Changing Soil Quality and Ecosystem Services Associated with Sand Mining in Northern Mississippi Valley

FRACTRACKER Alliance

Exploring data, sharing perspectives, and mapping impacts of the oil and gas industry

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“Frack Sand Mines in Pictures

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Silica Sand Production Then & Now

- THEN – Formerly the Riley and Hickory (Brady) formations in Texas and Old Creek formation in Oklahoma.
  - Regulatory hurdles less, cheap, close to original plays, and far from population centers
    - But stuff is angular/blocky and coarse
  - Similarly angular blocky Cretaceous-Miocene formations exist in the US east coast; The Hickory and St. Peter formations accounted for 90% of US frac sands during the initial stages of the US horizontal drilling boom, while the St. Peter and Brady formations account for 70-80% of production today; the Jordan has been producing since 2005
- NOW – St. Peter (Ottawa) underlying much of southern Wisconsin and Minnesota, Iowa, and northern Illinois and Missouri (Ordovican).
  - Secondary but less productive formations include the Jordan, Wonewoc, and Mt. Simon formations (Cambrian)
  - Fine and spherical, crush resistant, acid soluble, clay/silt free, requires less to no resin coating, close to the surface
    - Labeled "Silica Arabia" by industry journalist Mike O'Driscoll
    - Subject to far more river/stream and wind reworking
- Great Lakes region producing sands across grain size requirements
- 1.5-3.0K tons of frac sand per well (↑ from 150 tons per well in 2000)

Not Your Parent's Sand

Quartz-rich Minnesota sand grains (aka, Silica Sand)

Typical "glacial" sand on top of bedrock (aka, Sand & Gravel Sand)

Not Your Parent's Sand

- Frac Sands being explored with surface/strip-mining methodologies across primary silica basins in Great Lakes
  - Very fine stuff 212-850 micrometers; ≥ 0.6 Sphericity and Roundness

Difficulties Determining Stocks & Flows

- Actual production for each mine is unknown
  - Permitted production data is available for just 15-17% of known mines (129 mines in WI averaging 100-275 acres)
    - 60.1 million tons per year or 2.5 million tons per mine
      - 4,087-9,397 tons per acre
      - Wisconsin producing roughly 211-336 million tons per year
      - 93.8-149.3K horizontal wells (11-18% of current US O&G inventory)
        - » Ohio laterals averaging 6,300-6,400 feet but getting longer by the day

Difficulties Determining Stocks & Flows

- Barges, Trains, and Trucks
  - Patchy data quantity and quality
    - Possible sources include Corp of Engineers FOIA
    - WI production requiring 2.1-3.4 million railcars
      - » Rails-To-Trails and Orphaned rails repurposed to carry load and at speeds more than 4 times their original speed limits
      - » Rail turnover is anywhere from 0.8-2.5% per year

