Resource Assessment and Site Selection:

Wind Power Development and Pumped Energy Storage on Minnesota's Iron Range

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BARR

4700 West 77th Street
Minneapolis, MN 55435
Phone: (952) 832-2600
Fax: (952) 832-2601

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1.0 Introduction

1.1 CIRI Mine Pit Lake Hydrology, Habitat, and Energy Production Study

The Central Iron Range Initiative (CIRI) was established in 1998 as a partnership between the Minnesota Iron Range communities of Buhl, Chisholm, Hibbing, Balkan Township, and Great Scott Township. Part of CIRI's mission is to provide a forum for coordination and communication between central communities and other interested parties. The overall goal of CIRI is to promote regional economic development through workforce training, infrastructure enhancement, and cooperative ventures with public and private agencies.

For the 2005-2006 biennium, the Legislative Commission for Minnesota Resources (LCMR) appropriated funds to support a CIRI effort to characterize central Iron Range mine pit geology and morphometry, identify likely ultimate mine pit water levels, evaluate the mine pit lakes as a sport fishery, and evaluate mine pit lakes as a potential source of wind/pumped storage energy production.

The focus of this LCMR-funded study of wind/pumped storage energy production is to identify significant opportunities for alternative energy production. In the case of wind energy development, this means locating the best available sites for wind turbines. For pumped storage energy production, the goal is to identify sites at which there is a favorable combination of local geography, mine pit configuration, and long-term land use plans.

1.2 Related CIRSSD Efforts

In association with CIRI, the Central Iron Range Sanitary Sewer District (CIRSSD, or District) was formed in 2001 to facilitate cooperation in addressing regional water resources issues. The District consists of the cities of Hibbing, Chisholm, Buhl, and Kinney; Balkan and Great Scott townships; and Ironworld. The CIRSSD boundary and surrounding areas are shown on Figure 1. The CIRSSD governing board initiates and monitors district efforts such as planning, capital improvement projects, and regional sewer system operations and maintenance activities. Monthly meetings are held to review progress, discuss ongoing projects, etc.

In conjunction with the CIRI effort, the CIRSSD applied for and received (in 2005) a grant from the Minnesota state legislature to assist the District with its capital improvement projects. Funding was included for projects aimed toward increasing District sewer capacity, upgrading treatment plant capabilities, and replacing outdated facilities. The grant also included funds intended to allow the District to begin the process of developing renewable energy resources.

More specifically, funding was provided to allow the District to begin the preliminary design process for wind turbine installation(s), and for a pumped storage facility. It was understood that the District would be able to benefit directly and indirectly from the electrical energy made available by such development. The CIRSSD renewable energy design activities will occur during late 2006 and early 2007. The design effort will make use of the more preliminary information from the LCMR-funded study of potential wind power and pumped storage sites summarized herein.

1.3 Approach and Organization of this Study

For this study, an evaluation of the CIRSSD area's geography, land use, and energy production potential was made to identify significant opportunities for alternative energy production. A review of previous reports and other existing data was also conducted. Using the regional analysis and the results of the data review, a determination was made of the locations of the sites having the best possibilities for the development of wind and pumped storage energy production.

This report, providing the results of the determination, is structured as follows:

1. Introduction and background
2. General wind and pumped storage energy production concepts
3. Review of related reports and studies
4. Discussion of selection screening criteria
5. Identification and description of favorable wind turbine and pumped storage locations
6. Site evaluation using screening criteria
7. Discussion of integration of wind and pumped storage projects, and impact on site selection
8. Recommendations for future efforts

2.0 Wind Energy and Pumped Storage – General Concepts

2.1 Wind Energy

Humans have made direct use of wind energy for thousands of years. In the past century, means were developed to allow wind energy to produce electricity, making that energy available indirectly and at a distance. Over the past decade, interest in wind projects has been spurred by technological advances, by increased interest in non-polluting and renewable energy sources, and by government incentives. Both nationally and in Minnesota, electricity production from wind energy is on the increase.

2.1.1 Wind Projects – General

Equipment – Wind power is converted to electricity by a wind turbine. Wind turbines come in many sizes, with smaller residential turbines having rotor diameters of up to eight meters. Modern utility-scale turbines may have rotor diameters greater than 80 meters, and can produce nearly two megawatts (MW) of power.

A typical wind turbine consists of a three-bladed rotor that turns a shaft that operates a generator providing medium-voltage electricity. At the turbine, a transformer increases the voltage of the electric power to the distribution voltage so it can flow efficiently through underground lines to a collection point. In some cases, the electricity is sent directly to nearby farms, residences and towns. Otherwise, the distribution-voltage power is sent to a substation where the voltage is increased dramatically to transmission-voltage power. In this way, it can be sent through large transmission lines, if available, to distant users.

Siting – Wind projects are viable only in locations with relatively high average wind speeds. Average wind speed depends on many factors, including local climate patterns, land cover types, and regional topography. Seemingly minor wind speed differences between locations may greatly affect a project's viability, because harvestable wind energy varies in relation to the wind speed cubed. Twelve-mph winds have more than 70% more available energy than ten-mph winds.

Wind turbines cannot be placed immediately adjacent to each other. Each wind turbine has a "footprint" of approximately one acre, land beneath the turbine on which other uses are prohibited.

Also, turbines must be sited a certain minimum distance apart from each other – both side-to-side and front-to-back – to avoid "shadowing" each other and reducing power output.

Typical Project Process – The typical commercial wind project may involve many players. Usually, the main responsibility for the project lies with the developer. The developer identifies and negotiates with the landowner for the right to lease the land on which the turbine will be placed, and the right to "harvest" the wind above the land. The developer is also typically responsible for finding financing for the project, securing a contract with an electrical utility willing to buy the electricity produced, purchasing the turbine and associated equipment, contracting to have it installed, and arranging for operation of the project. The developer may or may not be the ultimate owner of the facility.

The development of a wind power project typically begins with the collection of on-site wind data. At least one year of on-site wind monitoring data are typically required by the turbine manufacturers and project financers for project development. While the statewide wind resource maps are helpful for general identification of wind resource areas, on-site wind monitoring is a necessary component of a wind power project. On-site monitoring data are used to better determine the viability of a wind project for a particular location.

2.1.2 Wind Energy Development in Minnesota

The American Wind Energy Association (AWEA) lists Minnesota as being ninth in the nation for wind energy potential. Minnesota is currently third in the nation with respect to wind power development, and the development of wind power in Minnesota is likely to continue.

Benefits and Incentives – Wind power development is a source of economic benefits for Minnesota communities. These benefits include construction-related jobs during site development and turbine installation. After construction, ongoing employment of workers is required for operation and maintenance activities. Also, depending on project-specific arrangements, local landowners may receive income through leasing arrangements, and tax revenue may be generated for the community.

Wind energy development in Minnesota has been spurred by mandates by the state legislature, tax credits and other financial incentives. Wind energy production in Minnesota received a jump-start in 1994 when Xcel Energy (then NSP) was required by the state to include wind energy in its electrical generation mix.

Minnesota has also established a Renewable Energy Objective (REO), which set a goal of having 10 percent of the state's energy production coming from renewable sources by 2015. Utilities are reviewed every two years to judge compliance with the REO. In 1995, the state passed legislation to encourage the development of locally owned wind energy projects. This Community-Based Energy Development (C-BED) legislation requires electric utilities to consider community-based wind energy projects when seeking to add wind generation to their supply mix. In addition, the C-BED legislation requires electrical utilities to offer developers electricity purchase rate incentives to help community-based wind development projects overcome financial barriers.

