Wisconsin Sand and Gravel Mining: From Nineteenth-Century Gravel Pits to Twenty-First-Century Frac Sand Mines

By
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Wisconsin is not typically thought of as a leading mining state or a place with a wealth of mineral resources. Its society and landscape have nonetheless been shaped by quarries, pits, and mines of all kinds. One of Wisconsin's most valuable minerals is sand and gravel. Even so, this nonmetallic resource has been overshadowed by metallic mining in the state's mining literature. Metals and fuels inspire images of lawless boom towns, men who struck it rich searching for gold, and environmental damage. The metallic mining rushes and the disastrous working conditions of coal mines are in the collective consciousness of many citizens of the United States. Every high school student in the U.S. is familiar with the California Gold Rush, the mining towns of the Old West, and the environmental damage that can result from irresponsible practices.

Although it may be true that metallic mining and mining for fuel have played an integral part in shaping the settlement of the U.S. and the knowledge of its citizens, it is also true that nonmetallic resources have shaped the U.S. in equal proportion. Materials such as sand and gravel are used to fulfill the relentless demand for new roads, bridges, dams, and buildings. Their production is methodical, mundane, and consistent, and has been a part of Wisconsin's landscape for over a century.

The tendency of people to ignore aggregate materials and focus on metallic resources is exemplified in the scholarship on the mining industry of Wisconsin. Very little has been written about sand and gravel, and few people seem to appreciate humanity's dependence on them for developing society's infrastructure. Instead, scholarship about Wisconsin has focused on lead, zinc, and iron. Part of the reason for this is that the state's early history was shaped by a demand for mineral resources.

Early Wisconsin settlers were drawn to the southwestern part of the state by lead deposits in the 1820s. During that era, lead was in high demand throughout the country for pipes, paint, and ammunition.[1] Robert C. Nesbit, author of *Wisconsin: A History*, explained that lead was "a more effective magnet for American penetration of Wisconsin than either furs or farming."[2] In an article for the *Wisconsin Academy Review,* Thomas Evans described the southwestern part of the state as "the birth place of Wisconsin and the principal lead producer for the young United States of America."[3]

The lead miners of southwestern Wisconsin helped shape the state's settlement patterns, transportation networks, and economy. However, lead mining peaked in the 1840s, as miners exhausted easily accessible deposits and national demand slowed.[4] Although lead mining in Wisconsin ultimately extended into the twentieth century and helped shape the state, it was productive only for a relatively short time and lead has not been mined in any appreciable quantity for decades.

Zinc and iron mining are also a part of Wisconsin's early mining heritage. Zinc was often discarded at early lead mines until people realized it could be sold as a commodity for brass, batteries, die casting, and to coat steel. By 1900, zinc production exceeded that of lead and peaked in the 1910s. Following World War I, its production quickly decreased.[5]

For iron mining, the two largest mines were the Cary and the Montreal. Both were in the Gogebic Range that extended into the Upper Peninsula of Michigan. The Cary Mine went down to 3,350 feet, and the Montreal Mine, opened in 1886, produced 44.7 million tons of iron ore. Despite these successes, both mines ceased operations in the 1960s.[6] Furthermore, Michigan cities in the Upper Peninsula profited more from the iron ore deposits in the Gogebic Range than their Wisconsin counterparts.[7] Unlike lead, zinc, and iron, sand and gravel mining in Wisconsin is still a productive and profitable venture with mines across the entire state.

Despite lead, zinc, and iron's important role in Wisconsin's origins, nonmetallic resources are the cornerstone of mining in Wisconsin. Sand and gravel have been the most valuable mineral resources in Wisconsin for at least the past sixty years.

According to the United States Bureau of Mines and United States Geological Survey's *Minerals Yearbook*, from 1952 through 2013 sand and gravel, as a category, was the most valuable material mined in Wisconsin in thirty-six of those sixty-two years. Furthermore, from 1952 through 1981 sand and gravel held the top spot twenty-six of the thirty years. It has been surpassed by stone twenty-six times, but that number is inflated due to a classification change in 1981. This change split sand and gravel into construction and industrial materials, each less valuable than stone. If the construction and industrial categories are recombined, sand and gravel continues its consistent dominance as the most valuable mined material in Wisconsin from 1952 through 2013.[8]

Despite sand and gravel's long-standing presence as mineral resources, they are rarely discussed in Wisconsin's mining literature. The author of *Law and Mineral Wealth: The Legal Profile of the Wisconsin Mining Industry*, James A. Lake, wrote that non-metallic resources were often ignored when calculating Wisconsin's mineral wealth, despite their greater contribution than lead, zinc, and iron. Ironically, Lake then proceeded to ignore these non-metallic resources in the rest of his book to focus on the metallic minerals.[9] Furthermore, in *Wisconsin History: An Annotated Bibliography*, the authors made no reference to the sand and gravel mining industry and explained in their annotation of Lake's book that little mining was being done in the state in the mid-twentieth century.[10] Although this may have been true of metallic resources, it was not the case with sand and gravel, which have been continuously mined in Wisconsin since the late 1800s. Sand and gravel were also undervalued in Nesbit's *Wisconsin: A*

History, which does not mention these resources.[11]

An Underappreciated Resource

Contrasting the commonplace nature of aggregate materials in Wisconsin with the more robust imagery that metallic mining offers, it is somewhat understandable that researchers have focused on the metallic minerals. The excitement generated by metallic resources is attention that sand and gravel historically has not been able to attract. However, in *Roadside Geology of Wisconsin,* Robert Dott and John Attig explained that "during the past century, lead, zinc, and iron mining have declined and ceased . . . but geologists continue to locate a variety of essential construction materials. These include stone for buildings, crushed stone as well as sand and gravel for road surfaces and for making concrete."[12] Although important to Wisconsin's early development, lead, zinc, and iron have not played a major role in the state's mining production for over a century, while many nonmetallic materials have.

One author, mining engineer Lawrence A. Roe, included a chapter focused on these materials in his book *A History of Wisconsin Mining.* He began by quoting James D. Cooper of the U.S. Bureau of Mines stating that "the importance of sand and gravel in the United States is illustrated by the fact that quantitative demand for these commodities is greater than the combined demand for the rest of the nonfuel nonmetallic minerals." Roe went on to explain that construction sand and gravel is the only mineral produced in all fifty states. Despite his acknowledgement of sand and gravel's importance, Roe also stated that "the history of industrial mineral production is not nearly as exciting as the story of the metal mining industry." Roe described sand and gravel as an important resource, but then he, too, down played them compared to metallic mining, even though evidence suggests that they are as essential as metals. Most concretes, plasters, and mortars require sand as a component, gravel is needed for railroad ballast, and few, if any, materials can replace sand and gravel for construction.[13]

With technological advancements in hydraulic fracturing ("fracking"), a technique used by the energy industry to improve the productivity of deep oil and natural gas wells, the demand for Wisconsin sand has skyrocketed. Wisconsin sand is ideal for fracking, and is used to keep wells open to allow oil or natural gas to flow freely out of them. Just as land rushes and boom periods have drawn attention to metallic resources, the frac sand boom has drawn attention to Wisconsin's sand mining industry. It is now impossible to continue to ignore the history of the state's rich nonmetallic mineral deposits.