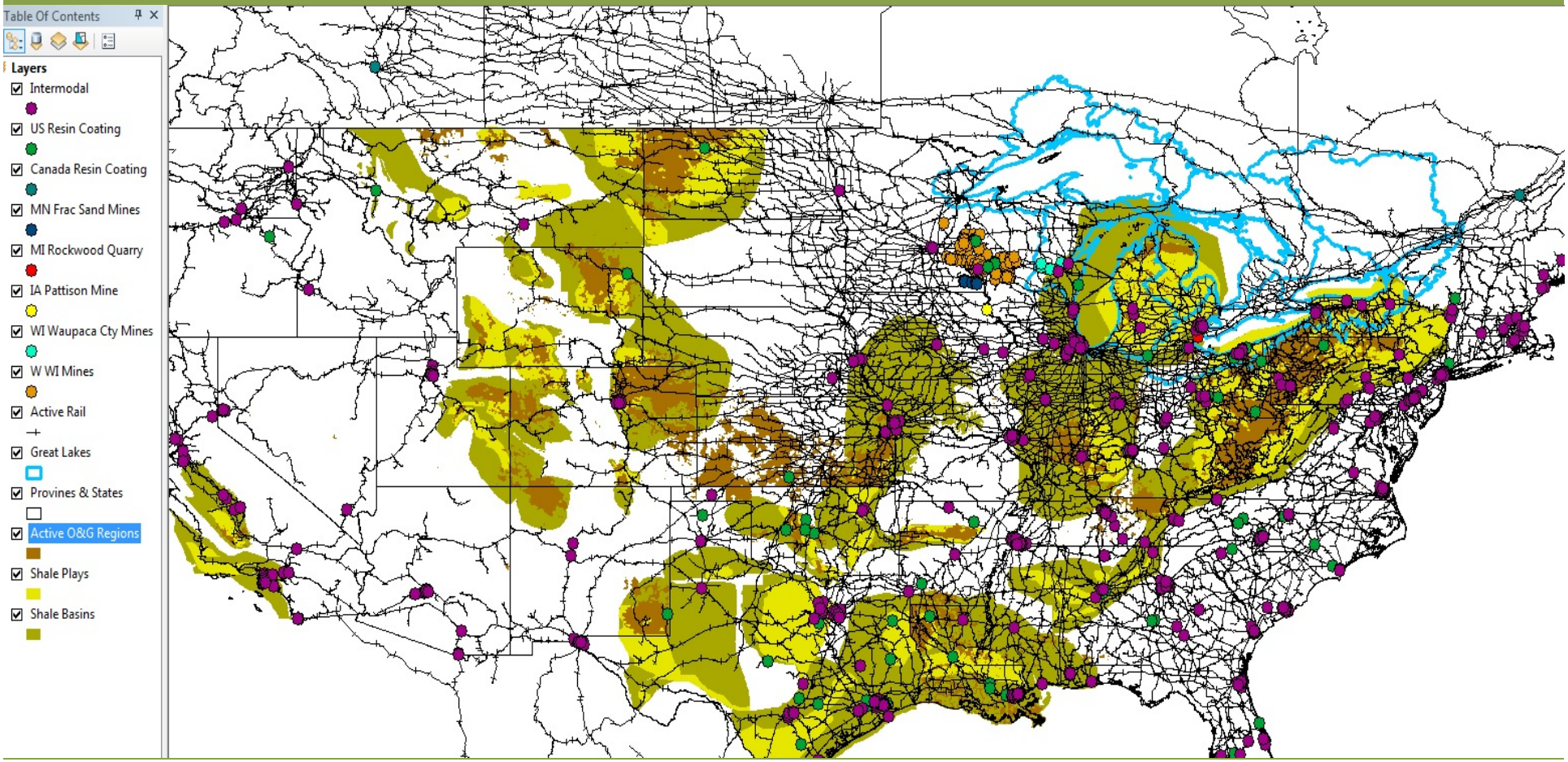
Ross Evavold/The Chippewa Herald

Ric Zarwell, Allamakee County Protectors

The Free Press Standard, Carrollton, OH

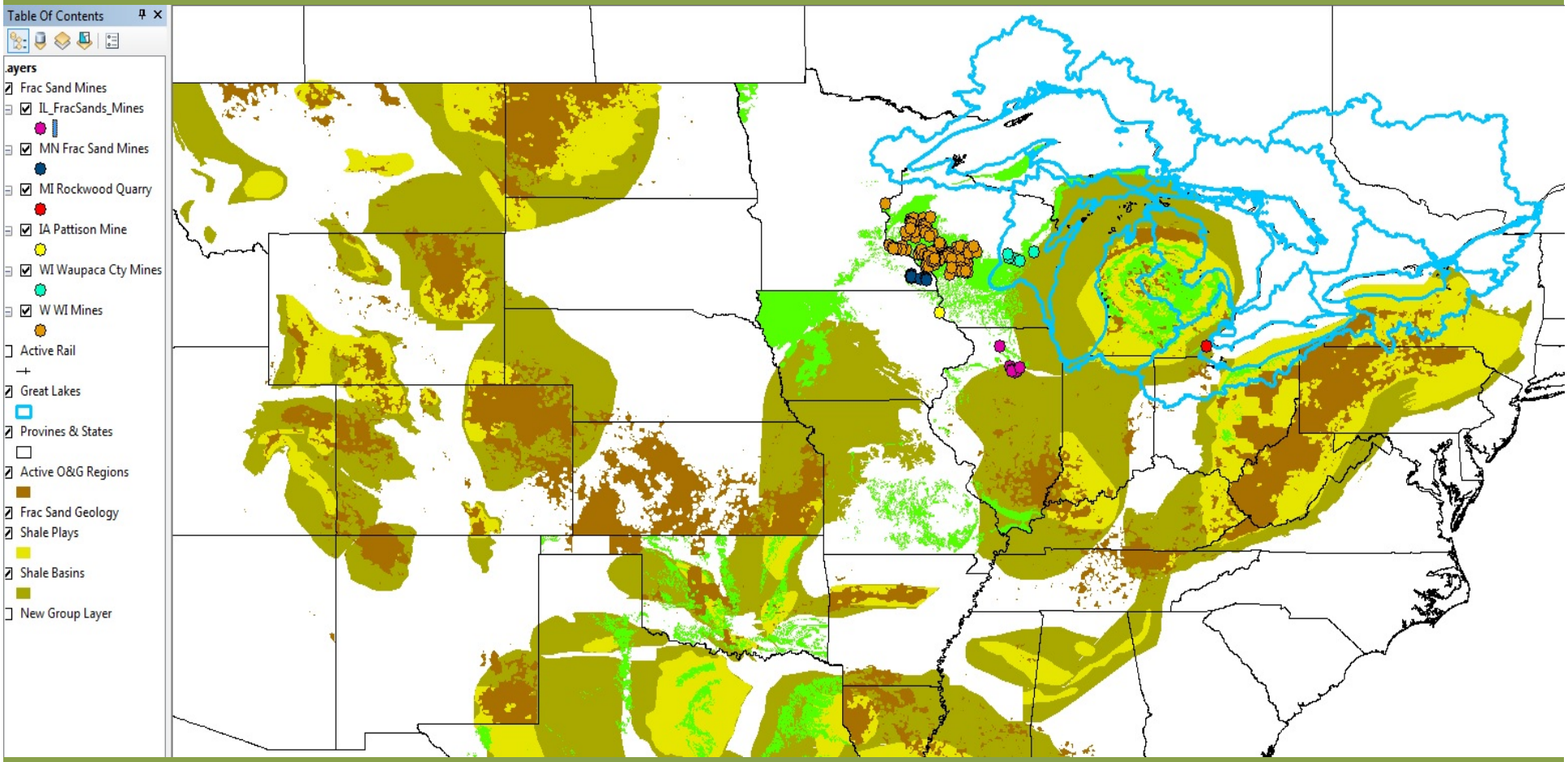
Difficulties Determining Stocks & Flows

- Barges, Trains, and Trucks
- Transload, intermodal, and resin coating facilities



Difficulties Determining Stocks & Flows

- Which plays is this stuff going to?