Technological Advances – The technology for generating electricity from wind has continued to improve over recent decades. Larger and more efficient turbines have been developed, allowing per-acre electricity production to increase. As a result of such advances, the per-kilowatt cost of wind-generated electricity has declined, making it increasingly competitive in the marketplace.

Facilitation of wind power development through technological improvements in wind turbines has been paralleled by greater understanding of Minnesota's wind resources. In 2006, detailed wind maps developed through atmospheric modeling for the Department of Commerce became available. These maps show expected wind resources statewide at 30, 80, and 100 meters above the ground, and provide capacity factor and energy production estimates for a 1.65 MW wind turbine at a height of 80 meters. The availability of better information allows for more efficient targeting of wind power development.

Iron Range Wind Development Potential – Statewide wind resource mapping shows that in general, Minnesota's best wind resources are located in the southwest part of the state. However, the existence of a significant wind resource along the Iron Range has been suggested for many years. The wind resource mapping indicates that despite the general lack of premium wind resource availability in northeastern Minnesota, there are areas within the CIRSSD where the wind resource is of good quality. And the combination of rising energy prices, state mandates and incentives, falling costs for high-efficiency turbines, and ridge land availability on the Iron Range may result in viable wind power development opportunities.

2.2 Pumped Storage

Pumped Storage Operation – Pumped storage facilities serve to produce electricity for use during periods of peak demand. Providing electricity via pumped storage involves storing energy by utilizing two reservoirs of water – one at a higher elevation, and one at a lower elevation. As the water storage capacity of the reservoirs increases, and as the elevation difference between the reservoirs increases, the energy storage potential also increases. A pumped storage facility also requires one or more pumps to move water from the lower reservoir to the upper reservoir, and one or more hydroelectric turbines that produce electricity when the water is allowed to flow through them back to the lower reservoir.

Water from the lower reservoir is pumped up to the higher reservoir at times of the day when the pumps can make use of off-peak, cheap electricity. Energy is later recovered by allowing the water to flow back down to the lower reservoir through hydroelectric turbines. The electricity generated can be used directly, sold to a local commercial or industrial user, or routed to the electrical grid and sold to power utilities. It can be seen that the upper reservoir serves as a sort of battery, discharged to provide electricity when needed and recharged when it is refilled by pumping water up from the lower reservoir.

<u>Electrical Production Economics</u> – It can be seen that generating electricity via pumped storage provides no net energy production. In fact, because neither the pumps nor the hydroelectric turbines are 100% efficient, the overall process results in a net energy loss. The electrical energy expended in pumping water up to the higher reservoir is greater than the electrical energy produced when the same quantity of water is allowed to flow back to the lower reservoir through the hydroelectric turbines.

Nevertheless, pumped storage can be a valuable part of the overall electricity supply formula. Electricity produced in this fashion can serve as a source of relatively cheap energy for peak-demand users. It can also provide a ready reserve of electrical power for industrial users that periodically require large surges.

Typically, pumped storage operation involves pumping water to the higher reservoirs during off-peak hours, when electricity demand and prices are lower. The hydroelectric turbines are then put into service during times when the electricity can be sold at higher, peak-demand prices. In this way, a pumped storage facility can provide revenue for the owners, who effectively are able to buy energy at low prices and re-sell it later at higher prices. Also, pumped storage facilities can take the place of peaking plants, and help delay the need for construction of additional base load production facilities.

<u>CIRSSD Pumped Storage</u> – Local geography is the primary determinant for whether or not pumped storage facilities can be economically viable. Such facilities require at least two large reservoirs in close proximity, with a significant elevation difference between them. Fortunately, on the Iron

Range and within the CIRSSD's boundaries, such reservoirs have already been developed as a result of the large-scale mining excavation that has taken place over the years on the Iron Range. Large volumes of water are, or can be, contained in the mine pit lakes. In addition, it is possible to establish large differences (several hundred feet, in some cases) in the elevation of the water surfaces of regional mine pit lakes. A further advantage lies in the fact that the mine pit lakes are relatively devoid of plant and animal life, meaning that environmental regulatory constraints for pumping operations may be less severe.

The idea of pumped storage development on the Iron Range is not new; using existing Minnesota Iron Range mine pits for pumped storage facility development has been discussed since at least the early 1990s. The concept remains attractive in 2006. Development of pumped storage by CIRSSD would be expected to provide regional economic benefits through providing construction and operations/maintenance jobs, and could provide the District with a direct source of electricity and/or revenue from electricity sales.

3.0 Previous Wind and Pumped Storage Studies

3.1 Minnesota Wind Power Studies

The most accurate and extensive source of public information on Minnesota’s wind energy resource is the Minnesota Department of Commerce Wind Resource Assessment Program (WRAP). Beginning in 1982, the state has monitored wind speeds and other data at sites throughout the state and published periodic reports. The WRAP seeks to accurately measure and map wind speeds in Minnesota, allowing any individual, company, utility or independent power producer to perform an initial assessment of the feasibility of a potential wind site.

The Department of Commerce’s wind mapping was updated in 2006. The new wind maps show the wind speed resources at 30, 80, and 100 meters, as well as capacity factor and energy production estimates for a 1.65 MW wind turbine at 80 meters. The new maps were developed at a finer resolution than the previously published wind maps, so that they can be expected to provide a better indication of the quality of the wind resource at a particular location. Figure 2 includes an overlay of the wind speed resources at 80 meters in the vicinity of the CIRSSD.

3.2 Pumped Storage Studies

As has been mentioned, the idea of developing pumped storage in Minnesota is not new; various pumped storage projects have been considered over the past few decades. More specifically, the idea of using existing mine pits for the development of one or more pumped storage energy facilities on the Iron Range has been discussed since at least the early 1990s. Known previous studies are summarized in the following paragraphs.

3.2.1 Canton–Biwabik Pits Pumped Storage Study

In 1993, Barr Engineering Company (Barr) developed a pumped storage concept plan using the Canton and Biwabik mine pits within the City of Biwabik (Barr, 1993). This site is referred to as Location 6 in this report (see Figure 3).

The Canton–Biwabik pits would be utilized as the lower reservoir for this project. The lower reservoir normal water surface would be about Elevation 1400, and the water surface area would be about 120 acres.

An upper reservoir would be created on forested high ground about a half mile north of the lower reservoir. Four dams with a total length of about 6,400 feet and a maximum height of about 120 feet would be constructed to create the reservoir. Elevation 1700 would be the upper reservoir normal water surface elevation, and the water surface area will be about 410 acres. The reservoirs would be connected by a 3,000-foot-long penstock. The powerhouse would be located along the north edge of the Biwabik pit.

The likely project power development is between 30 and 210 MW. Estimated project costs (1993) were between $40 million and $180 million, depending on project size. These costs do not include the electrical grid connection.

Required project properties were owned by about 15 entities at that time (1993). The primary owners were the federal government and mining companies.

At that time, it was thought that the regulatory community's reaction would have relatively few environmental concerns regarding pumped storage development at mine pits.

