TECHNICAL REFERENCE FOR MINNESOTA'S INDUSTRIAL MINERAL WASTES/BY-PRODUCTS

By

Julie A. Oreskovich, Lawrence M. Zanko, Richard L. Patelke, and John J. Heine

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Natural Resources Research Institute
Economic Geology Group
5013 Miller Trunk Highway
Duluth, MN 55811

EXECUTIVE SUMMARY

This investigation presents a single technical reference document, or "catalog," of industrial mineral mine wastes (by-products), focusing primarily on Minnesota's crushed stone and dimension stone industry, e.g., limestone, trap rock, granite, gneiss, and quartzite. Additional, but more limited, information from silica sand, clay, and Quaternary-based sand and gravel operations are also included. For this study's purposes, "wastes" are considered to be unsaleable or unmarketable materials that remain following the quarrying and/or processing of an operation's primary mineral products. Consequently, "waste" is largely an economic term, in that if the materials in question are not (or cannot be) sold or used under existing market conditions, they represent - in essence - an accumulating zero (or negative) value inventory. These wastes include fines, stripping materials, and marginal-grade stone in ponds, stockpiles or discard piles.

Survey responses, written correspondence, telephone interviews, site visits, and selected laboratory analyses were used in assembling the document's project data, including data for 56 hard rock quarries. The reference document includes the following information for each Minnesota operation: 1) location information, i.e., where the wastes are currently disposed (landfill, stockpile, settling pond, reclaim area, etc.); 2) the mechanism(s) of disposal (pipeline, dump truck, etc.); 3) volume and tonnage estimates; and 4) all other available technical information, i.e., rock type, particle size, chemistry, mineralogy, etc. It is similar in approach to the International Center for Aggregates Research (ICAR) report ICAR-101-1, *An Investigation of the Status of By-Product Fines in the United States*, by Hudson et al. (1997).

Project findings indicate that screening and wash fines, particularly those finer than 200 mesh, comprise the majority of problematic wastes generated by Minnesota's dimension stone, crushed stone, and sand and gravel producers. Nearly 2.3 million tons of on-site fines were reported in survey responses. Carbonate rock producers have an edge in that their fines can be sold as agricultural liming material (ag-lime). However, production exceeds demand and the fines accumulate in ponds or stockpiles. Granite and quartzite producers lack a market at the present time for their pond fines. Research at the University of Minnesota on using Minnesota granite fines as soil amendments has shown little promise to date. On the other end of the scale, Minnesota's dimension stone producers are saddled with huge grout stockpiles of oversized material, including unusable quarry stone, block rejects, and block cutoffs. Over 2.5 million tons in oversized material were reported. Stripping materials present another significant waste product, although they can be sold as fill and are often stockpiled in reserve for reclamation purposes.

Issues important to the survey respondents were also compiled. Environmental, permitting, and regulatory top the list of those issues having the most impact on a producer. Land use issues, including aggregate availability, ranked even in terms of impact with technical specifications issues. These include meeting Mn/DOT specs, producing a uniform product, and the magnesium sulfate soundness test on limestone. Business conditions were also identified as having the most impact in terms of the general economy and the financial health of retail granite dealers. Other issues reported as having the most impact were taxes, costs, funding for road projects, the public's ignorance to the importance of the aggregate industry to society; and an outstate producer's opportunity to access the metro buyer arena and gain acceptance in that arena.

Many of the same issues identified by the project's survey were identified by the Aggregate and Ready Mix (ARM) Association of Minnesota in 2001, i.e.,

1. difficult permitting process;
2. limited supply of quality aggregate;
3. conflicting land use; and
4. increased transportation costs

All four of these issues have been cited multiple times by the 2001 NRRI survey respondents. Additionally, a fifth issue (identified by ARM as critical to the ready mix industry) has also been heavily cited by the survey respondents as critical to the aggregate industry:

5. increasing environmental regulations

It is hoped that the availability of a single reference for Minnesota's industrial minerals producers makes it possible for anyone interested in developing alternative uses of industrial mineral mine wastes to efficiently assess each waste material's product potential, thereby saving time and resources that would otherwise be spent searching for information one operation at a time. Ultimately, this reference could act as a catalyst for generating innovative ideas on industrial mineral mine waste utilization. In both the short- and long-term, such ideas can benefit the waste user, the waste producer, and the state of Minnesota.

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NOTE: Much of the data reported herein were collected between 2000 and 2002, and are presented with respect to conditions that existed during that period of time, but do not necessarily exist now. For example, Meridian Aggregates Co. in St. Cloud, MN, is now Martin Marietta Aggregates. Fortunately, industrial mineral resources, pits, quarries, stockpiles, and plant locations are far less variable than the more dynamic world of company ownership. Even though some changes have occurred since 2002, most of the basic technical facts about industrial mineral wastes/by-products have not.

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INTRODUCTION

BACKGROUND

In 1995, the International Center for Aggregates Research (ICAR), located at the University of Texas at Austin, began researching issues surrounding the handling and disposal of fines resulting from aggregate crushing and processing. ICAR found that fines production (fines generally being defined as particles that pass a 200 mesh screen, i.e., finer than 0.075 mm.) exceeds demand, resulting in their accumulation in stockpiles and settling basins. This held true for the related dimension stone industry as well, posing both economic and environmental problems for producers. It is estimated that 5 % to 15 % of a plant's potential product is washed away as pond screenings (Stokowski, 1993).

Recognition of the fines problem came to light in the early 1990s. As population centers encroached on pits and quarries, space became a concern. This translated into a need to move waste stockpiles to access reserves, and to recover and stockpile wastes from settling basins to make room for more. Stated plainly, it meant that operators were getting squeezed.

Clearly, the best solution to this problem lies in making use of the wastes as-is, or turning them into saleable by-products, thus reducing and/or removing the problem while generating additional income. With nearly 115 million tons of pond screenings alone being produced annually (Stokowski, 1993), there are potentially one billion-plus tons of recoverable processed mineral fines available across the United States. This constitutes a tremendous resource.

Minnesota's industrial minerals industry is a significant contributor to the state's economy, and faces many of the same issues just discussed. The industry, comprised of crushed stone, dimension stone, sand and gravel, silica sand, and industrial clay producers, generates a variety of "waste" and/or by-products. Therefore, it was felt that a single technical reference (or "catalog") should be produced that identified the source, type, quantity, and quality of as many of these by-product materials as possible, to help increase the potential for their utilization.

ICAR STUDY

ICAR presented its findings in a 1997 report entitled, "*An Investigation of the Status of By-Product Fines in the United States.*" The report was the result of an effort to "quantify and characterize these fines, their location, character, and sales" (Hudson et al., 1997). Data were gathered from producers' responses to a mailed survey.

Numbers generated from ICAR survey responses illustrate the magnitude of the fines problem. Table 1 summarizes annual figures nation-wide relative to fines production, marketing, and accumulation, as presented in the ICAR report. The fines are broken down into two size fractions. Screenings account for the majority of the - 3/8 in. fines while pond fines account for most of the - # 200 fines. Of the estimated 470-500 million tons of - 3/8 in. fines produced annually, nearly 80 % are marketed, leaving around 20 %, or 90-100 million tons, to accumulate (Table 1). The ICAR study noted that some states were able to market all of their - 3/8 in. fines, most likely because materials finer than 3/8 in. but coarser than 200 mesh fit the definition of "fine aggregate." In contrast, only 23 % of the estimated 100-110 millions tons of - # 200 fines produced annually are marketed. While accumulating at a slower rate than the - 3/8 in. fines (75-80 million tons annually), the obvious problem here is a lack of identified markets.

Table 1 Nationwide estimates in millions of tons (after Hudson et al., 1997).

National Fines Production Estimates (MT)		
	- 3/8 in.	- # 200
Estimated Annual Production	470-500	100-110
Estimated Annual Amounts Marketed	380-400	20-30
Estimated Annual Amounts *Not* Marketed	90-100	75-80
Estimated Annual Amounts Stockpiled	300-325	400

ICAR has identified areas of usage to concentrate on for both the - 3/8 in. fines and the - # 200 fines. These will be presented in a later section dealing with current and potential uses for the fines. One of the recommendations of the ICAR study is to place greater emphasis on the - # 200 fines over the - 3/8 in. fines, due to the greater difficulty in marketing this size fraction (Hudson et al., 1997). Further recommendations include determination of exact stockpile locations, GIS maps for each state, and comprehensive market survey and usage research to develop effective marketing strategies.

PURPOSE, SCOPE, AND BENEFITS OF CURRENT PROJECT

The purpose of this project is to implement the recommendations of the ICAR study for the State of Minnesota by: 1) identifying accumulated wastes (stockpiled or held in settling ponds) that are generated by the processing of Minnesota's geological resources into aggregate, sand and gravel, dimension stone, and related products; 2) determining the location, amount, physical, chemical, and mineralogical characteristics of said wastes; 3) identifying current and potential uses for said wastes; and 4) compiling this information into a technical reference with accompanying GIS database. The byproducts of Minnesota's taconite mining industry, while voluminous, are not included in this study.

The scope of this project extends beyond the fines of the ICAR study to encompass any and all wastes/by-products resulting from the aforementioned processing of Minnesota's stone resources. Included as such is the already marketable ag-lime, a fines by-product of processing limestone and dolomite. The availability of analytical data on this by-product made it a logical choice for inclusion in the directory.

Project benefits include acknowledging and recognizing that these typically environmentally benign by-products (rock and mineral particles of various sizes, but mostly fines) are the end-result of a tremendous expenditure of energy and capital, yet they can go largely unexploited. However, in combination with other materials or processes, some of these by-products might have potential for use in one or more applications, e.g., construction, wastewater treatment, soil amendment, etc. For example, Dr. David W. Fowler (1999), Director, International Center for Aggregates Research (ICAR), states that, **"*....a major research effort still needs to be conducted to determine the exact nature and location of fines in different regions and by different aggregate sources such as limestone, granite, sand, gravel, etc. Also, since only 23% of the minus # 200 fines produced each year reach the market, more research is needed into uses for these difficult-to-market fines.*"**

Therefore, the availability of a single reference for Minnesota's industrial minerals producers makes it possible for anyone interested in developing alternative uses of industrial mineral mine wastes to efficiently assess each waste material's product potential, thereby saving time and resources that would otherwise be spent searching for information one operation at a time. Ultimately, the reference could act as a catalyst for generating innovative ideas on mine waste utilization. In both the short- and long-term, such ideas can benefit the waste user, the waste producer, and the state of Minnesota.

PROJECT APPROACH

The major dimension stone and crushed stone operations in Minnesota were initially identified from the Skillings 2000 Minnesota Mining Directory (Skillings, 2000). Visits to quarry and plant sites in 2001 provided a first-hand view of operations. Such visits initiated discussions regarding processing by-products viewed as waste materials, i.e., unsaleable or under-valued materials that cost money in terms of removal or re-moving. Ideas for possible usage were exchanged, along with acknowledgment that here lies a potential resource. Selected samples of accumulated by-products were collected for analysis.

A survey was developed inquiring about information on companies, plant/processing facilities, quarrys/pits, quarry/plant wastes, types of products produced, product and waste analytical data, and mining and processing details. The information requested followed the form of the ICAR study. Of particular interest, in addition to the identification of wastes/by-products, was a series of questions regarding wastes, marketing of wastes, potential uses of wastes, beneficial research relative to wastes, and identification of issues impacting business.

Initially, 45 surveys were distributed to dimension stone, crushed stone, silica sand, and clay operations throughout Minnesota, along with 3 to the organizations that represent many of them: the Minnesota Asphalt Pavement Association (MAPA), the Concrete Paving Association of Minnesota, and the Aggregate Ready-Mix Association of Minnesota. An additional 121 surveys were distributed to sand and gravel, ready-mix, bituminous, concrete product, and construction operations throughout the state. A copy of the survey is included in Appendix A. A listing of the survey recipients is provided in Appendix B.

PROJECT RESPONSE

The initial response (via the survey, other written response, e-mail, personal visit, or phone conversation) and subsequent site visits resulted in contact with 24 of the 45 original survey recipients, or 53%, which is an excellent response rate for a survey of this type. The ICAR (Hudson et al., 1997) study's response rate was 26.5%. Response by the second set of 121 survey recipients was very light, as expected; only 10 responses were generated from this group. The size and nature of sand and gravel operations (the focus of the second survey) versus dimension and crushed stone operations (the focus of the first) yields fewer opportunities for waste accumulation. While wash plant fines are one potential waste/by-product, apparently there is not sufficient accumulation in most sand and gravel pits to have warranted much survey interest. Still, the fact that a total of 34 survey responses were received is quite good considering that four Minnesota companies were queried by the ICAR (Hudson et al., 1997) study, and only one of them responded.

Twelve by-product samples were collected and one additional sample was submitted for analytical analysis. The samples analyzed included drilling fines, screening fines, hydrocyclone fines, rock saw fines, wash plant fines, and a lime filter cake product from a municipal water treatment plant.

DATA ACCUMULATION AND PRESENTATION

The information presented in this report comes from several sources, including previous investigations, Web searches, survey responses, site visits, interviews, and sample analyses. Reported analytical data were supplied by individual producers, obtained from published sources, or determined by experimental procedures. Collected samples were analyzed for particle size, geochemisty, and mineralogy. Particle size analysis was done by the settling tube (sedimentation) method at NRRI. Geochemistry was run by an independent laboratory, ACME Analytical Laboratories, Ltd., Vancouver, British Columbia; ACME's assay methods used are presented with the chemical data. Mineralogy was determined with a Philips X-ray diffractometer located in the University of Minnesota, Duluth, Department of Geological Sciences.

PROJECT TERMINOLOGY

Understanding the terminology used in any investigation can be nearly as important as the investigation's content itself. The following descriptions are presented to clarify the meaning of the terminology used in this report.

Wastes and/or by-products

Industrial mineral mine wastes are those unsaleable or unmarketable materials generated in the course of quarrying and/or processing primary mineral products. These wastes include stripping materials, marginal-grade stone, and fines; all are relegated to accumulate in on-site settling ponds, stockpiles, or discard piles. In looking towards finding a market for these materials, perhaps a better term to use is "by-products," thus eliminating the negative connotations of the term "wastes."

Dimension Stone By-products

Quarry by-products produced by dimension stone operations lay at opposite ends of the size spectrum. On the large end, there are unusable quarry blocks (grout blocks) of rock comparable in size to refrigerators and minivans. These blocks can weigh as much as forty tons. They amass in huge grout piles, and contain rejected quarry products that run the full gamut of sizes from dust to the 40-ton blocks just described.

On the fine end of the size spectrum, two by-products are produced: drilling fines and saw fines. Sand- to silty-sand-sized fines are generated by quarry drilling. At least one operation removes these fines subsequent to drilling by vacuuming them from the top of the rock ledge. The drilling fines are bagged and disposed of. A finer material, saw fines, is produced in the block processing plant where sawing, grinding, and polishing of the rock occurs. The sludge generated in these processes is pumped out to a tailings or settling basin, from which it must be dredged and stockpiled to make room for more. Saw fines tend to be predominantly silt-sized (62.5 μ to 2 μ), with some clay-sized (≤2 μ), but very little sand-sized (>62.5 μ), material present. They can also contain metal particles abraded from the saws.

Crushed Stone By-products

Quarry by-products produced by crushed stone operations are termed fine, finer, and finest. Their definition has been addressed by the Turner-Fairbank Highway Research Center (TFHRC) in McLean, VA, home to the Federal Highway Administration's (FHWAYS) Office of Research, Development, and Technology.

The TFHRC has posted two very useful articles related to quarry by-products, specifically fines, on its website. The first article, *Quarry By-products - Material Description* (http://www.tfhrc.gov/hnr20/recycle/waste/qbp121.htm), defines the three quarry by-products produced from blasting, crushing, washing, screening, and stockpiling operations as follows: 1) screenings; 2) settling pond fines; and 3) baghouse fines. The article examines current management options, market sources, highway uses and processing requirements, and material properties. The second article, *Quarry By-products - User Guideline (Flowable Fill)* (http://www.tfhrc.gov/hnr20/recycle/waste/qbp122.htm), looks at using the fines in flowable fill, including describing the engineering properties of the fines. Table 2 contains a summary of data assembled from the two articles.

Table 2 Characteristics of the three types of fines (summarized from Quarry By-products, 2001: a & b).

Type	Screenings	Settling Pond Fines	Baghouse Fines
Sieve Size	- # 4 sieve (4.75 m m); most are - 1/8 in. with 6% - 12% - # 200	- # 30 (0.59 m m) to 75% - 90% - # 200	- # 200 (0.075 mm)
Particle size	medium to fine sand, some silt	very fine sand to silt, some clay	silt to clay
Disposal	stockpiled	pumped to settling pond	collected dry or sluiced to settling pond
Recovery	standard excavation equipment; dump vehicles	dragline; stockpile; dewater; truck haul	wet fines recovered same as settling pond fines
Moisture	dry to slightly damp 5% - 10% moisture	wet high as 70% -80% moisture when dredged; low as 20% -30% final moisture	dry dry powder
Unit Wt.	greater than pond fines	less than screenings; slightly more than baghouse fines	slightly less than baghouse fines
Properties	fresh-fractured faces; fairly uniform gradation; few plastic fines	relatively consistent within a given quarry	non-plastic; relatively uniform over time for a given source and process

Screenings

Screenings are the portion of crushed rock that pass a # 4 sieve (4.75 mm). While most of the material is finer than 1/8 in., there is only a small fraction (6-12 %) that will pass a # 200 sieve (0.075 mm). Screenings fall into the medium to fine sand-size range and contain some silt-sized material. They tend to have freshly fractured faces and a fairly uniform gradation. Generally, screenings are produced dry and stockpiled; recovery is by standard excavating and hauling equipment. Moisture is in the 5-10 % range, although that can increase as the stockpile is exposed to the elements. Unit weight should be in the range of the parent rock source. The unit weight of the screenings will be heavier than that of the settling pond fines (Quarry By-products, 2001: a & b).

Settling Pond Fines

Settling pond fines are the result of washing crushed rock. These particles range in size from passing a # 30 sieve (0.59 mm) to 75-90 % passing a # 200 sieve. They range from very fine sand to silt and clay in size. While the + # 30 sieve material is recovered for use, the fines represent the overflow portion that is pumped out with the wash water to a settling basin. Draglines are often used to recover and stockpile the settling pond fines (Quarry By-products, 2001: a & b).

Moisture content is very high in the stockpiled pond fines, e.g., as much as 80% when initially dredged, and reduced to as low as 20-30% by natural dewatering (Quarry By-products, 2001: a). Stokowski (1993) places this figure much lower: 20-30 % moisture when recovered from the pond, reduced to 5-15 % during stockpiling. He states that recovery moisture varies according to rock type. The highest moisture occurs in sand and gravel wash pond fines; the lowest in the associated flume sands. Crushed stone pond fines generally have a 20-25 % recovery moisture. Carbonate rock pond fines are slower to dewater than granite or diabase pond fines, likely due to finer size, higher absorption, and angular grain shape. If the pond fines are rich in mica, dewatering is poor, often to the point of retaining close to the original recovery moisture (Stokowski 1993). When necessary, the moisture content of pond fines can be further reduced by means of mechanical dewatering devices such as hydrocyclones, belt presses, or rotary driers. The unit weight of the settling pond fines is generally less than that of the screenings and slightly greater than that of the baghouse fines for a given rock source (Quarry By-products, 2001: a & b).

Chemistry and mineralogy of the pond screenings differs from that of the washed aggregate (Stokowski, 1993). Because chemistry and mineralogy vary with grain size, variations will occur from the coarser to the finer fractions even within the screenings. Granites exhibit a slight increase in mica and CaO in the fines when compared to the washed aggregate, and the coarser fines have a higher quartz and mica content than those at the finer end, which are enriched in feldspar (Stokowski, 1993). In the case of plants processing a limestone and dolomite mixture, Stokowski (1993) states that there is an enrichment of $CaCO_3$, SiO_2, Al_2O_3, Fe_2O_3, and K_2O relative to $MgCO_3$ in the finest sizes, possibly due to both calcite's lower specific gravity and its relative softness compared to dolomite.

Baghouse Fines

Baghouse fines result from the use of dust collection systems in dry plant operations. These particles all pass a # 200 sieve and most pass a # 325 sieve (0.045 mm). They range from silt-size down to clay-size, and are comparable to a finely-sized fly ash in size and consistency. The baghouse fines can be recovered from the system as a dry powder or be sluiced out to a settling basin. Recovery from the settling basin would be as described above for settling pond fines. Baghouse fines are non-plastic. Their unit weight is generally slightly less than that of settling pond fines for a given rock source. Over time, the baghouse fines can be expected to be relatively uniform for a given source and process (Quarry By-products, 2001: a & b).

Ag-lime

Ag-lime refers to those by-products of carbonate rock processing that are applied to soils as agricultural liming material for neutralization purposes. Ag-lime serves as a source of Ca (and Mg, if the material is dolomitic) for plant uptake. In addition to carbonate rock quarries, another source of ag-lime is municipal water treatment plants where lime is used in the treatment process.

GEOLOGY

The geology of Minnesota's industrial mineral mines encompasses all three basic rock types: igneous, metamorphic, and sedimentary. These rocks range in age from Archean (older than 2.5 billion years) to Proterozoic (2.5 to 545 million years) to Phanerozoic (younger than 545 million years). Dimension stone and crushed stone producers operate in igneous granites and basalt, metamorphic gneisses, quartzites, and schists, and sedimentary carbonates (limestones and dolomites) and sandstones. Kaolinitic and illitic industrial clays that are Pre-Cretaceous (older than 150 million years) to Cretaceous (150 to 65 million years) in age are mined for brick-making, pottery clay, cement, and as filler for livestock feed. Sand and gravel operators mine the Quaternary (younger than 2 million years) glacial deposits, primarily those deposited in the last 10,000 years (Holocene). The geological units from which Minnesota's industrial mineral mine wastes/by-products are produced are identified for individual operations in Part III.

For additional background and context, the Minnesota Geological Survey's (MGS) *Minnesota at a Glance - Common Minnesota Rocks* (Lusardi et al., 2000) provides an excellent summary of the geologic sources of Minnesota's industrial minerals industry. For more detailed information about individual rock formations and/or locations, many more publications and resources are available at the following agency websites:

Minnesota Geological Survey
http://www.geo.umn.edu/mgs/currentpubs.htm

Minnestota Department of Natural Resources (MDNR), Division of Lands and Minerals
http://www.dnr.state.mn.us/lands_minerals/pubs.html

and

Natural Resources Research Institute (NRRI), Economic Geology Group
http://www.nrri.umn.edu/egg/

MINNESOTA'S INDUSTRIAL MINERAL MINE WASTES

The remainder of this document presents data compiled for many of Minnesota's industrial mineral operations between 2000 and 2002. Analytical data are presented in a series of tables and figures. For convenience, the document has been divided into three major parts, as follows:

PART I: SUMMARY OF FINDINGS

Types of mineral wastes generated, available quantities, current and potential uses, and related industry issues, as identified from survey results and site visits, are summarized and discussed.

PART II: SAMPLING/TESTING PROGRAM: ANALYTICAL DATA ON COLLECTED SAMPLES

Analytical data generated from the testing of waste samples collected/submitted for this project are summarized and discussed. Analytics include particle size, geochemistry, and mineralogy.

PART III: DETAILED SYNOPSES OF MINNESOTA'S INDUSTRIAL MINERAL PRODUCERS

Producers are grouped by primary commodity, i.e., crushed stone, dimension stone, sand and gravel, or related entities. Data in Part III include: producer information, quarry and/or pit locations, rock type, products, by-products, by-product size, by-product amount, by-product storage location, geology, and analytical data such as particle size, geochemistry, and mineralogy.

A series of Appendices (A to F) are also included, and are organized as follows:

APPENDIX A: Industrial Mineral Survey
APPENDIX B: Listing of Survey Recipients
APPENDIX C: Waste Resource / Quarry Listings
APPENDIX D: Minnesota Department of Agriculture Ag-Lime Analyses
APPENDIX E: U of M Rosen Study
APPENDIX F: Data/GIS Files

PART I: SUMMARY OF FINDINGS

Through on-site visits and survey responses, this project confirmed the findings that drove the ICAR study (Hudson et al., 1997); namely, that millions of tons of problematic waste materials have accumulated in stockpiles and settling ponds in quarries across the state of Minnesota. Of prime importance to the NRRI study is the identification of the types of wastes generated by Minnesota's industrial mineral operations, their current and potential uses, and present marketability. By providing technical data on specific wastes, it is hoped that global or niche market opportunities can be found to convert what are now considered wastes into marketable by-products.

OVERVIEW

Two major categories of problematic wastes were identified: 1) over-sized wastes; and 2) fine wastes (fines). These have been broken down into subtypes and are presented in Table 3, along with the number of operations cited in this report that are generating each. Two additional by-products of the industrial mineral industry can become problematic wastes when generated in excess volume. Stripping (overburden) is a by-product universally common to all operations. Because stripping is generally held for reclamation purposes, it was not generally identified as a waste material. Ag-lime (agricultural liming material) is a common by-product of the southeastern and south central Minnesota carbonate operations. Since ag-lime is a marketable product, it, too, was generally not identified as a waste material. A common response from producers choosing not to participate in the survey was a lack of problematic wastes.

Table 3 Minnesota's industrial mineral wastes, as identified from survey results.

	Over-size Wastes			Fines					
				Coarse (sand- to silt-sized)			Fine (silt- to clay-sized)		
	Grout Piles	Sand-stone Rubble	Over-size Rock	Drilling Fines	Screen-ings	Cyclone/ Hydro-cyclone Product	Saw Fines	Wash (Pond) Fines	Water Treatment Filter Cake
# of Operations	4	1	1	1	7	2	3	11	1

While not all survey respondents reported a tonnage figure on the amount of accumulated materials, a partial picture of the magnitude of the waste/by-product accumulation problem is seen in Table 4. Accumulated stripping amounted to 1.15 million tons for one producer alone. Five producers have together generated over 2.5 million tons of stockpiled over-size rock. Almost 90 % of this amount (2.25 million tons) is accounted for by two producers. Seven producers reported a total of nearly 2.27 million tons of fines, stockpiled or held in settling ponds.

Table 4 Total reported tonnage of Minnesota's industrial mineral wastes/by-products.

Waste/By-product	On-site Tonnage	# of Reporting Producers
Stripping	1,150,000	1
Over-size Wastes	2,526,000	5
Fines	2,268,500	7

Discussion

Stripping wastes, for most of Minnesota's industrial mineral producers, do not present a problem, as they are held in reserve for reclamation purposes. Fines, particularly the - # 200 material, are by far the most common type of waste material generated by all of Minnesota's stone operations. Larger materials are readily used or marketed for construction purposes. The exception is very large stone block (grout block) wastes generated by the dimension stone industry. The sheer bulk of these blocks (refrigerator- to minivan-sized) often makes them difficult to handle and crush with conventional aggregate production equipment, which requires that secondary breakage be performed first. It is important to remember that the main objective in dimension stone production is to produce very large blocks by keeping fracturing to a minimum during the quarrying process. Conversely, aggregate operations generally hope to achieve just the opposite, i.e., optimize fragmentation - via blasting - prior to crushing and screening. This difference is also a function of geology. Dimension stone sources are typically found in rock formations that have minimal natural jointing and fracturing, and/or are thick-bedded and monolithic, whereas most (but not all) crushed stone aggregate sources come from rock formations that are not as monolithic or physically pristine.

While the majority of wastes encountered during the project occupy opposite ends of the size spectrum, those at the fines end tend to be the most problematic. The largest waste materials always have potential for use in landscaping or as rip-rap, and can be reduced to more manageable sizes (albeit with some effort). Conversely, the finest wastes are often water saturated, contain impurities, and are not easily handled or transported. However, the biggest obstacle and most intractable problem currently associated with mineral fines is that there simply is little demand for such materials. The key to fines utilization is creativity and perhaps taking the path less traveled. Fortunately, fines generated by limestone and dolomite producers can at least be used as a soil amendment, i.e., agricultural lime, or ag-lime. However, these fines are the most attractive when they are reasonably dry and friable. If they cannot be spread easily, they are of little use to the farmer. In most crushed carbonate rock operations, the fines are generally dry.

STRIPPING

For Minnesota's dimension and crushed stone quarries, stripping materials (the overburden that is removed to access the economic units) generally consist of soils, glacial deposits, clays, and/or decomposed bedrock. For the sand and gravel operations, stripping materials typically consist of soils and clayey glacial materials. Stripping materials are often used for constructing berms at the quarry and pit sites, and can be sold for fill and topsoil. Many operations report that the stripping materials are stockpiled for future quarry and pit reclamation. Some operations, such as Bryan Rock Products, have very little stripping, e.g., just 2 ft., according to Bill Bryan (pers. comm., 2001).

Several dimension stone operations benefit from partnering with crushed stone operations that remove the rock overlying usable dimension stone units, processing it into aggregate. For example, Milestone Materials operates in the Biesanz Stone Co. quarry in Winona County, and Southern Minnesota Construction (SMC) operates in the Blue Earth County quarries of Mankato-Kasota Stone, Inc. and Vetter Stone Co.

In general, stripping materials are not considered a problematic waste as evidenced by lack of reference to them in the survey responses. Table 5 presents the location and amount of accumulated stripping materials at three Aggregate Industries crushed stone quarries. Stripping yardage for the three quarries totals 1.15 million cubic yards.

Table 5 Compilation of accumulated stripping resources.

Company	Waste Source	County	Waste Type	Waste Location	Waste Yards
Aggregate Industries North Central Region	Larson Quarry	Washington	Stripping	Stockpiles and berms	1,000,000
	Hastings Quarry	Dakota	Stripping	Stockpiles and berms	50,000
	Red Wing Quarry	Goodhue	Stripping	Stockpiles and berms	100,000
				Total:	1,150,000

OVER-SIZE WASTES/BY-PRODUCTS

Over-size wastes, in the form of block rejects and end cut-offs, are common to dimension stone producers. Large rocks and unsuitable rock types can also be encountered in crushed stone operations. Over-size wastes are particularly problematic to dimension stone producers in outstate Minnesota that quarry igneous and metamorphic rocks.

Dimension stone is produced from large blocks of rock that are quarried in such a way as to minimize fracturing. This is done by such means as drilling small diameter holes, wedging, and wire sawing. It would require the blasting, fragmentation, crushing, and screening of a crushed stone operation to reduce block rejects to a usable product. This is not economically feasible for most dimension stone producers. Because the granite, gneiss, and quartzite quarries are located well outside of the primary Twin Cities metropolitan area market, with other generally available and acceptable aggregate sources located nearby, the over-sized materials tend to accumulate where they are produced.

Carbonate rock dimension stone producers in Minnesota have the advantage of a somewhat softer (and, therefore, more easily processed) material, market demand, and crushed stone-producing partners operating out of the same quarries. These producers are located near the Twin Cities metropolitan area and high-growth communities, e.g., Rochester, of southeastern Minnesota. In these areas, aggregate is at a premium and in shortening supply. Economics are favorable for producing aggregate materials by processing quarry block rejects, cut-offs, and quarry rock unsuitable for dimension stone use.

Identified Resources

Huge grout piles (stockpiles that consist of quarry block rejects, block end cut-offs, and various size pieces that range from clay-sized to 40-ton blocks) have amassed at many of Minnesota's outstate dimension stone quarries. Tonnage figures for various quarries were provided by Cold Spring Granite Co. and Dakota Granite Co. (Table 6).

Table 6 Compilation of available grout pile resources.

Company	Quarry	Rock Type	Waste Type	Waste Location	Waste Size	Waste Tons
Cold Spring Granite Co.	Rainbow Quarry	Gneiss	Grout	Stockpile	Dust to 40-ton blocks	230,000
	Agate Quarry	Granite	Grout	Stockpile	Dust to 40-ton blocks	50,000
	Charcoal No. 3 Quarry	Granite	Grout	Stockpile	Dust to 40-ton blocks	750,000
	Diamond Pink Quarry	Granite	Grout	Stockpile	Dust to 40-ton blocks	85,000
	Isle Quarry	Granite	Grout	Stockpile	Dust to 40-ton blocks	250,000
	Lake Superior Green Quarry	Granite	Grout	Stockpile	Dust to 40-ton blocks	35,000
	Mesabi Black Quarry	Granite	Grout	Stockpile	Dust to 40-ton blocks	30,000
	Purple Crystal Quarry	Granite	Grout	Stockpile	Dust to 40-ton blocks	25,000
	Rockville No. 1 Quarry	Granite	Grout	Stockpile	Dust to 40-ton blocks	300,000
	Rockville No. 2 Quarry	Granite	Grout	Stockpile	Dust to 40-ton blocks	300,000
Dakota Granite Co.	Bellingham Quarry	Granite	Grout	Grout Pile	N.A.	200,000
					Total:	2,255,000

In addition to grout piles, a few other over-size wastes were identified in the survey (Table 7). Ulland Brothers, Inc., of Cloquet, MN, a trap-rock aggregate producer, reported an accumulation of over-size rocks from their basalt rock crushed stone operation. These are rocks in the 15- to 20-ton range, which have limited uses and are difficult to transport. The company has found use for smaller over-sized rock in breakwater walls, specialized landscaping, and erosion control. Mankato-Kasota Stone, Inc. reports a stockpile of scrap stone in varying sizes from their fabrication plant in Mankato. Milestone Materials hosts an accumulation of sandstone rubble at the Golberg Quarry in Houston County.

Table 7 Compilation of additional available over-size waste resources.

Company	Waste Source	County	Rock Type	Waste Type	Waste Location	Waste Size	Waste Tons
Ulland Brothers, Inc.	Becks Quarry	St. Louis	Basalt	Over Size Rocks	Stockpile	15-20 Tons	20,000
Mankato-Kasota Stone, Inc.	Fab Plant	Blue Earth	Dolomite	Scrap stone	Stockpile	Varies	1,000
Milestone Materials	Golberg Quarry	Olmsted	Sandstone	Sandstone Rubble	Stockpile	N.A.	250,000
						Total:	271,000

Current Uses

Current uses for over-size wastes/by-products include rip rap, road bed material, and berm construction material (Table 8). Mankato-Kasota Stone uses scrap limestone for rip rap, road bed material, and berm construction material. Ulland Brothers, Inc. has found use for the over-size rock at its basalt quarry in breakwater walls, erosion control, and specialized landscaping. Dakota Granite Co. splits some of its larger sizes of granite for ashlar stone work (a rectangular block of hewn stone used for building purposes). Some is also used as rip rap on dam raceways. Most of it, however, is discarded in grout piles. Cold Spring Granite Co. reported that their over-size granite and gneiss wastes go unused for the most part; hence the large grout piles at each of their quarries.

Table 8 Current and potential uses for Minnesota's over-size industrial mineral wastes/by-products.

Rock Types	Current Use	Potential Use
Basalt Dolomite Gneiss Granite Limestone	Ashlar Stone Work Berm Construction Breakwater Walls Erosion Control Rip Rap Road Bed Material Specialized Landscaping	Safe Harbor Construction Shoreline Protection

Potential Uses

There were few suggestions for potential use of over-size materials, particularly from dimension stone operations (Table 8). For carbonate dimension stone producers such as Mankato-Kasota Stone, there is not enough volume of over-sized scrap materials to economically market. However, the situation is totally different for the state's granite producers. Dakota Granite Co. (2001 survey response) expressed it in this manner: "*Our product is dimension stone and consequently our waste granite is usually large blocks. We cannot compete with crushing operations that quarry with large blast holes and fragmentation.*"

In the crushed rock arena, one company did provide a potential use for their over-size rocks. Ulland Brothers sees potential use for the over-size rock from their basalt quarry in safe harbor construction and shoreline protection.

FINE WASTES/BY-PRODUCTS

Fine wastes are generated by drilling, crushing, screening, washing, and sawing. They are inherent across the board to all industrial minerals operations. While fines are recoverable and saleable up to a point, the ubiquitous wash fines (predominantly - 200 mesh in size) are the most problematic. Wash fines are sluiced out to settling ponds, from which they must be recovered by excavation, and stockpiled, in order to make room for more. In the ever-tightening land-lock surrounding quarries today, space is at a premium. Finding a use for the stockpiled excavated fines would have the double benefit of resolving space issues in quarries and providing a large, untapped, raw material source for the entrepreneurial user.

Identified Resources

Fine wastes identified in this project range from - 3/8 in. to - # 200 (aka - 200 mesh) in size. They include screenings, quarry/drilling fines, hydrocyclone products, wash fines, rock saw fines, and a filter cake product that is generated at a municipal water treatment plant. Table 9 presents these fine wastes along with size data and accumulated tonnages, where available. The fine wastes are grouped from coarsest to finest.

Large tonnages of dolomitic limestone fines are available at Aggregate Industries' Larson Plant in St. Paul Park, as well as screenings from Milestone Materials' Hammond and Willey quarries, and Edward Kraemer & Sons, Inc.'s Burnsville Quarry. The latter are the coarsest of the fines cited in this report (- 3/8 in.; - 3/16 in. at the Burnsville Quarry). No other particle size data was provided. The "dirty" quartzite fines available at Sioux Rock Products' Jeffers Quarry are comparable in size to a marketed product, but contain too much - 200 mesh material to pass critical specs. The "dirty" fines are gravel- and sand-sized, for the most part, with 10.6 % of the material silt-sized or finer.

The quarry/drilling fines and hydrocyclone products are primarily sand sized, with a significant silt-size component and minor amount of clay-sized material. Hydrocyclones are used to separate out the coarser component of wash fines in order to recover a saleable product.

Southern Minnesota Construction's Morton Quarry fines are somewhat finer than the others listed in this group, running nearly 50:50 sand-size/finer than sand-sized. It should be noted here that the # 230 sieve (0.0625 mm) was used as the sand/silt cut-off for all samples tested at NRRI.

According to both survey responses and particle size testing results, the greatest percentage of the wash fines sent out to settling ponds is - # 200 sieve (0.075 mm) in size. Although a few of the tested samples contain a significant sand content, the pond fines are predominantly silt-sized. Tested quartzite wash fines from Sioux Rock Products' Jeffers Quarry and the New Ulm Quartzite Quarries plant contain a significant clay-sized (2 microns and smaller) fraction. Dolomitic limestone wash fines from Ed Kraemer & Sons' Burnsville Quarry proved the coarsest of the tested wash fines, with over 40 % sand-sized material. Gravel wash from Guaranteed Gravel & Sand's plant contain significant sand and clay fractions (15 % and 9 %, respectively). While there are stockpiles of recovered wash fines at most operations, the majority of this waste material remains in the ponds where they have settled out. Recovery and de-watering will be necessary prior to use.

Table 9 Reported available resources of fine wastes/by-products (excluding ag-lime) at Minnesota's industrial mineral operations.

Company	Waste Source	County	Rock Type	Waste Type	Waste Size	% Gravel	% Sand	% Silt	% Clay	Waste Tons	Waste Yards
Sioux Rock Products	Jeffers Quarry	Cottonwood	Quartzite	Dirty fines	-3/8"	40.24	49.18	8.37	2.21		
Agg. Industries No. Central Region	Larson Plant	Washington	Dolomitic Limestone	Limestone	-3/8"					200,000	
Milestone Materials	Hammond Quarry	Wabasha	Dolomitic Limestone	Screenings	-3/8"					30,000	
Milestone Materials	Willey Quarry	Olmsted	Dolomitic Limestone	Screenings	-3/8"					5,000	
Ed Kraemer & Sons, Inc.	Burnsville Quarry	Dakota	Dolomitic Limestone	Screened fines	-3/16"					262,000	151,000
Southern Minnesota Construction	Morton Quarry	Renville	Gneiss	Quarry fines	- # 10	0.74	51.19	40.04	8. 03		
Cold Spring Granite	Rockville Quarry	Stearns	Granite	Drilling fines	- # 10	0.45	67.43	28.40	3.72		
Meridian Aggregates	St. Cloud Quarry	Stearns	Granite	Hydrocyclone Product	- # 18	0.33	72.67	23.46	3.54		
Ortonville Stone Company	Ortonville Plant	Big Stone	Granite	Hydrocyclone Product	- # 50	0.01	65.28	32.63	2.08	5,000	
Guaranteed Gravel & Sand	Plant	Blue Earth	Gravel	Wash fines, pond	- # 100	0.11	14.58	76.46	8.85	10,000	7,000
Meridian Aggregates	St. Cloud Quarry	Stearns	Granite	Wash fines, pond	- # 200						
	Yellow Medicine Quarry	Yellow Medicine	Granite	Wash fines, pond	- # 200						
Ortonville Stone Company	Ortonville Stone Co. Quarry	Big Stone	Granite	Wash fines, pond	- # 200						
Sioux Rock Products	Jeffers Quarry	Cottonwood	Quartzite	Wash fines, pond	- # 200*	4.32	16.93	68.47	16.28	5,000	
New Ulm Quartzite Quarries, Inc.	Plant II (wash plant)	Nicollet	Quartzite	Wash fines, pond	- # 200*	0.00	3.40	81.37	15.23	400,000	
Roverude Construction, Inc.	Gengler Quarry	Houston	Dolomite	Wash fines, pond	- # 200						
Aggregate Industries North Central Region	Hastings plant	Dakota	Dolomitic Limestone	Wash fines, pond	- # 200					5,000	
	Larson Plant	Washington	Dolomitic Limestone	Wash fines, pond	- # 200					1,000,000	
Edward Kraemer & Sons, Inc.	Burnsville Quarry	Dakota	Dolomitic Limestone	Wash fines, pond	- # 200*	1.51	40.93	53.87	3.89	225,000	170,000
Milestone Materials	Golberg Quarry	Olmsted	Dolomitic Limestone	Wash fines, pond	- # 200						
*Ponded wash fines are typically designated as being - # 200 due to that size fraction comprising a high percentage of the material.											
Cold Spring Granite	Plant	Stearns	Granite	Rock saw fines	- # 200	0.02	4.40	80.96	14.62		
Biesanz Stone Company	Plant	Winona	Dolomite	Rock saw fines	- # 200	0.00	1.37	84.58	14.05		
Mankato-Kasotz Stone	Plant	Blue Earth	Dolomite	Rock saw fines	- # 200	1.76	4.58	72.42	21.24	500	250
City of Mankato	Water Treatment Plant	Blue Earth	Lime	Filter Cake	- # 200	0	0.45	95.52	4.03		

Testing of the rock saw fines from several dimension stone operations (granite and dolomite) determined that they are 94-98 % - # 200 in size. The rock saw fines are predominantly silt-sized with a clay-size content ranging from 14 - 21 %. These fines are sluiced out into settling ponds and must be recovered.

The City of Mankato's water treatment plant produces a filter cake product as a result of using lime to treat the city's water supply. This fine (> 95 % silt-sized) waste material is available to locals for use as an agricultural liming material. Other water treatment plants generate similar materials, especially those located in south-central and southeastern Minnesota. For example, the St. Paul Water Utility (SPWU) Treatment Plant shipped over 44,000 cubic yards of spent lime filter press material in 2001 for agricultural purposes, according to Ms. Martha Burckhardt, Water Quality Specialist, Saint Paul Regional Water Services (pers. comm., 2002).

Current Uses

Current uses of Minnesota's industrial mineral fines, as reported through survey results, site visits, and phone contacts, are presented in Table 10. The most common uses of carbonate rock fines are ag-lime and fill material. Edward Kraemer & Sons, Inc. has found a use for screened and blended lime fines in animal bedding. Wm. Mueller & Sons, Inc sells its quarry lime fines as baseball diamond dust for infields.

Table 10 Current uses of Minnesota's industrial minerals fines (excluding most pond fines).

Rock Type	Current Use
Dolomite Limestone	Ag-lime Animal Bedding Baseball Diamond Dust Fill Material
Granite, Quartzite	Seal Coat Chips Manufactured Sand
Schist	Driveways Blacktop Applications
Gravel	Fill

Sioux Rock Products' crushed quartzite fines (screenings) are washed to produce seal coat chips and manufactured sand. Bowman Construction Co. in International Falls uses their crushed schist fines in driveways and blacktop applications.

Some carbonate rock pond fines have a high soil neutralization value (i.e., at Milestone Material's Golberg Quarry), making them a saleable product. Guaranteed Gravel and Sand is able to sell a small percentage of their - 100 mesh gravel pond fines as fill material. In general, and especially for non-carbonate rock types, there has been little market in Minnesota for the - 200 mesh size fraction. Typical survey responses regarding use of pond fines included "stored on site," "sits in ponds," "no market yet," and "currently has no value." Such comments are an indication of the large size of this resource that is awaiting commercial utilization.

Potential Uses

Potential uses for Minnesota's industrial mineral fines have been identified from three sources: 1) particpants in this study; 2) a 1993 article written for Rock Products magazine by Steven Stokowski, Jr., titled "The Many Uses of Pond Screenings"; and 3) the 1997 ICAR report (Hudson et al., 1997).

NRRI Study

Several ideas were proposed during the project as a result of direct discussion with Minnesota's stone producers and through survey responses. These ideas are summarized in Table 11.

Table 11 Potential uses for Minnesota's industrial minerals fines wastes/by-products.

Carbonate Rock	Granite, Gneiss	Quartzite	Sand & Gravel
Ag-lime Soil amendment (particularly for acid soils of northern MN) Pelletized and spread with fertilizer as soil amendment Carrier of fertilizers Filler in roofing shingles Soil neutralizer Metallic mining reclamation Engineered fill Filler Binder	Filler in roofing shingles and plastics Microsurfacing applications Encapsulation of incinerator ash Fertilizer (in combination with poultry wastes) Soil amendment	Soil amendment Extender (in combination with bentonite) Filler Replacement for cement in concrete mixes Marker bed around fiber optic cables	Soil amendment Fertilizer (in combination with compost)

Survey responses regarding potential markets/uses for the fines material varied according to the type of parent rock. Granite/quartzite producers indicated mineral filler and soil amendment material as possibilities. Carbonate rock producers listed potential in soil neutralization, including metallic mining reclamation, engineered fill, filler, and taconite binder. Guaranteed Gravel & Sand sees potential for their - 100 mesh gravel fines in soil enhancement or conditioning. The gravel fines could be blended in during a composting operation.

Sites visits yielded more suggestions. Mr. Steve Beach of Mathy Construction Co./Milestone Materials (pers. comm., Jan., 2001) discussed potential agricultural uses for the carbonate rock fines. In addition to ag-lime, there is potential as a soil amendment, particularly in treating the acid soils of northern Minnesota. The fines could be pelletized and spread with fertilizer as a soil amendment. Additionally, the fines could serve as carriers of fertilizer. Another use discussed was as a filler in roofing shingles.

Mr. Jeff Carlstrom of New Ulm Quartzite Quarries (pers. comm., Jan., 2001) acknowledged that fines are a big issue. He proposed use of the quartzite fines as fillers, as a replacement for cement in concrete mixes, as a soil amendment, and blending the fines with bentonite as an extender. A rather novel idea suggested by Mr. Carlstrom was use of the New Ulm Quartzite Quarries fines to surround fiber optic cables in the ground. The unique purple color of the material would serve to warn anyone digging of the presence of the cables. Mr. Carlstrom also mentioned a Minnesota company that combines silica and lime, then forms and autoclaves it, to produce block.

Mr. Don Vry of Superior Minerals, formerly with Meridian Aggregates Co. (now Martin Marietta Aggregates), discussed using granite fines as fillers in roofing shingles and plastics, and the coarser portion of the fine fraction (> 350 mesh) in microsurfacing applications (pers. comm., Jan., 2001). He referred to the high micro-fines concrete of ICAR Project # 102-F (Ahn and Fowler, 2001). He also noted that there is a garbage-burning facility in Minneapolis that uses granite dust to help encapsulate the ash it produces to make it easier to handle. Currently this granite dust is brought from Wisconsin because Meridian Aggregates (now Martin Marietta) did not produce enough of the dust to supply the company with the 1,000 TPY needed. There is potential for combining fines from several Minnesota granite producers to meet this demand. One last potential use proposed by Mr. Vry was the combination of granite fines and poultry (turkey) wastes as a fertilizer.

Pond Screenings Study

Over 85 potential uses for pond screenings have been identified by Steven Stokowski, Jr. in an article written for Rock Products magazine titled "The Many Uses of Pond Screenings" (Stokowski, 1993). This article is an excellent resource for producers looking to find viable uses for these wastes. In discussing potential products, Stokowski states, "High fineness materials have value in applications where a chemical reaction takes place, where the material is to be mixed with other fine materials (such as in portland cement manufacture), or when specific minerals are being liberated from the original rock." (Stokowski, 1993, p. 39.) Actual uses will be plant-specific and determined by evaluation of the by-product and the economics of supplying the potential markets. Stokowski (1993) asserts that the key to a saleable product is large quantities of consistent material. A summery of Stokowski's product listing, geared toward the Minnesota producers in this report, appears in Table 12.

Table 12 Potential uses for pond screenings (after Stokowski, 1993).

Dolomite/Limestone	Granite/Gneiss/Quartzite	Traprock
Animal shelter absorbent	Animal shelter absorbent	Animal shelter absorbent
Feed additive; poultry grit	Horse tracks (light-colored)	Poultry grit
Horse tracks	Poultry grit	Sand-blasting grit
Manufactured topsoil	Manufactured topsoil	Manufactured topsoil
Ag-lime; physical soil amendment (sand-sized to improve drainage)	Trace mineral soil amendment; physical soil amendment (sand-sized to improve drainage)	Trace mineral soil amendment; physical soil amendment (sand-sized to improve drainage)
Electrical cable backfill	Glass, earthenware, stoneware, and porcelain ceramics, ceramic glazes	Glass ceramics
Portland Cement additive	Portland Cement additive	Portland Cement additive
Carpet backing filler	Floor Hardener	Floor Hardener
Asphalt blotter	Asphalt blotter	Asphalt blotter
Fill material: flowable, granular, under-slab, hydraulic, and reinforced earth fills	Fill material: flowable, granular, under-slab, hydraulic, and reinforced earth fills	Fill material: flowable, granular, under-slab, hydraulic, and reinforced earth fills
Pumped grout	Pumped grout	Pumped grout
Mineral filler in asphaltic concrete and slurry seal, masonry cement, and Portland Cement concrete products	Mineral filler in asphaltic concrete and slurry seal, masonry cement, and Portland Cement concrete products	Mineral filler in asphaltic concrete and slurry seal, masonry cement, and Portland Cement concrete products
Pyroprocessed products such as manufactured aggregate; as additive in brick, lightweight aggregate, glass foam, mineral and rock wool, and tile and pipe	Pyroprocessed products such as manufactured aggregate; as additive in brick, lightweight aggregate, glass foam, mineral and rock wool, and tile and pipe	Pyroprocessed products such as manufactured aggregate; as additive in brick, lightweight aggregate, glass foam, mineral and rock wool, and tile and pipe
Masonry and plastering sand; road grit for ice and snow	Masonry and plastering sand; road grit for ice and snow	Masonry sand; road grit for ice and snow
Roofing shingle components	Roofing shingle components	Roofing shingle components
Soil stabilizer	Soil stabilizer	Soil stabilizer
Tracks and play areas	Tracks and play areas	Tracks and play areas
Elastomers; paint; cleansers	Cleansers	
Daily cover - landfills	Daily cover - landfills	Daily cover - landfills
Hazardous-waste solidifier	Hazardous-waste solidifier	Hazardous-waste solidifier
Pond-liner separators (sand)	Pond-liner separators (sand)	Pond-liner separators (sand)
Sludge-dewatering aid (sand)	Sludge-dewatering aid (sand)	Sludge-dewatering aid (sand)
Sludge Stabilizer	Sludge Stabilizer	Sludge Stabilizer
Acid neutralization: acid-mine drainage, chemical- and dye-plant waste, highway construction, landfill-leachate, watersheds (acid-lake treatment)		

ICAR Study

Participants in the ICAR study were asked to identify current uses for their - 3/8-in. fines and - # 200 fines. The responses were compiled and are presented in Table 13.

Table 13 Reported current uses for quarry by-products fines (Hudson et al., 1997).

- 3/8 in. fines		- # 200 fines
Anti-Skid Bituminous Concrete Anti-Skid Abrasive Block Aggregate/Concrete Blocks/Block Mixes Base/Subbase Aggregate Products Fills Backfills Recreation Trails/Race Tracks/ Golf Courses/Baseball Diamonds, etc. Masonry Blocks/Bricks Subsurface Sewage Disposal Ice Control/Road De-icer Precast Units, Pipes, etc. DER Sand Poultry Grit/Traction Grit/Horse and Cattle Lots, etc.	Ag-lime Ready Mix Flowable Fills Septic Sand Mounds Stone for Shingles Soil Stabilization Glass Manufacture Desulfurization Residential Sanitary Systems Source of Calcite for Processing in Cement Kilns Fertilizer Filler Fertilizer Sub-ballast for Tracks Shooting Targets	Fill/Landfill Cover Material Base/Subbase Material Golf Courses/Ball Fields/Pool Liners Pipe Bedding Pond Liners/Embankments Backfills Reclamation Hot Mix Asphalt Septic System Fillers/Liners Top Soil Amendment Pugmix Cattle Bedding/Horse Stalls House Slab Fillers Ag-lime Bricks/Patio Slabs Blend With Cement Grade Limestone Block Production Ready Mix Blend With Compost Sediment Sand

The ICAR study recommended priority areas of focus for each of the two fines size fractions. For the minus 3/8-in. fines, the study proposes a focus on ready-mix flowable fills, cement-treated subbases, and low cost masonry uses. For the minus # 200 fines, the study proposes a focus on ready-mix flowable fills and solid waste landfills (Hudson et al., 1997). A barrier to the use of minus # 200 fines in construction is caused by current construction specifications. Most limit the minus # 200 fines proportion of a mix to 8 % or less (Hudson et al., 1997). Other inhibiting factors identified by ICAR that affect usage of minus # 200 fines include lack of information on their quantities, characteristics, and properties (which this NRRI report seeks to address for Minnesota operations), handling problems, and associated costs of processing and transport (Hudson et al., 1997).

University of Minnesota Study

In 1999, the University of Minnesota began a three-year study to determine if crystalline rock fines could be used as a nutrient source for crop production. The study was undertaken in response to the increasing amount of rock fines being generated and stockpiled in Minnesota, and the potential to reduce farm input costs of importing mined mineral products from outside of Minnesota, particularly for organic agriculture (Rosen et al., 1999).

The greatest nutrient benefit from rock fines for agriculture would be expected from the finer size fractions; they present more exposed surfaces for weathering, leading to nutrient release. Rock fines in two size fractions were collected from each of four quarries, three in Minnesota and one in Wisconsin: Meridian Aggregates' (now Martin Marietta) St. Cloud Quarry (granite cyclone sand and pond tailings) and Yellow Medicine Quarry (Granite Falls; granite tower sand and pond settlings), Cold Spring Granite's St. Cloud quarry (granite shot saw and East plant settlings), and Dresser Trap Rock's Dresser Quarry (Dresser, WI; coarse and fine basalt) (Rosen et al., 1999). The results of physical and chemical tests run on the above can be found in Appendix E.

Rock fines were applied to four fields in central Minnesota at two rates (10 tons and 20 tons per acre) (Rosen et al., 1999). Crops consisted of hay, oats and alfalfa, corn, and grass and clover (Rosen, 2000). Reports detailing the study can be obtained from Dr. Carl Rosen at the University of Minnesota's Department of Soil, Water, and Climate.

The results of this three-year study proved disappointing. Effects on crop yields were inconsistent. It was concluded that nutrient release from the rock fines is slow, and thus they would have minimal effects on soil fertility and crop yields in the short term (Rosen, 2001).

AG-LIME

As stated previously, because ag-lime is a marketable product from lime fines, these fines generally were not reported as wastes. However, the sheer volume of ag-lime material generated makes this by-product available for additional use. Typically, the sand-size fraction comprises over 50 % of this material.

Milestone Materials *did* include stockpiled tonnage figures on ag-lime material, reporting it as excess aggregate material (Table 14). Ag-lime material is available from most carbonate crushed stone quarries. For a listing of ag-lime source quarries in Minnesota for the year 2001, please see Appendix D. The complete Minnesota Department of Agriculture Ag-Lime Analysis Reports for 2001 and 2004 are provided on the enclosed CD (see Appendix D).

Table 14 Reported available resources of ag-lime at six of Milestone Materials' carbonate rock operations.

Company	Waste Source	County	Rock Type	Waste Type	Waste Tons	Waste Yards
Milestone Materials	Golberg Quarry	Olmsted	Dolomitic Limestone	Ag-lime	40,000	
	Wykoff Quarry	Fillmore	Dolomitic Limestone		15,000	54.5
	Eggert Quarry	Fillmore	Dolomitic Limestone		8,000	52.6
	Pilot Mound Quarry	Fillmore	Dolomite		3,000	47.8
	43 Quarry	Winona	Dolomitic Limestone		40,000	52.8
	Horn Quarry	Houston	Dolomitic Limestone		15,000	
				Total:	**81,000.00 T**	

INDUSTRY ISSUES: SURVEY RESPONSES

Of prime importance to this study was the identification of the most common types of wastes/by-products generated by Minnesota's industrial mineral producers, together with their current and potential uses and marketability. It is hoped that such listings, as provided above, will equip producers with new avenues of pursuit for the sale and reduction of waste materials. These issues were addressed in a series of questions posed on the final page of the study's survey packet (Appendix A).

Several related issues were also addressed here. Two questions were directed at learning what would be the most beneficial development to an operation in terms of waste material utilization and marketing, and what type of technical research would prove most beneficial. Survey recipients were also asked to identify issues of concern and impact as an operator doing business in Minnesota. Finally, the survey directed producers to project ahead by identifying the top three issues expected to impact their business in the next 5 to 10 years.

The full questions concerning related issues, with accompanying responses, are presented below. In addition, critical issues facing the aggregate industry in Minnesota as identified by the Aggregate and Ready Mix Association of Minnesota are presented and discussed.

1) What would be the most beneficial development for your operation, in terms of waste material utilization or sale?

Response:

1. Finding a use for rocks, so they wouldn't have to be crushed down.
2. Disposition of chunks.
3. Development of a market for fines.
4. Something that would require the removal of 10,000 to 15,000 tons of wash pond fines each year.
5. Drying the product, then bagging as gardening supplement.
6. To provide virgin and recycled aggregate products.
7. A high-volume local use for the waste, or a very inexpensive transport method.
8. Having a good relationship with a subcontractor who has ample markets for our scrap.

While the first two responses relate solely to dimension stone producers, the remainder are applicable to nearly all of the operations. Development of a market for wastes, particularly the pond fines, would benefit all of the industry's producers. Response seven above directs attention to the cost of transportation in relation to waste usage.

Response to this survey question was slim. Two possible interpretations for this could be: 1) wastes are not a concern; 2) the concept of wastes as a marketable product has been given little thought because historically the market hasn't been there. As one granite dimension stone producer wrote: "*It is difficult for us to invest a lot of money in our granite wastes in as much as their sale is such a rare thing.*"

2) What type of technical research would be most beneficial to your operation?

Response:

1. Development of a practical use for wash pond fines.
2. Chemical properties [of pond fines] in relation to soil benefits.
3. Chemical analysis of fines and all other products.
4. Finding the advantage of our particular rock.
5. Anything that would create a market for our waste.
6. Use of glass in concrete.

Chemical analysis of the wastes, as proposed in two of the responses, is basic to finding a solution for their use. As with the previous question, this one garnered little response. Three of the responses are very non-specific, indicating an unsureness on the part of producers as to how to begin finding a market for their wastes. Again, the past history of un-marketability plays a role here. Stated succinctly by one granite dimension stone producer: "*We are a technically oriented company, but granite wastes are mainly still that - wastes that accumulate.*"

The final response (#6 above) - use of glass in concrete - comes from Bowman Construction Co. in Grand Rapids, MN. Bowman Construction Co. has found ways to use all of its quarry wastes. In addition, the company is actively involved in recycling items, including old asphalt and concrete, and imports wood chips for composting. Extension of recycling to include the incorporation of glass into the quarry products for use in concrete is an avenue Bowman Construction Co. would like to pursue (Carl Bowman, pers. Comm., April, 2001).

3) What issues concern you the most as an operator doing business in Minnesota?

Response: See Table 15.

Table 15 presents a list of concerns reported by Minnesota's industrial mineral producers as operators doing business in Minnesota. Topping the list are the interrelated environmental, permitting, and regulatory issues. Increasing regulations at all levels of government covering air, land, water, wetlands, noise thresholds, and safety, and the paperwork and costs of compliance with said regulations, were concerns listed by a majority of those responding. Concerns regarding land use issues, such as mine expansion, zoning, and "NIMBY"ism (Not In My BackYard) and taxation were identified by multiple responders. Meeting technical specifications and the ASR (alkali-silica reaction) issue were the concerns of two producers. Additional reported concerns were: transportation concerns caused by resource exhaustion; material shortfall; excess stockpiles of RAP (recycled asphalt pavement), reported by the Minnesota Asphalt Pavement Association as not being utilized for sake of the buyers (taxpayers); and threat of litigation.

Table 15 Issues of concern as an operator doing business in Minnesota.

Issue	Sub-Issues	# of Responses
Environmental / Permitting / Regulatory Issues	Environmental issues	2
	Permitting new locations	2
	Increased government regulations: environmental and MSHA	2
	Costs ensuing from increased environmental and MSHA regulations	1
	Environmental paperwork	1
	Environmental permitting	1
	Dealing with the PCA	1
	Total Responses:	10
Land Use	NIMBY	2
	Mine expansion or new site development	1
	Zoning	1
	Total Responses:	4
Taxes	Total Responses:	3
Technical Specifications	Meeting MnDOT specs	1
	ASR issue	1
	Total Responses:	2
Transportation	Caused by resource exhaustion	1
Material Shortfall		1
Excess Stockpiles of RAP		1
Threat of Litigation		1

4) What issues impact you the most?

Response: See Table 16.

As seen in Table 16, intertwined environmental, permitting, and regulatory issues top the list of those issues having the most impact on a producer. Land use issues, including aggregate availability, ranked even in terms of impact with technical specifications issues. These include meeting Mn/DOT specs, producing a uniform product, and the magnesium sulfate soundness test on limestone. Business conditions were identified by a couple producers as having the most impact in terms of the general economy and the financial health of retail granite dealers. Other issues reported as having the most impact were taxes, costs, funding for road projects, the public's ignorance to the importance of the aggregate industry to society, and an outstate producer's opportunity to access the metro buyer arena and gain acceptance in that arena.

Table 16 Issues impacting Minnesota's industrial mineral operations.

Issue	Sub-Issues	Responses
Environmental / Permitting / Regulatory Issues	Environmental Issues: air, water, wetlands, etc.	3
	Permitting	3
	Paperwork related to environmental issues	1
	Dust control	1
	Noise control	1
	Total Responses:	9
Land Use	Aggregate availability	1
	Land Use	1
	NIMBY	1
	Space	1
	Total Responses:	4
Technical Specifications	MnDOT specs	2
	Magnesium sulfate soundness test on limestone	1
	Uniform product	1
	Total Responses:	4
Business Conditions	General Economy	1
	Financial health of retail granite dealers	1
	Total Responses:	2
Taxes		1
Costs		1
Funding for Road Projects		1
Public Ignorance to Aggregate Industry's Importance to Society		1
Access to the Buyer Arena and Acceptance in that Arena		1

5) What do you think will be the three top issues that impact your business in the next 5 to 10 years?

Response: See Table 17.

Table 17 Top three issues impacting business in the next five to ten years.

