2.5	20.0	sand	tan	clean	5	W	coarsens	grad.	-	2	1/2	Fine-medium sand, some silt layers, very little gravel
16	20.0	21.0	silty s & g	tan	silty	40	MP	-	grad.	-	1	2 1/2	Grades from fine sand matrix to silty coarse sand matrix
16	21.0	23.0	fine sand w/cobble	tan	silty	50	BM	-	sharp	-	2	2 1/2	Cobbles in fine sand
16	23.0	25.0	MR	-	-	0	-	-	-	-	-	-	-
16	25.0	26.0	silty s & g	tan	silty	50	MP	coarsens	grad.	non-calcareous	2-4mm	2 1/2	Ends at cobble lag
16	26.0	26.5	silt band	just/blue-gr	silty	15	M	-	sharp	-	2-4mm	1	Water table at 26, oxidation band, above oxidized, below unoxidized
16	26.5	31.0	sand w/gravel	gry	clean	15	MW	coarsens	grad.	mixed	2-4mm	1/2	Two sequences: fine sand, coarse sand/fine gravel
16	31.0	33.0	s & g	gry	clean	30	M	coarsens	grad.	mixed	2-4mm	2	Mostly medium sand with pebbles, one cobble, good pea gravel
16	33.0	40.5	s & g	gry	clean	60	MW	-	grad.	mixed	3/4	2	Coarse sand, gravel is granular, small pebbles with some large pebbles

Drill Hole	From (ft)	To (ft)	Sediment Type	Color	Silt Content (%)	Gravel (%)	Sorting	Downward Gradation	Upper Contact	Lithology	Dominant Gravel Size	Gravel Size	Comments
16	40.5	42.5	medium sand	gry	clean	5	W	coarsens	grad.	mixed	2	1 1/4	Medium-coarse sand
16	42.5	50.5	s & g	gry	clean	50	M	-	sharp	mixed	4	2	Medium sand, gravel ranges, some zones of better sorting (sandy, pebbly)
16	50.5	54.0	cobbly s & g	gry	clean	60	M	-	grad.	mixed	1	2 1/2	Cobbles scattered throughout, siltier at base, may end in lag.
16	54.0	57.0	medium sand w/gravel	brn-gry	clean	20	MW	coarsens	sharp	mixed	1/2	1 1/2	More oxidation-color change, medium sand with some pebbles
16	57.0	61.0	s & g	brn-gry	clean	50	M	-	sharp	mixed	1/2	1 3/4	Coarse sand, large pebbles are scattered/mixed
16	61.0	65.0	s & g	rust-brn	clean	35	M	-	grad.	mixed	2	2	More oxidation, fewer large pebbles, sand
16	65.0	66.0	silty s & g	olive-brn	very silty	25	M	-	sharp	mixed	1	2	Very silty, transition zone to till
16	66.0	67.0	slightly sandy till	gry	-	0	-	-	-	-	-	-	Till is crumbly, sandy, sorting listed as "non"
17	0.0	2.0	topsoil	blk	sandy	0	-	-	-	-	-	-	-
17	2.0	19.0	sand	buff	clean	5	W	-	grad.	-	2	1/2	Water level at 14.5, massive, some bands finer and coarser.
17	19.0	20.5	silty sand	grn	very silty	5	M	-	sharp	-	2	4mm	Silty sand, green color, massive
17	20.5	25.0	sand	buff	silty	5	W	-	grad.	-	2	4mm	Massive, medium-fine sand
17	25.0	34.0	sand w/gravel	brn	clean	10	W	more gravel	grad.	-	2	1	Mostly medium-coarse sand with occasional pebble
17	34.0	37.0	s & g	brn	clean	40	MW	coarsens	sharp	mixed	1/4-1/2	2	Top part of sequence from coarse gravel to sand and gravel
17	37.0	38.0	s & g	brn	clean	60	MW	coarsens	grad.	mixed	1/2-1	2	Bottom part of sequence from sand and gravel to cobble rich sand and gravel
17	38.0	45.0	s & g	org-brn	clean	50	M	coarsens	grad.	mixed	1/2-1	2 1/2	Grades from coarse sand with pebbles to cobble rich sand and gravel
17	45.0	48.5	s & g	grn	clean	65	M	-	grad.	mixed	1/4-1/2	2 +	Sand and gravel of coarse sand and mostly medium pebbles, occasional cobble
17	48.5	51.0	cobble rich s & g	grn	silty	80	M	silt increases	grad.	mixed	1 1/2	2 1/2	Cobble rich, green gravel
17	51.0	52.5	s & g	grn	silty	65	M	-	grad.	mixed	3/4	1 1/2	Sand and gravel, medium-coarse sand matrix, pebble rich
17	52.5	54.0	s & g	grn	clean	25	M	-	sharp	mixed	2-4mm	1	Mostly coarse sand with fine gravel, occasional "1" pebbles
17	54.0	56.0	gravel w/sand	grn	silty	80	MP	-	sharp	mixed	1/2-3/4	1/2	Mostly medium gravel with some occasional sand
17	56.0	57.5	s & g	grn	clean	40	M	-	sharp	mixed	1/4-1/2	2	Mix of medium sand and fine gravel with pebbles
17	57.5	65.0	s & g	gry	clean	60	MW	-	grad.	mixed	1/4-1/2	1 1/2	Higher gravel than above, coarse sand matrix
17	65.0	70.0	s & g	gry	clean	60	MW	-	sharp	mixed	1/4-1/2	1/2	A sequence grading from medium sand to 1/2" (photo)
17	70.0	82.5	cobble rich s & g	gry	very silty	70	MP	-	sharp	mixed	1 1/2	3 +	Alternating layers of cobbles with sand and gravel
17	82.5	85.0	fine sand w/gravel	gry	clean	10	W	-	grad.	mixed	1	3 +	Fine sand with occasional cobble.
18	0.0	1.0	topsoil	blk	-	0	-	-	-	-	-	-	Sandy loam
18	1.0	1.5	fine sand w/coarse gravel	dk brn	very silty	20	P	-	grad.	-	+3	+3	