Sand and gravel have progressed from late-nineteenth- and early twentieth-century road building materials to sand's use as a twenty-first-century component in hydraulic fracturing. Because of their various uses and sand's contribution to the energy industry, these materials are very lucrative and relevant to today's society. An understanding of the history of these materials is essential to explain the recent rush on the state's frac sand reserves. Moreover, sand and gravel mining permanently changes the natural landscape through their extraction, but also with their application to create features such as roads that alter the environment of the state.

This all means that sand and gravel can no longer be left out of Wisconsin's mining literature. With rich aggregate reserves and a tradition of quarrying and mining embedded in the state's culture, Wisconsin sand and gravel mining has a history that deserves to be told and an industry worthy of better understanding. Sand and gravel mining in Wisconsin is an historic, versatile, and lucrative business that helped to build the state's early roads, contribute materials to several industrial applications, bring in millions of dollars every year, and permanently change the environment. Furthermore, it has the potential to advance the state's economy and infrastructure, but only if citizens and policy makers choose to prioritize and embrace the industry.

Geology of Wisconsin Sand and Gravel

Wisconsin's wealth in sand and gravel is due to its geology. Wisconsin does not have many metallic mineral deposits and those that it does have are scattered throughout the state. Wisconsin has typically been renowned for things that reside on top of its landscape, like dairy farms, lakes, breweries, and rolling hills. It is less known for what resides within or beneath its landscape, like sand and gravel, glacial till, or other aggregates. The quarries and pits of Wisconsin extend downward to take advantage of sand and gravel resources, therefore a discussion of mining must first consider geology.

Many of the sand deposits in the state are due to shallow seas that covered Wisconsin hundreds of millions of years ago. In the late Precambrian Era and early Cambrian Period, the region had been eroded into a flat, sandy landscape. By about five hundred million years ago, an encroaching sea covered Wisconsin. This sea deposited sand that had been eroded into tiny spherical balls by wind for over one hundred million years. The sea was no deeper than a hundred feet and would occasionally drain, leaving the sands exposed for hundreds of thousands of years. Coarse sands and fine pebbles are the oldest Cambrian sediments to be preserved.[14]

During the Ordovician Period sea levels continued to fluctuate. Ultimately, about 480 million years ago, the sea level fell, exposing the region, and a new layer of quartz sand covered the land from the redepositing of Cambrian sand.[15]

Much of this sand is still in Wisconsin today. The Cambrian and Ordovician formations contain excellent deposits that can be used for industrial processes, like molding and filtering, and are valued for their nearly pure silica content, uniformity, and accessibility. Furthermore, it was these depositions of sand millions of years ago that endowed Wisconsin with its valuable frac sand reserves. This is the sand that the energy industry needs for hydraulic fracturing because Wisconsin "has some of the best frac sand in the country."[16]

In addition to the deposition by shallow seas, sand and gravel reserves are the result of glacial till, a mix of leftover debris carried by glaciers. One type of this debris is eskers, ridges of sand and gravel deposits from rivers that flowed in tunnels within layers of ice toward the glacial margin. When a glacier receded, the sand and gravel from these subglacial rivers and streams was left behind, forming eskers.[17] For example, the Kettle Moraine is an accumulation of sand and gravel deposited by a river running on top of the ice sheet when the Green Bay and Lake Michigan lobes moved apart.[18]

Eskers are easily recognizable and mined. Therefore, they were an early source of sand and gravel in southern Wisconsin, used for road and building material. Sand and gravel deposited in this way is a source of aggregate throughout much of the state. In fact, as David Mickelson explained in "Wisconsin's Glacial Landscapes," "aggregate typically comes from two sources: sand and gravel." Any concrete or asphalt that is used to build roads, driveways, parking lots, house foundations, or buildings needs large amounts of aggregate. Mickelson went on to explain that Wisconsin's "roads and buildings are structurally strong in part because of the high-quality aggregate that is often derived from glacial outwash." With its glacial geological formations, Wisconsin has been able to support a successful sand and gravel mining industry for over a century, with those materials applied over a wide range from building roads to extracting energy reserves.[19]

Building Wisconsin's Infrastructure

Wisconsin's glacial period endowed the state with rich geological reserves of aggregate materials excavated from gravel pits in the late nineteenth and early twentieth centuries. Gravel was essential to Wisconsin during that era because it was abundant, cheap, easily accessible, and could be used to improve the state's roads. Today, it is easy to forget how essential good roads are to modern society, however automobiles and highways were not always as widespread as they are now. In Wisconsin, good roads were only achieved after hard fighting by those who believed in their importance.

In the mid-1800s, after Wisconsin's statehood in 1848, local governments would raise a tax to fund roads. This tax was despised by farmers, many of whom chose to work it off on road crews rather than pay it. Unfortunately, these crews proved to be notoriously ineffective at building roads, and thus the state's roads remained poor. At the beginning of the twentieth century, only 17 percent of Wisconsin roads were improved with gravel or similar materials. The majority were poorly built mud or dirt roads, often impassible.[20] To understand how gravel played an integral role in building Wisconsin's infrastructure, it is important to understand the Good Roads Movement of the 1890s and the work done by the Wisconsin Geological and Natural History Survey through its road materials research.

The Good Roads Movement

Bicycle enthusiasts began the Good Roads Movement in Wisconsin in the 1890s, organizing the first major support for highway improvements in the state. Without decent roads, the sport of cycle touring could not exist.[21] In 1895, bicyclists and leading businessmen formed the Wisconsin League for Good Roads, "the first statewide highway improvement association in Wisconsin." While bicyclists joined for recreational purposes, businessmen were interested in roads for better transportation of goods and supplies. However, farmers were highly skeptical of changes to road policy and protested state aid to construction. Not until 1901 did the Wisconsin Dairymen's Association officially support state-financed roads.[22]

That same year the Wisconsin legislature created the Good Roads Commission to determine if country roads needed to be improved. The commission found that most citizens of Wisconsin favored the idea of state aid to improve highways.[23] With public opinion swinging in favor of improvements, efforts could be made to locate possible materials and formulate methods of extraction. The Wisconsin Geological and Natural History Survey (WGNHS) led these efforts.