Issue	% of Responses	Sub-Issues	Responses
Environmental/ Permitting/ Regulatory Issues	28 %	Environmental	4
		Permitting	4
		Regulations	1
		Increasingly restrictive rules pertaining to acceptable thresholds of dust and noise in plants and in the outside environment	1
		Regulation, especially as it affects property rights	1
		Regulations - everything from federal to state to local zoning	1
		Total Responses:	12
Land Use	12 %	NIMBY	2
		Land Use	1
		Reserve sterilization by competing land	1
		Zoning	1
		Total Responses:	5
Aggregate Resources	9 %	Aggregate availability	1
		Demand for High End Building Material	1
		Shortage of Aggregate Material in the Metro Area	1
		Shortage of permitted reserves	1
		Total Responses:	4
Costs	9 %	Energy costs	2
		Capital costs	1
		Transportation costs	1
		Total Responses:	4
Business Conditions	9 %	Overall Business Conditions	1
		Aggregate Prices	1
		Health of the Iron Mining Industry	1
		Prospects for outstate producer to compete with Metro Area suppliers	1
		Total Responses:	4
Funding	7 %	Highway funding	1
		Amount of regional construction	1
		Asphalt projects	1
		Total Responses:	3

Table 17 continued

Issue	% of Responses	Sub-Issues	Responses
Transportation	7 %	Transportation	1
		Transportation relative to resource exhaustion	1
		Transportation policy	1
		Total Responses:	3
Taxes	5 %	Total Responses:	2
Technical Specifications	5 %	Testing procedures	1
		ASR issue	1
		Total Responses:	2
Wastes	5 %	Pond Fines (mud)	1
		Fines Disposal Issues	1
		Total Responses:	2
Other	5 %	Employees	1
		Tentative Plan to Build DM&E Railroad Across the State	1
		Total Responses:	2

Named most often as one of the top three issues to impact a producer's business in the next 5 to 10 years are the interrelated environmental, permitting, and regulatory issues (Table 17). Coming in second were the land use issues, including reserve "sterilization" by competing land, so prevalent in the metro area.

Three categories tied for third place: aggregate resources, costs, and business conditions. Aggregate resources, particularly the coming shortage thereof in the Twin Cities metro area (Southwick et al., 2000), and the demand for high end products, will significantly impact many of the state's producers. This subject will be dealt with in more detail below. Costs specified were energy, capital, and transportation costs. Specific business conditions cited include aggregate prices, the health of northeastern Minnesota's iron mining industry and, with the shortage of materials in the metro area, the prospects for an outstate producer to break into the metro market.

Tied for fourth on the list of impacting issues were funding and transportation. A northeastern Minnesota producer is dependent upon the amount of construction going on in his area, and asphalt projects in general impact the membership of the Minnesota Asphalt Pavement Association. Funding for these projects is a key stimulus. Transportation issues include policies in general, and the need to transport over greater distances as local resources are exhausted. Transportation costs associated with increased hauling distances will have a significant impact.

Taxes, technical specifications, wastes, and other round out the list of impact issues. Minnesota's tax climate is not perceived as being business-friendly. While there has been some improvement in recent years, taxation will continue to be a burden on producers. Technical specification issues cited include testing procedures and the ASR issue. Waste issues include fines disposal and finding markets for pond fines. Two other issues significantly impacting producers were cited: 1) employees; and 2) the plan to build a DM & E Railroad line across southern Minnesota. Rail line construction would be a significant boon, particularly to outstate producers of products like railroad ballast.

6) Do you have anything else you would like to discuss?

Response:

1. Transportation costs to market materials at greater distances, and how rail and barge terminals might help.
2. Recycling concepts need to be marketed to the agencies.

Only two survey recipients responded to this question. The first response points to the need to find an effective way to deal with transportation costs as haulage distances increase. This is of particular interest to the aggregate industry. One possible solution being discussed is the construction of rail and barge terminals. These terminals would serve as hubs to the acquisition and dispensing of aggregate materials.

The second response comes from the Minnesota Asphalt Pavement Association. At issue is the use of recycled materials such as RAP (recycled asphalt pavement) in new construction. Current specs allow insufficient use of recycled materials, contributing to the accumulation of still another waste product. Marketing recycling concepts to regulatory agencies such as Mn/DOT, the Federal Highway Administration, and the Federal Aviation Administration can lead to greater acceptance and increased usage of such materials as RAP and recycled concrete products/pavement.

CRITICAL ISSUES FACING THE AGGREGATE INDUSTRY (ARM)

Four critical issues facing the aggregate industry have been identified by the Aggregate and Ready Mix (ARM) Association of Minnesota (Industry Information, 2001):

1. Difficult Permitting Process
2. Limited Supply of Quality Aggregate
3. Conflicting Land Use
4. Increased Transportation Costs

All four of these issues have been cited multiple times by the 2001 NRRI survey respondents. Additionally, a fifth issue (identified by ARM as critical to the ready mix industry) has also been heavily cited by the survey respondents as critical to the aggregate industry:

5. Increasing Environmental Regulations

All five issues are discussed in greater detail below.

Difficult Permitting Process

Survey respondents have spoken to the permitting issue, making it tops in issues of concern and impact, both presently and projecting five to ten years into the future. Regulations have increased from the federal (PCA and U.S.Army Corps of Engineers) to the state (MDNR and MPCA) to the local (county and municipal governments) levels. Agencies and communities do have valid concerns that must be addressed during the permitting process. Among these are the noise and dust produced, heavy truck traffic on roadways causing potential safety problems, and the effect an operation will have on water quality, wetlands, wildlife, and property values. Common sense must be used to address these concerns and balance them with the need for the aggregate resource. A difficult permitting process hinders development of new resources and contributes to the problems of aggregate shortage, increased haulage distances, and increased costs.

Limited Supply of Quality Aggregate

Limited supply of quality aggregate is a critical issue, particularly in the Twin Cities metropolitan area, where demand is high and local aggregate is soon to be in short supply. High end aggregate products required by SUperior PERforming Asphalt PAVEments (Superpave) asphalts and high-performance concrete may reduce the use of some limestones and dolomites that are so plentiful in southeastern Minnesota. According to Pit and Quarry Magazine's Quarryology 101 (2001), the cubicle particles of manufactured sand produced from many high-calcium limestone deposits won't meet the designated amount of angularity required by Superpave specs. The compressive strengths of some of the carbonate rocks may not be high enough to support the predicted compressive strength of future high-performance concrete. While the typical compressive strength of fresh, unweathered limestone ranges from 2,000 - 37,000 psi, the typical compressive strength of today's concrete (3,000 - 5,000 psi) can be expected to be increased to 15,000 psi. Granites range from 14,000 - 45,000 psi and basalts range from 16,000 - 49,000 (Quarryology 101, 2001).

The ASR (alkali-silica reaction) issue has the potential to limit use of some of Minnesota's aggregate resources. Reaction of the alkalis in cement with certain types of siliceous materials in the aggregate can cause a gel to form around the aggregate particles. This gel will swell with the addition of moisture. As it expands, it places increased pressure on the surrounding aggregate particles and cement matrix, causing cracking and potential buckling that diminishes the strength of the concrete (Alkali-Silica Reaction (ASR), 2001). Some specially formulated cements can reduce ASR, but they can be more costly than "typical" portland cement.

Conflicting Land Use

Conflicting land use is a critical issue facing aggregate producers situated in or near municipalities. Particularly in the Twin Cities metropolitan area, competition for land is high. Aggregate operations are forced to yield to demands for housing developments and retail space. As existing operations run out of space, it has become increasingly difficult to permit and develop new resources. The NIMBY issue is a particular deterrent in this region as neighborhoods voice strong public outcry against the increased truck traffic, dust, noise, and safety concerns such an operation would potentially create.

Increased Transportation Costs

As the aggregate industry is driven further away from the immediate metropolitan areas**,** haulage distances increase. According to industry representatives in the Minnesota Public Radio (MPR) news feature, "*A Shortage of Stone?*"(Losure, 2000), a haulage distance of 30 miles causes aggregate prices to double. Gene Wright, of the ARM of Minnesota, uses the example of the city of Duluth (population of nearly 100,000) to illustrate the impact on costs with increased haulage distance (Losure, 2000). For a 10-mile haul, Duluth's yearly aggregate cost would be $ 1 million. As the distance extends to 30- and 40-mile hauls, that cost becomes $ 3 million to $ 4 million. Such increases have considerable implications for the Twin Cities metro area where aggregate haulage amounts to over 1 million tractor-trailer loads each year. At the 2003 Aggregate Mining Conference held in St. Cloud, MN, Jerry Bauerly, President, Bauerly Brothers, reported that the daily number of truck trips required for hauling aggregate in the 7-County Metro Area was projected to increase from a 1999 level of 3,000 per day to 20,000 per day when the area's current resources are exhausted and new resources have to be transported from greater distances to meet anticipated demand.

Increasing Environmental Regulations

Environmental issues and regulations were cited among the top issues affecting dimension stone, crushed stone, sand and gravel, and related industry operators doing business in Minnesota by NRRI survey respondents. They also topped the list of issues having the most impact on business now, and projecting 5 to 10 years into the future. Complying with air and water quality standards, wetlands issues, acceptable dust and noise thresholds, and the cost of doing the necessary environmental paperwork surfaced as critical issues.

SUMMARY

Screening and wash fines, particularly those finer than 200 mesh, comprise the majority of problematic wastes generated by Minnesota's dimension stone, crushed stone, and sand and gravel producers. Nearly 2.3 million tons of on-site fines were reported in survey responses. Carbonate rock producers have an edge in that their fines can be sold as agricultural liming material (Ag-lime).

However, production exceeds demand and the fines accumulate in ponds or stockpiles. Granite and quartzite producers lack a market at the present time for their pond fines. Research at the University of Minnesota on using Minnesota granite fines as soil amendments has shown little promise to date. On the other end of the scale, Minnesota's dimension stone producers are saddled with huge grout stockpiles of oversized material, including unusable quarry stone, block rejects, and block cutoffs. Over 2.5 million tons in oversized material were reported. Stripping materials present another significant waste product, although they can be sold as fill and are often stockpiled in reserve for reclamation purposes.

The project's survey respondents indicated that environmental, permitting, and regulatory issues top the list of those issues having the most impact on a producer. Land use issues, including aggregate availability, ranked even in terms of impact with technical specifications issues. These include meeting Mn/DOT specs, producing a uniform product, and the magnesium sulfate soundness test on limestone. Business conditions were also identified as having the most impact in terms of the general economy and the financial health of retail granite dealers. Other issues reported as having the most impact were taxes, costs, funding for road projects, the public's ignorance to the importance of the aggregate industry to society; and an outstate producer's opportunity to access the metro buyer arena and gain acceptance in that arena.

The availability of a single reference for Minnesota's industrial minerals producers makes it possible for anyone interested in developing alternative uses of industrial mineral mine wastes to efficiently assess each waste material's product potential, thereby saving time and resources that would otherwise be spent searching for information one operation at a time. Ultimately, the reference could act as a catalyst for generating innovative ideas on industrial mineral mine waste utilization. In both the short- and long-term, such ideas can benefit the waste user, the waste producer, and the state of Minnesota.

PART II: SAMPLING/TESTING PROGRAM: ANALYTICAL DATA ON COLLECTED SAMPLES

Thirteen samples of processing wastes were analyzed for this project. Twelve of the samples were collected from Minnesota dimension and crushed stone operations, one was submitted by a sand & gravel operation, and one was collected from a filter cake by-product pile generated by the City of Mankato water treatment plant. An additional waste material (terra rossa) was sampled at Biesanz Stone Co. (Fig. 1), bringing the total number of samples analyzed to fourteen.

While not a processing waste, terra rossa (sample MW01008) is a common weathering by-product of the carbonate rocks in southern Minnesota. It is a clay made up of the insoluble residues left over in the weathering process. As such, it is unusable as dimension or crushed stone, and remains behind as a potential available resource, albeit in sporadic and volumetrically limited quantities. A possible use would be as a unique pottery clay, by itself or in combination with other clays.

Figure 1. Terra rossa seam (sample MW01008) at Biesanz Stone Co. quarry, Winona.

Table 18 presents a listing of the samples submitted for analysis. Each sample was analyzed for particle size, geochemistry, and mineralogy. Particle size analysis and mineralogy were run at NRRI, while geochemical analysis was performed by an independent testing laboratory.

Table 18 Sample listing.

Sample No.	Producer	Waste/By-product
MW01001	Sioux Rock Products	Stockpiled Pond Fines
MW01002	Sioux Rock Products	Stockpiled Dirty Fines from Screening Plant
MW01003	New Ulm Quartzite Quarries	Stockpiled Pond Fines
MW01004	Mankato Water Treatment Plant	Filter Cake
MW01005	Mankato-Kasota Stone	Stockpiled Rock Saw Pond Fines
MW01006	Ortonville Stone Co.	Stockpiled Hydrocyclone Product
MW01007	Biesanz Stone Co.	Rock Saw Fines Sludge
MW01008*	Biesanz Stone Co.	Terra rossa (carbonate weathering product)
MW01009	Cold Spring Granite	Rock Saw Fines Sludge from Clarifier
MW01010	Cold Spring Granite	Rockville Quarry Drilling Fines
MW01011	Ed Kramer & Sons	Stockpiled Pond Fines (Highest ENP)
MW01012	SMC Morton Quarry	Quarry Fines from Screen Plant
MW01013	Meridian Aggregate	Hydrocyclone Product
MW01014	Guaranteed Gravel & Sand	Wash Plant Fines

*MW01008 was collected incidental to this project, but was still analyzed.

PARTICLE SIZE ANALYSIS

Particle size analysis was run on fourteen samples, with one duplicate sample and a clay standard bringing the total number of analyses to sixteen. Approximately 20 grams of sample were weighed out, soaked overnight in 250 ml of water, processed with a malt mixer for 15 minutes, and washed through a # 230 sieve (62.5 μ). Particle size of the - # 230 sieve material was determined by the settling tube method. This method determines particle size according to phi size. Micron, millimeter, and sieve-size equivalents to the phi sizes are presented Table 19.

The + # 230 sieve material was dry sieved by means of a sonic sifter. The sieve sizes used in this procedure were # 10, # 18, # 35, # 60, and # 120. They are presented in Table 20 with their mesh, millimeter, and micron equivalents.

Table 19 Phi size equivalents in microns, millimeters, and sieve size.

Phi Size	4	4.5	5	5.5	6	7	8	9	10
Equivalent Microns (μ)	62.5	44	31	22.1	15.6	7.80	3.90	2.00	1.00
Equivalent Millimeters (mm)	0.063	0.044	0.031	0.022	0.016	0.008	0.004	0.002	0.001
Equivalent Sieve Size (#)	# 230	# 325	-	-	-	-	-	-	-
Equivalent Sieve Size (mesh)	250 mesh	325 mesh	500* mesh	625* mesh	800* mesh	1250* mesh	2500* mesh	-	-

*Mesh sizes given, where starred, are approximations for the phi size values used in particle size analysis. The actual micron equivalent for the sieve sizes starred above are as follows:
500 mesh = 25 μ 625 mesh = 20 μ 800 mesh = 15 μ 1250 mesh = 10 μ 2500 mesh = 5 μ

Table 20 Sonic sifting sieve size equivalents in mesh, millimeters, and microns.

Sieve Size (#)	10	18	35	60	120
Equivalent Sieve Size (mesh)	9	16	32	60	115
Equivalent Millimeters (mm)	2.0	1.0	0.5	0.25	0.125
Equivalent Microns (μ)	2000	1000	500	250	125

The full range of particle size data for the fourteen samples is presented, in terms of microns, in Table 21. The samples are listed according to rock type and generally from coarsest to finest within a given rock type. The filter cake from the City of Mankato water treatment plant is grouped with carbonate rock fines.

Generalized findings based on particle size data are presented in Tables 22 and 23. More complete data on each sample can be found by referencing the individual companies in Part III of this report.

Table 22 provides a listing of the samples, ranked in terms of size from coarsest to finest, that were found to be predominantly sand-sized. These include quarry and drilling fines from both dimension stone and crushed stone operations, and the hydrocyclone product produced by the wash plants of crushed stone operations. The sand-sized fraction appears to be dominated by igneous and metamorphic rocks, which, as a whole, tend to be harder. However, it is likely that the lack of carbonate rock in this particular listing is due to the fact that sand-sized carbonate material is sold as agricultural liming material and, therefore, is generally not considered waste.

Table 21 Particle size distribution of collected/submitted samples.

SAMPLE	COMPANY	SAMPLE TYPE	PERCENT PASSING EQUIVALENT SPHERICAL DIAMETER IN MICRONS													
			Sand					Silt							Clay	
			2000 μ	1000 μ	500 μ	250 μ	120 μ	62.5 μ	44 μ	31 μ	22.1 μ	15.6 μ	7.8 μ	3.9 μ	2 μ	1 μ
CARBONATE ROCK																
MW01011	Ed Kramer & Sons	Stockpiled Pond Fines (Highest ENP)	98.49	97.85	97.35	96.24	87.46	57.56	37.20	27.45	19.37	13.92	8.87	5.76	3.89	2.83
MW01005	Mankato-Kasota Stone	Stockpiled Rock Saw Pond Fines	98.24	97.64	97.45	97.18	96.53	93.66	88.36	82.31	74.69	65.93	49.25	33.30	21.24	12.71
MW01007	Biesanz Stone Co.	Rock Saw Fines Sludge	100.00	99.98	99.94	99.76	99.54	98.63	92.88	87.46	78.83	69.59	46.58	26.44	14.05	6.95
MW01004	Mankato Water Treatment Plant	Filter Cake	100.00	100.00	99.99	99.96	99.84	99.55	99.15	98.74	94.43	83.30	42.45	13.94	4.03	1.39
GRANITE, GNEISS																
MW01010	Cold Spring Granite	Rockville Quarry Drilling Fines	99.55	94.43	81.52	62.49	45.73	32.12	25.50	21.36	17.29	14.16	9.55	5.86	3.72	2.65
MW01013	Meridian Aggregate	Hydrocyclone Product	99.67	99.36	96.54	83.73	54.07	27.00	17.94	13.70	10.85	8.82	6.24	4.54	3.54	3.00
MW01006	Ortonville Stone Co.	Stockpiled Hydrocyclone Product	99.99	99.88	99.70	97.11	71.30	34.71	17.43	10.12	4.86	3.45	2.33	1.94	2.08	1.89
MW01012	SMC Morton Quarry	Quarry Fines from Screen Plant	99.26	97.95	96.49	93.14	77.85	48.07	32.35	25.45	20.53	17.37	13.07	9.97	8.03	6.66
MW01009	Cold Spring Granite	Rock Saw Fines Sludge from Clarifier	99.98	99.89	99.58	99.14	98.23	95.58	89.43	83.81	74.51	65.26	45.08	26.63	14.62	6.93
QUARTZITE																
MW01002	Sioux Rock Products	Stockpiled Dirty Fines from Screening Plant	59.76	44.17	34.05	23.55	15.55	10.58	9.12	7.58	6.84	6.10	4.44	N.A.	2.21	2.04
MW01001	Sioux Rock Products	Stockpiled Pond Fines	95.68	94.59	93.73	92.18	88.49	78.75	62.87	55.89	49.12	42.54	29.11	16.94	10.28	6.42
MW01003	New Ulm Quartzite Quarries	Stockpiled Pond Fines	100.00	99.95	99.84	99.65	99.11	96.60	89.51	80.19	69.06	59.19	39.77	25.20	15.23	9.12
GRAVEL, CLAY																
MW01014	Guaranteed Gravel & Sand	Wash Plant Fines	99.89	99.00	97.88	96.89	94.90	85.31	61.24	50.81	38.62	29.24	17.87	12.09	8.85	6.39
MW01008	Biesanz Stone Co.	Terra Rossa	98.49	98.06	95.73	82.47	71.64	68.04	64.98	64.25	62.76	60.38	59.32	57.12	55.30	54.08

Table 22 Sand-silt-clay fraction of predominantly sand-sized samples.

Sample #	Company / Property	County	Rock Type	Sample Type	% Sand	% Silt	% Clay
MW01002	Sioux Rock Products Jeffers Quarry	Cottonwood	Quartzite	Stockpiled Dirty Fines from Screening Plant	89.42	8.37	2.21
MW01013	Meridian Aggregates St. Cloud Quarry	Stearns	Granite	Hydrocyclone Product	73.00	23.46	3.54
MW01006	Ortonville Stone Co. Quarry	Big Stone	Granite	Stockpiled Hydrocyclone Product	65.29	32.63	2.08
MW01010	Cold Spring Granite Co. Rockville Quarry	Stearns	Granite	Rockville Quarry Drilling Fines	67.88	28.40	3.72
MW01012	SMC Morton Quarry	Renville	Gneiss	Quarry Fines from Screen Plant	51.93	40.04	8.03

Table 23 Sand-silt-clay fraction of predominantly silt-sized samples.

Sample #	Company / Property	Rock Type	Sample Type	% Sand	% Silt	% Clay
MW01011	Ed Kramer & Sons Burnsville Quarry	Dolomitic Limestone	Stockpiled Pond Fines (Highest ENP)	42.44	53.67	3.89
MW01001	Sioux Rock Products Jeffers Quarry	Quartzite	Stockpiled Pond Fines	21.25	68.47	10.28
MW01014	Guaranteed Gravel & Sand	Gravel	Wash Plant Fines	14.69	76.46	8.85
MW01005	Mankato-Kasota Stone Jefferson Quarry	Dolomite	Stockpiles Rock Saw Pond Fines	6.34	72.42	21.24
MW01009	Cold Spring Granite Cold Spring Plant	Granite, Gneiss	Rock Saw Fines Sludge from Clarifier	4.42	80.96	14.62
MW01003	New Ulm Quartzite Quarries New Ulm Quarry	Quartzite	Stockpiled Pond Fines	3.40	81.37	15.23
MW01007	Biesanz Stone Co. Biesanz Stone Co.Quarry	Dolomite	Rock Saw Fines Sludge	1.37	84.58	14.05
MW 01004	City of Mankato Water Treatment Plant	Sludge	Filter Cake	0.45	95.52	4.03

Table 23 provides a listing of the samples found to be predominantly silt-sized. They are ranked from coarsest to finest in terms of sand content. These samples include washed fines from crushed stone and sand & gravel operations that were sent out to settling ponds and recovered, and sawing/grinding fines generated by dimension stone plants. Also included is the filter cake produced from the City of Mankato water treatment plant. All contain a significant clay-sized fraction, except the dolomitic limestone pond fines, which consist of over 40 % sand-sized material, and the water treatment plant filter cake, which is almost 96 % silt-sized. The filter cake is the result of the lime used in the water treatment process, and the size is reflective of the product used in the original application.

CHEMISTRY

The fourteen samples were sent to an independent testing laboratory (ACME Analytical Laboratories, Ltd., Vancouver, British Columbia) for geochemical analysis. Whole rock analysis, trace element analysis by both aqua regia and ICP 4-acid digestion methods, and additional analyses for organic C, CO_2, SO_4, F, FeO, pH, H_2O+, and H_2O-, were run on each of the samples. The results are presented in the following tables:

Table 24: Whole Rock Analysis by ICP;
Table 25a and 25b: Ultratrace Analysis by ICP-MS/Aqua Regia Digestion;
Table 26a and 26b: Trace Element Analysis by Optima ICP-ES/4-Acid Digestion; and
Table 27: Additional Analyses.

The samples are listed in the same order as in Table 21 (Particle size distribution of collected/submitted samples) for ease of comparison. They are listed by rock type and generally in order from coarsest to finest. To review geochemical data by company and specific waste material, see Part III of this report.

Description of the geochemical analytical procedures follows, as per the ACME Analytical Laboratories, Ltd., 2002 catalog (Year 2002 Price Brochure). Whole rock analysis includes the major oxides plus additional elements that were determined by a $LiBO_2$ fusion and ICP analysis, total carbon and total sulphur that were determined by Leco, and LOI determined by loss on ignition. The ultratrace analysis used the ICP-Mass Spectrometer with aqua regia digestion to yield a total to near total leach for precious and base metals, and a partial leach for rock-forming elements (Al, B, Ba, Ca, Cr, Fe, K, La, Mg, Mn, Na, Ni, P, S, Sc, Sr, Th, Ti, U, V, W). Trace element analysis used a mixture of HNO_3, $HClO_4$, HF, and HCl to digest the samples at a high temperature leading to near-total to total concentrations as most minerals were effectively dissolved. The Optima ICP-Emission Spectrometer was used to analyze the solutions. This analysis detects the presence and concentration of elements that would be unlikely to leach out under normal conditions. Several additional assays were requested in addition to the standard ones above. These were: Organic C, CO_2, SO_4, F, FeO, pH, H_2O+, and H_2O- (ACME Analytical Laboratories, Ltd., 2002).

Table 24 Whole rock analysis by ICP.*

Sample**	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	P_2O_5 %	MnO %	Cr_2O_3 %	Ba ppm	Cu ppm	Zn ppm	Ni ppm	Co ppm	Sr ppm	Zr ppm	Ce ppm	Y ppm	Nb ppm	Sc ppm	Ta ppm	LOI %	TOT/C %	TOT/S %	SUM%
CARBONATE ROCK																											
MW01007	7.57	1.2	0.46	18	29	0	0.9	0	0	0	0	62	23	104	<20	<20	70	24	<20	<10	24	1	<20	43	11.96	<.01	100
MW01005	10.51	1.83	0.9	18	27	0	1.4	0	0	0	0	59	<20	47	<20	<20	112	214	40	<10	47	1	<20	41	11.17	<.01	99.9
MW01011	10.34	1.47	1.65	20	24	0.2	0.7	0	0	0.1	0	64	<20	38	<20	<20	52	43	<20	<10	<10	1	<20	41	11.07	0	99.9
MW01004	0.99	0.04	0.18	3.3	50	0	<.02	<.01	0	0	0	57	<20	< 20	57	<20	477	44	40	<10	43	<1	<20	45	11.37	0.1	99.6
GRANITE, GNEISS																											
MW01009	61.93	14.58	5.66	1.9	4.1	3.5	4.9	0.6	0.2	0	0	1088	284	116	38	168	350	284	144	14	59	7	<20	2	0.8	0	99.9
MW01012	70.83	12.56	3.92	1.4	2.5	3	2.6	0.5	0.2	0	0	608	25	94	32	<20	236	216	<20	21	<10	7	<20	2	0.35	<.01	100
MW01010	68.63	14.39	3.61	0.7	1.6	3.4	6	0.5	0.1	0	0	1116	20	71	<20	<20	166	266	110	25	54	7	<20	1	0.04	<.01	100
RMW01010	68.35	14.25	3.69	0.7	1.5	3.3	6.4	0.5	0	0	0	1115	<20	93	33	<20	165	308	157	23	60	6	<20	1	0.05	<.01	99.9
MW01013	66.38	13.22	4.83	1.7	3.1	2.9	5.1	0.6	0.2	0	0	857	21	114	<20	<20	294	295	94	20	40	12	<20	2	0.16	<.01	99.9
MW01006	70.07	12.9	3.15	0.8	1.6	2.8	6.8	0.5	0.2	0	0	1354	<20	49	<20	<20	279	426	323	<10	47	1	<20	1	0.15	<.01	99.7
QUARTZITE																											
MW01003	73.49	15.27	3.11	0.2	0.2	0	0.4	0.6	0.2	0	0	139	29	29	32	<20	400	282	253	43	26	10	<20	6	0.25	<.01	99.9
MW01001	81.61	10.2	1.52	0	0.2	0.1	0.1	0.3	0.1	0	0	165	25	<20	33	<20	478	160	55	20	51	5	<20	5	0.1	<.01	99.4
MW01002	91.75	4.43	0.94	0	0	<.01	0	0.2	0	0	0	90	<20	<20	<20	<20	314	39	<20	15	<10	3	<20	2	0.02	<.01	99.9
GRAVEL, CLAY																											
MW01014	48.9	5.95	4.31	5.9	13	0.9	1.5	0.4	0.1	0.2	0	431	24	86	30	<20	167	189	92	15	52	5	<20	18	4.36	0	99.9
MW01008	65.76	13.46	5.82	1.26	0.78	0.04	0.99	0.4	0.05	0.31	0.01	328	55	332	21	<20	25	116	<20	17	17	8	<20	10.9	0.11	<.01	99.89

*Analysis by ACME Analytical Laboratories, Vancouver, British Columbia: 0.2 gm sample by $LiBO_2$ fusion, analysis by ICP-ES. LOI by loss on ignition. Total C & S by LECO (not included in the sum). Sample type: rock chip PSCB.

**

MW01007	Biesanz Stone Co.	Rock Saw FinesSludge
MW01005	Mankato-Kasota Stone	Stockpiled Rock Saw Pond Fines
MW01011	Ed Kramer & Sons	Stockpiled Pond Fines (Highest ENP)
MW01004	Mankato Water Treatment Plant	Filter Cake
MW01009	Cold Spring Granite	Rock Saw Fines Sludge from Clarifier
MW01012	SMC Morton Quarry	Quarry Fines from Screen Plant
MW01010	Cold Spring Granite	Rockville Quarry Drilling Fines
RMW01010	Cold Spring Granite (Dup.)	Rockville Quarry Drilling Fines
MW01013	Meridian Aggregate	Hydrocyclone Product
MW01006	Ortonville Stone Co.	Stockpiled Hydrocyclone Product
MW01003	New Ulm QuartziteQuarries	Stockpiled Pond Fines
MW01001	Sioux Rock Products	Stockpiled Pond Fines
MW01002	Sioux Rock Products	Stockpiled Dirty Finesfrom Screening Plant
MW01014	Guaranteed Gravel & Sand	Wash Plant Fines

Table 25a Ultratrace analysis by ICP-MS/aqua regia digestion.

SAMPLE	Mo ppm	Cu ppm	Pb ppm	Zn ppm	Ag ppb	Ni ppm	Co ppm	Mn ppm	Fe %	As ppm	U ppm	Au ppb	Th ppm	Sr ppm	Cd ppm	Sb ppm	Bi ppm	V ppm	Ca %
CARBONATE ROCK																			
MW01007	0.2	20.94	7.66	94	141	2.6	3.2	292	0.3	0.8	0.4	1.6	0.7	66.9	0.1	0.09	0.02	9	18.1
MW01005	0.5	6.8	14.84	5.9	213	3.9	14.2	473	0.5	1.4	0.5	0.6	1.1	100.8	0	0.12	0.03	9	17.51
MW01011	0.6	6.03	7.02	11	47	1.6	1.3	1027	1	0.8	0.6	0.3	0.7	48.7	0	0.06	0.02	14	16.84
MW01004	0.2	2.13	0.13	2.9	5	0.9	<.1	395	0	1.8	7.1	<.2	0.1	491.3	0	0.1	<.02	3	36.03
GRANITE, GNEISS																			
MW01009	6.9	129.4	11.78	62	2166	30	138.1	332	2.8	0.8	1.8	0.7	20	47.7	0.1	0.25	0.04	47	1.43
MW01012	0.4	13.08	10.37	60	30	14	8.1	423	2	0.9	3.8	<.2	20	14	0	0.05	0.04	37	0.47
MW01010	1.2	5.73	9.64	53	22	4.8	6.9	280	2.1	0.8	3	<.2	17	11.1	0	<.02	0.03	21	0.3
RMW01010	1.4	5.69	9.79	53	26	4.8	6.8	280	2.1	0.8	3.2	<.2	18	11.5	0	<.02	0.03	21	0.31
MW01013	1.5	14.97	11.01	61	57	8.4	8.2	365	2.2	0.7	4.1	1.2	14	21	0.1	0.02	0.12	39	0.73
MW01006	0.2	5.47	12.47	40	28	2.5	4.2	81	1.7	<.1	0.6	<.2	34	11.9	0	<.02	<.02	23	0.32
QUARTZITE																			
MW01003	1.6	6.2	15.12	12	88	4.2	2	155	1.8	3.5	0.9	3.4	10	57.1	0	0.8	0.03	11	0.1
MW01001	0.7	2.77	3.89	8.4	22	4.9	0.8	144	0.9	1.4	0.5	1.3	3.8	85.3	0	0.7	0.04	9	0.08
MW01002	0.4	0.92	1.95	2.4	13	1.6	0.2	86	0.5	0.6	0.3	0.7	2.7	73.4	0	0.48	0.02	4	0.04
GRAVEL, CLAY																			
MW01014	1	13.17	9.65	36	59	22	12.9	1351	2.4	9.8	1	0.8	3.6	49.8	0.2	0.22	0.08	30	7.92
MW01008	0.8	44.43	22.3	255.6	48	25.3	10.8	2384	2.9	6.2	0.3	1.1	7.6	10.9	0.4	0.14	0.23	56	0.51

Ultratrace analysis by ICP-MS/aqua regia digestion on submitted waste samples. Analysis by ACME Analytical Laboratories, Vancouver, British Columbia: 0.25 gm sample digested with $HClO_4$-HNO_3-Hcl-HF to 10 ml. Upper limits - Ag, Au, W = 200 ppm; Mo, Co, Cd, Sb, Bi, Th, & U = 4,000 ppm; Cu, Pb, Zn, Ni, Mn, As, V, La, Cr = 10,000 ppm. Digestion is partial for some minerals and may volatize some elements. Analysis by ICP-ES. Sample type: rock chip PSCB.

Table 25b Ultratrace analysis by ICP-MS/aqua regia digestion (continued).

SAMPLE	P %	La ppm	Cr ppm	Mg %	Ba ppm	Ti %	B ppm	Al %	Na %	K %	W ppm	Sc ppm	Tl ppm	S %	Hg ppb	Se ppm	Te ppm	Ga ppm	Smp gm
CARBONATE																			
MW01007	0.01	2.6	6.3	8.7	11.5	<.001	7	0	0.01	0.03	<.2	0.6	0.06	0.03	9	0.2	0.07	0.3	15
MW01005	0.01	4.4	9	9.5	11.2	0	10	0.1	0	0.06	1.2	0.9	0.02	0.03	7	0.4	0.08	0.9	15
MW01011	0.01	3.5	5.3	9	15.5	<.001	5	0.1	0.01	0.05	<.2	0.5	0.04	0.04	7	0.9	0.07	0.5	15
MW01004	0	0.8	0.6	1.8	57.8	<.001	23	0	0.03	<.01	<.2	0.2	<.02	0.12	< 5	0.5	0.17	0.1	15
GRANITE, GNEISS																			
MW01009	0.07	73	48	0.6	155.8	0.126	4	1.2	0.212	0.42	41	1.8	0.2	0.03	< 5	<.1	<.02	5.5	15
MW01012	0.08	56	26	0.6	86.2	0.149	2	0.9	0.03	0.4	<.2	1.9	0.32	<.01	8	0.1	<.02	5.2	15
MW01010	0.05	84	8.7	0.4	115.9	0.172	2	0.9	0.06	0.54	6.4	3.1	0.28	<.01	< 5	<.1	<.02	5.7	15
RMW01010	0.05	86	8.7	0.4	116	0.164	2	0.9	0.06	0.53	6.6	3	0.29	<.01	< 5	<.1	<.02	5.7	15
MW01013	0.07	47	23	0.7	100.7	0.172	2	1.1	0.06	0.45	0.4	3	0.33	<.01	< 5	<.1	<.02	5.2	15
MW01006	0.07	82	5.2	0.4	104	0.09	3	0.5	0.04	0.41	<.2	1.1	0.17	<.01	< 5	<.1	<.02	4	15
QUARTZITE																			
MW01003	0.02	17	26	0	35.3	0	4	0.4	0	0.05	1.4	1	0.04	<.01	12	0.4	<.02	1.3	15
MW01001	0.02	9.9	18	0	73.6	0	1	0.4	0.01	0.02	<.2	0.5	0.02	0.01	11	0.1	0.02	1	15
MW01002	0.01	6.9	8.2	0	52.8	0	1	0.2	0	<.01	<.2	0.3	<.02	<.01	< 5	0.1	<.02	0.5	15
GRAVEL																			
MW01014	0.06	14	17	3.4	144.2	0.04	10	0.6	0.02	0.12	<.2	1.7	0.24	0.01	18	0.5	0.04	2.3	15
MW01008	0.02	20.9	23.6	0.46	256	0.01	7	2.72	0.01	0.19	<.2	4.1	0.75	<.01	85	0.1	0.04	8.3	15

Ultratrace analysis by ICP-MS/aqua regia digestion on submitted waste samples. Analysis by ACME Analytical Laboratories, Vancouver, British Columbia: 0.25 gm sample digested with $HClO_4$-HNO_3-Hcl-HF to 10 ml. Upper limits - Ag, Au, W = 200 ppm; Mo, Co, Cd, Sb, Bi, Th, & U = 4,000 ppm; Cu, Pb, Zn, Ni, Mn, As, V, La, Cr = 10,000 ppm. Digestion is partial for some minerals and may volatize some elements. Analysis by ICP-ES. Sample type: rock chip PSCB.

Table 26a Trace element analysis by Optima ICP-ES/4-acid digestion.

SMP	Mo ppm	Cu ppm	Pb ppm	Zn ppm	Ag ppm	Ni ppm	Co ppm	Mn ppm	Fe %	As ppm	U ppm	Au ppm	Th ppm	Sr ppm	Cd ppm	Sb ppm	Bi ppm	V ppm	Ca %	P %	La ppm
CARBONATE																					
MW 01007	0.8	23	7	90	0.8	4	3	308	0.3	5	< 1	< 4	< 1	81	< .2	1	< 1	10	23.84	0	3
MW 01005	1.2	8	14	4	0.8	6	17	490	0.64	5	< 1	< 4	< 1	124	< .2	< 1	< 1	14	22.32	0.01	5
MW 01011	1.3	8	7	13	0.7	4	1	1094	1.17	3	< 1	< 4	< 1	65	< .2	< 1	< 1	17	21.33	0.02	4
MW 01004	1.1	1	< 3	3	0.7	4	< 1	432	0.13	4	4	< 4	< 1	517	< .2	1	1	< 1	41.21	0	< 1
GRANITE, GNEISS																					
MW 01009	7.7	131	24	79	2.2	40	186	589	3.99	< 2	7	< 4	19	363	< .2	< 1	2	69	3.27	0.07	89
MW 01012	0.7	7	20	75	0.2	18	10	556	2.85	3	8	< 4	20	234	< .2	< 1	< 1	54	1.84	0.08	70
MW 01010	1.9	4	21	63	< .2	5	8	339	2.63	2	8	< 4	13	172	< .2	< 1	< 1	25	1.24	0.05	102
RMW 01010	2.9	4	21	63	< .2	5	7	338	2.51	< 2	7	< 4	11	168	< .2	< 1	1	27	1.23	0.05	99
MW 01013	1.7	7	24	85	0.2	10	11	656	3.65	4	10	< 4	12	290	< .2	< 1	1	71	2.36	0.07	66
MW 01006	0.6	4	30	50	0.2	3	5	141	2.2	< 2	8	< 4	61	296	< .2	< 1	< 1	24	1.29	0.08	192
QUARTZITE																					
MW 01003	2.2	6	28	17	1	5	2	160	2.07	10	9	< 4	19	408	< .2	4	< 1	17	0.13	0.07	151
MW 01001	1.1	2	8	12	< .2	8	1	143	1.03	4	2	< 4	6	501	< .2	3	< 1	13	0.16	0.06	29
MW 01002	0.6	2	4	5	< .2	3	< 1	74	0.6	4	2	< 4	2	335	< .2	2	< 1	5	0.08	0.04	16
GRAVEL, CLAY																					
MW 01014	1.4	12	13	48	0.5	27	14	1520	3.13	13	< 1	< 4	3	166	< .2	< 1	1	55	10.18	0.06	20
MW 01008	1.5	46	23	304	0.2	35	13	2505	4.03	9	< 1	< 4	5	28	0.4	1	1	94	0.58	0.03	21

Trace element analysis by Optima ICP-ES/4-acid digestion on submitted waste samples. Analysis by ACME Analytical Laboratories, Vancouver, British Columbia: 1 5.00 gm sample, 90 ml 2-2-2 HCl-HNO$_3$-H$_2$O at 95° C for 1 hour and is diluted to 300 ml, analysis by ICP/ES & MS. Upper limits - Ag, Au, Hg, W, Se, Te, Tl, Ga, Sn = 100 ppm; Cu, Pb, Zn, Ni, Mn, As, V, La, Cr = 10,000 ppm. Sample type: rock chip PSCB.

Table 26b Trace element analysis by Optima ICP-ES/4-acid digestion (continued).

SAMPLE	Cr ppm	Mg %	Ba ppm	Ti %	Al %	Na %	K %	W ppm	Zr ppm	Ce ppm	Sn ppm	Y ppm	Nb ppm	Ta ppm	Be ppm	Sc ppm	Li ppm	S %	Rb ppm	Hf ppm
CARBONATE																				
MW 01007	9	10.84	70	0.03	0.75	0.04	0.85	< 2	10.4	9	2.2	2.5	< .2	< .5	< 1	1	2	< .02	7	< 1
MW 01005	13	10.98	67	0.05	1.14	0.03	1.25	2	14.5	13	1.4	2.7	< .2	< .5	< 1	2	4	< .02	12	< 1
MW 01011	9	10.44	73	0.03	0.66	0.06	0.62	< 2	12.4	10	< .5	2.1	< .2	< .5	< 1	1	4	< .02	7	< 1
MW 01004	2	2.09	65	0	0.05	0.03	< .01	< 2	1.4	2	2.1	1.2	< .2	< .5	< 1	1	2	0.05	< 1	< 1
GRANITE, GNEISS																				
MW 01009	52	1.09	1179	0.382	7.36	2.512	2.79	65	148.3	154	13.2	14	10.7	< .5	2	7	22	0.04	112	4
MW 01012	40	0.81	631	0.306	6.48	2.186	2.24	< 2	154.8	125	2.4	18.4	11.5	< .5	2	7	34	< .02	124	5
MW 01010	5	0.4	1172	0.293	7.08	2.524	3.39	22	163.8	186	1.2	23.2	15.5	< .5	2	8	44	< .02	145	5
RMW 01010	6	0.4	1156	0.293	6.98	2.487	3.39	13	158.9	183	1.4	22.4	15.4	< .5	2	7	44	< .02	140	5
MW 01013	29	0.98	907	0.378	6.97	2.218	2.89	2	209.2	129	1.9	18.6	12.3	0.5	2	13	50	< .02	138	6
MW 01006	4	0.47	1449	0.252	6.73	2.082	3.59	< 2	195.3	318	0.6	9.3	2.6	< .5	1	2	11	< .02	110	6
QUARTZITE																				
MW 01003	27	0.08	141	0.102	7.46	0.04	0.41	4	213.7	301	2.1	23.7	2.6	< .5	1	9	33	0.03	7	6
MW 01001	12	0.05	168	0.102	4.87	0.09	0.11	< 2	109.1	60	1.8	12.4	2.6	< .5	1	4	39	0.02	3	3
MW 01002	4	0.02	89	0.06	2.02	0.03	0.02	< 2	75.4	34	0.6	8	1.4	< .5	< 1	2	19	< .02	1	2
GRAVEL, CLAY																				
MW 01014	30	3.65	459	0.185	3.39	0.803	1.16	< 2	57.4	44	< .5	13.3	3.7	< .5	1	5	17	< .02	42	2
MW 01008	39	0.67	357	0.241	6.53	0.042	0.95	2	83.7	52	2.3	13.4	10.4	< .5	3	9	37	< .02	40	3

Trace element analysis by Optima ICP-ES/4-acid digestion on submitted waste samples. Analysis by ACME Analytical Laboratories, Vancouver, British Columbia: 1 5.00 gm sample, 90 ml 2-2-2 HCl-HNO$_3$-H$_2$O at 95° C for 1 hour and is diluted to 300 ml, analysis by ICP/ES & MS. Upper limits - Ag, Au, Hg, W, Se, Te, Tl, Ga, Sn = 100 ppm; Cu, Pb, Zn, Ni, Mn, As, V, La, Cr = 10,000 ppm. Sample type: rock chip PSCB.

Table 27 Additional analyses.

SAMPLES	COMPANY	WASTE TYPE	C/ORG %	CO_2 %	SO_4 %	F ppm	pH -	FeO %	H_2O+ %	H_2O- %
Carbonate Rock										
MW 01007	Biesanz Stone Co.	Rock Saw Fines Sludge	0.23	43	< .03	154	9.3	0.2	1.1	0.1
MW 01005	Mankato-Kasota Stone	Stockpiled Rock Saw Pond Fines	0.16	40.31	< .03	189	9.3	0.3	1.5	0.2
MW 01011	Ed Kraemer & Sons	Stockpiled Pond Fines (Highest ENP)	< .03	41.08	0.06	196	9.4	0.9	1.2	0.2
MW 01004	City of Mankato Water Treatment Plant	Filter Cake	0.17	41.08	0.23	307	9.8	< .1	4.4	0.6
Granite, Gneiss										
MW 01009	Cold Spring Granite	Rock Saw Fines Sludge from Clarifier	0.37	1.31	0.06	649	9.3	3.9	3.4	0.2
MW 01012	SMC Morton Quarry	Quarry Fines from Screen Plant	0.26	0.35	< .03	668	8.6	1.9	1.8	0.5
MW 01010	Cold Spring Granite	Rockville Quarry Drilling Fines	< .03	0.23	< .03	1211	9.1	2.4	1.5	0.1
RMW 01010	Cold Spring Granite	Rockville Quarry Drilling Fines	< .03	0.23	< .03	1264	9.1	2.4	1.4	0.1
MW 01013	Meridian Aggregates	Hydrocyclone Product	< .03	0.65	< .03	961	9.2	3.2	1.4	0.2
MW 01006	Ortonville Stone Co.	Stockpiled Hydrocyclone Product	< .03	0.65	< .03	572	8.7	1.1	1.3	< .1
Quartzite										
MW 01003	New Ulm Quartzite Quarries	Stockpiled Pond Fines	0.12	0.46	< .03	105	6.8	0.4	4.6	0.2
MW 01001	Sioux Rock Products	Stockpiled Pond Fines	0.06	0.15	0.03	460	7.1	< .1	3.2	0.2
MW 01002	Sioux Rock Products	Stockpiled Dirty Fines from Screening Plant	< .03	0.15	< .03	162	7.4	0.1	2.2	0.1
Gravel, Clay										
MW 01014	Guaranteed Gravel & Sand	Wash Plant Fines	0.16	15.39	< .03	583	8.9	0.5	2.3	0.9
MW 01008	Biesanz Stone Co.	Terra Rossa	< .03	0.46	< .03	356	8.2	0.3	6.1	4.2

Analysis by ACME Analytical Laboratories, Vancouver, British Columbia: CO_2 - Digest with warm 15% $HCLO_4$, evolved CO_2 analyzed by LECO. SO_4 - Residue sulphur after ignited at 800° C for 1 hour. C/ORG - Total C minus graphite C and carbonate. F - NaOH fusion - specific ion electrode anaylsis. FEO by dichromate titration. H_2O+ at 1500° C. H_2O- at 110° C. Sample type: rock chip PSCB.

MINERALOGY

The fourteen samples were analyzed by means of x-ray diffractometry (XRD) to determine their mineralogical make-up. The samples have been grouped by rock type as in the particle size and geochemistry data. The mineralogy presented here is for general comparative purposes. Some mineral species have been grouped by type and some trace minerals have been omitted. The complete mineralogy of each sample is presented in Part III under the individual company heading.

Carbonate Rock

Dolomite is the primary mineral present in the rock saw fines from Biesanz Stone Co. and Mankato-Kasota Stone Co., and in the washed pond fines from Ed Kraemer & Sons (Table 28). Parent material for the two types of fines is the Oneota Dolomite and the dolomitic limestone of the Shakopee Formation, respectively. Minor amounts of quartz are present in all three samples, while potassium- (K-) feldspar is present in minor amounts in the rock saw fines and in a trace amount in the washed pond fines. Minor and trace amounts, respectively, of the carbonate mineral ankerite were detected in the Biesanz rock saw fines and the Ed Kraemer pond fines.

Table 28 Mineralogy of the carbonate rock samples.

Smp	Company	Waste/ By-product	Dolomite	Calcite	Quartz	K-Feldspar	Ankerite	Hydro-biotite	Chlorite	Illite
MW 01007	Biesanz Stone Co.	Rock Saw Fines	M	t	m	m	t		t	
MW 01005	Mankato-Kasota Stone	Rock Saw Fines	M		m	t				
MW 01011	Ed Kramer & Sons	Pond Fines	M		m	t	m	t		t
MW 01004	Mankato Water Treatment Plant	Filter Cake		M						

The filter cake from the City of Mankato water treatment plant consists solely of the mineral calcite, due to the use of lime in the water treatment process.

Granite, Gneiss

Quartz is a major mineral constituent of all fines generated from the quarrying and processing of igneous granitic rock and metamorphosed gneiss, as seen in Table 29. K-feldspar is a major component of Cold Spring Granite's rock saw and drilling fines, and Meridian Aggregate's hydrocyclone product, while only trace amounts of it are found in SMC's quarry fines and Ortonville Stone Company's hydrocyclone product. Biotite is a major component of Cold Spring Granite's rock saw fines and both Meridian Aggregate and Ortonville Stone Companies' hydrocyclone products, while it is a minor constituent of the quarry fines from SMC's Morton

Quarry and Cold Spring Granite's Rockville Quarry. These same two quarry samples both contain trace amounts of chlorite.

Table 29 Mineralogy of the granite and gneiss samples.

Smp	Company	Waste / By-product	Quartz	Plag - Feldspar	K-Feldspar	Annite (Biotite)	Kaol-inite	Illite	Mont-morillonite	Chlorite
MW 01009	Cold Spring Granite	Rock Saw Fines	M	m	M	M		m	M	
MW 01012	SMC Morton Quarry	Quarry Fines	M	m	t	m		t	t	t
MW 01010	Cold Spring Granite	Drilling Fines	M	t	M	m	m			t
MW 01013	Meridian Aggregate	Hydrocyclone Product	M		M	M				
MW 01006	Ortonville Stone Co.	Hydrocyclone Product	M	t	t	M				

The clay mineral montmorillonite is another major constituent of Cold Spring Granite's rock saw fines, while trace amounts of it are found in SMC's quarry fines. In conjunction with the montmorillonite is the clay mineral illite, found in the same two samples in minor and trace amounts, respectively. These are likely derived from the plagioclase feldspar found in minor amounts in both samples. Traces of plagioclase feldspar are found in the Cold Spring Granite drilling fines and the Ortonville Stone Company hydrocyclone product. Another clay mineral, kaolinite, occurs in minor amounts in Cold Spring Granite's drilling fines, where there is only a trace of plagioclase feldspar.

Quartzite

Screenings and pond fines from the quartzite quarried by Sioux Rock Products and New Ulm Quartzite Quarries (NUQQ) consist primarily of quartz and kaolinite (Table 30). Minor hematite and chlorite are also present in the screenings. Illite is present in minor amounts in the NUQQ pond fines and occurs in trace amounts as the mixed-layer clay illite-montmorillonite in the Sioux Rock Products pond fines. The latter also contains trace amounts of K-feldspar, while the NUQQ pond fines contain a trace amount of the iron carbonate siderite, from which it likely derives its distinctive color. Biotite and chlorite are present in trace amounts in both pond fines samples.

Gravel, Clay

The wash plant fines from the Guaranteed Gravel & Sand pit consist primarily of quartz and dolomite, with minor amounts of K-feldspar and plagioclase feldspar (Table 31), implying a glacial mix of Paleozoic sediments and crystalline bedrock. Trace amounts of mica (biotite), the Fe-carbonate ankerite, cordierite, and weathering products kaolinite clay and chlorite are also present.

Table 30 Mineralogy of the quartzite samples.

Smp	Company	Waste/By-product	Quartz	Kaolinite	Annite (Biotite)	Siderite	Hematite	K-Feldspar	Illite	Illite-Montmorillonite	Chlorite
MW 01003	New Ulm Quartzite Quarries	Pond Fines	M	M	t	t			m		t
MW 01001	Sioux Rock Product	Pond Fines	M	M	t			t		t	t
MW 01002	Sioux Rock Products	Dirty Fines	M	M			m				m

Table 31 Mineralogy of the gravel and clay samples.

Smp	Company	Waste/By-product	Quartz	Dolomite	Annite (Biotite)	Kaolinite	Chlorite	Plag-Feldspar	K-Feldspar	Ankerite	Cordierite
MW 01014	Guaranteed Gravel & Sand	Wash Plant Fines	M	M	m	m	t	t	t	t	t

Smp	Company	Waste/By-product	Quartz	Illite-Montmorillonite	Illite	Chlorite	Pyrophyllite	Hematite
MW 01008	Biesanz Stone Co.	Terra Rossa	M	M	m	m	t	t

The terra rossa clay, common to the carbonate rocks of southern Minnesota, formed from the weathering of local dolomite and limestone. It consists of the insoluble residue left behind, primarily quartz and the mixed-layer illite/montmorillonite clay, along with minor illite and mixed-layer smectite/chlorite clays. Trace amounts of hematite give the clay its earthy red hue, hence the name "terra rossa."

CARBONATE ROCK AG-LIME ANALYSES

Ag-lime analyses, where available, have been included in Part III with the analytical data of the wastes/by-products produced by carbonate rock operations. An explanation of terminology used is necessary to understanding the data.

Ag-lime Analytical Components

CCE (% Calcium Carbonate Equivalence) CCE is a measure of the acid-neutralizing capacity, or "purity," of an agricultural liming material (Knudsen, rev. 2000). CCE is based on pure calcium carbonate equaling 100 %. Pure magnesium carbonate, dolomite, and calcium hydroxide (hydrated lime) also have acid-neutralizing capacities amounting to CCE's of 119, 108, and 120-136, respectively. Where liming materials contain impurities with no neutralizing value, such as chert or shale, the CCE is reduced (Knudsen, rev. 2000).

FI (Fineness Index) Fineness is a measure of the particle size of a given liming material with regard to percent passing a # 8, # 20, and # 60 sieve (2.36 mm, 0.850 mm, and 0.250 mm, respectively) (Knudsen, rev. 2000). A Fineness Efficiency Factor (FEF) has been determined for both the particle size range - # 8 to + # 20 and - # 20 to + # 60 . These FEF's equal 0.2 and 0.6, respectively. This refers to each size range's neutralization efficiency over a period of three years. Because - # 60 material is 100 % available in 3 years, its FEF = 1.0. The Fineness Index (FI) is determined by multiplying the percent of material in each size range by the FEF for that size range and then totaling the three results (Agricultural Liming, 2001).

ENP (Effective Neutralizing Power) CCE x FI = ENP, the Effective Neutralizing Power of the liming material. Purity and fineness are the determining factors in soil neutralization effectiveness of any given liming material (Knudsen, rev. 2000).

Min Lbs. ENP / Ton % ENP x 2000 pounds x % dry matter = Min. Lbs. ENP/Ton. It is equal to the number of pounds of pure calcium carbonate considered available per ton of the liming material over a three-year period. The percent dry matter is determined by subtracting the material's percent moisture from 100 %. The minimum pounds ENP per ton is required labeling for agricultural liming material (Agricultural Liming, 2001).

ECC (Effective Calcium Carbonate) CCE x FI = ECC (Knudsen, rev. 2000). Effective Calcium Carbonate is equivalent to ENP (Effective Neutralizing Power).

PART III: DETAILED SYNOPSES OF MINNESOTA'S INDUSTRIAL MINERAL PRODUCERS

This section is arranged by producer type, as follows:

- Crushed Stone
- Dimension Stone
- Sand and Gravel

CRUSHED STONE OPERATIONS

Crushed stone producers, listed below, are profiled on the following pages. Included are quarry locations, geologic and production data, types and amounts of wastes/by-products generated, and analytical data pertinent to the wastes/by-products.

Site visits were made to the headquarters of several of the major crushed stone producers in Minnesota in January of 2001. These included: Edward Kraemer & Sons, Inc., Meridian Aggregates Co. (now Martin-Merietta), Milestone Materials, New Ulm Quartzite Quarries, Ortonville Stone Co., W. Hodgman and Sons/Sioux Rock Products, and Southern Minnesota Construction Co. (SMC). In addition, survey responses were received from Aggregate Industries North Central Region, Roverud Construction, Inc., and Ulland Brothers, Inc. Samples were collected from all of the visited sites with the exception of Milestone Materials' crushed stone operations.

Company	Corporate Headquarters	Quarry Locations by County	Rock Type
Aggregate Industries North Central Region	Eagan, MN	Dakota Goodhue Washington	Dolomitic Limestone Dolomitic Limestone Dolomitic Limestone
Bowman Construction Co.	International Falls, MN	Koochiching	Biotite Schist
Bryan Rock Products, Inc.	Shakopee, MN	Scott Washington	Carbonate Dolomitic Limestone
Kielmeyer Construction Co.	Nerstrand, MN	Goodhue	Limestone
Knoblauch Lime & Rock Company	Canon Falls, MN	Goodhue	Limestone
Edward Kraemer & Sons, Inc.	Burnsville, MN	Dakota	Dolomitic Limestone
Meridian Aggregates Co.	Waite Park, MN	Stearns Yellow Medicine	Granite Gneiss
Milestone Materials	Onalaska, WI	Fillmore Houston Olmsted Wabasha Winona	Dolomite Dolomitic Limestone Dolomitic Limestone Dolomitic Limestone Dolomitic Limestone
New Ulm Quartzite Quarries	New Ulm, MN	Nicollet	Quartzite
Ortonville Stone Co.	Ortonville, MN	Big Stone	Granite
Osmundson Brothers Contractors, Inc.	Adams, MN	Mower	Dolomitic Limestone
Pedersen Bros. Of Harmony	Harmony, MN	Fillmore	Dolomite, Limestone
Roberson Lime & Rock, Inc.	Zumbro Falls, MN	Wabasha	Dolomitic Limestone
Roverud Construction, Inc.	Spring Grove, MN	Fillmore Goodhue	Dolomite Dolomite, Limestone
Sioux Rock Products	Fairmont, MN	Cottonwood	Quartzite
Stussy Construction, Inc.	Mantorville, MN	Dodge Olmsted	Dolomitic Limestone Dolomitic Limestone
Southern Minnesota Construction Co.	Mankato, MN	Renville	Gneiss
Ulland Brothers, Inc.	Cloquet, MN	St. Louis	Basalt
Wm. Mueller & Sons, Inc.	Hamburg, MN	Scott	Limestone

Aggregate Industries
North Central Region

2915 Waters Road
Suite 105
Eagan, MN 55121

Phone: (651) 683-0600
Fax: (651) 683-8108

Contact: J.D. Lehr, Regional Geologist
jd.lehr@aggregate.com

Parent Company: Aggregate Industries PLC
www.aggregate-us.com

Quarry	T	R	S	County	Rock Type	Products	By-products	Size	On-site Amount	Annual Production	Location
Hastings Quarry & Plant	114	17	34	Dakota	Dolomitic Limestone	Crushed stone, ag-lime, breaker rock	Stripping	N.A.	50,000 CY	10,000 CY	Stockpiles & Berms
							Limestone Fines	-200 mesh	5,000 T	2,000 T	Pond
Larson Quarry & Plant	27	22	23 24 25 26	Washing-ton	Dolomitic Limestone	Crushed stone, ag-lime, manufactured sand, filter blanket, rip rap	Stripping	N.A.	1,000,000 CY	70,000 CY	Stockpiles & Berms
							Limestone Fines	-200 mesh	1,000,000 T	140,000 T	Pond
							Limestone	-3/8 in.	200,000 T	100,000 T	Stockpile
Red Wing Quarry	112	15	5 6	Goodhue	Dolomitic Limestone	Crushed stone, ag-lime, rip rap, breaker rock	Stripping	N.A.	100,000 CY	20,000 CY	Stockpiles & Berms

Aggregate Industries North Central Region, a subsidiary of Aggregate Industries PLC, is headquartered in Eagan, MN. It operates three dolomitic limestone quarries in three counties in southeastern Minnesota: Larson Quarry in St. Paul Park, Washington County; Hastings Quarry in Hastings, Dakota County; and Red Wing Quarry in Red Wing, Goodhue County.

Larson Quarry

Geologic Unit: Shakopee and Oneota Formations (dolomitic limestone); 130 ft. thickness

Production: Rock is excavated and moved by means of shovel, backhoe, loader, dozer, scrapers, and truck. The Larson Quarry houses a permanent plant that uses impact crushers for primary and secondary crushing, and a cone crusher for tertiary crushing. Both wet and dry classification are used. 100,000 tons are shipped by truck and 1.3 million tons are barged to market.

Product Line: 2, CA3, 6, 7, 67, and 89 Key; 3-in. minus; 3/8-in. minus; Ag-lime; manufactured sand; filter blanket; Rip Rap I, II, III, IV, and V; Class 5, Mod. Class 5, and Class 2.

Hastings Quarry

Geologic Unit: Shakopee Formation (dolomitic limestone); upper 80 ft. of the Prairie du Chien Group

Production: Loaders and scrapers are used to excavate and move rock. A portable plant processes the rock by means of jaw and horizontal impact crushers. Dry classification is used. 250,000 tons of product are shipped to market by truck.

Product Line: Breaker Rock; CA-3, 7 and 68 Key; Ag-lime; Class 5; Mod. Class 5; and Class 2

Red Wing Quarry

Geologic Unit: Shakopee and Oneota Formations (dolomitic limestone); 170 ft. thickness

Production: Loaders and scrapers are used to excavate and move rock; a backhoe is used as a secondary breaker. A portable plant processes the rock by means of impact and jaw crushers. Dry classification is used. 125,000 tons of product are shipped to market by truck.

Product Line: Breaker Rock; CA-3, 7, and 67 Key; Ag-lime; and Rip Rap I, II, III, IV, and V

Wastes/By-products

Waste/By-product	How Used	Most Difficult To Market	Easiest To Market	Potential Markets/Uses
Crusher fines	Ag-lime	Fines	N.A.	N.A.
Stripping	Reclamation			

Mineral wastes/by-products generated at the three quarries consist of **stripping/overburden** and **limestone fines**. Stripping is stockpiled. It is used in berms and for reclamation. The fines are sold as ag-lime; however, more fines are produced than the market can absorb. Aggregate Industries has available **significant quantities of screenings (200,000 tons stockpiled at the Larson Quarry) and pond fines (1,000,000 tons at the Larson Quarry; 5,000 tons at the Hastings Quarry).**

The Larson Quarry holds 1,000,000 yds. of stripping located in stockpiles and berms; the Red Wing quarry holds 100,000 yds. and the Hastings Quarry holds 50,000 yds. Annually, the Larson Quarry generates 70,000 yds. of stripping and overburden material destined for stockpiles. The Red Wing Quarry generates 20,000 yds. of stripping annually, while the Hastings Quarry generates 10,000 yds.

Both the Larson and Hastings Quarries have accumulated plant-generated - # 200 limestone fines in settling ponds. The Larson resource contains over 1,000,000 tons of this material; the Hastings resource consists of 5,000 tons. There are no reported plant wastes stored on-site at the Red Wing Quarry. Annually, 140,000 tons of plant-generated fines are produced at the Larson Plant. The

Hastings plant produces less than 2,000 tons of fines yearly. In addition to ponded fines, the Larson Quarry houses 200,000 tons of stockpiled -3/8 in. limestone wastes. Annually, 100,000 tons of this material is produced.

Waste/By-product Analytical Data

Analytical data available for the Hastings and Red Wing quarries comes from the MN Dept. of Agriculture Ag-Lime Analysis Report (2001). It includes data for ag-lime and pond fines from the Hastings Quarry and ag-lime from the Red Wing Quarry, as presented in Table 32. There was no data in the report from the Larson Quarry.

Table 32 Ag-lime analytical data for Aggregate Industries North Central Region quarries.

Ag-lime Analysis*												
Quarry	**County**	**Date**	**Sample Type**	**Rec. #**	**Moisture Content**	**Fineness Index (FI)**	**% CCE**	**% ENP**	**MIN LBS ENP/TON**	**% Pass 8**	**% Pass 20**	**% Pass 60**
Hastings	Dakota	092600	Ag-lime	13.0	5.8	69.0	70.5	48.6	916	98.0	77.3	46.1
Hastings	Dakota	092600	Pond Fines	14.0	9.6	97.2	69.5	67.5	1221	99.5	98.7	94.5
Red Wing	Goodhue	092600	Ag-lime	42	5.0	56.3	90.0	50.7	963	80.8	58.6	41.8

*Ag-Lime Analysis Report (2001)

Table 32 gives an indication of the relatively fine nature of the pond fines when compared to material classified as ag-lime: 94 % of the pond fines sample passes the # 60 sieve vs. 46 % and 42 % for the ag-lime.