Drill Hole (ft)	To (ft)	Sediment Type	Color	Silt Content (%)	Gravel (%)	Sorting	Downward Gradation	Upper Contact	Lithology	Dominant Gravel Size	Gravel Size	Comments
18	1.5	fine-medium sand and silt w/medium-gravel	lt brn	very silty	25	MP	-	grad.	-	1	2	Some silt zones, more granite at base, dominant gravel size is less than one inch.
18	7.5	graded sand w/medium-coarse gravel	lt brn	very silty	30	P	coarsens	sharp	-	-	3+	Small iron nodule in upper 6 inches, 1 cored rock, several 1-2" pebbles, dominant gravel size is granule
18	10.5	fine sand w/graded gravel	tan	very silty	30	P	-	grad.	-	up to 3/4	3+	Granule ~3/4" dominant gravel size, 2 partially cored rocks
18	14.0	coarse and w/fine gravel	brn	very silty	20	-	-	grad/sharp	-	-	1	Silt balls in lower
18	16.0	medium-coarse sand w/fine-medium gravel	brn	silty	25	MP	-	grad.	-	-	3	Partially cored rock at 19', 4" sorted med. sand at 29 & 30' with coarse sand and fine gravel, sharp contacts, dominant gravel size is granule
18	33.0	coarse sand w/fine gravel	brn	silty	20	M	-	sharp	-	-	2 1/2'	Dominant gravel size is granule, one silty medium-coarse and with gravel at 39-40 feet
18	47.0	coarse sand w/fine-coarse gravel	brn	very silty	20	MP	-	grad.	-	3/4	3+	3 1/2 inch rock at 48 feet-not cored
18	49.0	silty clay	brn-blk	-	10	MW	-	sharp	calcareous	1	3+	Lake sediments, dk dominated w/light gray layers, each layer less than 1 mm, shattered basalt at 49-50 feet, mod calcareous, < 1" dominant
18	50.5	graded sand w/medium gravel	brn-gry	very silty	25	-	-	sharp	-	1-2	2	-
18	51.0	medium-coarse sand and medium-coarse gravel	brn-gry	very silty	45	P	-	grad.	-	1 1/2	3	3 rocks 2 1/2 inches or greater, under 1 1/2 inch dominant
18	54.5	coarse sand w/fine gravel	brn-gry	very silty	30	MP	coarsens	sharp	-	1/2	3+	-
18	58.0	medium-coarse sand w/fine-medium gravel	brn-gry	very silty	40	P	coarsens	-	-	1-2	3+	-
18	62.0	N.S.	-	-	0	-	-	-	-	-	-	-
18	65.0	fine-medium sand and coarse gravel	brn-gry	very silty	50	BM	-	-	-	1 1/2-2 1/2	3+	One cored rock at 66', less coarse pebbles at lower foot
18	73.0	coarse sand w/fine-coarse gravel	gry-brn	silty	20	-	coarsens	sharp	-	up to 1/2	3	2' fine-medium slightly silty sand at top, one 4" section at 77' is very silty, two lining up sequences, dominant gravel size is
18	78.0	coarse sand w/medium-coarse gravel	brn-gry	very silty	40	P	-	grad.	-	-	2	Mostly black and gray pebbles, lots of dark gray in 1/2" or less and granule size
18	84.0	diamicton	olv-gry	-	5	P	-	sharp	mixed	-	1	Fine sandy silt with pebble, very sharp upper contact, lithology is 50% white, 40% gray, 10% red, no weathering on top, matrix supported
18	86.0	graded sand w/gravel	brn-gry	very silty	30	P	-	sharp	-	0-1/2	1 1/2	Upper 6" has diamicton balls and coarse silty, upper contact is undulating sharp
18	86.5	medium-coarse sand w/occ. gravel	gry-brn	silty	10	MW	coarsens	sharp	-	1/2	2 1/2	2-2 1/2" black pebbles in lower 6 inches, coarse sand in lower foot, occasional 1/2 inch or less gravel throughout.
18	90.0	medium sand w/rare gravel	gry-brn	clean	0	MW	coarsens	sharp	non-calcareous	-	1/2	Trace gravel %, 2" very fine sand with under 1 mm laminations at top, 2 blk shales this layer, 50 mm blk shale throughout, occ coarse sand thin zones
18	94.8	very fine sand and silt	gry	clean	0	W	-	sharp	-	-	-	Small layers as at 90
19	0.0	topsoil	blk	very silty	5	P	-	-	non-calcareous	-	-	Stony, sandy silt loam
19	0.5	granite	pnk	-	0	-	-	-	-	-	-	Pink spar, black mineral has green incls
19	2.0	medium-coarse sand w/occ. fine gravel	dk org-brn	silty	15	MP	coarsens	-	non-calcareous	-	-	Lower topsoil horizon
19	2.5	fine sand	org-brn	silty	5	-	-	sharp	-	-	2	Occasional graded pebble to 2"
19	4.0	fine-medium sand w/occ. fine gravel	dk org-brn	silty	10	MP	-	sharp	-	-	1/2	Upper and lower contacts based on color, lithology is similar
19	4.3	fine-medium sand w/occ. fine gravel	lt brn	silty	0	M	-	sharp	calcareous	-	1 1/2	-
19	5.0	coarse sand w/fine gravel	org-brn	very silty	35	M	coarsens	sharp	-	-	-	Graded gravel in lower to silt and gravel in upper, 2" silt cap with gravel, dominant gravel size is granule pea

Drill Hole (ft)	To (ft)	Sediment Type	Color	Silt Content (%)	Gravel (%)	Sorting	Downward Gradation	Upper Contact	Lithology	Dominant Gravel Size	Gravel Size	Comments
19	7.0	medium-coarse sand w/fine gravel	org-brn	silty	20	M	coarsens	sharp	-	-	1/2	Grades from fine to coarse to fine
19	8.5	fine sand	org-brn	very silty	0	W	-	sharp	-	-	-	Black granules at top.
19	9.0	graded sand and medium-coarse gravel	brn	silty	45	MP	-	sharp	-	-	-	Silt layers with pebbles at 10-10.25, 12-12.5, 13.5-13.75, 15-15.5, 16.6-16.75, minor rust spot at 18'
19	10.0	graded sand and medium-coarse gravel	lt-dk brn	very silty	55	MP	-	sharp	-	1/2-1 1/2	+2	It is possible this is pebble supported, single core chunk, top 15" is cemented sand and granules, calcified
19	19.5	silt w/fine-medium gravel	olv-brn	silty	30	P	-	sharp	-	1/2-1	1 1/2	
19	21.0	silt and fine sand	lt tan	very silty	0	W	-	sharp	-	-	-	Possibly less silt in upper, red-brown at 26-27, gray-black at 32-34.5, cut and broken boulder in upper foot
19	22.0	fine-medium sand and medium-coarse gravel	n/red/gry-brn	very silty	40	MP	-	grad.	-	-	2 1/2	Siltier in lower two feet, vertical gradation goes from coarse to fine to coarse, dominant gravel size is granule
19	35.5	coarse sand and fine gravel	olv-brn	silty	45	M	-	sharp	-	-	1	Granule size gravel also dominant
19	39.5	coarse sand and coarse gravel	olv-grn	very silty	60	MP	-	sharp	-	1 1/2	3	Sharp color change (over one inch)
19	44.5	medium-coarse sand w/gravel	lt gry	silty	30	MP	-	sharp	-	1 1/2-2 1/2	2 1/2	Some 1-2 inch rocks, coarse sand zones in the middle
19	46.0	medium sand	gry-brn	clean	0	MW	-	sharp	-	-	1/4	
19	51.0	fine-medium sand	brn-gry	clean	0	W	-	sharp	-	-	-	
19	51.5	medium sand and coarse gravel	gry-brn	silty	40	MP	coarsens	sharp	-	+2	2 1/2	Pebbles fine up
19	54.5	coarse sand with fine gravel	gry-brn	silty	30	MW	coarsens	sharp	-	-	4	Dominant gravel size is granule, vertical gradation lines up slightly
19	64.5	coarse-medium sand w/occ. fine gravel	brn	clean	5	MW	coarsens	sharp	-	-	1/4	Vertical gradation gradually fines up.
19	69.0	graded sand and fine-coarse gravel	brn-gry	very silty	50	MP	coarsens	sharp	-	up to 1	3 1/2	Sandy silt with pebble in lower foot, upper 6 inches is washed 1/2-1 1/2" pebbles, cored boulder at 73, 74, 75, 77, 78, possibly 2 lines up sequences
19	78.0	coarse sand and gravel	brn	silty	40	M	-	sharp	-	-	1 1/2	Dominant gravel size is granule
19	79.0	sandy silt with gravel	gry	very silty	50	P	-	sharp	calcareous	-	+ 3 1/2	At least 5 cored rocks, slightly calcareous
19	80.5	fill	gry	-	5	P	-	sharp	calcareous	-	-	Till with pebbles, clayey silt, 2 cored rocks in upper 1 1/2 feet, very calcareous below 82'
20	0.0	sandy loam	blk	-	0	-	-	-	-	-	-	Occasional fine gravel
20	0.5	loamy coarse sand	brn-blk	-	0	-	-	grad.	-	-	-	Trace percentage of gravel, occasional fine gravel
20	1.8	medium-coarse sand	lt brn	silty	0	M	-	grad.	-	-	-	2" weakly cemented fine gravelly sand at 2.5'
20	2.5	medium-coarse sand w/occ. fine-medium gravel	brn	silty	10	M	-	-	-	up to 1	1 1/2	Most of the gravel is concentrated in layers 0.5" to 2" thick with 30-40% gravel, some sharp contacts within units
20	22.5	fine-medium sand w/occ. fine gravel	lt brn	silty	15	MP	coarsens	sharp	-	1	1	Dominant gravel size is less than one inch
20	25.0	fine sand w/occ. fine gravel	gry-brn	very silty	25	P	-	-	-	-	-	Partially cored rock (MV)
20	26.0	fine-medium sand w/fine-medium gravel	dk-lt brn	silty	25	MP	-	grad.	-	1/4	1 1/2	Contains 1-2" clean medium sand layer with sharp contacts, coarser gravel in lower, occasional 1 1/2" rock, granule-pea dominant size
20	30.0	fine sand w/occ. fine gravel	lt brn	silty	12	MW	-	sharp	-	1	1-1 1/2	All gravel is in lower half, dominant gravel size is under one inch
20	35.0	medium-coarse sand w/fine gravel	org-brn	silty	15	MW	-	sharp	-	-	1 1/2	Gravel zones within unit, 1 1/2" rocks occasional, maximum gravel size is granule, vertical gradation varies