The Iron Range Resources and Rehabilitation Board (IRRRB) had also indicated interest in providing support for developing pumped storage at the Biwabik site. A detailed feasibility study was proposed, but no further progress ensued.

3.2.2 Hull-Rust Pumped Storage Evaluation

In 2000, Barr developed a concept plan for a pumped storage development that would utilize the Hull-Rust Mine on the north side of the City of Hibbing (Location 2, Figure 3). The east end of the Hull-Rust pit was to serve as the lower reservoir. A dam would be constructed to separate the east pit from the west side of the pit, with a powerhouse located at the northeast corner of the pit.

The project was to have two phases. In the first phase of the project, the abandoned Albany pit would serve as the primary upper reservoir. A 7,000-foot-long channel would be constructed adjacent to U.S. 169 to connect the Albany pit with the Pillsbury, Glen, Twin City and other pits located near Chisholm. This combined upper reservoir would be large, having a potential surface area of thousands of acres.

A potential second phase of the project would add to the reservoirs the western portion of the Hull-Rust pit and the existing Hibbing Taconite tailings basin.

At the time, local utilities expressed interest in pursuing the Hull-Rust project. Preliminary discussions were held with FERC regarding the necessity of FERC licensing for the project. The city of Chisholm was also contacted, and the city expressed support for the concept. However, because of a lack of funding, the project never went beyond the concept design stage.

3.2.3 Giants Ridge Pumped Storage Study

During 2001, the Canton–Biwabik study was updated and renamed the Giants Ridge Pumped Storage Project (Barr, 2001). The name was changed to reflect the site's proximity to the Giants Ridge ski area, which is about two miles northeast of the proposed upper reservoir. Figure 3 shows the location of the Giants Ridge facility (Location 6).

This re-study primarily updated the estimated project cost. The updated cost varied between $48 million and $270 million for projects between 30 MW and 210 MW. A recommendation was made that the city of Biwabik initiate acquisition of tax-forfeited properties in the area of the proposed lower pool. A detailed feasibility study was proposed.

3.2.4 Hill Annex State Park Pumped Storage

During 1992-1995, the Minnesota Department of Natural Resources (DNR) and Minnesota Power and Light Company studied the feasibility of a pumped storage project at the Hill Annex State Park in the City of Calumet. During October 1993, the report <u>Feasibility of Pumped Hydropower Development</u> was completed. During 1995, the DNR Division of Parks and Recreation issued a Request for Development Interest (MDNR, 1995). This site is referenced as Location 4 on Figure 3.

The plan used the Hill Annex mine for the lower reservoir and the nearby Majorca Pit and adjacent tailings basin as the upper reservoir. The upper reservoir water level would vary between Elevation 1395 and 1450. Similarly, the lower reservoir water level would vary between Elevation 1105 and 1130. The maximum head would be about 345 feet and the minimum head would be about 265 feet. An assumed operating head of 315 feet was used in this study.

The study concluded that about 70 to 75 MW would be developed using either two 35 MW units or one 75 MW unit. The estimated project capital cost was $48.6 million. At that time, required properties were owned by the state and Blandin Paper Company.

During 1994, an internal DNR task force conducted a preliminary review of project environmental concerns. This group found that the environmental issues could be resolved through the environmental review and permitting process. The project would impact wetlands within the tailings basin and it was estimated that about 250 acres of replacement wetlands would be required by the Wetlands Conservation Act.

3.2.5 Lake Superior Pumped Storage

In the 1960s, Barr completed a feasibility study of a proposed pumped storage facility on Lake Superior. The proposed generating capacity ranged from 73 to 520 MW, with discharge capacity up to 14,000 cfs. Preliminary plans and cost estimates were prepared for dams, a powerhouse, pump-turbine equipment, an inlet-turbine channel, a penstock/pressure tunnel, and other facilities. The study was prepared for the Lake Superior District Power Company, and the concept was proposed to Northern States Power Company. Concerns over the expense of transmission line construction formed a major impediment to the project.

3.2.6 Lake Pepin Pumped Storage

In 1992, the Southern Minnesota Municipal Power Association (SMMPA), along with Iowa Electric Light and Power Company and Interstate Power Company, proposed building a pumped storage facility on the bluffs overlooking Lake Pepin. A preliminary study was developed, the proposed site was evaluated, and a conceptual design was set forth. However, environmental concerns kept the project from moving forward.

3.2.7 DTE Pumped Storage Interest

In the summer of 2001, DTE Energy Resources Inc. requested that Barr prepare a proposal for conducting an initial screening of potential sites for pumped storage projects along the Iron Range. The evaluation was to be based on potential generating capacity, generating equipment requirements, civil engineering design considerations, transmission line availability, and property availability. However, the detailed screening required for site selection was not pursued.

4.0 Screening Criteria

In evaluating the feasibility of investing in wind or pumped storage projects, several factors are important, and they are described in the following paragraphs.

4.1 Resource Potential

4.1.1 Wind Resource Potential

For wind projects, the "resource potential" relates to the amount of available at a particular wind turbine hub height. The typical hub height for modern wind turbine rotors is 80 meters, so wind speed measurements or estimates for the 80-meter height give useful information about wind speeds that would be experienced by the turbine's rotor blades as they sweep through their circular path. As would be expected, higher average wind speeds are desirable, because they provide greater power for conversion to electrical energy at the wind turbine.

As is typical, the diurnal cycle of wind speeds over the Iron Range can be expected to be much different at 80 meters than it is at the surface. The extent of the variation depends on local and regional conditions. For the CIRSSD area, better local estimates of the wind resource are needed to be able to determine the extent of this variation and more reliably estimate the wind resource potential.

The wind resource maps available from the DOC show that the Iron Range wind resource is best within the CIRSSD – along the Mesabi Ridge, and also downwind of tailings basin areas (Figure 2). As has been mentioned, however, these maps provide the results of meteorological modeling, and do not generally reflect site-specific data. The DOC is currently operating a meteorological data collection program with instrumentation up to 90 meters on a communications tower at Bovey MN, next to a former mine site. In general, there is a lack of wind monitoring data along the Mesabi Ridge at the 50-120 meter level. Site-specific data in the project area is needed for optimizing turbine placement.

With respect to the wind resource potential in the CIRSSD area, two competing factors are involved. First, the area is generally heavily forested, and forested areas are typically poor sites for wind resource development because the drag of forested areas removes power from the wind. It is true that modern wind turbines are placed at heights well above most of the forest canopy, but it is not clear how much the wind strength would be affected at those heights.

Second, and in contrast to the wind-reducing effects of the forest, the general terrain features of the Mesabi Iron Range serve to increase the wind resource by accelerating the wind up over the east-west ridgeline that runs through the area. In addition, tailings basins covering many acres provide large expanses and long “fetch” lengths over which wind speeds can increase. Smaller but still significant man-made local features – such as waste rock piles – may also come into play. It is unclear how much benefit may be expected from these regional and local terrain features.

All of these considerations make the collection of on-site data very important to reliably estimate the wind resource potential for the CIRSSD project.

4.1.2 Pumped Storage Resource Potential

For pumped storage projects, the “resource potential” refers to the estimate of the energy that can be utilized as water flows from the upper reservoir to the lower reservoir. That energy is a function both of the elevation (or “head”) difference between the reservoirs, and the amount of flow that can be sustained throughout the power generation portion of the cycle. Therefore, it is best to have large upper and lower reservoirs, with large differences in elevation between them.