Data Sources

2001 Survey Response
Ag-Lime Analysis Report, 2001
Lehr, J.D., pers. comm., 2001

Bowman Construction Co.

3399 Highway 11 E
International Falls, MN 56649

Phone: (218) 286-5078

Contact: Carl Bowman

Quarry	T	R	S	County	Rock Type	Product	By-product	Amount
Ranier Quarry	71	23	31 32	Koochiching	Schist	Crushed schist	Fines, stripping	No waste, all by-products used or sold

Bowman Construction Co. produces aggregate from biotite schist in the Ranier Quarry, which is located east of International Falls in Koochiching County, MN.

Geologic Unit: Biotite Schist

Wastes/By-products

Nothing produced in the quarry is considered waste. **Stripping** is sold for topsoil; **fines** are used in blacktopping. Bowman Construction Co. is actively involved in recycling old asphalt and concrete, among other items. Bowman Construction Co. also imports wood wastes from Boise Cascade for composting purposes (Carl Bowman, pers. com., April, 2001).

Data Sources

Carl Bowman, pers. com., April, 2001
ASIS Database, 2001
Nelson et al., 1990

Bryan Rock Products, Inc.

Box 215
Shakopee, MN 55379

Phone: (952) 445-3900
Fax: (952) 445-0809
Toll-Free: (800) 382-3756

Contact: Bill Bryan

www.bryanrock.com

Quarry	T	R	S	County	Rock Type	Product	By-product	Size	Location
Front Quarry	115	23	21	Scott	Dolomitic Limestone	Crushed Stone	Ag-lime	- # 4	Stockpile
Bayport Quarry	29	20	15 20	Washington	Dolomitic Limestone	Crushed Stone	Ag-lime	- # 4	Stockpile

Bryan Rock Products, Inc. is a carbonate rock aggregate producer based in Shakopee, Scott County, MN.

Geologic Unit: Front Quarry: Prairie du Chien Group
Bayport Quarry: N.A.

Waste/By-products

Everything produced in the quarrying process is used. Stripping does not present a problem as there are only 2 ft. of overburden to strip (Bill Bryan, pers. com., April, 2001). Fines generated during processing are sold as **ag-lime**.

By-product Analytical Data - Ag-lime

Table 33 presents analytical data on the fines sold as ag-lime from the Front and Bayport quarries, as provided by the MN Dept. of Agriculture Ag-Lime Analysis Report (2001).

Table 33 Ag-lime analytical data for Bryan Rock Products, Inc. quarries.

Ag-lime Analysis*												
Quarry	**County**	**Date**	**Sample Type**	**Rec. #**	**Moisture Content**	**Fineness Index (FI)**	**% CCE**	**% ENP**	**MIN LBS ENP/TON**	**% Pass 8**	**% Pass 20**	**% Pass 60**
Front	Scott	8/23/00	Ag-lime	120	4.4 %	52.4	89.4	46.8	895	83.1	54.9	34.5
Bayport	Washington	8/23/00	Ag-lime	136	6.7 %	60.5	91.3	55.3	1031	91.0	62.8	43.0
Bayport	Washington	8/22/00	Ag-lime	137	3.9 %	59.0	93.4	55.1	1059	89.9	61.4	41.1

*Ag-Lime Analysis Report, 2001

Data Sources

Ag-Lime Analysis Report, 2001
Bill Bryan, pers. com., April, 2001
Nelson et al., 1990
www.bryanrock.com

Kielmeyer Construction Co.

86 Main Street
P.O. Box 158
Nerstrand, MN 55053

Phone: (507) 334-6088

Quarry	T	R	S	Forty	County	Rock Type	Product	By-product
Hernke Quarry	111	17	30	S ½ NW 1/4	Goodhue	Limestone	Crushed Stone	Ag-lime
Foss Quarry	110	17	8	SE-NE	Goodhue	Limestone	Crushed Stone	Ag-lime
Triple D Quarry	N.A.	N.A.	N.A.	N.A.	Goodhue	Carbonate	Crushed Stone	Ag-lime

Kielmeyer Construction Co. produces crushed aggregate from several carbonate rock quarries located in Goodhue County, Minnesota. Three of these quarries, the Hernke, Foss, and Triple D quarries, are included here because of analytical data available from the MN Dept. of Agriculture Ag-Lime Analysis Report (2001). No survey response was received.

Geologic Unit: Hernke Quarry: Prosser Formation
Foss Quarry: Prosser Formation
Triple D Quarry: N.A.

Waste/By-products

Fines generated from processing at the Hernke, Foss, and Triple D quarries are sold as **ag-lime**.

By-product Analytical Data - Ag-lime

Table 34 presents analytical data on the fines sold as ag-lime from the Hernke, Foss, and Triple D quarries, as obtained from the MN Dept. of Agriculture Ag-Lime Analysis Report (2001).

Table 34 Ag-lime analytical data for Kielmeyer Construction Co. quarries.

Ag-lime Analysis*												
Quarry	**County**	**Date**	**Sample Type**	**Rec. #**	**Moisture Content**	**Fineness Index (FI)**	**% CCE**	**% ENP**	**MIN LBS ENP/TON**	**% Pass 8**	**% Pass 20**	**% Pass 60**
Hernke	Goodhue	090800	Ag-lime 2000 Production	44	5.5 %	65.6	88.4	58	1096	98.3	70.1	44.7
Hernke	Goodhue	091400	1998/1999 Ag-lime	45	5.7 %	65.7	86.1	56.6	1068	98.5	70.7	44.4
Foss	Goodhue	111600	Ag-lime 2000 Production	46	4.8 %	68.8	87.2	60.0	1143	99	74.2	48.4
Triple D	Goodhue	111600	Ag-lime 2000 Production	47	3.9 %	60.2	87.2	52.5	1009	96.9	60.2	41.9

*Ag-Lime Analysis Report, 2001

Data Sources

Ag-Lime Analysis Report, 2001
Nelson et al., 1990

Knoblauch Lime & Rock Company

9260 County 17 Boulevard
Cannon Falls, MN 55009

Phone: (507) 263-2995

Contact: Cliff Knoblauch

Quarry	T	R	S	Forty	County	Rock Type	Product	By-product
Spring Garden Quarry	111	17	14	SW 1/4 SW 1/4	Goodhue	Limestone	Crushed Stone	Ag-lime

Knoblauch Lime & Rock Company is a small operation that leases one 10-acre quarry, the Spring Garden Quarry, in Goodhue County, MN, for aggregate production.

Geologic Unit: Prosser Formation.

Wastes/By-products

The only "waste" generated at the Spring Garden Quarry is stripping. Stripping material is used to berm the operation and will be used for reclamation (Cliff Knoblauch, phone conversation, April, 2001). **Ag-lime** is a by-product generated by crushing operations at the quarry.

By-product Analytical Data - Ag-lime

Fines generated by Knoblauch Lime & Rock Company are sold as **ag-lime**. Table 35 presents ag-lime analytical data for the Spring Garden Quarry obtained from the MN Dept. of Agriculture Ag-Lime Analysis Report (2001).

Table 35 Ag-lime analytical data for Knoblauch Lime & Rock Company Spring Garden Quarry.

Ag-lime Analysis*												
Quarry	County	Date	Sample Type	Rec. #	Moisture Content	Fineness Index (FI)	% CCE	% ENP	MIN LBS ENP/TON	% Pass 8	% Pass 20	% Pass 60
Spring Garden	Goodhue	102400	Ag-lime	40	5.9 %	64	83.4	53.4	1005	98	67.7	43.3
*Ag-Lime Analysis Report, 2001												

Data Sources

Ag-lime Analysis Report, 2001
Cliff Knoblauch, pers. com., April, 2001
Nelson et al., 1990

Edward Kraemer & Sons, Inc.

1020 Cliff Rd West
Burnsville, MN 55337

Phone: (952) 890-2820
Fax: (952) 890-2996

Contact: Jim Small, Geological Services Manager
jsmall@edkraemer.com

www.edkraemer.com

Quarry	T	R	S	Forty	County	Rock Type	Product	By-product	Size	Amount	Location
Burnsville (Cliff Rd.) Quarry	27	24	33	N 1/2	Dakota	Dolomitic Limestone	Crushed Stone	Pond Fines	- 60 mesh	225,000 T	Stockpile & Ponds
								Screened Fines	- 3/16 in.	262,000 T	Stockpiles

Edward Kraemer & Sons, Inc., produces crushed rock from the dolomitic limestone of the Burnsville (Cliff Rd) Quarry in Dakota County, MN.

Geologic Unit: Willow River and New Richmond Members of the Shakopee Formation of the Prairie du Chien Group; 90-ft. thickness

History: The quarry was first opened in 1958. Current active quarry extent is 200 acres.

Production: Rock is drilled and blasted, then excavated and moved by means of backhoe, loaders, and trucks. Six crushers are used in aggregate production: one jaw, four cones, and one VSI. Both wet and dry classification are used. There are two wash plants and four settling ponds. Trucking accounts for 95 % of product shipments; barge haul accounts for < 5 %, and shipments by rail are also possible.

Product Line: Base material (Class 5, Class 2, 3 in. minus, and 3/8 in. minus), clean products (3 in., 1 7/8 in., 1 in., 3/4 in., and 3/8 in.), manufactured sand, rip rap (all sizes), and ag-lime.

Wastes/By-products

Waste/By-product	How Used	Most Difficult To Market	Easiest To Market	Potential Markets/Uses
Wash pond fines	Ag-lime, animal bedding	-3/16 in. screened fines	Overburden (peat, sand & gravel)	Engineered fill, liming material, taconite binder
Dry screened fines (-3/16 in.)				
Overburden	Fill			

Three wastes/by-products are generated at the Burnsville Quarry: **wash pond fines, dry screened fines,** and **overburden**. Annually, the quarry produces 120,000 tons (80,000 yds.) of pond fines and 105,000 tons (70,000 yds.) of screened fines. Accumulation of these materials has resulted in **262,000 tons (151,000 yd.) of stockpiled screened fines** and **225,000 tons (170,000 yds.) of stockpiled and ponded wash fines**.

Fines are screened, blended, and sold as agricultural liming material and animal bedding. Most of the fines are used for ag-lime purposes, but a significant amount still remains unused (J. Small, pers. comm., 2001). Because of the rate of production vs. demand, the -3/16 in. screened fines have been the most difficult for Edward Kraemer & Sons, Inc. to market. Overburden has been the easiest waste/by-product to market as it consists of peat and good quality sand and gravel, both of which have a high demand in the region.

Waste/By-product Analytical Data - Pond Fines

A sample of the pond fines, MW01011, was collected on-site in the Burnsville Quarry in January of 2001. Particle size analysis, geochemistry, and x-ray diffractometry for mineral content were run on this sample. In addition, other analytical data was provided by Ed Kraemer & Sons, Inc. and obtained from the MN Dept. of Agriculture Ag-Lime Analysis Report (2001).

Particle Size Analysis

Particle size data on sample MW01011, Burnsville Quarry pond fines, is presented in Table 36. These fines are coarser than some, with over 42 % falling in the sand-size fraction and over 53 % falling in the silt-sized fraction. Less than 4 % of the particles are clay-sized. Table 37 presents the complete set of particle size assay data on sample MW01011.

Table 36 Sand-silt-clay fraction: Ed Kraemer & Sons, Inc. pond fines (MW01011).

SAND - SILT - CLAY FRACTION*				
SAMPLE	SAMPLE TYPE	% SAND	% SILT	% CLAY
MW01011	Pond Fines	42.44	53.66	3.89
*Sand >= 62.5 microns (# 230 sieve), silt < 62.5 microns and >= 2 microns, clay < 2 microns.				

Table 37 Complete particle size assay data for Ed Kraemer & Sons, Inc. pond fines (MW01011).

Percent Passing Equivalent Spherical Diameter in Microns*														
	SAND					SILT							CLAY	
SAMPLE	2000 µ	1000 µ	500 µ	250 µ	120 µ	62.5 µ	44 µ	31 µ	22.1 µ	15.6 µ	7.8 µ	3.9 µ	2 µ	1 µ
MW01011	98.49	97.85	97.35	96.24	87.46	57.56	37.20	27.45	19.37	13.92	8.87	5.76	3.89	2.83
* + # 230 sieve fraction determined by sonic sifting; - # 230 sieve fraction determined by settling tube method.														

Figure 2 presents the particle size analysis of sample MW01011 in graphic form. The graph plots the weight percent of the sample that is: 1) finer than, and 2) coarser than, the equivalent spherical diameter (in microns) of a given particle size.

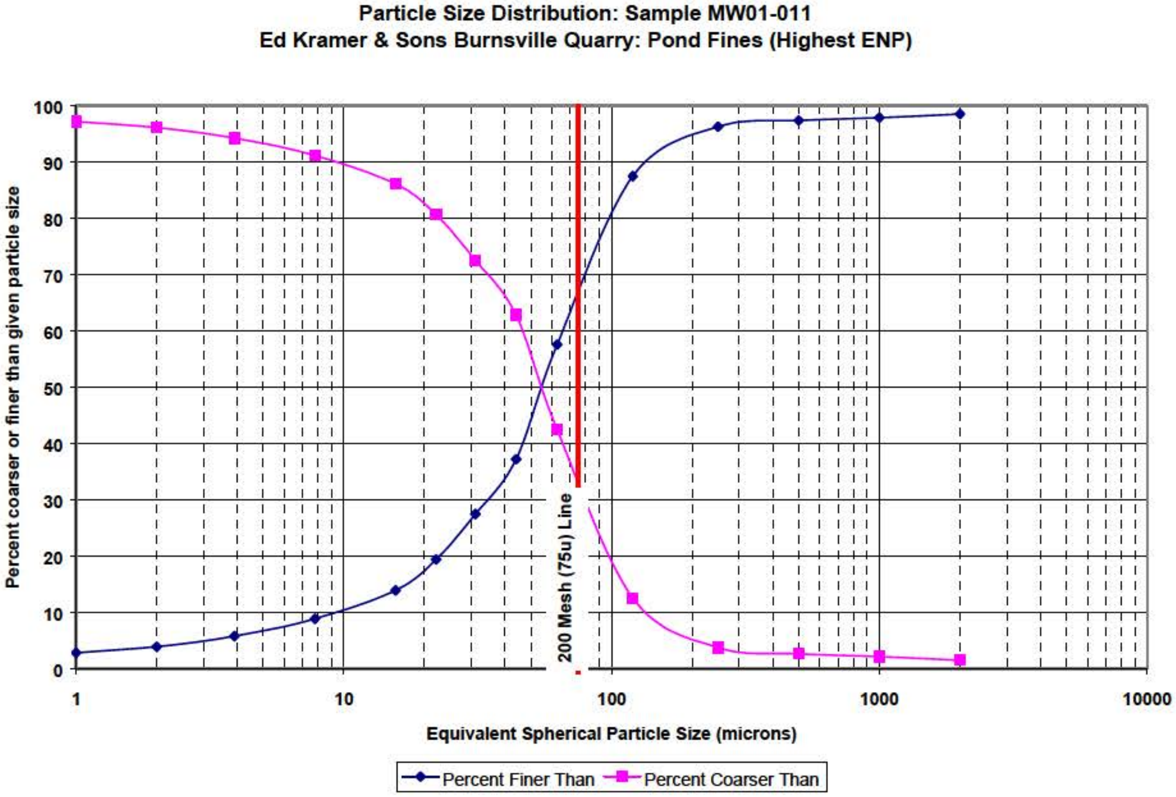


Figure 2. Particle size analysis in graphic form of Ed Kraemer & Sons, Inc. pond fines (MW01011).

Chemistry

The geochemical analysis of sample MW01011 is presented in Table 38.

Table 38 Geochemical analysis of Ed Kraemer & Sons, Inc. pond fines (MW01011).

Whole Rock[1]				Ultratrace - Aqua Regia[3]				Acid Digestion[4]			
SiO_2 wt %	10.34	Sc ppm	1	Mo (ppm)	0.59	Cr (ppm)	5.3	Mo (ppm)	1.3	Cr (ppm)	9
Al_2O_3 wt %	1.47	Ta ppm	< 20	Cu (ppm)	6.03	Mg %	9.02	Cu (ppm)	8	Mg %	10.44
Fe_2O_3 wt %	1.65	LOI %	41	Pb (ppm)	7.02	Ba (ppm)	15.5	Pb (ppm)	7	Ba (ppm)	73
MgO wt %	19.84	SUM %	99.87	Zn (ppm)	10.6	Ti %	< .001	Zn (ppm)	13	Ti %	0.026
CaO wt %	24.48			Ag (ppb)	47	B (ppm)	5	Ag (ppm)	0.7		
Na_2O wt %	0.15			Ni (ppm)	1.6	Al %	0.1	Ni (ppm)	4	Al %	0.66
K_2O wt %	0.69			Co (ppm)	1.3	Na %	0.012	Co (ppm)	1	Na %	0.059
TiO_2 wt %	0.04	Additional Analyses[2]		Mn (ppm)	1027	K %	0.05	Mn (ppm)	1094	K %	0.62
P_2O_5 wt %	0.05	C/ORG %	< .03	Fe %	1.01	W (ppm)	< .2	Fe %	1.17	W (ppm)	< 2
MnO wt %	0.13	CO_2 %	41.08	As (ppm)	0.8	Sc (ppm)	0.5	As (ppm)	3	Zr (ppm)	12.4
Cr_2O_3 wt %	0.002	TOT/C %	11.07	U (ppm)	0.6	Tl (ppm)	0.04	U (ppm)	< 1	Ce (ppm)	10
Ba ppm	64	SO_4 %	0.06	Au (ppb)	0.3	S %	0.04	Au (ppm)	< 4	Sn (ppm)	< .5
Cu ppm	< 20	TOT/S %	0.01	Th (ppm)	0.7	Hg (ppb)	7	Th (ppm)	< 1	Y (ppm)	2.1
Zn ppm	38			Sr (ppm)	48.7	Se (ppm)	0.9	Sr (ppm)	65	Nb (ppm)	< .2
Ni ppm	< 20	F (ppm)	196	Cd (ppm)	0.05	Te (ppm)	0.07	Cd (ppm)	< .2	Ta (ppm)	< .5
Co ppm	< 20			Sb (ppm)	0.06	Ga (ppm)	0.5	Sb (ppm)	< 1	Be (ppm)	< 1
Sr ppm	52	FeO %	0.9	Bi (ppm)	0.02			Bi (ppm)	< 1	Sc (ppm)	1
Zr ppm	43			V (ppm)	14			V (ppm)	17	Li (ppm)	4
Ce ppm	< 20	pH	9.4	Ca %	16.84			Ca %	21.33	S %	< .02
Y ppm	< 10	H_2O+ %	1.2	P %	0.014			P %	0.015	Rb (ppm)	7
Nb ppm	< 10	H_2O- %	0.2	La (ppm)	3.5			La (ppm)	4	Hf (ppm)	< 1

[1] 0.2 gm sample by $LIBO_2$ fusion, analysis by ICP-ES. LOI by loss on ignition.

[2] CO_2 - Digest with warm 15% $HCLO_4$, evolved CO_2 analyzed by LECO. SO_4 - Residue sulphur after ignited at 800 °C for 1 hour. C/ORG - Total C minus graphite C and carbonate. F - NaOH fusion - specific ion electrode analysis. FeO by dichromate titration. H_2O+ at 1500 °C. H_2O- at 110 °C.

[3] 15.00 gm sample, 90 ml 2-2-2 $HCl-HNO_3-H_2O$ at 95 °C for 1 hour and is diluted tp 300 ml, analysis by ICP/ES & MS.

[4] 0.25 gm sample digested with $HClO_4-HNO_3-HCl-HF$ to 10 ml. Digestion is partial for some minerals & may volatize some elements, analysis by ICP-ES.

Mineralogy

X-ray diffractometry run on sample MW01011 indicates that dolomite and the Fe-bearing carbonate mineral ankerite are the predominant mineral species present, accompanied by minor quartz (Table 39). Trace amounts of K-feldspar (microcline), biotite, and the clay mineral illite were detected. Figure 3 presents the XRD trace for sample MW01011.

Table 39 Mineralogy of Ed Kraemer & Sons, Inc. pond fines (MW01011).*

Mineralogy of Ed Kraemer & Sons, Inc. sample MW01011- Burnsville Quarry pond fines*						
	Dolomite	Ankerite	Quartz	Microcline	Hydrobiotite	Illite
MW01011	M	M	m	t	t	t
Component Mineral Compostion						
Mineral			Composition			
Dolomite	$CaMg(CO_3)_2$		Illite-2M1		$(K,H_3O)Al_2Si_3AlO_{10}(OH)_2$	
Ankerite	$Ca(Mg_{0.67}Fe_{0.33})(CO_3)_2$		Hydrobiotite		$K\text{-}Mg\text{-}Fe\text{-}Si\text{-}Al\text{-}Fe\text{-}O\text{-}OH\text{-}H_2O$	
Quartz., low	SiO_2		Microcline		$KAlSi_3O_8$	
* Mineralogy determined by XRD; M = major, m = minor, t = trace.						

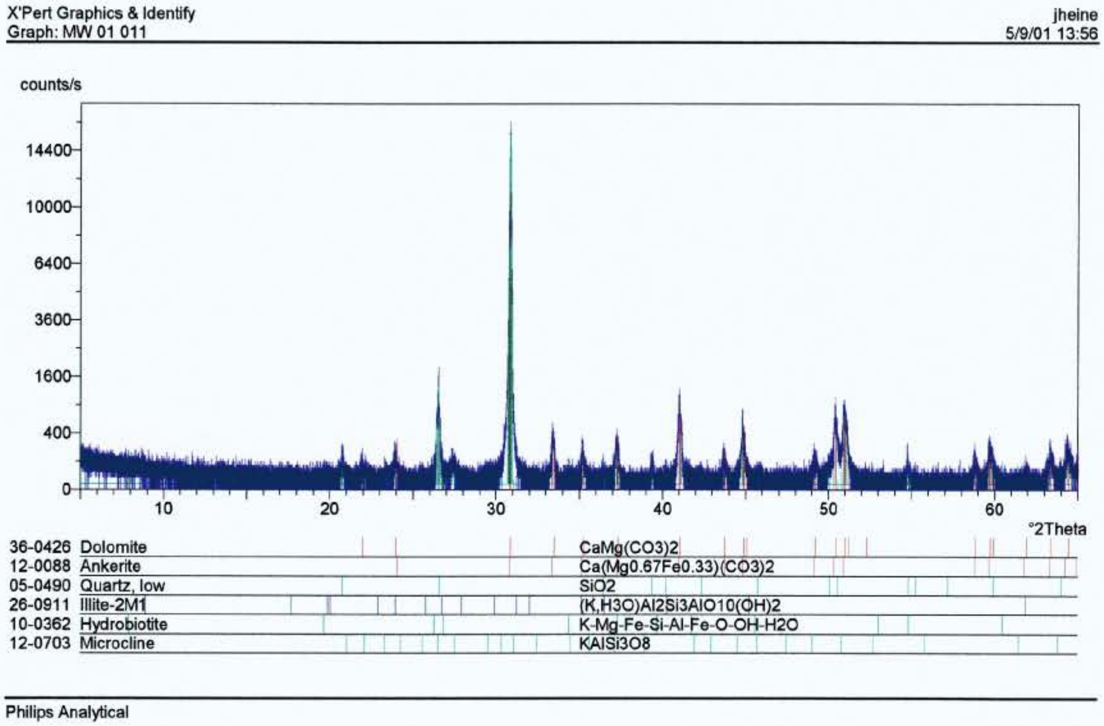


Figure 3. XRD trace depicting the mineralogy of Ed Kraemer & Sons, Inc. Burnsville Quarry pond fines (MW01011).

Product/By-product Analytical Data - Lime Sand and Ag-lime

Analytical data on various fines products generated at the Burnsville Quarry was provided by Ed Kraemer & Sons, Inc. Additionally, analytical data on Burnsville Quarry fines sold as ag-lime was obtained from the MN Dept. of Agriculture Ag-Lime Analysis Report (2001).

Particle Size Analysis

Sieve analysis and other physical property data was provided by Ed Kraemer & Sons, Inc. on two types of ag-lime material produced at the Burnsville Quarry: pep screen ag-lime and dry plant ag-lime. Both are classified as silty sand. Moisture content, assumed specific gravity, and sieve analyses of the samples are presented in Table 40.

Table 40 Sieve analysis and other physical property data on Ed Kraemer & Sons, Inc. ag-lime samples.*

Sample	Sample Type	Soil Classification	Analyzed	Moisture Content	Specific Gravity	Mass (gm)	% Pass 3/8 in.	% Pass 4	% Pass 10	% Pass 20	% Pass 40	% Pass 100	% Pass 200
Pep Screen Ag-Lime	Bag	Limestone fines - Silty sand (SM)	8/18/00	7.8%	2.66[1]	2591	100.0	98.4	85.0	69.4	60	37.7	25.9
Dry Plant Ag-Lime	Bag	Limestone fines - Silty sand (SM)	8/18/00	9.29	2.66[1]	2658	100.0	99.6	88.0	63.2	50.5	30.9	20.3
[1]Specific gravity is assumed value.													
*Data provided by Ed Kraemer & Sons, Inc.													

Chemistry

Table 41 contains chemical data provided by Ed Kraemer & Sons, Inc. on four samples, two of lime sand and two of ag-lime, from various plant locations. The samples were analyzed both "as is" and dried.

Ag-lime Analyses

Ag-lime analyses were run on these same four samples. The samples were tested "as is" and dried. Moisture content was determined on the "as is" material; sieve analyses were run on the dried material. Percent CCE and ECC were determined for both the "as is" and dried material. The resultant data are presented in Table 42.

Table 41 Geochemical analysis of Ed Kraemer & Sons, Inc. plant samples.*

	L187 - As Is	L187 - Dry	L188 - As Is	L188 - Dry	L189 - As Is	L189 - Dry	L190 - As Is	L190 - Dry
	Lime Sand Portable Plant	Lime Sand Portable Plant	Lime Sand Main Plant	Lime Sand Main Plant	Ag-lime PEP Screen	Ag-lime PEP Screen	Ag-lime Dry Plant	Ag-lime Dry Plant
Ca	17.8	18.4	17.4	18.2	15.9	17.0	18.7	19.3
Ca as Ca Oxide	24.9	25.8	24.3	25.5	22.3	23.7	26.1	27.0
Ca as Ca Carb	44.4	46.0	43.4	45.4	39.8	42.4	46.6	48.2
Mg	10.1	10.5	10.0	10.5	9.2	9.8	10.8	11.2
Mg as Mg Oxide	16.8	17.4	16.7	17.4	15.2	16.2	17.9	18.5
Mg as Mg Carb	35.1	36.3	34.8	36.5	31.8	33.9	37.4	38.7
Mg as CaCo3 Equiv	41.7	43.1	41.4	43.3	37.8	40.2	44.3	45.9
Na	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
K	0.07	0.08	0.08	0.09	0.13	0.13	0.11	0.11
S	0.29	0.30	0.27	0.28	0.19	0.20	0.24	0.25
Fe (ppm)	10689.05	11058.40	9300.17	9738.40	9710.20	10338.80	8554.90	8856.00
Mn (ppm)	1079.69	1117.00	1021.28	1069.40	960.05	1022.2	1029.66	1065.90
Cu (ppm)	13.63	14.10	13.66	14.30	13.71	14.60	14.97	15.50
Zn (ppm)	36.25	37.50	32.47	34.00	40.29	42.90	38.74	40.10
B (ppm)	30.45	31.50	24.83	26	23.86	25.4	25.50	26.4

* Data provided by Ed Kraemer & Sons, Inc.

Table 42 Ag-lime analytical data for Ed Kraemer & Sons, Inc. plant samples.*

Sample	Date	Sample Type	Moisture Content	% CCE	% E.C.C.	% Pass 8	% Pass 20	% Pass 60	% Pass100
L187 - As Is	1221/99	Lime Sand Portable Plant	3.3 %	87.7	29				
L187 - Dry	12/21/99	Lime Sand Portable Plant		90.7	30	66.1	37.1	14.6	9.7
L188 - As Is	12/21/99	Lime Sand Main Plant	4.5%	93.0	34				
L188 - Dry	12/21/99	Lime Sand Main Plant		97.4	36	61.1	39.6	25.3	17.3
L189 - As Is	12/21/99	Ag-lime PEP Screen	6.1 %	79.9	53				
L189 - Dry	12/21/99	Ag-lime PEP Screen		85.0	56	91.6	72.1	51.2	41.1
L190 - As Is	12/21/99	Ag-lime Dry Plant	3.4%	92.4	52				
L190 - Dry	12/21/99	Ag-lime Dry Plant		95.7	54	92.2	59.7	40.5	32.3

* Data provided by Ed Kraemer & Sons, Inc.

Ag-lime analytical data on four additional samples was provided by Ed Kraemer & Sons, Inc. These samples include pep screened, blended, and regular ag-lime, and pond fines. Additional ag-lime analytical data on three samples was obtained from the MN Dept. of Agriculture Ag-Lime Analysis Report (2001). These samples consist of screened pond fines, pep screened ag-lime, and blended ag-lime. The data are presented in Table 43.

Table 43 Ag-lime analytical data for additional Ed Kraemer & Sons, Inc. samples.

Ag-lime Analysis										
Sample / Rec. #	**Date**	**Sample Type**	**Moisture Content**	**Fineness Index (FI)**	**% CCE**	**% ENP**	**MIN LBS ENP/TON**	**% Pass 8**	**% Pass 20**	**% Pass 60**
EK-719 *	4/27/00	PEP Screened Ag-lime	5.7%	76.2	77	58.7	1107	96.4	80.5	61.8
EK-712 *	4/6/00	Blended Ag-lime	7.3%	76	86.2	65.5	1215	97.3	78.4	63.0
EK-649 *	9/2/00	Regular Ag-lime	3.8%	62.9	90.8	57.1	1098	94.7	67.1	42.7
EK-646 *	9/2/00	Pond Fines	8.2%	97.9	86.9	85.1	1562	98.5	98.0	97.5
10 **	5/3/00	Screened Pond Fines	9.2 %	98.3	82.4	81.0	1471	99.5	99.2	96.8
11 **	8/9/00	Pep Screened Ag-lime	1.8 %	69.1	74.4	51.4	1009	88.2	73.1	55.5
12 **	8/25/00	Blended Ag-lime	7.3 %	74.5	87.4	65.2	1208	95.1	77	61.8
*Data provided by Ed Kraemer & Sons, Inc.										
**Ag-Lime Analysis Report, 2001										

Data Sources

2001 Survey Response
Ag-Lime Analysis Report, 2001
www.edkraemer.com

Martin Marietta Aggregates
(formerly Meridian Aggregate Co.)

P.O. Box 69
St. Cloud, MN 56302

Phone: (320) 251-7141
Fax: (320) 229-2113

Contact: Dan Bokinskie
Sales and Technical Services
dan.bokinskie@martinmarietta.com

www.martinmarietta.com

Quarry	T	R	S	County	Rock Type	Product(s)	By-product	Size
St. Cloud Quarry	124	28	17, 18	Stearns	Granite, Metamorphic Rocks	Crushed Stone	Drilling Dust	N.A.
							Baghouse Dust	- # 200
							Hydrocyclone Product	- 50 mesh
							Pond Settlings	N.A.
Yellow Medicine Quarry	116	39	28 ,29 32 ,33	Yellow Medicine	Gneiss	Crushed Stone	Tower Sand	N.A.
							Pond settlings	N.A.

Meridian Aggregate Co. is located in Waite Park, MN, just outside of the city of St. Cloud in Stearns County. Meridian Aggregate Co. produces crushed stone from the red St. Cloud Granite, the gray Reformatory Granite, and dark-colored metamorphic rocks of the St. Cloud Quarry (Shurr et al., 1991). Meridian Aggregate Co. also quarries the Montevideo Gneiss at the Yellow Medicine Quarry, located just outside of Granite Falls in Yellow Medicine County.

Geologic Unit:		
	St. Cloud Quarry:	St. Cloud and Reformatory Granites, metamorphics
	Yellow Medicine Quarry:	Montevideo Gneiss

Wastes/By-products

Waste/By-product	How Used	Most Difficult To Market	Easiest To Market	Potential Markets/Use
St. Cloud Quarry and Plant				Quarry/plant fines as soil amendment, filler in shingles and plastics, aid in ash encapsulation (garbage burning facilities), and combined with poultry wastes as fertilizer. Coarser pond settlings (>350 mesh) in microsurfacing applications.
Drilling Dust	N.A.	N.A.	N.A.	
Baghouse Dust				
Cyclone Sand				
Wash Plant Fines (Pond Settlings)				
Yellow Medicine Quarry				
Tower sand	N.A.	N.A.	N.A.	
Pond Settlings				

There are four wastes/by-products generated at the St. Cloud operation: **drilling dust, baghouse dust, cyclone sand (hydrocyclone product),** and **wash plant fines (pond settlings)**. A sample of the hydrocyclone product was provided by Meridian Aggregate Co. for analysis. By-products from the Yellow Medicine Quarry include **tower sand** and **pond settlings**.

A separate study by the University of Minnesota evaluated the use of rock fines from both quarries as a sustainable soil amendment for agriculture (Rosen et al., 1999, 2000, 2001). The full report from this study can be found in Appendix E. Analytical data from the study are presented below and in Appendix E.

Waste/By-product Analytical Data - Hydrocyclone Product

A sample, MW01013, was provided by Meridian Aggregate Co. from the wash plant hydrocyclone overflow in January of 2001. Particle size analysis, geochemistry, and x-ray diffractometry for mineral content was run on the sample.

Particle Size Analysis

Particle size data on sample MW01013, Meridian Aggregate Co. hydrocyclone product, is presented in Table 44. As shown, this is a rather coarse product, with 73 % of the particles falling into the sand-sized fraction. The silt-sized fraction comprises 23.5 % of the sample while only 3.5 % of the sample particles are clay-sized. Table 45 presents the complete set of particle size assay data on sample MW01013.

Table 44 Sand-silt-clay fraction: Meridian Aggregate Co. hydrocyclone product (MW01013).

SAND - SILT - CLAY FRACTION*				
SAMPLE	SAMPLE TYPE	% SAND	% SILT	% CLAY
MW01013	Hydrocyclone Product	73.00	23.46	3.54

*Sand >= 62.5 microns (# 230 sieve), silt < 62.5 microns and >= 2 microns, clay < 2 microns.

Table 45 Complete particle size assay data for Meridian Aggregate Co. hydrocyclone product (MW01013).

Percent Passing Equivalent Spherical Diameter in Microns*														
	SAND					SILT							CLAY	
SAMPLE	2000 µ	1000 µ	500 µ	250 µ	120 µ	62.5 µ	44 µ	31 µ	22.1 µ	15.6 µ	7.8 µ	3.9 µ	2 µ	1 µ
MW01013	99.67	99.36	96.54	83.73	54.07	27.00	17.94	13.70	10.85	8.82	6.24	4.54	3.54	3.00

* + # 230 sieve fraction determined by sonic sifting; - # 230 sieve fraction determined by settling tube method.

Figure 4 presents the particle size analysis of sample MW01013 in graphic form. The graph plots the weight percent of the sample that is: 1) finer than, and 2) coarser than, the equivalent spherical diameter (in microns) of a given particle size.

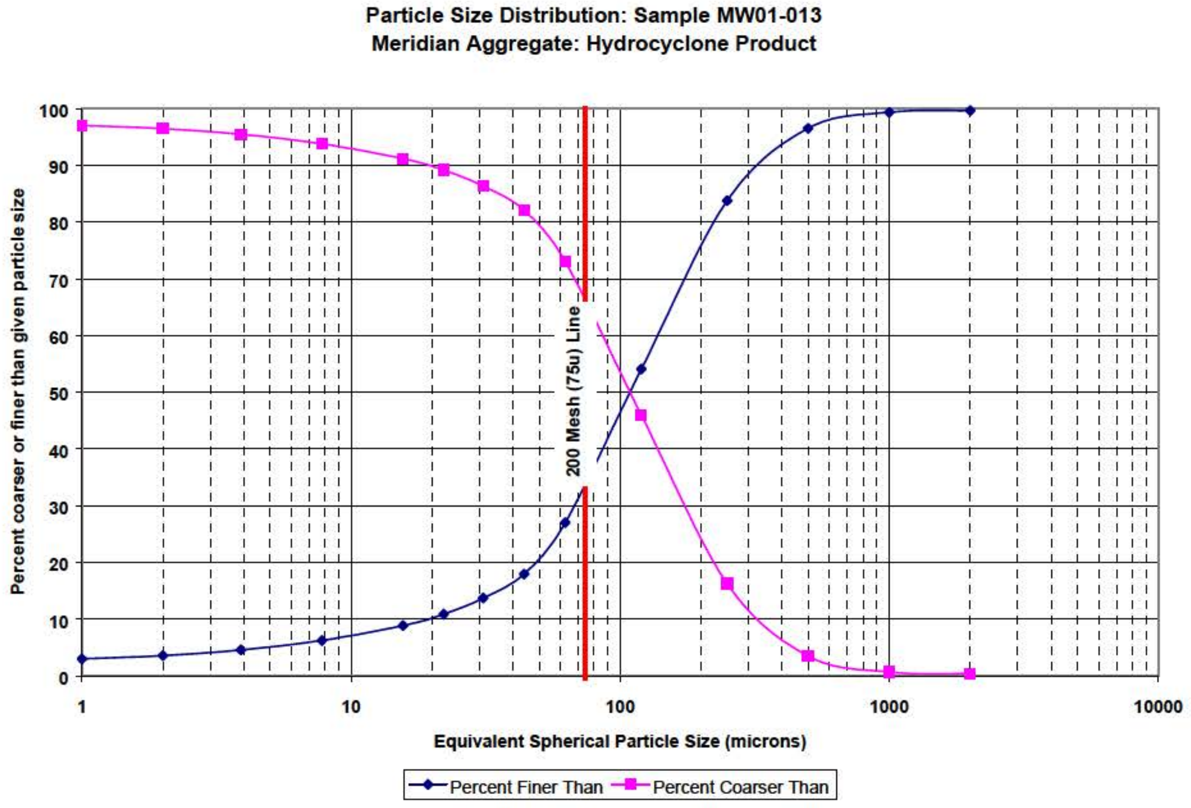


Figure 4. Particle size analysis in graphic form of Meridian Aggregate Co. hydrocyclone product (MW01013).

Chemistry

Table 46 presents the geochemical analysis of sample MW01013, Meridian Aggregate Co. hydrocyclone product.

Table 46 Geochemical analysis of Meridian Aggregate Co. hydrocyclone product (MW01013).

Whole Rock [1]				Ultratrace - Aqua Regia [3]				Acid Digestion [4]			
SiO_2 wt %	66.38	Sc ppm	12	Mo (ppm)	1.52	Cr (ppm)	22.7	Mo (ppm)	1.7	Cr (ppm)	29
Al_2O_3 wt %	13.22	Ta ppm	< 20	Cu (ppm)	14.97	Mg %	0.68	Cu (ppm)	7	Mg %	0.98
Fe_2O_3 wt %	4.83	LOI %	1.7	Pb (ppm)	11.01	Ba (ppm)	100.7	Pb (ppm)	24	Ba (ppm)	907
MgO wt %	1.65	SUM %	99.9	Zn (ppm)	60.7	Ti %	0.172	Zn (ppm)	85	Ti %	0.378
CaO wt %	3.06			Ag (ppb)	57	B (ppm)	2	Ag (ppm)	0.2		
Na_2O wt %	2.87			Ni (ppm)	8.4	Al %	1.05	Ni (ppm)	10	Al %	6.97
K_2O wt %	5.12			Co (ppm)	8.2	Na %	0.059	Co (ppm)	11	Na %	2.218
TiO_2 wt %	0.62			Mn (ppm)	365	K %	0.45	Mn (ppm)	656	K %	2.89
P_2O_5 wt %	0.15	C/ORG %	< .03	Fe %	2.17	W (ppm)	0.4	Fe %	3.65	W (ppm)	2
MnO wt %	0.08	CO_2 %	0.65	As (ppm)	0.7	Sc (ppm)	3	As (ppm)	4	Zr (ppm)	209.2
Cr_2O_3 wt %	0.007	TOT/C %	0.16	U (ppm)	4.1	Tl (ppm)	0.33	U (ppm)	10	Ce (ppm)	129
Ba ppm	857	SO_4 %	< .03	Au (ppb)	1.2	S %	< .01	Au (ppm)	< 4	Sn (ppm)	1.9
Cu ppm	21	TOT/S %	< .01	Th (ppm)	14.1	Hg (ppb)	< 5	Th (ppm)	12	Y (ppm)	18.6
Zn ppm	114			Sr (ppm)	21	Se (ppm)	< .1	Sr (ppm)	290	Nb (ppm)	12.3
Ni ppm	< 20	F (ppm)	961	Cd (ppm)	0.12	Te (ppm)	< .02	Cd (ppm)	< .2	Ta (ppm)	0.5
Co ppm	< 20			Sb (ppm)	0.02	Ga (ppm)	5.2	Sb (ppm)	< 1	Be (ppm)	2
Sr ppm	294	FeO %	3.2	Bi (ppm)	0.12			Bi (ppm)	1	Sc (ppm)	13
Zr ppm	295			V (ppm)	39			V (ppm)	71	Li (ppm)	50
Ce ppm	94	pH	9.2	Ca %	0.73			Ca %	2.36	S %	< .02
Y ppm	20	H_2O+ %	1.4	P %	0.068			P %	0.07	Rb (ppm)	138
Nb ppm	40	H_2O- %	0.2	La (ppm)	47.1			La (ppm)	66	Hf (ppm)	6

[1] 0.2 gm sample by $LIBO_2$ fusion, analysis by ICP-ES. LOI by loss on ignition.

[2] CO_2 - Digest with warm 15% $HCLO_4$, evolved CO_2 analyzed by LECO. SO_4 - Residue sulphur after ignited at 800 °C for 1 hour. C/ORG - Total C minus graphite C and carbonate. F - NaOH fusion - specific ion electrode analysis. FeO by dichromate titration. H_2O+ at 1500 °C. H_2O- at 110 °C.

[3] 15.00 gm sample, 90 ml 2-2-2 $HCl-HNO_3-H_2O$ at 95 °C for 1 hour and is diluted tp 300 ml, analysis by ICP/ES & MS.

[4] 0.25 gm sample digested with $HClO_4-HNO_3-HCl-HF$ to 10 ml. Digestion is partial for some minerals & may volatize some elements, analysis by ICP-ES.

Mineralogy

X-ray diffractometry run on sample MW01013, Meridian Aggregate Co. hydrocyclone product, determined that quartz and the K-feldspar sanidine are the predominant mineral species present (Table 47). Minor muscovite and the Ca-plagioclase feldspar anorthite were detected, as well as trace amounts of the Na-plagioclase feldspar albite, the K-feldspar orthoclase, annite (biotite), amphibole (richterite), clay minerals illite, kaolinite, and the mixed-layer illite/montmorillonite, and the chlorite mineral clinochlore. Figure 5 presents the XRD trace for sample MW01013.

Table 47 Mineralogy of Meridian Aggregate Co. hydrocyclone product (MW01013).*

	Quartz	Sanidine	Anorthite	Muscovite	Illite	Illite-Mont-morillonite	Kaolinite	Richterite	Albite
MW01013	M	M	m	m	t	t	t	t	t
	Orthoclase	Clinochlore	Annite						
MW01013	t	t	t						

Component Mineral Compostion			
Albite, ordered	$NaAlSi_3O_8$	Muscovite-2M2	$KAl_2(Si_3Al)O_{10}(OH)_2$
Orthoclase	$KAlSi_3O_8$	Illite-2M2	$K_{0.7}Al_{2.1}(Si,Al)_4O_{10}(OH)_2$
Richterite, potassian	$KNaCaMg_5Si_8O_{22}(OH)_2$	Annite-1M	$KFe_3(Si,Al)_4O_{10}(OH)_2$
Anorthite, sodian, ordered	$(Ca,Na)(Al,Si)_2Si_2O_8$	Clinochlore-1Mla, ferr	$(Mg,Fe,Al)_6(Si,Al)_4O_{10}(OH)_8$
Sanidine, disordered	$K(Si_3Al)O_8$	Illite-Montmorillonite	$KAl_4(Si,Al)_8O_{10}(OH)_4!4H_2O$
Quartz., low	SiO_2	Kaolinite-1A	$Al_2Si_2O_5(OH)_4$

* Mineralogy determined by XRD; M = major, m = minor, t = trace.

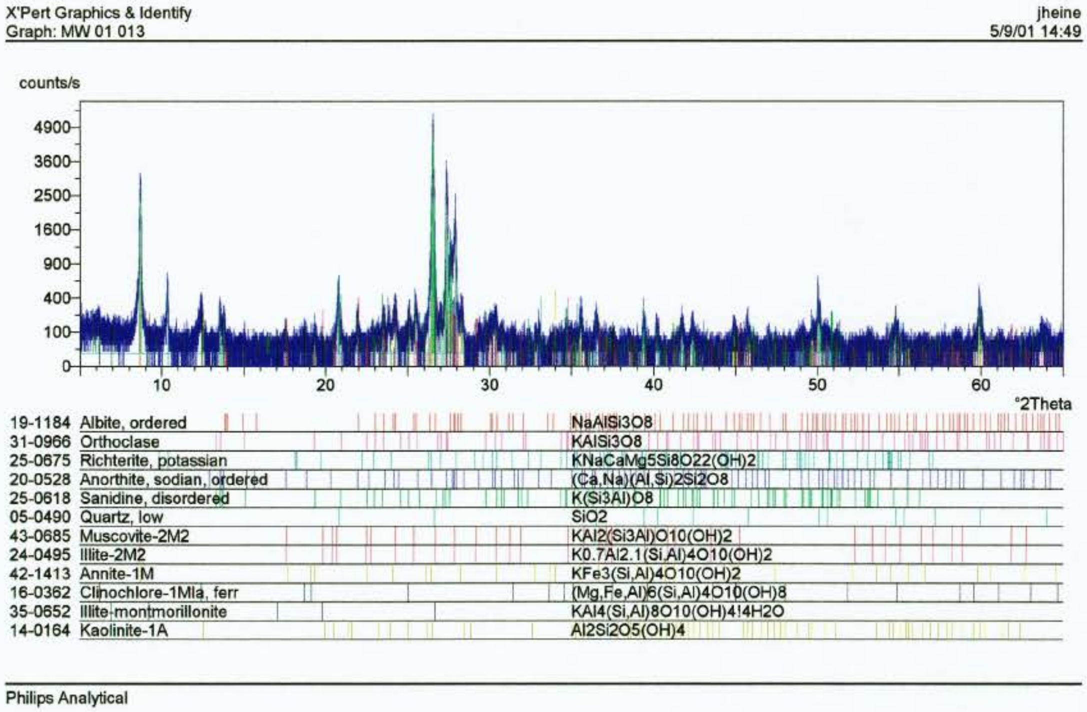


Figure 5. XRD trace depicting the mineralogy of Meridian Aggregate Co. hydrocyclone product (MW01013).

University of Minnesota Study Analytical Data - Cyclone Sand and Pond Tailings; Tower Sand and Pond Settlings

The University of Minnesota Department of Soil, Water, and Climate began a study in 1999 to evaluate rock fines as a sustainable soil amendment. Selected for use in the study were cyclone sand and pond tailings from the Meridian Aggregate Co. quarry in St. Cloud, MN, and tower sand and pond settlings from the Yellow Medicine Quarry at Granite Falls, MN. Some of the analytical data from the study is presented below. For the full report of the University of Minnesota project, including additional analytical data, please see Appendix E.

Particle Size Analysis

Particle size data on the cyclone sand and pond tailings from St. Cloud and the tower sand and pond settlings from Granite Falls, obtained from the U of M study, is presented in Table 48. A further breakdown of the sand size fraction is presented in Table 49. The analyses were performed by sieve and hydrometer method (Rosen et al., 1999).

Table 48 Particle size distribution of selected rock fines (after Rosen et al., 1999).

Location	Rock Type	By-product	% Gravel > 2.0 mm		% Sand 0.05m - 2.0 mm		% Silt 0.002 - 0.05 mm		% Clay < 0.002 mm	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD
St. Cloud	Granite	Cyclone Sand	0.08	0.04	86.6	2.8	12.3	2.4	1.0	0.4
		Pond Tailing	0.05	0.05	78.1	3.8	19.4	3.5	2.5	0.6
Granite Falls	Granite	Tower Sand	0.03	0.04	85.0	2.5	13.7	2.8	1.3	0.4
		Pond Settlings	0.03	0.04	9.7	0.8	80.0	0.8	10.3	0.4

Table 49 Sand fraction size distribution of selected rock fines (after Rosen et al., 1999).

Location	Rock Type	By-product	Sand %									
			> 1mm Very Coarse		1.0 - 0.5 mm Coarse		0.5 - 0.25 mm Medium		0.25 - 0.1 mm Fine		0.1 - 0.05 mm Very Fine	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
St. Cloud	Granite	Cyclone Sand	1.4	0.8	5.2	2.4	15.9	6.8	39.8	4.0	24.2	10.6
		Pond Tailing	1.1	0.3	4.1	0.4	14.7	1.2	37.4	2.4	20.9	0.4
Granite Falls	Granite	Tower Sand	0.6	0.6	2.6	2.1	8.8	6.2	35.1	4.2	37.9	11.9
		Pond Settlings	0.2	0.1	0.3	0.1	0.3	0.1	1.0	0.2	8.1	0.7

Chemistry

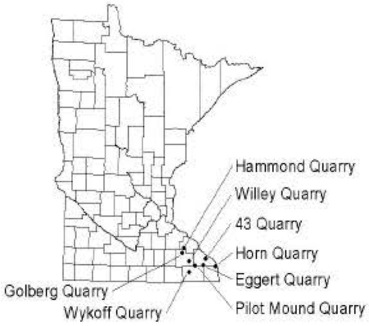
Additional analytical data on the St. Cloud cyclone sand and pond tailings and the Granite Falls tower sand and pond settlings is presented in Table 50. Included are pH, cation exchange capacity (CEC), total nitrogen, organic carbon, moisture content, and soluble chloride. Elemental chemistry relative to plant nutrient availability is presented in Appendix E.

Table 50 Additional analytical data on the Meridian Aggregate Co. rock fines from St. Cloud and Granite Falls (after Rosen et al., 1999).

		pH		CEC Meq / 100 gm		Total N (%)		Organic C (%)		Moisture (%) dry wt.		Cl ppm	
Location	By-product	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
St. Cloud	Cyclone Sand	9	0	1.2	0.1	0.044	0.004	0.04	0.02	16	1	15	3
	Pond Tailings	8.6	0.1	1.4	0.2	0.027	0.005	0.03	0.03	10	1	3	0
Granite Falls	Shot Saw Fines	9.5	0.1	4.3	0	0.032	0.003	0.4	0.04	22	0	428	33
	East Plant Fines	8.8	0.1	9.9	0.2	0.02	0.003	0.3	0.02	25	2	15	1

Data Sources

2001 Site Visit
2001 NRRI Sample Analysis
Nelson et al., 1990
Rosen et al., 1999
Shurr et al., 1991
Vry, D., pers. comm., 2001
www.martinmarietta.com



Milestone Materials

920 10th Ave. N.
Onalaska, WI 54650

Phone: (608) 783-6411
Fax: (608) 783-4311

Contact: Steve Beach

Parent Company: Mathy Construction Co.
Contact: Scott Mathy, Vice President

Quarry	T	R	S	Forty	County	Rock Type	Products	By-products	Amount Location
43 Quarry	106	7	16	SE-NW	Winona	Dolomite	Crushed Stone	Ag-lime	40,000 T
Eggert Quarry	104	8	2	NE-NE	Fillmore	Dolomite	Crushed Stone	Ag-lime	8,000 T
Golberg Quarry	108	14	36	SE- SW SW-SE	Olmsted	Dolomitic Limestone	Crushed Stone	Sandstone Rubble	250,000 T
								Ag-lime	40,000 T
Hammond Quarry	109	13	29	SE1/4	Wabasha	Dolomite	Crushed Stone	Screenings	30,000 T
Horn Quarry	104	4	17	NW-NW	Houston	Dolomite	Crushed Stone	Ag-lime	15,000 T
Pilot Mound Quarry	104	10	3	SW-SW	Fillmore	Dolomite	Crushed Stone	Ag-lime	3,000 T
Willey Quarry	105	12	2	NE-NW	Olmsted	Dolomite	Crushed Stone	Screenings	5,000 T
Wykoff Quarry	103	12	26	SE 1/4	Fillmore	Limestone	Crushed Stone	Ag-lime	15,000 T

Milestone Materials, based in Onalaska, Wisconsin, operates several carbonate rock quarries in southeastern Minnesota to produce crushed stone products. Operations are located in Fillmore, Houston, Olmsted, and Winona counties.

Geologic Unit: 43, Eggert, Hammond, and Horn quarries: Oneota Formation
Golberg and Pilot Mound quarries: Shakopee Formation
Willey Quarry: Prosser Formation
Wykoff Quarry: Stewartville Formation

Wastes/By-products

Waste/By-products	How Used	Most Difficult To Market	Easiest To Market	Potential Markets/Uses
Lime fines	Quarry reclamation fill	Screenings (3/8 in. minus stone)	Pond washout	Soil neutralization uses, including metallic mining reclamation.
Ag-lime	Sold at discount to farmers			
Screenings	Fill			
Pond washout				

Wastes/by-products generated by Milestone Materials operations include **lime fines, ag-lime, screenings,** and **pond fines. Sandstone rubble** has been stockpiled at the Golberg Quarry in Olmsted County. Lime fines are used as fill in quarry reclamation and sold at a discount to farmers for agricultural liming. The screenings, which are sold for fill, have been the most difficult to market because contractors can use local clays and borrow pits instead. The Golberg Quarry pond fines have been the easiest waste/by-product to market because their high soil neutralization value (min. lbs. ENP / ton = 1526; Table 51) gives them enhanced value as ag-lime material. A **significant resource of screenings (5,000 to 30,000 tons) and ag-lime materials (3,000 to 40,000 tons)** is available at the various Milestone Materials operations.

Waste/By-product Analytical Data - Ag-lime

No waste/by-product samples were collected from or submitted by Milestone Materials. Ag-lime analytical data, however, was provided by Milestone Minerals and also obtained from the MN Dept. of Agriculture Ag-Lime Analysis Report (2001).

Ag-lime Analysis

Table 51 presents the ag-lime analytical data for the Milestone Materials quarries listed above. Quarry data was submitted by Milestone Materials. Table 52 presents the ag-lime analytical data for additional Milestone Materials quarries as listed in the MN Dept. of Agriculture Ag-Lime Analysis Report (2001).

Table 51 Ag-lime analytical data for quarries submitted by Milestone Materials.

Quarry	Date	Sample Type	Rec. #	Moisture Content	Fineness Index (FI)	% CCE	% ENP	MIN LBS ENP/TON	% Pass 8	% Pass 20	% Pass 60
43	10032000	Ag-lime	141	5.5 %	66.0	95.3	62.9	1188	90.0	67.1	52.8
Eggert	10052000	Ag-lime	26	5.4 %	68.7	90.3	62.0	1173	94.5	71.8	52.6
Golberg	09152000	Pond Fines	80	7.2 %	97.4	84.4	82.2	1526	99.6	99.2	94.6
Golberg	09132000	Cattle Bedding	81	4.1 %	55.6	82.4	45.9	879	96.2	70.7	20.3
Hammond	09112000	Ag-lime	132	5.0 %	59.9	94.4	56.5	1074	92.3	63.6	39.9
Pilot Mound	10052000	Ag-lime	29	5.4 %	66.9	94.3	63.1	1194	94.9	72.1	47.8
Willey	09112000	Ag-lime	78	5.7 %	54.0	79.3	42.9	808	89.8	56.6	33.6
Wykoff	10052000	Ag-lime	27	7.3 %	64.1	95.3	61.1	1132	90.0	65.3	49.9
Wykoff	11162000	Ag-lime - 2000 Production	33	6.5 %	68.7	96.4	66.3	1239	94.0	70.3	54.5

*Ag-Lime Analysis Report, 2001

Table 52 Ag-lime analytical data for additional quarries listed as operated by Milestone Materials.

Quarry	Date	Sample Type	Rec. #	Moisture Content	Fineness Index (FI)	% CCE	% ENP	MIN LBS ENP/TON	% Pass 8	% Pass 20	% Pass 60
Bly	10052000	Ag-lime	28	7.6 %	59.5	88.8	52.8	976	91.7	61.5	41.3
Rifle Hill	10052000	Ag-lime	30	4.1 %	52.9	84.3	44.6	855	86.9	55.0	33.8
Greene	10112000	Ag-lime	31	5.8 %	60.6	77.3	46.9	883	89.0	63.0	44.1
Fountain	10242000	Ag-lime	32	2.5 %	75.3	83.7	63.0	1229	96.3	82.4	57.7
Walsh	09012000	Ag-lime	77	2.6 %	81.1	86.5	70.2	1367	98.2	88.4	65.3
RSG	09112000	Pond Fines	79	5.9 %	91.3	64.7	59.1	1112	98.3	96.1	83.0
Sixty Three	10242000	Ag-lime	82	2.8 %	54.9	87.9	48.2	938	88.4	57.9	35.1
Hammell	11152000	Ag-lime	83	5.2 %	55.0	78.7	43.3	820	86.2	57.5	36.8
Sigenthaler	09082000	Ag-lime	130	5.1 %	55.5	83.4	46.3	878	82.3	58.3	39.2
Becker	09082000	Ag-lime	131	7.4 %	63.1	83.8	52.9	979	93.9	68.1	42.7
Moyer	09142000	Ag-lime	133	6.4 %	53.1	75.7	40.2	753	79.7	57.2	35.8
McGuire	09272000	Ag-lime	138	5.4 %	56.3	87.4	49.2	931	81.8	59.3	40.6
Hornberg	09272000	Ag-lime	139	7.1 %	68.8	87.4	60.2	1118	97.3	76.0	47.4
Hornberg	10032000	Ag-lime	142	4.6 %	61.6	86.2	53.1	1014	93.2	65.4	42.1
Biesanz	01032000	Ag-lime	140	5.7 %	65.0	93.9	61.0	1150	89.2	66.3	51.5

*Ag-Lime Analysis Report, 2001

Data Sources

2001 Survey Response
Ag-lime Analysis Report, 2001
ASIS Database, 2001
Nelson et al., 1990

New Ulm Quartzite Quarries

45755 571st Lane
New Ulm, MN 56073

Phone: (507) 354-2925
Fax: (507) 359-7870

Contact: Jeff Carlstrom, General Manager
jcarlstrom@nuqq.com

www.nuqq.com

Quarry	T	R	S	Forty	County	Rock Type	Product	By-product	Size	Amount	Location
New Ulm Quarry	110	30	35		Nicollet	Quartzite	Crushed Stone	Settled wash fines	- 200 mesh	400,000 T	Pond & Stockpile

New Ulm Quartzite Quarries (NUQQ) is located just east of the city of New Ulm in Nicollet County, Minnesota. NUQQ quarries the Sioux Quartzite to produce crushed stone products.

Geologic Unit: Sioux Quartzite; 700-ft. thickness at New Ulm "dominated by a tightly cemented, purple, silica-cemented quartz sand" (Carlstrom, J., with Martin, D., 1996).

History: First opened in 1861, the New Ulm Quartzite Quarry was operated for 60 years. Continuous operation since its re-opening in 1958 brings the active life of the quarry to over 100 years. Reserve estimates indicate many more decades of operation (Carlstrom, J., with Martin, D., 1996).

Production: The quarry operation consists of drilling and blasting, followed by hydraulic shovel excavation and truck haulage. Processing, consisting of crushing, sizing, and washing, is carried out in three stages, with a separate bagging plant for the poultry grit. Mining and processing run from April to November. Shipping is year-round by truck and rail (Carlstrom, J., with Martin, D., 1996). Annual production is 300,000-500,000 tons.

Product Line: concrete and clean aggregate, structural base, bituminous aggregates, erosion control products (bedding and rip rap), decorative/utility products (including filter rock and # 200 minus fines: wash pond mineral silt), and Cherrystone poultry grit.

Wastes/By-products

Waste/By-product	How Used	Most Difficult To Market	Easiest To Market	Potential Markets/Uses
Wash Pond Fines	Stored on site	Wash Pond Fines	N.A.	Filler or amendment

The **wash pond fines** from the screening plant are the only waste/by-product that NUQQ has been unable to market. **Over 400,000 tons of settled wash fines** are stored on site in a permanent stockpile and in an adjacent pond. An additional **9,000+ tons of pond fines are produced annually**. Indicative of the fact that there is little market at present for these fines, the "# 200 Minus Fines" (wash pond mineral silt) can currently be purchased for $1.00/ton (Our Price List, 2004).

Waste/By-product Analytical Data - Pond Fines

A sample of NUQQ's pond fines, MW01003, generated from the screening plant wash, was collected on-site in the New Ulm Quarry in January of 2001. The pond is located east of the main aggregate production area. Particle size analysis, geochemistry, and x-ray diffractometry for mineral content were run on this sample. Figure 6 shows the north bank of the pond.

Figure 6. Photograph of New Ulm Quartzite Quarry fines pond.

Particle Size Analysis

Particle size data on sample MW01003, NUQQ pond fines, is presented in Table 53. The data indicates that the predominance of particles are silt-size (81.4 %). Only 3.4 % of the particles are sand size, while 15.2 % of the particles are clay size. Table 54 presents the complete set of particle size analytical data for sample MW01003.

Table 53 Sand-silt-clay fraction: NUQQ pond fines (MW01003).

SAND - SILT - CLAY FRACTION*				
SAMPLE	SAMPLE TYPE	% SAND	% SILT	% CLAY
MW01003	Pond Fines	3.40	81.37	15.23
*Sand >= 62.5 microns (# 230 sieve), silt < 62.5 microns and >= 2 microns, clay < 2 microns.				

Table 54 Complete particle size assay data for NUQQ pond fines (MW01003).

Percent Passing Equivalent Spherical Diameter in Microns*														
	SAND					SILT							CLAY	
SAMPLE	2000 µ	1000 µ	500 µ	250 µ	120 µ	62.5 µ	44 µ	31 µ	22.1 µ	15.6 µ	7.8 µ	3.9 µ	2 µ	1 µ
MW01003	100.00	99.95	99.84	99.65	99.11	96.60	89.51	80.19	69.06	59.19	39.77	25.20	15.23	9.12
* + # 230 sieve fraction determined by sonic sifting; - # 230 sieve fraction determined by settling tube method.														

Figure 7 presents the particle size analysis of sample MW01003 in graphic form. The graph plots the weight percent of the sample that is: 1) finer than, and 2) coarser than, the equivalent spherical diameter (in microns) of a given particle size.