WGNHS was responsible for determining sources for road construction materials during the early 1900s and evaluated gravel pits and quarries for concrete aggregate near new highways. Survey geologists also evaluated mines and advised bridge and highway projects. In 1896, the Survey published a map of Wisconsin showing every quarry in the state, from the Wisconsin-Illinois border to the shores of Lake Superior. Survey geologists identified over fifty quarries in total, every one on or near a railroad track. This map indicated the importance of transportation networks for these materials.[24]

The Survey also issued a report in 1903 on highway construction in the state. This report found that eastern and southern Wisconsin had "inexhaustible" supplies of gravel, and that in "all parts of the state, except the southwestern, gravel is very plentiful." The report even mentioned that gravel was the material used most to improve highways, more so than crushed stone or clays. Gravel was usually the cheapest, and applying a generous supply of it could greatly improve the condition of a road. However, the report also found that gravel was rarely a good permanent solution and was not by itself suitable for heavily trafficked roads. Therefore, gravel represented a step in the right direction toward ultimately paving a road.[25]

Although local, state, and national sentiment was moving toward developing networks of roads and highways, improvement efforts of the early 1900s were still minimal. To counteract this, the federal Office of Public Roads (OPR), under the leadership of Logan W. Page, sought, according to one historian, "to teach local road supervisors the practical knowledge they needed to sustain effective road-improvement programs after OPR experts left town."[26] OPR helped city officials manage quarries to make use of local materials when building roads. Initiatives like this were underway across the country to ensure better infrastructure for transportation with the rise of the automobile. In fact, the WGNHS report of 1903 prophesized that the automobile could one day demand the development of a permanent system of roads and highways.

> There may come a time when the steel rail will be discarded in interurban and rural transportation, and be replaced by a smooth pavement. There may come a time when state and even trans-continental highways will be built of smooth, permanent pavements over which the automobile can travel with the same speed that the interurban car travels today.[27]

This declaration, made when roads were predominantly gravel, sand, stone, or clay, predicted the rise of interstate highways and interconnected routes of transportation across the country and the state of Wisconsin.

As the Good Roads Movement gained speed, WGNHS made serious efforts to test a variety of road materials and to research costs. In 1906, it found that "both gravel and crushed stone may be spread upon a well-drained, well crowned earth road without any further preparation and in time will be beaten down by the traffic into a fairly good surface." The agency explained that the cost of roads depended on the price of labor and material, the latter being largely depending on the distance it had to be hauled. "A well-constructed gravel road," the report stated, "should be about $300 to $350 per mile." This would equal approximately $8,400 to $9,800 today. The closer the material was to the road, the cheaper the road would be to build. This meant that Wisconsin's widespread reserves of gravel and other aggregates would make it much easier to construct roads throughout the state.[28]

Madison is an example of a city that benefited from widespread aggregates and owned a quarry to help decrease its cost of road building. In his "Historical and Financial Survey of the Madison Municipal Quarry" of 1908, researcher Benjamin Tighe explained that in the 1890s, road material was "badly needed upon the public streets of Madison," and that this ultimately forced the city to purchase the quarry. By 1908, Madison had spent $17,771 on the quarry, $488,702 in today's dollars.[29] This quarry supplied Madison with aggregate materials for the roads that helped to spur the city's growth and illustrated the importance of aggregates to road improvement efforts. A need for public funding to improve and maintain roads was becoming more apparent to Wisconsinites.

By 1908, public opinion had moved in favor of state aid due to WGNHS research and to an increase in the value of farm products that compelled farmers to want better transportation for their goods. In 1908, by a margin of 116,107 to 46,762, Wisconsin residents voted to make it constitutional for the state to provide aid for highway construction. The State Aid Road Law, passed in 1911, made it possible for the state government to disperse funds to municipalities and county governments to fund their road-improvement efforts. Major railroads in Wisconsin even offered to haul road materials at reduced rates for state-financed highway construction projects.[30]

By 1914, just six years after the passage of the road law, all of Wisconsin's counties accepted state funding, and, by 1918, 23 percent of the state's rural roads were surfaced. The State Aid Road Law marked the beginning of the concentrated effort to construct, improve, and connect road networks throughout the state that has shaped its current infrastructure. From 1907 to 1911, the state gave $10,000 ($243,000 today) a year for state aid, $400,000 ($9.5 million) in 1912, over $850,000 ($20.5 million) in 1913, and $1,230,000 ($29.3

million) in 1914.[31] Gravel roads replaced mud, and, over time, concrete, cement, and asphalt replaced gravel. The Wisconsin Geological and Natural History Survey explained in 1914 that

> Wisconsin is exceedingly fortunate in having a great abundance of road material. There are few states in the Mississippi Valley which have road material of a satisfactory character so widely distributed. Nearly every county in the state has within its boundaries material that will serve for the construction of the major portion of its roads. . . . It is apparent that at present, and always in the future, it will be possible to build roads more cheaply in Wisconsin than in most of the neighboring states where material must be shipped long distances.[32]

Wisconsin's abundance of aggregate materials supported road improvements across the state.

Granite Gravel Company, 1914-37

Increasing road-improvement efforts across the state motivated Wisconsinites to find more efficient and effective construction methods. In 1911, the Wisconsin Highway Commission published a report on the cost of county-built roads across the state. The difference in costs depended on charges for crushing, loading, and hauling of the material and increased based on how far it had to be transported. In all cases, roads could be built much more cheaply using gravel rather than crushed stone.

The following year, 1912, the Wisconsin Highway Commission issued a best-practices guide for building stone and gravel roads. The guide explained proper grading, flushing, trimming, and trench work. It also discussed how to deal with fences and private entrances that might be in the way, how to build culverts and bridges, and how to lay out subgrades. It stipulated that most of Wisconsin's roads would be built with a stone or gravel subsurface about nine feet wide, which, from experience, "has proven to be ample for 90 per cent of even the main traveled roads."[33]

Also in 1912, the Highway Commission published a list of the crushed stone producers of Wisconsin showing forty-four companies with mines across the state. Many, however, had offices in Chicago, indicating that quarrying and nonmetallic mining in Wisconsin had drawn interest from outside investors who recognized potential profit in selling road construction materials. This list of producers also indicated every railroad line in proximity to each mine, again illustrating the necessity of inexpensive transportation for heavy, low-value materials like sand, gravel, and stone.[34]

Further exemplifying the need for rail lines and transportation networks for nonmetallic materials, as well as the extent of business opportunities in Wisconsin's quarrying industry, was the Granite Gravel Company. Incorporated on 8 August 1914 at Kronenwetter in Marathon County by members of the "Wausau Group," the company sought "to develop granite gravel for road purposes."[35] In January 1917, a Mr. Hirst, of the state's highway commission, confirmed that the company's granite gravel was "very valuable for road making purposes," and the following month the dean of the University of Wisconsin's College of Mechanics and Engineering wrote that "this sort of material has been very successfully used for road work."[36] Unfortunately, the good news for the Granite Gravel Company stopped there.