Land-Use Change & Watershed Integrity

- Listening Project and Truck/Barge/Train Count

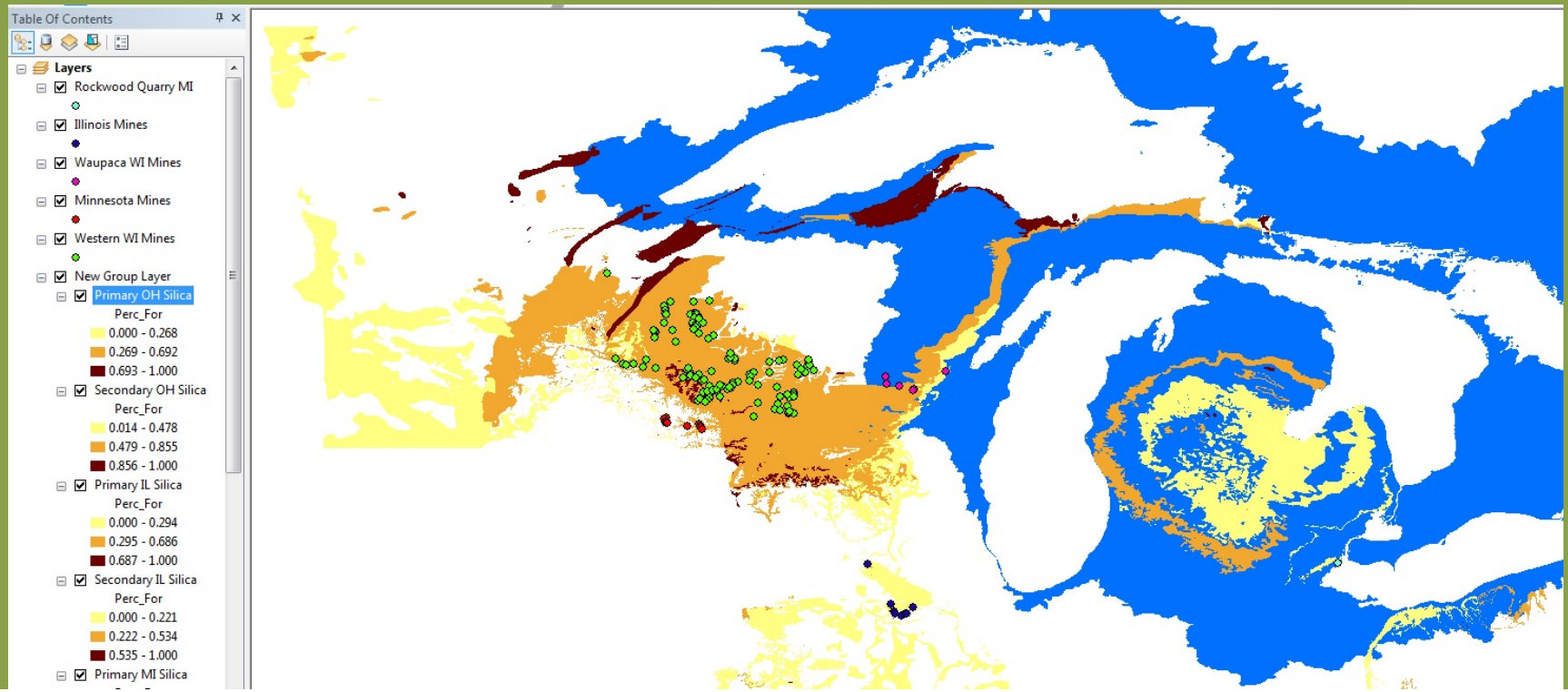
"[Wisconsin] farmers are unable to farm the hills, so they are often used as timber (windbreaks or woodlots). In the "olden days," cattle and pigs would free graze in the woodlots but seldom do that now. As a result, **today's mechanized farmer sees the hills as an impediment to "fence to fence" monoculture agriculture and looks on the sand mining as a way to get the hills pared down to a gentler slope so that he can use the machinery to plant more of the land to whatever row crop** he is growing on the rest of the farm - not recognizing that the land that will be there after the mine will be nowhere near as fertile as the rest of the farm!"

"[Chippewa Co. Land Conservation agent] has indicated that the **highest level that can be attained in the reclamation process is to convert it to land to be used for raising corn.** Since there are no reclaimed areas in the county as a result of frac sand mining nor even in other counties, it is difficult to say what quality of land this will be as it is reclaimed. At best, corn may be grown.....**but with the addition of lots and lots of water plus fertilizers (nitrates)** to allow for nutrition for growing of the crop. It may not be possible in many places to raise corn.

"The most difficult thing for the Frac-sand industry will be to reclaim mined properties to meet their end use...Most of the hills that are being mined have **extremely shallow topsoil as well as limited sub-soil**... In addition due to the source of a large part of the materials-forested hillsides-it is expected to have a rather **low ph, fertility issues, and poor moisture holding ability**. It is the opinion of many of us that the end result will be a **very poor stand of grass with some woody plants of very poor quality and little value on the whole for wildlife**...In addition we fear that due to the loosely consolidated nature of the profile and nearness of the mine floor to the water table (3-5 feet in some cases) there will be a substantial risk of groundwater contamination from pesticides and fertilizers in these cases."