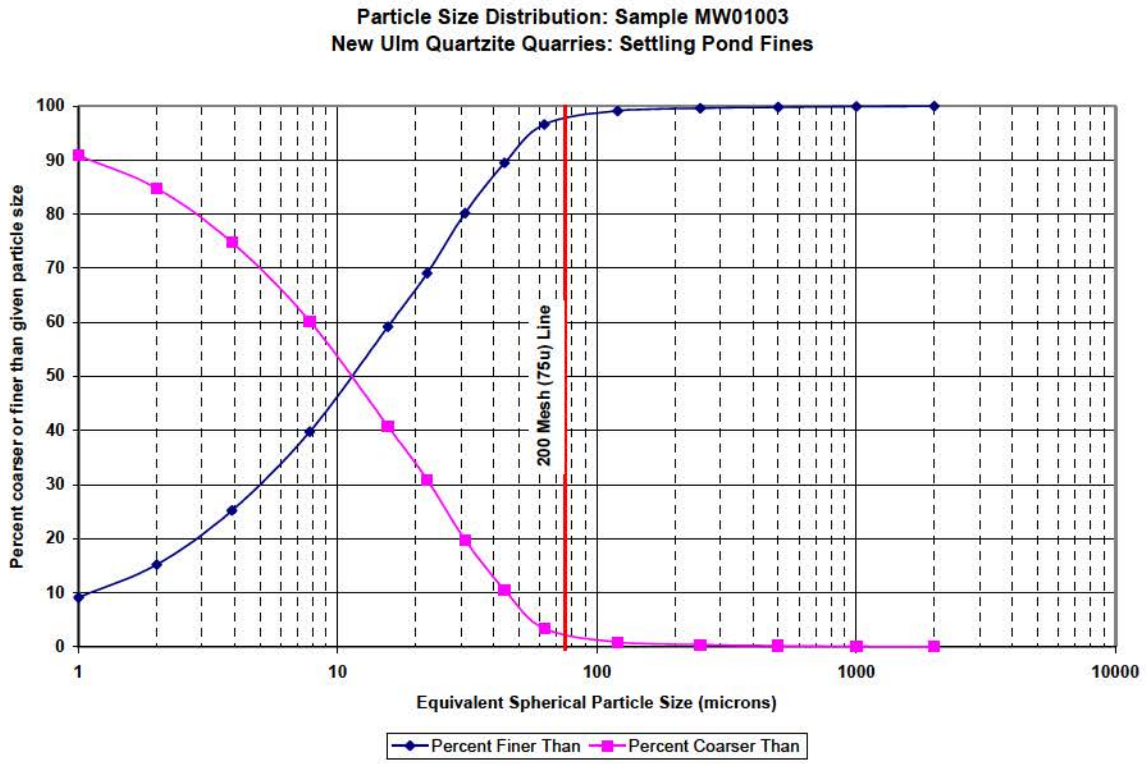


Figure 7. Particle size analysis in graphic form of NUQQ pond fines (MW01003).

Chemistry

The chemical composition of sample MW01003, NUQQ pond fines, is presented in Table 55.

Table 55 Geochemical analysis of NUQQ pond fines (MW01003).

Whole Rock[1]				Ultratrace - Aqua Regia[3]				Acid Digestion[4]			
SiO_2 wt %	73.49	Sc ppm	10	Mo (ppm)	1.62	Cr (ppm)	25.7	Mo (ppm)	2.2	Cr (ppm)	27
Al_2O_3 wt %	15.27	Ta ppm	< 20	Cu (ppm)	6.2	Mg %	0.08	Cu (ppm)	6	Mg %	0.08
Fe_2O_3 wt %	3.11	LOI %	6.3	Pb (ppm)	15.12	Ba (ppm)	35.3	Pb (ppm)	28	Ba (ppm)	141
MgO wt %	0.16	SUM %	99.91	Zn (ppm)	12	Ti %	0.001	Zn (ppm)	17	Ti %	0.102
CaO wt %	0.17			Ag (ppb)	88	B (ppm)	4	Ag (ppm)	1		
Na_2O wt %	0.08			Ni (ppm)	4.2	Al %	0.44	Ni (ppm)	5	Al %	7.46
K_2O wt %	0.37			Co (ppm)	2	Na %	0.007	Co (ppm)	2	Na %	0.044
TiO_2 wt %	0.55	Additional Analyses[2]		Mn (ppm)	155	K %	0.05	Mn (ppm)	160	K %	0.41
P_2O_5 wt %	0.22	C/ORG %	0.12	Fe %	1.8	W (ppm)	1.4	Fe %	2.07	W (ppm)	4
MnO wt %	0.02	CO_2 %	0.46	As (ppm)	3.5	Sc (ppm)	1	As (ppm)	10	Zr (ppm)	213.7
Cr_2O_3 wt %	0.013	TOT/C %	0.25	U (ppm)	0.9	Tl (ppm)	0.04	U (ppm)	9	Ce (ppm)	301
Ba ppm	139	SO_4 %	< .03	Au (ppb)	3.4	S %	< .01	Au (ppm)	< 4	Sn (ppm)	2.1
Cu ppm	29	TOT/S %	< .01	Th (ppm)	10.2	Hg (ppb)	12	Th (ppm)	19	Y (ppm)	23.7
Zn ppm	29			Sr (ppm)	57.1	Se (ppm)	0.4	Sr (ppm)	408	Nb (ppm)	2.6
Ni ppm	32	F (ppm)	105	Cd (ppm)	0.04	Te (ppm)	< .02	Cd (ppm)	< .2	Ta (ppm)	< .5
Co ppm	< 20			Sb (ppm)	0.8	Ga (ppm)	1.3	Sb (ppm)	4	Be (ppm)	1
Sr ppm	400	FeO %	0.4	Bi (ppm)	0.03			Bi (ppm)	< 1	Sc (ppm)	9
Zr ppm	282			V (ppm)	11			V (ppm)	17	Li (ppm)	33
Ce ppm	253	pH	6.8	Ca %	0.1			Ca %	0.13	S %	0.03
Y ppm	43	H_2O+ %	4.6	P %	0.015			P %	0.068	Rb (ppm)	7
Nb ppm	26	H_2O- %	0.2	La (ppm)	17.3			La (ppm)	151	Hf (ppm)	6

[1] 0.2 gm sample by $LIBO_2$ fusion, analysis by ICP-ES. LOI by loss on ignition.

[2] CO_2 - Digest with warm 15% $HCLO_4$, evolved CO_2 analyzed by LECO. SO_4 - Residue sulphur after ignited at 800 °C for 1 hour. C/ORG - Total C minus graphite C and carbonate. F - NaOH fusion - specific ion electrode analysis. FeO by dichromate titration. H_2O+ at 1500 °C. H_2O- at 110 °C.

[3] 15.00 gm sample, 90 ml 2-2-2 HCl-HNO_3-H_2O at 95 °C for 1 hour and is diluted tp 300 ml, analysis by ICP/ES & MS.

[4] 0.25 gm sample digested with $HClO_4$-HNO_3-HCl-HF to 10 ml. Digestion is partial for some minerals & may volatize some elements, analysis by ICP-ES.

Mineralogy

X-ray diffractometry run on sample MW01003, NUQQ pond fines, determined that quartz and kaolinite are the predominant mineral species present (Table 56). Illite is present in minor amount. Traces of annite (biotite), the Fe-carbonate mineral siderite, clay minerals dickite and pyrophyllite, and the chlorite mineral clinochlore were detected. Figure 8 presents the XRD trace for sample MW01003.

Table 56 Mineralogy of NUQQ pond fines (MW01003).

		Quartz	Kaolinite	Illite	Dickite	Annite	Clino-chlore	Siderite	Pyrophyllite
MW01003		M	M	m	t	t	t	t	t
Component Mineral Composition									
Kaolinite-1A		$Al_2Si_2O_5(OH)_4$			Clinochlore-2MIIb		$Mg_5Al(Si_3Al)O_{10}(OH)_8$		
Dickite-2M1		$Al_2Si_2O_5(OH)_4$			Siderite		$FeCO_3$		
Quartz, syn		SiO_2			Illite		$KAl_2Si_3AlO_{10}(OH)_2$		
Annite-1M		$KFe_3(Si,Al)_4O_{10}(OH)_2$			Pyrophyllite		$Al_2Si_4O_{10}(OH)_2$		
* Mineralogy determined by XRD; M = major, m = minor, t = trace.									

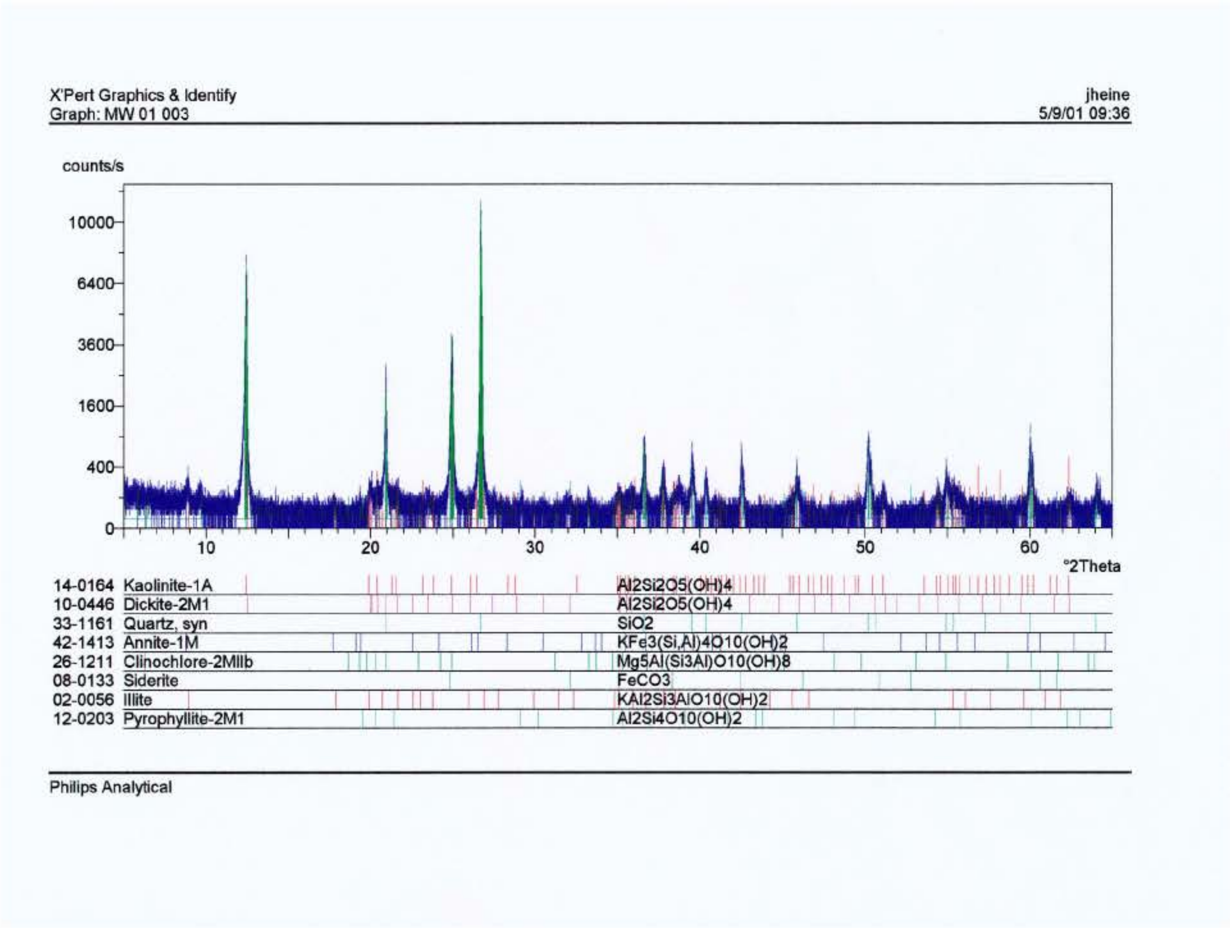


Figure 8. XRD trace depicting the mineralogy of NUQQ pond fines (MW01003).

Product/By-product Analytical Data - Cyclone Overflow and Underflow

Particle size data was provided by NUQQ on the cyclone overflow and underflow materials. The overflow material is recovered for incorporation into the regular product line. Cyclone underflow material goes out to a settling pond. This currently low-valued material is recovered and sold as #200 Minus Fines (wash pond mineral silt).

Particle Size Analysis

Table 57 presents grain size distribution submitted by NUQQ on the cyclone underflow and overflow.

Table 57 Particle size analysis of cyclone underflow and overflow.

Grain Size Distribution of Cyclone Underflow and Cyclone Overflow**

Sample	Date	% pass # 10	% pass # 40	% pass # 100	% pass # 200	% pass 22.5 mic.	% pass 2 mic
cyclone overflow	5-06-93	100	100	96*	68*	20*	1*
cyclone overflow	5-13-93	100	100	96*	74*	34*	0
cyclone underflow	7-07-93	100	99	95	94	48*	12*

*Values are approximate as read from graph.

**Data provided by NUQQ.

Product Analytical Data - Quartzite

Chemistry

Chemistry data was provided by NUQQ on the New Ulm Quartzite (Table 58). It is of interest to compare the chemical composition of the NUQQ pond fines (Table 55) with that of the parent rock as shown here. The percent SiO_2 is decreased in the fines. This is offset by the increased percent of Al_2O_3 in the form of kaolinite and illite clays.

Table 58 Chemical composition of the New Ulm Quartzite.

Chemical Composition of the New Ulm Quartzite*			
Oxide	Composition %	Oxide	Composition %
SiO_2	94.81	K_2O	0.063
Al_2O_3	2.98	TiO_2	0.086
Fe_2O_3	0.68	P_2O_5	0.038
MgO	< 0.01	FeO	0.21
CaO	< 0.01	H_2O	1.14
Na_2O	0.17	Total	100.2
*Data provided by NUQQ			

Data Sources

2001 Site Visit
2001 Survey Response and Submitted Data
2001 NRRI Sample Analysis
Carlstrom, J., with Martin, D., 1996
www.nuqq.com

Ortonville Stone Co.

P.O. Box 67
Ortonville, MN 56278

Phone: (320) 839-6131
Fax: (320) 839-6132

Contact: Dale Aesoph, Superintendent
daesoph@info-link.net

Parent Company: L.G. Everist, Inc.
www.lgeverist.com

Quarry	T	R	S	Forty	County	Rock Type	Products	By-product	Size	Amount	Location
Ortonville Stone Company Quarry	121	46	26	S 1/2	Big Stone	Granite	Crushed Stone Manufactured Sand	Mineral Filler	- 50 mesh	5,000 T	Stockpile

Ortonville Stone Co. is located near the city of Ortonville in Big Stone County, MN. Ortonville Stone Co. produces crushed stone products from granite.

Geologic Unit: Ortonville Granite (Fig. 9)

Figure 9. Quarry face of Ortonville Granite at Ortonville Stone quarry.

Production: Rock is drilled and blasted, then excavated and moved by means of shovels (Fig. 10), loaders, and trucks. Jaw and cone crushers are used to process the material. The operation has two wash plants. Shipping is by truck (200,000 TPY) and rail (300,000 TPY).

Figure 10. Ortonville Stone quarry and shovel.

Product Line: Ballast, MN CA-50, fines (½ in. down), and manufactured sand.

Wastes/By-products

Waste/By-product	How Used	Most Difficult To Market	Easiest To Market	Potential Markets/Uses
Granite Fines	No market yet	Granite Fines	N.A.	Mineral Filler

While no quarry wastes are produced, the wash plant generates a waste/by-product: **hydrocyclone fines**. These - 50 mesh fines are dewatered and stockpiled, intended for such uses as mineral filler. Since there is currently no market for this material, a 5,000 ton stockpile of the hydrocyclone fines has amassed on-site.

Waste/By-product Analytical Data - Hydrocyclone Product

Sample MW01006 was collected from the fines pile at the Ortonville Stone Co. Quarry in January of 2001. Particle size analysis, geochemistry, and x-ray diffractometry for mineral content was run on the sample.

Particle Size Analysis

Particle size data on sample MW01006, Ortonville Stone Co. stockpiled hydrocyclone fines, is presented in Table 59. These fines are relatively coarse, with 65.3 % falling in the sand-sized fraction. Silt-sized particles account for 32.6 % of the sample, while only 2.1 % of the particles are clay size. Table 60 presents the complete set of particle size analytical data for sample MW01006.

Table 59 Sand-silt-clay fraction: Ortonville Stone Co. hydrocyclone product (MW01006).

SAND - SILT - CLAY FRACTION*				
SAMPLE	SAMPLE TYPE	% SAND	% SILT	% CLAY
MW01006	Fines	65.29	32.62	2.08
*Sand >= 62.5 microns (# 230 sieve), silt < 62.5 microns and >= 2 microns, clay < 2 microns				

Table 60 Complete particle size assay data for Ortonville Stone Co. hydrocylone product (MW01006).

Percent Passing Equivalent Spherical Diameter in Microns*													
	SAND					SILT						CLAY	
SAMPLE	2000 µ	1000 µ	500 µ	250 µ	120 µ	62.5 µ	44 µ	31 µ	22.1 µ	15.6 µ	7.8 µ	3.9µ	2 µ	1 µ
MW01006	99.99	99.88	99.70	97.11	71.30	34.71	17.43	10.12	4.86	3.45	2.33	1.94	2.08	1.89
* + # 230 sieve fraction determined by sonic sifting; - # 230 sieve fraction determined by settling tube method.														

Figure 11 presents the particle size analysis of sample MW01006 in graphic form. The graph plots the weight percent of the sample that is: 1) finer than, and 2) coarser than, the equivalent spherical diameter (in microns) of a given particle size.

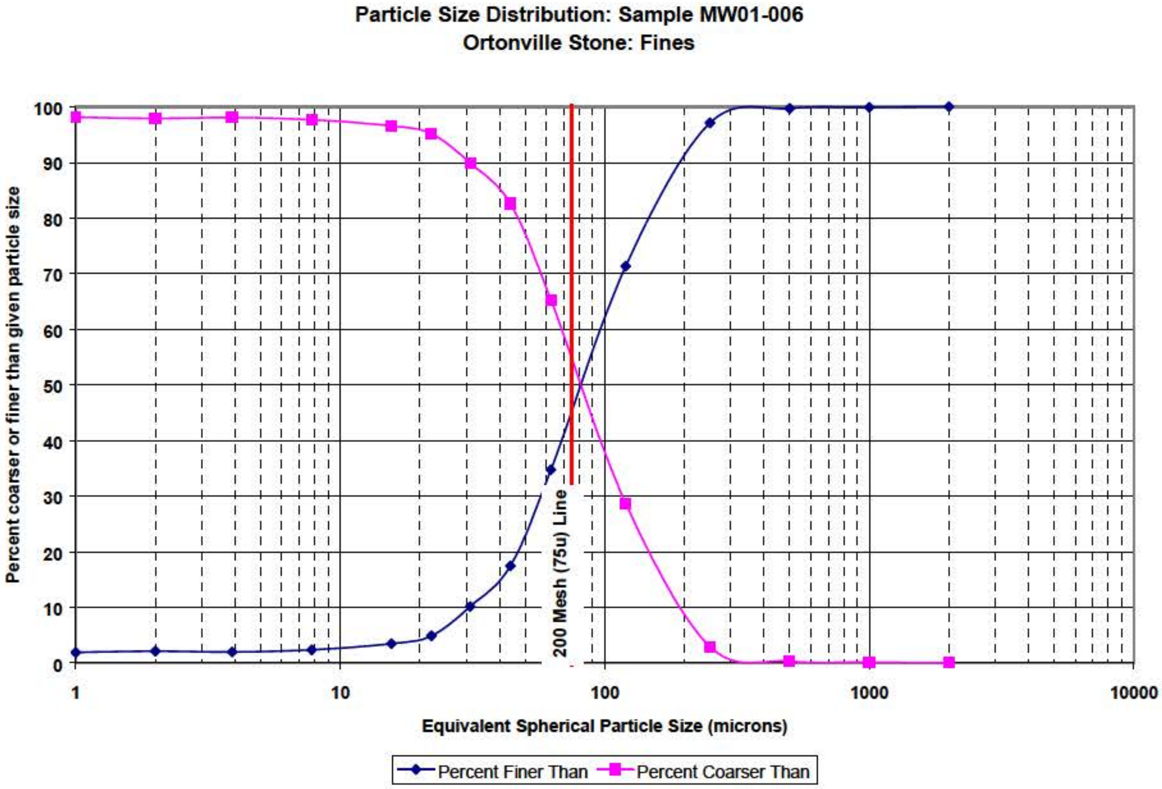


Figure 11. Particle size analysis in graphic form of Ortonville Stone Co. hydrocyclone product (MW01006).

Ortonville Stone Co. provided additional particle size data on the fines from a sample taken from Belt 1230P (sample 6232000), as well as the year 2000 composite data. This data is presented in Table 61.

Table 61 Sieve analysis on Ortonville Stone Co. fines.

Percent Passing Given Sieve*					
Sample	% Pass 30	% Pass 40	% Pass 50	% Pass 100	% Pass 200
6232000	100	100	99.4	80.3	41.1
YR 2000	100	100	99.0	79.0	40.0

*Data provided by Ortonville Stone Co.

Chemistry

The chemical composition of sample MW01006, Ortonville Stone Co. stockpiled hydroclyclone fines, is presented in Table 62.

Table 62 Geochemical analysis of Ortonville Stone Co. hydrocyclone product (MW01006).

Whole Rock[1]				Ultratrace - Aqua Regia[3]				Acid Digestion[4]			
SiO_2 wt %	70.07	Sc ppm	1	Mo (ppm)	0.21	Cr (ppm)	5.2	Mo (ppm)	0.6	Cr (ppm)	4
Al_2O_3 wt %	12.9	Ta ppm	< 20	Cu (ppm)	5.47	Mg %	0.44	Cu (ppm)	4	Mg %	0.47
Fe_2O_3 wt %	3.15	LOI %	0.7	Pb (ppm)	12.47	Ba (ppm)	104	Pb (ppm)	30	Ba (ppm)	1449
MgO wt %	0.79	SUM %	99.72	Zn (ppm)	40.1	Ti %	0.093	Zn (ppm)	50	Ti %	0.252
CaO wt %	1.6			Ag (ppb)	28	B (ppm)	3	Ag (ppm)	0.2		
Na_2O wt %	2.76			Ni (ppm)	2.5	Al %	0.54	Ni (ppm)	3	Al %	6.73
K_2O wt %	6.81			Co (ppm)	4.2	Na %	0.039	Co (ppm)	5	Na %	2.082
TiO_2 wt %	0.45	Additional Analyses[2]		Mn (ppm)	81	K %	0.41	Mn (ppm)	141	K %	3.59
P_2O_5 wt %	0.17	C/ORG %	< .03	Fe %	1.66	W (ppm)	< .2	Fe %	2.2	W (ppm)	< 2
MnO wt %	0.02	CO_2 %	0.65	As (ppm)	< .1	Sc (ppm)	1.1	As (ppm)	< 2	Zr (ppm)	195.3
Cr_2O_3 wt %	0.003	TOT/C %	0.15	U (ppm)	0.6	Tl (ppm)	0.17	U (ppm)	8	Ce (ppm)	318
Ba ppm	1354	SO_4 %	< .03	Au (ppb)	< .2	S %	< .01	Au (ppm)	< 4	Sn (ppm)	0.6
Cu ppm	< 20	TOT/S %	< .01	Th (ppm)	33.5	Hg (ppb)	< 5	Th (ppm)	61	Y (ppm)	9.3
Zn ppm	49			Sr (ppm)	11.9	Se (ppm)	< .1	Sr (ppm)	296	Nb (ppm)	2.6
Ni ppm	< 20	F (ppm)	572	Cd (ppm)	0.01	Te (ppm)	< .02	Cd (ppm)	< .2	Ta (ppm)	< .5
Co ppm	< 20			Sb (ppm)	< .02	Ga (ppm)	4	Sb (ppm)	< 1	Be (ppm)	1
Sr ppm	279	FeO %	1.1	Bi (ppm)	< .02			Bi (ppm)	< 1	Sc (ppm)	2
Zr ppm	426			V (ppm)	23			V (ppm)	24	Li (ppm)	11
Ce ppm	323	pH	8.7	Ca %	0.32			Ca %	1.29	S %	< .02
Y ppm	< 10	H_2O+ %	1.3	P %	0.074			P %	0.083	Rb (ppm)	110
Nb ppm	47	H_2O- %	< .1	La (ppm)	82.2			La (ppm)	192	Hf (ppm)	6

[1] 0.2 gm sample by $LIBO_2$ fusion, analysis by ICP-ES. LOI by loss on ignition.

[2] CO_2 - Digest with warm 15% $HCLO_4$, evolved CO_2 analyzed by LECO. SO_4 - Residue sulphur after ignited at 800 °C for 1 hour. C/ORG - Total C minus graphite C and carbonate. F - NaOH fusion - specific ion electrode analysis. FeO by dichromate titration. H_2O+ at 1500 °C. H_2O- at 110 °C.

[3] 15.00 gm sample, 90 ml 2-2-2 $HCl\text{-}HNO_3\text{-}H_2O$ at 95 °C for 1 hour and is diluted tp 300 ml, analysis by ICP/ES & MS.

[4] 0.25 gm sample digested with $HClO_4\text{-}HNO_3\text{-}HCl\text{-}HF$ to 10 ml. Digestion is partial for some minerals & may volatize some elements, analysis by ICP-ES.

Mineralogy

X-ray diffractometry run on sample MW01006 indicates that quartz and biotite are the predominant mineral species present (Table 63). Trace amounts of the K-feldspar microcline, the Na-plagioclase feldspar albite, and the mica mineral muscovite were also detected. Figure 12 presents the XRD trace for sample MW01006. For a comparison to the source rock, refer to the section on petrology below.

Table 63 Mineralogy of Ortonville Stone Co. hydrocyclone product (MW01006).

<table>
<tr><td></td><td>Quartz</td><td>Biotite</td><td>Microcline</td><td>Albite</td><td>Muscovite</td></tr>
<tr><td>MW01006</td><td>M</td><td>M</td><td>t</td><td>t</td><td>t</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="6">Component Mineral Composition</td></tr>
<tr><td colspan="3">Microcline, ordered</td><td colspan="3">$KAlSi_3O_8$</td></tr>
<tr><td colspan="3">Biotite-2M1</td><td colspan="3">$KMg_3 (Si_3Al)O_{10}(OH)_2$</td></tr>
<tr><td colspan="3">Albite, calcian, ordered</td><td colspan="3">$(Na,Ca)Al(Si,Al)_3O_8$</td></tr>
<tr><td colspan="3">Quartz, syn</td><td colspan="3">SiO_2</td></tr>
<tr><td colspan="3">Muscovite-2M2</td><td colspan="3">$(K,Na)Al_2(Si,Al)_4O_{10}(OH)_2$</td></tr>
<tr><td colspan="6">* Mineralogy determined by XRD; M = major, m = minor, t = trace.</td></tr>
</table>

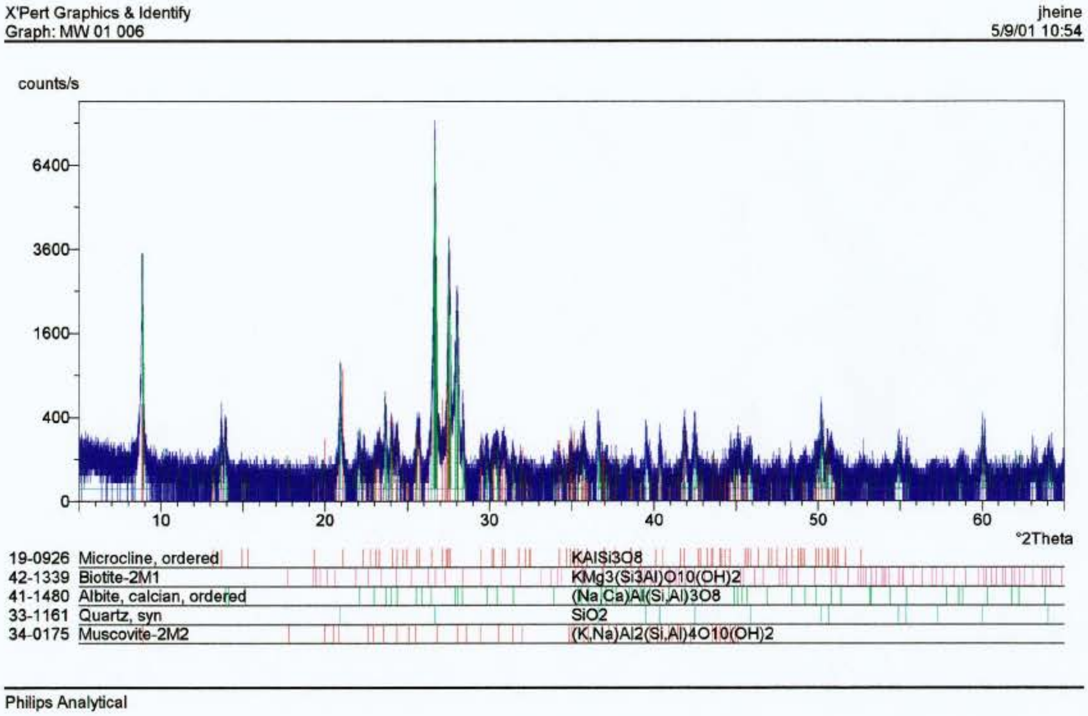


Figure 12. XRD trace depicting the mineralogy of Ortonville Stone Co. hydrocyclone product (MW01006).

Source Rock Analytical Data

Petrology

Ortonville Stone Co. provided a petrographic analysis of the source rock in the Ortonville Stone Co. Quarry. The rock is described as "a medium gray to pink, massive, medium to coarse-grained hornblende-biotite monzonite." Monzonites consist of very little quartz and nearly equal amounts of plagioclase and potassic feldspars. This can be seen in Table 64. Quartz content is 10 %, and the plagioclase feldspar content at 40 % is nearly equal to that of the K-feldspar content (microcline and orthoclase) at 45 %. Monzonites exhibit a granitoid texture. The Ortonville Stone Co. rock is equigranular, although grain size can range from less than 1 mm to over 5 mm. A typical grain measures 2-3 mm in each direction.

Table 64 Mineralogy of Ortonville Stone Co. source rock sample.*

Sample	Plagioclase	Microcline	Orthoclase	Quartz	Biotite	Iron Oxide	Zircon	Sericite	Rutile
monzonite	40 %	25 %	20 %	10 %	2 %	2 %	< 1 %	< 1 %	< 1 %

*Data provided by Ortonville Stone Company.

By comparing the mineralogy of the source rock (Table 64) to that of the hydrocyclone fines (Table 63), it becomes apparent that the dominant feldspars of the parent rock are readily reduced in size during the crushing process. This leaves behind the minor quartz and biotite component that become the major constituents of the hydrocyclone fines, the coarser of the fines fraction.

Chemistry

Table 65 presents chemical data provided by Ortonville Stone Co. on its Granite # 50 and a quartzite. Again, the monzonitic nature of Granite # 50 can be seen in the reduced % SiO_2 and increased % Al_2O_3. Also elevated are Fe_2O_3, Na_2O, and K_2O.

Table 65 Geochemistry of Ortonville Stone Co. rock samples.

Sample Type	SiO_2%	Al_2O_3%	Fe_2O_3%	CaO%	MgO%	Mn_2O_3%	Na_2O%	K_2O%	TiO_2%	P_2O_5%	LOI
Quartzite	97.4	1.1	0.28	0.15	0.17	0.013	0.73	0.053	0.051	<0.050	0.22%
Granite # 50	55.6	23.0	11.3	1.58	0.82	0.041	5.83	8.56	0.41	<0.050	0.41%

*Data provided by Ortonville Stone Co.

Data Sources

2001 Site Visit
2001 Survey Response and Submitted Data
2001 NRRI Sample Analysis

Osmundson Brothers Contractors, Inc.

211 West Main Street
P.O. Box 269
Adams, MN 55909

Phone: (507) 582-3360

Quarry	T	R	S	County	Rock Type	Product	By-product
Grand Meadow Quarry	103	14	9	Mower	Dolomitic Limestone	Crushed Carbonate Rock	Ag-lime

Osmundson Brothers Contractors, Inc. produces carbonate crushed stone from the Grand Meadow Quarry near Grand Meadow in Mower County, MN. No survey response was received.

Geologic Unit: Devonian-aged Cedar Valley Formation

Wastes/By-products

Ag-lime is a by-product of crushing operations at the Grand Meadow Quarry.

By-product Analytical Data - Ag-lime

Ag-lime data for the Grand Meadow Quarry is available from the MN Dept. of Agriculture Ag-Lime Analysis Report (2001). The data is presented in Table 66.

Table 66 Ag-lime analytical data for Osmundson Brothers Contractors, Inc. Grand Meadow Quarry.

Quarry	County	Date	Sample Type	Rec. #	Moisture Content	Fineness Index (FI)	% CCE	% ENP	MIN LBS ENP/TON	% Pas 8	% Pass 20	% Pass 60
Grand Meadow	Mower	09012000	Ag-lime	74	9.4 %	70.6	105.9	74.8	1355	98.2	75.4	51.9
*Ag-Lime Analysis Report, 2001												

Data Sources

Ag-lime Analysis Report, 2001
Nelson et al., 1990

Pederson Bros. of Harmony, Inc.

725 Main Ave. N
Harmony, MN 55939

Phone: (507) 886-3371

Quarry	T	R	S	County	Rock Type	Products	By-product
Big Springs Quarry	101	10	9	Fillmore	Limestone	Carbonate Crushed Rock	Ag-lime
Engle Quarry	N.A.	N.A.	N.A.	Fillmore	Carbonate	Carbonate Crushed Rock	Ag-lime
Grabau Quarry	102	12	17	Fillmore	Dolomite	Carbonate Crushed Rock	Ag-lime

Pederson Brothers of Harmony, Inc. produces carbonate crushed rock products from the Big Springs, Engle, and Grabau quarries in Fillmore County, MN. Harmony is located near the Minnesota-Iowa state line. No survey response was received.

Geologic Unit: Big Springs Quarry: Prosser and Cummingsville Formations of the Galena Group
Engle Quarry: N.A.
Grabau Quarry: Stewartville Formation of the Galena Group

Wastes/By-products

Ag-lime is a by-product of crushing operations at the Big Springs, Engle, and Grabau quarries.

By-product Analytical Data - Ag-lime

Ag-lime data for the Big Springs, Engle, and Grabau quarries is available from the MN Dept. of Agriculture Ag-Lime Analysis Report (2001). The data is presented in Table 67.

Table 67 Ag-lime analytical data for Pederson Bros. of Harmony, Inc. quarries.

Quarry	County	Date	Sample Type	Rec. #	Moisture Content	Fineness Index (FI)	% CCE	% ENP	MIN LBS ENP/TON	% Pass 8	% Pass 20	% Pass 60
Big Springs	Fillmore	10042000	Ag-Lime	23	4.6 %	66.1	87.4	57.8	1102	98.6	72.6	43.3
Engle	Fillmore	10042000	Ag-Lime	24	6.4 %	68.5	92.2	63.1	1182	96.0	70.9	52.3
Grabau	Fillmore	10052000	Ag-Lime	25	4.5 %	68.0	79.9	54.3	1037	98.1	71.8	49.1
*Ag-Lime Analysis Report, 2001												

Data Sources

Ag-Lime Analysis Report, 2001
Nelson et al., 1990

Roberson Lime & Rock, Inc.

Rt. 2, Box 223
Zumbro Falls, MN 55991

Phone: (507) 753-2313

Quarry	T	R	S	County	Rock Type	Products	By-product
Moeching Quarry	110	12	15	Wabasha	Dolomitic Limestone	Carbonate Crushed Rock	Ag-lime
Roberson Quarry	110	13	27	Wabasha	Carbonate Rock	Carbonate Crushed Rock	Ag-lime

Roberson Lime and Rock, Inc. of Zumbro Falls, MN, produces carbonate crushed stone products from several quarries in Wabasha County, including the Moeching and Roberson quarries. No survey response was received.

Geologic Unit: Moeching Quarry: Oneota Formation
Roberson Quarry: NA

Wastes/By-products

Ag-lime is a by-product of crushing operations at the Moeching and Roberson quarries.

By-product Analytical Data - Ag-lime

Ag-lime data for the Moeching and Roberson quarries is available from the MN Dept. of Agriculture Ag-Lime Analysis Report (2001). The data is presented in Table 68.

Table 68 Ag-lime analytical data for Roberson Lime & Rock, Inc.

Quaarry	County	Date	Sample Type	Rec. #	Moisture Content	Fineness Index (FI)	% CCE	% ENP	MIN LBS ENP/TON	% Pass 8	% Pass 20	% Pass 60
Moeching	Wabasha	09112000	Ag-lime	134	4.3 %	54.3	96.9	52.7	1008	83.3	56.2	38
Roberson	Wabasha	09142000	Ag-lime	135	4.7 %	53.1	92.3	49.1	935	84.3	55.3	35.4
*Ag-Lime Analysis Report, 2001												

Data Sources

Ag-Lime Analysis Report, 2001
ASIS Database, 2001

Roverud Construction, Inc.

601 Hwy 44 E.
Box 606
Spring Grove, MN 55974

Phone: (507) 498-3377
Fax: (507) 498-5835

Contact: Shawn Krivachek, Materials Technician

Quarry	T	R	S	Forty	County	Rock Type	Products	By-products
Gengler Quarry	102	5	21	NW-NW	Houston	Dolomite	Crushed Stone	Stripping, ag-lime, - 200 mesh pond fines
Engrav Quarry	101	7	19	NW-NW	Fillmore	Dolomite	Crushed Stone	
Peterson Quarry	103	8	8	SW 1/4	Fillmore	Dolomite	Crushed Stone	
Pool Hill	101	4	33	SW 1/4	Houston	Dolomite	Crushed Stone	
Underpass Quarry	101	7	20	N ½ NE 1/4	Houston	Limestone	Crushed Stone	
Zaiger Quarry	103	4	22	N ½ SE 1/4	Houston	Dolomite	Crushed Stone	

Roverud Construction, Inc., headquartered at Spring Grove, MN, in Houston County, operates several carbonate rock crushed stone quarries in Fillmore and Houston Counties. Limestone rock is mined at the Underpass Quarry in Houston County while dolomitic rocks are mined at the Engrav, Gengler, Peterson, Pool Hill, and Zaiger quarries.

Geologic Unit:		
	Gengler Quarry:	Oneota Formation; 140-ft. thickness
	Engrav Quarry:	Shakopee Formation; 65-ft. thickness
	Peterson Quarry:	Oneota Formation; 150-ft. thickness
	Pool Hill Quarry:	Oneota Formation; 142-ft. thickness
	Zaiger Quarry:	Oneota Formation; 110-ft. thickness
	Underpass Quarry:	Platteville Formation; 27-ft. thickness

Production: At the Gengler Quarry, rock is drilled and blasted, then excavated and moved by means of backhoe, loader, and trucks. A universal jaw crusher and hammer mill are used for processing in conjunction with a portable rock plant and wash plant. Shipping is by truck.

Product Line (Gengler Quarry): 3/4 in. road rock, 1-1/2 in. with fines, ag-lime, filter stone, concrete aggregate, manufactured sand, and washed chips

Product Line (Remaining Quarries): mainly 3/4 in. road rock (Class 2)

Wastes/By-products

Waste/By-product	How Used	Most Difficult To Market	Easiest To Market	Potential Markets/Uses
Stripping	Fill	Pond wastes	Lime	Pond wastes as fill material
Ag-lime	Agricultural material			
Wash (pond) fines	Fill			

Roverud Construction, Inc. cited **stripping material, ag-lime,** and - **# 200 wash (pond) fines** as wastes/by-products produced by its various operations. The company does not consider these materials to be wastes, however. All three are sold, with the pond wastes going as fill. The pond wastes remain the most problematic, however, as the there is no strong market for them.

Waste/By-product Analytical Data - Ag-lime

Ag-lime data was reported for six Roverud Construction, Inc. operations in the MN Dept. of Agriculture Ag-Lime Analysis Report (2001). Data for four of the above listed quarries and two additional quarries is presented in Table 69.

Table 69 Ag-lime analytical data for Roverud Construction, Inc. quarries.

Location	County	Date	Sample Type	Rec. #	Moisture Content	Fineness Index (FI)	% CCE	% ENP	MIN LBS ENP/TON	% Pass 8	% Pass 20	% Pass 60
Peterson	Fillmore	10112000	Ag-lime	34	6.2 %	63.3	94.7	60	1125	88.3	65.6	48.5
Engrav	Fillmore	10112000	Ag-lime	35	5.9 %	69.5	94.9	66.0	1242	98.2	76.1	48.6
Pool Hill	Houston	09122000	Ag-lime	66	5.9 %	67.8	89.0	60.4	1136	97.6	72.7	48.1
Gengler	Houston	09122000	Ag-lime	67	5.2 %	66.9	95.1	63.6	1206	91.5	70.3	51.1
Buford Anderson	Fillmore	10112000	Ag-lime	36	5.5 %	60.6	87.3	52.9	999	92.8	65.5	39.5
Dobler	Houston	09112000	Ag-lime	65	5.0 %	72.3	95.5	69.0	1311	98.5	76.4	55
*Ag-Lime Analysis Report, 2001												

Data Sources

2001 Survey Response
Ag-Lime Analysis Report, 2001
Nelson et al., 1990

Sioux Rock Products

1100 Marcus Street
Fairmont, MN 56031

Phone: (507) 235-3321
Fax: (507) 235-3160

Contact: Mark Johnson, Vice President

Parent Company: W. Hodgman & Sons, Inc.

Quarry	T	R	S	Forty	County	Rock Type	Product	By-products	Size	Amount	Location
Jeffers Quarry	107	35	8	SE 1/4	Cottonwood	Quartzite	Crushed Stone	Crushed Fines Wash Fines	- # 40 to - # 200	> 5,000 T	Stockpile & Pond

Sioux Rock Products, a subsidiary of W. Hodgman & Sons, Inc., is located near Fairmont in Cottonwood County, MN. Sioux Rock Products produces crushed stone products from the massive reddish-purple quartzite beds of the Jeffers Quarry.

Geological Unit: Sioux Quartzite

Production: Rock is excavated and moved by backhoe and front end loaders. One jaw and two cone crushers are used to process the quartzite. Dry classification is used. The Jeffers Quarry operation also includes a wash plant and settling pond. Shipping is by truck. Annual production is nearly 300,000 tons.

Product Line: CA-5, 1-1/2 in. concrete aggregate, 3/4 in. and ½ in. asphalt stone, Cl-2 shoulder aggregate, open graded aggregate base, FA-2 and FA-3 aggregate for seal coat, and washed manufactured sand.

Wastes/By-products

Waste/By-product	How Used	Most Difficult To Market	Easiest To Market	Potential Markets/Uses
Crushed fines	seal coat chips, manufactured sand	Settling pond fines: currently have no value	Crushed fines	N.A.
Settling pond fines	not used			

On-site wastes/by-products consist of over 5,000 tons of stockpiled and ponded **crushed fines** and **settling pond fines (sludge)** (minus # 40 and minus # 200, respectively). The crushed fines are washed to produce seal coat chips and manufactured sand. The settling pond fines are considered a waste product and currently have no value.

By-product Analytical Data - Pond Sludge and Dirty Fines

Two samples were collected from the Jeffers Quarry in January of 2001. The first, MW01001, consists of sludge from the settling pond (Fig. 13). The second, MW01002, consists of "dirty" fines from the production stockpile area (Fig. 14). The dirty fines are fairly coarse, but have too high a fines content (> 8 % minus # 200) to meet critical specs. Therefore, they are a reduced value product. Particle size analysis, geochemistry, and x-ray diffractometry for mineral content were run on both samples.

Figure 13. Quartzite settling pond sludge stockpile at Sioux Rock Products' Jeffers Quarry.

Figure 14. Quartzite aggregate production stockpiles, Sioux Rock Products, Jeffers Quarry.

Particle Size Analysis

Particle size data on sample MW01001, Jeffers Quarry settling pond sludge, and on sample MW01002, Jeffers Quarry "dirty" fines is presented in Table 70. The majority of the pond sludge is silt-sized (68.5 %). The remainder consists of 21.3 % sand-sized particles and 10.3 % clay-sized particles. The "dirty" fines are much coarser, with 40 % of the material fine gravel-sized or larger. While Table 70 would indicate that the dirty fines consist of 89.4 % sand-sized material, the more complete breakdown in Table 71 shows that only 59.7 % of the material is sand-sized (-2000 microns) or finer. Silt-sized particles make up 8.4 % of the sample while clay-sized particles account for 2.2 % of the sample.

Table 70 Sand-silt-clay fraction: Sioux Rock Products pond sludge (MW01001) and dirty fines (MW01002).

SAND - SILT - CLAY FRACTION*				
SAMPLE	SAMPLE TYPE	% SAND	% SILT	% CLAY
MW01001	Pond Sludge	21.25	68.48	10.28
MW01002	Dirty Fines	89.42	8.37	2.21

*Sand >= 62.5 microns (# 230 sieve), silt < 62.5 microns and >= 2 microns, clay < 2 microns

Table 71 Complete particle size assay data for Sioux Rock Products pond sludge (MW01001) and dirty fines (MW01002).

Percent Passing Equivalent Spherical Diameter in Microns*														
	SAND					SILT							CLAY	
SAMPLE	2000 µ	1000 µ	500 µ	250 µ	120 µ	62.5 µ	44 µ	31 µ	22.1 µ	15.6 µ	7.8 µ	3.9 µ	2 µ	1 µ
MW01001	95.68	94.59	93.73	92.18	88.49	78.75	62.87	55.89	49.12	42.54	29.11	16.94	10.28	6.42
MW01002	59.76	44.17	34.05	23.55	15.55	10.58	9.12	7.58	6.84	6.10	4.44	NA	2.21	2.04

* +# 230 sieve fraction determined by sonic sifting; - # 230 sieve fraction determined by settling tube method.

Sioux Rock Products provided the typical gradation of the dirty fines from its Minnesota production for the year 2000 (Table 72). Less than 50 % of the material is sand-sized or finer, on average, vs. 60 % for collected sample MW01002.

Table 72 Typical gradation of Sioux Rock Products dirty fines for the year 2000.

Dirty Fines - Typical Gradation for Year 2000*					
% Pass 4	% Pass 10	% Pass 20	% Pass 40	% Pass 100	% Pass 200
82	48	31	23	12	7.8

*Data provided by Sioux Rock Products

Figures 15 and 16 present the particle size analyses of samples MW01001 and MW01002 in graphic form, respectively. The graph plots the weight percent of the sample that is: 1) finer than, and 2) coarser than, the equivalent spherical diameter (in microns) of a given particle size.

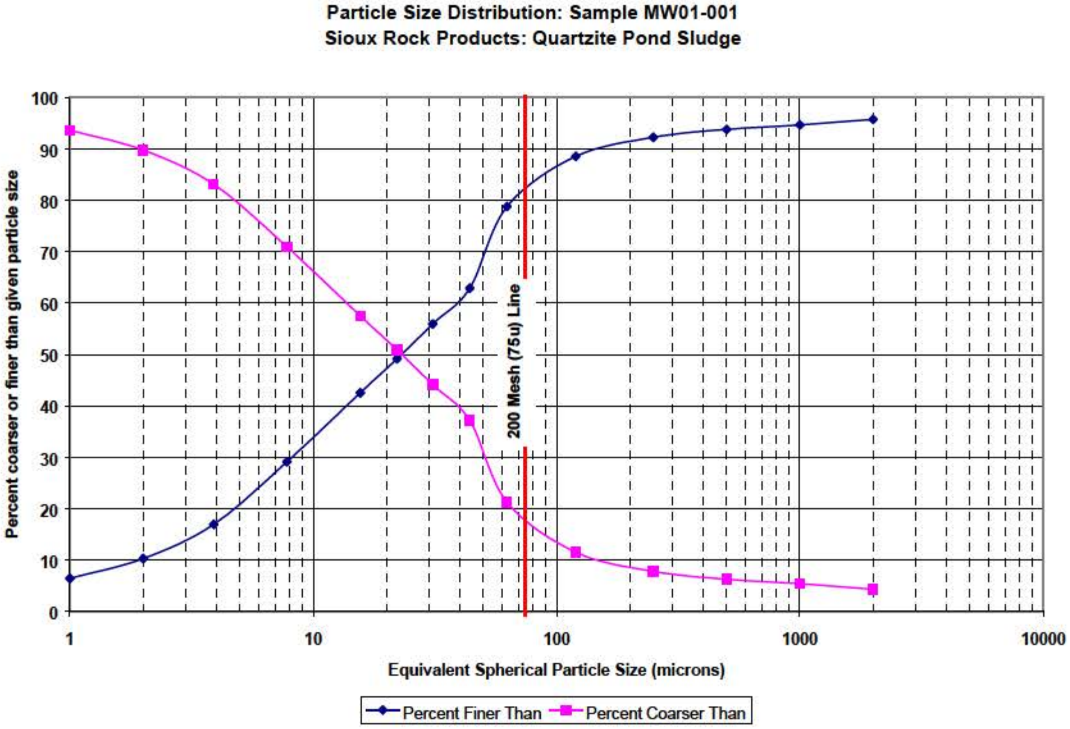


Figure 15. Particle size analysis in graphic form of Sioux Rock Products pond sludge (MW01001).

Chemistry

The chemical composition of samples MW01001, Jeffers Quarry pond sludge, and MW01002, Jeffers Quarry "dirty" fines, is presented in Table 73.

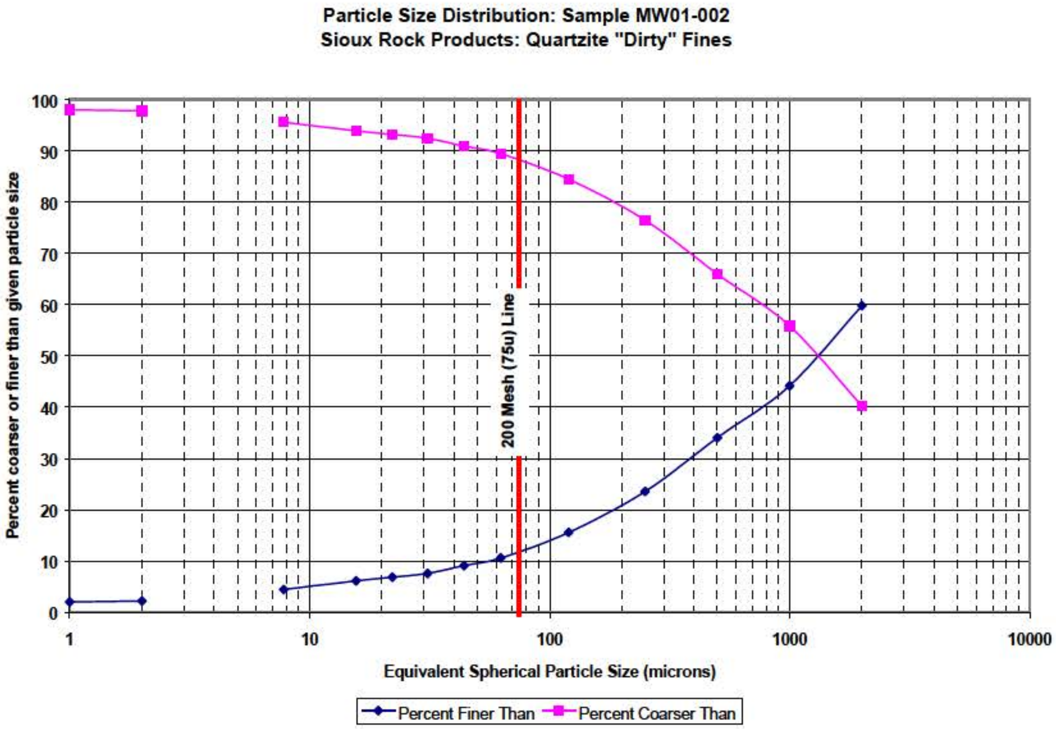


Figure 16. Particle size analysis in graphic form of Sioux Rock Products dirty fines (MW01002).

Mineralogy

X-ray diffractometry run on sample MW01001 (Jeffers Quarry pond sludge) and MW01002 (Jeffers Quarry "dirty" fines) indicates that quartz and kaolinite are the predominant mineral species in both samples (Table 74). The chlorite mineral clinochlore is present in both samples but to a larger degree in the coarser fraction (minor occurrence vs. trace occurrence in the pond fines). The "dirty" fines contain minor hematite, an iron-oxide, which was not detected in the finer fraction. The pond sludge contains trace amounts of the K-feldspar microcline, annite (biotite), and clay minerals dickite and mixed-layer illite-montmorillonite. Figures 17 and 18 present the XRD traces for samples MW01001 and MW01002, respectively.

Table 73 Geochemical analysis of Sioux Rock Products pond sludge (MW01001) and dirty fines (MW01002).

Whole Rock [1]			Ultratrace - Aqua Regia [3]			Acid Digestion [4]		
	MW01001	MW01002	MW01002	MW01001	MW01002		MW01001	MW01002
SiO_2 wt %	81.61	91.75	Mo (ppm)	0.74	0.36	Mo (ppm)	1.1	0.6
Al_2O_3 wt %	10.2	4.43	Cu (ppm)	2.77	0.92	Cu (ppm)	2	2
Fe_2O_3 wt %	1.52	0.94	Pb (ppm)	3.89	1.95	Pb (ppm)	8	4
MgO wt %	0.09	0.02	Zn (ppm)	8.4	2.4	Zn (ppm)	12	5
CaO wt %	0.18	0.09	Ag (ppb)	22	13	Ag (ppm)	< .2	< .2
Na_2O wt %	0.11	< .01	Ni (ppm)	4.9	1.6	Ni (ppm)	8	3
K_2O wt %	0.1	0.03	Co (ppm)	0.8	0.2	Co (ppm)	1	< 1
TiO_2 wt %	0.34	0.18	Mn (ppm)	144	86	Mn (ppm)	143	74
P_2O_5 wt %	0.14	0.09	Fe %	0.87	0.53	Fe %	1.03	0.6
MnO wt %	0.02	0.01	As (ppm)	1.4	0.6	As (ppm)	4	4
Cr_2O_3 wt %	0.004	0.007	U (ppm)	0.5	0.3	U (ppm)	2	2
Ba ppm	165	90	Au (ppb)	1.3	0.7	Au (ppm)	< 4	< 4
Cu ppm	25	< 20	Th (ppm)	3.8	2.7	Th (ppm)	6	2
Zn ppm	< 20	< 20	Sr (ppm)	85.3	73.4	Sr (ppm)	501	335
Ni ppm	33	< 20	Cd (ppm)	0.04	0.01	Cd (ppm)	< .2	< .2
Co ppm	< 20	< 20	Sb (ppm)	0.7	0.48	Sb (ppm)	3	2
Sr ppm	478	314	Bi (ppm)	0.04	0.02	Bi (ppm)	< 1	< 1
Zr ppm	160	39	V (ppm)	9	4	V (ppm)	13	5
Ce ppm	55	< 20	Ca %	0.08	0.04	Ca %	0.16	0.08
Y ppm	20	15	P %	0.018	0.012	P %	0.056	0.036
Nb ppm	51	< 10	La (ppm)	9.9	6.9	La (ppm)	29	16
Sc ppm	5	3	Cr (ppm)	18	8.2	Cr (ppm)	12	4
Ta ppm	< 20	< 20	Mg %	0.04	0.01	Mg %	0.05	0.02
LOI %	5	2.3	Ba (ppm)	73.6	52.8	Ba (ppm)	168	89
SUM %	99.44	99.9	Ti %	0.002	0.005	Ti %	0.102	0.061
			B (ppm)	1	1			
			Al %	0.36	0.17	Al %	4.87	2.02
Additional Analyses [2]			Na %	0.01	0.006	Na %	0.088	0.034
	MW01001	MW01002	K %	0.02	< .01	K %	0.11	0.02
C/ORG %	0.06	< .03	W (ppm)	< .2	< .2	W (ppm)	< 2	< 2
CO_2 %	0.15	0.15	Sc (ppm)	0.5	0.3	Zr (ppm)	109.1	75.4
TOT/C %	0.1	0.02	Tl (ppm)	0.02	< .02	Ce (ppm)	60	34
SO_4 %	0.03	< .03	S %	0.01	< .01	Sn (ppm)	1.8	0.6
TOT/S %	< .01	< .01	Hg (ppb)	11	< 5	Y (ppm)	12.4	8
			Se (ppm)	0.1	0.1	Nb (ppm)	2.6	1.4
F (ppm)	460	162	Te (ppm)	0.02	< .02	Ta (ppm)	< .5	< .5
			Ga (ppm)	1	0.5	Be (ppm)	1	< 1
FeO %	< .1	0.1				Sc (ppm)	4	2
						Li (ppm)	39	19
pH	7.1	7.4				S %	0.02	< .02
H_2O+ %	3.2	2.2				Rb (ppm)	3	1
H_2O- %	0.2	0.1				Hf (ppm)	3	2

[1] 0.2 gm sample by $LIBO_2$ fusion, analysis by ICP-ES. LOI by loss on ignition.

[2] CO_2 - Digest with warm 15% $HCLO_4$, evolved CO_2 analyzed by LECO. SO_4 - Residue sulphur after ignited at 800 °C for 1 hour. C/ORG - Total C minus graphite C and carbonate. F - NaOH fusion - specific ion electrode analysis. FeO by dichromate titration. H_2O+ at 1500 °C. H_2O- at 110 °C.

[3] 15.00 gm sample, 90 ml 2-2-2 $HCl\text{-}HNO_3\text{-}H_2O$ at 95 °C for 1 hour and is diluted tp 300 ml, analysis by ICP/ES & MS.

[4] 0.25 gm sample digested with $HClO_4\text{-}HNO_3\text{-}HCl\text{-}HF$ to 10 ml. Digestion is partial for some minerals & may volatize some elements, analysis by ICP-ES.

Table 74 Mineralogy of Sioux Rock Products samples MW01001 (pond sludge) and MW01002 (dirty fines).*

<table>
<tr><th></th><th>Quartz</th><th>Kaolinite</th><th>Hematite</th><th>Clinochlore</th><th>Microcline</th><th>Annite</th><th>Dickite</th><th>Illite-Mont-morillonite</th></tr>
<tr><td>MW01001</td><td>M</td><td>M</td><td></td><td>t</td><td>t</td><td>t</td><td>t</td><td>t</td></tr>
<tr><td>MW01002</td><td>M</td><td>M</td><td>m</td><td>m</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="9"></td></tr>
<tr><td colspan="9">Component Mineral Composition</td></tr>
<tr><td colspan="4">MW0100-pond sludge</td><td colspan="5">MW01002-dirty fines</td></tr>
<tr><td>Dickite-2M1</td><td colspan="3">$Al_2Si_2O_5(OH)_4$</td><td colspan="2">Kaolinite-1A</td><td colspan="3">$Al_2Si_2O_5(OH)_4$</td></tr>
<tr><td>Kaolinite-1A</td><td colspan="3">$Al_2Si_2O_5(OH)_4$</td><td colspan="2">Quartz., low</td><td colspan="3">SiO_2</td></tr>
<tr><td>Quartz</td><td colspan="3">SiO_2</td><td colspan="2">Clinochlore-1MIIb</td><td colspan="3">$(Mg,Al)_6(Si,Al)_4O_{10}(OH)_8$</td></tr>
<tr><td>Microcline, intermediate</td><td colspan="3">$KAlSi_3O_8$</td><td colspan="2">Hematite, syn</td><td colspan="3">Fe_2O_3</td></tr>
<tr><td>Annite-1M</td><td colspan="3">$K(Fe,Mg)_3AlSi_3O_{10}(OH)_2$</td><td colspan="2" rowspan="3"></td><td colspan="3" rowspan="3"></td></tr>
<tr><td>Illite-Montmorillonite, regular</td><td colspan="3">$K\text{-}Al\ _4(SiAl)_8O_{20}(OH)_4!xH_2O$</td></tr>
<tr><td>Clinochlore-2MIIb</td><td colspan="3">$Mg_5Al(Si_3Al)O_{10}(OH)_8$</td></tr>
<tr><td colspan="9">* Mineralogy determined by XRD; M = major, m = minor, t = trace.</td></tr>
</table>

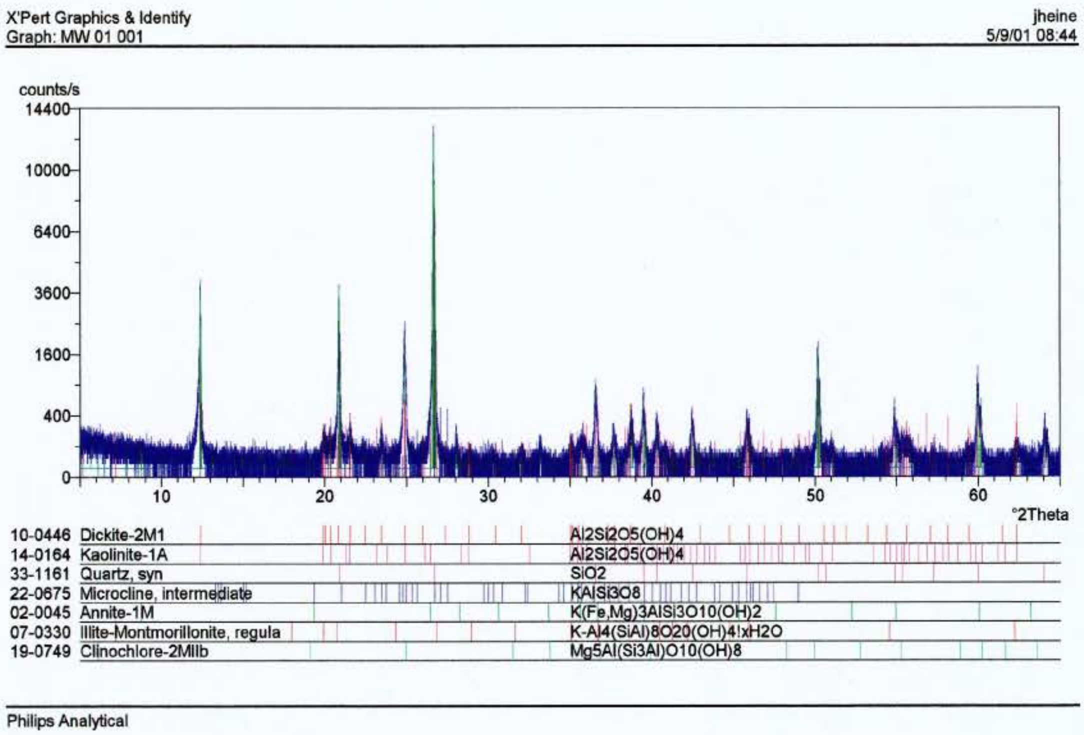


Figure 17. XRD trace depicting the mineralogy of Sioux Rock Products pond sludge (MW01001).

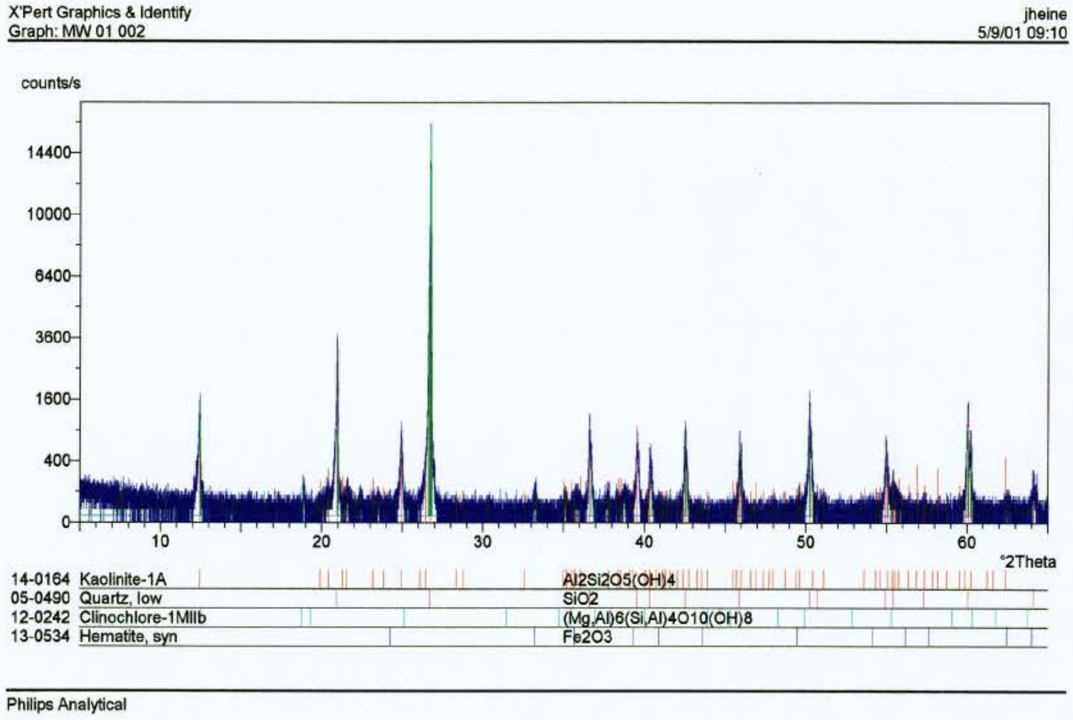


Figure 18. XRD trace depicting the mineralogy of Sioux Rock Products dirty fines (MW01002).