Drill Hole (ft)	To (ft)	Sediment Type	Color	Silt Content (%)	Gravel (%)	Sorting	Downward Gradation	Upper Contact	Lithology	Dominant Gravel Size	Gravel Size	Comments
20	44.0	very fine-medium sand w/rare fine gravel	gry-rust-brn	clean	5	MW	-	sharp	-	-	-	Vertical gradation varies, 2 fine up, coarse sand with fine gravel zones are rusty brown and occur at 50-51', 49-49:25', 46.5-47'
20	53.0	fine sand	wht-gry	clean	0	W	coarsens	sharp	non-calcareous	-	-	95% quartz, 5% matrix
20	55.0	coarse sand w/fine-medium gravel	gry-brn	silty	35	MP	-	-	-	up to 1	2 1/2	Top 6 inches fines to medium-coarse sand, fines up to about 60' then fines to top, vertical gradation varies
20	68.0	fine-medium sand	lt gry	very silty	0	W	-	grad.	-	-	-	Trace percentage of gravel, maximum gravel size is pea-sized
20	69.0	boulders	-	-	0	-	-	-	-	-	-	Cored granite and broken basalt (dark)
20	69.5	medium-coarse sand w/rare fine gravel	brn	clean	5	MW	fines	sharp	-	-	3/4	Gravel occurs in about the top 2', dominant gravel size is granule
20	73.0	coarse sand w/fine-coarse gravel	gry-brn	silty	40	MP	-	sharp	-	1/2	3 1/2 +	Cored granite at 73', well graded gravel
20	82.0	N.S.	-	-	0	-	-	-	-	-	-	-
20	85.0	coarse sand and coarse gravel	gry	very silty	50	P	coarsens	-	-	up to 3	3 1/2 +	Cored rock at 88.5
20	89.0	coarse sand w/coarse gravel	brn-gry	very silty	35	P	coarsens	sharp	-	-	3 1/2	Siltier at base, granule and 1-3 inches are dominant gravel sizes
20	93.5	medium sand	lt brn	clean	0	W	-	sharp	-	-	-	Dominant gravel size and maximum gravel size are both granule, trace percentage of gravel
20	95.0	fine sandy silt w/pebbles	olv-brn/gry	-	3	P	-	-	-	-	2	1-2' band of clean med sand in bottom of core at 99.5', no lag here, diamicton till, no med & coarse sand in interfills, upper part of fill missing?
21	0.0	topsoil	blk	-	0	-	-	-	-	-	-	-
21	0.0	topsoil	blk	-	0	-	-	-	-	-	-	-
21	1.0	s & g	brn	silty	40	M	fines/siltier	grad.	mixed	2-4mm	1/2	Grades from pea gravel to silty sand
21	1.0	s & g	brn	silty	40	M	fines/siltensr	grad.	mixed	2-4mm	1/2	-
21	2.5	cobble-rich s & g	brn	silty	30	M	-	sharp	mixed	1 1/2	2	Silty sand with large pebbles/small cobbles
21	2.5	cobbly s & g	brn	silty	30	M	-	sharp	mixed	1 1/2	2	Cobble rich sand and gravel. Silty sand with large pebble/small cobbles
21	4.5	diamicton	org-brn	silt	0	-	-	grad.	-	-	-	Water level at 5.5, oxidized, sandy
21	4.5	diamicton	org-brn	silt	0	-	-	grad.	-	-	-	Water level at 5.5 feet, oxidized, sandy
21	5.5	fine sand	org-brn	silty	5	W	-	sharp	-	2	-	Mostly fine sand, few rocks
21	5.5	fine sand	org-brn	silty	5	W	-	sharp	-	2	-	Mostly fine sand, few rocks.
21	8.0	s & g	org-brn	silty	25	M	coarsens/siltier	grad.	mixed	2	1 1/2	Silt layer 9-9.5 feet
21	8.0	s & g	org-brn	silty	25	M	coarsens/siltier	grad.	mixed	2	1 1/2	-
21	11.5	medium sand	org-brn	clean	5	W	-	sharp	-	2	1/2	Predominantly fine sand
21	11.5	medium sand	org-brn	clean	5	W	-	sharp	-	2	1/2	Very silt-rich
21	14.0	silty s & g	brn	silt	35	P	-	sharp	mixed	1/4	2	Very silt rich
21	14.0	silty s & g	brn	silt	35	P	-	sharp	mixed	1/4	2	Very silt rich