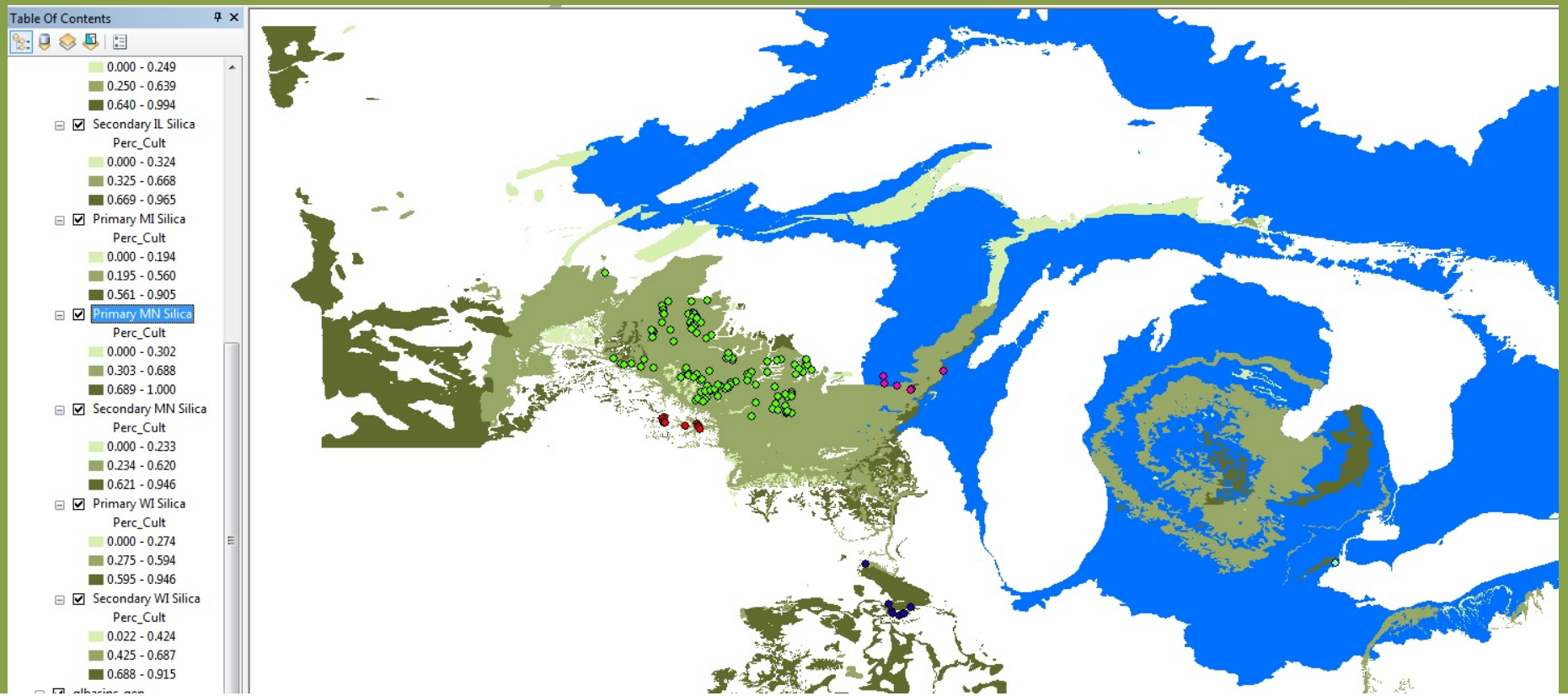
Land-Use Change & Watershed Integrity

- What we stand to lose
  - In WI 21,542 and 28,349 km^2 of forest and cultivated land
    - Forests generate 12.4-24.1 million tons woody biomass per year + 11.0-23.8 MT foliage + 754,521-1,634,647 MT roots = 72-114 M m^2 basal area
      - Woody Biomass = $401-782 million value; 703,409-1.37 million per capita equivalents
    - 4.5-9.8 MT SOC ($677 million to $1.5 billion value)