By contrast to wind energy, which is dependent on climate and geography and therefore beyond human control, the energy available in a pumped storage system may be increased by means of engineered structures. Dams and levees may be constructed to contain water and create and augment reservoir capacity. Elevation differences between upper and lower reservoirs, however, are typically dependent primarily on local geography.

4.2 Existing Infrastructure

In assessing the feasibility of wind and pumped storage projects, the existing infrastructure must be evaluated. For both wind and pumped storage projects, access to the site must be provided to allow construction, and to allow operations and maintenance activities after the project is constructed. The pre-existence of roads providing access to the site reduces the need for costly road building.

To make use of electrical generation provided by wind or pumped storage projects, power transmission is also required. Because the establishment of power lines and substations is difficult, the accessibility and capacity of the existing local power grid are important factors in feasibility assessments. The easier the access to the grid, the cheaper and more feasible an energy development project becomes.

4.3 Land Use and Suitability

Current land use in the area surrounding a proposed wind or pumped storage project site is important in evaluating feasibility. Wind turbines, for example, are not typically sited in urban areas. State or federal parklands may be off limits. And aesthetic, practical, and ecological concerns may prevent turbines from being sited near recreational areas, airports, or migratory bird flyways.

Furthermore, subsurface (geological) conditions at a proposed site may be more or less favorable for placing wind turbines or pumped storage facility components. Unconsolidated rock, for example, provides a poor foundation for wind turbines. Similarly, highly porous soils may make it much more difficult and costly to develop and maintain a reservoir to be used for pumped storage.

4.4 Land Ownership, Availability and Timing

Even when there is good resource potential and land use and geologic conditions are favorable at a particular site, property ownership issues may restrict wind power development. The situation in the Iron Range is further complicated by the fact that both surface land ownership and mineral rights (sub-surface property) ownership may need to be considered. Furthermore, surface property rights and mineral rights may be held by unrelated people or organizations.

Ownership issues must be taken into account in power development plans. Current landowners may or may not be amenable to selling or leasing their land for use in energy projects. Landowners may demand excessively high prices, reducing the feasibility of the project. Or, landowners may simply not want to make their land available for wind or pumped storage projects. On the Iron Range, mine owners may have concerns about wind or pumped storage projects interfering with their ongoing and future operations. Others may object on aesthetic grounds.

With Iron Range pumped storage projects, which are expected to utilize mine pits now filled or filling with water, additional ownership considerations come into play. The development of a pumped storage project would proceed only if the mine pits could reasonably be expected to be available for use for several decades.

Some of the mine pits presenting good resource potential may be unavailable due to ongoing mining operations. As a result, pumped storage development at such locations may be precluded, or may have to be postponed for years or decades to allow a continuation of current mining activities.

Although mining companies may be open to the idea of using existing and currently abandoned mine pit lakes for pumped storage projects, they are typically not comfortable with the idea of foregoing all future access to ore bodies accessible via their mine pits. The mine companies may prefer to maintain indefinite access to some of their currently abandoned mine pits and the access to ore bodies that they provide. Such properties are thus also effectively made indefinitely unavailable for pumped storage projects.

4.5 Environmental and Permitting Considerations

Relative to other forms of power generation (nuclear, coal, natural gas, or even hydroelectric) both wind and pumped storage power generation are generally considered to be less environmentally damaging. This may be especially true on the Iron Range, where existing large-scale land disturbances are already pronounced. The mine pit lakes, for example, have been thought to be particularly well-suited for pumped storage development because of the relative scarcity of aquatic life in their cold and non-productive waters. Despite some anticipated advantages with respect to environmental permitting, however, environmental concerns (and related regulatory permitting issues) must be taken into account in conducting feasibility screening for both wind and pumped storage projects.

4.5.1 Public Utility Commission Approvals

The Minnesota Public Utility Commission (PUC) governs electrical power generation in Minnesota, so Iron Range wind power development and/or pumped storage facility development would be subject to regulation by the PUC.

It is likely that an Iron Range pumped storage project would also require a site permit from the PUC under the Power Plant Siting Act (Minnesota Statutes §§ 116C.51-.69). A site permit is required to build a “large electric power generating plant,” or LEPGP. An LEPGP is defined as a power plant and associated facilities capable of operating at a capacity of 50 megawatts or more. The rules for the administration of power plant site permits are found at Minnesota Rules Chapter 4400.

A site permit from the Public Utilities Commission is also required to construct a Large Wind Energy Conversion System (LWECS), which is any combination of wind turbines and associated facilities with the capacity to generate five megawatts or more of electricity. This requirement became law in 1995 under Minnesota Statutes §§ 116C.691-.697. The rules to implement the permitting requirements for an LWECS are found in Minnesota Rules Chapter 4401.

Under the Power Plant Siting Act (Minnesota Statutes §§ 116C.51 to 116C.69) a route permit from the Public Utilities Commission is required to build a high voltage transmission line (HVTL). An HVTL is defined as a transmission line with associated facilities capable of operation at 100 kilovolts or more. The rules for the administration of transmission line route permits are found in Minnesota Rules Chapter 4400.

A pumped storage facility will require transmission lines to connect the project to electrical generation facilities and ultimate users of the energy generated by the hydro-turbine. A wind turbine project will require transmission lines to connect the project to the users of the wind-generated electricity. A pumped storage facility will require connection to an electrical supply for the pumps, and to transmission lines feeding the electricity generated by the hydro turbines to the ultimate users. The interconnection voltage for wind or pumped storage projects may be greater or less than 100 kV, depending on several considerations such as connecting substation voltages and length of the interconnecting transmission line. A state route permit may or may not be required.

The pumped storage project, the wind project and/or the transmission lines interconnecting those projects may also require a Certificate of Need (CON) from the PUC. In Minnesota, a CON is required for: any electric power generating plant or combination of plants at a single site with a combined capacity of 50,000 kilowatts or more and transmission lines directly associated with the plant that are necessary to interconnect the plant to the transmission system; any high-voltage transmission line with a capacity of 200 kilovolts or more and greater than 1,500 feet in length; and any high-voltage transmission line with a capacity of 100 kilovolts or more for more than ten miles of its length. CON requirements are specified under Minnesota Statutes §§ 216B. The rules to implement the permitting requirements for a CON are found in Minnesota Rules Chapter 7849.

The purpose of the site and route permitting and the CON processes is to implement the state policy to locate large electric power facilities in an orderly manner, compatible with environmental preservation and the efficient use of resources. The legislature has directed the PUC to designate sites that minimize adverse human and environmental impact while ensuring continuing electric power system reliability and integrity. An additional goal is to ensure that electric energy needs are met and fulfilled in an orderly and timely fashion.

4.5.2 Other State and Local Permits

At least two other major state permits will be required before establishing a pumped storage facility: an appropriations permit from the Minnesota Department of Natural Resources, and a National

Pollution Discharge Elimination System (NPDES) permit from the Minnesota Pollution Control Agency.

Generally, large energy projects do not require local approval. In fact, if a state site or route permit is obtained, such a permit supersedes any local zoning requirements and such local approvals are explicitly not required by the Power Plant Siting Act. The Act does offer an applicant an alternative process to the state siting and route approval process for certain smaller projects, where in lieu of PUC approval, local approval may be pursued. Such an option may be attractive for certain portions of the wind/pumped storage project (e.g. the transmission interconnection line) and should be evaluated as a potential alternative permitting strategy as development proceeds.