After confirming that its product was valuable, the Granite Gravel Company's second order of business was to attract a rail line to its property. In a letter of 14 June 1917, the Railway Commission of Wisconsin ordered the Chicago, Milwaukee, and St. Paul Railway to build and maintain a spur track to the gravel pit that would be paid for by the Granite Gravel Company. The commission made this decision, in part, because the spur track was "practically indispensable to the successful operation of the petitioner's industry."[37]

Five days later, C. B. Bird, the gravel company's attorney, wrote to the company's president, B. F. Wilson, suggesting that it might be a good idea to let the quarry's business rest until the Chicago and North Western also extended a line into the area. Then, Bird explained, they could negotiate with each railroad from a position of advantage rather than overpaying for a spur from the St. Paul.[38] Although it is unclear from existing sources what negotiations were attempted, they ended badly for the mine. Granite Gravel reached no agreement with either railroad, and no railroad track was ever extended to the gravel pit.

With no access to a railroad, the company had no easy way to get its product to market, and, therefore, no way to make any money. Years passed and its gravel pit sat untouched. In May 1924, a decade after its incorporation, the company's secretary reported to the collector of U.S. Internal Revenue that the "corporation has no funds on hand."[39] Two years later, Deputy Tax Collector E. J. Hopkins confirmed that "the Granite Gravel Company owns a potential gravel pit. . . . It was thought at one time that a railroad spur would be built near it. Since this was not done, the pit has never been operated and therefore the company is a liability rather than an asset."[40]

More years went by, and, still without a rail line, the gravel pit sat undeveloped and unworkable. B. F. Wilson explained in 1934, twenty years after the company's founding, that "on account of this material not being used as anticipated, nothing has been done to develop this property. We are simply paying taxes from year to year, hoping something may develop, so that we can make use of this material."[41] The gravel pit had little value, not because of the material itself, but because of its location. With no means of transportation, no money could be made. Finally and mercifully, after twenty-three years of nothing but paying taxes on a plot of land and holding out hope for a railroad, the company was dissolved on 8 October 1937.[42]

Despite never transacting any business or gaining a railroad connection, the Granite Gravel Company attracted much attention early in its existence. Throughout 1914, its year of incorporation, the company received a deluge of letters from mining equipment companies throughout the country. Most of these came from companies based in Chicago, such as the J. C. Buckbee Company, Chalmers and Williams, and Fairbanks Morse and Company. However, companies from outside of Chicago also contacted Granite Gravel. Some included the Universal Crushers Company of Cedar Rapids, Iowa, the Schofield-Burkett Construction Company of Macon, Georgia, and the Mertes Machinery Company of Milwaukee. These companies sold excavators, elevators, crushers, screens, conveyors, hoppers, storage units, and other mining equipment.

Numerous journals also contacted Granite Gravel with invitations to subscribe to their publications. Some examples included *Cement and Engineering News* and *Rock Products and Building Materials*, both from Chicago.[43] The sheer number of people who contacted Granite Gravel suggests both the large amount of equipment needed to operate a gravel pit and the extent to which gravel and other nonmetallic materials mining could be profitable.

The use of sand and gravel as road building materials proved to be essential to the early development of Wisconsin's infrastructure. The sand and gravel mining industry got kick started by the Good Roads Movement and was aided and documented in its early years by the Wisconsin Geological and Natural History Survey. Using improved transportation networks that the industry itself helped create, sand and gravel mining in Wisconsin grew throughout the twentieth century.

Although sustained by a demand for road materials, sand and gravel's uses extend into other industries and sectors as well. Due to the versatility of these materials, sand and gravel mining has persisted well beyond Wisconsin's Good Roads Movement and after the Wisconsin Geological and Natural History Survey stopped supporting the industry with research. Their versatility make sand and gravel reliable and valuable materials to this day. With satisfactory markets and transportation networks, this type of mining can thrive.

Modern Frac Sand Mines

Due to a recent sand mining boom, huge mines have opened throughout Wisconsin to extract this mineral resource. These mines are much larger than nineteenth-century gravel pits and serve a far different purpose. The sand extracted from them is known as frac sand, and unlike materials from local gravel pits, it is shipped out of state to places like the Permian Basin in Texas or the Bakken and Marcellus shale fields in North Dakota. Once there, the energy industry uses it in oil and natural gas wells.

In 2015, the United States Geological Survey published a report on frac sand mining in the United States. It stated that "a new mineral rush is underway . . . in Wisconsin and Minnesota, for deposits of high-quality frac sand." The report explained that Wisconsin accounts for almost one-half of the frac sand capacity of the United States because of its "premium sand deposits, railway infrastructure, and long-term presence in the industry."[44] In 2013 the *Wall Street Journal* dubbed sand "the new gold" in fracking and, in some ways, its mining even mirrors metallic rushes.[45] The boom has made sand and gravel mining in Wisconsin relevant to thousands of people across the state by drawing attention to the industry that it previously could not generate.

The recent frac sand boom in Wisconsin happened on a scale never seen before. Since frac sand mining was first recorded in 1959, it has grown enormously in both value and production.[46] In 1984, Wisconsin produced over 1 million short tons of industrial sand valued at $11.8 million dollars. Over the next twenty-six years, Wisconsin's production increased to 3.6 million short tons in 2010, worth $156 million dollars.[47] Only four years after that, however, in 2014, Wisconsin's production of industrial sand and gravel had soared to 38 million short tons valued at a whopping $3.1 billion dollars.[48]

Frac sand is needed in very large volumes; one oil or natural gas well can require ten thousand tons of silica sand—an enormous amount, but only a fraction of the thirty-eight million short tons that Wisconsin produced in 2014.[49] High-grade frac sand sells for $60 to $80 per ton, more than five times the price of construction sand and gravel.[50] Because of this demand, Wisconsin sand is consumed in large amounts and draws high prices, stimulating development of the industry. In July 2011, 41 sand mines in Wisconsin were classified as either active, in development, or proposed.[51] By May 2016, 128 industrial sand facilities existed in the state.[52]

During the frac sand excitement in Wisconsin, the nation was experiencing a similar boom. The 2015 USGS report on frac sand mining found that 2.2 million tons of frac sand were sold in 2003, a 45 percent increase from 2002. The report attributed this growth to "aggressive horizontal drilling and hydraulic fracturing programs," by the petroleum industry.[53] Total U.S. production increased to 13 million tons valued at $546 million dollars in 2010, and to 26 million tons valued at $1.33 billion dollars in 2011. By 2014, these totals had reached 81 million short tons and over $7 billion dollars.[54]

The billions of dollars of Wisconsin sand mined for the energy industry is devoted to a technology known as hydraulic fracturing (or fracking, fracturing or hydrofracking). Developed by Stanolind Oil in 1949, it is a technique used to extract previously inaccessible natural gas and oil reserves from deep rock formations. Companies drill down thousands of feet into deposits, create or exploit small cracks in the rock, and pump a combination of frac sand, water, and chemicals into the wells under enormous pressure to keep the cracks open. This allows oil and gas to flow to the surface. Sand is an essential component of this process, functioning as a "proppant," propping open the fissures in the rock.[55]