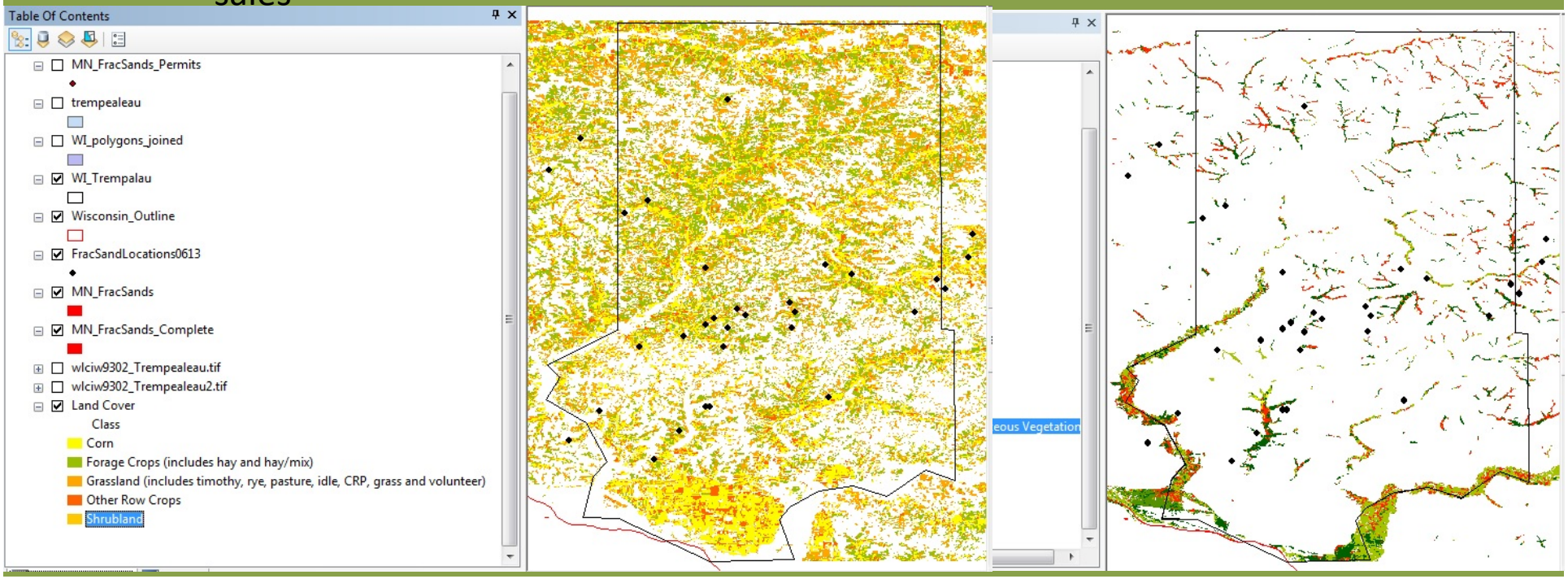
Land-Use Change & Watershed Integrity

- What we stand to lose
  - In WI 21,542 and 28,349 km^2 of forest and cultivated land
    - 27.8 million tons of crop biomass per year worth an estimated $4.9 billion
    - 101.8 MT CO_2 or per capita emissions of 5.8 million Americans
      - $1.5-5.1 billion CO_2 valuation
      - 60 MT of SOC (220 MT CO_2); 1 MT SON ($514 million to $1.2 billion dollar value)