Data Sources

2001 Site Visit
2001 Survey Response and Submitted Data
2001 NRRI Sample Analysis

Southern Minnesota Construction Co.

1905 Third Avenue
Mankato, MN 56001

Phone: (507) 625-4848

Contact: Larry Nurre, President

www.smc-co.com

Quarry	T	R	S	Forty	County	Rock Type	Products	By-product	Size	Amount	Location
Morton Quarry	113	34			Renville	Gneiss	Crushed Stone	Quarry Fines	- 10 mesh	N.A.	N.A.
Kasota Quarry	109	26	20	NE 1/4	Blue Earth	Dolomite	Crushed Stone	Ag-lime	N.A.	N.A.	N.A.
Owatonna Quarry	108	20	33	SE 1/4	Steele	Limestone	Crushed Stone	Ag-lime	N.A.	N.A.	N.A.

Southern Minnesota Construction Co. (SMC), based in Mankato, MN, is a major crushed stone producer. SMC operates two carbonate quarries, the Kasota Quarry in Blue Earth County and the Owatonna Quarry in Steele County, and one crystalline rock quarry, the Morton Quarry in the Morton Gneiss of Renville County (Fig. 19). Figure 20 shows a shot rock (post-blasting) pile of the distinctive Morton Gneiss. In addition, SMC processes carbonate rejects and non-dimension stone intervals from Mankato-Kasota Stone, Inc. and Vetter Stone Co. quarries in Blue Earth County.

Figure 19. Southern Minnesota Construction's Renville County Morton Gneiss quarry.

Figure 20. Shot rock pile at SMC Morton Gneiss quarry, Renville County.

Geological Unit:	Morton Quarry:	Morton Gneiss
	Kasota Quarry:	Oneota Formation (dolomite)
	Owatonna Quarry:	Prosser Formation (limestone)

Wastes/By-products

Gneissic quarry fines are a waste/by-product generated at the Morton Quarry. **Ag-lime** is a by-product of operations at SMC's Kasota and Owatonna carbonate quarries.

By-product Analytical Data: Quarry Fines (Morton Gneiss)

A sample of the gneissic quarry fines, MW01012, was collected on-site at the Morton Quarry in January of 2001. These fines are the result of crushing and screening operations. The sample was taken from a pile below the conveyor belt from the screen plant. Particle size analysis, geochemistry, and x-ray diffractometry for mineral content were run on this sample.

Particle Size Analysis

Particle size analysis run on sample MW01012 indicates that approximately half of the material (51.9 %) is sand-sized (Table 75). The remainder consists of 40 % silt-sized particles and 8 % clay-sized particles. Table 76 presents the complete set of particle size data for sample MW01012.

Table 75 Sand-silt-clay fraction: SMC Morton Quarry quarry fines (MW01012).

SAND - SILT - CLAY FRACTION*				
SAMPLE	SAMPLE TYPE	% SAND	% SILT	% CLAY
MW01012	Quarry fines	51.93	40.04	8.03

*Sand >= 62.5 microns (# 230 sieve), silt < 62.5 microns and >= 2 microns, clay < 2 microns

Table 76 Full particle size assay data for SMC Morton Quarry quarry fines (MW01012).

Percent Passing Equivalent Spherical Diameter in Microns*													
	SAND					SILT						CLAY	
SAMPLE	2000 µ	1000 µ	500 µ	250 µ	120 µ	62.5 µ	44 µ	31 µ	22.1 µ	15.6 µ	7.8 µ	3.9 µ	2 µ	1 µ
MW01012	99.26	97.95	96.49	93.14	77.85	48.07	32.35	25.45	20.53	17.37	13.07	9.97	8.03	6.66

* +# 230 sieve fraction determined by sonic sifting; - # 230 sieve fraction determined by settling tube method.

Figure 21 presents the particle size analysis results for sample MW01012 in graphic form. The graph plots the weight percent of the sample that is: 1) finer than, and 2) coarser than, the equivalent spherical diameter (in microns) of a given particle size.

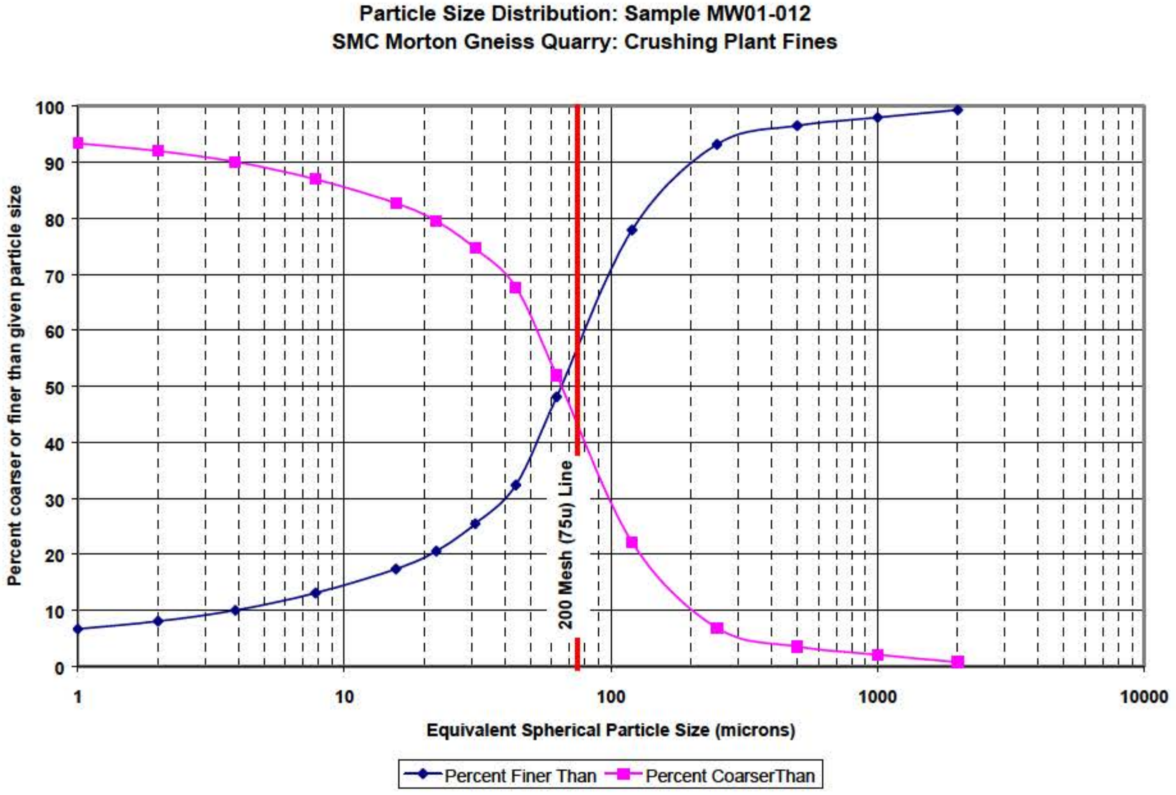


Figure 21. Particle size analysis in graphic form of SMC Morton Quarry quarry fines (MW01012).

Chemistry

The chemical composition of sample MW01012 is presented in Table 77.

Table 77 Geochemical analysis of SMC Morton Quarry quarry fines (MW01012).

Whole Rock[1]				Ultratrace - Aqua Regia[3]				Acid Digestion[4]			
SiO_2 wt %	70.83	Sc ppm	7	Mo (ppm)	0.44	Cr (ppm)	26.3	Mo (ppm)	0.7	Cr (ppm)	40
Al_2O_3 wt %	12.56	Ta ppm	< 20	Cu (ppm)	13.08	Mg %	0.62	Cu (ppm)	7	Mg %	0.81
Fe_2O_3 wt %	3.92	LOI %	2.3	Pb (ppm)	10.37	Ba (ppm)	86.2	Pb (ppm)	20	Ba (ppm)	631
MgO wt %	1.42	SUM %	99.98	Zn (ppm)	60.4	Ti %	0.149	Zn (ppm)	75	Ti %	0.306
CaO wt %	2.51			Ag (ppb)	30	B (ppm)	2	Ag (ppm)	0.2		
Na_2O wt %	2.95			Ni (ppm)	13.6	Al %	0.94	Ni (ppm)	18	Al %	6.48
K_2O wt %	2.56			Co (ppm)	8.1	Na %	0.033	Co (ppm)	10	Na %	2.186
TiO_2 wt %	0.53	Additional Analyses[2]		Mn (ppm)	423	K %	0.4	Mn (ppm)	556	K %	2.24
P_2O_5 wt %	0.17	C/ORG %	0.26	Fe %	2.01	W (ppm)	< .2	Fe %	2.85	W (ppm)	< 2
MnO wt %	0.07	CO_2 %	0.35	As (ppm)	0.9	Sc (ppm)	1.9	As (ppm)	3	Zr (ppm)	154.8
Cr_2O_3 wt %	0.005	TOT/C %	0.35	U (ppm)	3.8	Tl (ppm)	0.32	U (ppm)	8	Ce (ppm)	125
Ba ppm	608	SO_4 %	< .03	Au (ppb)	< .2	S %	< .01	Au (ppm)	< 4	Sn (ppm)	2.4
Cu ppm	25	TOT/S %	< .01	Th (ppm)	20.1	Hg (ppb)	8	Th (ppm)	20	Y (ppm)	18.4
Zn ppm	94			Sr (ppm)	14	Se (ppm)	0.1	Sr (ppm)	234	Nb (ppm)	11.5
Ni ppm	32	F (ppm)	668	Cd (ppm)	0.09	Te (ppm)	< .02	Cd (ppm)	< .2	Ta (ppm)	< .5
Co ppm	< 20			Sb (ppm)	0.05	Ga (ppm)	5.2	Sb (ppm)	< 1	Be (ppm)	2
Sr ppm	236	FeO %	1.9	Bi (ppm)	0.04			Bi (ppm)	< 1	Sc (ppm)	7
Zr ppm	216			V (ppm)	37			V (ppm)	54	Li (ppm)	34
Ce ppm	< 20	pH	8.6	Ca %	0.47			Ca %	1.84	S %	< .02
Y ppm	21	H_2O+ %	1.8	P %	0.081			P %	0.078	Rb (ppm)	124
Nb ppm	< 10	H_2O- %	0.5	La (ppm)	55.8			La (ppm)	70	Hf (ppm)	5

[1] 0.2 gm sample by $LIBO_2$ fusion, analysis by ICP-ES. LOI by loss on ignition.

[2] CO_2 - Digest with warm 15% $HCLO_4$, evolved CO_2 analyzed by LECO. SO_4 - Residue sulphur after ignited at 800 °C for 1 hour. C/ORG - Total C minus graphite C and carbonate. F - NaOH fusion - specific ion electrode analysis. FeO by dichromate titration. H_2O+ at 1500 °C. H_2O- at 110 °C.

[3] 15.00 gm sample, 90 ml 2-2-2 $HCl\text{-}HNO_3\text{-}H_2O$ at 95 °C for 1 hour and is diluted tp 300 ml, analysis by ICP/ES & MS.

[4] 0.25 gm sample digested with $HClO_4\text{-}HNO_3\text{-}HCl\text{-}HF$ to 10 ml. Digestion is partial for some minerals & may volatize some elements, analysis by ICP-ES.

Mineralogy

X-ray diffractometry of sample MW01012 indicates that quartz is the predominant mineral species present (Table 78). Minor amounts of annite (biotite) and Ca-plagioclase feldspar (anorthite) were detected, as well as trace amounts of Na-plagioclase feldspar (albite), K-feldspar (orthoclase), chlorite (clinochlore), amphibole (richterite), and clays (illite and mixed-layer illite-montmorillonite). Figure 22 presents the XRD trace for sample MW01012.

Table 78 Mineralogy of SMC Morton Quarry quarry fines (MW01012).*

	Quartz	Anorthite	Annite (Biotite)	Albite	Ortho-clase	Richterite	Clino-chlore	Illite	Illite-Mont-morillonite
MW01012	M	m	m	t	t	t	t	t	t

Component Mineral Composition			
Albite, ordered	$NaAlSi_3O_8$	Annite-1M, syn	$KFe_3(Si_3AlO_{10})(OH)_2$
Anorthite, ordered	$CaAl_2Si_2O_8$	Clinochlore-1MIIb, ferr	$(Mg,Al)_6(Si,Al)_4O_{10}(OH)_8$
Orthoclase	$KAlSi_3O_8$	Illite-2M1	$(K,H_3O)Al_2Si_3AlO_{10}(OH)_2$
Quartz., syn	SiO_2	Illite-Montmorillonite	$KAl_4(Si,Al)_8O_{10}(OH)_4!4H_2O$
Richterite, potassian	$KNaCaMg_5Si_8O_{22}(OH)_2$		

* Mineralogy determined by XRD; M = major, m = minor, t = trace.

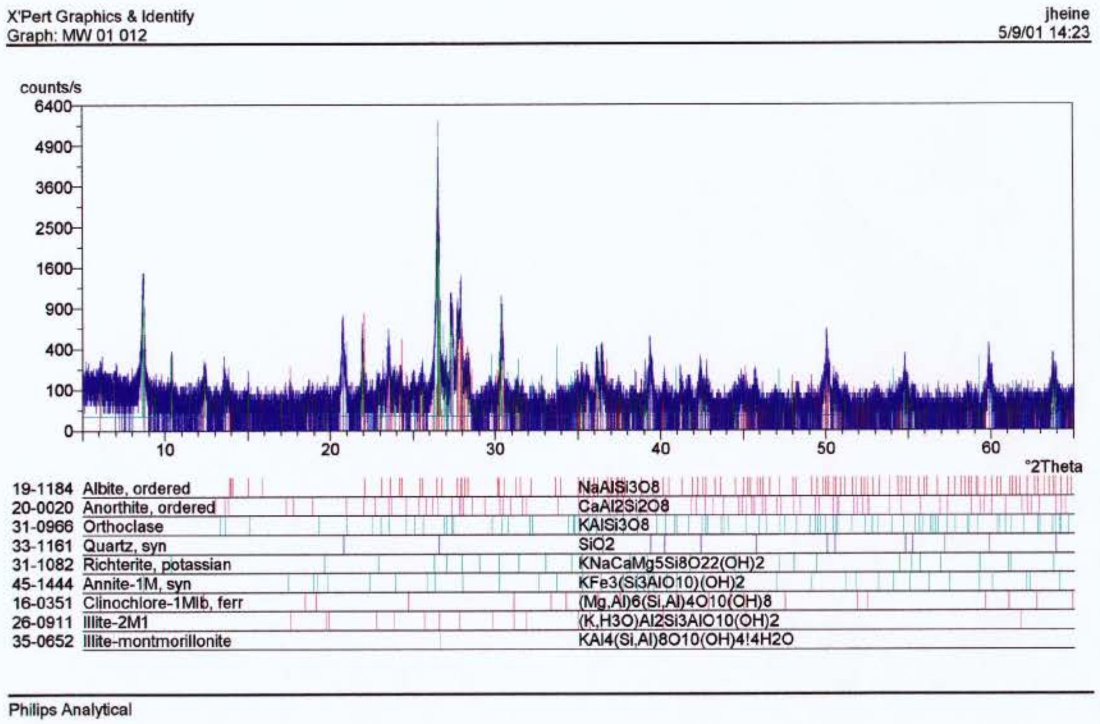


Figure 22. XRD trace depicting the mineralogy of SMC Morton Quarry quarry fines (MW01012).

By-product Analytical Data - Ag-lime

Ag-lime data for the Kasota and Owatonna quarries is available from the MN Dept. of Agriculture Ag-Lime Analysis Report (2001). The data is presented in Table 79.

Table 79 Ag-lime analytical data for SMC Kasota and Owatonna Quarries.

Ag-lime Analysis*												
Quarry	**County**	**Date**	**Sample Type**	**Rec #**	**Moisture Content**	**Fineness Index (FI)**	**% CCE**	**% ENP**	**MIN LBS ENP/TON**	**% Pass 8**	**% Pass 20**	**% Pass 60**
Kasota	Blue Earth	10122000	Ag-lime	4	7.4 %	66.0	85.8	56.6	1048	90.2	67.4	52.4
Owatonna	Steele	09012000	Ag-lime	129	6.4 %	57.8	80.5	46.6	872	85.0	58.9	43.2
*Ag-Lime Analysis Report, 2001												

Data Sources

2001 Site Visit
2001 NRRI Sample Analysis
Ag-Lime Analysis Report, 2001
Nelson et al., 1990
www.smc-co.com

Stussy Construction, Inc.

Dodge Co. Highway 21
P.O. Box 187
Mantorville, MN 55955-0187

Phone: (507) 635-2421

Quarry	T	R	S	Forty	County	Rock Type	Products	By-Product
Mantorville Quarry	107	16	21	SW 1/4	Dodge	Dolomitic Limestone	Crushed Carbonate Rock	Ag-lime
Rock Dell Quarry	105	15	9	NW-NE	Olmsted	Dolomitic Limestone	Crushed Carbonate Rock	Ag-lime
Mayowood Quarry	106	14	16 21	SW 1/4 NW-NW	Olmsted	Dolomitic Limestone	Crushed Carbonate Rock	Ag-lime

Stussy Construction, Inc. of Mantorville in Dodge County, MN, produces carbonate crushed stone from the Mantorville Quarry in Dodge County and the Rock Dell and Mayowood quarries in Olmsted County. No survey response was received.

Geologic Unit: Mantorville Quarry: Prosser Formation
Rock Dell Quarry: Prosser Formation
Mayowood Quarry: Prosser and Cummingsville Formations of the Galena Group

Wastes/By-products

Ag-lime is a by-product of crushing operations at the Stussy Construction, Inc. quarries.

Waste/By-product Analytical Data: Ag-lime

Ag-lime data for the Mantorville, Rock Dell, and Mayowood quarries is available from the MN Dept. of Agriculture Ag-Lime Analysis Report (2001). The data is presented in Table 80.

Table 80 Ag-lime analytical data for Stussy Construction, Inc. quarries.*

Quarry	County	Date	Sample Type	Rec. #	Moisture Content	Fineness Index (FI)	% CCE	% ENP	MIN LBS ENP/TON	% Pass 8	% Pass 20	% Pass 60
Mantorville	Dodge	09012000	Ag-lime	22	5.1 %	77.5	94.4	73.2	1389	99.4	86.1	58.0
Rock Dell	Olmsted	09012000	Ag-lime	75	4.7 %	75.1	91.0	68.4	1303	99.8	82.1	55.8
Mayowood	Olmsted	09012000	Ag-lime	76	4.2 %	74.2	71.4	53	1015	99.8	84.1	51.5

*Ag-Lime Analysis Report, 2001

Data Sources

Ag-Lime Analysis Report, 2001
Nelson et al., 1990

Ulland Brothers, Inc.

P.O. Box 340
Cloquet, MN 55720

Phone: (218) 348-4266
Fax: (218) 384-4110

Contact: Dave Nartnik, Quarry Manager

www.ullandbros.com

Quarry	T	R	S	Forty	County	Rock Type	Product	Wastes/By-products	Amount	Location
Becks Quarry	49	15	32	E 1/2 of NE 1/4	St. Louis	Basalt	Crushed stone	Over-size rocks	20,000 T	Stockpile

Ulland Brothers, Inc. operates numerous pits throughout northeastern and southern Minnesota, producing basalt and limestone products and sand and gravel. Offices are located in Cloquet, Hibbing, and Albert Lea. Becks Quarry (basalt) is located near Duluth in southern St. Louis County.

Becks Quarry

Geologic Unit: Basalt from the North Shore Volcanic Group

Production: Rock is drilled and blasted; excavation and haulage is by loader. Size reduction occurs via cone and jaw crushers. Product shipping is by truck.

Product Line: Full range of crushed basalt rock products including BA 3/4 and BA ½ bituminous mix, ballast, CA-50 and CA-70 concrete aggregate, crusher fines, and rip rap.

Wastes/By-products

Waste/ By-product	How Used	Most Difficult To Market	Easiest To Market	Potential Markets/Uses
Oversize Rock	Break water walls Specialized landscaping Erosion control	15 - 20 ton rocks: limited uses, transportation difficulty.	Smaller types of oversize rock: commonly used as rip rap.	Safe Harbor construction Erosion control Shoreline protection

Over-sized rocks have been identified by Ulland Brothers, Inc. as a problematic waste/by-product at Becks Quarry. A stockpile containing 20,000 tons of rock is located on-site.

Waste/By-product Analytical Data: Oversize Rocks

Physical property data on the Becks Quarry basalt was submitted by Ulland Brothers, Inc. The data is presented in Table 81.

Table 81 Physical properties of Ulland Brothers, Inc. Becks Quarry basalt.*

Quarry	Sample Type	Color	LAR	Magnesium Sulfide Loss	Specific Gravity	Absorption	Freeze-Thaw Durability	Compressive Strength
Becks Quarry	Basalt	Blue	10%	0.9%	2.81	1.0%	.001%	20,000 + psi

* Data provided by Ulland Brothers, Inc.

Data Sources

2001 Survey Response
www.ullandbros.com

Wm. Mueller & Sons, Inc.

831 Park Ave.
Hamburg, MN 55339

Phone: (952) 467-2720
Fax: (952) 467-3894

Contact: Richard Smith, Vice President

Quarry	T	R	S	Forty	County	Rock Type	Product	Wastes/By-products
Weckman Quarry	115	23	15	NW 1/4	Scott	Limestone	Crushed road rock	Stripping Quarry fines Wash fines Ag-lime

Wm. Mueller & Sons, Inc. of Hamburg in Carver County, MN, is an aggregate producer/road construction company whose operations include a permanent and portable asphalt plant, a limestone quarry, and several sand and gravel pits. Crushed carbonate road rock is produced at the Weckman Quarry in Scott County, along with natural sand and gravel.

Weckman Quarry limestone

Geologic Unit: N.A.

Wastes/By-products

Waste/By-products	How Used	Most Difficult To Market	Easiest To Market	Potential Markets/Uses
Stripping	Reclamation	N.A.	Overburden is stockpiled for pit restoration. All materials are used or recycled. They are sold for construction or building purposes.	Refer to "How Used"
Quarry Fines	Baseball diamond dust for infields			
Wash Fines	Fill material			

Three wastes/by-products are generated by the quarrying and sand and gravel operations of Wm. Mueller & Sons, Inc.'s Weckman Quarry: **stripping, quarry fines, and wash fines**. The company has found ways to make use of each of these wastes/by-products. Stripping material is held in reserve for reclamation. Quarry fines are sold as baseball diamond dust for infields and as ag-lime. Wash fines are sold as fill material.

Most of the **wash fines** sold by the company are generated by the sand & gravel operation in its Carver (Mueller) pit in Carver County (see Wm. Mueller & Sons, Inc. listing under Sand and Gravel Operations, this report). Previously stockpiled, it was discovered that these fines, once dewatered, made a good base under concrete pads, thus making them a marketable product. **Baghouse fines**, generated by the company's asphalt plants, are put back into the mix.

In addition to its own generated wastes/by-products, Wm. Mueller & Sons, Inc. takes back **concrete wash** and **culled bricks** from ready-mix plants. These are used to make recycled Class 5 (with the inclusion of some bituminous). A complete listing of Wm. Mueller & Sons, Inc.'s wastes/by-products is provided in the company's profile under Sand & Gravel Operations. Wm. Mueller & Sons, Inc. attempts to take all the materials out of a quarry so that it can return it to a natural state, i.e., wetlands, etc. (R. Smith, pers. comm., 2001).

Waste/By-product Analytical Data - Ag-lime

Ag-lime data for the Weckman Quarry is available from the MN Dept. of Agriculture Ag-Lime Analysis Report (2001). The data is presented in Table 82.

Table 82 Ag-lime analytical data for Wm. Mueller & Sons, Inc.'s Weckman Quarry.

Quarry	County	Date	Sample Type	Rec. #	Moisture Content	Fineness Index (FI)	% CCE	% ENP	MIN LBS ENP/TON	% Pass 8	% Pass 20	% Pass 60
Weckman	Scott	82300	Ag-lime	119	4.6	54.5	88	47.9	915	90.8	56.5	34.3

*Ag-Lime Analysis Report, 2001

Data Sources

2001 Survey Response
Ag-Lime Analysis Report, 2001
Richard Smith, pers. com., 2001

DIMENSION STONE OPERATIONS

The following pages present individual dimension stone producer profiles. Included are quarry locations, geologic and production data, types and amounts of wastes/by-products generated, and analytical data pertinent to the wastes/by-products.

Visits were made to the headquarters of all of Minnesota's active dimension stone companies in January of 2001. These companies were: Biesanz Stone Co., Inc., Winona; Mankato-Kasota Stone, Inc. and Vetter Stone Co., Mankato; Jasper Stone Co., Jasper, and Cold Spring Granite, Cold Spring. In addition, a survey response was received from Dakota Granite Co., headquartered in Milbank, SD. Dakota Granite operates the Bellingham Quarry in Lac Qui Parle County, MN.

Company	Corporate Headquarters	Quarry Location by County	Rock Type
Biesanz Stone Co., Inc.	Winona, MN	Winona	Dolomite
Cold Spring Granite	Cold Spring, MN	Big Stone Lake Mille Lacs Renville Stearns	Granite Granite Granite Gneiss Granite
Dakota Granite Co.	Milbank, SD	Lac Qui Parle	Granite
Jasper Stone Co.	Jasper, MN	Rock	Quartzite
Mankato-Kasota Stone, Inc.	Mankato, MN	Blue Earth	Dolomite
Vetter Stone Co.	Kasota, MN	Blue Earth	Dolomite

Biesanz Stone Co.

4600 Goodview Road
Winona, MN 55987

Phone: (507) 454-4336
Fax: (507) 454-8140
Toll Free: (800) 247-8322

Charles W. Biesanz, Jr., President

www.biesanzstone.com

Quarry	T	R	S	Forty	County	Rock Type	Product	By-product	Size	Amount	Location
Biesanz Stone Quarry	107	07	19	SW 1/4	Winona	Dolomite	Dimension Stone	Rock saw fines	-200 mesh	100 CY/YR	Settling Pond
								Block cut-offs (ends)	varies	N.A.	Stockpiles & Berms

Biesanz Stone Co., located in the city of Winona in Winona County, MN, quarries the dolomitic rock of the Oneota Dolomite formation. The more massive basal portion of the formation is the source for Biesanz Stone's two major stone types: an upper yellow stone and a lower gray stone. Figure 23 shows the exposed quarried portion relative to the more highly bedded overlying material. Typical quarried blocks are shown in Figure 24. Table 83 presents a descriptive geology of the Biesanz Stone Quarry as taken from Stauffer and Thiel, 1941.

Geologic Unit: Oneota Formation

Table 83 Descriptive geology of the Biesanz Stone Quarry (Stauffer and Thiel, 1941).

GEOLOGY OF THE BIESANZ STONE QUARRY					
From Ft.	**To Ft.**	**Thickness (ft.)**	**Unit Type**	**Unit Name**	**Unit Description**
0.0	0.5	0.5			Soil and residual material
0.5	4.5	4.0	Oneota Dolomite	"Bastard Rock"	Dolomite, hard gray
4.5	6.8	2.3	Oneota Dolomite	"The Freestone Ledge"	Dolomite, close grained, buff, works easily
6.8	16.8	10	Oneota Dolomite		Dolomite, gray to drab, used for crushing only
16.8	19.3	2.5	Oneota Dolomite	"The Cream Ledge"	Dolomite, buff
19.3	21.5	2.2	Oneota Dolomite		Dolomite, buff to gray -- rough
21.5	24.0	2.5	Oneota Dolomite	"The Yellow Ledge"	Dolomite, somewhat pitted, buff
24.0	26.0	2.0	Oneota Dolomite	"The White Ledge"	Dolomite, gray to light gray, fossiliferous
26.0	26.7	0.7	Oneota Dolomite	"The Upper Gray Ledge"	Dolomite, gray to drab, fossiliferous
26.7	27.5	0.8	Oneota Dolomite	"The Lower Gray Ledge"	Dolomite, gray, fossiliferous
27.5	30.8	3.3	Oneota Dolomite	"The Main Pink Ledge"	Dolomite, massive, gray to pink with gastropods and cavities or holes that may have been fossils
30.8	32	1.2	Oneota Dolomite	"The Lower or Light Pink Ledge"	Dolomite, gray to pink
32.0	37.0	5.0	Oneota Dolomite		Dolomite, rough gray to drab, used for rubble
37.0	61.0	24.0	Oneota Dolomite		Dolomite, rough, arenaceous, gray containing several layers of sandstone, not used

Figure 23. Oneota Dolomite at Biesanz Stone Co.; note the massive dimension stone unit at base of exposure.

Figure 24. Stacked quarry blocks of Oneota Dolomite at Biesanz Stone Co.

Wastes/By-products

Waste/By-product	How Used	Most Difficult To Market	Easiest To Market	Potential Markets/Uses
Rock saw fines	Not used for the most part.	Rock saw fines	Block cut-offs (ends)	?
Block cut-offs (ends)				Crush for road construction

Rock saw fines are the main waste/by-product generated at Biesanz Stone Co. **About ten 10-yd^3 truck loads of fines are produced annually**, and are currently placed in a settling pond. Due to space limitations, the company seeks to market this material. A secondary, less problematic, waste/by-product is **block cut-offs** (or ends) that could be crushed and used for road construction. These are stored on site in berms and stockpiles.

Waste/By-product Analytical Data - Rock Saw Fines

A sample of the rock saw fines, MW01007, was collected from a saw plant trough in January, 2001. Particle size analysis, geochemistry, and x-ray diffractometry for mineral content were run on the sample.

Particle Size Analysis

Particle size analysis of sample MW01007 indicates that the Biesanz Stone Co. rock saw fines are mostly silt-sized, with a fair amount of clay-sized material and minimal sand (Table 84). Table 85 presents the complete particle size assay data on sample MW01007. Test data indicates that almost 70% of the sample is fine silt or finer. What little sand-sized material is present is very fine.

Table 84 Sand-silt-clay fraction: Biesanz Stone Co. rock saw fines (MW01007).

SAND-SILT-CLAY FRACTION*				
SAMPLE	SAMPLE TYPE	% SAND	% SILT	% CLAY
MW01007	Rock Saw Fines Sludge	1.37	84.58	14.05
*Sand >= 62.5 microns (# 230 sieve), silt < 62.5 microns and >= 2 microns, clay < 2 microns				

Table 85 Complete particle size assay data for Biesanz Stone Co. rock saw fines (MW01007).

Percent Passing Equivalent Spherical Diameter in Microns*														
	SAND					SILT							CLAY	
SAMPLE	2000 μ	1000 μ	500 μ	250 μ	120 μ	62.5 μ	44 μ	31 μ	22.1 μ	15.6 μ	7.8 μ	3.9 μ	2 μ	1 μ
MW01007	100.00	99.98	99.94	99.76	99.54	98.63	92.88	87.46	78.83	69.59	46.58	26.44	14.05	6.95
* + # 230 sieve fraction determined by sonic sifting; - # 230 sieve fraction determined by settling tube method.														

Figure 25 presents the particle size analysis of sample MW01007 in graphic form. The graph plots the weight percent of the sample that is: 1) finer than, and 2) coarser than, the equivalent spherical diameter (in microns) of a given particle size. For a size comparison of Biesanz Stone Co.'s rock saw fines with those of Cold Spring Granite and Mankato-Kasota Stone, see Fig. 41.

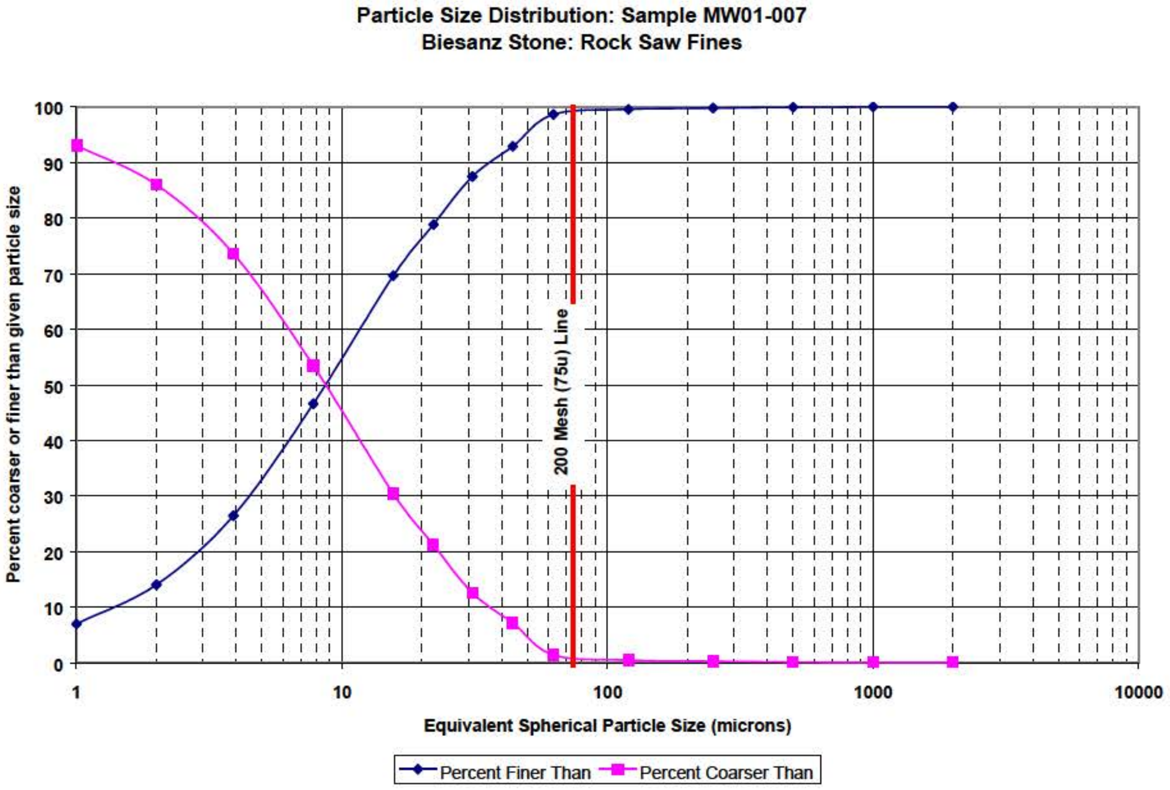


Figure 25. Particle size analysis in graphic form of Biesanz Stone Co. rock saw fines (MW01007).

Chemistry

Table 86 presents the geochemical composition of sample MW01007, Biesanz Stone Co. rock saw fines.

Mineralogy

Table 87 presents the results of x-ray diffractometry run on sample MW01007, Biesanz Stone Co. rock saw fines. Dolomite is the predominant mineral species present. Traces of two other carbonate minerals, calcite and ankerite, were detected. Minor quartz and the K-feldspar microcline are present, as well as traces of the K-feldspar sanidine and the chlorite mineral clinochlore. The XRD trace for sample MW01007 is presented in Figure 26.

Table 86 Geochemical analysis of Biesanz Stone Co. rock saw fines (MW01007).

Whole Rock [1]				Ultratrace - Aqua Regia [3]				Acid Digestion [4]			
SiO_2 wt %	7.57	Sc ppm	1	Mo ppm	0.16	Cr ppm	6.3	Mo ppm	0.8	Cr ppm	9
Al_2O_3 wt %	1.2	Ta ppm	< 20	Cu ppm	20.94	Mg %	8.67	Cu ppm	23	Mg %	10.84
Fe_2O_3 wt %	0.46	LOI %	42.7	Pb ppm	7.66	Ba ppm	11.5	Pb ppm	7	Ba ppm	70
MgO wt %	17.87	SUM %	99.98	Zn ppm	93.7	Ti %	< .001	Zn ppm	90	Ti %	0.034
CaO wt %	29.1			Ag ppb	141	B ppm	7	Ag ppm	0.8		
Na_2O wt %	0.03			Ni ppm	2.6	Al %	0.06	Ni ppm	4	Al %	0.75
K_2O wt %	0.87			Co ppm	3.2	Na %	0.013	Co ppm	3	Na %	0.037
TiO_2 wt %	0.06	Additional Analyses [2]		Mn ppm	292	K %	0.03	Mn ppm	308	K %	0.85
P_2O_5 wt %	0.04	C/ORG %	0.23	Fe %	0.26	W ppm	< .2	Fe %	0.3	W ppm	< 2
MnO wt %	0.04	CO_2 %	43	As ppm	0.8	Sc ppm	0.6	As ppm	5	Zr ppm	10.4
Cr_2O_3 wt %	0.004	TOT/C %	11.96	U ppm	0.4	Tl ppm	0.06	U ppm	< 1	Ce ppm	9
Ba ppm	62	SO_4 %	< .03	Au ppb	1.6	S %	0.03	Au ppm	< 4	Sn ppm	2.2
Cu ppm	23	TOT/S %	< .01	Th ppm	0.7	Hg ppb	9	Th ppm	< 1	Y ppm	2.5
Zn ppm	104			Sr ppm	66.9	Se ppm	0.2	Sr ppm	81	Nb ppm	< .2
Ni ppm	< 20	F ppm	154	Cd ppm	0.14	Te ppm	0.07	Cd ppm	< .2	Ta ppm	< .5
Co ppm	< 20			Sb ppm	0.09	Ga ppm	0.3	Sb ppm	1	Be ppm	< 1
Sr ppm	70	FeO %	0.2	Bi ppm	0.02	Sample	15	Bi ppm	< 1	Sc ppm	1
Zr ppm	24			V ppm	9			V ppm	10	Li ppm	2
Ce ppm	< 20	pH	9.3	Ca %	18.1			Ca %	23.84	S %	< .02
Y ppm	< 10	H_2O+ %	1.1	P %	0.007			P %	0.007	Rb ppm	7
Nb ppm	24	H_2O- %	0.1	La ppm	2.6			La ppm	3	Hf ppm	< 1

[1] 0.2 gm sample by $LIBO_2$ fusion, analysis by ICP-ES. LOI by loss on ignition.

[2] CO_2 - Digest with warm 15% $HCLO_4$, evolved CO_2 analyzed by LECO. SO_4 - Residue sulphur after ignited at 800 °C for 1 hour. C/ORG - Total C minus graphite C and carbonate. F - NaOH fusion - specific ion electrode analysis. FeO by dichromate titration. H_2O+ at 1500 °C. H_2O- at 110 °C.

[3] 15.00 gm sample, 90 ml 2-2-2 $HCl\text{-}HNO_3\text{-}H_2O$ at 95 °C for 1 hour and is diluted to 300 ml, analysis by ICP/ES & MS.

[4] 0.25 gm sample digested with $HClO_4\text{-}HNO_3\text{-}HCl\text{-}HF$ to 10 ml. Digestion is partial for some minerals & may volatize some elements, analysis by ICP-ES.

Table 87 Mineralogy of Biesanz Stone Co. rock saw fines (MW01007).*

Sample	Dolomite	Microcline	Quartz	Calcite	Clinochlore	Ankerite	Sanidine
MW01007	M	m	m	t	t	t	t

Component Mineral Composition

Mineral	Composition	Mineral	Composition
Dolomite	$CaMg(CO_3)_2$	Clinochlore-2MIIb	$Mg_5Al(Si_3Al)O_{10}(OH)_8$
Microcline, intermediate	$KAlSi_3O_8$	Ankerite	$Ca(Fe,Mg)(CO_3)_2$
Calcite, syn	$CaCO_3$	Sanidine, disordered	$K(Si_3Al)O_8$
Quartz., low	SiO_2		

* Mineralogy determined by XRD; M = major, m = minor, t = trace.

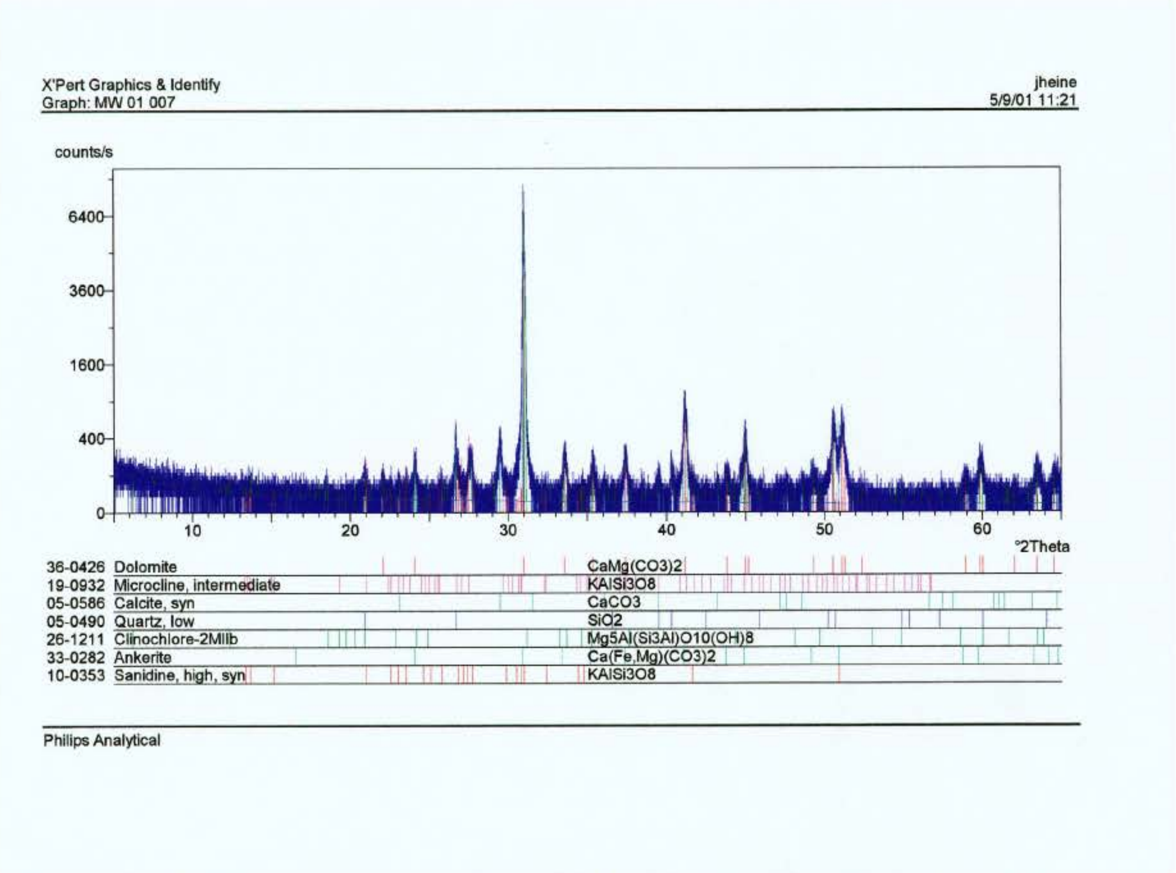


Figure 26. XRD trace depicting the mineralogy of Biesanz Stone Co. rock saw fines (MW01007).

Waste/By-product Analytical Data - Ag-lime

Operating out of the same quarry, Milestone Materials of Onalaska, WI, runs a crushed stone operation using stone from the quarry face that is not suitable for dimension stone (Fig. 27). The resultant fines are sold by Milestone Materials as agricultural liming material. Analysis of the ag-lime material is presented in Table 88.

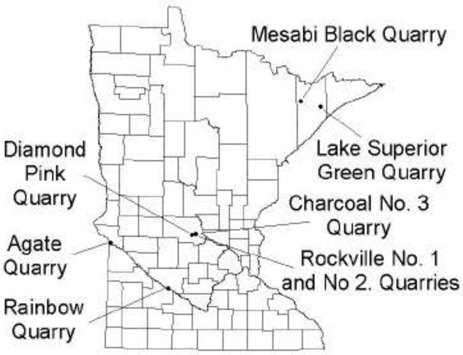
Figure 27. Stockpiles of quarrying by-products at Biesanz Stone Co. used for aggregate.

Table 88 Ag-lime analytical data for Biesanz Stone Quarry.

Ag-lime Analysis*											
Quarry	Date	Sample Type	Rec. #	Moisture Content	Fineness Index (FI)	% CCE	% ENP	MIN LBS ENP/TON	% Pass 8	% Pass 20	% Pass 60
Biesanz	01032000	Ag-Lime	140	5.7 %	65.0	93.9	61.0	1150	89.2	66.3	51.5
*Ag-Lime Analysis Report 2001											

Data Sources

2001 Site Visit and submitted materials
2001 NRRI Sample Analysis
Ag-Lime Analysis Report, 2001
Nelson et al., 1990
www.biesanzstone.com



Cold Spring Granite

202 South Third Avenue
Cold Spring, MN 56320

Phone: (320) 685-3621
Fax: (320) 685-8490

Contact: Don Sieger, Quarry Engineer
dsieger@coldspringgranite.com
www.coldspringgranite.com

Quarry	T	R	S	Forty	County	Rock Type	Product	By-product	Size	Amount	Location
Cold Spring West Plant					Stearns	Granite	Dimension Stone	Fine Stone	N.A.	9,000 CY	Stockpile
Charcoal No. 3 Quarry	124	28	21	NE-SE	Stearns	Granite	Dimension Stone	Grout	Dust to 40-ton blocks	750,000 T	Stockpile
Diamond Pink Quarry	124	29	26	NE-NE	Stearns	Granite	Dimension Stone	Grout	Dust to 40-ton blocks	85,000 T	Stockpile
Purple Crystal Quarry	124	29	27	NW-NE	Stearns	Granite	Dimension Stone	Grout	Dust to 40-ton blocks	25,000 T	Stockpile
Rockville No. 1 Quarry	123	29	9	SE-SW	Stearns	Granite	Dimension Stone	Drill Fines	- 3/8 in.	N.A.	Stockpile?
								Grout	Dust to 40-ton blocks	300,000 T	Stockpile
Rockville No. 2 Quarry	123	29	16	NE-NW	Stearns	Granite	Dimension Stone	Grout	Dust to 40-ton blocks	300,000 T	Stockpile
Agate Quarry	121	46	22	SW-SE	Big Stone	Granite	Dimension Stone	Grout	Dust to 40-ton blocks	50,000 T	Stockpile
Lake Superior Green Quarry	60	7	35	NW-NE	Lake	Gabbro	Dimension Stone	Grout	Dust to 40-ton blocks	35,000 T	Stockpile
Mesabi Black Quarry	61	11	24	SW-SW	Lake	Gabbro	Dimension Stone	Grout	Dust to 40-ton blocks	30,000 T	Stockpile
Isle Quarry	41	25	3	SE-NE	Mille Lacs	Granite	Dimension Stone	Grout	Dust to 40-ton blocks	250,000 T	Stockpile
Rainbow Quarry	113	34	32	NW-SW	Renville	Gneiss	Dimension Stone	Grout	Dust to 40-ton blocks	230,000 T	Stockpile

Cold Spring Granite, whose main office and plant are located in Cold Spring, Stearns County, MN, is one of the world's largest dimension stone producers. The plant produces dimension stone from eight quarries in five Minnesota counties and from rock imported from quarries around the world.

Geologic Unit:

Charcoal No. 3, Diamond Pink, Purple Crystal, Rockville No. 1 and No. 2, Agate, and Isle quarries:	Various granites
Lake Superior Green and Mesabi Black quarries:	Duluth Complex gabbroic rocks
Rainbow Quarry:	Morton Gneiss

Production: Rock is extracted and moved by means of hydraulic-pneumatic drills, 10-yd articulated loaders, and off-road trucks; processed by diamond wire saws; and shipped by flatbed trucks and containers.

Product Line: Dimension Stone

Wastes/By-products

Waste/By-product	How Used	Most Difficult To Market	Easiest To Market	Potential Markets/Uses
Grout (Chunks of non-usable granite)	Not used for the most part.	Grout, because the chunks cost to further process. Stone fines, because they have no application.	N.A.	Rip rap
Drilling Fines				?
Rock Saw Fines				?

Three wastes/by-products are generated by the Cold Spring Granite dimension stone operations: **grout** (chunks of non-usable granite); **drilling fines**; and **rock saw fines** (sludge produced in the cutting, grinding, and polishing process at the Cold Spring plant).

While grout ranges in size from dust to 40-ton blocks, most of it consists of large chunks weighing in excess of one ton. **Over 2.5 million tons of non-usable granite is stockpiled** at Cold Spring Granite's various quarries. The difficulty in marketing this material lies in the cost of further processing. Block cut-offs (Figs. 28 and 29) are generally taken by a local contractor and crushed for rip-rap and aggregate production. The same contractor is making an attempt to process the large quarry block rejects for the same purposes.

Figure 28. Cold Spring Granite cut-off blocks transported via conveyor to demolition container.

Figure 29. Cold Spring Granite quarry block slabs.

There are **9,000 CY of stockpiled rock saw fines** at the Cold Spring plant. Samples of both the drilling fines and the rock saw fines were collected for analysis. In addition, a separate study by the University of Minnesota evaluated the use of rock fines from the Cold Spring East plant as a sustainable soil amendment for agriculture (Rosen et al., 1999, 2000, 2001). Analytical data from the study are presented below and in Appendix E. The full U of MN report appears in Appendix E.

Waste/By-product Analytical Data - Rock Saw Fines and Drilling Fines

Two samples were collected from Cold Spring Granite in January, 2001. Particle size analysis, geochemistry, and x-ray diffractometry for mineral content were run on both samples.

Sample MW01009 consists of sludge fines from the Cold Spring plant clarifier. The sludge comprises sawing, grinding, and polishing fines that have settled out of the recycle water after being.pumped to an on-site sludge basin. Analytical data from this sample should be regarded as a "snapshot" of the material being produced at the time. Stone from all of Cold Spring Granite's Minnesota quarries and also from their quarries throughout the world are brought to the Cold spring plant for cutting. While large volumes of saw and grinding fines are produced, analytical data are only as good as the material being processed at the time. Figure 30 depicts typical dimension stone blocks being prepared for cutting at Cold Spring's operation, from which sludge fines are generated.

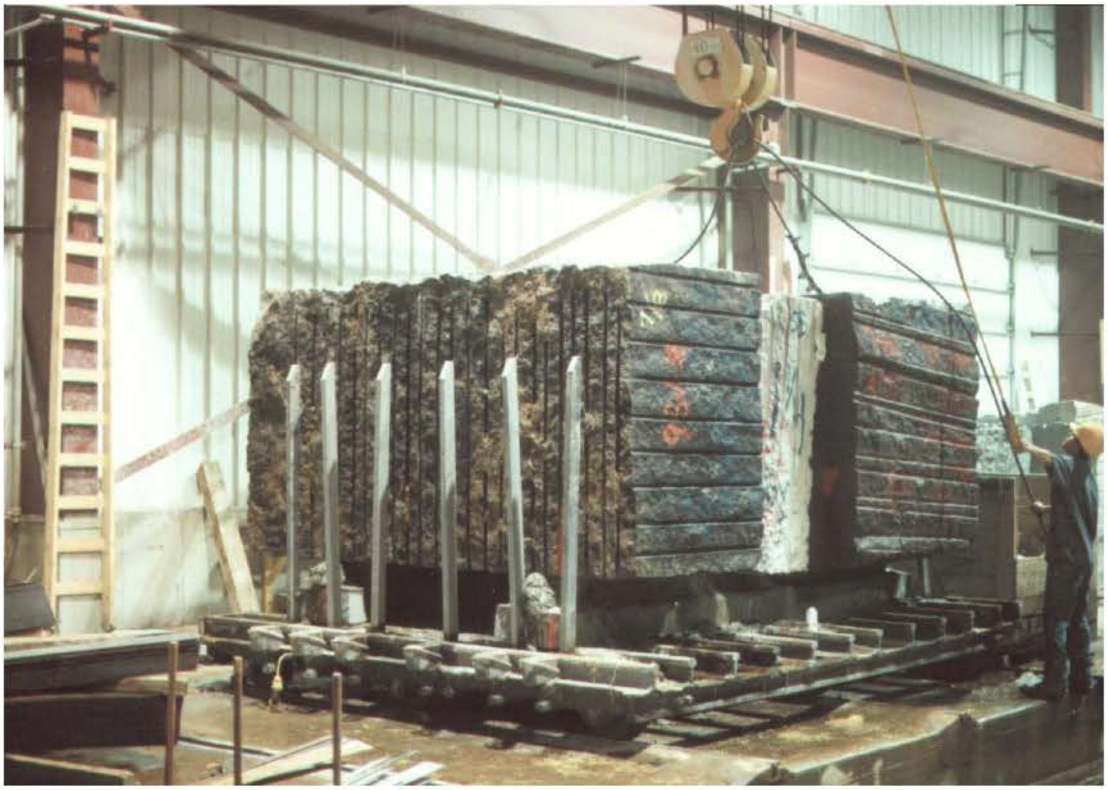


Figure 30. Typical dimension stone blocks at Cold Spring Granite being positioned for cutting.

Sample MW01010 consists of drilling fines collected from the Rockville Quarry (Figs. 31 and 32). These fines are essentially "vacuumed" off the rock slab surface after drilling and bagged for disposal. Analytical data on this sample should be representative of material from the Rockville Quarry.

Figure 31. Overview of Cold Spring Granite's Rockville quarry.

Figure 32. Drilling of quarry blocks at Cold Spring Granite's Rockville quarry.

Particle Size Analysis

Particle size analysis of sample MW01009 indicates that Cold Spring Granite's rock saw fines are comparable in size to those of Biesanz Stone Co. (MW01007). They are -200 mesh, consist mainly of silt-sized particles, and have 14.6 % clay-sized particles with minimal sand (Table 89). The drilling fines, MW01010, are coarser, with 2/3 of the sample consisting of sand-sized particles, while the remaining 1/3 consists mainly of silt-sized particles with only minimal clay-sized material (3.72 %). Table 90 presents the complete particle size assay data on samples MW01009 and MW01010.

Table 89 Sand-silt-clay fraction: Cold Spring Granite rock saw fines (MW01009) and Rockville Quarry drilling fines (MW01010).

SAND - SILT - CLAY FRACTION*				
SAMPLE	SAMPLE TYPE	% SAND	% SILT	% CLAY
MW01009	Rock Saw Fines (Sludge from Clarifier)	4.42	80.96	14.62
MW01010	Drilling Fines	67.88	28.39	3.72

*Sand >= 62.5 microns (# 230 sieve), silt < 62.5 microns and >=2 microns, clay < 2 microns

Table 90 Complete particle size assay data for Cold Spring Granite rock saw fines (MW01009) and Rockville Quarry drilling fines (MW01010).

Percent Passing Equivalent Spherical Diameter in Microns*														
	SAND					SILT							CLAY	
SAMPLE	2000 µ	1000 µ	500 µ	250 µ	120 µ	62.5 µ	44 µ	31 µ	22.1 µ	15.6 µ	7.8 µ	3.9 µ	2 µ	1 µ
MW01009	99.98	99.89	99.58	99.14	98.23	95.58	89.43	83.81	74.51	65.26	45.08	26.63	14.62	6.93
MW01010	99.55	94.43	81.52	62.49	45.73	32.12	25.50	21.36	17.29	14.16	9.55	5.86	3.72	2.65

* + # 230 sieve fraction determined by sonic sifting; - # 230 sieve fraction determined by settling tube method.

Figures 33 and 34 present the particle size analyses of samples MW01009 and MW01010, respectively, in graphic form. The graph plots the weight percent of the sample that is: 1) finer than, and 2) coarser than, the equivalent spherical diameter (in microns) of a given particle size. For a size comparison of Cold Spring Granite's rock saw fines with those of Biesanz Stone Co. and Mankato-Kasota Stone, see Fig. 41.

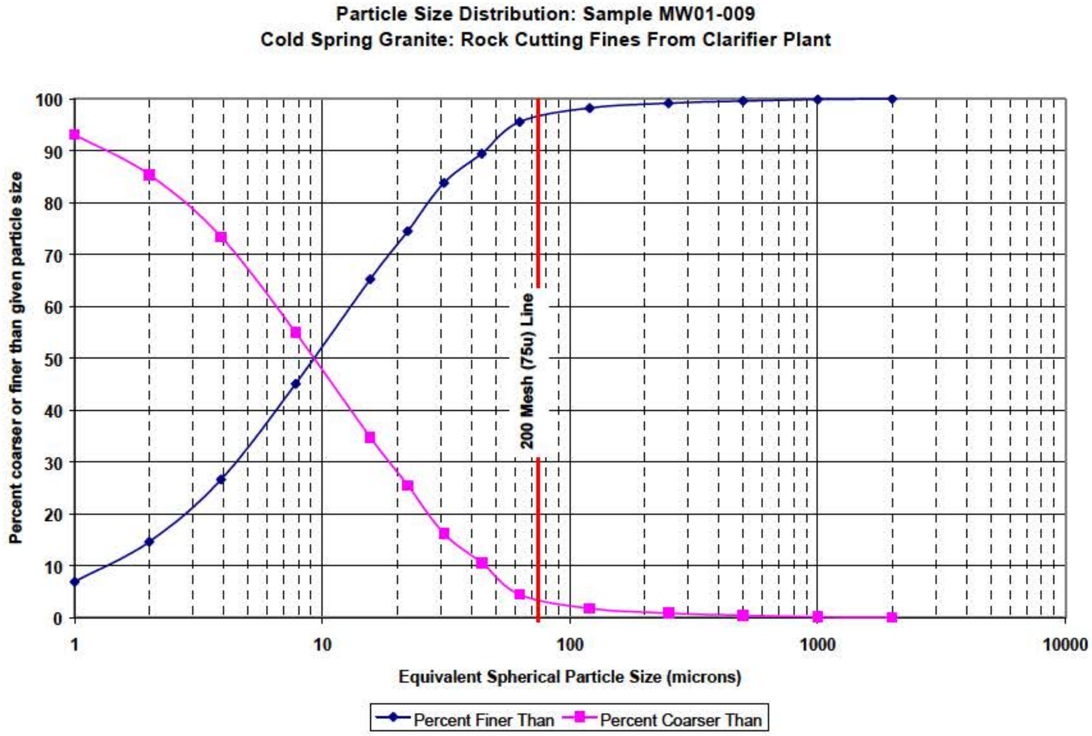


Figure 33. Particle size analysis in graphic form of Cold Spring Granite rock saw fines (MW01009).

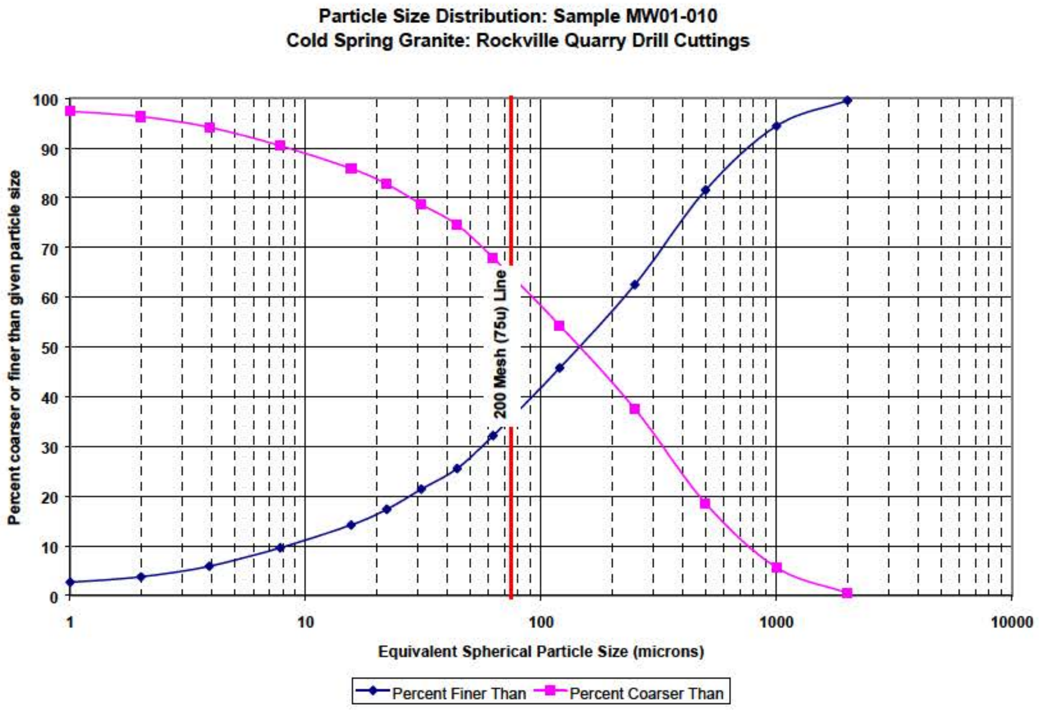


Figure 34. Particle size analysis in graphic form of Cold Spring Granite Rockville Quarry drilling fines (MW01010).

Because the Rockville Quarry drilling fines are predominantly sand-sized, a dry sieve analysis was also run. Results are presented in Table 91. Dry sieving resulted in a reduced silt-sized fraction (19.2 % passing a # 200 sieve vs. 32.1 % passing a # 230 sieve (Table 91)). This can be attributed to the much larger sample size (5,425 gm vs. 20 gm) and to the dry sieving process itself.

Table 91 Dry sieve analysis of Cold Spring Granite Rockville Quarry drilling fines (MW01010).

Sample	Mass (gm)	% Pass #4	% Pass #8	% Pass #10	% Pass #16	% Pass #20	% Pass #30	% Pass #40	% Pass #50	% Pass #60	% Pass #100	% Pass #200
MW01010	5424.7	100	99.82	98.94	96.02	90.85	83.42	73.55	62.56	57.74	38.45	19.2

Chemistry

Table 92 presents the chemical composition of samples MW01009, rock saw fines, and MW01010, Rockville Quarry drilling fines. Sample RMW01010 is a duplicate run of sample MW01010.

Mineralogy

X-ray diffractometry on sample MW01009, Cold Spring Granite rock saw fines, indicates that quartz, K-feldspar (microcline), biotite, and the clay mineral montmorillonite are the predominant mineral species present (Table 93). Minor calcite, Ca-plagioclase feldspar anorthite, and clay mineral illite were detected. Also detected were trace amounts of truscotite, the clay mineral sepiolite, and tosudite (interlayered chlorite and montmorillonite). Figure 35 presents the XRD trace for sample MW01009.

The Rockville Quarry drilling fines, sample MW01010, contain quartz and K-feldspar (sanidine) as the predominant mineral species (Table 93). Minor biotite, muscovite, kaolinite and tosudite are present. Trace amounts of anorthite and the chlorite mineral clinochlore were detected. Figure 36 presents the XRD trace for sample MW01010.

Table 92 Geochemical analysis of Cold Spring Granite rock saw fines (MW01009) and Rockville Quarry drilling fines (MW01010, RMW01010).