Drill Hole	From (ft)	To (ft)	Sediment Type	Color	Silt Content (%)	Gravel (%)	Sorting	Downward Gradation	Upper Contact	Lithology	Dominant Gravel Size	Gravel Size	Comments
21	15.0	17.0	medium sand	brn	clean	5	W	-	sharp	mixed	2	3/4	-
21	15.0	17.0	medium sand	brn	clean	5	W	-	sharp	mixed	2	3/4	Grades from sandy light-gray till to dark-gray complete till, no sorting
21	17.0	25.0	till	gry	-	0	-	more compact	sharp	mixed	2	3/4	Grades from sandy light gray till to dark gray, compact till
21	17.0	25.0	till	gry	-	0	N	compacts more	grad.	mixed	-	-	Loamy
22	0.0	1.5	topsoil	blk	-	0	-	-	-	-	-	-	Very silty sand and gravel with pebble zones.
22	1.5	6.0	silty s & g	lt tan	very silty	35	MP	-	grad.	mixed	1/4	2	Very oxidized with water level at about 7 to 7.5, medium sand with occasional pebble
22	6.0	8.0	s & g	rust-brn	silty	30	M	-	sharp	mixed	1/4	1 1/2	Water level at 9.5 has a black horizon, very silty, coarse gravel at base
22	8.0	9.5	silty s & g	buff	very silty	25	MP	coarser, cleaner	sharp	mixed	1/4	2	Massive
22	9.5	10.5	silt	tan	silt	0	W	-	sharp	calcareous	-	-	Mix, no layers
22	10.5	12.5	s & g	brn	clean	30	M	-	sharp	non-calcareous	1/4	1 1/4	Massive, with 6 inch layer of medium sand
22	12.5	25.0	fine sand	lt tan	clean	3	W	-	sharp	-	2	1/4	Mostly fine gravel with coarse to medium sand, occasional pebble, small cobbles
22	25.0	30.0	s & g	brn	clean	50	M	-	5	calcareous	2-4mm	2 1/2	Silt clay, transition zone to fill, sandy diamict
22	30.0	30.5	diamiction	lt gry	silt	0	-	-	-	-	-	-	-
22	30.5	40.0	till	dk gray	-	0	-	-	-	-	-	-	-
23	0.0	1.0	topsoil	blk	-	0	-	-	-	-	-	-	-
23	1.0	2.5	soil horizon	buff	very silty	0	-	-	-	-	-	-	-
23	2.5	10.0	fine sand	buff	clean	5	W	-	grad.	-	2-4mm	1/2	Occasional cobble
23	10.0	14.0	s & g	buff	clean	25	MW	-	grad.	mixed	2-4mm	1	Rust zone at 11, mostly fine-medium sand
23	14.0	15.0	silty s & g	lt brn	silt	30	P	-	sharp	mixed	1/2	2	High clay balls
23	15.0	17.0	silty sand w/gravel	org-brn	very silty	10	M	-	sharp	mixed	2-4mm	1 1/2	Highly oxidized, mostly medium-coarse dirty sand with some gravel.
23	17.0	22.5	s & g	brn	clean	40	M	-	sharp	non-calcareous	1/4-1/2	2	Mostly coarse sand with some fine gravel, 2 small fining up sequences
23	22.5	25.0	sand w/gravel	brn	clean	10	W	-	sharp	-	2	1/2	Mostly medium-coarse sand with a few pebbles
23	25.0	27.0	gravel w/sand	dk-brn	clean	70	M	-	sharp	mixed	1	2	Dirty gravel, mostly large pebbles with sand and silt
23	27.0	28.5	coarse sand/fine gravel	brn	clean	40	W	-	grad.	calcareous	2-4mm	1/2	Coarse sand/fine gravel
23	28.5	29.0	medium sand	brn	clean	5	W	-	sharp	calcareous	2	1/4	Medium sand and gravel
23	29.0	30.0	cobbly sand	org-brn	clean	60	M	-	sharp	mixed	1 1/2	3 +	Cobble medium-sand matrix.
23	30.0	32.0	fine sand	brn	clean	5	W	-	sharp	-	-	-	Fine to medium sand
23	32.0	36.0	s & g	brn	clean	35	MW	coarsens	sharp	mixed	1/4	1 1/2	Coarsens from medium to fine gravel



Drill Hole	From (ft)	To (ft)	Sediment Type	Color	Silt Content (%)	Gravel (%)	Sorting	Downward Gradation	Upper Contact	Lithology	Dominant Gravel Size	Gravel Size	Comments
23	36.0	37.5	silty s & g	brn	very silty	40	MP	cleaner	grad.	mixed	4	1 1/2	Mixed, less silty down
23	37.5	42.0	s & g	brn	clean	40	M	-	grad.	mixed	4	1 1/2	Similar to above, but less silt. Organic zones, old water level at about 38.5
23	42.0	44.5	fine sand w/gravel	tan	clean	10	MW	-	sharp	mixed	1/4	3/4	Mostly fine to medium sand with some gravel
23	44.5	50.0	silty s & g	gry-brn	silty	35	M	-	grad.	-	1	1 1/2	Matrix is fine sand with gravel
23	50.0	51.5	sand w/gravel	brn	clean	15	MW	-	sharp	mixed	1 1/2	3+	Sand with occasional coarse gravel layers
23	51.5	52.5	s & g	gry	silty	40	MP	-	grad.	mixed	2-4mm	2	Dirty sand and gravel, washed till?
23	52.5	60.0	till	dk gry	-	0	-	-	-	-	-	-	-
24	0.0	2.0	topsoil	blk	-	0	-	-	-	-	-	-	Sandy
24	2.0	4.0	sand w/gravel	dk brn	silty	15	MW	silt & gravel inc	grad.	mixed	1/4	2	Medium sand grading to silty gravel
24	4.0	8.0	sand	tan	clean	5	W	-	sharp	mixed	-	-	Fine sand, massive
24	8.0	10.5	sand	gry-tan	silty	10	M	cleaner	grad.	mixed	2-4mm	1/2	Silty fine sand
24	10.5	11.5	medium sand	brn	clean	10	W	-	sharp	mixed	2-4mm	1/2	Clean, medium sand
24	11.5	12.0	medium sand	buff-brn	clean	5	W	finer	grad.	mixed	2	1/4	clean, medium sand
24	12.0	16.5	silty sand	gry-brn	very silty	10	MP	siltier	sharp	mixed	2	2	Dirty sandy silt
24	16.5	26.5	medium-fine sand	tan/brn	clean	3	W	finer	grad.	mixed	2	1/2	Clean, medium to fine sand, silt layer at 25 feet
24	25.7	28.0	silt	brn	-	0	W	-	sharp	calcareous	-	-	Massive silt
24	26.5	27.5	sand	brn	clean	3	BM	-	sharp	calcareous	2	1/4	Bimodal sand, coarse and fine sand/matrix supported
24	28.0	35.0	medium sand	brn-rust	clean	5	W	finer	sharp	mixed	2	1/2	Medium sand, grading fine downward
24	35.0	38.0	fine sand	gry	clean	5	W	-	sharp	mixed	2	1/2	Washed till
24	38.0	40.0	sand till	gry	-	0	VP	-	sharp	calcareous	-	-	Composed till
24	40.0	44.0	till	dk gry	-	0	-	-	grad.	calcareous	-	-	Till balls, sand
24	44.0	51.0	medium sand	gry	clean	15	W	ne-cs, fine san	grad.	mixed	2	3/4	Compact
24	51.0	54.0	till	dk gry	-	0	-	-	grad.	calcareous	-	-	Layers of compact till
24	54.0	64.0	sandy till	dk gry	-	0	-	-	grad.	calcareous	-	-	Compact
24	64.0	65.0	till	dk gry	-	0	-	-	grad.	calcareous	-	-	Compact
24	64.0	65.0	till	dk gry	-	0	-	-	grad.	calcareous	-	-	Organic rich sand and gravel
25	0.0	1.0	s & g	brn	-	0	-	-	-	-	-	-	Ends in cobble lay, increase of silt
25	1.0	6.0	s & g	buff	silty	15	MW	silt increases	grad.	mixed	2-4mm	2 1/2	