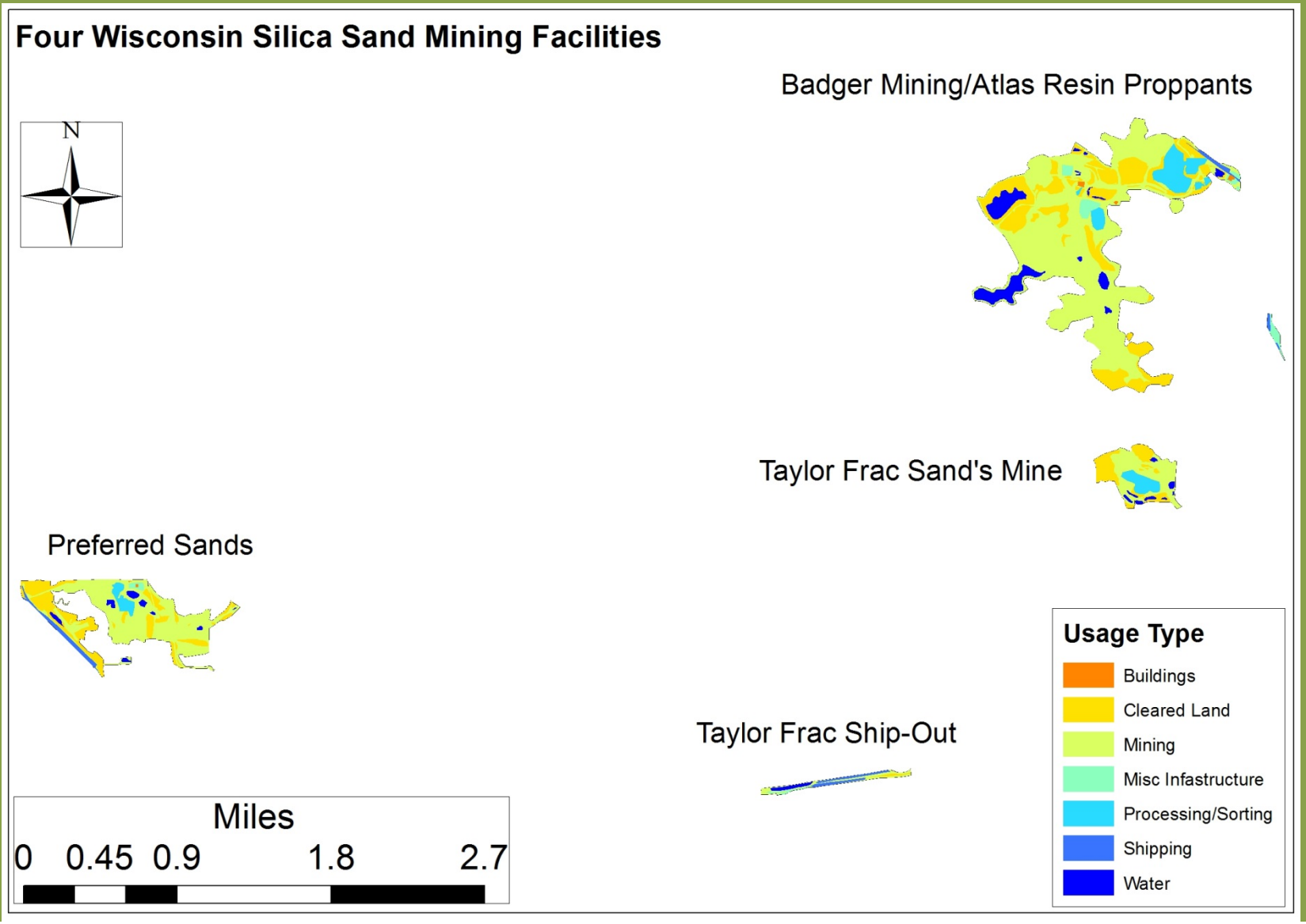
Land-Use Change & Watershed Integrity

- Wisconsin County Case Study
  - 6% of county is forested
  - 781 of 1,705 square miles is agricultural (45.8%)
  - 1,265 of 72,136 total acres in frac sand mine production is in agriculture (1.8%)
    - Selectively picking off forested bluffs
    - Why? Because mining is sold as a way to lessen slope of forested fractions, making land available for production, generating leasing royalties, and revenue from timber sales



Land-Use Change & Watershed Integrity

- Wisconsin's Current inventory of 78 silica mines



Land-Use Change & Watershed Integrity

- Wisconsin's Current inventory of 78 silica mines
  - 1,130 acres of forest and 3,710 acres of cropland were displaced
  - 130 and 6K tons of soil carbon and nitrogen, respectively (i.e., $6.0-7.2K per acre)
    - Crop losses amount to $2.1K per acre or $98K per farm
    - 450K tons of forest productivity with a stumpage value of $176-275K
    - $75-176K in lost nitrogen

Table 1: *Land cover change between 2006 (Columns) and 2013 (Rows). Read each cell as the amount of land of type 'column' replaced by type 'row' in 2013 (Acres).*