Whole Rock[1]				Ultratrace - Aqua Regia[3]				Acid Digestion[4]			
	MW01009	MW01010	RM-W01010		MW01009	MW01010	RM-W01010		MW01009	MW01010	RM-W01010
SiO_2 wt %	61.93	68.63	68.35	Mo (ppm)	6.93	1.19	1.36	Mo (ppm)	7.7	1.9	2.9
Al_2O_3 wt %	14.58	14.39	14.25	Cu (ppm)	129.37	5.73	5.69	Cu (ppm)	131	4	4
Fe_2O_3 wt %	5.66	3.61	3.69	Pb (ppm)	11.78	9.64	9.79	Pb (ppm)	24	21	21
MgO wt %	1.88	0.73	0.73	Zn (ppm)	62	53.3	53.3	Zn (ppm)	79	63	63
CaO wt %	4.12	1.55	1.54	Ag (ppb)	2166	22	26	Ag (ppm)	2.2	< .2	< .2
Na_2O wt %	3.47	3.41	3.33	Ni (ppm)	30	4.8	4.8	Ni (ppm)	40	5	5
K_2O wt %	4.85	5.98	6.4	Co (ppm)	138.1	6.9	6.8	Co (ppm)	186	8	7
TiO_2 wt %	0.64	0.48	0.49	Mn (ppm)	332	280	280	Mn (ppm)	589	339	338
P_2O_5 wt %	0.15	0.11	0.09	Fe %	2.77	2.07	2.1	Fe %	3.99	2.63	2.51
MnO wt %	0.07	0.04	0.04	As (ppm)	0.8	0.8	0.8	As (ppm)	< 2	2	< 2
Cr_2O_3 wt %	0.01	0.003	0.006	U (ppm)	1.8	3	3.2	U (ppm)	7	8	7
Ba ppm	1088	1116	1115	Au (ppb)	0.7	< .2	< .2	Au (ppm)	< 4	< 4	< 4
Cu ppm	284	< 20	< 20	Th (ppm)	20	17	18	Th (ppm)	19	13	11
Zn ppm	116	71	93	Sr (ppm)	47.7	11.1	11.5	Sr (ppm)	363	172	168
Ni ppm	38	< 20	33	Cd (ppm)	0.12	0.01	0.03	Cd (ppm)	< .2	< .2	< .2
Co ppm	168	< 20	< 20	Sb (ppm)	0.25	< .02	< .02	Sb (ppm)	< 1	< 1	< 1
Sr ppm	350	166	165	Bi (ppm)	0.04	0.03	0.03	Bi (ppm)	2	< 1	1
Zr ppm	284	266	308	V (ppm)	47	21	21	V (ppm)	69	25	27
Ce ppm	144	110	157	Ca %	1.43	0.3	0.31	Ca %	3.27	1.24	1.23
Y ppm	14	25	23	P %	0.07	0.05	0.052	P %	0.069	0.05	0.049
Nb ppm	59	54	60	La (ppm)	73	84.3	85.8	La (ppm)	89	102	99
Sc ppm	7	7	6	Cr (ppm)	47.7	8.7	8.7	Cr (ppm)	52	5	6
Ta ppm	< 20	< 20	< 20	Mg %	0.63	0.37	0.38	Mg %	1.09	0.4	0.4
LOI %	2.2	0.8	0.7	Ba (ppm)	155.8	115.9	116	Ba (ppm)	1179	1172	1156
SUM %	99.87	99.96	99.85	Ti %	0.126	0.172	0.164	Ti %	0.382	0.293	0.293
				B (ppm)	4	2	2				
				Al %	1.22	0.87	0.88	Al %	7.36	7.08	6.98
				Na %	0.212	0.061	0.061	Na %	2.512	2.524	2.487
Additional Analyses[2]				K %	0.42	0.54	0.53	K %	2.79	3.39	3.39
C/ORG %	0.37	< .03	< .03	W (ppm)	41	6.4	6.6	W (ppm)	65	22	13
CO_2 %	1.31	0.23	0.23	Sc (ppm)	1.8	3.1	3	Zr (ppm)	148.3	163.8	158.9
TOT/C %	0.8	0.04	0.05	Tl (ppm)	0.2	0.28	0.29	Ce (ppm)	154	186	183
SO_4 %	0.06	< .03	< .03	S %	0.03	< .01	< .01	Sn (ppm)	13.2	1.2	1.4
TOT/S %	0.01	< .01	< .01	Hg (ppb)	< 5	< 5	< 5	Y (ppm)	14	23.2	22.4
				Se (ppm)	< .1	< .1	< .1	Nb (ppm)	10.7	15.5	15.4
F (ppm)	649	1211	1264	Te (ppm)	< .02	< .02	< .02	Ta (ppm)	< .5	< .5	< .5
				Ga (ppm)	5.5	5.7	5.7	Be (ppm)	2	2	2
FeO %	3.9	2.4	2.4					Sc (ppm)	7	8	7
								Li (ppm)	22	44	44
pH	9.3	9.1	9.1					S %	0.04	< .02	< .02
H_2O+ %	3.4	1.5	1.4					Rb (ppm)	112	145	140
H2O- %	0.2	0.1	0.1					Hf (ppm)	4	5	5

[1] 0.2 gm sample by $LIBO_2$ fusion, analysis by ICP-ES. LOI by loss on ignition.

[2] CO_2 - Digest with warm 15% $HCLO_4$, evolved CO_2 analyzed by LECO. SO_4 - Residue sulphur after ignited at 800 °C for 1 hour. C/ORG - Total C minus graphite C and carbonate. F - NaOH fusion - specific ion electrode analysis. FeO by dichromate titration. H_2O+ at 1500 °C. H_2O- at 110 °C.

[3] 15.00 gm sample, 90 ml 2-2-2 $HCl-HNO_3-H_2O$ at 95 °C for 1 hour and is diluted tp 300 ml, analysis by ICP/ES & MS.

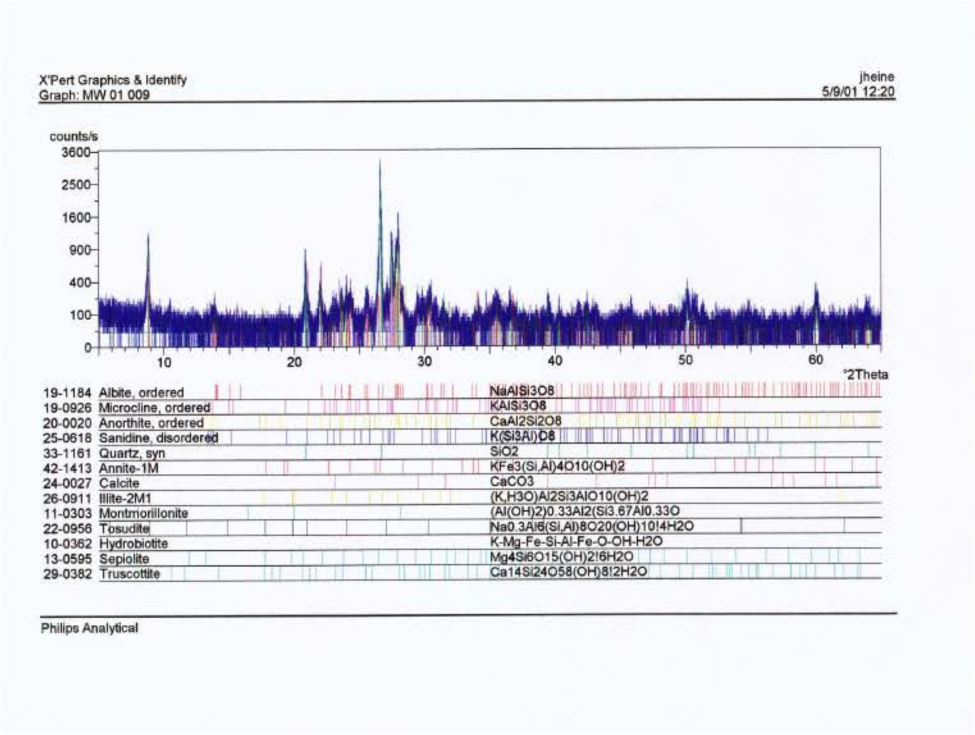
[4] 0.25 gm sample digested with $HClO_4-HNO_3-HCl-HF$ to 10 ml. Digestion is partial for some minerals & may volatize some elements, analysis by ICP-ES.

Table 93 Mineralogy of Cold Spring Granite rock saw fines (MW01009) and Rockville Quarry drilling fines (MW01010).*

	Quartz	Microcline	Sanidine	Annite (Biotite)	Mont-morillonite	Ilite	Muscovite	Anorthite	Calcite
MW01009	M	M		M	M	m		m	m
MW01010	M		M	m			m	t	
	Kaolinite	Tosudite	Albite	Clino-chlore	Sepiolite	Truscottite			
MW01009		t			t	t			
MW01010	m	m	t	t					

Component Mineral Compostion of Cold Spring Granite Samples			
MW01009 - rock saw fines		MW01010 - Rockville Quarry drilling fines	
Mineral	Composition	Mineral	Composition
Albite, ordered	$NaAlSi_3O_8$	Albite, ordered	$NaAlSi_3O_8$
Microcline, ordered	$KAlSi_3O_8$	Anorthite, ordered	$CaAl_2Si_2O_8$
Anorthite, ordered	$CaAl_2Si_2O_8$	Sanidine, disordered	$K(Si_3Al)O_8$
Sanidine, disordered	$K(Si_3Al)O_8$	Muscovite-2M2	$KAl_2(Si_3Al)O_{10}(OH)_2$
Quartz, syn	SiO_2	Quartz., low	SiO_2
Annite-1M	$KFe_3(Si,Al)_4 O_{10}(OH)_2$	Annite-1M	$KFe_3(Si,Al)_4 O_{10}(OH)_2$
Calcite	$CaCO_3$	Tosudite	$Na_{0.3}Al_6(Si,Al)_8O_{20}(OH)_{10}!4H_2O$
Illite-2M1	$(K,H_3O)Al_2Si_3AlO_{10}(OH)_2$	Kaolinite-1A	$Al_2Si_2O_5(OH)_4$
Montmorillonite $_4(SiAl)_8O_{20}(OH)_4!xH_2O$	$(Al(OH)_2)_{0.33}Al_2(Si_{3.67}Al_{0.33})O$	Clinochlore-1MIIb	$(Mg,Al)_6(Si,Al)_4O_{10}(OH)_8$
Tosudite	$Na_{0.3}Al_6(Si,Al)_8O_{20}(OH)_{10}!4H_2O$		
Sepiolite	$Mg_4Si_6O_{15}(OH)_2!6H_2O$		
Truscottite	$Ca_{14}Si_{24}O_{58}(OH)_8!2H_2O$		

* Mineralogy determined by XRD; M = major, m = minor, t = trace.


X'Pert Graphics & Identify
Graph: MW 01 009

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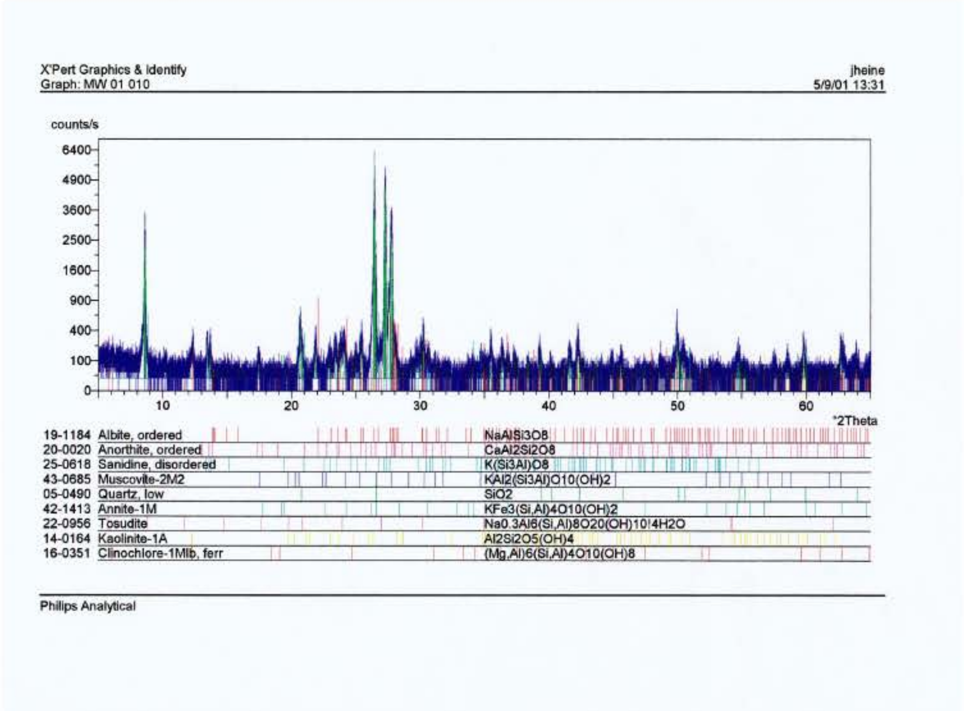
19-1184	Albite, ordered	NaAlSi3O8
19-0926	Microcline, ordered	KAlSi3O8
20-0020	Anorthite, ordered	CaAl2Si2O8
25-0618	Sanidine, disordered	K(Si3Al)O8
33-1161	Quartz, syn	SiO2
42-1413	Annite-1M	KFe3(Si,Al)4O10(OH)2
24-0027	Calcite	CaCO3
26-0911	Illite-2M1	(K,H3O)Al2Si3AlO10(OH)2
11-0303	Montmorillonite	(Al(OH)2)0.33Al2(Si3.67Al0.33O
22-0956	Tosudite	Na0.3Al6(Si,Al)8O20(OH)10!4H2O
10-0362	Hydrobiotite	K-Mg-Fe-Si-Al-Fe-O-OH-H2O
13-0595	Sepiolite	Mg4Si6O15(OH)2!6H2O
29-0382	Truscottite	Ca14Si24O58(OH)8!2H2O

Philips Analytical

Figure 35. XRD trace depicting the mineralogy of Cold Spring Granite rock saw fines (MW01009).


X'Pert Graphics & Identify
Graph: MW 01 010

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19-1184	Albite, ordered	NaAlSi3O8
20-0020	Anorthite, ordered	CaAl2Si2O8
25-0618	Sanidine, disordered	K(Si3Al)O8
43-0685	Muscovite-2M2	KAl2(Si3Al)O10(OH)2
05-0490	Quartz, low	SiO2
42-1413	Annite-1M	KFe3(Si,Al)4O10(OH)2
22-0956	Tosudite	Na0.3Al6(Si,Al)8O20(OH)10!4H2O
14-0164	Kaolinite-1A	Al2Si2O5(OH)4
16-0351	Clinochlore-1Mlb, ferr	(Mg,Al)6(Si,Al)4O10(OH)8

Philips Analytical

Figure 36 XRD trace depicting the mineralogy of Cold Spring Granite Rockville Quarry drilling fines (MW01010).

University of Minnesota Study Analytical Data - Shot Saw and East Plant Fines

The University of Minnesota Department of Soil, Water, and Climate undertook a study in 1999 (Rosen et al., 1999) to evaluate rock fines as a sustainable soil amendment. Selected as part of the study were the shot saw fines and plant fines from Cold Spring Granite East in Cold Spring, MN. Analytical data from the study are presented below. For the full project report and more analytical data, see Appendix E.

Particle Size Analysis

Particle size data on the shot saw and East plant fines, obtained from the U of M study, are presented in Tables 94 and 95. The analyses were performed by sieve and hydrometer method (Rosen et al., 1999).

Table 94 Particle size distribution of selected Cold Spring Granite rock fines (after Rosen et al., 1999).

Location	Rock Type	By-product	% Gravel > 2.0 mm		% Sand 0.05m - 2.0 mm		% Silt 0.002 - 0.05 mm		% Clay < 0.002 mm	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cold Spring	Granite	Shot Saw Fines	0.00	0.00	14.6	1.2	79.4	1.3	6.0	0.7
		Plant Fines	0.00	0.00	11.7	1.1	69.0	2.0	19.3	0.8

Table 95 Sand fraction size distribution of selected Cold Spring Granite rock fines (after Rosen et al., 1999).

Location	Rock Type	By-product	Sand %									
			> 1mm Very Coarse		1.0 - 0.5 mm Coarse		0.5 - 0.25 mm Medium		0.25 - 0.1 mm Fine		0.1 - 0.05 mm Very Fine	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cold Spring	Granite	Shot Saw Fines	0.1	0.0	0.6	0.2	1.7	0.2	4.4	0.8	7.9	0.8
		Plant Fines	0.4	0.2	2.4	0.5	3.5	0.6	2.9	0.6	2.5	0.6

Chemistry

Table 96 presents pH, cation exchange capacity (CEC), total nitrogen, organic carbon, moisture content, and soluble chloride analyses performed on the shot saw and plant fines (Rosen et al., 1999).

Table 96 pH, CEC, Total N, Organic C, Moisture Content, and Soluble Cl in Cold Spring Granite rock fines (after Rosen et al., 1999).

	pH		CEC Meq / 100 gm		Total N (%)		Organic C (%)		Moisture (%) dry wt.		Cl ppm	
By-product	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Shot Saw Fines	9.5	0.1	4.3	0.0	0.032	0.003	0.40	0.04	22	0	428	33
Plant Fines	8.8	0.1	9.9	0.2	0.020	0.003	0.30	0.02	25	2	15	1

Data Sources

2001 Site Visit
2001Survey Response
2001 NRRI Sample Analysis
Rosen et al., 1999, 2000, 2001
www.coldspringgranite.com

Dakota Granite Co.

14964 484th Avenue
Milbank, SD 57252

Phone: (800) 843-3333
Fax: (800) 338-5346

Jack Stengel, President

www.dakotagranite.com

Quarry	T	R	S	County	Rock Type	Product	By-product	Size	Amount	Location
Bellingham Quarry	120	45	16	Lac Qui Parle	Granite	Dimension Stone	Grout	Large Sizes	200,000 T	Stockpile

Dakota Granite Co., headquartered in Milbank, SD, quarries dimension stone from the brown granite of the Bellingham Quarry, located in Lac Qui Parle County in southwestern Minnesota. "Bellingham Granite" is a medium-grained granite, ranging in color from pinkish-red to brown.

Geologic Unit: Bellingham Granite

Production: Annual production of Bellingham Granite is 30,000 tons.

Wastes/By-products

Waste/By-product	How Used	Most Difficult To Market	Easiest To Market	Potential Markets/Uses
Large sizes of granite	Some split for ashlar stone work; most discarded and placed in grout piles.	Large granite blocks	Dimension stone too multi-colored to market for monuments–the waste slabs can be split for ashlar facing.	Very little; sometimes used as rip rap on dam raceways.

Because Dakota Granite Co.'s product is dimension stone, the waste granite generally occurs as large blocks. The company cannot economically compete with crushing operations that quarry by means of large blast holes and fragmentation. As a result, a **200,000 ton grout pile** containing **large granite blocks** has accumulated on-site.

Waste/By-product Analytical Data - Large Granite Blocks

Analytical data presented here on the Bellingham Granite was submitted by Dakota Granite Co.

Mechanical Properties

Mechanical properties of the Bellingham Granite (compression, % absorption, and compact unit weight) were provided for this report by Dakota Granite Co. The data is presented in Table 97.

Table 97 Mechanical properties of the Bellingham Granite.*

Compression Strength	% of Absorption	Compact Unit Weight
23, 000 psi	.016	185 lbs/ft.^{3}
*Data provided by Dakota Granite Co.		

Chemistry

Chemistry of the Bellingham granite was provided by Dakota Granite Co. (Table 98).

Table 98 Chemistry of the Bellingham Granite.*

Silica	Aluminum Oxide	Iron Oxide	Calcium Oxide	Magnesium Oxide	Alkalies
68.9 %	19.3 %	1.2 %	1.4 %	.9 %	8.0 %
*Data provided by Dakota Granite Co.					

Mineralogy

Mineralogy of the Bellingham Granite was provided by Dakota Granite Co. (Table 99). Plagioclase feldspar, quartz, and the K-feldspar microcline are the predominant mineral species present, with minor biotite.

Table 99 Mineralogy of the Bellingham Granite.*

Plagioclase Feldspar	Quartz	Microcline	Biotite
34 %	29 %	28 %	4 %
*Data provided by Dakota Granite Co.			

Data Sources

2001 Survey Response
Nelson et al., 1990
www.dakotagranite.com

Jasper Stone Co.

P.O. Box 5829
Sioux Falls, SD 57117-5829

Phone: (800) 643-2032

A Division of L.G. Everist, Inc.

Quarry	T	R	S	Forty	County	Rock Type	Products	By-product	Amount	Location
Jasper Stone Quarry	104	46	6	NE 1/4	Rock	Quartzite	Grinding Media Ball Mill Liners	Boulders	N.A.	Stockpile

Jasper Stone Co., a division of L.G. Everist, Inc., hand quarries its products from the Jasper Stone Quarry (Fig. 37) located in the southwestern Minnesota town of Jasper, near the Pipestone / Rock County line. Originally quarried for architectural purposes, Jasper Stone now produces decorative, landscape, and industrial stone products. The high density of the Jasper Quartzite makes it ideal for grinding media and ball mill liners.

Figure 37. Quartzite dimension stone sign at entrance of Jasper Stone Quarry.

Geologic Unit: Sioux Quartzite

Product Line: Decorative landscape stone, hand crafted landscaping products, and industrial stone products (grinding media, lining blocks, and monument stone).

Wastes/By-products

Waste/By-product	How Used	Most Difficult To Market	Easiest To Market	Potential Markets/Uses
Quartzite boulders	Benches, fireplaces, signs, grave markers	N.A.	N.A.	N.A.
Quartzite fines	-			Fines are of little concern

A large stockpile of **quartzite boulders** represents the major, currently unused, by-product of this operation, as depicted in the background of the photograph (Fig. 38). Partial use is made of these quarry rejects in the fabrication of items like benches, fireplaces, signs, and grave markers. **Fines** are of little or no concern at Jasper Stone.

Figure 38. Photograph of quartzite quarry and quartzite boulder/grout block stockpile at Jasper Stone Quarry.

Analytical Data - Quartzite Boulders

Density of "Jasper Stone": 167 lbs./ft^3 (Bare, pers. comm., 2001)

Data Sources

2001 Site Visit and Submitted Data
Bare, pers. comm., Jan., 2001
www.jasperstoneco.com

Mankato-Kasota Stone, Inc.

818 North Willow Street
Mankato, MN 56002

Phone: (507) 625-2746
Fax: (507) 625-2748

Contact: Rick Westmark, Plant Manager

Parent Company: Minnesota Quarries, Inc.

www.mankato-kasota-stone.com

Quarry	T	R	S	Forty	County	Rock Type	Product(s)	By-product	Size	Amount	Location
Jefferson Quarry	108	26	6	NW 1/4	Blue Earth	Dolomite	Dimension Stone	Saw Fines	- # 200	500 T	Settling Pond Stockpile
								Scrap Stone	Varies	1,000 T	Stockpile

Mankato-Kasota Stone, Inc. (M-KS), is located in Mankato in Blue Earth County, MN. M-KS produces dimension stone from the Jefferson Quarry (Fig. 39).


Figure 39. View of Mankato-Kasota Stone, Inc., Jefferson Quarry.

Geologic Unit: Oneota Formation (dolomite)

Production: Drilling, blasting, and overburden removal are contracted out. Rock is extracted by air drill and saws and moved by loader. Annual production of "Mankato-Kasota Stone" amounts to 18,000 tons (9,000 yds.). Various sizes are produced. Non-dimension stone rock produced by M-KS is crushed and screened by Southern Minnesota Construction (SMC) for use in construction applications.

Product Line: Dimension Stone

Wastes/By-products

Waste/By-product	How Used	Most Difficult To Market	Easiest To Market	Potential Markets/Uses
Scrap limestone	riprap road bed material farm rock berm construction material	Rock saw fines	Scrap limestone	Not enough volume of fines to economically market
Rock saw fines	-			

Scrap stone and **lime fines** are wastes/by-products produced by the MK-S fabrication plant. Both are stored on-site. There are **1,000 tons (500 yds.) of stockpiled scrap stone** in various sizes and **500 tons (250 yds.) of stockpiled granular lime fines**. The scrap stone is easiest to market as rip rap and road bed rock are in high demand. The granular fines, generated during the process of sawing and cutting, are an issue for M-KS. They are currently sent to a settling pond behind the plant. This pond must be periodically excavated, and the excavated fines are stockpiled on site.

Waste/By-product Analytical Data - Rock Saw Fines

A sample of the rock saw fines, MW01005, was collected from the M-KS fabrication plant in January, 2001. Particle size analysis, geochemistry, and x-ray diffractometry for mineral content were run on the sample.

Particle Size Anaylsis

Particle size analysis of sample MW01005, M-KS rock saw fines, indicates that the predominance of saw fines particles lies in the silt range (Table 100). At 72 %, this is a 10 % reduction compared to the silt fraction of the saw fines from Biesanz Stone Co. and Cold Spring Granite (85 % and 81 %, respectively). M-KS saw fines contain a significantly higher percentage of clay-sized particles than the other two samples (24 % vs. 14 % and 14.5 %, respectively). The sand fraction is slightly elevated above that of the saw fines from Cold Spring Granite. Table 101 presents the complete particle size assay data on sample MW01005.

Table 100 Sand-silt-clay fraction: Mankato-Kasota Stone rock saw fines (MW01005).

SAND - SILT - CLAY FRACTION*				
SAMPLE	SAMPLE TYPE	% SAND	% SILT	% CLAY
MW01005	Rock Saw Fines	6.34	72.41	21.24
*Sand ≥62.5 microns (# 230 sieve), silt < 62.5 microns and ≥2 microns, clay < 2 microns				

Table 101 Full particle size assay data for Mankato-Kasota Stone rock saw fines (MW01005).

Percent Passing Equivalent Spherical Diameter in Microns*														
	SAND					SILT							CLAY	
SAMPLE	2000 µ	1000 µ	500 µ	250 µ	120 µ	62.5 µ	44 µ	31 µ	22.1 µ	15.6 µ	7.8 µ	3.9 µ	2 µ	1 µ
MW01005	98.24	97.64	97.45	97.18	96.53	93.66	88.36	82.31	74.69	65.93	49.25	33.30	21.24	12.71
* + # 230 sieve fraction determined by sonic sifting; - # 230 sieve fraction determined by settling tube method.														

Figure 40 presents the particle size analysis of sample MW01005 in graphic form. The graph plots the weight percent of the sample that is: 1) finer than, and 2) coarser than, the equivalent spherical diameter (in microns) of a given particle size. Figure 41 shows that the Mankato-Kasota Stone rock saw fines are comparable in size to saw fines from Cold Spring Granite (MW01009) and Biesanz Stone Co. (MW01007).

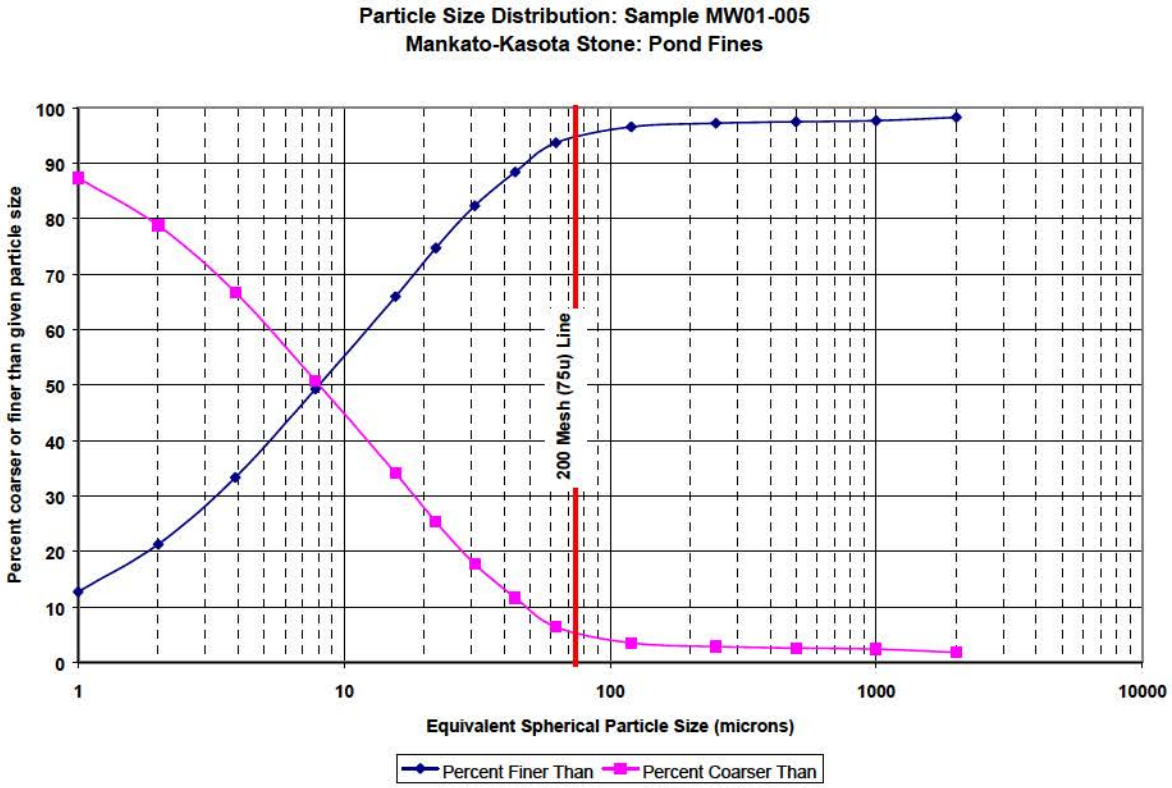


Figure 40. Particle size analysis in graphic form of Mankato-Kasota Stone rock saw fines (MW01005).

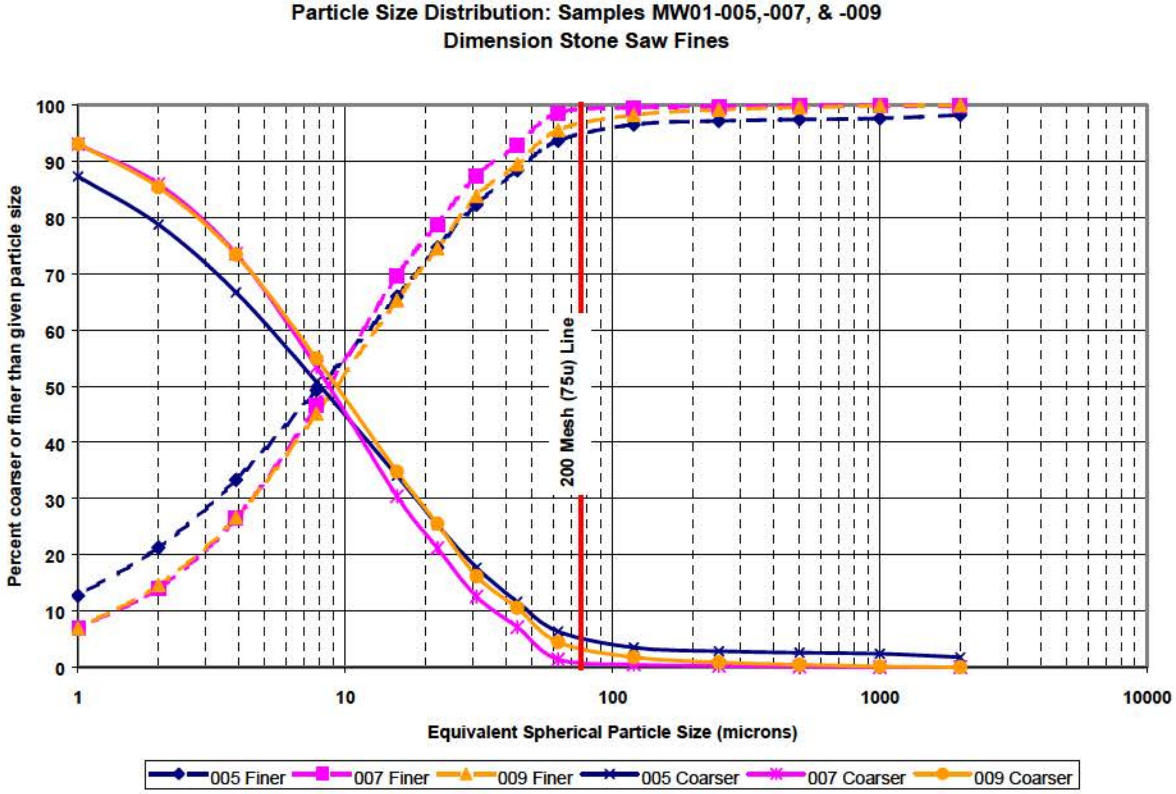


Figure 41. Similarity of particle size distribution for dimension stone producer rock saw fines: Mankato-Kasota Stone (MW01005); Cold Spring Granite (MW01009); and Biesanz Stone Co. (MW01007).

Chemistry

Table 102 presents the chemical composition of sample MW01005, M-KS rock saw fines.

Table 103 presents geochemical data submitted by Mankato-Kasota Stone, Inc. on three dolomite parent rock samples from which rock saw fines are derived. The parent rock samples are from the Jefferson Quarry. The determination was made by x-ray diffractometry.

Table 102 Geochemical analysis of Mankato-Kasota Stone rock saw fines (MW01005).

Whole Rock[1]				Ultratrace - Aqua Regia[3]				Acid Digestion[4]			
SiO_2 wt %	10.51	Sc ppm	1	Mo (ppm)	0.54	Cr (ppm)	9	Mo (ppm)	1.2	Cr (ppm)	13
Al_2O_3 wt %	1.83	Ta ppm	< 20	Cu (ppm)	6.8	Mg %	9.47	Cu (ppm)	8	Mg %	10.98
Fe_2O_3 wt %	0.9	LOI %	40.7	Pb (ppm)	14.84	Ba (ppm)	11.2	Pb (ppm)	14	Ba (ppm)	67
MgO wt %	17.6	SUM %	99.85	Zn (ppm)	5.9	Ti %	0.002	Zn (ppm)	4	Ti %	0.049
CaO wt %	26.62			Ag (ppb)	213	B (ppm)	10	Ag (ppm)	0.8		
Na_2O wt %	0.03			Ni (ppm)	3.9	Al %	0.1	Ni (ppm)	6	Al %	1.14
K_2O wt %	1.38			Co (ppm)	14.2	Na %	0.009	Co (ppm)	17	Na %	0.027
TiO_2 wt %	0.08	Additional Analyses[2]		Mn (ppm)	473	K %	0.06	Mn (ppm)	490	K %	1.25
P_2O_5 wt %	0.06	C/ORG %	0.16	Fe %	0.54	W (ppm)	1.2	Fe %	0.64	W (ppm)	2
MnO wt %	0.06	CO_2 %	40.31	As (ppm)	1.4	Sc (ppm)	0.9	As (ppm)	5	Zr (ppm)	14.5
Cr_2O_3 wt %	0.005	TOT/C %	11.17	U (ppm)	0.5	Tl (ppm)	0.02	U (ppm)	< 1	Ce (ppm)	13
Ba ppm	59	SO_4 %	< .03	Au (ppb)	0.6	S %	0.03	Au (ppm)	< 4	Sn (ppm)	1.4
Cu ppm	< 20	TOT/S %	< .01	Th (ppm)	1.1	Hg (ppb)	7	Th (ppm)	< 1	Y (ppm)	2.7
Zn ppm	47			Sr (ppm)	100.8	Se (ppm)	0.4	Sr (ppm)	124	Nb (ppm)	< .2
Ni ppm	< 20	F (ppm)	189	Cd (ppm)	0.08	Te (ppm)	0.08	Cd (ppm)	< .2	Ta (ppm)	< .5
Co ppm	< 20			Sb (ppm)	0.12	Ga (ppm)	0.9	Sb (ppm)	< 1	Be (ppm)	< 1
Sr ppm	112	FeO %	0.3	Bi (ppm)	0.03			Bi (ppm)	< 1	Sc (ppm)	2
Zr ppm	214			V (ppm)	9			V (ppm)	14	Li (ppm)	4
Ce ppm	40	pH	9.3	Ca %	17.51			Ca %	22.32	S %	< .02
Y ppm	< 10	H_2O+ %	1.5	P %	0.013			P %	0.014	Rb (ppm)	12
Nb ppm	47	H_2O- %	0.2	La (ppm)	4.4			La (ppm)	5	Hf (ppm)	< 1

[1] 0.2 gm sample by $LIBO_2$ fusion, analysis by ICP-ES. LOI by loss on ignition.

[2] CO_2 - Digest with warm 15% $HCLO_4$, evolved CO_2 analyzed by LECO. SO_4 - Residue sulphur after ignited at 800 °C for 1 hour. C/ORG - Total C minus graphite C and carbonate. F - NaOH fusion - specific ion electrode analysis. FeO by dichromate titration. H_2O+ at 1500 °C. H_2O- at 110 °C.

[3] 15.00 gm sample, 90 ml 2-2-2 HCl-HNO_3-H_2O at 95 deg. C for 1 hour and is diluted tp 300 ml, analysis by ICP/ES & MS.

[4] 0.25 gm sample digested with $HClO_4$-HNO_3-HCl-HF to 10 ml. Digestion is partial for some minerals & may volatize some elements, analysis by ICP-ES.

Table 103 Parent rock geochemistry.*

Dolomite Type	Si Wt %	Al Wt %	Fe Ox Wt %	Ti Ox Wt %	Phos Ox Wt %	Ca Carb Wt %	Mg Carb Wt %
Buff	6.43	0.73	1.23	0.04	0.02	50.45	40.11
Gray	11.86	1.93	1.10	0.09	0.04	45.01	37.35
Cream	11.81	1.50	1.14	0.07	0.03	46.65	37.07

*Data provided by Mankato-Kasota Stone, Inc.

Mineralogy

X-ray diffractometry on sample MW01005, M-KS rock saw fines, indicates that dolomite is the predominant mineral species present (Table 104). Minor quartz and trace K-feldspar in the form of sanidine were detected. Figure 42 presents the XRD trace for sample MW01005.

Table 104 Mineralogy of Mankato-Kasota Stone rock saw fines (MW01005).

<table>
<tr><th>Sample</th><th>Dolomite</th><th>Quartz</th><th>K-feldspar</th></tr>
<tr><td>MW01005</td><td>M</td><td>m</td><td>t</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4">Component Mineral Composition</td></tr>
<tr><td colspan="2">Mineral</td><td colspan="2">Composition</td></tr>
<tr><td colspan="2">Dolomite</td><td colspan="2">$CaMg(CO_3)_2$</td></tr>
<tr><td colspan="2">Quartz, syn</td><td colspan="2">SiO_2</td></tr>
<tr><td colspan="2">Sanidine, disordered</td><td colspan="2">$K(Si_3Al)O_8$</td></tr>
<tr><td colspan="4">* Mineralogy determined by XRD; M = major, m = minor, t = trace.</td></tr>
</table>

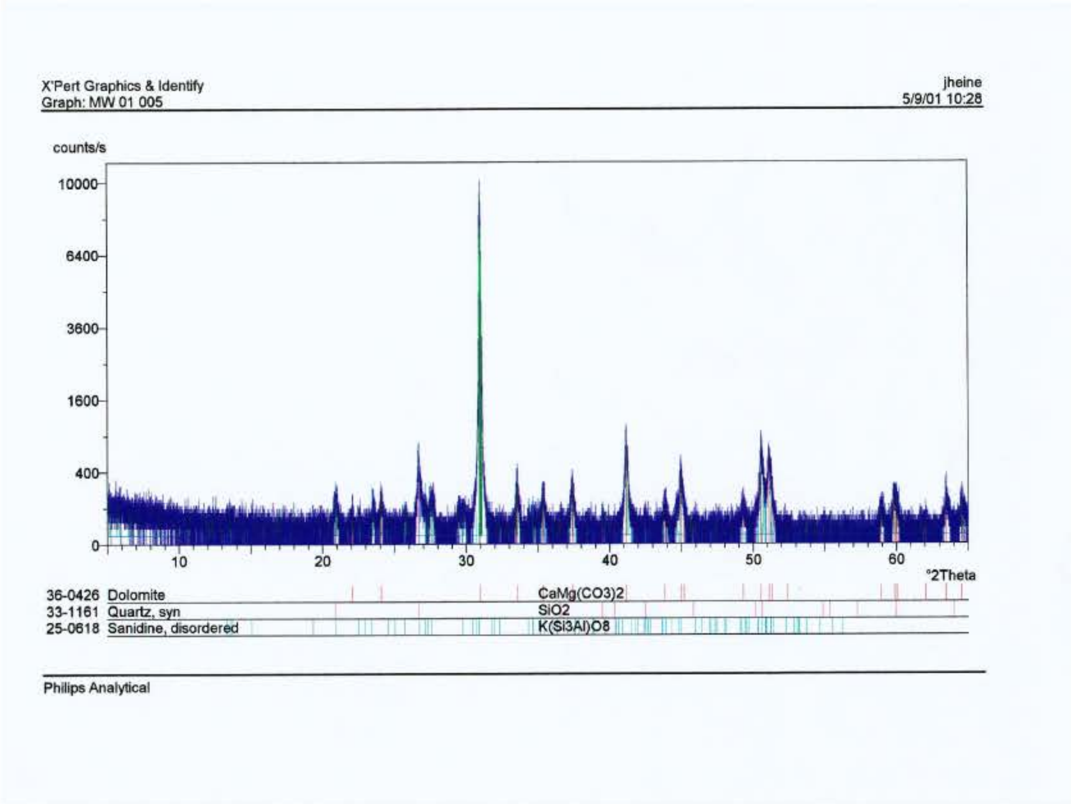


Figure 42. XRD trace depicting the mineralogy of Mankato-Kasota Stone rock saw fines (MW01005).

Data Sources

2001 Site Visit
2001 Survey Response and Submitted Data
2001 NRRI Sample Analysis
Nelson et al., 1990
www.mankato-kasota-stone.com

Vetter Stone Co.

P.O. Box 38
Kasota, MN 56050

Phone: (507) 345-4568
Fax: (507) 345-4777

www.vetterstone.com

Quarry	T	R	S	Forty	Counties	Rock	Products	By-product	Amount	Location
Vetter Stone Co. Main Quarries	109	26	20	SW 1/4	Blue Earth Le Seuer Scott	Dolomite	Dimension Stone	Ag-lime (?)	N.A.	N.A.

Vetter Stone Co. is located in Kasota, Minnesota, north of Mankato in Le Sueur County. Like Biesanz Stone Co. and Mankato-Kasota Stone, Inc., Vetter Stone Co. quarries the Oneota dolomite for dimension stone. It operates quarries in Blue Earth, Le Sueur, and Scott Counties. As with Biesanz Stone Co., Southern Minnesota Construction (SMC) handles the non-dimension stone rock for Vetter Stone Co. Vetter Stone Co. reports no problematic wastes.

Geologic Unit: Oneota Formation (Dolomite)

Data Sources

2001 Site Visit
Nelson et al., 1990
www.vetterstone.com

SAND & GRAVEL OPERATIONS

The following pages profile individual sand and gravel producers. Included are pit locations, geologic and production data, types and amounts of wastes/by-products generated, and analytical data pertinent to the wastes/by-products.

Surveys were sent out to 121 sand and gravel, ready-mix, bituminous, concrete product, and construction operations throughout the state of Minnesota. Operations included were obtained from the USGS Aggregates Industry Atlas (2001) and the Aggregate & Ready Mix Association of Minnesota directory, with a few obtained randomly from on-line Yellow Pages searches. A complete listing of these operations is included in Appendix B. As expected, the response in this category was very light, numbering only seven. Of these, five were sand and gravel operations. They are listed below. Only one operation, Guaranteed Gravel & Sand, a Mathy Construction/Milestone Materials company, responded with an available waste/by-product. A sample of the gravel fines from the Guaranteed Gravel & Sand pit, a by-product of the washing process, was submitted for analysis.

Company	Corporate Headquarters	Pit/Quarry Locations
Bauerly Bros., Inc.	Sauk Rapids, MN	Central Minnesota
Brinks Sand & Gravel, Inc.	Grand Rapids, MN	Grand Rapids, MN
Carlson Brothers, Inc.	Springfield, MN	Southwestern Minnesota
Guaranteed Gravel & Sand	Mankato, MN	Mankato, MN, area
Northern Con-Agg, Inc.	Plymouth, MN	Lyon and Rock Counties
Wm. Mueller & Sons, Inc.	Hamburg, MN	Carver, Sibley, and Scott Counties

Bauerly Bros., Inc.

4787 Shadow Wood Dr. N.E.
Sauk Rapids, MN 56379

Phone: (320) 251-9472
Fax: (320) 251-0011

Contact: Laurie Seifert-Kissner, Environmental Manager
laurie.kissner@bauerly.com

www.bauerly.com

Bauerly Bros., Inc., headquartered in Sauk Rapids, Benton County, MN, supplies aggregate, asphalt, and concrete to 29 counties in the state. The Aggregate Division operates 19 mobile crushing, screening, and washing plants throughout central Minnesota.

Wastes/By-products

Bauerly Bros., Inc. responded to the survey with a statement that **no mine/quarry wastes are generated** and that all products/materials produced are marketable (Seifert-Kissner, survey).

Data Source

2001 Survey Response
www.bauerly.com

Brink Sand & Gravel, Inc.
Brink Redi-Mix, Inc.

3000 Rangeline Road
Grand Rapids, MN 55744

Phone: (218) 326-6681
Fax: (218) 326-6682

Contact: Peggy Bishop, Vice President

Pit	T	R	S	Forty	County	Rock Type	Product	By-product	Amount	Location
Brink Gravel Pit	55	25	7	SW-NW	Itasca	Sand & Gravel	Construction Aggregate	Wash fines	Fines are recovered and reused	Tailings Pond

Brink Sand & Gravel, Inc./Brink Redi-Mix, Inc. is located in Grand Rapids, Itasca County, MN.

Production: Sand and gravel is excavated and moved by backhoes, loaders, dozers, and trucks. The operation includes crusher, screens, wash plant, and settling pond. Product shipping is by truck.

Product Line: 3/8-in., 3/4-in., 1-in., 1-1/2-in., and 4- to 8-in. crushed rock; boulders, 1-1/2-in. and 3/8- to 3/4-in. round rock; mason, regular, winter, and fill sand; and Class 5 and Class 6 gravel.

Wastes/By-products

Waste/By-product	How Used	Most Difficult To Market	Easiest To Market	Potential Markets/Uses
Pond Fines	Dug out and reprocessed	N.A.	Boulders	N.A.
Boulders	Sold for landscaping			

Wastes/by-products produced at the Brink Gravel pit are **pond fines,** generated from the wash plant, and **boulders**. These by-products are not considered to be problematic wastes, however. The wash fines go out to a tailings pond from which they are recovered and reprocessed for use. Boulders did present a problematic waste in past years, with many stockpiles on-site. This changed, however, in the last few years as the boulders have been sold for landscaping purposes.

Data Source

2001 Survey Response

Carlson Brothers, Inc.

P.O. Box 141
Springfield, MN 56087

Phone: (507) 723-6612
Fax: (507) 723-6270

Contact: Ken Tews, Superintendent
cbi@springfield-sanborn.net

Pit	Rock Type	Products
Various gravel pits in southwestern MN	Gravel	Gravel base for roads

Carlson Brothers, Inc., is headquartered in Springfield, MN, in Brown County. The company operates various gravel pits in southwestern Minnesota to produce gravel base for roads.

Production: Rock is excavated and moved by wheel loaders, dozers, and 16-yd. belly dump trucks. The company uses a 50-V crusher with portable screens and conveyors. Shipping is by belly dump trucks. Annual production is 250,000 tons (178,000+ CY).

Product Line: Products range in size from ½ in. to 2 in. and include CL-1, CL-3, CL-5, and BA-2.

Wastes/By-products

No waste products are generated.

Data Source

2001 Survey Response

Guaranteed Gravel & Sand

1905 3rd Ave.
Mankato, MN 56001

Phone: (507) 387-3111
Fax: (507) 387-2591

Contact: Mark Brielmaier, Quarry Manager

Parent Company: Southern Minnesota Construction, Inc.
www.smc-co.com

Pit	T	R	S	Forty	County	Rock Type	Product	By-product	Size	Amount	Locations
Guaranteed Gravel & Sand	108	27	35	NW Corner	Blue Earth	Sand & Gravel	Road Material	Gravel Fines	- 100 mesh	10,000 T (7,000 CY)	Pond Small stockpile

Guaranteed Gravel and Sand, a subsidiary of Southern Minnesota Construction, Inc. (SMC), operates its plant out of the Guaranteed Gravel & Sand Pit in Mankato, Blue Earth County, MN. Material is hauled from the Sanger, Zelinsky, and Baaresh pits to blend the resource to meet MnDOT specs.

Wastes/By-products

Waste/By-product	How Used	Most Difficult To Market	Easiest To Market	Potential Markets/Uses
- 100 mesh gravel fines.	Fill Reclamation	Gravel fines	N.A.	Possible soil enhancement or conditioner; blend in during composting operation.

The **-100 mesh gravel wash fines** produced present a problematic waste/by-product for Guaranteed Gravel & Sand. While a small percentage is sold as fill, most of it remains in a settling pond or is used in reclamation. Factors affecting its marketability include fineness, moisture content, and absorption.

Waste/By-product Analytical Data - Gravel Wash Fines

A sample of the gravel wash fines, MW01014, was sent by Guaranteed Gravel & Sand to the NRRI in April of 2001. Particle size analysis, geochemistry, and x-ray diffractometry for mineral content were run on this sample. This is the project's only sand and gravel sample for which analytical data were generated.

Particle Size Analysis

Particle size analysis run on sample MW01014 indicates that 76.5 % of the material consists of silt-sized particles (Table 105). The remainder of the material consists of 14.7 % sand-sized particles and 8.8 % clay-sized particles. Table 106 presents the complete set of particle size assay data on sample MW01014.

Table 105 Sand-silt-clay fraction: Guaranteed Gravel & Sand gravel wash fines (MW01014).

SAND - SILT - CLAY FRACTION*				
SAMPLE	SAMPLE TYPE	% SAND	% SILT	% CLAY
MW01014	Gravel Fines	14.69	76.46	8.85

*Sand >= 62.5 microns (# 230 sieve), silt < 62.5 microns and >= 2 microns, clay < 2 microns

Table 106 Complete particle size assay data for Guaranteed Gravel & Sand gravel wash fines (MW01014).

Percent Passing Equivalent Spherical Diameter in Microns*													
	SAND					SILT						CLAY	
SAMPLE	2000 μ	1000 μ	500 μ	250 μ	120 μ	62.5 μ	44 μ	31 μ	22.1 μ	15.6 μ	7.8 μ	3.9 μ	2 μ	1 μ
MW01014	99.89	99.00	97.88	96.89	94.90	85.31	61.24	50.81	38.62	29.24	17.87	12.09	8.85	6.39

* + # 230 sieve fraction determined by sonic sifting; - # 230 sieve fraction determined by settling tube method.

Figure 43 presents the particle size analysis of sample MW01014 in graphic form. The graph plots the weight percent of the sample that is: 1) finer than, and 2) coarser than, the equivalent spherical diameter (in microns) of a given particle size.

Chemistry

The chemical composition of sample MW01014, Guaranteed Gravel & Sand gravel wash fines, is presented in Table 107.

Mineralogy

X-ray diffractometry of sample MW01014, Guaranteed Gravel & Sand gravel wash fines, detected major quartz and dolomite (Table 108), indicating a provenance of both crystalline and carbonate bedrock in this glacial deposit. Minor annite (biotite) and kaolinite are present. Trace amounts of K-feldspar were detected in the form of sanidine, microcline, and orthoclase, as well as trace amounts of the plagioclase feldspar albite. Other mineral species detected in trace amounts were the Fe-carbonate ankerite, chlorite minerals clinochlore and tosudite, and cordierite. Figure 44 presents the XRD trace for sample MW01014.

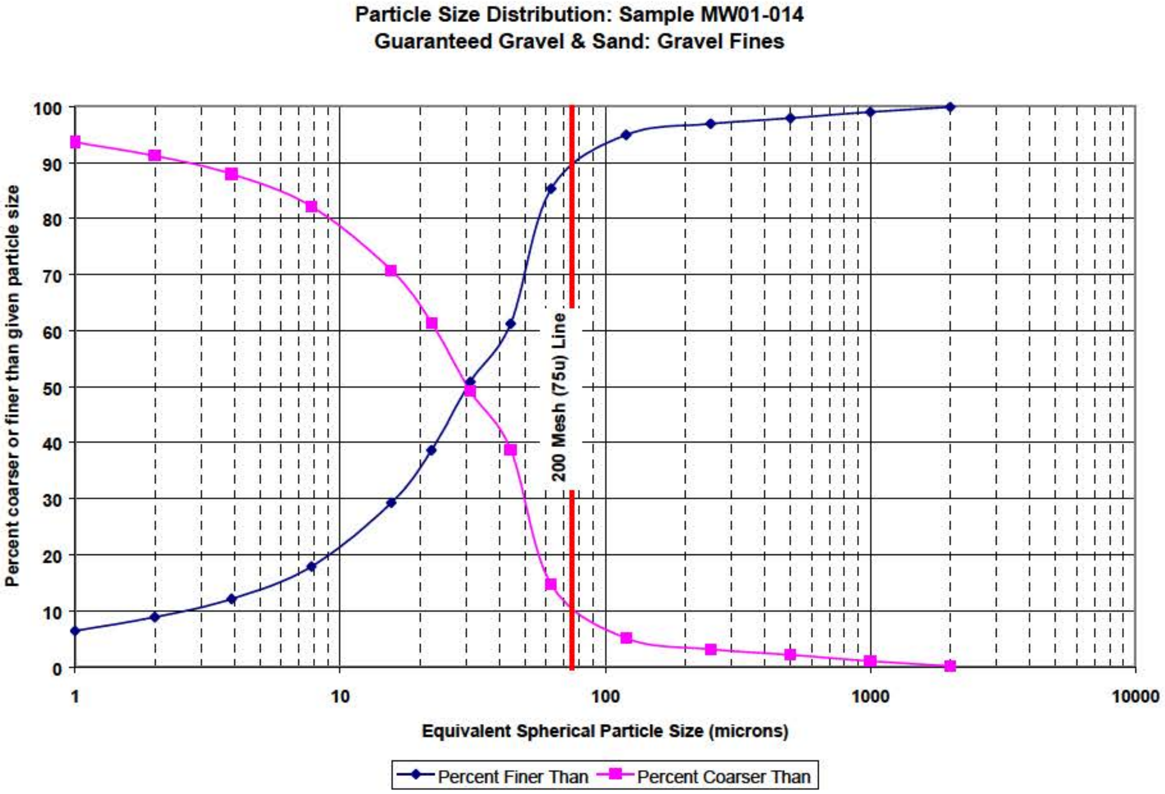


Figure 43. Particle size analysis in graphic form of Guaranteed Gravel & Sand gravel wash fines (MW01014).

Table 107 Geochemical analysis of Guaranteed Gravel & Sand gravel wash fines (MW01014).

Whole Rock[1]				Ultratrace - Aqua Regia[3]				Acid Digestion[4]			
SiO_2 wt %	48.9	Sc ppm	5	Mo (ppm)	0.96	Cr (ppm)	16.7	Mo (ppm)	1.4	Cr (ppm)	30
Al_2O_3 wt %	5.95	Ta ppm	< 20	Cu (ppm)	13.17	Mg %	3.38	Cu (ppm)	12	Mg %	3.65
Fe_2O_3 wt %	4.31	LOI %	18.3	Pb (ppm)	9.65	Ba (ppm)	144.2	Pb (ppm)	13	Ba (ppm)	459
MgO wt %	5.85	SUM %	99.85	Zn (ppm)	36.3	Ti %	0.04	Zn (ppm)	48	Ti %	0.185
CaO wt %	13.31			Ag (ppb)	59	B (ppm)	10	Ag (ppm)	0.5		
Na_2O wt %	0.94			Ni (ppm)	22.1	Al %	0.62	Ni (ppm)	27	Al %	3.39
K_2O wt %	1.46			Co (ppm)	12.9	Na %	0.018	Co (ppm)	14	Na %	0.803
TiO_2 wt %	0.35	Additional Analyses[2]		Mn (ppm)	1351	K %	0.12	Mn (ppm)	1520	K %	1.16
P_2O_5 wt %	0.14	C/ORG %	0.16	Fe %	2.35	W (ppm)	< .2	Fe %	3.13	W (ppm)	< 2
MnO wt %	0.19	CO_2 %	15.39	As (ppm)	9.8	Sc (ppm)	1.7	As (ppm)	13	Zr (ppm)	57.4
Cr_2O_3 wt %	0.007	TOT/C %	4.36	U (ppm)	1	Tl (ppm)	0.24	U (ppm)	< 1	Ce (ppm)	44
Ba ppm	431	SO_4 %	< .03	Au (ppb)	0.8	S %	0.01	Au (ppm)	< 4	Sn (ppm)	< .5
Cu ppm	24	TOT/S %	0.01	Th (ppm)	3.6	Hg (ppb)	18	Th (ppm)	3	Y (ppm)	13.3
Zn ppm	86			Sr (ppm)	49.8	Se (ppm)	0.5	Sr (ppm)	166	Nb (ppm)	3.7
Ni ppm	30	F (ppm)	583	Cd (ppm)	0.22	Te (ppm)	0.04	Cd (ppm)	< .2	Ta (ppm)	< .5
Co ppm	< 20			Sb (ppm)	0.22	Ga (ppm)	2.3	Sb (ppm)	< 1	Be (ppm)	1
Sr ppm	167	FeO %	0.5	Bi (ppm)	0.08			Bi (ppm)	1	Sc (ppm)	5
Zr ppm	189			V (ppm)	30			V (ppm)	55	Li (ppm)	17
Ce ppm	92	pH	8.9	Ca %	7.92			Ca %	10.18	S %	< .02
Y ppm	15	H_2O+ %	2.3	P %	0.059			P %	0.058	Rb (ppm)	42
Nb ppm	52	H_2O- %	0.9	La (ppm)	14.4			La (ppm)	20	Hf (ppm)	2

[1] 0.2 gm sample by $LIBO_2$ fusion, analysis by ICP-ES. LOI by loss on ignition.

[2] CO_2 - Digest with warm 15% $HCLO_4$, evolved CO_2 analyzed by LECO. SO_4 - Residue sulphur after ignited at 800 °C for 1 hour. C/ORG - Total C minus graphite C and carbonate. F - NaOH fusion - specific ion electrode analysis. FeO by dichromate titration. H_2O+ at 1500 °C. H_2O- at 110 °C.

[3] 15.00 gm sample, 90 ml 2-2-2 HCl-HNO_3-H_2O at 95 °C for 1 hour and is diluted tp 300 ml, analysis by ICP/ES & MS.

[4] 0.25 gm sample digested with $HClO_4$-HNO_3-HCl-HF to 10 ml. Digestion is partial for some minerals & may volatize some elements, analysis by ICP-ES.

Table 108 Mineralogy of Guaranteed Gravel & Sand gravel wash fines (MW01014).

	Quartz	Dolomite	Annite (Biotite)	Kaolinite	Albite	Sanidine	Microcline	Orthoclase	Ankerite
MW01014	M	M	m	m	t	t	t	t	t
	Clino-chlore	Tosudite	Cordierite						
MW01014	t	t	t						

Component Mineral Composition			
Albite, ordered	$NaAlSi_3O_8$	Annite-1M	$KFe_3(Si,Al)_4O_{10}(OH)_2$
Sanidine	$(K,Na)(Si_3Al)O_8$	Clinochlore	Mg-Fe-Al-Si-Al-O-OH
Microcline, ordered	$KAlSi_3O_8$	Tosudite	$Na_{0.3}Al_6(Si,Al)_8O_{20}(OH)_{10}!4H_2O$
Dolomite	$CaMg(CO_3)_2$	Cordierite, syn	$Mg_2Al_4Si_5 O_{18}$
Quartz., syn	SiO_2	Kaolinite-1A	$Al_2Si_2O_5(OH)_4$
Ankerite	$Ca(Fe,Mg)(CO_3)_2$	Orthoclase	$KAlSi_3O_8$

* Mineralogy determined by XRD; M = major, m = minor, t = trace.

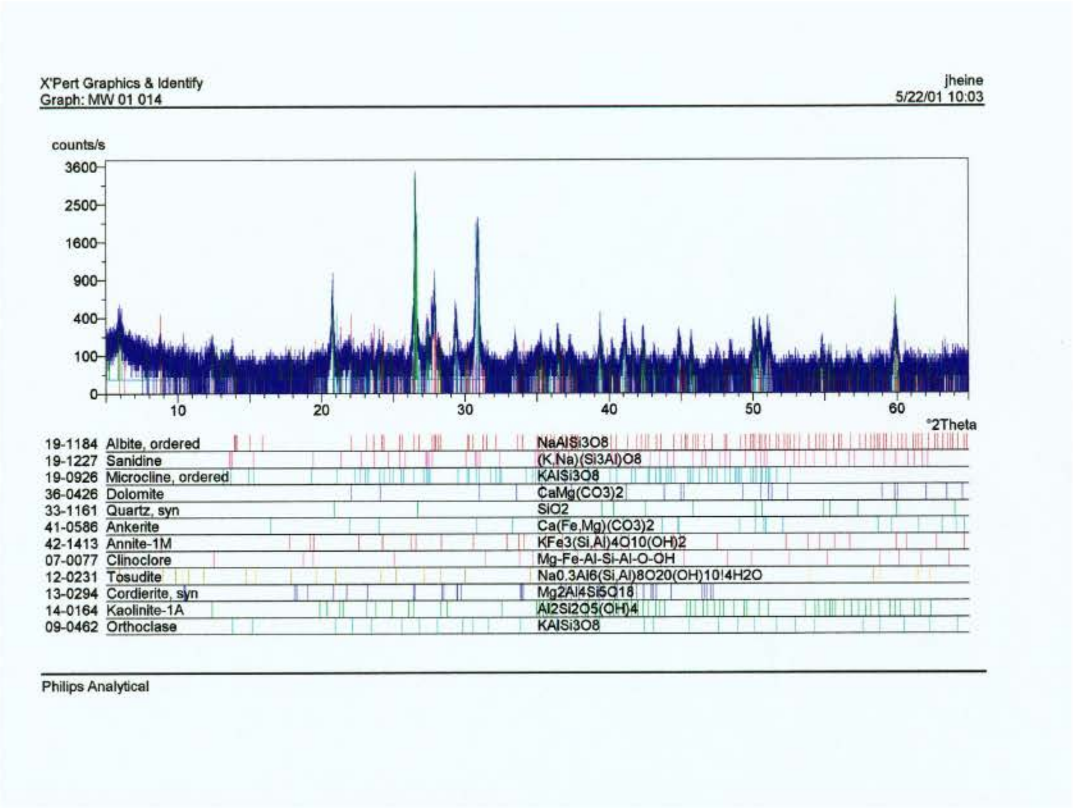
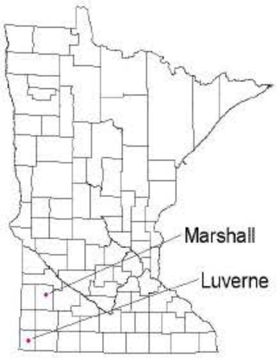


Figure 44. XRD trace depicting the mineralogy of Guaranteed Gravel & Sand gravel wash fines (MW01014).

Data Sources

2001 Survey Response
2001 NRRI Sample Analysis
www.smc-co.com



Northern Con-Agg, Inc.

3231 Fernbrook Lane North
Plymouth, MN 55447

Phone: (763) 509-9344
Toll Free: 1-800-835-1817

www.northernconagg.com

Pit Location	County	Rock Type	Product
Luverne	Rock	Sand &Gravel	Washed sand, rock
Marshall	Lyon	Sand &Gravel	Washed sand, rock

Northen Con-Agg, Inc., headquartered in Plymouth, MN, has both sand and gravel and kaolin clay operations in Minnesota. The sand and gravel operations are located at Luverne in Rock County and Marshall in Lyon County.

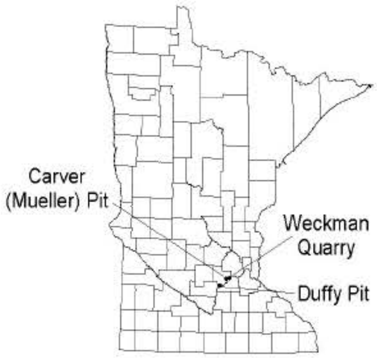
Product Line: Luverne - Washed Sand, 3/4" minus Concrete Rock, Pea Rock, 1-1/2" Rock, Oversize Rock
Marshall - Washed Sand, 7/8" minus Concrete Rock, Pea Rock, 1-1/2" Rock, Class 5

Wastes/By-products

Northern Con-Agg, Inc. responded to the survey, via phone, that the company has no hard rock issues or any waste material to report.