The earliest fracturing treatments used river or construction sand. However, these deposits are now considered too impure and too angular. With today's advancements, frac sand must meet specific requirements established by the American Petroleum Institute and the International Organization for Standardization.[56] Such sand needs to be homogenous, high in silica content, devoid of impurities, spherical, and resistant to crushing. Ideal deposits are geologically accessible, loose, unconsolidated, close to the surface, and on or near truck and rail networks.[57] Many Wisconsin sand deposits meet all of these specifications. Thus, they are desirable and bring the highest prices. Without Wisconsin sand, hydraulic fracturing would be far less profitable and efficient, and without hydraulic fracturing far less demand for Wisconsin sand would exist. Despite environmental concerns about hydraulic fracturing, it appears that the technique will continue to be used.[58]

Frac sand mining operations in Wisconsin are spread across much of the state. However, they all follow the same basic principles and procedures. Once a deposit is located and the proper infrastructure is established, mining operations start by removing the overburden and placing it into piles that create a sound and sight barrier for neighboring properties. Frac sands in Wisconsin sit close to the surface so there is not much overburden to remove. The sand is then excavated.[59]

If the sand is tightly cemented, miners will drill into the deposit and dislodge it with explosives. The blasting's noise, vibrations, dust emissions, and hazards are restricted by the U.S. Mine Safety and Health Administration (MSHA). The Wisconsin Department of Safety and Professional Services also regulates blasts through SPS 307 of the Wisconsin Administrative Code, which requires record keeping, the notification of neighbors, and limits seismic activity.

Following blasting, the loosened deposits are crushed and processed, to separate the grains that meet industry requirements from those that do not, prior to shipment. The final step is mine reclamation, regulated by Wisconsin Administrative Code NR 340, which requires operators to provide financial assurances before beginning production.[60]

All of these procedures are like those of other sand-mining operations in the state, and they follow the same principles that have been used for decades in Wisconsin's nonmetallic mining industry. Consequently, Wisconsin has a history of industrial sand mining that has recorded very few problems in over one hundred years.[61]

In theory, mining for frac sand is a subset of sand and gravel mining and simply produces a specific aggregate product. However, in practice, frac sand mining presents its own set of challenges and nuances that differ from mining construction sand and gravel. Particle size requirements, a volatile market, processing methods different from ordinary sand and gravel mining, and specific equipment are all operational challenges that distinguish frac sand mines from construction sand, gravel or other aggregate mines.

The first challenge and main barrier to entry for companies with established facilities is whether their sites have the proper particle size. McLanahan Corporation's director of process engineering, Scott O'Brien, has observed that proper particle size "is either something you have or don't have." As he put it: "People are always interested in changing the shape of their particle. If the shape of a piece of sand is that easily changed, it is probably not going to meet the compressive strength required."[62]

If a mine is fortunate enough to have a suitable deposit, it must prepare itself to supply a volatile market by investing in new equipment and processing plants. After frac sand is pulled from the ground it must go through extensive and highly specialized washing, screening, and drying processes. O'Brien explained that "in the concrete and asphalt business you are dealing with specs that you can drive a bus through." Frac sand specs, however, are very narrow. The drying process for frac sand is unlike drying aggregate for asphalt. Even the shipping process adds an extra complication and cost because producers need to transport the dried sand in a pressure-differential container.[63]

An added complication for Wisconsin's surface mines is the state's notorious winters. Its sand deposits are only accessible, at most, nine months of the year. This means that operators must stockpile sand from the wet processing plant to feed the dry finishing plant to meet demand year-round. It takes much planning and complex logistics to keep product flowing to market all through the year.[64]

Converting an existing plant into one that can handle frac sand or building a new plant altogether is no easy feat. It takes much time, money, and knowledge of the intricacies of the market and the narrow specifications required for hydraulic fracturing. Adding up all the expenses, a new frac sand plant can cost twenty to forty million dollars.[65] Three companies that completed this transition successfully were NBR Sand in Texas, Southern Ohio Sand, and A. F. Gelhar Company in Markesan, Wisconsin.

NBR began as a supplier of golf course sand, Southern Ohio Sand started as a traditional sand and gravel plant, and A. F. Gelhar Company opened in 1919 as a provider of silica sand. All three operations recognized that their sites had rich, pure deposits of frac sand, and each decided to make the jump into that industry. NBR Sand adjusted its screening process so that its product would fit the proper sizes and specifications to qualify as a frac sand. Southern Ohio Sand bought a Hydrosizer from McLanahan Corporation meant for extremely fine classifications.[66] The Hydrosizer uses the same technology as used in specialty construction sand production but applies it to frac sand.[67]

A. F. Gelhar Company also brought on McLanahan Corporation, but instead of purchasing a Hydrosizer, A. F. Gelhar had McLanahan custom build a system that washes and classifies both coarse and fine sands. Gelhar would be mining essentially the same sand as it had since 1919, but implementing a different sizing process to produce the right fractions. This allowed the company to maximize the utility of its deposit, producing a variety of frac sand and industrial sand applications fitting the company's history as a silica sand supplier.[68]

McLanahan Corporation has been a major contributor to helping mines enter the business of frac sand. The operations manager at Taylor Frac in Wisconsin, Rob Hargrave, noted that "the frac sand market changes quite frequently," and that "the McLanahan system gives you the flexibility to adjust your product according to what the market wants almost instantaneously."[69]

McLanahan has hosted frac sand educational events to help producers understand what equipment will benefit their operations, co-sponsored the inaugural Frac Sand Insider Conference organized by the trade magazine *Rock Products*, and created a portable frac sand plant in response to the growing demand for highly specialized frac sand.[70]

Although McLanahan has been a leading supplier of mining equipment, other organizations have also developed new technology or resources to meet the needs of an evolving industry. Wabashi MPI developed a proppant crush-test press specifically for frac sand. The equipment tests a sand's crush resistance to allow mines to determine if it can be used for hydraulic fracturing.[71] Terex Washing Systems has created the FracStac, a modular frac sand plant that can produce up to three grades of frac sand. The company claims that FracStac is the world's first modular frac sand plant.[72] *Rock Products*, a monthly leading aggregate-industry journal, has been producing "Frac Sand Insider" segments in each edition since October 2012. The frac sand industry has grown so large so quickly that it has been worth having this outlet for special technical information regarding the industry.[73]

The Public Interest

Beyond the private sector, the public is also interested in acquiring technical information about its relationship with frac sand mining. To help people learn about the tools their communities possess to manage frac sand mining, the Center for Land Use Education at the University of Wisconsin–Madison, conducted two studies in 2012. These studies determined how prepared the state's seventy-two counties were to handle an influx of frac sand mining.

The first study concerned comprehensive plans, the tools counties use for natural resource planning. Results showed that the plans of thirty-one counties included goals or objectives for nonmetallic resources, twenty-six included only policies, and twenty-six did not mention any goals, objectives, or policies at all. Within the frac sand mining area of the state, seven counties did not have plans or had plans that could not be located. For example, Trempealeau County, with several frac sand operations, only had a map. The study's results showed that very few counties were taking advantage of the tools that they had to manage their resources.[74]

The Center's researchers then looked at zoning ordinances and found a similar lack of government oversight. Zoning ordinances can explicitly control how mines operate.[75] However, the study found that thirty-two of Wisconsin's seventy-two counties did not have any type of zoning ordinances for nonmetallic mines. Eighteen of the thirty-two counties without such ordinances had potential for frac sand mining. As examples, Monroe County had no zoning ordinances but several frac sand operations, and Trempealeau County had very few standards but many frac sand facilities.