Drill Hole (ft)	To (ft)	Sediment Type	Color	Silt Content (%)	Gravel (%)	Sorting	Downward Gradation	Upper Contact	Lithology	Dominant Gravel Size	Gravel Size	Comments
25	6.0	18.0 sand	brn	clean	5	MW	coarsens	sharp	mixed	2-4mm	1/4	Coarsening down sequence, water table at 9.5 feet, layers of fine, medium, and coarse sand
25	18.0	32.0 sand	gry	clean	10	MW	coarsens	sharp	mixed	2-4mm	1/2	Cobble lab at 15 feet, some fining up sequence, mostly sand with some small gravel
25	32.0	40.0 fine sand	gry	silty	3	MW	gravel increase	sharp	-	2	1	Mostly fine sand with rocks
25	40.0	41.0 s & g	gry	clean	20	M	-	grad.	mixed	1/4	2 1/2	Washed?
25	41.0	51.0 sandy till	gry	-	0	-	-	-	-	-	-	Compacted
25	51.0	55.0 till	dk gry	-	0	-	-	-	-	-	-	Transition zone to sand
25	55.0	57.0 sandy till	gry	-	0	-	-	grad.	-	-	-	-
25	57.0	58.5 sand w/till	gry	-	0	-	-	-	-	-	-	-
25	58.5	61.0 fine sand	gry	clean	5	W	-	grad.	-	2	1/4	Sand with till clumps
25	61.0	65.0 medium sand	gry	very silty	25	MP	-	grad.	calcareous	2-4mm	1/4	Compacted till
25	65.0	67.0 till	dk gry	-	0	-	-	sharp	-	-	-	Root mass, loamy sand
26	0.0	0.3 topsoil	blk	-	0	-	-	-	-	-	-	Mix of sand, gravel, and topsoil
26	0.3	1.3 topsoil w/ s & g	brn-blk	-	0	-	-	grad.	-	-	1 1/2	-
26	1.3	2.3 loam	blk	-	0	-	-	grad.	-	-	-	Splashes of black loamy sand and orange mottles throughout
26	2.3	5.0 medium-coarse sand	gry-brn/blk	silty	0	M	-	sharp	-	-	3/4	Bag has 1" extra black sandy sluff at 7', some fine-medium sand in top foot, bright orange stain from 6-9'
26	5.0	9.0 medium-coarse sand	lt brn-lt org	clean	2	MW	coarsens	-	-	-	1/2	Trace percentage of gravel
26	9.0	9.2 medium-coarse sand	blk/org-brn	clean	0	MW	-	-	-	-	-	Very sharp upper contact
26	9.2	9.3 fine-medium sand	yel-brn	clean	0	W	-	sharp	-	-	-	2 rocks over 2", oxidized, very sharp upper contact, dominant gravel size is less than a half inch.
26	9.3	10.0 graded sand w/coarse gravel	brn	very silty	40	P	-	sharp	-	1/2	3	Trace percentage of gravel, at 10-12', have a 1.5" of dark sandy sluff with grass blades
26	10.0	12.5 graded sand	lt brn/lt org	clean	0	MW	-	-	-	-	-	-
26	12.5	14.5 graded sand and coarse gravel	dk brn	very silty	60	P	-	grad.	-	1-2	2	Soft, not much clay, mostly silt and ultra-fine sand, 2 pebbles in lower 1 1/2", lower part between sandy and with traces of gravel.
26	14.5	21.0 diamicton	gry	-	3	P	-	sharp	-	-	2 1/2	Forms clod, muddy
26	21.0	24.5 silty s & g & fine gravel	gry	very silty	35	P	-	sharp	-	1	2 1/2	Upper foot fines to medium sand, dominant gravel size is granule
26	24.5	29.0 coarse sand and fine gravel	brn-grv	silty	50	M	coarsens	sharp	-	-	1	-
26	29.0	31.0 fine-medium sand	brn-grv	clean	0	W	-	sharp	-	-	-	Upper 6 inches is coarse sand and fine gravel, three half inch black sand streaks at 32-35'
26	31.0	38.0 medium sand	lt gry-brn	clean	0	MW	fines	sharp	-	-	1/2	Clay silt (not diamicton) ball 1 1/2" or larger at 44', occasional coarse gravel throughout
26	38.0	45.5 medium-coarse sand and fine-medium gravel	gry-brn	silty	35	MP	coarsens	-	-	up to 1/2	3	Muddy, dominant gravel size is graded
26	45.5	46.0 fine-coarse gravel	dk gry	very silty	60	P	-	sharp	-	-	2 1/2	-

Drill Hole (ft)	From (ft)	To (ft)	Sediment Type	Color	Silt Content	Gravel (%)	Sorting	Downward Gradation	Upper Contact	Lithology	Dominant Gravel Size	Gravel Size	Comments
26	46.0	55.0	claymicton	yel-gry	silt	5	P	-	-	-	-	1	Lots of dominant granules, till is fairly silty, hard
27	0.0	1.5	topsoil	-	-	0	-	-	-	-	-	-	Disturbed topsoil
27	1.5	4.5	till	tan	-	0	N	-	grad.	-	-	-	No sorting, rusty-gray mottles, sandy till
27	4.5	5.5	medium sand	rust-brn	clean	5	W	-	sharp	-	2-4mm	1/2	Medium sand
27	5.5	7.5	till	tan	-	0	-	-	grad.	-	-	-	Sandy till
27	7.5	8.5	medium sand w/gravel	brn	silty	20	M	cleaner	grad.	calcareous	2-4mm	1	Mostly medium sand with some gravel
27	8.5	10.0	silty s & g	brn	very silty	40	M	cleaner	sharp	calcareous	1/4	1 1/2	Mostly sand with few pebbles, water table at 13 feet.
27	10.0	21.0	medium sand	brn	clean	10	W	-	-	mixed	2-4mm	1	Very compact, organically rich woody fragments
27	21.0	23.0	till	dk gry	-	0	N	-	-	-	-	-	Grades from coarse sand and fine gravel to medium sand
27	23.0	27.0	medium sand	tan	clean	15	MW	finer	sharp	calcareous	2-4mm	1/2	-
27	27.0	29.0	fine sand	tan-lt gry	clean	0	W	-	sharp	-	-	-	Turns color at 31 feet
27	29.0	40.0	till	tan-gry	-	0	-	-	-	-	-	-	-

## **APPENDIX C**

### **SIMPLIFIED ROTOSONIC DRILL HOLE LOG DESCRIPTION WITH GRADATIONS**

Some layers have more than one sample. For those layers, the sample number looks like:

04027 - 29

which represents the weighted average of samples 04027, 04028, and 04029.















## **APPENDIX D**

### **SAMPLE INTERVALS**

Samples were processed at two laboratories:

DOT = Quality Analysis at MNDOT Aggregate Lab in Detroit Lakes.  
DNR = Gradations at DNR Minerals Lab in Hibbing.

The sample is identified by a “smart” number.

First two digits = hole sample  
Last three digits = sample number

Hole ID	Sample ID	Sample Number	Depth From (ft)	Depth To (ft)	Lab Type
1	15	01015	0	55	DOT
1	16	01016	0	11.5	DNR
1	17	01017	11.5	12.5	DNR
1	18	01018	12.5	15	DNR
1	19	01019	15	25	DNR
1	20	01020	25	35	DNR
1	21	01021	35	41.5	DNR
1	22	01022	41.5	50	DNR
1	23	01023	50	55	DNR
1	24	02192	55	61.5	DNR
2	192	02192	0	12	DOT
2	193	02193	12	54	DOT
2	194	02194	0	12	DNR
2	195	02195	12	25	DNR
2	196	02196	25	36.5	DNR
2	197	02197	36.5	45	DNR
2	198	02198	45	54	DNR
3	137	03137	0	31.5	DOT
3	138	03138	31.5	64.5	DOT
3	139	03139	0	11	DNR
3	140	03140	11	19.5	DNR
3	141	03141	19.5	31.5	DNR
3	142	03142	31.5	37	DNR
3	143	03143	37	44	DNR
3	144	03144	44	48.5	DNR
3	145	03145	48.5	57	DNR
3	146	03146	57	64.5	DNR
4	25	04025	2	23.5	DOT
4	26	04026	23.5	65	DOT
4	27	04027	2	14.75	DNR
4	28	04028	14.75	23.5	DNR
4	29	04029	23.5	30	DNR
4	30	04030	30	37	DNR
4	31	04031	40	45.25	DNR
4	32	04032	45.25	52	DNR
4	33	04033	59	65	DNR
4	34	04034	52	59	DNR
5	228	05228	1	37	DOT
5	229	05229	37	94	DOT
5	230	05230	29	37.5	DNR
5	231	05231	37.5	48	DNR
5	232	05232	48	64	DNR
5	233	05233	64	75	DNR
5	234	05234	75	85.5	DNR
6	108	06108	34	38	DNR
6	109	06109	45.5	55	DNR