Data Source

2001 Survey Response, via phone
www.northernconagg.com



Wm. Mueller & Sons, Inc.

831 Park Ave.
Hamburg, MN 55339

Phone: (952) 467-2720
Fax: (952) 467-3894

Contact: Richard Smith, Vice President

Pit	T	R	S	Forty	County	Rock Type	Products	By-products
Carver (Mueller) Pit	115	24	25	N ½ N ½	Carver	Sand & Gravel	Sand & Gravel Bituminous	Pond Fines
Duffy Pit	114	25	33	SW 1/4	Sibley	Sand & Gravel	Sand & Gravel Bituminous	Pond Fines
Weckman Quarry	115	23	15	NW 1/4	Scott	Sand & Gravel Limestone	Sand & Gravel Crushed Stone	Pond Fines Ag-lime

Wm. Mueller & Sons, Inc. of Hamburg in Carver County, MN, is an aggregate producer/road construction company whose operations include several sand and gravel pits, a limestone quarry, and a permanent and portable asphalt plant. The business is approximately 50% road construction and 50% rock products/bituminous. The Carver Pit is the company's main sand and gravel operation, accounting for roughly 2/3 to 3/4 of the rock products produced, while the Weckman Quarry produces roughly 1/3 to 1/4. Several other smaller sand and gravel pits are leased for operation.

Production: The Carver (Mueller) and Duffy pits host both sand and gravel operations and bituminous plants. The Carver bituminous plant is permanent; the Duffy plant is portable. Carver Pit contains two wash plants and three settling ponds. Natural sand and gravel and crushed limestone rock are produced from the Weckman Quarry.

Product line: Road base, washed sand & gravel, fill, limestone products, and bituminous.

Wastes/By-products

Waste/By-products	How Used	Most Difficult To Market	Easiest To Market	Potential Markets/Uses
Stripping	Reclamation	N.A.	All materials are used or recycled. They are sold for construction or building purposes. Overburden is stockpiled for pit restoration.	Refer to "How Used"
Quarry Fines	Baseball diamond dust for infields			
Wash Fines	Fill material			
Baghouse Fines	Put back into the mix			
Concrete wash and culled bricks from ready-mix plants	Recycled Class 5 (includes some bituminous)			

Pond fines and **baghouse dust** are by-products generated by Wm. Mueller & Sons, Inc.'s sand and gravel and bituminous operations. Nearly 95 % of the fines are recovered from the primary settling pond in the Carver Pit. This - # 200 material is used by masons to form a base under concrete slabs. Baghouse fines are put back into the bituminous mix. Wm. Mueller & Sons, Inc. accepts demolition job rubble and broken concrete blocks. These wastes are crushed back into road base. All materials at the various operations are used or recycled, thus eliminating waste.

In addition to its own generated wastes/by-products, Wm. Mueller & Sons, Inc. takes back **concrete wash** and **culled bricks** from ready-mix plants. These are used to make recycled Class 5 (with the inclusion of some bituminous). The company attempts to take all the materials out of a quarry so that it can return it to a natural state, i.e., wetlands, etc. (R. Smith, pers. comm.).

Data Sources

2001 Survey Response;
Richard Smith, pers. com., 2001

RELATED ENTITIES

The following entities that responded to the survey do not fit neatly into the dimension stone, crushed stone, and sand & gravel categories. Included in this section are the City of Mankato water treatment plant, a producer of concrete products, one of the trade associations, a major corporation with industrial mineral interests, Minnesota's sole brick producer (which finds itself in need of the very wastes/by-products that generated this project and report), and a contract crushing operation.

Company	Corporate Headquarters	Location (County)
City of Mankato Water Treatment Plant	Mankato, MN	Blue Earth
Marshall Concrete Products, Inc.	Minneapolis, MN	Hennepin
Minnesota Asphalt Pavement Association	New Brighton, MN	Ramsey
3M: Industrial Minerals Product Engineering	St. Paul, MN	Ramsey
Ochs Brick Company	Springfield, MN	Brown
Premier Aggregates, Inc.	Virginia, MN	St. Louis

City of Mankato
Water Treatment Plant

760 Mound Avenue
Mankato, MN 56001

Phone: (507) 387-8661

Source	City	County	Rock Type	Product	By-product	Size	Location
Water Treatment Plant	Mankato	Blue Earth	Lime	Water	Filter Cake (dewatered sludge)	- # 200	

The city of Mankato, MN, uses lime in its water treatment plant to soften the city's water supply (Mankato Water Treatment, 2001). Softened water reduces the amount of soap required and also controls corrosion in the water mains. Lime (calcium hydroxide) reacts with dissolved minerals in the water such as calcium and magnesium bicarbonates to form calcium carbonate and magnesium hydroxide. The calcium carbonate and magnesium hydroxide precipitate out of the water, forming a sludge which is pumped out to a basin and dewatered. The filter cake produced by dewatering the sludge is disposed of as a waste product in an area accessible to the residents of Mankato and the surrounding area (Fig. 45). This calcium carbonate waste product is often used by local residents, especially farmers, for soil treatment.

Figure 45. Mankato water treatment plant filter cake stockpiles.

Waste/By-product Analytical Data - Filter Cake

Sample MW01004, filter cake (dewatered sludge) produced by the City of Mankato Water Treatment Plant, was collected in January of 2001 (Fig. 46). Particle size analysis, geochemistry, and x-ray diffractometry for mineral content were run on this sample.

Figure 46. Close-up of Mankato water treatment plant filter cake material and sample.

Particle Size Analysis

Particle size analysis of sample MW01004 indicates that this waste/by-product is 95 % silt-sized, with 4 % clay-sized particles (Table 109). It is produced as a precipitate rather than being the result of a rock-crushing process, thus yielding a tighter size range. Table 110 presents the complete set of particle size assay data on sample MW01004.

Table 109 Sand-silt-clay fraction: City of Mankato Water Treatment Plant filter cake (MW01004).

SAND - SILT - CLAY FRACTION*				
SAMPLE	SAMPLE TYPE	% SAND	% SILT	% CLAY
MW01004	Filter Cake	0.45	95.51	4.03
*Sand >= 62.5 microns (# 230 sieve), silt < 62.5 microns and >= 2 microns, clay < 2 microns				

Table 110 Complete particle size assay data for the City of Mankato Water Treatment Plant filter cake (MW01004).

Percent Passing Equivalent Spherical Diameter in Microns*														
	SAND					SILT							CLAY	
SAMPLE	2000 µ	1000 µ	500 µ	250 µ	120 µ	62.5 µ	44 µ	31 µ	22.1 µ	15.6 µ	7.8 µ	3.9 µ	2 µ	1 µ
MW01004	100.00	99.99	99.99	99.96	99.84	99.55	99.15	98.74	94.43	83.30	42.45	13.94	4.03	1.39
* + # 230 sieve fraction determined by sonic sifting; - # 230 sieve fraction determined by settling tube method.														

Figure 47 presents the particle size analysis of sample MW01004 in graphic form. The graph plots the weight percent of the sample that is: 1) finer than, and 2) coarser than, the equivalent spherical diameter (in microns) of a given particle size.

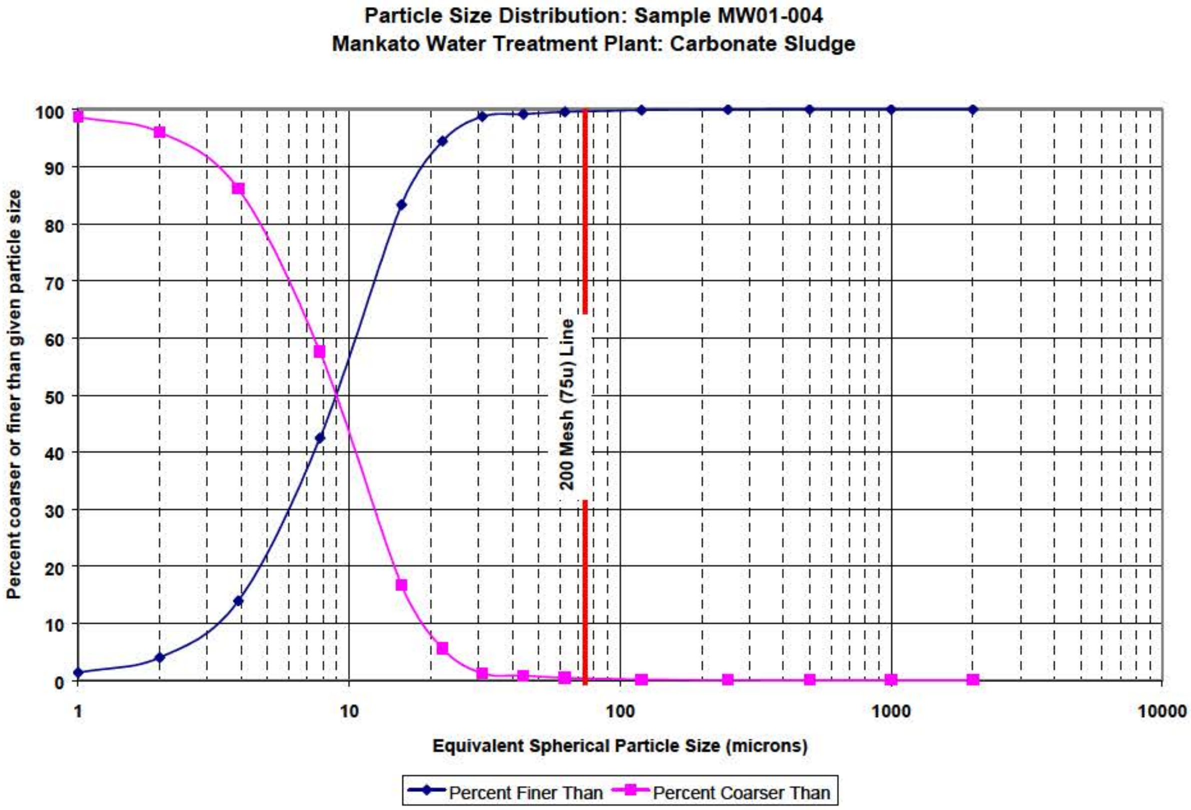


Figure 47. Particle size analysis in graphic form of the City of Mankato Water Treatment Plant filter cake (dewatered sludge; MW01004).

Chemistry

The chemical composition of sample MW01004 is presented in Table 111.

Table 111 Geochemical analysis of the City of Mankato Water Treatment Plant filter cake (MW01004).

Whole Rock [1]				Ultratrace - Aqua Regia [3]				Acid Digestion [4]			
SiO2 %	0.99	Sc ppm	< 1	Mo (ppm)	0.16	Cr (ppm)	0.6	Mo (ppm)	1.1	Cr (ppm)	2
Al2O3 %	0.04	Ta ppm	< 20	Cu (ppm)	2.13	Mg %	1.84	Cu (ppm)	1	Mg %	2.09
Fe2O3 %	0.18	LOI %	44.7	Pb (ppm)	0.13	Ba (ppm)	57.8	Pb (ppm)	< 3	Ba (ppm)	65
MgO %	3.34	SUM %	99.63	Zn (ppm)	2.9	Ti %	< .001	Zn (ppm)	3	Ti %	0.004
CaO %	50.14			Ag (ppb)	5	B (ppm)	23	Ag (ppm)	0.7		
Na2O %	0.04			Ni (ppm)	0.9	Al %	0.04	Ni (ppm)	4	Al %	0.05
K_2O %	< .02			Co (ppm)	< .1	Na %	0.025	Co (ppm)	< 1	Na %	0.034
TiO2 %	< .01	Additional Analyses [2]		Mn (ppm)	395	K %	< .01	Mn (ppm)	432	K %	< .01
P_2O_5 %	0.04	C/ORG %	0.17	Fe %	0.08	W (ppm)	< .2	Fe %	0.13	W (ppm)	< 2
MnO %	0.05	CO_2 %	41.08	As (ppm)	1.8	Sc (ppm)	0.2	As (ppm)	4	Zr (ppm)	1.4
Cr_2O_3 %	0.002	TOT/C %	11.37	U (ppm)	7.1	Tl (ppm)	< .02	U (ppm)	4	Ce (ppm)	2
Ba ppm	57	SO_4 %	0.23	Au (ppb)	< .2	S %	0.12	Au (ppm)	< 4	Sn (ppm)	2.1
Cu ppm	< 20	TOT/S %	0.08	Th (ppm)	0.1	Hg (ppb)	< 5	Th (ppm)	< 1	Y (ppm)	1.2
Zn ppm	< 20			Sr (ppm)	491.3	Se (ppm)	0.5	Sr (ppm)	517	Nb (ppm)	< .2
Ni ppm	57	F (ppm)	307	Cd (ppm)	0.02	Te (ppm)	0.17	Cd (ppm)	< .2	Ta (ppm)	< .5
Co ppm	< 20			Sb (ppm)	0.1	Ga (ppm)	0.1	Sb (ppm)	1	Be (ppm)	< 1
Sr ppm	477	FeO %	< .1	Bi (ppm)	< .02			Bi (ppm)	1	Sc (ppm)	1
Zr ppm	44			V (ppm)	3			V (ppm)	< 1	Li (ppm)	2
Ce ppm	40	pH	9.8	Ca %	36.03			Ca %	41.21	S %	0.05
Y ppm	< 10	H_2O+ %	4.4	P %	0.008			P %	0.009	Rb (ppm)	< 1
Nb ppm	43	H_2O- %	0.6	La (ppm)	0.8			La (ppm)	< 1	Hf (ppm)	< 1

[1] 0.2 gm sample by $LIBO_2$ fusion, analysis by ICP-ES. LOI by loss on ignition.

[2] CO_2 - Digest with warm 15% $HCLO_4$, evolved CO_2 analyzed by LECO. SO_4 - Residue sulphur after ignited at 800 °C for 1 hour. C/ORG - Total C minus graphite C and carbonate. F - NaOH fusion - specific ion electrode analysis. FeO by dichromate titration. H_2O+ at 1500 °C. H_2O- at 110 °C.

[3] 15.00 gm sample, 90 ml 2-2-2 $HCl-HNO_3-H_2O$ at 95 °C for 1 hour and is diluted tp 300 ml, analysis by ICP/ES & MS.

[4] 0.25 gm sample digested with $HClO_4-HNO_3-HCl-HF$ to 10 ml. Digestion is partial for some minerals & may volatize some elements, analysis by ICP-ES.

Mineralogy

X-ray diffractometry of sample MW01004 detected only calcite and a hydrated form of calcite (Table 112). Figure 48 presents the XRD trace for sample MW01014.

Table 112 Mineralogy of City of Mankato Water Treatment Plant filter cake (MW01004).*

Sample	Calcite
MW01004	M
Component Mineral Composition	
Calcite, syn	$CaCO_3$
Monohydrocalcite	$CaCO_3!O_{.65}H_2O$
* Mineralogy determined by XRD.	

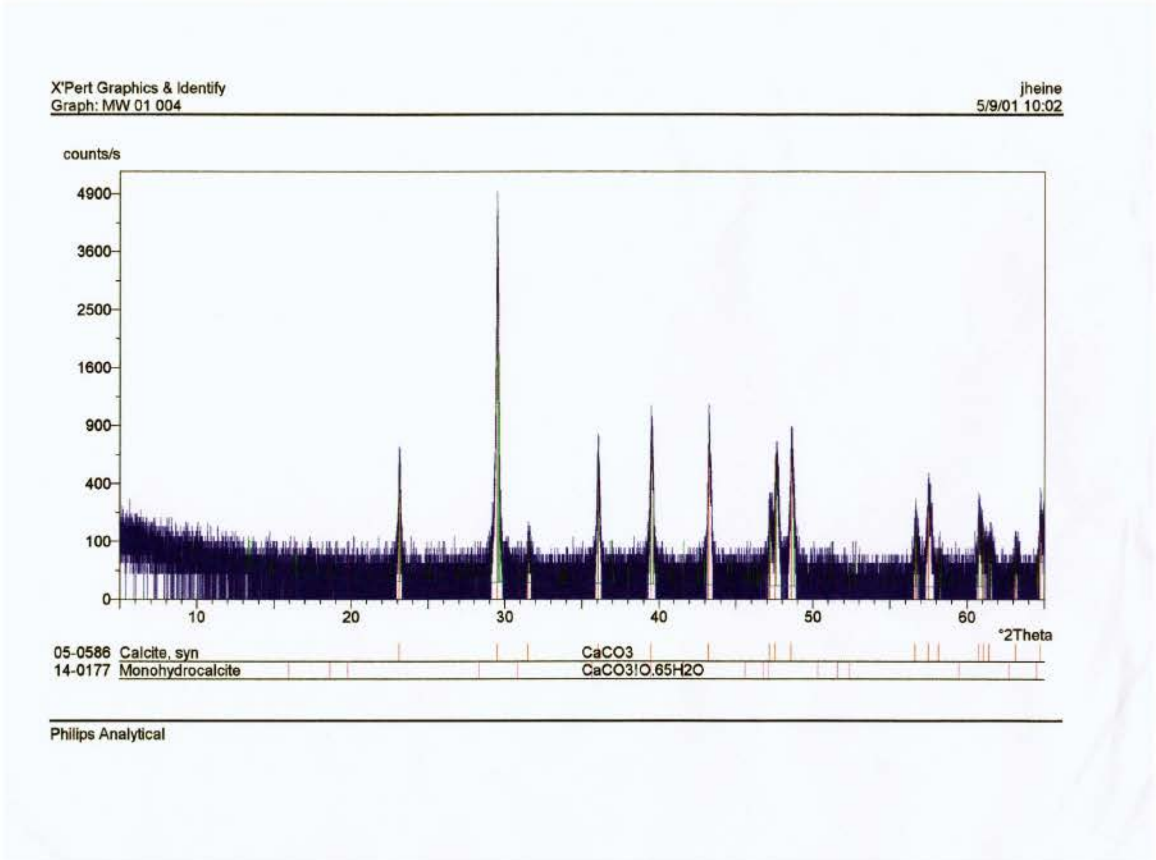


Figure 48. XRD trace depicting the mineralogy of the City of Mankato Water Treatment Plant filter cake (dewatered sludge; MW01004).

Data Sources

2001 Site Visit
2001 NRRI Sample Analysis

Marshall Concrete Products, Inc.

2610 Marshall St. N.E.
Minneapolis, MN 55418

Phone: (612) 789-4305
Fax: (612) 789-5387
Toll Free: (877) 817-5926

Contact: John M. Fischer, General Manager
jmartinfischer@uswest.net

www.marshallconcreteproducts.com

Pit	Rock Type	Products
No mining - All rock is purchased	Granite Dolomite Sand & Gravel	Concrete Concrete block

Marshall Concrete Products, Inc. of Minneapolis, MN, does not operate any pits or quarries. The company purchases quarried granite, dolomite, and sand & gravel for use in its concrete products.

Wastes/By-products

Waste/By-product	How Used	Most Difficult To Market	Easiest To Market	Potential Markets/Uses
Leftover concrete and concrete block rejects.	Crushed on-site for resale or hauled back to gravel pits for crushing and re-use.	N.A.	N.A.	N.A.

By-products identified by Marshall Concrete Products, Inc. include **leftover concrete** and **concrete block rejects**. These are not considered to be wastes as they are crushed by the company for resale or hauled back to gravel pits for crushing and re-use.

Data Source

2001 Survey Response
www.marshallconcreteproducts.com

Minnesota Asphalt Pavement Association (MAPA)

900 Long Lake Road
Suite 100
New Brighton, MN 55112

Phone: (651) 636-4666
Fax: (651) 636-4790

Contact: Richard O. Wolters, P.E., Director
info@mnapa.org

www.asphaltisbest.com

Wastes/By-products

Waste/By-product	How Used	Most Difficult To Market	Easiest To Market	Potential Markets/Uses
aggregate base crushed concrete recycle asphalt pavement	aggregate recycle hot mix asphalt	All three	Recycle aggregate	The hot mix contractor community

Minnesota Asphalt Pavement Association (MAPA) is an organization that represents nearly 96 percent of Minnesota's asphalt industry. MAPA's membership includes 28 asphalt producers and 8 asphalt non-producers, along with over 80 associate members that are materials suppliers to the hot mix asphalt (HMA) industry (About MAPA, 2004).

Typical wastes/by-products generated by MAPA's member producers include recycle or salvaged roadway materials. These materials include **aggregate base, crushed concrete, and recycle asphalt pavement**. Some of these by-products are allowed back into the marketplace as aggregate and hot mix asphalt.

Recycle aggregate is generally the easiest of the three to market because it is usually a smaller quantity than millings or recycle asphalt pavement. However, the association considers all three to be problematic wastes at times because, while permissible to use per Mn/DOT specifications, the buyer may not allow their use.

Data Source

2001 Survey Response
www.asphaltisbest.com

Minnesota Mining and Manufacturing (3M)
Industrial Minerals Products Engineering

P.O. Box 33331
Bldg. 21-1E-06
St. Paul, MN 55133-3331

Phone: (651) 778-4508
Fax: (651) 778-7022

Contact: Bruce W. Kramer, Geo-Engineering Specialist
bwkramer@mmm.com

www.mmm.com

Wastes/By-products

Waste/By-product	How Used	Most Difficult To Market	Easiest To Market	Potential Markets/Uses
-40 mesh silicate rock fines	Ceramic tile Brick filler Fill Bedding Mine drainage buffering Superpave	Wastes associated with poor market locations	N.A.	N.A.

While 3M operates no quarries or pits in Minnesota, it does do so outside the state and responded to the survey accordingly. The waste/by-product generated by its operations is **-40 mesh silicate rock fines**. Multiple uses have been found for these fines including ceramic tile, brick filler, mine drainage buffering, fill, bedding, and in Superpave asphalt mixes. Location rather than product limits marketability.

Data Source

2001 Survey Response

Ochs Brick Company

801 Rock Street
P.O. Box 106
Springfield, MN 56087-0106

Phone: (507) 723-4221
Fax: (507) 723-4223

Contact: Steven Koenig, Kiln/Lab Supervisor

www.ochsbrick.com

Pit	T	R	S	County	Rock Type	Product	By-product	Size	Amount	Location
Springfield Pit	109	35	26	Brown	Clay	Clay Brick	Process Waste	N.A.	N.A	N.A

Ochs Brick Company, of Springfield, MN, in Brown County, is Minnesota's sole clay brick producer. Its market is nationwide. Ochs Brick Company mines kaolin and ball clays from the Springfield Pit for use in its brick line.

Wastes/By-products

Waste/By-product	How Used	Most Difficult To Market	Easiest To Market	Potential Markets/Uses
process waste	reground and added back into the system as filler/grog	none to market	N.A.	N.A.

Ochs Brick Company has no wastes/by-products to report as all **process waste** is used on-site. The material, primarily waste brick, is reground and added back into the system as filler/grog to the brick. Because of increased brick recovery rates and increased use of waste material for grog, Ochs Brick Company is experiencing a shortfall of material to use as filler/grog.

Data Source

2001 Survey Response
www.ochsbrick.com

Premier Aggregates, Inc.

401 N. Hoover Road
P.O. Box 961
Virginia, MN 55792

Phone: (218) 749-6530
Fax: (218) 749-2730

Contact: Eric Lendrum, Business Manager

Premier Aggregates, Inc., located in the city of Virginia in St. Louis County, MN, is solely a contract crushing operation that processes materials for others. The company does not own any mineral resources. Premier Aggregates, Inc. has six portable crushing plants operating in three states, a wash plant, and a screening plant.

Data Source

2001 Survey Response

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APPENDICES

APPENDIX A

Industry Survey

Page 1

COMPANY INFORMATION	
Company Name	
Parent Company (if applicable)	
Street Address or PO Box	
City/Town	
County	
State	
Zip Code	
Contact Person	
Title	
Telephone	
Fax	
e-mail	
Web Address	
PLANT/PROCESSING FACILITY LOCATION (if different from previous)	
Name of Plant	
Company Name	
Street Address or PO Box	
City	
County	
State	
Zip Code	
Contact Person	
Title	
Telephone	
Fax	
e-mail	

Page 2

QUARRY/PIT LOCATION (please provide separate responses for multiple properties)	
Quarry/Pit Name	
Operator Name	
MnDOT Source Number	
Street Address or PO Box	
City (or closest city or town)	
County	
State	
Zip Code	
Rock Type(s)	
Rock Description	
Geologic Formation Name	
Thickness (feet)	
Status (Active or Inactive?)	
If Inactive, date last active	
Date first opened	
Township #	
Range #	
Section #	
Forty (e.g., SW-NW)	
USGS Quadrangle	
Total Acreage	
Property Owner	

QUARRY/PLANT WASTES (wastes can include fines, rejects, cuttings, stripping material, etc.)

WASTES STORED ON SITE

QUARRY WASTES (please identify, and list in order of tons or cubic yards on site)

	PIT/QUARRY NAME	TYPE	SIZE	TONS	YARDS	LOCATION (stockpile, pond, etc.)
Waste 1						
Waste 2						
Waste 3						
Waste 4						
Waste 5						

PLANT WASTES (please identify, and list in order of tons or cubic yards on site)

	PLANT NAME	TYPE	SIZE	TONS	YARDS	LOCATION (stockpile, pond, etc.)
Waste 1						
Waste 2						
Waste 3						
Waste 4						
Waste 5						

QUARRY/PLANT WASTES (wastes can include fines, rejects, cuttings, stripping material, etc.)

WASTES PRODUCED ANNUALLY

QUARRY WASTES (please identify, and list in order of tons or cubic yards)

	PIT/QUARRY NAME	TYPE	SIZE	TONS	YARDS	DESTINATION (stockpile, pond, etc.)
Waste 1						
Waste 2						
Waste 3						
Waste 4						
Waste 5						

PLANT WASTES (please identify, and list in order of tons or cubic yards)

	PLANT NAME	TYPE	SIZE	TONS	YARDS	DESTINATION (stockpile, pond, etc.)
Waste 1						
Waste 2						
Waste 3						
Waste 4						
Waste 5						

ROCK PRODUCTS (please identify, and list in order of tons or cubic yards produced annually)

	SOURCE (PIT NAME)	PRODUCT TYPE	TRADE NAME	PRODUCT SIZE	TONS	YARDS	COLOR
Product 1							
Product 2							
Product 3							
Product 4							
Product 5							
Product 6							
Product 7							
Product 8							
Product 9							
Product 10							

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PRODUCT ANALYTICAL/TEST DATA (check all that apply)
NOTE: Any or all analytical or testing results that you are comfortable providing would be appreciated.

	Product 1	Product 2	Product 3	Product 4	Product 5	Product 6	Product 7	Product 8	Product 9	Product 10
Chemical Analyses										
Gradation										
Mineralogy										
pH value										
Permeability										
Color										
Particle strength										
Particle shape										
Angularity										
Clay content										
Plasticity index										
Moisture content										
Loose unit weight										
Compact unit weight										
LAR										
OTHERS										

WASTE ANALYTICAL/TEST DATA (check all that apply)

	Waste 1	Waste 2	Waste 3	Waste 4	Waste 5					
Chemical Analyses										
Gradation										
Mineralogy										
pH value										
Permeability										
Color										
Particle strength										
Particle shape										
Angularity										
Clay content										
Plasticity index										
Moisture content										
Loose unit weight										
Compact unit weight										
LAR										
OTHERS										

MINING AND PROCESSING DETAILS

Do you have a production flow sheet? If so, could you return a copy with this survey?

Do you drill and blast?

Mobile Equipment	**Type**	**Number**	**Size**
Trucks			
Shovels			
Drag Line			
Barge-mounted excavator			
Backhoes			
Scrapers			
Loaders			
Dozers			
Drills			
Other			

Processing Equipment	**Type**	**Number**	**Size**
Crushers			
Conveyors			
Ball mill			
Rod mill			
Hammer mill			
Log washers			
Wash plant			
Screens			
Wet or dry classification?			
Spiral classifiers			
Saws			
Cyclones			
Hydrocyclones			
Dust collection			
Belt filter press			
Settling pond			
Bagging			
Pumps			
Other			

Loading Capabilities	**Type**	**Number**	**Size**
Silos			
Conveyors			
Backhoes			
Front end loaders			
Other			

Product Shipping Method	**Type**	**Number**	**Tons**
Truck			
Rail			
Barge			
Other			

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PROPERTY MAPS AVAILABLE? (please indicate YES or NO)
NOTE: Any maps that you are comfortable providing would be appreciated.

	Paper?	Digital (CAD/GIS)?	Software type	Map Date?
Property survey/plan map				
Elevation/contour map				
Pits				
Roads				
Stockpiles				
Rock Dumps				
Tailings Basins				
Settling Ponds				
Other				

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GENERAL QUESTIONS

The following questions are intended for you to provide more detail, and for discussing issues that are important to you and your company. Attach additional sheets as needed.

1 What are the most common types of wastes/byproducts generated by your operation?

2 How are they used?

3 What types of waste(s) have been the most difficult for you to market, and why?

4 What types of waste(s) have been the easiest for you to market, and why?

5 What do you see as potential markets/uses for your wastes?

6 What would be the most beneficial development for your operation, in terms of waste material utilization or sale?

7 What type of technical research would be most beneficial to your operation?

8 What issues concern you the most as an operator doing business in Minnesota?

9 What issues impact you the most?

10 What do you think will be the three top issues that impact your business in the next 5 to 10 years?

11 Do you have anything else you would like to discuss?

APPENDIX B

Listing of Survey Recipients

Company	Address	City	State	ZipCode
3M Industrial Minerals Products Engineering	P.O. Box 33331, Bldg. 21-1E-06	St. Paul	MN	55133-3331
Aggregate Industries - Aggregate Division	2915 Waters Road, Suite 105	Eagan	MN	55121
Aggregate Industries North Central Region	2915 Waters Road, Suite 105	Eagan	MN	55121
Aggregate Ready Mix Association of Minnesota	275 Market Street, Suite C13	Minneapolis	MN	55405
Alexandria Concrete	1401 Fallon Ave.	Monticello	MN	55362
Ames Sand & Gravel	2702 1st Ave. N	Fargo	ND	58102
Anderson Bros. Construction Company of Brainerd	P.O. Box 668	Brainerd	MN	56401
Annandale Rock Products	12128 State Highway 55 NW	Annandale	MN	55302
Arrowhead Concrete Works	5572 Miller Trunk Highway	Duluth	MN	55811
AVR, INC./AME GROUP	14698 Galaxie Avenue	Apple Valley	MN	55124
Barton Sand & Gravel Co.	10633 89th Avenue North, P.O. Box 1480	Maple Grove	MN	55311-6480
Bauerly Companies	4787 Shadow Wood Dr. N.E.	Sauk Rapids	MN	56379
Bauerly Companies	P.O. Box 237	North Branch	MN	55056
Bauerly Companies	311 Hwy 7 East, P.O. Box 48	Hutchinson	MN	55350
Bauerly Companies	P.O. Box 2746	Baxter	MN	56425
Biesanz Stone Co., Inc.	4600 Goodview Road	Winona	MN	55987
Bornhoft Concrete, Inc.	150 County Rd. 8, R.R. 1, Box 49	Tyler	MN	56178
Botcher Construction Co.	Rt. 2	Houston	MN	55943
Bowman Construction Co.	P.O. Box 151	International Falls	MN	56649
Braaten Aggregate, Inc.	Hwy 71 North, Box 215	Bertha	MN	56437
Brink Redi-Mix, Inc., Brink Sand & Gravel, Inc.	3000 Rangeline Rd.	Grand Rapids	MN	55744
Bryan Rock Products, Inc.	Box 215	Shakopee	MN	55379
Buffalo Bituminous, Inc.	Highway 55 W	Buffalo	MN	55313
Builders Sand & Gravel	3770 Salem Rd. SW	Rochester	MN	55902
C.S. McCrossan, Inc.	P.O. Box 1240	Maple Grove	MN	55311-6240
Caledonia Ready Mix	134 Bissen St.	Caledonia	MN	55921
Carlson Brothers, Inc.	P.O. Box 141	Springfield	MN	56087
Cemstone Products Company	2025 Centre Pointe Blvd., Ste. 300	Mendota Heights	MN	55120
Central Concrete, Inc.1316 No. Broad	P.O. Box 606"	Mankato	MN	56002-0606
Central Specialties, Inc.	6325 County Road 87 SW	Alexandria	MN	56308
Central-Allied Enterprises, Inc.	605 Lakeland Dr. NE, P.O. Box 1317	Willmar	MN	56201
Clarks Grove Ready Mix, LLC.	Rt. 1, Box 179	Clarks Grove	MN	56016
Cold Spring Granite Co.	202 S. Third Avenue	Cold Spring	MN	56320-2593
Commercial Asphalt Co.10633 89th Avenue N	P.O. Box 1480"	Maple Grove	MN	55311-6480

Company	Address	City	State	ZipCode
Concrete Minnesota of Albert Lea, Inc.	2424 Myers Road	Albert Lea	MN	56007
Concrete Paving Association of Minnesota	6300 Shingle Creek Parkway, Suite 325	Brooklyn Center	MN	55430
CON-MIX, LLC	1011 East Babcock Blvd, P.O. Box H	Delano	MN	55328
Coons Aggregate Supply Co., Division of Wissota Sa	4607 Canosia Rd.	Saginaw	MN	55779
Crane Creek Construction, Inc.	P.O. Box 246	Owatonna	MN	55060
D.H. Blattner & Sons, Inc.	400 County Road 50	Avon	MN	56310
Dakota Granite Co.	P.O. Box 1351	Milbank	SD	57252
DBA Kruckow Rock & Ready Mix	Highway 44, 244 East McKinley Street	Caledonia	MN	55921
Del Zotto Products, Incorporated	1900 County Road 1	Wrenshall	MN	55797
Donarski Bros., Inc.	401 Golf Terrace Drive	Crookston	MN	56716
Dresel Contracting	24110 July Ave.	Chisago City	MN	55013
Duininck Bros., Inc.	Box 208	Prinsburg	MN	56281
Economy Ready-Mix, Inc.	400 Fayal Rd, P.O. Box 685	Eveleth	MN	55734
Edward Kraemer & Sons, Inc.	1020 West Cliff Road	Burnsville	MN	55337
Edwin E. Thoreson, Inc.	P.O. Box 579	Grand Marais	MN	55604
Ernest C.Anderson Gravel & Ready-Mixed, Inc.	28741 County Highway 26	Detroit Lakes	MN	56501
EVTAC Mining	P.O. Box 80	Eveleth	MN	55734
Fischer Sand & Aggregate Co.	14698 Galaxie Ave. W	Apple Valley	MN	55124
Forest Concrete Products, Inc.	1715 E. Sheridan Street	Ely	MN	55731
Fred Carlson Co., Inc.	900 Montgomery Street, P.O. Box 48	Decorah	IA	52101
Gesell Concrete Products, Inc.	5151 Highway 2 W	Bemidji	MN	56601
Glacier Paving, Inc.	1000 Tall Pine Lane	Cloquet	MN	55720
Granite City Ready-Mix Companies	2450 U.S. Hwy #10 South, P.O. Box 1305	St. Cloud	MN	56302
Guaranteed Gravel & Sand	1905 3rd Ave.	Mankato	MN	56001
H.R. Loveall Construction, Inc.	120 6th Avenue SE	Winnebago	MN	56098
Hansen Gravel, Inc.	1305 S. Grade Rd. SW	Hutchinson	MN	55350
Hanson Pipe & Products	P.O. Box 167	Mankato	MN	56001
Hardrives, Inc.	P.O. Box 579	St. Cloud	MN	56302
Hardrives, Inc.	14475 Quiram Drive	Rogers	MN	55374
Hassan Sand & Gravel, Inc.	13530 Willandale Rd.	Rogers	MN	55374
Hawkinson Construction Co., Inc.	P.O. Box 278	Grand Rapids	MN	55744
Hedberg Aggregate, Inc.	1205 Nathan Lane N.	Plymouth	MN	55441
Hedberg Aggregates, Inc.	4375 170th St. W	Farmington	MN	55024
Henrich & Sons, Inc.	RR1, Box 62	Bellingham	MN	56212
Holm Brothers Construction Co.	Box 235	Goodhue	MN	55027

Company	Address	City	State	ZipCode
Holnam, Inc.	P.O. Box 1008	Mason City	IA	50401
Holst Excavating, (Inc.)	Rt. 1, Box 36	Prescott	WI	54021
Holst Excavating, Inc.	2750 Glendale Rd.	Hastings	MN	55033
Hopkins Sand & Gravel, Inc.	100 Highway 61 N	Pine City	MN	55063
Iowa Limestone Company	500 New York Avenue	Des Moines	IA	50313-4908
Iron Range Ready Mix	511 West 25th Street, P.O. Box 545	Hibbing	MN	55746
Itasca Redi-Mix, Inc.	Box 56	Grand Rapids	MN	55744
J & S Gravel, Inc.	216 S. Main St.	Crookston	MN	56716
Jasper Stone Co.		Jasper	MN	56144
Johnson Aggregates	RR 1, Box 12	Le Sueur	MN	56058
Kappers Aggregates, Inc.	1015 Industrial Drive	Spring Valley	MN	55975
Kielmeyer Construction Co.	P.O. Box 158	Nerstrand	MN	55053
Knoblauch Lime & Rock Company	9260 County 17 Boulevard	Cannon Falls	MN	55009
Koski Ready Mix	97 Thomson Road	Esko	MN	55733
Leitzen Concrete Products	4019 Hwy. 14 West	Rochester	MN	55901
Leustek Sand & Gravel	5525 Highway 73	Chisholm	MN	55719
Loeffler Gravel Pit, Inc.	Highway 59 N	Halma	MN	56729
Luhman's Construction Co.	17351 Short Cut Road	Welch	MN	55089
M.R. Paving & Excavating, Inc.	1000 North Front Street, P.O. Box 787	New Ulm	MN	56073
Mankato-Kasota Stone, Inc.	P.O. Box 1358	Mankato	MN	56002-1358
Mark Sand & Gravel Co.	1230 Pebble Lake Road, P.O. Box 458	Fergus Falls	MN	56538-0458
Marshall Concrete Products, Inc.	2610 Marshall St. NE	Minneapolis	MN	55418
Marshall Sand & Gravel, Inc.	2471 State Highway 23	Marshall	MN	56258
Mathy Construction Company	920 10th Ave. North	Onalaska	WI	54650
McLaughlin & Schulz, Inc.	P.O. Box 21	Marshall	MN	56258-0201
McNamara Contracting, Inc.	5001 160th Street West	Rosemount	MN	55068
Meeker Washed Sand & Gravel	20090 640th Ave.	Darwin	MN	55324
Menagha Concrete Products, Inc.	Highway 71 North, P.O. Box 282	Menagha	MN	56464
Meridian Aggregate Co.	P.O. Box 69	St. Cloud	MN	56302
Mesabi Bituminous, Inc.	P.O. Box 728	Gilbert	MN	55741
Midwest Asphalt Corp.	P.O. Box 5477	Hopkins	MN	55343
Midwest Asphalt Corp.	6401 Industrial Dr.	Eden Prairie	MN	55346
Midwest Asphalt Corp.	1400 Old Highway 8	New Brighton	MN	55112
Milestone Materials	920 10th Avenue North	Onalaska	WI	54650
Minnesota Asphalt Pavement Association	900 Long Lake Road, Suite 100	New Brighton	MN	55112

Company	Address	City	State	ZipCode
Minnesota Valley Minerals, Inc.	704 Chapman Street	Mankato	MN	56001
Mobilcrete, Inc.	RR #3, Box 2B	Le Sueur	MN	56058
Modern Ready Mix, Inc.	4980 W. 6th Street	Winona	MN	55987
Morris Sand & Gravel	Route 1, Box 795	Morris	MN	56267
New Ulm Quartzite Quarries, Inc.	Rt. 5, Box 21	New Ulm	MN	56073
North Star Concrete Co.	P.O. Box 240599, 6055 150th Street West	Apple Valley	MN	55124-0599
Northern Con-Agg	101 Locust Street	St. Peter	MN	56082
Northern Improvement Co.	4000 12th Ave. NW	Fargo	ND	58102
Northern Paving, Inc.	102 West 5th Street, P.O. Box 708	Crookston	MN	56716
Northland Constructors of Duluth, Inc.	4843 Rice Lake Road	Duluth	MN	55803
Ochs Brick Company	801 Rock Street	Springfield	MN	56087
Omar's Sand & Gravel	705 County Road 61	Carlton	MN	55718
Ortonville Stone Company	P.O. Box 67	Ortonville	MN	56278
Osmundson Brothers Contractors, Inc.	211 West Main Street	Adams	MN	55909
Ottertail Ready Mix	N Main St.	Ottertail	MN	56571
Owatonna Concrete Products, Inc.	639 Riverside Ave., P.O. Box 294	Owatonna	MN	55060
Paulson Rock Products	510 9th Avenue S.W.	Rochester	MN	55902
Pederson Brothers of Harmony, Inc.	Box 606, Highway 52 North	Harmony	MN	55939
Pipestone Concrete	620 3rd Ave. SE	Pipestone	MN	56164
Plaisted Companies, Inc.	11555 205th Ave. NW	Elk River	MN	55330
Porta-Mix Concrete	1201 2nd Street NE, Box 293	East Grand Forks	MN	56721
Premier Aggregates, Inc.	401 N. Hoover Road	Virginia	MN	55792
Prior Lake Aggregates, Inc.	8680 158th St. W	Prior Lake	MN	55372
Pronk Ready Mix	Box 367	Leota	MN	56153
R & R Ready Mix, Inc.	13947 State Highway 29 N	Miltona	MN	56354
Riley Brothers Construction, Inc.	RR1 P.O. Box 535	Morris	MN	56267
Riteway-Vitalis Aggregates	28055 St. Croix Trail	Shafer	MN	55074
River Bend Asphalt Co.	P.O. Box 217	Kasota	MN	56050
Roberson Lime & Rock, Inc.	Rt. 1, Box 223	Zumbro Falls	MN	55991
Rochester Ready Mix Concrete Company	412 2nd Ave. NW	Rochester	MN	55901
Rochester Sand & Gravel, Inc.	4105 E. River Road N.E.	Rochester	MN	55906
Roverud Construction, Inc.	601 Highway 44 East	Spring Grove	MN	55974
Seppi Brothers Concrete Products Corp.	718 North Fourth Street, P.O. Box 1006	Virginia	MN	55792
Shakopee Gravel, Inc.	1650 County Road 83, P.O. Box 650	Shakopee	MN	55379
Shamrock Enterprises	6415 Bandle Road	Rochester	MN	55901

Company	Address	City	State	ZipCode
Shamrock Enterprises	6415 Bandel Rd NW	Rochester	MN	55901
Sherbrooke Asphalt, Inc.	P.O. Box 515	Detroit Lakes	MN	56501
Sibley Aggregates, Inc.	County Road 60	Belle Plaine	MN	56011
Sioux Rock Products	1100 Marcus Street	Fairmont	MN	56031-1100
Sioux Valley Ready Mix	1716 North Front Street, P.O. Box 70	New Ulm	MN	56073
Smitty's Ready Mix	3852 County Road 61	Barnum	MN	55707
Solberg Aggregates Co.	3615 145th St. E	Rosemount	MN	55068
Southern Minnesota Construction Co., Inc.	1905 Third Avenue	Mankato	MN	56001
Steve Foerester Gravel Co.	P.O. Box 178	Halma	MN	56729
Stommes Construction Co.	8137 Old Highway Rd. N	St. Cloud	MN	56301
Strata Corporation	P.O. Box 13500	Grand Forks	ND	58208
Stussy Construction, Inc.	Dodge Co. Highway 21	Mantorville	MN	55955-0187
T.A. Schifsky & Sons, Inc.	2370 E. Highway 36	No. St. Paul	MN	55109
The Bosshart Company	217 N. 1st Ave. W., P.O. Box 220	Truman	MN	56088
The Mathiowetz Construction Co.	30676 County Road 24	Sleepy Eye	MN	56085
Thorson, Inc.	P.O. Box 40	Bemidji	MN	56619-0040
Tower Asphalt, Inc.	P.O. Box 15001	Lakeland	MN	55043
Tri-City Paving & Ready-Mix	P.O. Box 326	Little Falls	MN	56345
Turner Sand & Gravel, Inc.	RR1, Box 73	Wolverton	MN	56594
Twin City Silica, Inc.	499 Cottage Grove Drive	Woodbury	MN	55129
Ulland Brothers, Inc.	P.O. Box 340	Cloquet	MN	55720
Ulland Brothers, Inc.	2400 Myers Road	Albert Lea	MN	56007
Unimin Corp.	Rt. 1, Box 119A	LeSueur	MN	56058
Vetter Stone Co.	P.O. Box 38	Kasota	MN	56050
W.B. Miller, Inc.	6701 Norris Lake Road NW	Elk River	MN	55330
Wabasha Sand, Gravel, & Ready Mixed Co.	905 Church Ave.	Wabasha	MN	55981
Wells Concrete Products Company	P.O. Box 308	Wells	MN	56097
Winona Aggregate Div.	6545 W. 5th St.	Winona	MN	55987
Wm. Mueller & Sons, Inc.	831 Park Avenue	Hamburg	MN	55339
Worms Ready Mix	535 Main Street	New Munich	MN	56356

APPENDIX C

Waste Resource / Quarry Listings:

1) Listing by County

2) Listing by Rock Type

WASTE/BY-PRODUCT SOURCE QUARRY LISTING BY COUNTY

County	Quarry	Operator	Rock Type	Waste/By-product
Big Stone	Agate Quarry	Cold Spring Granite Co.	Granite	Stockpiled Grout
	Ortonville Stone Co. Quarry	Ortonville Stone Co.	Granite	- 50 mesh wash fines
Blue Earth	Jefferson Quarry	Mankato-Kasota Stone, Inc.	Dolomitic Limestone	Scrap stone Lime fines
	Kasota Quarry	Southern Minnesota Construction (SMC)	Dolomite	Ag-lime
Cottonwood	Jeffers Quarry	Sioux Rock Products	Quartzite	- 40 mesh fines - 200 mesh fines
Dakota	Burnsville Quarry	Edward Kraemer & Sons, Inc.	Dolomitic Limestone	- 3/16 in. screened fines - 60 mesh pond fines
	Hastings Quarry	Aggregate Industries North Central Regional	Dolomitic Limestone	Stripping - 200 mesh pond fines
Dodge	Mantorville Quarry	Stussy Contruction , Inc.	Dolomitic Limestone	Ag-lime
Fillmore	Big Springs Quarry	Pederson Bros. of Harmony	Limestone	Ag-lime
	Eggert Quarry	Milestone Materials	Dolomitic Limestone	Excess ag-lime material
	Engrav Quarry	Roverude Construction, Inc.	Dolomite	Stripping - 200 wash fines
	Grabau Quarry	Pederson Bros. of Harmony	Dolomite	Ag-lime
	Peterson Quarry	Roverude Construction, Inc.	Dolomite	Stripping - 200 wash fines
	Pilot Mound Quarry	Milestone Materials	Dolomite	Excess ag-lime material
	Wykoff Quarry	Milestone Materials	Dolomitic Limestone	Excess ag-lime material
Goodhue	Foss Quarry	Kielmeyer Construction Co.	Limestone	Ag-lime
	Hernke Quarry	Kielmeyer Construction Co.	Limestone	Ag-lime
	Spring Garden	Knoblauch Lime & Rock Company	Limestone	Ag-lime
	Red Wing Quarry	Aggregate Industries North Central Regional	Dolomitic Limestone	Stripping
Houston	Gengler Quarry	Roverude Construction, Inc.	Dolomite	Stripping - 200 wash fines
	Horn Quarry	Milestone Materials	Dolomitic Limestone	Excess ag-lime material
	Pool Hill Quarry	Roverude Construction, Inc.	Dolomite	Stripping - 200 wash fines
	Underpass Quarry	Roverude Construction, Inc.	Dolomite	Stripping - 200 wash fines
	Zaiger Quarry	Roverude Construction, Inc.	Dolomite	Stripping - 200 wash fines
Koochiching	Ranier Quarry	Bowman Construction Co.	Schist	Sstripping Fines
Lac Qui Parle	Bellingham Quarry	Dakota Granite Co.	Granite	Stockpiled grout
Lake	Lake Superior Green Quarry	Cold Spring Granite Co.	Granite	Stockpiled grout
	Mesabi Black	Cold Spring Granite Co.	Granite	Stockpiled grout
Mille Lacs	Isle Quarry	Cold Spring Granite Co.	Granite	Stockpiled grout

County	Quarry	Operator	Rock Type	Waste/By-product
Mower	Grand Meadow Quarry	Osmundson Brothers Contractors, Inc.	Dolomitic Limestone	Ag-lime
Nicollet	New Ulm Quarry	New Ulm Quartzite Quarries, Inc.	Quartzite	Settled wash fines
Olmsted	Golberg Quarry	Milestone Materials	Dolomitic Limestone	Sandstone rubble Excess ag-lime material
	Mayowood Quarry	Stussy Contruction , Inc.	Dolomitic Limestone	Ag-lime
	Rock Dell Quarry	Stussy Contruction , Inc.	Dolomitic Limestone	Ag-lime
	Willey Quarry	Milestone Materials	Dolomitic Limestone	Excess ag-lime material
Renville	Morton Quarry	Southern Minnesota Construction (SMC)	Gneiss	Screened quarry fines
	Rainbow Quarry	Cold Spring Granite Co.	Gneiss	Stockpiled grout
Rock	Jasper Stone Quarry	Jasper Stone Co.	Quartzite	Quartzite boulders
Scott	Front Quarry	Bryan Rock Products, Inc.	Dolomitic Limestone	Ag-lime
	Weckman Quarry	Wm. Mueller & Sons, Inc.	Limestone	Ag-lime
St. Louis	Beck's Quarry	Ulland Brothers, Inc.	Basalt	Over-sized rock
Stearns	Charcoal No. 3 Quarry	Cold Spring Granite Co.	Granite	Stockpiled grout
	Diamond Pink Quarry	Cold Spring Granite Co.	Granite	Stockpiled grout
	Purple Crystal Quarry	Cold Spring Granite Co.	Granite	Stockpiled grout
	Rockville No. 1 Quarry	Cold Spring Granite Co.	Granite	Stockpiled grout
	Rockville No. 2 Quarry	Cold Spring Granite Co.	Granite	Stockpiled grout
	St. Cloud Quarry	Meridian Aggregates Co.	Granite	Drilling dust - 50 mesh wash fines Baghouse fines
Steele	Owatonna Quarry	Southern Minnesota Construction (SMC)	Limestone	Ag-lime
Wabasha	Hammond Quarry	Milestone Materials	Dolomitic Limestone	Excess ag-lime material
	Moeching Quarry	Roberson Lime & Rock, Inc.	Dolomitic Limestone	Ag-lime
	Roberson Quarry	Roberson Lime & Rock, Inc.	Dolomitic Limestone	Ag-lime
Washington	Bayport Quarry	Bryan Rock Products, Inc.	Dolomitic Limestone	Ag-lime
	Larson Quarry	Aggregate Industries North Central Regional	Dolomitic Limestone	Stripping Screened fines Pond fines
Winona	43 Quarry	Milestone Materials	Dolomitic Limestone	Excess ag-lime material
	Biesanz Stone Quarry	Biesanz Stone Co.	Dolomite	Block cut-offs Rock saw fines
Yellow Medicine	Yellow Medicine Quarry	Meridian Aggregates Co.	Gneiss	Tower sand Pond settlings

WASTE/BY-PRODUCT SOURCE QUARRY LISTING BY ROCK TYPE
(Data sources are listed under individual producer profiles in Part III.)

CARBONATE QUARRIES

43 Quarry

Operated by Milestone Materials near Rushford, Winona County, in southeastern Minnesota. Mining dolomitic limestone in the Oneota Fomration of the Lower Ordovician Prairie du Chien Group to produce crushed aggregate. Waste (excess aggregate material) consists of 40,000 T of ag-lime.

Bayport Quarry

Operated by Bryan Rock Products, Inc. near Bayport, Washington County, on the Minnesota-Wisconsin border. Mining dolomitic limestone to produce crushed aggregate. Fines are sold as ag-lime.

Biesanz Stone Quarry

Operated by Biesanz Stone Co. in Winona, Winona County, in southeastern Minnesota. Mining dolomite in the Oneota Formation of the Lower Ordovician Prairie du Chien Group to produce dimension stone. Waste products consist of block cut-offs (ends) that are stockpiled or used in berms and 100 CY/YR of rock saw fines that accumulate in settling ponds. Milestone Materials produces crushed rock from the non-dimension stone rock in the Biesanz Stone Quarry; fines are sold as ag-lime.

Big Springs Quarry

Operated by Pederson Bros. Of Harmony, Inc. west of Harmony in Fillmore County in the southeastern corner of Minnesota. Mining limestone from the Prosser and Cummingsville Formations of the Ordovician Galena Group to produce crushed aggregate. Fines are sold as ag-lime.

Burnsville Quarry

Operated by Edward Kraemer & Sons, Inc. in Burnsville, Dakota County, in the south metro area. Mining dolomitic limestones in the Willow River and New Richmond members of the Shakopee Formation of the Lower Ordovician Prairie du Chien Group to produce road material, sand, rip rap, and ag-lime. Waste materials consist of 262,000 T of -3/16 in. screened fines and 225,000 T of -60 mesh pond fines.

Eggert Quarry

Operated by Milestone Materials in Fillmore County in southeastern Minnesota. Mining dolomitic limestone in the Oneota Formation of the Lower Ordovician Prairie du Chien Group to produce crushed aggregates. Waste (excess aggregate material) consists of 8,000 T of ag-lime.

Engrav Quarry

Operated by Roverud Construction, Inc. near Mabel in Fillmore County. Mining dolomite in the Shakopee Formation of the Lower Ordovician Prairie du Chien Group to produce road rock, concrete aggregate, ag-lime, and filter stone. Stripping materials and -200 wash out are sold (wash fines are sold as fill); these are not considered wastes.

Foss Quarry

Operated by Kielmeyer Construction Co. in Wanimingo Township, Goodhue County, in southeastern Minnesota. Mining limestone in the Ordovician Prosser Formation to produce crushed aggregate. Fines are sold as ag-lime.

Front Quarry

Operated by Bryan Rock Products, Inc. near Shakopee, Scott County, in southeastern Minnesota. Mining dolomitic limestone in the Ordovician Oneota Formation to produce crushed aggregate. Fines are sold as ag-lime.

Gengler Quarry

Operated by Roverud Construction, Inc. near Caledonia in Houston County, in far southeastern Minnesota. Mining dolomite in the Oneota Formation of the Lower Ordovician Prairie du Chien Group to produce road rock, concrete aggregate, ag-lime, and filter stone. Stripping materials and -200 wash out are sold (wash fines are sold as fill); these are not considered wastes.

Golberg Quarry

Operated by Milestone Materials in Olmsted County in southeastern Minnesota. Mining dolomitic limestone in the Shakopee Formation of the Lower Ordovician Prairie du Chien Group to produce crushed aggregate. Wastes (excess aggregate materials) consist of 250,000 T of sandstone rubble and 40,000 T of ag-lime.

Grabau Quarry

Operated by Pederson Bros. of Harmony, MN southeast of Spring Valley, Fillmore County, in southeastern corner of Minnesota. Mining dolomite in the Stewartville Formation of the Ordovician Galena Group to produce crushed aggregate. Fines are sold as ag-lime.

Grand Meadow Quarry

Operated by Osmundson Brothers Contractors, Inc. near Grand Meadow, Mower County, in southeastern Minnesota. Mining dolomitic limestone of the Devonian Cedar Valley Formation to produce crushed aggregate. Fines are sold as ag-lime.

Hammond Quarry

Operated by Milestone Materials in Wabasha County in southeastern Minnesota. Mining dolomitic limestone in the Oneota Formation of the Lower Ordovician Prairie du Chien Group to produce crushed aggregate. Waste (excess aggregate material) consists of 30,000 T of screenings.

Hastings Quarry

Operated by Aggregate Industries in Eagan, Dakota County, in the south metro area. Mining dolomitic limestone in the Shakopee Formation of the Lower Ordovician Prairie du Chien Group to produce crushed aggregate. Waste products consist of stripping: 50,000 CY stockpiled or used in berms, with 10,000 CY produced annually; and a limited quantity of -200 mesh pond fines: 5,000 T accumulated in a settling pond, with 2,000 T generated annually.

Hernke Quarry

Operated by Kielmeyer Construction Co. in Goodhue County in southeastern Minnesota. Mining limestone of the Ordovician Prosser Formation to produce crushed aggregate. Fines are sold as ag-lime.

Horn Quarry

Operated by Milestone Materials in Houston County in southeastern Minnesota. Mining dolomitic limestone in the Oneota Formation of the Lower Ordovician Prairie du Chien Group to produce crushed aggregate. Waste (excess aggregate material) consists of 15,000 T of ag-lime.

Jefferson Quarry

Operated by Mankato-Kasota Stone, Inc. in Mankato, Blue Earth County, about 90 miles south of the metro area. Mining dolomitic limestone in the Oneota Formation of the Lower Ordovician Prairie du Chien Group to produce dimension stone. Wastes include scrap stone from the fabrication process and lime fines from the processing plant. Southern Minnesota Construction (SMC) produces crushed rock from the non-dimension stone rock in the Jefferson Quarry.

Kasota Quarry

Operated by Southern Minnesota Construction (SMC) near Kasota, Blue Earth County, in south central Minnesota. Mining dolomite of the Ordovician Oneota Formation to produce crushed aggregate. Fines are sold as ag-lime.

Larson Quarry

Operated by Aggregate Industries in St. Paul Park, Washington County, in the southeast metro area. Mining dolomitic limestones in the of the Shakopee and Oneota Formations of the Lower Ordovician Prairie du Chien Group to produce crushed aggregates. Wastes consist of stripping, -3 / 8 in. screened fines, and -200 mesh pond fines. There are 1,000,000 CY of stripping materials stockpiled or used in berms, with 70,000 CY generated annually. There are 200,000 T of screened fines stockpiled, with 100,000 T produced annually. There are 1,000,000 T of pond finds, with 140,000 T produced annually.

Mantorville Quarry

Operated by Stussy Construction, Inc. southwest of Mantorville, Dodge County, in southeastern Minnesota. Mining dolomitic limestone in the Ordovician Prosser Formation to produce crushed aggregate. Fines are sold as ag-lime.

Mayowood Quarry

Operated by Stussy Construction, Inc. in Rochester Township, Olmsted County, in southeastern Minnesota. Mining dolomitic limestone of the Ordovician Prosser and Cummingsville Formations of the Galena Group to produce crushed aggregate. Fines are sold as ag-lime.

Moeching Quarry

Operated by Roberson Lime & Rock, Inc. in West Albany Township, Wabasha County, in southeastern Minnesota. Mining dolomitic limestone of the Ordovician Oneota Formation to produce crushed aggregate. Fines are sold as ag-lime.

Owatonna Quarry

Operated by Southern Minnesota Construction Co. (SMC) near Owatonna, Steele County, in southern Minnesota. Mining limestone of the Ordovician Prosser Formation to produce crushed aggregate. Fines are sold as ag-lime.

Peterson Quarry

Operated by Roverud Construction, Inc. near Peterson in Fillmore County, southeastern Minnesota Mining in the Oneota Formation of the Lower Ordovician Prairie du Chien Group to produce road rock, concrete aggregate, ag-lime, and filter stone. Stripping materials and -200 wash out are sold (wash fines are sold as fill); these are not considered wastes.

Pilot Mound Quarry

Operated by Milestone Materials near Pilot Mound, Fillmore County, in southeastern Minnesota. Mining dolomite in the Shakopee Formation to produce crushed aggregates. Waste (excessive aggregate material) consists of 3,000 T of ag-lime.

Pool Hill Quarry

Operated by Roverud Construction, Inc. near New Albin, Iowa, but located in Houston County, southeastern Minnesota. Mining dolomite in the Oneota Formation of the Lower Ordovician Prairie du Chien Group to produce road rock, concrete aggregate, ag-lime, and filter stone. Stripping materials and -200 wash out are sold (wash fines are sold as fill); these are not considered wastes.

Red Wing Quarry

Operated by Aggregate Industries in Redwing, Goodhue County, in southeastern Minnesota. Mining dolomitic limestones in the Shakopee and Oneota Formations of the Lower Ordovician Prairie du Chien Group to produce crushed aggregates. Waste consists of 100,000 CY of stripping materials, stockpiled and used in berms; 20,000 CY are generated annually.

Roberson Quarry

Operated by Roberson Lime & Rock, Inc. in Gillford Township, Wabasha County, in southeastern Minnesota. Mining dolomitic limestone to produce crushed aggregate. Fines are sold as ag-lime.

Rock Dell Quarry

Operated by Stussy Construction, Inc. east of Rock Dell, Olmsted County, in southeastern Minnesota. Mining dolomitic limestone in the Ordovician Prosser Formation to produce crushed aggregate. Fines are sold as ag-lime.

Spring Garden Quarry

Operated by Knoblauch Lime & Rock Company in Leon Township, Goodhue County, in southeastern Minnesota. Mining limestone in the Ordovician Prosser Formation to produce crushed aggregate. Fines are sold as ag-lime.

Underpass Quarry

Operated by Roverud Construction, Inc. near Spring Grove in Houston County, far southeastern Minnesota. Mining dolomite in the Middle Ordovician Platteville Formation to produce road rock, concrete aggregate, ag-lime, and filter stone. Stripping materials and -200 wash out are sold (wash fines are sold as fill); these are not considered wastes.

Weckman Quarry

Operated by Wm. Mueller & Sons, Inc. in Jackson Township, Scott County, in southeastern Minnesota. Mining limestone to produce crushed aggregate. Stripping materials are held in reserve for reclamation. Quarry fines are sold as baseball diamond dust.

Willey Quarry

Operated by Milestone Materials near Eyota, Olmsted County, in southeastern Minnesota. Mining dolomitic limestone in the Prosser Formation of the Ordovician Galena Group to produce crushed aggregates. Waste (excessive aggregate material) consists of 5,000 T of screenings.

Wykoff Quarry

Operated by Milestone Materials in Fillmore County in southeastern Minnesota. Mining dolomitic limestone in the Stewartville Formation of the Ordovician Galena Group to produce crushed aggregates. Waste (excessive aggregate material) consists of 15,000 T of ag-lime.

Zaiger Quarry

Operated by Roverud Construction, Inc. near Brownsville in Houston County, southeastern Minnesota. Mining dolomite in the Oneota Formation of the Lower Ordovician Prairie du Chien Group to produce road rock, concrete aggregate, ag-lime, and filter stone. Stripping materials and -200 wash out are sold (wash fines are sold as fill); these are not considered wastes.

GNEISS QUARRIES

Morton Quarry

Operated by Southern Minnesota Construction (SMC) near Morton in Renville County in southwestern Minnesota. Mining the Archean Morton Gneiss to produce crushed aggregates. Waste consists of quarry fines from the crushing operation.

Rainbow Quarry

Operated by Cold Spring Granite Co., located near Morton in Renville County in southwestern Minnesota. Mining the Archean black and pink Morton Gneiss to produce dimension stone. Waste consists of 230,000 T of stockpiled grout, dust-sized to 40-ton blocks.

GRANITE QUARRIES

Agate Quarry

Operated by Cold Spring Granite Co., located near Ortonville in Big Stone County in far west central Minnesota. Mining a brown and orange, medium-grained granite to produce dimension stone. Waste consists of 50,000 T of stockpiled grout, dust-sized to 40-ton blocks.

Bellingham Quarry

Operated by Dakota Granite Co., in Bellingham, Lac Qui Parle County in western Minnesota. Mining a medium grained brown granite, the "Bellingham Granite," to produce dimension stone. Waste consists of a 200,000 T grout pile containing large granite blocks. There is currently not enough need nor material to justify the cost of crushing this oversize rock for sale as aggregate.