This study again showed that few counties were taking advantage of the tools available to manage their resources.[76] A lack of understanding of the value and rich history of nonmetallic minerals within Wisconsin contributed to counties being overwhelmed by the demand for frac sand because county officials and residents did not understand the potential of aggregate materials.

The frac sand boom that caught many Wisconsinites off guard declined around Thanksgiving of 2014.[77] Supply quickly caught up to demand and with lower prices the advantage shifted to larger companies that had the infrastructure, experience, and cash available to survive the downturn. In June 2015, Wisconsin had sixty-three frac sand sites active, but fifty-eight inactive.[78] The market was not sustainable, and when it crashed some company stocks plummeted more than 90 percent; Hi-Crush Proppants stock, for example, dropped 98 percent.[79]

The health of the frac sand industry depends on how much hydraulic fracturing is occurring, since more fracturing requires more sand.[80] Because hydraulic fracturing is a more expensive method of extracting fossil fuels, it is only profitable in times of high prices for oil. In May 2016, a barrel of West Texas Intermediate crude oil was $44.66, down 25 percent from 2015 and over 50 percent from 2014. Pumping more sand down a well increases the well's cost but has the potential to double its output. When prices are high, operators can afford to buy more frac sand to increase the yield from their wells. But when prices are low, they have a tougher time making a profit and won't buy as much Wisconsin sand.[81]

Although frac sand is valuable, it is also a volatile commodity because it has a specific application in an industry prone to market fluctuations. With Wisconsin's more than twenty-five hundred quarries and pits including just over one hundred industrial sand operations, frac sand is only a fraction of a much larger and historic industry in Wisconsin.[82] Boom and bust periods like those in Wisconsin's frac sand industry can create economic uncertainty and turmoil. Thankfully, most mines in Wisconsin do not yet have a significant share of their local economies, so the downturn in frac sand did not dramatically affect most town revenues.

Permanent prosperity from mining will probably not be found with frac sand alone, but it could be achieved by mining for frac sand and other nonmetallic resources and aggregate materials that have smaller profit margins than frac sand but more stable markets. Despite a slow-down, frac sand officials are confident that the market will recover. Large investments in infrastructure mean that companies are not likely to abandon Wisconsin any time soon. Barring any major, long-term changes to the petroleum industry, Wisconsin is likely to remain the largest supplier of frac sand.[83]

Frac sand mining in Wisconsin is a complex and nuanced topic that requires more than a pro-jobs versus pro-environment debate. Any consideration of mining will raise environmental, quality-of-life, and health concerns. However, the reality of sand mining in Wisconsin is that it is not very damaging to public health or to the environment. This is one of the reasons why it has not garnered much attention in the past. The industry has operated for over a century with very few problems.

However, the frac sand boom has drawn attention to the sand and gravel mining industry that it previously did not attract. It has also caused many citizens to consider how these mines can affect their communities. Professor Thomas Pearson, University of Wisconsin–Stout, explains that frac sand mines "can disrupt the visual connections to a once familiar place," and "fuel objections to a proposed mine well before environmental or health considerations are even discussed."[84] Therefore, it is important to consider how mining in Wisconsin has changed the landscape and to reflect on its significance to the state.

Altered Landscapes

Many mining practices have the potential to dramatically change the landscape, making it unrecognizable compared to what it once was. However, society depends on mined resources and unless something changes in the way civilizations are built, resource extraction will need to continue. Nonmetallic mines typically have localized impacts on the environment, however the materials excavated from them can make profound changes to the land across a far greater region. Geographer Clarence W. Olmstead explained in *Wisconsin: Land and Life* that "landscapes are part of the everyday lives of people, yet they challenge scholars both to define exactly what they are and to understand how they develop and change." He continued that landscapes are "a record of ourselves—who and what we are, what we have created, what we value."[85]

Wisconsin's landscape is often associated with an abundance of the lakes, farms, and rolling hills quintessential to rural Wisconsin. However, the state is also dotted with quarries and pits that create marks on the earth different from anything else in the region. The nonmetallic mines spread across the state provide materials for road construction, bridges, buildings, and the oil industry.[86] As Christopher Wells explained in *Car Country*, "gravel pits . . . bear less obvious connections [than changes such as new roads or increased traffic] to the forces that called them into being and require some specialized knowledge to see the connections clearly."[87] Society needs, creates, and values these features and resources, and the evidence to prove this is right out in the open at a local quarry.

Quarries and pits are so prevalent throughout the state that six of them easily can be identified from one Google Earth image of Madison, Wisconsin, from 12 June 2014, as seen in figures 1 through 7. These six quarries are on the fringes of the city between the urban-suburban and rural division in the landscape. They are surrounded by suburbs or farmland, are a considerable distance from downtown, and supply their surrounding areas with important materials.

Additional quarries just like these are scattered all over the state near other towns, including