Hole ID	Sample ID	Sample Number	Depth From (ft)	Depth To (ft)	Lab Type
7	1	07001	2.5	10.5	DOT
7	2	07002	2.5	10.5	DNR
7	3	07003	10.5	20.5	DNR
7	4	07004	20.5	24.7	DNR
7	5	07005	24.7	35.7	DNR
7	6	07006	35.7	42.5	DNR
7	7	07007	42.5	54.5	DNR
7	8	07008	54.5	63	DOT
7	9	07009	63	102	DOT
7	10	07010	54.5	63	DNR
7	11	07011	63	75.5	DNR
7	12	07012	75.5	90	DNR
7	13	07013	90	102	DNR
7	14	07014	102	105	DNR
8	36	08036	12	16.5	DNR
8	37	08037	17.5	21.5	DNR
8	41	08041	38.5	43	DNR
8	42	08042	43	46.5	DNR
8	43	08043	47	100.5	DOT
8	44	08044	47	54	DNR
8	45	08045	54	61	DNR
8	46	08046	61	69	DNR
8	47	08047	69	75	DNR
8	48	08048	75	82	DNR
8	49	08049	82	87	DNR
8	50	08050	90	95	DNR
8	51	08051	95	100.5	DNR
8	52	08052	100.5	102	DNR
8	53	08053	102	105	DNR
8	54	08054	105	109.5	DNR
8	55	08055	109.5	115	DNR
8	56	08056	115	122	DNR
8	57	08057	122	125	DNR
8	58	08058	125	127.5	DNR
8	59	08059	127.5	129.1	DNR
8	60	08060	129.1	135	DNR
8	61	08061	135	143.5	DNR
8	62	08062	143.5	145	DNR
9	225	09225	16.5	55	DOT
9	226	09226	15	31	DNR
9	227	09227	32	55	DNR
10	123	10123	7	15.5	DOT
10	124	10124	5	7	DNR
10	125	10125	7	15.5	DNR

Hole ID	Sample ID	Sample Number	Depth From (ft)	Depth To (ft)	Lab Type
11	176	11176	2	43	DOT
11	177	11177	43	68.5	DOT
11	178	11178	1.5	10	DNR
11	179	11179	10	15	DNR
11	180	11180	15	20	DNR
11	181	11181	20	30	DNR
11	182	11182	30	43	DNR
11	183	11183	43	55	DNR
11	184	11184	55	70	DNR
12	110	12110	14.5	41	DOT
12	111	12111	45	75.5	DOT
12	112	12112	1.5	4.5	DNR
12	113	12113	4.5	14.5	DNR
12	114	12114	14.5	25	DNR
12	115	12115	25	35	DNR
12	116	12116	35	41	DNR
12	117	12117	45	50	DNR
12	118	12118	50	54	DNR
12	119	12119	54	58	DNR
12	120	12120	61	65	DNR
12	121	12121	65	72	DNR
12	122	12122	72	75.5	DNR
13	166	13166	0	44.5	DOT
13	167	13167	44.5	84.5	DOT
13	168	13168	2	19	DNR
13	169	13169	19	24.5	DNR
13	170	13170	24.5	34.5	DNR
13	171	13171	34.5	45.5	DNR
13	172	13172	45.5	60	DNR
13	173	13173	60	68.5	DNR
13	174	13174	68.5	75	DNR
13			75	77	NS
13	175	13175	77	84.5	DNR
14	156	14156	0	46	DOT
14	157	14157	46	77.5	DOT
14	158	14158	1.5	16	DNR
14	159	14159	16	22	DNR
14	160	14160	22	31	DNR
14	161	14161	31	38.5	DNR
14	162	14162	32	46	DNR
14	163	14163	46	61	DNR
14	164	14164	61	73	DNR
14	165	14165	73	78	DNR

Hole ID	Sample ID	Sample Number	Depth From (ft)	Depth To (ft)	Lab Type
15	147	15147	19	65	DOT
15	148	15148	65	91	DOT
15	149	15149	19	30	DNR
15	150	15150	30	40	DNR
15	151	15151	40	51	DNR
15	152	15152	51	65	DNR
15	153	15153	65	78	DNR
15	154	15154	78	84	DNR
15	155	15155	84	91	DNR
16	235	16235	25	26	DOT
16	236	16236	26	65	DOT
16	237	16237	2.5	10	DNR
16	238	16238	10	20	DNR
16	239	16239	20	26	DNR
16	240	16240	26	31	DNR
16	241	16241	31	42.5	DNR
16	242	16242	42.5	54	DNR
16	243	16243	54	65	DNR
17	202	17202	2	45	DOT
17	203	17203	45	82	DOT
17	204	17204	2	19	DNR
17	205	17205	19	25	DNR
17	206	17206	25	34	DNR
17	207	17207	34	45	DNR
17	208	17208	45	57.5	DNR
17	209	17209	27.5	70	DNR
17	210	17210	70	82.5	DNR
18	78	18078	1.5	14	DOT
18	79	18079	14	49	DOT
18	80	18080	50.5	84	DOT
18	81	18081	1.5	7.5	DNR
18	82	18082	7.5	10.5	DNR
18	83	18083	10.5	14	DNR
18	84	18084	14	25	DNR
18	85	18085	25	33	DNR
18	86	18086	33	40	DNR
18	87	18087	40	49	DNR
18	88	18088	50.5	54.5	DNR
18	89	18089	54.5	62	DNR
18	90	18090	65	73	DNR
18	91	18091	73	78	DNR
18	92	18092	78	84	DNR
18	93	18093	86	95	DNR

Hole ID	Sample ID	Sample Number	Depth From (ft)	Depth To (ft)	Lab Type
19	63	19063	5	44.5	DOT
19	64	19064	44.5	79	DOT
19	65	19065	2	5	DNR
19	66	19066	5	10	DNR
19	67	19067	10	19.5	DNR
19	68	19068	19.5	25	DNR
19	69	19069	25	32	DNR
19	70	19070	32	35.5	DNR
19	71	19071	35.5	44.5	DNR
19	72	19072	44.5	54.5	DNR
19	73	19073	54.5	64.5	DNR
19	74	19074	64.5	69	DNR
19	75	19075	69	75	DNR
19	76	19076	75	77	DNR
19	77	19077	77	79	DNR
20	94	20094	2.5	44	DOT
20	95	20095	55	93.5	DOT
20	96	20096	2.5	12	DNR
20	97	20097	12	22.5	DNR
20	98	20098	22.5	26	DNR
20	99	20099	26	35	DNR
20	100	20100	35	44	DNR
20	101	20101	44	53	DNR
20	102	20102	53	55	DNR
20	103	20103	55	68	DNR
20	104	20104	68	73	DNR
20	105	20105	73	82	DNR
20	106	20106	85	93.5	DNR
20	107	20107	93.5	95	DNR
21	221	21221	1	17	DOT
21	222	21222	1	17	DNR
22	199	22199	1.5	25	DOT
22	200	22200	1.5	12.5	DNR
22			12.5	25	NS
22	201	22201	25	30	DNR
23	185		25	32	DOT
23	186	23186	3	10	DNR
23	187	23187	10	17	DNR
23	188	23188	17	27	DNR
23	189	23189	27	32	DNR
23	190	23190	32	42	DNR
23	191	23191	42	52	DNR
24	211		2	35	DOT
24	212	24212	2	15	DNR
24	213	24213	15	28	DNR
24	214	24214	28	38	DNR