5.0 Potential Wind Project Sites

This section describes the three general areas within the CIRSSD that appear to be best-suited for wind power development. Only general areas are described; specific turbine sites are not identified. On-site measurements, site surveys, and discussions with property owners would be necessary before specific sites could be selected.

The three areas are shown on Figure 2. Based on the 80-meter wind resource map for the region, accelerated wind regimes could be expected in each of these areas. Figure 2 also identifies key features (elevated terrain, transmission lines) in the study area.

Much of the land in the CIRSSD project area is owned by mining companies. Large industrial-use lands provide many advantages, including the possibility of utilizing previously disturbed land and greater setback from residential areas. On the other hand, despite these advantages, the mine use and mine plans are dynamic, so any turbine locations need to consider future mining activities.

Due to economy of scale, in general it is more efficient to design the largest wind project possible at a particular location. Based on the siting analysis conducted to date, it would seem possible that as many as a dozen or more turbines may be located in each of the three identified potential project areas. The ideal turbine locations would be close to transmission lines, away from residential areas, on elevated terrain, and would not interfere with other future uses of the sites.

5.1 Area A: Hibbing Taconite Company Property

Area A is an active taconite mine and processing facility with all of the property being owned by Hibbing Taconite Company (HTC). The area includes several square miles bounded on the south by the Hull Rust and other active open pit taconite mines, on the east by County Road 5, on the west by an existing Minnesota 115kV transmission line, and the HTC tailing basin to the north.

5.2 Area B: West Chisholm

Area B is a four to five square mile area immediately west of Chisholm and east of the HTC plant. It is an inactive overburden dump owned primarily by RGGS Land and Minerals, Ltd.

5.3 Area C: North Hibbing

Area C covers several square miles south of the Hull Rust open pit mine and northwest of downtown Hibbing. The area has several property owners, including multiple mining interests, and includes inactive mine pits and waste rock stockpiles.

6.0 Potential Pumped Storage Project Sites

Initially for this study, seven different potential pumped storage facility sites at various locations on the Iron Range were initially identified and examined. These seven sites were evaluated based on the potential availability of sizeable upper and lower reservoirs in proximity to each other. Several of the seven sites have been discussed in previous studies (see Section 3).

The locations of the seven potential sites are shown on Figure 3. For each of the seven sites, Table 1 (see following page) lists the physical aspects relating to the feasibility of pumped storage facility development.

Only three of the seven potential sites lie within the boundaries of the CIRSSD, so only these three (Sites 1, 2, and 3; Figure 3) are considered in detail in this study. A description of the main features of these sites is given in Sections 6.1 through 6.3.

For the preliminary screening of these sites, the power potential for each site was estimated using the same criteria. This power potential was computed assuming that (1) the maximum reservoir range would be 20 vertical feet for the smallest of the upper and lower reservoir, (2) power would be generated for 12 hours per day, and (3) the overall efficiency of converting hydraulic energy to electrical energy would be 80 percent.

Table 1

Potential Pumped Storage Site Data

Location	Maximum Power [1] MW	Maximum Head Feet	Upper Reservoir		Lower Reservoir	
			Maximum Elevation	Surface Area Acres	Minimum Elevation	Surface Area Acres
1 Keewatin	9	230	1550	140	1320	30
2 Hull Rust	157	415	1475	Thousands, Potentially	1060	284
3 Buhl	40	277	1750	110	1473	185
4 Hill Annex Mine	71	320	1450	168	1130	235
5 Virginia	133	350	1650	420	1300	285
6 Canton-Biwabik	40	300	1700	405	1400	100
7 Hoyt Lakes-Babbitt	27	280	1630	105	1350	73

(1) A power potential index computed by assuming the maximum operating range is 20 vertical feet for the smallest reservoir, power is generated for 12 hours per day and the overall efficiency is 80 percent.

6.1 Location 1: Keewatin Site

The Keewatin site is located immediately northeast of the City of Keewatin (see Figure 4). A 30-acre abandoned mine pit would be used as the lower reservoir. This reservoir's water surface would be at Elevation 1320. A powerhouse would be located on the northeasterly shore of this reservoir. A 1,300-foot-long penstock would connect the upper and lower reservoirs. The upper reservoir would consist of two abandoned mine pits, one located northeast and the other south of the lower reservoir. These upper reservoirs have a combined surface area of about 140 acres at Elevation 1550. The upper reservoirs would be connected by means of a channel about 4,500 feet long. This site is capable of developing about 9 MW of power. It seems likely that the site can be easily connected to the electrical grid. Civic and environmental impacts are likely to be minor due to the use of previously impacted mine lands. Cost-effectiveness of this site is probably not as great due to the low power potential and the large cost associated with constructing the long channel that would connect the upper reservoirs.

6.2 Location 2: Hull-Rust Site

Figure 5 shows a pumped storage concept that uses the Hull-Rust Mine on the north side of the City of Hibbing. The project was conceived of as a two-phase operation. Project features are presented below.

The east end of the Hull-Rust pit would serve as the lower reservoir. A dam would be constructed to separate the east pit from the west side of the pit. The likely reservoir water surface would be Elevation 1040, and the water surface area would be about 284 acres. A powerhouse would be located at the northeast corner of the pit.

In the first phase of the project, the abandoned Albany pit would be the primary upper reservoir. A 7,000-foot-long channel could be constructed adjacent to U.S. 169 to connect the Albany pit with the Pillsbury, Glen, Twin City and other pits located near Chisholm (see Figure 5). This combined upper reservoir would likely have an operating water surface range between Elevation 1460 and 1475 and a potential surface area of thousands of acres.

A potential second phase of the project would make use of the western portion of the Hull-Rust pit and the existing Hibbing Taconite tailings basin. The Hull Rust pit would be the lower reservoir at Elevation 1040 and the tailings basin would be the upper reservoir at Elevation 1520. The lower reservoir surface area would be about 869 acres.

The first phase could likely develop about 157 MW of power.

In general, the Hull-Rust site is believed to be favorably located with respect to the electrical grid. It is believed that environmental and civic impacts would be comparatively minor due to the use of existing pits, which have been previously impacted.

6.3 Location 3: Buhl Site

This possibility for a pumped storage facility is located within the City of Buhl (see Figure 6). The Iron Chief/Grant/Sharon/Wabigon abandoned mine pits would serve as the lower reservoir. This lower reservoir would be at Elevation 1473 and have a surface area of about 185 acres. An upper reservoir would be created about 1.5 miles north of the lower reservoir near the Continental Divide. This reservoir would be at Elevation 1750 and have a surface area of about 110 acres. About 7,000 feet of perimeter dam with a maximum height of 70 feet would be required to create this reservoir.

A powerhouse would be located on the northerly shore of the lower reservoir. A 7,300-foot-long penstock would connect the reservoirs. This site has limited power production potential; estimates are that it would have a maximum power generation potential of only about 40 MW.

Proximity to the existing electrical grid is a favorable aspect of this location. However, it is believed that the civic and environmental impacts would be great due to the need to develop an upper reservoir near and upstream of Buhl. Another difficulty is that it is likely that the upper reservoir perimeter dikes would be considered high-hazard dams due to the development in the valley downstream of the dikes.