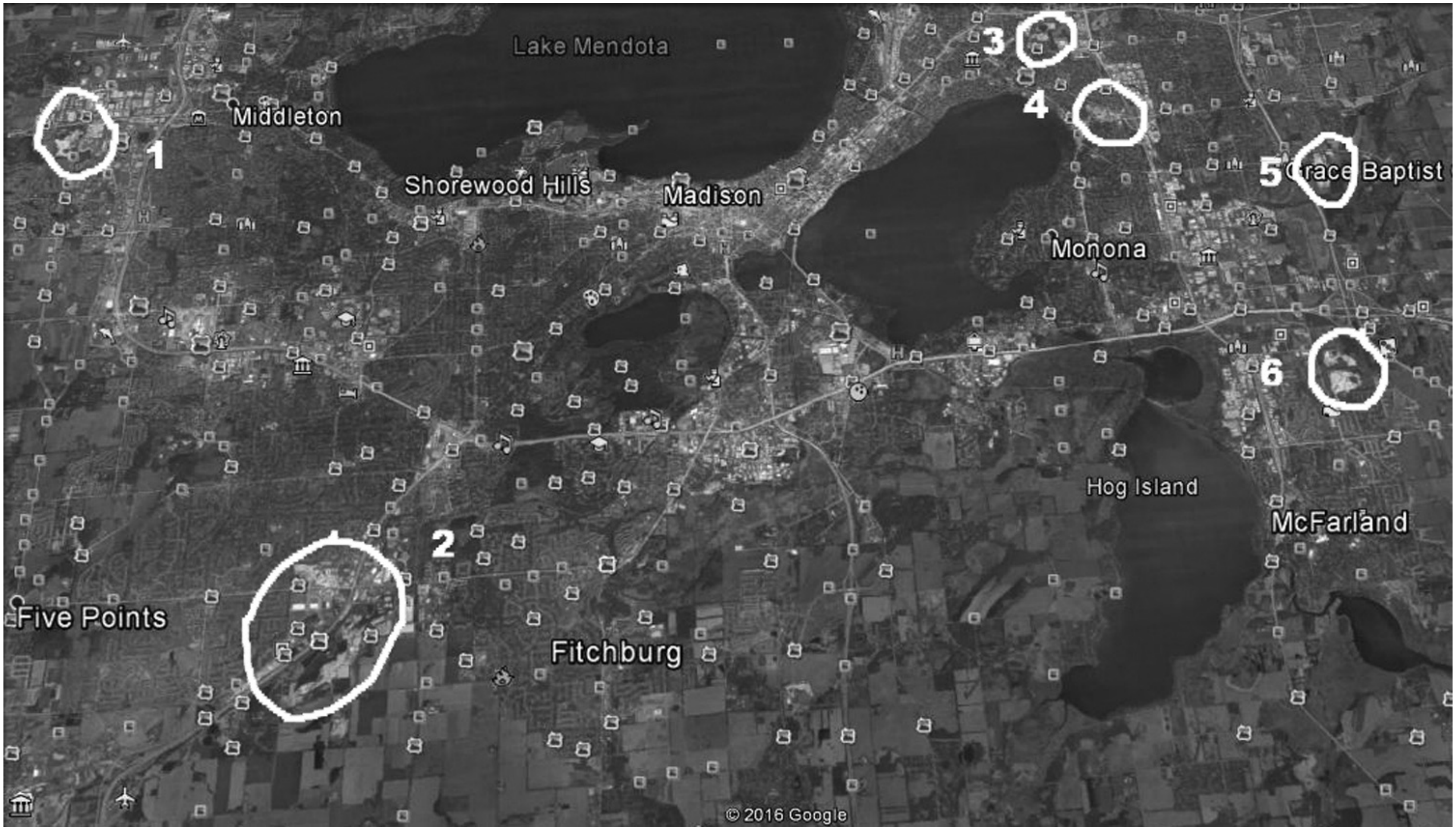


Figure 1. Google Earth Satellite Image of Madison, WI (12 June 2014). Six quarries exist in the greater Madison area, all of which are on the fringes between the urban/suburban landscape and the rural countryside.

Figure 2. Quarry 1 lies to the west of Middleton with a golf course to the south, farmland to the west, and a hospital to the east. (Google Earth, 12 June 2014.)

Figure 3. Quarry 2 sits next to Quarry Ridge, a popular Madison mountain biking destination, and Military Ridge bike path. Farmland lies to the south and east and suburbs to the west. (Google Earth, 12 June 2014.)

Figure 4. Quarry 3 is located north of Lake Monona and east of Lake Mendota. This quarry is surrounded mainly by a residential area and has a retention pond at its center. (Google Earth, 12 June 2014.)

Figure 5. Quarry 4 is just east of Lake Monona, surrounded by suburbs. Not far east of here, the area becomes much less populated. (Google Earth, 12 June 2014.)

Figure 6. Quarry 5 has suburbs to the north and west, but a much more lightly populated area to its south and east, where farmland begins to become more prevalent. (Google Earth,12 June 2014.)

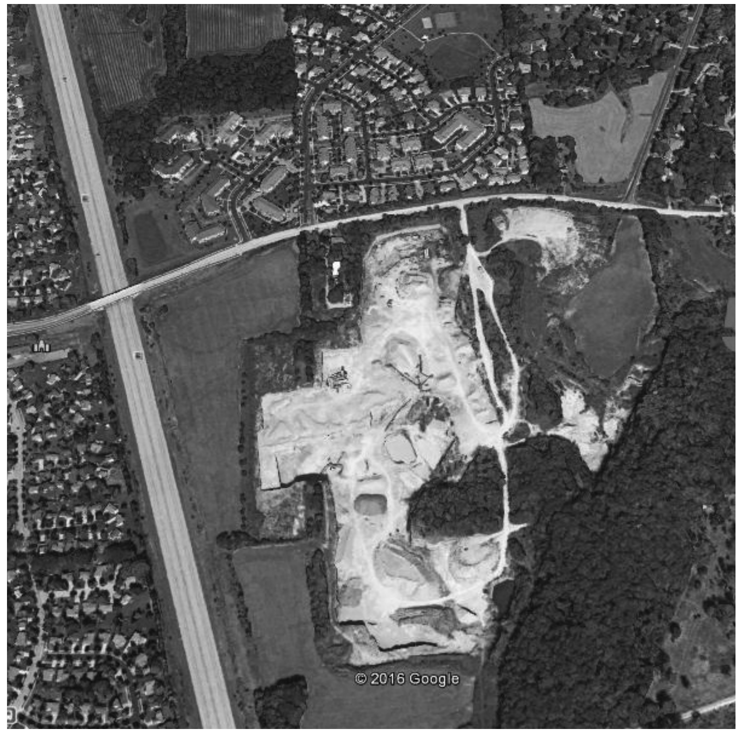


Figure 7. Small neighborhoods to the west and south bump against quarry 6, with farmland near to the east. (Google Earth, 12 June 2014.)

Redgranite, White Lake, and New Auburn. An abandoned quarry filled with water now serves as a swimming hole in Redgranite (Figure 8); a small pit lies near the Wolf River at White Lake (Figure 9); and a busy, rail-served, frac sand mine operates near New Auburn (Figure 10).

Each of these three mines highlights interesting aspects of quarrying. Redgranite's experience illustrates that eventually quarries outlive their initial usefulness but remain as a mark on the landscape for many years after production stops. The small pit in White Lake highlights that even small, rural towns need supplies of aggregate. And the active frac sand mine in New Auburn connects Wisconsin's mining to the larger economic sphere of the energy industry. This mine is particularly interesting because only a few years earlier, in 2010, this landscape had been an expanse of farmland. The mine has grown rapidly because of the demand for frac sand during the recent boom years, and it now dominates the surrounding area. What was once farmland is now an expansive sand mine (Figures 12 A and B). Each of these mines served a different purpose, but all will remain on the landscape as marks of Wisconsinites' past activities.

Other features indicating the past activities of Wisconsinites are the structures that the excavated sand and gravel have been used to build. Wisconsinites have used sand and gravel resources to alter the state's landscape and built environment for almost two centuries. Mining these materials can alter the landscape in dramatic ways because they are needed in large quantities to create massive structures like railroads, highways, bridges, roads, and buildings. The thousands of quarries, pits, roads, railways, and buildings across Wisconsin leave significant features on the earth that will last for generations after production ceases or people stop using them. The accompanying il-

Figure 8. An abandoned quarry in the heart of Redgranite, Wisconsin, now filled with water and used for swimming. (Google Earth, 7 Oct. 2013.)