Hole ID	Sample ID	Sample Number	Depth From (ft)	Depth To (ft)	Lab Type
25	215	25215	0	32	DOT
25	216	25216	0	18	DNR
25	217	25217	18	41	DNR
26	126	26126	9	14.5	DOT
26	127	26127	24.5	45.5	DOT
26	128	26128	5	9.3	DNR
26	129	26129	9.3	14.5	DNR
26	130	26130	21	24.5	DNR
26	131	26131	24.5	29	DNR
26	132	26132	29	31	DNR
26	133	26133	31	38	DNR
26	134	26134	38	45.5	DNR
26	135	26135	45.5	46	DNR
27	218	27128	7	21	DOT
27	219	27219	2	12	DNR
27	220	27220	12	21	DNR

# **APPENDIX E**

## **VOLUME ESTIMATES**

## VOLUME ESTIMATE

The volume estimate is a statistical representation of the sand and gravel deposit. The statistics are based on information gathered from the 27 rotosonic drill holes over 735 acres of land. The natural variance of a sand and gravel deposit coupled with the distance between drill holes (>1000 feet) affects the accuracy of a statistical representation. Due to this reason, the estimate is given a “indicated mineral resource” categorization specified within the *Guide for Reporting Exploration Information, Mineral Resources, and Mineral Reserves*.

The best engineering volume of the sand and gravel was estimated as being:

(Cubic Yards)	Subarea A	Subarea B	Subarea C	AREA 1
	County Pit	North of Pit	Remainder	Total
Above Water Table		900,000	3,400,000	4,300,000
Below Water Table	5,900,000*	2,000,000	11,900,000	19,800,000
Total	5,900,000*	2,900,000	15,300,000	<b>24,100,000</b>

Using classical statistics and geo statistics to calculate variances within the deposit, there is an 15 to 20 percent probability that the volume will be no less than:

(Cubic Yards)	Subarea A	Subarea B	Subarea C	AREA 1
	County Pit	North of Pit	Remainder	Total
Above Water Table		500,000	1,000,000	1,500,000
Below Water Table	3,300,000*	1,100,000	4,300,000	8,700,000
Total	3,300,000*	1,600,000	5,300,000	<b>10,200,000</b>

\*NOTE: Because the water table is at or near the pit floor, this estimate combines the gravel above or below the water table.

## **APPENDIX F**

### **GRADATIONS (SIEVE ANALYSIS)**

The sieve analysis is based on the amount of sediment passing through a specified sieve size. The amount passing is represented by a percent of the total weight.

Sample #	1.75	1.25	1	3/4	3/8	#4	#10	#35	#50	#200
01016	96	91	86	79	67	54	32	9	6	2.7
01017	100	97	93	91	84	78	60	27	21	8.3
01018	100	96	92	87	77	59	32	12	9	4.4
01019	100	97	93	87	76	58	31	6	4	1.8
01020	94	88	83	80	68	53	28	5	3	1.5
01021	93	89	83	78	69	59	44	13	9	3.2
01022	100	100	100	100	97	95	88	26	9	0.8
01023	91	89	81	77	64	55	41	9	5	1.7
01024	100	97	94	93	91	90	81	23	10	1.8
02194	80	74	69	67	56	43	23	6	4	1.6
02195	84	83	79	75	60	47	26	7	5	2.4
02196	91	91	88	88	85	80	59	21	12	1.0
02197	77	73	70	68	59	53	41	16	9	1.4
02198	90	85	81	78	72	64	47	12	6	2.3
03139	100	95	94	90	77	62	33	5	3	1.4
03140	79	76	67	58	44	34	21	4	3	1.0
03141	100	86	81	78	63	49	27	6	4	1.3
03142	43	32	31	28	22	17	12	4	3	1.0
03143	98	91	81	78	64	56	35	5	3	1.2
03144	81	72	64	56	43	33	20	7	6	2.7
03145	85	81	78	75	62	48	24	5	3	1.3
03146	59	53	53	43	31	23	14	7	4	0.6
04027	91	86	82	74	52	36	17	3	2	0.7
04028	87	72	66	56	37	30	22	5	2	0.4
04029	87	80	73	70	58	48	31	9	6	1.7
04030	74	72	68	65	56	44	24	3	2	1.1
04031	91	83	80	72	55	44	29	6	4	2.1
04032	92	84	79	74	58	48	29	9	6	2.8
04033	100	100	98	95	91	82	45	3	2	1.3
04034	97	92	88	86	82	77	47	4	3	1.1
05230	91	91	91	90	84	78	65	20	11	3.7
05231	93	81	76	69	56	42	24	8	6	2.6
05232	96	93	90	89	84	77	62	16	6	0.6

Sample #	1.75	1.25	1	3/4	3/8	#4	#10	#35	#50	#200
05233	92	85	84	81	73	64	49	15	9	1.5
05234	91	82	78	73	59	50	31	7	5	1.6
06108	100	92	92	92	90	87	79	63	53	14.1
06109	100	100	100	98	98	97	94	88	80	9.7
07002	91	83	80	76	65	56	42	19	14	3.5
07003	100	100	100	100	97	92	83	51	33	6.2
07004	93	88	86	83	75	71	60	15	9	2.4
07005	100	100	98	98	96	94	88	41	25	5.1
07006	88	88	88	87	82	78	65	27	16	3.5
07007	100	94	93	93	89	85	75	39	25	1.7
07010	100	100	98	96	91	84	67	28	16	3.2
07011	92	92	86	83	71	59	36	11	7	2.3
07012	100	96	91	90	88	84	74	31	18	2.8
07013	79	69	65	61	51	39	23	7	5	2.3
07014	100	100	100	100	99	97	92	45	30	4.6
08036	100	100	100	100	100	100	98	87	70	17.0
08037	100	100	100	98	94	89	77	42	29	6.2
08041	94	89	86	84	78	69	54	33	27	7.5
08042	100	100	100	98	94	92	73	34	22	2.4
08044	95	92	86	77	55	39	15	6	4	2.0
08045	86	83	78	72	54	36	11	3	2	1.6
08046	100	100	99	90	87	85	72	16	7	1.2
08047	97	83	79	73	65	57	39	11	7	2.1
08048	95	80	77	73	60	52	35	10	6	1.4
08049	79	44	22	17	6	3	0	0	0	0.0
08050	91	83	74	64	43	31	14	4	3	1.6
08051	94	89	83	75	59	43	21	10	8	4.7
08052	100	100	97	93	87	82	74	41	32	7.8
08053	100	100	100	100	100	99	92	70	55	3.4
08054	90	90	90	87	85	84	77	29	19	3.9
08055	100	100	100	100	100	99	89	21	15	3.6
08056	100	100	100	100	100	99	97	38	16	0.9
08057	100	100	100	100	100	99	99	89	63	2.4

