Please complete the project summary and return the completed form to April Snyder, Associate Administrator for the Institute on the Environment at aprilsnyder@umn.edu. Paper copies will not be accepted. Please also attach any photos, publications, brochures, event agendas or other materials that were a result of the mini grant summary.

**Date of Report Submission:** 07/18/2014  
**Project PI & Dept/School:**  
Neil A. Wilmot  
Department of Economics  
Labovitz School of Business and Economics  
University of Minnesota Duluth  
**Project Title:** Interdisciplinary Exploration of Minnesota Frac Sand Mining  
**Grant Amount $:** $2,300.00

**Project Context & Purpose**  
*Please include the original project purpose statement and revise for any changes that occurred in the project after the start date with a short explanation of the changes.*

The original intent of the Institute on the Environment Mini Grant was to bring together researchers from different groups, who shared a common interest centered around Minnesota’s Silica (or Frac) Sand Mining industry, which is primarily located in Southeastern Minnesota. The interests of the group were expected to be wide ranging covering aspects from economic to health, tourism to transportation. The hope was that by taking a broad view of the ‘impacts’ from the industry, many areas of overlap would be discovered increasing the potential for researchers to leverage their skills in numerous areas. The group would convene with the intent of sharing ideas, learning from specialists and guest speakers with the goal of searching out and securing a Grant to proceed with the desired project(s).
Please provide a summary of the work that was completed for the mini grant project.

In general, the work undertaken can be classified into three distinct areas. First, a UMD student (Jenna Jacobson) was hired to research the Frac sand industry in Minnesota, with particular attention paid to the current state industry (i.e. moratoriums) as well as the geography of the industry in Minnesota. She was also investigating potential contacts in the Frac sand industry to consider as guest speakers.

Secondly, several members of the working group constructed a grant proposal for submission to the Legislative – Citizen Commission on Minnesota Resources (LCCMR). The grant, Silica Sand Mining and the Minnesota Economy, was a joint effort by faculty from the UMD Department of Economics (Dr. N. Wilmot, Dr. C. R. McIntosh) and the LSBE Bureau of Business and Economic Research (J. Skurla). The goal of the project was to assess the socio-economic impacts of frac sand mining on the economy of Minnesota. The team was interested in the impacts on key areas: 1. The impact on output and employment of the Frac sand industry in the state of Minnesota, and future demand for Frac Sand. 2. The impact of Frac sand mining on local property values. 3. Would a sovereign wealth fund, deriving revenues from the extraction of Minnesota resource be both of benefit to the state as well as an efficient means of spreading the benefits to future generations of Minnesotans. The grant submission is available on the LCCMR website. Thirdly, the grant was used to bring in a guest speaker to inform the working group of the current status of the fracking industry and the need for silica sand from Minnesota. Early phone conversations with Lisa Hanni, Goodhue county surveyor, suggested that an industry professional with a background in geology by the name of Jeff Broberg would be a good resource. In May, 2014, Jeff Broberg, a Licensed Profession Geologist, with McGhie & Betts, gave a presentation on Silica Sand in the Upper Mississippi Valley (see attached). The presentation was attended by approximately 12 – 15 individuals representing the Department of Economics (UMD), the Natural Resource Research Institute (NRRI) and the Bureau of Business and Economic Research (BBER). The presentation was followed by a valuable discussion on the current state of the industry, the geology of the formations in Minnesota and a general question and answer session.
Partnerships & Collaborations

Please provide a summary of the project personnel, partnerships and collaborations that worked directly on the project or were started as a direct result of the mini grant project.

The personnel involved in the projects primarily included Dr. N Wilmot (UMD), Dr. C McIntosh (UMD), J. Skurla (BBER), J. Oreskovich (NRRI) and the student worker (Jenna Jacobson). Other individuals attended the presentation and discussions.

Some of the collaborations that occurred from this grant include the submission of a grant to the LCCMR by Dr. N Wilmot (UMD), Dr. C McIntosh (UMD), J. Skurla (BBER). Additionally, Dr. Wilmot and Dr. McIntosh are collaborating on a project looking at how a sovereign wealth fund, which would be funded by extraction taxes, have been used and benefit other governments, with a view to understanding how such an concept might be applied in Minnesota. It is expected that researchers from the NRRI will be incorporated into the project in the future.
The mini grant has led to several outcomes. As discussed previously, a grant proposal was submitted to the 2015 round of the Legislative – Citizens Committee on Minnesota Resources (LCCMR) entitled Silica Sand Mining and the Minnesota Economy. Unfortunately, the proposal was not recommended for funding by the committee. This result was not surprising, given what was learned from the Broberg presentation. It seems that the boom of frac sand mining in Wisconsin has rapidly increased the supply of available silica sand, resulting in a significant reduction in price. The result is a reduction in the need for Silica sand mining in Minnesota, with relatively few new mines expected to open. This does not mean there are no impacts from such mining, since a large amount of the sand extracted in Wisconsin is transported (via trucks or rail) through Minnesota. It was determined that future research examining the impact on Transportation (particularly rail) in Southern Minnesota (to North Dakota and Texas) and delays in shipping agricultural products, could be a fruitful area of research.