7.0 Site Screening

7.1 Wind Site Screening

7.1.1 Screening Summary

Using the screening criteria described in Section 4, the three potential wind project areas that have been identified were compared. The results of that comparison are shown in Table 2. Additional work is needed to better assess the relative suitability of these areas, but Table 2 provides a rational basis by which development efforts can proceed.

Table 2

Wind Turbine Site Screening Results

Screening Criteria	Area A	Area B	Area C
Wind Resource Potential	+	o	o
Existing Infrastructure	+	o	+
Land Use and Suitability	o	+	o
Land Ownership, Availability and Timing	?	+	?
Environmental & Permitting Considerations	o	o	o
Overall Relative Ranking	1	2	3

Situation Favorable: **+**, Unfavorable: **-**, Neutral: **o** (Relative to other areas)

7.1.2 Discussion of Screening Results

7.1.2.1 Wind Resource Potential

The wind resource potential is the paramount consideration when evaluating a potential wind project site; therefore, this criterion is weighted more heavily in our screening than the other criteria. Area A includes property that falls into a higher wind resource area, as is indicated on the wind resource maps (see Figure 2). It also includes property southeast of the HTC tailings basin, where the large unvegetated expanse of the tailings basin is expected to be advantageous. Area B is east of Area A and has many of the advantages of Area A. Area B, however, is generally at a lower elevation than Area A, so the wind resource is likely to be less robust. Published wind resource maps indicate that Area C has a wind resource similar to that of Area B.

7.1.2.2 Existing Infrastructure

Areas A, B, and C are all generally accessible from existing roadways. However, all three areas would likely require construction of additional roads to the turbine sites for construction and maintenance.

Transmission substations are located near each of the sites. The suitability of the substations for interconnection has not been evaluated, however.

7.1.2.3 Land Use and Suitability

Area A is part of an active mining and taconite processing facility, so it is likely that there will be constraints for wind project development. Area B has been previously disturbed by mining activities, but is now idle. Area C is comprised primarily of inactive mined areas and waste rock stockpiles northwest of the City of Hibbing.

The waste rock stockpiles in Areas A and C and the overburden dump in Area B present both opportunities and challenges for wind generation development. The elevation relief over adjacent areas created by these man-made fill areas can enhance the wind resource potential at these locations. However, the uncontrolled placement of the soil and rock fill materials can complicate and increase the cost of turbine tower foundation design and construction. Additional foundation engineering and economic analysis will be necessary to determine if the stockpile and dump areas are attractive locations for siting wind turbines.

7.1.2.4 Land Ownership, Availability and Timing

None of the identified areas are on property owned by the CIRSSD. Purchase, lease, or some sort of partnership arrangement will need to be negotiated to develop any of the three sites. Partnership arrangements are common in wind power projects, however, as there are typically several parties involved. Cooperation from the mining companies and other large landowners in the area will be critical to the CIRSSD project development. Discussions with Cleveland Cliffs and HTC, owners of the property within Area A, have already been initiated. Similarly, discussions with RGGS Land and Minerals, Ltd, the major landowner in Area B have been initiated. Because of the many landowners in Area C, specific access discussions in that area have not been made.

7.1.2.5 Environmental and Permitting Considerations

All of the sites would be expected to have similar state permitting requirements (see Section 4.5).

Wind power projects typically face the most opposition over the environmental issues of noise generation, bird and bat mortality, and aesthetic (visual pollution) concerns. Bird mortality concerns have been reduced in recent years, because today's larger turbine blades rotate at fairly slow rates, allowing birds to see and avoid the blades. However, noise issues remain important if there are residential areas near the turbine sites. And for areas where scenic vistas are important, the placement of wind turbines is likely to be opposed.

Fortunately, none of the wind development areas currently under consideration within the CIRSSD boundaries is likely to meet with strong environmental opposition. Any of the sites would be distant enough from residential areas to avoid noise and visual pollution concerns.

7.2 Pumped Storage Site Screening

7.2.1 Screening Summary

Screening of the three identified potential pumped storage project sites within the CIRSSD was conducted using the screening criteria described in Section 4. Results are summarized in Table 3. Additional work will be needed to more fully assess the relative suitability of these areas, but Table 3 makes use of currently available information to focus future development efforts.

Table 3

Pumped Storage Site Screening Results

Screening Criteria	Loc. 1	Loc. 2	Loc. 3
Generation Potential	-	+	o
Existing Infrastructure	o	o	o
Land Use and Suitability	+	+	-
Land Ownership, Availability and Timing	?	?	?
Environmental & Permitting Considerations	+	+	-
Overall Relative Ranking	3	1	2

Situation Favorable: **+**, Unfavorable: **-**, Neutral: **o** (Relative to other areas)

Based on this screening, the Hull Rust Mine site (Location 2) appears to offer the best possibilities for development. The next steps would be to obtain a better understanding of land and mineral rights ownership and the owners' willingness to support a project of this nature in the near future. In the event that the ownership and availability is not favorable, attention could be turned to Location 1, the Keewatin site.

7.2.2 Discussion of Screening Results

7.2.2.1 Power Potential

The power potential for each site was estimated using the standardized approach described in Section 6.0 of this report.

The maximum power potential calculation results are shown in Table 1. Of the three CIRSSD sites, Location 2 (Hull Rust) has the greatest power potential at 157 MW. Other CIRSSD sites had much less power potential; each of the remaining sites had an estimated power potential of less than 40 MW.

7.2.2.2 Existing Infrastructure

All three locations are generally accessible from existing roadways. However, all areas would likely require construction of additional smaller access roads for construction and maintenance.

Transmission substations are located nearby each of these potential sites. However, the suitability of the substations for interconnection has not been evaluated.

7.2.2.3 Land Use and Suitability

All three sites include some lands that have been previously impacted by mining activities. The development of pumped storage facilities at Locations 1 and 2 would cause minimal disturbance to natural lands. For these reasons, those locations were given a favorable rating with regard to land use and suitability.

Pumped storage development at Location 3 would require the development of the upper reservoir on vacant forested land. In addition, it would cause further disturbance to natural lands in that it would require the development of perimeter dikes to contain the upper reservoir. For these reasons, Location 3 was scored as unfavorable with regard to existing land use and suitability.

7.2.2.4 Land Ownership, Availability and Timing

None of the identified locations are on property owned by CIRSSD. Purchase or leasing would need to be negotiated to develop any of these sites. Partnership arrangements may also be a possibility, depending on the landowners' and mineral rights owners' interest in such a partnership. Location 2 (Hull Rust) is currently being used by HTC, and discussions with HTC regarding their interest in pumped storage development are underway.

In general, landowners and mineral rights holders have expressed concerns about placing encumbrances on their properties because of the continuing opportunity for mineral extraction at many of the identified sites. This is further complicated by the lack of specificity and desire for flexibility in the development of mining plans that extend out 50 years or more. Specifically regarding the Hull Rust site, it is unlikely that agreement for use of the Hull Rust pit for a lower reservoir could be obtained in the near term.

7.2.2.5 Environmental and Permitting Considerations

All three sites have similar state permitting requirements. Pumped storage development would likely face the most opposition over the environmental issues of wetland impacts and impacts to groundwater level and quality. Impacts to uplands would be of concern for those locations that require upland reservoirs.