Figure 9. A small pit near the rural town of White Lake, Wisconsin, and the Wolf River. (Google Earth, 2 Sep. 2013.)

lustrations offer visual examples of how sand and gravel have helped to permanently alter the built environment of Wisconsin (Figure 13).

All of these images suggest that even if a mine is reclaimed or a road demolished, the place where it was located will never return to what it was before the mine opened or the road was built. Although this may be disconcerting to those worried about humans' long-term effects on Wisconsin's environment, Geologist Thomas Friz of the Wisconsin Geological and Natural History Survey says that "pits are the easiest form of surface mine to reclaim." Topsoil can be replaced, the land can be graded, and plants can be regrown. Oftentimes, pits and quarries can be reclaimed as lakes or converted to other uses, such as sanitary landfills. Once their usefulness as an extraction site ends, neighborhoods and shopping centers can even be built over them as well. Property values may actually increase after mines close if they are reclaimed properly, and communities are able to benefit from previously mined sites if they plan accordingly.[88]

Wisconsin's Sand and Gravel

Sand and gravel are Wisconsin's most valuable and heavily mined mineral resources. Despite this, they have been largely ignored or downplayed in historical writing about the state. Although not as well-known as lead, zinc, iron, or other metals, the effects of these materials on society are as significant. Sand and gravel made it possible for Wisconsinites to build better transportation networks. They can be applied to other constructions and industrial applications, including as molding sand and for filtering.

In the twenty-first century sand's most lucrative employment is in the energy industry as a proppant for hydraulic fracturing, and it is in this segment of the market that Wisconsin dominates all other states. Despite Wisconsin's position as

Figure 10. A frac sand mine spread across the countryside at New Auburn, Wisconsin. (Google Earth, 29 Sep. 2015.)

Figure 12A. The same area as in Figure 10. What is now a large frac sand operation was farmland only four years before. (USDA Farm Survey Agency, 2 Oct. 2011)

Figure 11. A close-up of the southern section of the New Auburn frac sand mine in Figure 10. (Google Earth, 29 Sep. 2015.)

Figure 12B. The same area as Figure 11, four years earlier. (USDA Farm Survey Agency, 2 Oct. 2011)

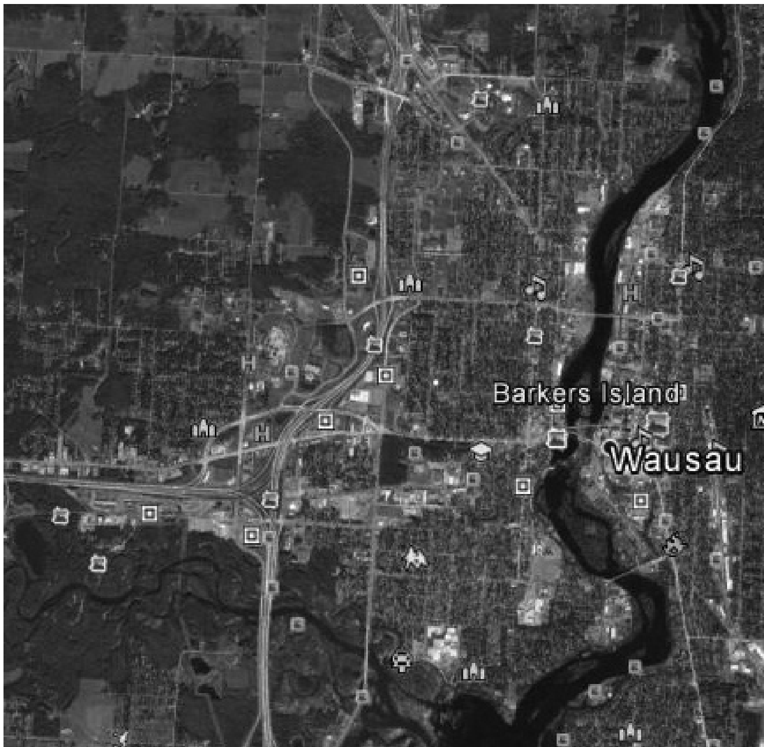
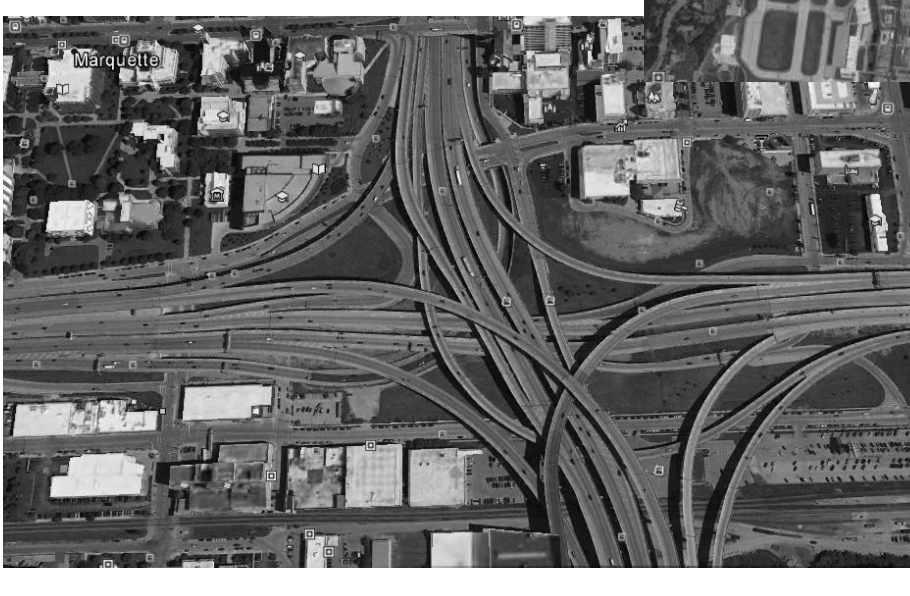


Figure 13. Above: Wausau Wisconsin's highway network. (Google Earth, 15 Sep. 2013.) Right: Madison Airport and the quarry to its north. (Google Earth, 12 June 2014.) Below: Milwaukee freeways. (Google Earth, 18 June 2015.)



the leading supplier of frac sand in the country, the recent boom years caught many county governments and citizens off guard. It is for these reasons that it is important to study sand and gravel's history within the state. An understanding of all of the natural resources available is a prerequisite to creating a sustainable society. This includes even the ones like sand and gravel that appear to be ubiquitous and are used in mundane fashions.

Formed through millions of years of geological activity, shallow seas, and glaciers, Wisconsin's sand and gravel are abundant resources that have geologic and historic value. These are versatile materials with multiple applications, produced by a lucrative industry that earns millions of dollars every year. The industry's significance comes from creating jobs, helping to build infrastructure, facilitating the extraction of other resources, and permanently altering the state's landscape. Although Lawrence Roe stated that "the history of industrial mineral production is not nearly as exciting as the story of the metal mining industry," and authors like James Lake and Robert Nesbit did not discuss sand and gravel when describing Wisconsin's mineral resources, they are materials essential to the state both historically and presently.[89]

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