Sample #	1.75	1.25	1	3/4	3/8	#4	#10	#35	#50	#200
08058	100	100	100	100	100	100	98	41	23	3.0
08059	100	100	100	100	100	99	96	79	67	7.6
08060	100	100	100	100	99	99	97	79	63	6.4
08061	100	100	100	100	99	97	88	37	20	4.4
08062	100	100	100	100	98	96	91	42	24	7.5
09227	100	100	100	100	100	100	100	99	97	23.8
10124	100	100	100	100	97	95	94	90	78	15.2
10125	97	92	88	87	84	80	65	25	16	3.9
11178	85	80	78	77	68	59	44	18	13	4.6
11179	94	88	82	78	63	54	38	16	11	3.4
11180	80	78	74	71	63	51	32	14	10	3.6
11181	87	85	78	74	64	53	34	8	4	0.0
11182	100	97	95	93	87	77	54	15	7	1.2
11183	86	81	74	69	52	40	24	10	7	2.7
11184	83	80	78	74	63	55	38	10	6	2.0
12112	100	100	100	95	88	85	75	33	24	4.7
12113	100	100	100	97	96	95	93	60	28	4.7
12114	95	92	87	85	71	62	44	15	8	2.3
12115	100	92	91	88	79	69	51	18	10	2.7
12116	100	96	90	88	81	74	60	18	10	3.3
12117	79	71	65	56	39	30	20	10	8	2.5
12118	89	89	89	88	82	73	43	11	7	2.9
12119	78	73	68	59	43	32	20	9	7	2.4
12120	89	89	87	85	79	70	47	15	9	2.6
12121	100	100	100	98	95	91	76	24	14	3.2
12122	100	96	95	91	72	53	28	12	10	3.7
13168	100	100	99	98	93	86	72	34	23	7.5
13169	88	84	83	80	71	59	39	11	6	2.3
13170	81	78	75	73	62	56	43	11	6	1.5
13171	100	96	96	95	93	91	82	17	7	1.6
13172	85	79	75	68	56	49	36	10	7	3.5
13173	94	92	89	84	65	54	37	12	7	1.7
13174	100	92	84	80	65	54	37	11	6	1.7

Sample #	1.75	1.25	1	3/4	3/8	#4	#10	#35	#50	#200
13175	94	92	88	86	79	70	51	21	13	2.6
14158	93	85	82	79	66	56	39	17	14	5.6
14159	81	79	76	72	60	51	39	19	14	4.6
14160	100	91	86	81	65	53	34	11	7	2.8
14161	100	95	92	89	75	66	51	19	13	4.7
14162	96	96	91	87	75	64	43	15	10	3.7
14163	84	78	74	68	58	49	32	10	7	2.8
14164	96	90	84	80	65	54	34	13	10	4.9
14165	79	72	65	61	50	43	30	12	10	4.2
15149	85	83	78	76	66	60	47	21	13	1.5
15150	76	72	70	68	60	51	32	9	6	2.0
15151	96	90	88	85	77	65	38	11	6	1.9
15152	85	79	72	69	62	55	35	10	7	2.5
15153	86	86	84	82	80	78	72	22	12	1.2
15154	95	89	85	83	73	64	42	9	6	2.2
15155	73	73	70	66	57	46	28	11	9	2.8
16237	100	100	100	100	100	99	93	71	51	9.0
16238	100	100	100	100	100	99	94	67	55	12.5
16239	100	94	90	83	68	58	46	25	20	5.6
16240	93	93	93	93	89	84	68	25	17	2.9
16241	87	83	78	75	62	44	20	5	3	0.7
16242	95	91	86	83	73	62	43	11	6	1.6
16243	96	92	90	86	74	64	45	14	9	3.0
17204	100	100	100	99	97	95	89	43	24	5.5
17205	100	100	100	100	99	98	92	45	30	9.8
17206	100	100	100	96	92	88	76	23	12	2.6
17207	94	84	79	77	64	53	34	10	6	1.8
17208	80	64	63	57	43	33	20	5	3	1.3
17209	72	53	48	42	32	24	13	4	3	0.7
17210	92	92	88	84	67	50	29	10	6	1.7
18081	96	89	87	84	75	66	50	27	23	6.9
18082	100	86	85	83	74	65	46	15	11	5.3
18083	100	95	89	86	75	66	51	27	22	9.1



Sample #	1.75	1.25	1	3/4	3/8	#4	#10	#35	#50	#200
18084	90	90	85	83	74	65	44	10	7	3.0
18085	93	93	92	89	79	67	48	14	7	0.0
18086	100	100	98	97	92	83	61	27	21	7.3
18087	100	100	100	97	90	81	56	14	10	3.8
18088	77	71	64	58	38	29	19	6	5	2.2
18089	86	83	78	74	66	53	31	8	5	1.4
18090	100	89	83	78	65	54	39	21	15	4.7
18091	100	96	94	90	82	72	48	13	9	4.4
18092	91	84	77	73	61	51	34	14	10	4.0
18093	100	100	100	100	96	92	88	58	34	4.5
19065	100	100	94	94	91	85	75	46	31	5.3
19066	94	91	85	83	71	62	45	28	22	5.8
19067	93	87	82	77	66	55	39	21	17	4.1
19068	91	83	80	76	69	61	46	27	22	7.1
19069	97	92	87	76	54	34	16	7	5	2.5
19070	95	93	93	79	64	49	25	7	5	2.8
19071	93	89	86	81	67	52	25	5	4	1.4
19072	95	88	83	80	75	71	63	27	16	2.2
19073	95	95	91	90	83	75	46	8	5	1.7
19074	100	100	100	100	100	96	70	20	13	3.8
19075	83	76	68	62	48	36	21	9	8	4.0
19076	100	94	89	85	63	46	23	9	7	4.1
19077	78	78	75	72	61	50	36	18	15	3.6
20096	100	100	100	97	89	78	57	13	10	4.7
20097	100	98	92	89	80	74	65	25	16	3.9
20098	100	100	96	91	83	76	63	28	21	6.9
20099	100	98	95	94	87	78	62	38	27	3.8
20100	100	100	96	94	89	81	67	25	16	4.4
20101	100	100	100	99	97	94	85	57	40	7.7
20102	100	100	100	100	100	100	99	98	95	34.3
20103	94	88	83	78	69	58	39	12	8	2.5
20104	93	93	93	90	88	84	74	27	13	2.2
20105	90	87	79	76	65	55	35	8	6	2.3

Sample #	1.75	1.25	1	3/4	3/8	#4	#10	#35	#50	#200
20106	73	65	63	59	52	45	32	12	10	4.4
20107	100	94	92	92	90	88	86	57	28	7.1
21222	93	89	87	85	82	76	61	32	25	7.8
22200	94	91	87	85	74	63	44	18	13	4.5
22201	93	89	88	85	70	59	32	19	16	2.7
23186	100	100	98	95	94	91	86	62	44	6.3
23187	89	83	82	81	74	69	59	22	15	1.2
23188	97	91	82	75	67	57	43	18	11	3.4
23189	87	82	79	77	73	69	59	37	27	1.6
23190	96	94	90	86	75	64	46	20	12	2.4
23191	100	100	95	94	89	85	73	40	28	4.2
24212	95	92	90	88	87	85	81	41	23	4.4
24213	100	93	93	93	92	91	88	71	52	2.1
24214	100	100	100	99	98	96	80	27	18	2.7
25216	95	92	91	90	86	83	74	35	23	4.1
25217	100	85	83	83	82	81	75	41	28	2.4
26128	100	100	98	98	97	95	89	35	20	2.5
26129	86	86	79	76	67	62	52	18	11	2.5
26130	100	91	91	88	79	70	56	33	24	6.1
26131	100	100	99	97	93	86	60	17	9	1.5
26132	100	100	100	100	100	99	98	85	62	1.0
26133	100	100	98	98	96	94	91	51	32	2.4
26134	97	93	89	87	79	63	36	13	9	2.9
26135	91	75	68	59	45	35	22	12	10	5.5
27219	100	96	94	91	81	71	49	18	12	5.7
27220	95	95	95	95	93	92	86	33	12	2.1