It can be assumed that pumped storage development at Location 3 would face the greatest environmental concerns and permitting challenges due to the impacts to uplands and wetlands. There would also be a need to obtain permits for perimeter dams for Location 3. As a result, Location 3 received the lowest rating with respect to environmental and permitting considerations.

8.0 Integrating Wind and Pumped Storage Projects

The development of wind and pumped storage energy projects could occur in tandem, or the two could be approached independently. The following sections discuss the matter of integrating the two efforts, and whether or not the integration would be helpful or necessary.

8.1 Integrated Projects

There is conceptual appeal in integrating the wind energy and pumped storage development projects. A typical criticism of wind generation is that it is not dispatchable, meaning that an operator cannot control when a wind turbine will be turned on and off. Coupling wind turbines with pumped storage provides a means for storing the energy generated by the wind so that the energy can later be used when demand dictates. When the wind blows and the electricity generated by the wind turbine is not needed, the electricity provided by the wind turbines would be used by the pumps to move water from the lower water reservoir to the upper reservoir. The electricity would then be "re-generated" by the pumped storage facility when the water flows back to the lower reservoir at the time it is needed.

In reality, there are difficulties with this concept. First, construction of two electric generating facilities, the wind turbine, and the hydro-turbine would be necessary to produce only a single unit of electrical energy. Second, integrating the two facilities would require the development of the two projects in a similar timeframe. Because of the continued potential for mining in many of the identified pumped storage locations, it is unlikely the development of a pumped storage facility could proceed in the near term. On the other hand, there is an immediate opportunity for wind power project development.

Finally, providing storage for wind-generated power on the Iron Range is really not necessary. Integration of the project into the area's regional transmission and electric generation systems would provide an outlet and a market for the electricity as it is generated.

8.2 Independent Projects

The wind energy and pumped storage development could proceed independently. Under this model, the wind turbines would be connected directly to the existing electrical grid. Whenever the wind was blowing and electricity was produced, it would be sold directly to the electricity markets through the transmission system. In this way, the wind turbines could produce revenue independently of the pumped storage facility.

The pumped storage facility could also be connected directly to the electrical grid, and the facility would function independently of the wind turbines. Electricity would be drawn directly from the grid during off-peak hours when it is relatively inexpensive to fill the upper reservoirs. During peak demand periods the water in the upper reservoirs would be released to generate electricity that would be sold back to the electricity markets through the transmission grid at a rate that would provide sufficient revenue to support the capital and profit burden and the operating costs of the facility.

8.3 Timing and Sequencing Issues

Timing and sequencing issues may effectively prevent the wind and pumped storage facility development from proceeding in tandem. It is likely that wind power development could proceed at a much faster pace than pumped storage development. If it were necessary to have the two projects proceed in a synchronized fashion, progress would likely be greatly delayed.

Property availability issues are likely to be substantially more problematic for pumped storage development than for wind power development. Also, for wind power development, property and environmental issues are somewhat less complicated than for pumped storage development.

A relatively small amount of land is required for each turbine. Land acquisition or leasing may be relatively straightforward. And provided that arrangements can be made with property owners, permitting, design, and construction could take place within a short period of time – operating turbines could be in place within three years.

By contrast, the difficulties with rapidly proceeding with pumped storage development are greater. Much larger tracts of land would be involved, making the property ownership discussions more difficult. The pumped storage reservoirs would be developed using mine pits – below which may lie mineral reserves that owners will want to continue to be able to access. Property acquisition for the project is therefore likely to be difficult. And both because of the large area involved, and because of the moving of water and associated biota from one reservoir to another, the environmental permitting is likely to be substantially more complicated. Furthermore, design and construction of the pumped storage facility – potentially involving dams, dikes, and relatively large-scale construction and installation of machinery – is likely to be substantially more difficult and prolonged than it would be for wind energy development.

9.0 Conclusions and Recommendations

9.1 Sites Recommended for Future Focus

We recommend that future project development efforts focus on Area A, the Hibbing Taconite Property, for the wind turbine component. For the pumped storage component, Location 2, the Hull Rust Site, appears to be most favorable.

9.2 Integration of Pumped Storage and Wind Power Projects

We recommend that the wind power and pumped storage projects proceed independently. Wind power development is likely to be able to proceed much more quickly than pumped storage development; the divergent time frames for the two projects lead us to believe that the wind project is best developed independently of a pumped storage project. Furthermore, a direct linkage of the projects is not necessary to provide benefits to the CIRSSD and the region. However, the potential for future integration of the two components should be considered as the two projects move into the design phase.

We recommend that the wind energy and pumped storage development proceed independently because we believe the wind project development can proceed more quickly than a pumped storage project and that.

9.3 Other Key Considerations for Preliminary Design Process

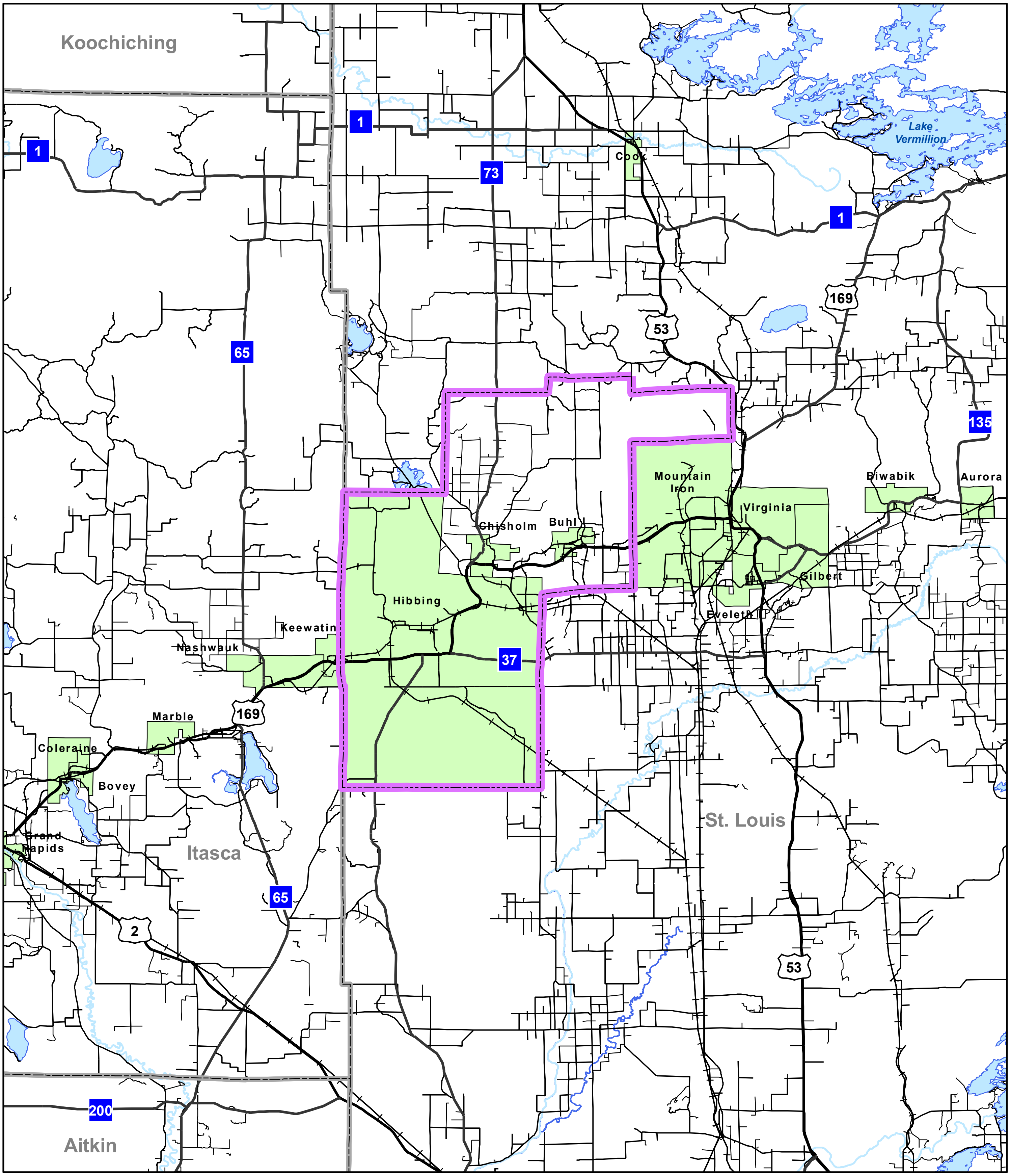
9.3.1 Additional Wind Resource Data Collection