A new area of research, sovereign wealth funds, has been developed jointly by Profs. Wilmot and McIntosh. Additionally, Dr. Wilmot plans to pursue the economic impact of Frac Sand mining on the Minnesota economy, particular with respect to residential real estate values in the future, while continuing to pursue additional grant opportunities in related areas.
Quartz-rich sand grains from bedrock of upper Midwest ("silica sand")

High strength
Chemically inert
Spherical
Large grains

Southeastern Minnesota
Silica Sand Geologic and Landscape Context
Tony Runkel
Minnesota Geological Survey, University of Minnesota

"Common" sand
Silica sand has been mined in the midcontinent over 100 years.

Some Purposes:
- Tunneling for storage
- Storm sewer system
- Glass making
- Foundry sand
- Abrasives
- Cattle bedding
- General fill
- Underground buildings
- Hydrofracking

“The shale gas revolution in North America is forecast to drive future growth in the market,” concurs a recent report by Global Industry Analysts Inc. “Given the fact that an average oil well requires over 15,000 tons of industrial silica sand, the rise in hydraulic fracturing projects across the Atlantic Coast is forecast to drive demand in the coming years.”

Availability: N.A. demand grew from <5 to 35 million tons/year in less than 6 years

Quality: Initially bulk unsorted sand was acceptable, now high-test sorting specifications must be met.

Price: In less than a year the FOB price of sand in the Midwest fell from $35/T to $15/T.

“Oversupply presents the main challenge for the U.S. proppant market”: Barclays analyst, James C. West, told Rigzone in late 2013. –

The 35 million ton/year oil and gas markets for Silica Sand are all 400-800 miles from the Upper Mississippi River Valley
Oil and Gas Traps

Hydraulic Fracturing

Hydraulic fracturing, or "fracking," involves the injection of more than a million gallons of water, sand, and chemicals at high pressure down and across into horizontally drilled wells as far as 10,000 feet below the surface. The pressurized mixture causes the rock layers, like the Marcellus Shale, to crack. These fissures are held open by the sand particles so that natural gas from the shale can flow up the well.

Graphic by Al Granberg
Artist’s Worms-eye view of Fracked Rock

Baker-Hughes

Shale Gas Plays, Lower 48 States
Fracking at the Wellhead

Forbes Magazine, Halliburton & Sand master

Six key plays account for nearly all recent growth in oil and natural gas production
Figure 2. Tight oil production for selected plays

The next graphic (Figure 6) is a stratigraphic column that represents the vertical order, or stratigraphy, of Paleozoic rock units with the oldest on the bottom and the youngest on the top.

Figure 6. Generalized Stratigraphy of Paleozoic rock in southeast Minnesota (left) and actual exposed rock (right). Source: MDHNR and MNSR.
Cambrian silica sheet sands were deposited in high energy near shore marine and beach environments that winnowed and washed all the silt and clay away.

Figure 10. The extent of the major bedrock units in Minnesota is shown on this simplified geologic map. The extent of these units is not the same as the extent of the major structural anomalies and deforming areas.
High-resolution sequence stratigraphy of lower Paleozoic sheet sandstones in central North America: The role of special conditions of cratonic interiors in development of stratal architecture

Anthony C. Runkel†1, James F. Miller§2, Robert M. McKay#3, Allison R. Palmer*4 and John F. Taylor‡5
Silica sand quality:

pure quartz, single grain, round, sorted to the desired size profile (20-40 for oil, 40-70 for gas hard (>6000psi crush strength)

• MN Jordan Sandstone
The Price of Sand; not to scale

Logistics and sand quality are value added propositions
Silica Sand = Bulk Commodity
current demand 35 million tons/year
Elements of mine prospect value:
Oil Field Demand
Location, location, location: (Roads, Railroads or Barge)
Sand quality and volume
Regulations and Permits
Price: Currently $100/ton at wellhead

Images from the movie “The Price of Sand” by Jim Tuttle
Mining and Processing

Many sites include most of the following:

Removal of overlying material  
Excavation (backhoe, blasting)  
Dewatering of pit (some sites)  

Transport to processing facility, or process on site, which then includes…

Crushing  
Washing/sieving to remove fines/sort sizes  
Settling of fines in ponds  
Drying of coarser sand  
Transport to rail (or barge)