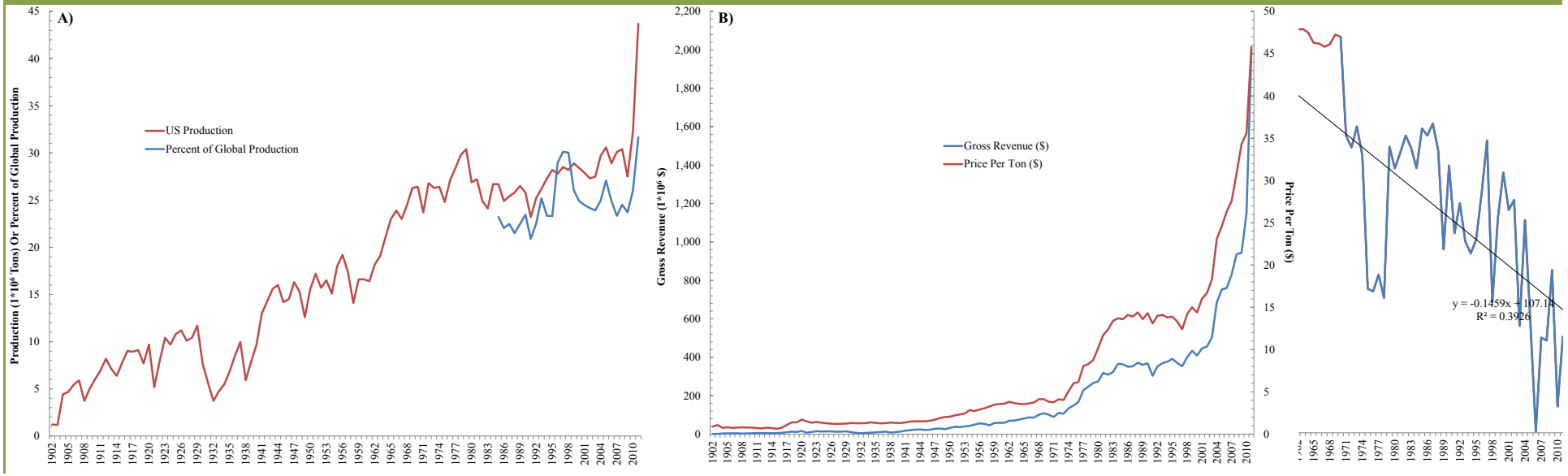
	Water	Developed	Barren	Deciduous	Evergreen	Mixed Forest	Shrubland	Herbaceous	Farmed	Wetland	Total Area
Buildings		22.73	1.65	4.01	1.33			1.46	30.73	0.25	61.83
Cleared Land	9.36	81.57	39.04	260.46	8.88	5.81	23.75	51.77	753.91	38.25	1273.43
Mining	22.68	146.43	244.63	689.54	54.26	8.45	58.49	79.62	2082.28	38.25	3424.65
Misc Infrastructure		7.75	4.67	5.67	1.11		0.44	0.67	73.04	2.89	96.07
Processing/Sorting		11.12	70.50	23.35	3.34		1.33	0.89	259.57	4.23	374.29
Shipping	1.11	35.81	0.67	9.34	1.78		1.11	19.62	111.98	8.23	189.48
Water	129.28	5.68	81.42	46.77	3.69	4.45	1.17	9.04	402.39	22.80	706.32
Total Area	162.44	311.09	442.59	1039.14	74.40	18.71	86.31	163.07	3713.90	114.90	6126.08

Land-Use Change & Watershed Integrity

- Chieftain Metals Corp Barron County proposal (8.9 mi^2)
  - Currently 47% forest, 35% forage and grasslands, 15% crops, and 2% wetlands
  - Mining would remove 3.3-6.8 million tons of built up aboveground CO_2 or the per capita emissions of 202-416K Wisconsinites ($43-77 million worth of soil fertility)
  - The carbon capture/storage potential of this land is currently valued at $1.490-6,334 per acre per year
- Total value of ecosystem services = $8.8-16.6 million per year ($1,552-2,927 per acre per year)
  - If converted to mines services generated would decline to $5.0-9.5 million

Silica Supply/Demand Economics

- Frac sand usage now rivals and might supersede previous major players
  - glass production, fine aggregate for mortar and concrete, bedding sand for dairy operations, road paving, and drinking water filtration
- Since late 90s silica demand has entered exponential – and heretofore undocumented – phase of growth trajectory (Note: TX Barnett up and running mid-90s)
  - 23% of historical production and 54% of gross revenue
    - "Those who have sand or access to sand can pretty much charge what they want for that sand" EOG Resources CEO Park Papa
  - Net consumption is declining to the tune of -0.15% per year, which means that theoretically somewhere in the US there exists various stocks equivalent to 72.68 million tons or the horizontal well equivalent of 32,303 wells assuming 1.5-3.0K tons of frac sand per well.



Future Concerns & Extent

- The St. Peter and Wonewoc Formations extend across MN, WI, IA, IL, MO, AR, and OK
- Demand increasing by 80 tons per lateral Per Quarter (PQ)
  - 3.5-4.3K tons per lateral
- Lateral length increasing by 50-55 PQ
- Average mine proposal increasing
- Average Yield = 105-130K tons per acre
  - 27-33 Utica Laterals worth of sand per acre
  - 2.7-3.3K laterals worth of sand per mine

Variable	Avg	Increase Per Quarter
Lateral Length (ft)	6,440-6,380	+ 50-55 feet
Drill Cuttings (Tons)	608	4.7-5.2
Landfill Drilling Muds (Tons Per Facility)	28,098	15,319
Water Usage (Gallons)*		
OH**	6.2-7.0 MGs	405-410K
% of Residential Demand	11-18%	
% of "Available Water"	5-8% (11% w/in 1 year)	
Gallons Water Per Gallon Oil	16-38	3.6
WV	6.9 MGs	450K
Silica Sand (Tons)	4,303	86
Injection Waste (Gallons Per Quarter)	117 MGs	5.4 MGs