Charcoal No. 3 Quarry

Operated by Cold Spring Granite Co., located near St. Cloud in Stearns County in central Minnesota. Mining a gray granite to produce dimension stone. Waste consists of 750,000 T of stockpiled grout, dust-sized to 40-ton blocks.

Diamond Pink Quarry

Operated by Cold Spring Granite Co., located south of Waite Park in Stearns County in central Minnesota. This inactive quarry mined a light gray granite to produce dimension stone. Waste consists of 85,000 T of stockpiled grout, dust-sized to 40-ton blocks.

Isle Quarry

Operated by Cold Spring Granite Co., located near Isle in Mille Lacs County in east central Minnesota. Mining a white to gray granite - the Isle Granite - to produce dimension stone. Waste consists of 250,000 T of stockpiled grout, dust-sized to 40-ton blocks.

Lake Superior Green Quarry

Operated by Cold Spring Granite Co., located near Isabella in Lake County in the Arrowhead Region of northeastern Minnesota. Opened in 1994. Mining a green granite to produce dimension stone. Waste consists of 35,000 T of stockpiled grout, dust-sized to 40-ton blocks.

Mesabi Black Quarry

Operated by Cold Spring Granite Co., located near Babbitt in Lake County in the Arrowhead Region of northeastern Minnesota. Opened in 1995. Mining a black granite to produce dimension stone. Waste consists of 30,000 T of stockpiled grout, dust-sized to 40-ton blocks.

Ortonville Stone Co. Quarry

Operated by Ortonville Stone Co. in Ortonville, Big Stone County, in western Minnesota. Mining the Archean Ortonville Granite to produce ballast, aggregate, and sands. Waste consists of 5,000 T of -50 mesh stockpiled hydrocyclone product, the wash plant fines.

Purple Crystal Quarry

Operated by Cold Spring Granite Co. near St. Joseph in Stearns County in central Minnesota. This inactive quarry mined a light gray granite to produce dimension stone. Waste consists of 25,000 T of stockpiled grout, dust-sized to 40-ton blocks.

Rockville No. 1 Quarry

Operated by Cold Spring Granite Co. near Rockville in Stearns County in central Minnesota. Mining a white to beige granite to produce dimension stone. Waste consists of 300,000 T of stockpiled grout, dust-sized to 40-ton blocks.

Rockville No. 2 Quarry

Operated by Cold Spring Granite Co. near Rockville in Stearns County in central Minnesota. Mining a white to beige granite to produce dimension stone. Waste consists of 300,000 T of stockpiled grout, dust-sized to 40-ton blocks.

St. Cloud Quarry

Operated by Meridian Aggregates Co. in Waite Park, Stearns County, in central Minnesota. Mining granite from the St. Cloud and Reformatory Granites (Heine) to produce crushed aggregates. Wastes consist of drilling dust, -50 mesh hydrocyclone product from the wash plant, and baghouse dust.

Yellow Medicine Quarry

Operated by Meridian Aggregates Co. in Granite Falls, Yellow Medicine County, in southwestern Minnesota. Mining the Archean Montevideo Gneiss to produce crushed aggregates.

SCHIST QUARRIES

Ranier Quarry

Operated by Bowman Construction Co. near International Falls, Koochiching County, on the northern border of Minnesota. Mining biotite schist to produce crushed aggregate. No by-products are considered wastes: stripping is sold for topsoil; fines are used in blacktopping; old asphalt and concrete are recycled; and wood wastes are imported from Boise Cascade for composting purposes.

QUARTZITE QUARRIES

Jasper Stone Quarry

Operated by Jasper Stone Co. in Jasper near the Pipestone/Rock County line in southwestern Minnesota. Mining the Sioux Quartzite to produce grinding media and ball mill liners. Waste consists of a large stockpile of quartzite boulders which is partially being used by a small ancillary business to produce grave markers, benches, fireplaces, and signs.

Jeffers Quarry

Operated by Sioux Rock Products near Jeffers in Cottonwood County. Mining the Precambrian Sioux Quartzite to produce crushed and screened aggregate, and washed sands. Wastes consist of over 5,000 T of - # 40 sieve to -200 mesh quartzite fines from the washing process, stockpiled or in the settling pond.

New Ulm Quarry

Operated by New Ulm Quartzite Quarries, Inc. east of New Ulm in Nicollet County. Mining the Precambrian Sioux Quartzite to produce crushed aggregates, railroad ballast, landscape rock, rip rap, and poultry grit. Waste consists of 400,000 T of settled wash fines from the crushing plant, stockpiled or in ponds.

TRAP ROCK QUARRIES

Becks Quarry

Operated by Ulland Brothers, Inc. near the city of Duluth in St. Louis County, northeastern Minnesota. Mining Middle Proterozoic basalt of the North Shore Volcanic Group to produce concrete aggregate, bituminous mix, ballast, and rip rap. Waste consists of 20,000 T of stockpiled over-sized rock.

APPENDIX D

MINNESOTA DEPARTMENT OF AGRICULTURE AG-LIME ANALYSES

1) **Minnesota Quarry Listings from the 2001 Minnesota Department of Agriculture Ag-Lime Analysis Report**
   (<u>Ag-Lime Analysis Report</u>, 2001)

2) **2001 Minnesota Department of Agriculture Ag-Lime Analysis Report**
   (on CD: 2001 MN DEPT OF AG AG-LIME ANALYSES.xls)
   (<u>Ag-Lime Analysis Report</u>, 2001)

3) **2004 Minnesota Department of Agriculture Ag-Lime Analysis Report**
   (on CD: LIME_WEB.pdf)
   (provided by the Minnesota Department of Agriculture)

MINNESOTA QUARRY LISTINGS FROM THE 2001 MN DEPARTMENT OF AGRICULTURE AG-LIME ANALYSIS REPORT

Producer	County	City,State	Phone	Production Site	Type	Min Lbs ENP/Ton	Record No.	Analyzed	Sieve 8	Sieve 20	Sieve 60	Fineness	CCE	ENP	% Water
AGGREGATES INDUSTRIES-AGGREGATE DIV	Dakota	EAGAN, MN	651-683-0600	HASTINGS QUARRY	QUARRY	916	13	09/26/00	98.0	77.3	46.1	69.0	70.5	48.6	5.8
AGGREGATES INDUSTRIES-AGGREGATE DIV	Dakota	EAGAN, MN	651-683-0600	HASTINGS QUARRY - POND FINES	QUARRY	1221	14	09/26/00	99.5	98.7	94.5	97.2	69.5	67.5	9.6
AGGREGATES INDUSTRIES-AGGREGATE DIV	Goodhue	EAGAN, MN	651-683-0600	RED WING QUARRY	QUARRY	963	42	09/26/00	80.8	58.6	41.8	56.3	90.0	50.7	5.0
AGGREGATES INDUSTRIES-AGGREGATE DIV	Hennepin	EAGAN, MN	651-683-0600	YARD D	QUARRY	1110	49	10/11/00	91.6	68.5	50.8	66.0	87.8	58.0	4.3
AGGREGATES INDUSTRIES-AGGREGATE DIV	Ramsey	EAGAN, MN	651-683-0600	YARD A - CHILDS RD.	QUARRY	1023	106	09/26/00	90.1	60.4	41.4	58.7	89.9	52.8	3.1
ANDERSON TRUCKING	Goodhue	CANNON FALLS, MN	507-263-3526	WAGNER QUARRY - 2000 AG-LIME	QUARRY	973	38	09/14/00	98.4	71.1	44.9	66.1	77.7	51.3	5.2
ANDERSON TRUCKING	Goodhue	CANNON FALLS, MN	507-263-3526	WAGNER QUARRY - 1999 AG-LIME	QUARRY	1032	39	09/14/00	98.1	68.1	43.6	64.3	86.4	55.6	7.1
BONANZA GRAIN INC	Houston	CALEDONIA, MN	507-724-2044	NO 1. CALEDONIA QUARRY	QUARRY	1199	62	09/12/00	89.3	67.5	55.5	67.1	94.4	63.3	5.3
BONANZA GRAIN INC	Houston	CALEDONIA, MN	507-724-2044	CONKIFF QUARRY	QUARRY	1126	63	09/12/00	91.6	64.9	49.3	64.0	92.6	59.3	5.0
BONANZA GRAIN INC	Houston	CALEDONIA, MN	507-724-2044	EITZEN QUARRY	QUARRY	1049	64	11/15/00	91.1	62.9	42.7	60.5	90.3	54.6	3.9
BRYAN ROCK PRODUCTS INC	Scott	SHAKOPEE, MN	612-445-3900	FRONT QUARRY	QUARRY	895	120	08/23/00	83.1	54.9	34.5	52.4	89.4	46.8	4.4
BRYAN ROCK PRODUCTS INC	Washington	SHAKOPEE, MN	612-445-3900	BAYPORT QUARRY - OLD STOCKPILE	QUARRY	1031	136	08/23/00	91.0	62.8	43.0	60.5	91.3	55.3	6.7
BRYAN ROCK PRODUCTS INC	Washington	SHAKOPEE, MN	612-445-3900	BAYPORT QUARRY - 2000 PRODUCTION	QUARRY	1059	137	08/22/00	89.9	61.4	41.1	59.0	93.4	55.1	3.9
EDWARD KRAEMER & SONS INC	Dakota	BURNSVILLE, MN	952- 890-361	CLIFF RD QUARRY - SCREENED POND FINES	QUARRY	1471	10	05/03/00	99.5	99.2	96.8	98.3	82.4	81.0	9.2
EDWARD KRAEMER & SONS INC	Dakota	BURNSVILLE, MN	952-890-3611	CLIFF RD QUARRY - PEP SCREENED AG-LIME	QUARRY	1009	11	08/09/00	88.2	73.1	55.5	69.1	74.4	51.4	1.8
EDWARD KRAEMER & SONS INC	Dakota	BURNSVILLE, MN	952-890-3611	CLIFF RD QUARRY - BLENDED AG-LIME	QUARRY	1208	12	08/25/00	95.1	77.0	61.8	74.5	87.4	65.2	7.3
IOWA LIMESTONE CO	Scott	DES MOINES, IA	515-243-8106	SAVAGE MN PLANT-CC35 AG-LIME BLEND	QUARRY	1038	115	04/14/00	100.0	65.5	22.1	55.0	94.3	51.9	0.0
IOWA LIMESTONE CO	Scott	DES MOINES, IA	515-243-8106	SAVAGE, MN PLANT - CC45 AG-LIME #2	QUARRY	1499	116	04/14/00	100.0	99.9	49.5	79.8	94.0	75.0	0.0
IOWA LIMESTONE CO	Scott	DES MOINES, IA	515-243-8106	SAVAGE MN PLANT - CC60 AG-LIME 200	QUARRY	1806	117	04/17/00	100.0	100.0	94.8	97.9	92.2	90.3	0.0
IOWA LIMESTONE CO	Scott	DES MOINES, IA	515-243-8106	SAVAGE MN PLANT - CC30 AG-LIME #3	QUARRY	704	118	04/17/00	100.0	40.2	2.0	36.9	95.5	35.2	0.0
KIELMEYER CONSTRUCTION INC	Goodhue	NERSTRAND, MN	507-334-6088	HERNKE QUARRY - 2000 PRODUCTION	QUARRY	1096	44	09/08/00	98.3	70.1	44.7	65.6	88.4	58.0	5.5
KIELMEYER CONSTRUCTION INC	Goodhue	NERSTRAND, MN	507-334-6088	HERNKE QUARRY - 1998/1999 AG-LIME	QUARRY	1068	45	09/14/00	98.5	70.7	44.4	65.7	86.1	56.6	5.7
KIELMEYER CONSTRUCTION INC	Goodhue	NERSTRAND, MN	507-334-6088	FOSS QUARRY-2000 PRODTN (SOUTH END)	QUARRY	1143	46	11/16/00	99.0	74.2	48.4	68.8	87.2	60.0	4.8
KIELMEYER CONSTRUCTION INC	Goodhue	NERSTRAND, MN	507-334-6088	TRIPLE D QUARRY - 2000 PRODUCTION	QUARRY	1009	47	11/16/00	96.9	60.2	41.9	60.2	87.2	52.5	3.9
KNOBLAUCH LIME/ROCK CO	Goodhue	CANNON FALLS, MN	507-263-2995	SPRING GARDEN QUARRY	QUARRY	1005	40	10/24/00	98.0	67.7	43.3	64.0	83.4	53.4	5.9

Producer	County	City,State	Phone	Production Site	Type	Min Lbs ENP/Ton	Record No.	Analyzed	Sieve 8	Sieve 20	Sieve 60	Fineness	CCE	ENP	% Water
MILESTONE MATERIALS	Fillmore	ONALASKA, WI	608-783-6411	EGGERT QUARRY	QUARRY	1173	26	10/05/00	94.5	71.8	52.6	68.7	90.3	62.0	5.4
MILESTONE MATERIALS	Fillmore	ONALASKA, WI	608-783-6411	WYKOFF QUARRY	QUARRY	1132	27	10/05/00	90.0	65.3	49.9	64.1	95.3	61.1	7.3
MILESTONE MATERIALS	Fillmore	ONALASKA, WI	608-783-6411	BLY QUARRY	QUARRY	976	28	10/05/00	91.7	61.5	41.3	59.5	88.8	52.8	7.6
MILESTONE MATERIALS	Fillmore	ONALASKA, WI	608-783-6411	PILOT MOUND QUARRY	QUARRY	1194	29	10/05/00	94.9	72.1	47.8	66.9	94.3	63.1	5.4
MILESTONE MATERIALS	Fillmore	ONALASKA, WI	608-783-6411	RIFLE HILL QUARRY	QUARRY	855	30	10/05/00	86.9	55.0	33.8	52.9	84.3	44.6	4.1
MILESTONE MATERIALS	Fillmore	ONALASKA, WI	608-783-6411	GREENE QUARRY	QUARRY	883	31	10/11/00	89.0	63.0	44.1	60.6	77.3	46.9	5.8
MILESTONE MATERIALS	Fillmore	ONALASKA, WI	608-783-6411	FOUNTAIN QUARRY	QUARRY	1229	32	10/24/00	96.3	82.4	57.7	75.3	83.7	63.0	2.5
MILESTONE MATERIALS	Fillmore	ONALASKA, WI	608-783-6411	WYKOFF QUARRY - 2000 PRODUCTION	QUARRY	1239	33	11/16/00	94.0	70.3	54.5	68.7	96.4	66.3	6.5
MILESTONE MATERIALS	Olmsted	ONALASKA, WI	608-783-6411	WALSH QUARRY	QUARRY	1367	77	09/01/00	98.2	88.4	65.3	81.1	86.5	70.2	2.6
MILESTONE MATERIALS	Olmsted	ONALASKA, WI	608-783-6411	WILLEY QUARRY	QUARRY	808	78	09/11/00	89.8	56.6	33.6	54.0	79.3	42.9	5.7
MILESTONE MATERIALS	Olmsted	ONALASKA, WI	608-783-6411	RSG QRY - POND FINES	QUARRY	1112	79	09/11/00	98.3	96.1	83.0	91.3	64.7	59.1	5.9
MILESTONE MATERIALS	Olmsted	ONALASKA, WI	608-783-6411	GOLDBERG QUARRY - POND FINES	QUARRY	1526	80	09/15/00	99.6	99.2	94.6	97.4	84.4	82.2	7.2
MILESTONE MATERIALS	Olmsted	ONALASKA, WI	218-783-6411	GOLDBERG QUARRY - CATTLE BEDDING	QUARRY	879	81	09/13/00	96.2	70.7	20.3	55.6	82.4	45.9	4.1
MILESTONE MATERIALS	Olmsted	ONALASKA, WI	608-783-6411	SIXTY THREE QUARRY	QUARRY	938	82	10/24/00	88.4	57.9	35.1	54.9	87.9	48.2	2.8
MILESTONE MATERIALS	Olmsted	ONALASKA, WI	608-783-6411	HAMMELL QUARRY	QUARRY	820	83	11/15/00	86.2	57.5	36.8	55.0	78.7	43.3	5.2
MILESTONE MATERIALS	Wabasha	ONALASKA, WI	608-783-6411	SIGENTHALER QUARRY	QUARRY	878	130	09/08/00	82.3	58.3	39.2	55.5	83.4	46.3	5.1
MILESTONE MATERIALS	Wabasha	ONALASKA, WI	608-783-6411	BECKER QUARRY	QUARRY	979	131	09/08/00	93.9	68.1	42.7	63.1	83.8	52.9	7.4
MILESTONE MATERIALS	Wabasha	ONALASKA, WI	608-783-6411	HAMMOND QUARRY	QUARRY	1074	132	09/11/00	92.3	63.6	39.9	59.9	94.4	56.5	5.0
MILESTONE MATERIALS	Wabasha	ONALASKA, WI	608-783-6411	MOYER QUARRY	QUARRY	753	133	09/14/00	79.7	57.2	35.8	53.1	75.7	40.2	6.4
MILESTONE MATERIALS	Winona	ONALASKA, WI	608-783-6411	MC GUIRE QUARRY	QUARRY	931	138	09/27/00	81.8	59.3	40.6	56.3	87.4	49.2	5.4
MILESTONE MATERIALS	Winona	ONALASKA, WI	608-783-6411	FABIAN QUARRY	QUARRY	1118	139	09/27/00	97.3	76.0	47.4	68.8	87.4	60.2	7.1
MILESTONE MATERIALS	Winona	ONALASKA, WI	608-783-6411	BIESANZ QUARRY	QUARRY	1150	140	01/03/00	89.2	66.3	51.5	65.0	93.9	61.0	5.7
MILESTONE MATERIALS	Winona	ONALASKA, WI	608-783-6411	HWY 43 QUARRY	QUARRY	1188	141	10/03/00	90.0	67.1	52.8	66.0	95.3	62.9	5.5
MILESTONE MATERIALS	Winona	ONALASKA, WI	608-783-6411	HORNBERG QUARRY	QUARRY	1014	142	10/03/00	93.2	65.4	42.1	61.6	86.2	53.1	4.6
NELROCK INC	Goodhue	HAGER CITY, WI	715-792-2943	FLUEGER QUARRY	QUARRY	1328	43	10/04/00	99.1	78.1	53.0	72.3	96.9	70.0	5.2
ORVAL SORUM & SONS	Fillmore	WINONA, MN	507-454-3170	SORUM QUARRY	QUARRY	1118	37	10/11/00	94.1	71.3	47.5	66.3	85.8	56.9	1.8
OSMUNDSON BROS CONTRACTORS INC	Mower	ADAMS, MN	507-582-3503	GRAND MEADOW QUARRY	QUARRY	1355	74	09/01/00	98.2	75.4	51.9	70.6	105.9	74.8	9.4
PEDERSON BROS OF HARMONY INC	Fillmore	HARMONY, MN	507-886-3371	BIG SPRINGS QUARRY	QUARRY	1102	23	10/04/00	98.6	72.6	43.3	66.1	87.4	57.8	4.6
PEDERSON BROS OF HARMONY INC	Fillmore	HARMONY, MN	507-886-3371	ENGLE QUARRY	QUARRY	1182	24	10/04/00	96.0	70.9	52.3	68.5	92.2	63.1	6.4

Producer	County	City,State	Phone	Production Site	Type	Min Lbs ENP/Ton	Record No.	Analyzed	Sieve 8	Sieve 20	Sieve 60	Fineness	CCE	ENP	% Water
PEDERSON BROS OF HARMONY INC	Fillmore	HARMONY, MN	507-886-3371	GRABAU QUARRY	QUARRY	1037	25	10/05/00	98.1	71.8	49.1	68.0	79.9	54.3	4.5
ROBERSON LIME & ROCK INC	Wabasha	ZUMBRO FALLS, MN	507-753-2313	MOECHING QUARRY	QUARRY	1008	134	09/11/00	83.3	56.2	38.0	54.3	96.9	52.7	4.3
ROBERSON LIME & ROCK INC	Wabasha	ZUMBRO FALLS, MN	507-753-2313	ROBERSON QUARRY	QUARRY	935	135	09/14/00	84.3	55.3	35.4	53.1	92.3	49.1	4.7
ROVERUD CONSTRUCTION INC	Fillmore	SPRING GROVE, MN	507-498-3377	PETERSON QUARRY	QUARRY	1125	34	10/11/00	88.3	65.6	48.5	63.3	94.7	60.0	6.2
ROVERUD CONSTRUCTION INC	Fillmore	SPRING GROVE, MN	507-498-3377	ENGRAV QUARRY	QUARRY	1242	35	10/11/00	98.2	76.1	48.6	69.5	94.9	66.0	5.9
ROVERUD CONSTRUCTION INC	Fillmore	SPRING GROVE, MN	507-498-3377	BUFORD ANDERSON QUARRY	QUARRY	999	36	10/11/00	92.8	65.5	39.5	60.6	87.3	52.9	5.5
ROVERUD CONSTRUCTION INC	Houston	SPRING GROVE, MN	507-498-3377	DOBLER QUARRY	QUARRY	1311	65	09/11/00	98.5	76.4	55.0	72.3	95.5	69.0	5.0
ROVERUD CONSTRUCTION INC	Houston	SPRING GROVE, MN	507-498-3377	POOL HILL QUARRY	QUARRY	1136	66	09/12/00	97.6	72.7	48.1	67.8	89.0	60.4	5.9
ROVERUD CONSTRUCTION INC	Houston	SPRING GROVE, MN	507-498-3377	GENGLER QUARRY	QUARRY	1206	67	09/12/00	91.5	70.3	51.1	66.9	95.1	63.6	5.2
RUMPCA EXCAVATING INC	Goodhue	COTTAGE GROVE, MN	651-731-1066	RIES QUARRY (NW STOCKPILE)	QUARRY	772	41	10/04/00	67.8	50.4	36.2	48.2	84.4	40.7	5.1
SOLBERG AGGREGATE CO	Dakota	ROSEMOUNT, MN	651-437-6672	JACOB AVE QUARRY	QUARRY	1012	15	05/03/00	84.4	64.9	44.6	60.7	87.4	53.0	4.6
SOUTHERN MINNESOTA CONSTRUCTION	Blue Earth	MANKATO, MN	507-625-4848	KASOTA QUARRY	QUARRY	1048	4	10/12/00	90.2	67.4	52.4	66.0	85.8	56.6	7.4
SOUTHERN MINNESOTA CONSTRUCTION	Steele	MANKATO, MN	507-625-4848	OWATONNA QUARRY	QUARRY	872	129	09/01/00	85.0	58.9	43.2	57.8	80.5	46.6	6.4
STUSSY CONSTRUCTION INC	Dodge	MANTORVILLE, MN	507-635-2421	MANTORVILLE QUARRY	QUARRY	1389	22	09/01/00	99.4	86.1	58.0	77.5	94.4	73.2	5.1
STUSSY CONSTRUCTION INC	Olmsted	MANTORVILLE, MN	507-635-2421	ROCKDELL QUARRY	QUARRY	1303	75	09/01/00	99.8	82.1	55.8	75.1	91.0	68.4	4.7
STUSSY CONSTRUCTION INC	Olmsted	MANTORVILLE, MN	507-635-2421	MAYOWOOD QUARRY	QUARRY	1015	76	09/01/00	99.8	84.1	51.5	74.2	71.4	53.0	4.2
WM MUELLER & SONS INC	Scott	HAMBURG, MN	612-467-2720	WECKMAN QUARRY	QUARRY	915	119	08/23/00	90.8	56.5	34.3	54.5	88.0	47.9	4.6

APPENDIX E

University of Minnesota Study:
Evaluation of Rock Fines as a Sustainable Soil Amendment for Agriculture

Evaluation of Rock Fines as a Sustainable Soil Amendment for Agriculture

Final Report

Submitted to the
Minnesota Department of Natural Resources

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By

Carl Rosen, Monica Carrasco, and
Matthew McNearney

Department of Soil, Water, Climate
University of Minnesota
St. Paul, MN

Introduction

In Minnesota, over 50 million tons of aggregate are produced each year for road construction and buildings in which people live and work. Population growth and societal demands are driving aggregate consumption because crushed rock is a needed component for many of our roads and buildings. The current use of aggregate products is estimated to be 10 tons per person per year in Minnesota. Crystalline rock quarries (granite, basalt, quartzite) throughout the state generate in excess of 100,000 tons per year of rock fines. The amount of fines generated annually is likely to increase due to an increase in the state's population and stricter construction specifications. In the past, some of these rock fines were used as filler in asphalt products; however, state and federal agencies now restrict the percentage of fines in asphalt products and require an increasing amount of larger size crystalline rock for highway purposes. As part of the overall aggregate production, increased use of crystalline rock is increasing the amount rock fines generated. Currently, rock fines are being stockpiled as a waste product.

The overall objective of this research is to determine whether rock fines can be used as a nutrient source for crop production. If rock fines can be successfully recycled as a viable soil amendment, the use of fines could be an unexpected gain for state agriculture and reduce the amount of land used for surface storage. Farm input costs, particularly for organic agriculture, could potentially be reduced by using the rock fines compared to mined mineral products that must be shipped in from out of state. The results presented in this report represent the analytical phase of the project. This is the first step required in a three-year study to evaluate the agronomic potential for using the rock fines as a beneficial soil amendment.

Materials and Methods

Laboratory Analyses: Rock fines from four quarries were collected during the winter and spring of 1999. Six to eight subsamples were collected form each pile and then mixed to make up one composite sample. At each quarry, fines from two size fractions were collected and analyzed separately. The following samples were collected:

Location	**Rock type**	**Vendor**
Granite Falls, MN	Granite -Tower Sand	Meridian
Granite Falls, MN	Granite -Pond Settings	Meridian
St. Cloud, MN	Granite -Cyclone sand	Meridian
St. Cloud, MN	Granite -Pond Tailings	Meridian
St Cloud, MN	Granite -East	Cold Spring
St Cloud, MN	Granite -Shot Saw	Cold Spring
Dresser, WI	Basalt -Fines	Trap Rock
Dresser, WI	Basalt -Coarse	Trap Rock

The granite fines from Meridian and basalt fines from Trap Rock were from single quarries and represent the waste from aggregate production. In contrast, the granite from Cold Spring is shipped in from quarries all over the world for grave stone and monument production and fines represent a mixture of different types of granite. The different types of waste fines from each location are due to different processes involved with generation and management of the wastes.

Both chemical and physical properties of each rock fine type were determined in triplicate. Except for the saturation extract, all elemental determinations are expressed on a dry weight basis. For the saturation extract, elemental concentrations in the extract are presented. The following analyses were performed by the Research Analytical Laboratory at the University of Minnesota:

** Particle size fractionation B sieve and hydrometer method
** Moisture content
** pH, 1:1,(fines:water (wt/vol)
** Cation exchange capacity
** Total Nitrogen and Carbon
** Saturated paste extract (water) B soluble salts, pH, and soluble elements
** 0.01 N acetic acid extract - slightly soluble and plant available

** ammonium acetate extractable cations - (plant available)

** DTPA extractable micronutrients - (plant available)

** 1 Normal Nitric acid extractable elements - long term (1-5 years) plant available

** Microwave (concentrated nitric acid) digest - long term (1-100 years) plant available

For the saturated paste, acetic acid, 1 N nitric acid and concentrated nitric acid extracts, the following elements were determined using an inductively couple plasma spectrometer: Al, As, B, Ba, Be, Ca, Cd, Cl, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni., Pb, Rb, S, Si, Sr, Ti, V, and Zn. ICP was also used for ammonium acetate and DTPA extractions however, only a subset of these elements were determined.

Details of the methods used for extraction are available upon request.

Field Demonstrations: Four fields in central Minnesota were selected for rock fine application. For each field three rock fine types applied at two rates (10 tons and 20 tons per acre) as well as a non-amended control were tested. Each treatment was replicated three times. The following treatments were tested at each site:

Crop	**Rock fine types**
Corn	Basalt coarse; Granite east, Granite pond tailings
Hay	" "
Oats/clover	" "
grass/clover	Granite pond settlings, Granite east, Granite pond tailings

Applications were made with a lime spreader in the corn and oats/clover fields in mid-May and incorporated with a chisel plow. Surface applications were made with a lime spreader in the hay field in mid-May and in the grass/clover field in mid-June.

Soil samples at the 0-6 inch and 6-12 inch depths were collected from each field prior to rock fine application.

Results

Physical analysis:

Particle size distribution of the rock fines is presented in Tables 1 and 2. Highest amounts of clay size particles were found in the Cold Spring Granite east and the Granite Falls pond settlings. The coarsest rock fines were granite tower sand from Granite Falls, the Cyclone sand from St. Cloud and the Basalt coarse fraction from Dresser. In general, the greatest nutrient benefit from rock fines for agriculture will come from the finer fractions due to an increase in exposed surfaces for weathering and subsequent nutrient release. This generalization may not hold true if the finer fractions are made up of the more inert elements such as Si.

Chemical Analysis

pH, CEC, N, C, and Cl: The pH of all rock fines ranged between 8.6 and 9.7 (Table 3). This high pH was unexpected since none of the rock fines reacted with concentrated hydrochloric acid (fizz test). Total carbon and nitrogen were at very low levels and not considered significant from an agricultural amendment standpoint. All rock fines had a measurable cation exchange capacity indicating a slight negative charge capable of holding positively charged ions. The granite east sample had the highest CEC which corresponded to the highest clay content. In general, the higher the clay content the higher the CEC. A high CEC is desirable at cations adsorbed to the exchange complex are readily available to plant roots. Soluble chloride was generally low in all rock fines except for the shot saw sample. The high Cl in this sample is believed to be due the hydrochloric acid used in the processing of the fines.

Saturated Paste Extract: This extract was used to determine the concentrations of water soluble elements from rock fines. Soluble elements represent those that would be immediately available to plant roots. The pH of the saturated paste extract was 1 to 1.5 units lower than the 1:1 pH reading (Table 4). All reading were still in the alkaline range. Reasons for the lower readings with the more concentrated extract are probably due to due lower solubility of the mineral compounds (check). Except for the shot saw rock fine, the electrical conductivity (EC) of the saturated paste extract was less than 2 mmhos/cm. The higher EC of the shot saw sample is likely due to the processing of the fines rather than true solubility of the minerals. In general the finer the rock fine, the higher the EC values. This finding is expected since the finer particle are likely to be more soluble than the coarser ones. Since the electrical conductivity was low it is also not surprising that the concentrations of soluble elements were also low. Measurable concentrations of water soluble elements included: Al, B, Ba, Ca, Cl, Fe, K, Mg, Mn, Na, P, S, and Si. Cold Spring Shot Saw had the highest levels of soluble elements, with Na and Cl being the highest at 270 and 686 ppm, respectively.

Ammonium Acetate Extract: This extract is used to measure elements that are slightly adsorbed to soil particles. The extract is used extensively to estimate nutrient availability in sandy soils or potting mixes. Concentrations of Ca, K, Mg, Mn, Na, and S were at levels that could contribute to plant growth (Table 5). Granite Falls pond settlings and both Cold Spring samples had the highest levels of extractable Ca, Mg, and K.

Ammonium Acetate Extractable Cations and DTPA Extractable Microelements: These extracts are used extensively in soils and are calibrated to determine fertilizer needs. Granite Falls pond settlings and both Cold Spring samples had the highest levels of extractable Ca, Mg, and K (Table 6). The levels of these nutrients were slightly higher than those found in typical soils. For the other rock fine samples, Ca levels were similar to soil, but K and Mg were at levels generally considered to be medium of low for soils. Extractable Cu levels were highest in the fine basalt sample (Table 7). None of the samples had high levels of DTPA extractable Zn. Extractable levels of Pb, Ni, Cd, and Cr were either below detection limits or at levels typical for soil.

One Normal Nitric Acid Extractable Elements: This extract measures elements that are moderately bound. Availability of these elements to plants is not expected to be immediate. Depending on weathering conditions, 5 or more years may be required before elements extracted by this procedure become available. Generally, the trends for this extractant were similar to the acetic acid extract except that the concentrations of elements were higher (Table 8). The higher concentrations reflect the harsher extractant. All elements except Rb were generally above detection limits of the ICP. One rock fine, Cold Spring Shot Saw, had unusually high Co levels.

Concentrated Nitric Acid Microwave Digest Extractable Elements: The microwave digest was the harshest extractant used in this study. Theoretically, concentrations of all elements should be the highest with this extractant. However, As, B, Be, Cd, Mo, Pb, and Rb were often below detection limits (Table 9). For the other elements, concentrations were higher than the other extractants. The reason for this apparent anomaly is due to the greater dilution used for the microwave extract, which raised the detection limit. For elements in lower concentrations in the rock fines, the greater dilution caused them to be below detection limits. For elements at higher concentrations such as Al, Fe, Ca, K, Mg, Na, P, S, Si, Ti, V, and Zn, the microwave digest extracted higher levels of elements than the 1 N nitric acid digest.

Implications for Rock Fine Application to Agricultural Fields

All rock fines had relatively low levels of soluble elements for crop production. An estimate of the amount of K per ton of rock fines as a function of the various extractants is presented in Table 10. While the more harsher chemicals extracted higher levels of elements, the total amount of K supplied per ton relative to plant requirements is relatively low. For example, a typical fertilizer recommendation for corn or alfalfa may be 100 to 200 lbs K per acre. Assuming all the K from the microwave digest is available, 10 to 20 tons per acre of the granitic rock fines would be required and 50 to 100 tons of the basalt rock fines would be required to meet plant demands. The basalt rock fines had a much lower level of K but higher level of Mg than granitic rock fines. Thus the granitic rock fines would be more appropriate for low K soils and the basalt rock fines would be more appropriate for low Mg soils.

Ultimate nutrient availability from rock fines will depend on weathering processes. Therefore, the finer the particle size and the higher the elemental composition, the more beneficial the rock fines will be from a nutrient standpoint. Nutrient release from the rock fines will be studied over the next three years in field studies

Field Study - preliminary report

Four fields were selected in central Minnesota to test the effects of rock fines on crop production. Soil tests were taken prior to application and results are presented in Tables 11-14. In general, soil K levels were in the low to medium range, where a crop response to K would be expected. Crop yields, soil nutrient levels, and tissue nutrient levels will be measured over the next two growing seasons to evaluate the potential for rock fines to be used as a beneficial soil amendment.

Table 1: Particle size distribution of selected Rock Fines

Location	**Rock Type**	**% Clay <0.002mm**		**%Silt 0.002-0.05mm**		**%Sand 0.05-2.0mm**		**%Gravel >2.0mm**	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Granite Falls	Granite –Tower Sand	1.3	0.4	13.7	2.8	85.0	2.5	0.03	0.04
Granite Falls	Granite - Pond Settlings	10.3	0.4	80.0	0.8	9.7	0.8	0.03	0.04
St, Cloud	Granite - Cyclone Sand	1.0	0.4	12.3	2.4	86.6	2.8	0.08	0.04
St, Cloud	Granite - Pond Tailing	2.5	0.6	19.4	3.5	78.1	3.8	0.05	0.05
Cold Spring	Granite - East	19.3	0.8	69.0	2.0	11.7	1.1	0.00	0.00
Cold Spring	Granite - Shot Saw	6.0	0.7	79.4	1.3	14.6	1.2	0.00	0.00
Dresser, WI	Basalt - Fines	6.8	0.8	73.8	1.3	19.9	1.1	0.00	0.00
Dresser, WI	Basalt - Coarse	1.7	0.0	7.9	1.2	90.2	1.2	0.13	0.09

Table 2: Sand fraction size distribution of selected Rock Fines

Location	**Rock Type**	**Sand %**									
		>1 mm **Very Coarse**		1-0.5mm **Coarse**		0.5-0.25 mm **Medium**		0.25-0.1 mm **Fine**		0.1-0.05 mm **Very Fine**	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Granite Falls	Granite -Tower Sand	0.6	0.6	2.6	2.1	8.8	6.2	35.1	4.2	37.9	11.9
Granite Falls	Granite -Pond Settlings	0.2	0.1	0.3	0.1	0.3	0.1	1.0	0.2	8.1	0.7
St. Cloud	Granite - Cyclone Sand	1.4	0.8	5.2	2.4	15.9	6.8	39.8	4.0	24.2	10.6
St. Cloud	Granite - Pond Tailings	1.1	0.3	4.1	0.4	14.7	1.2	37.4	2.4	20.9	0.4
Cold Spring	Granite - East	0.4	0.2	2.4	0.5	3.5	0.6	2.9	0.6	2.5	0.6
Cold Spring	Granite - Shot Saw	0.1	0.0	0.6	0.2	1.7	0.2	4.4	0.8	7.9	0.8
Dresser, WI	Basalt-Fines	0.1	0.1	0.1	0.0	0.2	0.1	4.9	0.4	14.7	0.8
Dresser, WI	Basalt -Coarse	0.8	0.1	8.1	0.5	33.9	1.5	31.9	0.2	15.6	0.8

Table 3: Moisture Content, pH, CEC, Total N, Organic Carbon and Soluble CL in Granite and Basalt Rock Fines

		Property											
		pH		**CEC** Meq/100 gm		**Total N** (%)		**Organic Carbon** (%)		**Moisture** (%) dry wt.		**Cl** ppm	
Location	**Rock type**	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Granite Falls	Granite -Tower Sand	9.3	0.1	1.3	0.2	0.011	0.005	0.02	0.01	6	0	4	1
Granite Falls	Granite -Pond Settlings	9.0	0.1	5.9	0.1	0.013	0.004	0.10	0.01	30	1	14	4
St. Cloud	Granite -Cyclone sand	9.0	0.0	1.2	0.1	0.044	0.004	0.04	0.02	16	1	15	3
St. Cloud	Granite -Pond Tailings	8.6	0.1	1.4	0.2	0.027	0.005	0.03	0.03	10	1	3	0
Cold Spring	Granite -East	8.8	0.1	9.9	0.2	0.020	0.003	0.30	0.02	25	2	15	1
Cold Spring	Granite -Shot Saw	9.5	0.1	4.3	0.0	0.032	0.003	0.40	0.04	22	0	428	33
Dresser, WI	Basalt -Fines	9.7	0.0	2.5	0.1	0.014	0.006	0.01	0.00	1	0	16	1
Dresser, WI	Basalt -Coarse	9.4	0.1	1.2	0.1	0.008	0.003	0.02	0.01	1	0	4	1

Table 4: Saturated paste extractable elements from Granite and Basalt Rock Fines

		Elements in solution																
		pH		**EC** mmhos/cm		**Al**		**As**	**B**		**Ba**		**Be**	**Ca**		**Cd**	**Cl**	
Location	**Rock type**	Mean	SD	Mean	SD	Mean	SD	Mean	Mean	SD	Mean	SD	Mean	Mean	SD	Mean	Mean	SD
Granite Falls	Granite -Tower Sand	8.3	0.1	0.4	0.0	0.3	0.0	<0.04	0.1	0.00	0.03	0.01	<0.002	28	1	<0.006	8	1
Granite Falls	Granite -Pond Settlings	7.8	0.1	0.9	0.1	<0.4		<0.04	0.2	0.01	0.05	0.01	<0.002	49	7	<0.006	37	3
St. Cloud	Granite - Cyclone sand	7.6	0.1	0.7	0.0	<0.6		<0.04	0.1	0.01	0.06	0.04	<0.002	71	6	<0.006	53	1
St. Cloud	Granite -Pond Tailings	7.5	0.1	1.3	0.1	0.4	0.1	<0.04	0.1	0.00	0.04	0.01	<0.002	139	2	<0.006	11	1
Cold Spring	Granite -East	8.2	0.0	0.8	0.1	1.0	0.0	<0.04	0.1	0.00	0.04	0.03	<0.002	21	0	<0.006	49	6
Cold Spring	Granite -Shot Saw	8.6	0.1	2.9	0.1	<0.2		<0.04	0.1	0.01	0.07	0.01	<0.002	24	1	<0.006	686	17
Dresser, WI	Basalt - Fines	8.8	0.1	0.6	0.0	0.7	0.1	<0.04	0.0	0.01	<0.01		<0.002	6	0	<0.006	58	3
Dresser, WI	Basalt - Coarse	8.8	0.0	0.3	0.0	1.7	0.5	<0.04	0.1	0.01	0.01	0.00	<0.002	6	1	<0.006	15	2

Table 4, continued: Saturated paste extractable elements from Granite and Basalt Rock Fines

		Elements mg/Kg																		
		Co	**Cr**		**Cu**		**Fe**		**K**		**Li**		**Mg**		**Mn**		**Mo**		**Na**	
Location	**Rock type**	Mean	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Granite Falls	Granite -Tower Sand	<0.012	<0.014		<0.026		0	0	13	1	<0.02		9	0	0.02	0.00	0.05	0	22	1
Granite Falls	Granite -Pond Settlings	<0.012	<0.014		<0.029		1	1	20	1	0.03	0.0	19	3	0.03	0.02	0.10	0	67	3
St. Cloud	Granite - Cyclone sand	<0.012	<0.014		<0.027		1	1	20	3	0.05	0.0	27	2	0.03	0.01	0.08	0	31	4
St. Cloud	Granite -Pond Tailings	<0.012	<0.014		<0.026		1	0	26	1	0.06	0.0	50	1	0.03	0.01	0.08	0	47	1
Cold Spring	Granite -East	<0.012	<0.014		<0.026		1	0	27	1	<0.02		3	0	0.02	0.00	0.20	0	121	4
Cold Spring	Granite -Shot Saw	<0.012	0.015	0.0	<0.026		0	0	180	66	0.10	0.0	136	7	0.01	0.00	0.08	0	270	17
Dresser, WI	Basalt - Fines	<0.012	<0.014		<0.026		1	0	15	1	<0.02		2	0	0.01	0.00	<0.01		104	1
Dresser, WI	Basalt - Coarse	<0.012	<0.014		0.060	0.0	2	1	8	0	<0.02		4	1	0.04	0.02	0.01	0	52	3

Table 4, continued: Saturated paste extractable elements from Granite and Basalt Rock Fines

		Elements mg/Kg																
		Ni	**P**		**Pb**	**Rb**	**S**		**Si**		**Sr**		**Ti**		**V**		**Zn**	
Location	**Rock type**	Mean	Mean	SD	Mean	Mean	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Granite Falls	Granite -Tower Sand	<0.02	0.05	0.01	<0.08	<2.65	35	1	5	0	0	0	<0.01		<0.02		<0.01	
Granite Falls	Granite -Pond Settlings	<0.02	0.08	0.03	<0.08	<2.65	82	11	7	1	1	0	<0.03		<0.02		<0.01	
St. Cloud	Granite - Cyclone sand	<0.02	0.10	0.05	<0.08	<2.65	79	6	6	1	0	0	<0.04		<0.02		0.03	0.01
St. Cloud	Granite -Pond Tailings	<0.02	0.09	0.05	<0.08	<2.65	183	1	5	0	1	0	<0.02		<0.02		0.02	0.01
Cold Spring	Granite -East	<0.02	0.11	0.01	<0.08	<2.65	53	1	5	0	0	0	<0.01		<0.02		<0.01	
Cold Spring	Granite -Shot Saw	<0.02	0.19	0.01	<0.08	<2.65	92	4	5	1	0	0	<0.01		<0.02		0.01	0.01
Dresser, WI	Basalt - Fines	<0.02	0.08	0.01	<0.08	<2.65	5	0	7	0	0	0	0.01	0.01	0.03	0.0	<0.01	
Dresser, WI	Basalt - Coarse	<0.02	0.14	0.10	<0.08	<2.65	15	1	8	0	0	0	0.07	0.01	0.03	0.0	0.01	0.00

Table 5: 0.1 N Acetic Acid extractable elements from Granite and Basalt Rock Fines

		Elements mg/Kg																	
		Al		**B**		**Ca**		**Cd**	**Co**	**Cr**	**Cu**		**Fe**		**K**		**Li**	**Mg**	
Location	**Rock type**	Mean	SD	Mean	SD	Mean	SD	Mean	Mean	Mean	Mean	SD	Mean	SD	Mean	SD	Mean	Mean	SD
Granite Falls	Granite -Tower Sand	<0.9		<0.11		915	127	<0.03	<0.06	<0.07	0.19	0.03	4.20	0.2	36	1	<0.1	44	2
Granite Falls	Granite -Pond Settlings	<0.9		0.21	0.01	1448	7	<0.03	<0.06	<0.07	<0.13		<0.08		114	4	<0.1	181	6
St. Cloud	Granite – Cyclone sand	1.5	0.1	<0.11		757	26	<0.03	<0.06	<0.07	0.22	0.00	2.20	0.3	35	4	<0.1	45	2
St. Cloud	Granite -Pond Tailings	1.2	0.1	<0.11		1029	36	<0.03	<0.06	<0.07	0.16	0.01	1.80	0.3	47	2	<0.1	64	4
Cold Spring	Granite -East	<0.9		0.24	0.01	1163	26	<0.03	<0.06	<0.07	<0.13		<0.08		220	7	<0.1	92	2
Cold Spring	Granite -Shot Saw	<0.9		0.21	0.02	1401	38	<0.03	<0.06	<0.07	<0.13		<0.08		206	11	0.2	369	15
Dresser, WI	Basalt - Fines	<0.9		0.21	0.03	1061	28	<0.03	<0.06	<0.07	0.25	0.02	0.30	0.0	92	3	<0.1	88	2
Dresser, WI	Basalt - Coarse	1.6	0.2	<0.11		117	26	<0.03	<0.06	<0.07	1.40	0.30	1.90	0.1	16	2	<0.1	18	3

Table 5, continued: 0.1 N Acetic Acid extractable elements from Granite and Basalt Rock Fines

		Elements mg/Kg																			
		Mn		**Mo**	**Na**		**Ni**		**NO_3-N**		**NH_4-N**		**P**		**Pb**	**S**		**Ti**	**V**	**Zn**	
Location	**Rock type**	Mean	SD	Mean	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	Mean	SD	Mean	Mean	Mean	SD
Granite Falls	Granite -Tower Sand	18	3	<0.05	16	1	0.15	0.02	2	0.1	2	0	<0.19		<0.42	16	1	<0.07	<0.09	0.22	0.01
Granite Falls	Granite -Pond Settlings	15	1	<0.05	79	8	0.15	0.01	2	0.2	4	1	<0.19		<0.42	45	7	<0.07	<0.09	0.05	0.01
St. Cloud	Granite - Cyclone sand	16	7	<0.05	17	2	<0.11		1	0.1	3	0	0.20	0.06	<0.42	25	8	<0.07	<0.09	0.62	0.07
St. Cloud	Granite -Pond Tailings	16	1	<0.05	24	1	0.14	0.01	4	0.2	2	0	<0.17		<0.42	66	2	<0.07	<0.09	0.60	0.06
Cold Spring	Granite -East	8	1	<0.05	218	20	0.19	0.01	3	0.1	7	2	0.19	0.04	<0.42	35	6	<0.07	<0.09	0.05	0.01
Cold Spring	Granite -Shot Saw	1	0	<0.05	236	9	<0.11		1	0.1	2	0	0.19	0.01	<0.42	64	1	<0.07	<0.09	<0.03	
Dresser, WI	Basalt - Fines	8	0	<0.05	141	5	<0.11		2	0.1	4	0	0.19	0.02	<0.42	3	0	<0.07	<0.09	0.07	0.01
Dresser, WI	Basalt - Coarse	2	0	<0.05	25	4	<0.11		2	0.3	2	0	0.76	0.10	<0.42	3	1	<0.07	<0.09	0.06	0.02

Table 6: Ammonium Acetate Extractable Cations from Granite and Basalt Rock Fines.

		Elements mg/kg									
		Ca		**K**		**Mg**		**Mn**		**Na**	
Location	**Rock type**	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Granite Falls	Granite -Tower Sand	1360	40	33	0	49	1	23	1	11	0
Granite Falls	Granite -Pond Settlings	2888	10	146	14	251	7	37	1	71	2
St. Cloud	Granite -Cyclone sand	1215	30	38	3	53	2	16	1	13	0
St. Cloud	Granite -Pond Tailings	1343	118	49	6	71	6	17	2	20	1
Cold Spring	Granite -East	2510	30	525	14	153	3	14	1	214	7
Cold Spring	Granite -Shot Saw	3408	103	423	16	993	55	3	0	251	11
Dresser, WI	Basalt -Fines	1364	12	96	0	84	1	6	0	129	1
Dresser, WI	Basalt -Coarse	633	40	30	1	60	6	6	0	38	1

Table 7: DTPA extractable elements from Granite and Basalt Rock Fines.

		Elements mg/kg															
		Fe		**Mn**		**Zn**		**Cu**		**Pb**		**Ni**		**Cd**		**Cr**	
Location	**Rock type**	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Granite Falls	Granite -Tower Sand	11	0	3	0	0	0.0	1	0.0	1.00	0.0	<0.04		0.01	0.0	<0.02	
Granite Falls	Granite -Pond Settlings	37	2	6	1	1	0.1	6	0.1	2.00	0.0	0.10	0.0	<0.01		0.05	0.0
St. Cloud	Granite - Cyclone sand	13	0	3	0	1	0.0	1	0.0	3.00	0.1	<0.04		0.01	0.0	<0.02	
St. Cloud	Granite -Pond Tailings	14	1	3	0	1	0.1	1	0.1	3.00	0.2	<0.04		0.01	0.0	<0.02	
Cold Spring	Granite -East	239	8	37	1	1	0.0	7	0.4	1.00	0.0	1.30	0.1	0.03	0.0	<0.02	
Cold Spring	Granite -Shot Saw	68	3	6	0	3	0.2	9	0.4	2.00	0.1	1.20	0.1	<0.01		0.20	0.0
Dresser, WI	Basalt -Fines	23	0	3	0	0	0.0	21	0.2	<0.16		<0.04		<0.01		<0.02	
Dresser, WI	Basalt - Coarse	10	0	3	0	0	0.0	5	0.1	<0.16		<0.04		<0.01		<0.02	

Table 8: 1 Normal Nitric Acid extractable elements from Granite and Basalt Rock Fines

		Elements mg/Kg																			
		Al		**As**		**B**		**Ba**		**Be**		**Ca**		**Cd**		**Co**		**Cr**		**Cu**	
Location	**Rock type**	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Granite Falls	Granite -Tower Sand	1125	11	2	0.0	1	0.1	18	0	0.04	0.00	5314	177	0.4	0.00	<0.1		4	0.2	10	0.2
Granite Falls	Granite -Pond Settlings	2203	41	3	0.0	2	0.1	38	1	0.10	0.00	7615	67	0.8	0.04	<0.2		6	0.5	29	0.2
St. Cloud	Granite - Cyclone sand	835	14	2	0.1	1	0.1	17	0	0.06	0.00	4887	127	0.4	0.02	<0.1		2	0.1	5	0.2
St. Cloud	Granite -Pond Tailings	1026	23	3	0.1	1	0.1	21	0	0.07	0.01	5138	96	0.4	0.01	<0.1		3	0.1	6	0.1
Cold Spring	Granite -East	3210	49	6	0.1	6	0.2	72	1	0.10	0.00	6301	359	2.7	0.05	<1.2		14	0.3	35	0.4
Cold Spring	Granite -Shot Saw	3199	75	5	0.1	6	0.1	52	1	0.10	0.00	9610	486	1.3	0.10	136.0	5	14	2.0	55	1.0
Dresser, WI	Basalt - Fines	2089	15	2	0.1	2	0.0	6	0	0.05	0.01	4254	32	0.4	0.01	1.5	0	4	0.0	70	0.4
Dresser, WI	Basalt - Coarse	575	18	1	0.0	1	0.0	2	0	<0.02		2939	66	0.1	0.01	0.4	0	2	0.1	33	1.0

Table 8, continued: 1 Normal Nitric Acid extractable elements from Granite and Basalt Rock Fines

		Elements mg/Kg																			
		Fe		**K**		**Li**		**Mg**		**Mn**		**Mo**		**Na**		**Ni**		**P**		**Pb**	
Location	**Rock type**	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Granite Falls	Granite -Tower Sand	2816	37	1184	7	4	0.0	889	10	147	5	1	0.0	40	1	3	0	821	21	6	0
Granite Falls	Granite -Pond Settlings	5569	267	1544	11	5	0.0	1912	26	254	3	1	0.0	143	4	6	0	717	1	16	0
St. Cloud	Granite - Cyclone sand	2217	39	931	12	4	0.1	572	3	109	5	1	0.0	56	25	1	0	650	1	11	0
St. Cloud	Granite -Pond Tailings	2646	39	1113	15	5	0.1	686	21	122	4	1	0.0	56	1	1	0	688	5	14	2
Cold Spring	Granite -East	23344	465	1467	11	4	0.1	1344	137	280	3	2	0.0	379	6	30	0	204	6	17	1
Cold Spring	Granite -Shot Saw	10136	965	1319	40	4	0.1	4677	280	122	9	2	0.2	701	24	21	1	598	6	19	1
Dresser, WI	Basalt - Fines	2566	14	629	4	1	0.0	1752	15	90	1	1	0.0	308	2	6	0	874	8	4	0
Dresser, WI	Basalt - Coarse	775	13	775	13	0	0.0	561	17	37	1	0	0.0	86	2	2	0	697	3	1	0

Table 8, continued: 1 Normal Nitric Acid extractable elements from Granite and Basalt Rock Fines

		Elements mg/Kg												
		Rb	**S**		**Si**		**Sr**		**Ti**		**V**		**Zn**	
Location	**Rock type**	Mean	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Granite Falls	Granite -Tower Sand	<26.5	25	1	1332	6	6	0	89	0	3	0	13	0
Granite Falls	Granite -Pond Settlings	<26.5	61	9	1835	24	20	0	74	2	6	0	25	1
St. Cloud	Granite - Cyclone sand	<26.5	33	1	927	5	6	0	73	0	3	0	11	0
St. Cloud	Granite -Pond Tailings	<26.5	76	3	1003	18	7	0	74	1	4	0	13	0
Cold Spring	Granite -East	<26.5	19	1	4470	78	19	0	37	1	25	1	18	0
Cold Spring	Granite -Shot Saw	<26.5	120	8	3769	80	22	1	66	2	7	0	25	1
Dresser, WI	Basalt - Fines	<26.5	15	0	1705	10	7	0	39	0	7	0	8	0
Dresser, WI	Basalt - Coarse	<26.5	12	1	553	20	5	0	14	1	3	0	3	0

Table 9: Microwave digest with concentrated Nitric Acid extractable elements from Granite and Basalt Rock Fines

		Elements mg/Kg																		
		Al		**As**		**B**	**Ba**		**Be**		**Ca**		**Cd**		**Co**		**Cr**		**Cu**	
Location	**Rock type**	Mean	SD	Mean	SD	Mean	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Granite Falls	Granite -Tower Sand	7480	846	<3.1		<3.60	65	6	<0.16		6329	236	<0.53		10	1	50	6	24	1
Granite Falls	Granite -Pond Settlings	13735	1132	<3.3		<1.84	105	1	0.32	0	9727	422	<0.48		17	0	61	5	70	1
St. Cloud	Granite - Cyclone sand	8251	770	3.8	0.5	<1.84	72	5	0.24	0	6806	683	<0.48		9	0	19	1	13	1
St. Cloud	Granite -Pond Tailings	10124	351	3.9	0.1	<1.84	87	3	0.32	0	7641	276	<0.48		11	0	23	2	14	1
Cold Spring	Granite -East	9863	307	6.5	0.2	<1.84	149	5	0.24	0	7560	302	<0.48		12	0	31	1	49	0
Cold Spring	Granite -Shot Saw	13202	590	4.4	0.2	<1.84	159	2	0.24	0	13996	332	<0.48		136	10	36	1	80	3
Dresser, WI	Basalt - Fines	26055	5791	<3.2		<1.84	15	3	<0.16		16163	6812	<0.48		41	1	34	1	121	3
Dresser, WI	Basalt - Coarse	15353	870	3.4	0.1	<1.84	8	0	<0.16		6695	664	0.68	0.1	33	1	24	1	121	10

Table 9, continued: Microwave digest with concentrated Nitric Acid extractable elements from Granite and Basalt Rock Fines

		Elements mg/Kg																			
		Fe		**K**		**Li**		**Mg**		**Mn**		**Mo**		**Na**		**Ni**		**P**		**Pb**	
Location	**Rock type**	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Granite Falls	Granite -Tower Sand	18208	2040	4281	162	22	1	6987	461	309	12	<0.88		207	106	28	2	865	16	<6.7	
Granite Falls	Granite -Pond Settlings	30807	1037	5960	165	32	1	11927	249	487	5	<0.88		555	72	38	1	796	5	15.0	0
St. Cloud	Granite - Cyclone sand	19304	1394	4519	235	38	2	6161	336	289	20	<1.00		229	38	8	0	697	25	10.0	1
St. Cloud	Granite -Pond Tailings	22161	603	5094	114	42	1	7135	156	320	14	<0.88		380	77	10	0	741	19	14.0	4
Cold Spring	Granite -East	55336	947	4298	147	18	0	4003	71	526	6	<1.00		1246	108	42	1	478	4	12.0	1
Cold Spring	Granite -Shot Saw	29279	474	5683	213	19	0	8679	449	283	13	3.00	1	2856	353	32	1	601	3	12.0	1
Dresser, WI	Basalt - Fines	40209	4016	1478	141	13	1	22322	283	656	45	<0.88		1556	489	84	1	892	3	<6.7	
Dresser, WI	Basalt - Coarse	29760	1776	998	17	10	0	17372	556	490	18	<0.88		421	47	69	2	729	12	<6.7	

Table 9, continued: Microwave digest with concentrated Nitric Acid extractable elements from Granite and Basalt Rock Fines

		Elements mg/Kg												
		Rb	**S**		**Si**		**Sr**		**Ti**		**V**		**Zn**	
Location	**Rock type**	Mean	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Granite Falls	Granite -Tower Sand	<212	118	24	368	148	11	2	1212	187	34	6	54	3
Granite Falls	Granite -Pond Settlings	<212	217	3	563	36	34	5	1631	37	54	3	101	3
St. Cloud	Granite - Cyclone sand	<212	238	13	222	44	13	2	1449	175	36	3	52	3
St. Cloud	Granite -Pond Tailings	<212	300	14	289	13	19	1	1758	32	43	1	60	3
Cold Spring	Granite -East	<212	184	10	855	21	35	1	1111	38	91	1	46	10
Cold Spring	Granite -Shot Saw	<212	445	10	668	133	54	1	1282	5	57	6	56	2
Dresser, WI	Basalt - Fines	<212	63	18	451	104	53	2	1803	226	82	10	81	2
Dresser, WI	Basalt - Coarse	<212	48	4	378	24	18	3	924	110	53	4	64	2

Table 10: Lbs. per Ton in selected Rock Fines based on four extractants

Location	**Rock type**	**0.01 N Acetic Acid**	**1 N Ammonium Acetate**	**1 N Nitric acid**	**Conc. Nitric acid**
Granite Falls	Granite -Tower Sand	0.07	0.07	2.4	8.6
Granite Falls	Granite -Pond Settlings	0.23	0.29	3.1	11.9
St. Cloud	Granite –Cyclone Sand	0.07	0.08	1.9	9.0
St. Cloud	Granite -Pond Tailings	0.09	0.10	2.2	10.2
Cold Spring	Granite –East	0.44	1.10	2.9	8.6
Cold Spring	Granite –Shot Saw	0.41	0.85	2.6	11.9
Dresser, WI	Basalt -Fines	0.18	0.19	1.3	3.0
Dresser, WI	Basalt - Coarse	0.03	0.06	1.6	2.0

Table 11a: Initial soil samples collect at Gutches Grove-Corn field- May 1999.

Soil Depth Inches	**Organic Matter** %	**pH**	Elements ppm							
			Bray P	**Olsen P**	**K**	**Ca**	**Mg**	**Na**	**SO_4-S**	**B**
0 - 6	2.8	6.0	9	5	48	1431	130	7	3	0.4
6 - 12	1.8	6.2	9	4	37	1163	108	7	2	0.3

Table 11b: Initial soil samples collected at Gutches Grove- Corn field- May 1999.

Soil Depth Inches	Elements ppm							
	Fe	**Mn**	**Zn**	**Cu**	**Pb**	**Ni**	**Cd**	**Cr**
0 - 6	68	16	1.0	0.5	0.5	1.0	0.06	<0.02
6 - 12	59	8	0.5	0.4	0.4	0.8	0.03	<0.02

Table 12a: Initial soil samples collected at Gutches Grove-Oats field- May 1999.

Soil Depth Inches	**Organic Matter** %	**pH**	Elements ppm							
			Bray P	**Olsen P**	**K**	**Ca**	**Mg**	**Na**	**SO_4-S**	**B**
0 - 6	4.2	6.6	8	6	60	2550	221	7	6	0.5
6 - 12	2.8	6.4	4	4	54	2275	239	11	2	0.4

Table 12b: Initial soil samples collected at Gutches Grove- Oats field- May 1999.

Soil Depth Inches	Elements ppm							
	Fe	**Mn**	**Zn**	**Cu**	**Pb**	**Ni**	**Cd**	**Cr**
0 - 6	151	44	1.0	0.7	0.8	1.6	0.06	<0.02
6 - 12	188	44	0.7	0.9	0.7	1.8	0.04	<0.02

Table 13a: Initial soil samples collected at Gutches Grove-Hay field- May 1999.

Soil Depth Inches	**Organic Matter** %	**pH**	Elements ppm							
			Bray P	**Olsen P**	**K**	**Ca**	**Mg**	**Na**	**SO_4-S**	**B**
0 - 6	5.4	7.3	3	4	75	3910	455	15	5	0.6
6 - 12	3.5	7.2	3	3	61	3224	365	14	4	0.5

Table 13b: Initial soil samples collected at Gutches Grove-Hay field- May 1999.

Soil Depth Inches	Elements ppm							
	Fe	**Mn**	**Zn**	**Cu**	**Pb**	**Ni**	**Cd**	**Cr**
0 - 6	90	28	1.0	0.9	1.1	1.4	0.07	0.04
6 - 12	147	57	0.7	1.0	1.0	1.7	0.05	0.04

Table 14a: Initial soil samples collected at Eagle Bend, clover field- May 1999.

Soil Depth Inches	**Organic Matter** %	**pH**	Elements ppm							
			Bray P	**Olsen P**	**K**	**Ca**	**Mg**	**Na**	**SO_4-S**	**B**
0 - 6	3.6	6.2	14	9	39	1781	136	6	3	0.45
6 - 12	2.2	6.3	7	5	28	1360	95	5	2	0.34

Table 14b: Initial soil samples collected at Eagle Bend, clover field- May 1999.

Soil Depth Inches	Elements ppm							
	Fe	**Mn**	**Zn**	**Cu**	**Pb**	**Ni**	**Cd**	**Cr**
0 - 6	67	19	1.8	0.6	0.7	0.8	0.08	<0.02
6 - 12	147	9	0.8	0.4	0.4	0.9	0.04	<0.02

APPENDIX F

Data/GIS Files

The following files are provided on the enclosed CD:

Data Files

mn_indmin_byproducts.mdb	Microsoft Access 97 database consisting of three tables: By-Products, By-Prod_Analytical_Data, and By-Prod_Chemistry.
mn_indmin_byproducts.xls	Microsoft Excel 97 workbook consisting of three worksheets: By-Products, By-Prod_Analytical_Data, and By-Prod_Chemistry.

Content: wastes/by-products info, analytical data, quarry, pit, and plant info, operator info.

GIS Files (ArcView 3.2)

mn_indmin_byproducts.dbf
mn_indmin_byproducts.shp
mn_indmin_byproducts.shx

Content: wastes/by-products info, quarry, pit, and plant info, operator info.

mn_indmin_byprod_data.dbf
mn_indmin_byprod_data.shp
mn_indmin_byprod_data.shx

Content: by-product analytical data, including physical properties, size analyses, and mineralogy.

mn_indmin_byprod_chemdata.dbf
mn_indmin_byprod_chemdata.shp
mn_indmin_byprod_chemdata.shx

Content: by-product geochemical data.

Metadata

mn_indmin_byproducts.html

Zip File

mn_indmin_byproducts.zip

Content: contains all of the above data, GIS, and metadata files.