Minneapolis River Valley operations and landscape settings

Quartz-rich sandstone bedrock layers at or near (approx 50 ft) land surface

Quartz-rich formations  
St Peter at/near surface  
Jordan at/near surface  
Waconia at/near surface  
Silica sand mines (locations approx)  
Active  
"Proposed" (formally or informally)

Relatively flat landscape  
Excavation below surrounding topography  
Dewatered
Examples of mine operations and landscape settings

Typical landscape setting where St Peter Sandstone is near or at land surface (and Wonewoc in Wisc)

Removing a topographic high
Commonly no dewatering

Examples of mine operations and landscape settings

Typical landscape setting in Minnesota where Jordan and Wonewoc Sandstones are near or at land surface

Not currently practiced, nor formally proposed

Underground mining
Unimin Kasota Mines and Prairie Restoration
Conservation protection, prairie and wetland restorations have been key contributions of sand mining in the Minnesota River Valley.

The USGS in 2012 writes:

“Except for temporarily disturbing the immediate area while operations are active, sand and gravel mining usually has limited environmental impact,” it goes on to note that the “increase in frac sand production and sales had a profound effect on the transportation of industrial sand and gravel to sites of first use.” This observation may be important in terms of potential occupational exposure to respirable silica dust, as USGS estimates that in 2011, “of all industrial sand and gravel produced, 65% was transported by truck from the plant to the site of first sale or use, up from 25%” from the amount shipped by truck in 2010.
The cost of sand is defined by transportation costs

- Proximity to rail defines the costs
- Closer = cheaper

10 miles
30 minutes
$4.50/ton

20 miles
1 hour
$10.00/ton

- Too far
- Too costly

Abutting $0

- No trucking
- +Site efficiencies

Photo by Jim Tuttle: The Price of Sand
On-time delivery requires logistics

Courtesy Smart Sand and Canadian Pacific
C. Example Map Output:

(Figure 23) shows rail access—and lack thereof—serving the mining and processing areas in southeast Minnesota.
Comments I’ve Heard

• “I think I’m rich. I have sand”
• “The proposed mine will kill my property value. Nobody wants to be near a silica mine.”
• “My taxes are going to go up to pay for the mines”
• “The mines pay so much taxes my taxes are going down.”
EQB Report Covers
• Background on silica sand
• Fracking market & socioeconomics
• Air quality
• Water Quality
• Water Quantity
• Transportation
• Governance
• Potential impact on sensitive resources

The report summarizes what is known and potential research topics

www.eqb.state.mn.us/documents/23_March_Final_Silica_Sand_report.pdf

The context of scale is as important as understanding the nature of the physical processes that deposited silica sand versus loess

- Exaggerated scale: 2 mm gravel to 1 mm sand, 0.06 mm silt and 0.0039 mm clay
- 2.5 um respriable dust is 20 to 40 times finer than 20-40 sand
Loess; not to scale – resolution >50nm

SEM pictures were taken with a Cambridge Stereoscan Microscope
Typical Wisconsin and Minnesota Driftless Area Loess, windblown silt.

Cambrian Sst
*100% silica
*<0.1% smaller than 10μm
*<0.1% Respirable Silica

Winowac Sand

Mt. Carroll Loess

Driftless Area Loess
*40-60% silica
*20% smaller than 10μm
*8-12% Respirable Silica
Availability: N.A. demand grew from <5 to 35 million tons/year in less than 6 years

Quality: Initially bulk unsorted sand was acceptable, now high-test sorting specifications must be met.

Price: In less than a year the FOB price of sand in the Midwest fell from $35/T to $15/T FOB Winona

“Oversupply presents the main challenge for the U.S. proppant market”: Barclays analyst, James C. West, told Rigzone in late 2013.
Global demand for industrial silica sand is projected to grow 4.8 percent annually to 280 million metric tons in 2016. Glass production and foundries will continue to be the largest markets.”

“Oversupply presents the main challenge for the U.S. proppant market”,
Barclays analyst James C. West told Rigzone.

See more at:
http://www.eia.gov/todayinenergy/detail.cfm?id=15731
Demand for pressure pumping surged. Midsize fracturing companies and private equity-backed startups built their fleets to make up more than half the fracturing market by the end of last year.

“Too many people added too much capacity,” said Alex Robart, a partner at Houston-based consulting group PacWest. “Really, it was just a matter of over-exuberance.”

When prices dropped
But startups and established fracturing companies alike were unprepared for a massive drop in natural gas prices that began in late 2011. It steered oil producers away from gas-rich reservoirs that require higher horsepower to fracture, like the Haynesville Shale in Arkansas and Louisiana.

“It happened a lot quicker than we anticipated,” Lanham said.

http://pacwestcp.com/research/pumpingiq/
New energy security for US

U.S. Natural Gas Production, 1990-2035