Although a recommended general location (Area A) for siting wind turbines has been identified, it should be kept in mind that this area was selected based on limited wind resource data obtained from the published wind resource maps. Because the wind resource along the Mesabi Iron Range is not well quantified, more data collection is required to be able to make informed project decisions. A suitable location in Area A should be selected for installation of a meteorological tower for use in verifying that a suitable wind resource exists in this area.

A draft wind monitoring program has been developed for this project. The plan was given to the DOC to determine their level of interest in participating in this project. It is recommended that monitoring begin as soon as practical, given that at least one year of meteorological data are required.

9.3.2 Land Owner Discussions

Availability of suitable property for development of wind and a pumped storage projects is necessary for these projects to move forward. Resource potential for both wind and pumped storage development exists in the region, but if access to and use of the desirable property cannot be obtained, project development cannot proceed. Discussion with the current landowners to obtain access agreements and reserve the necessary property for project features should continue in parallel with preliminary design activities.



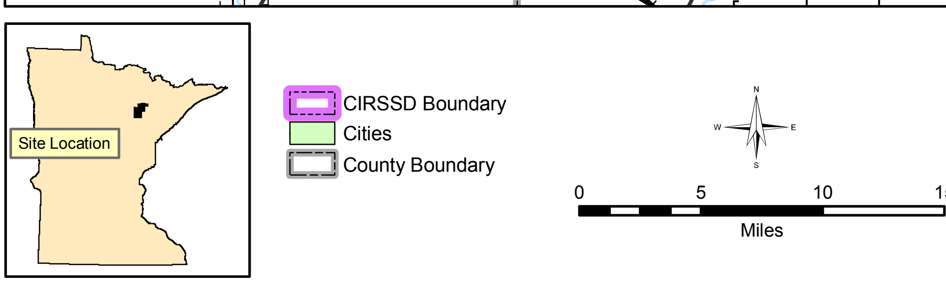


Figure 1

LOCATION MAP WITH
CIRSSD BOUNDARIES
Central Iron Range Initiative
St. Louis County, Minnesota

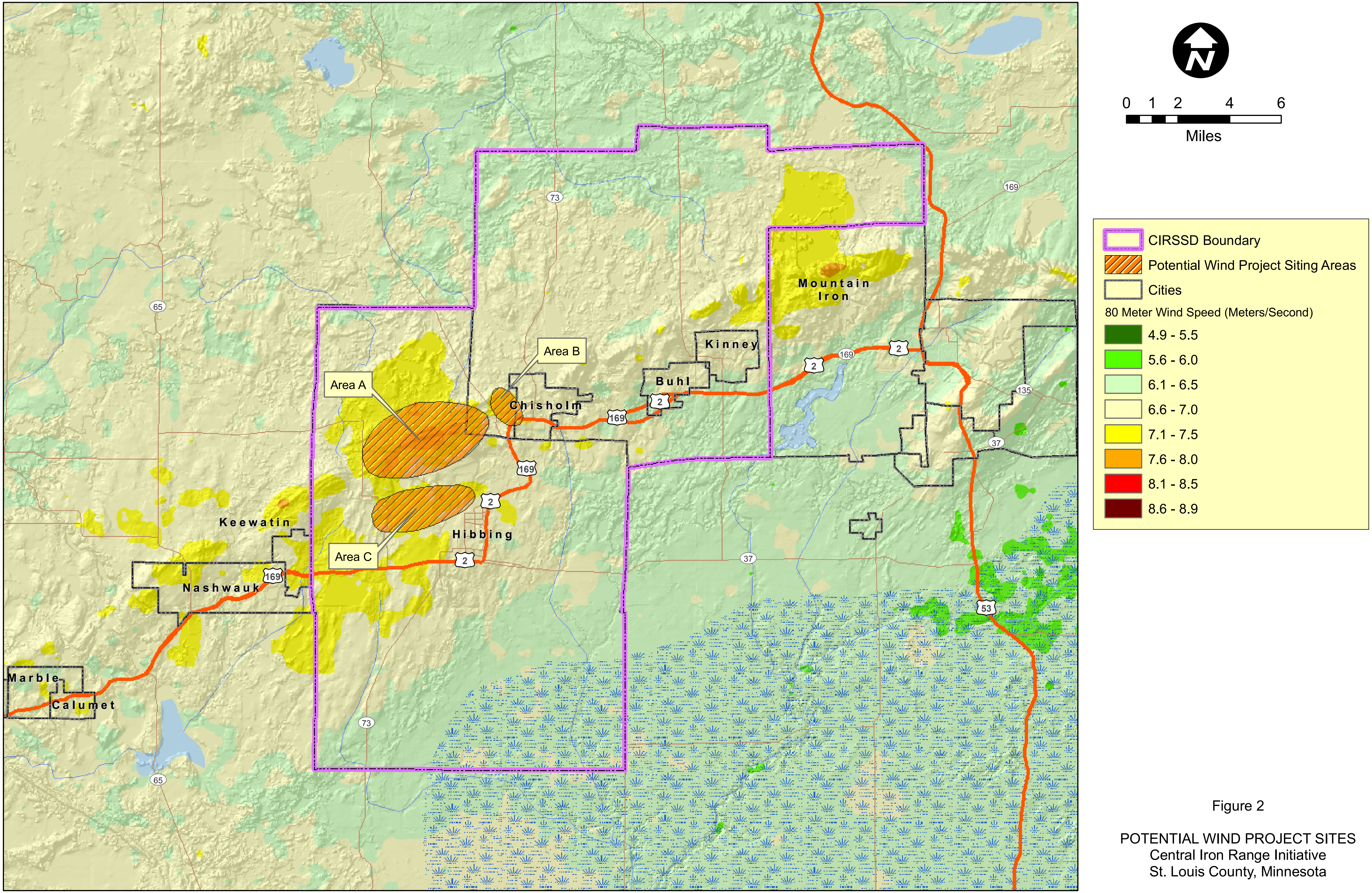


Figure 2

POTENTIAL WIND PROJECT SITES
Central Iron Range Initiative
St. Louis County, Minnesota

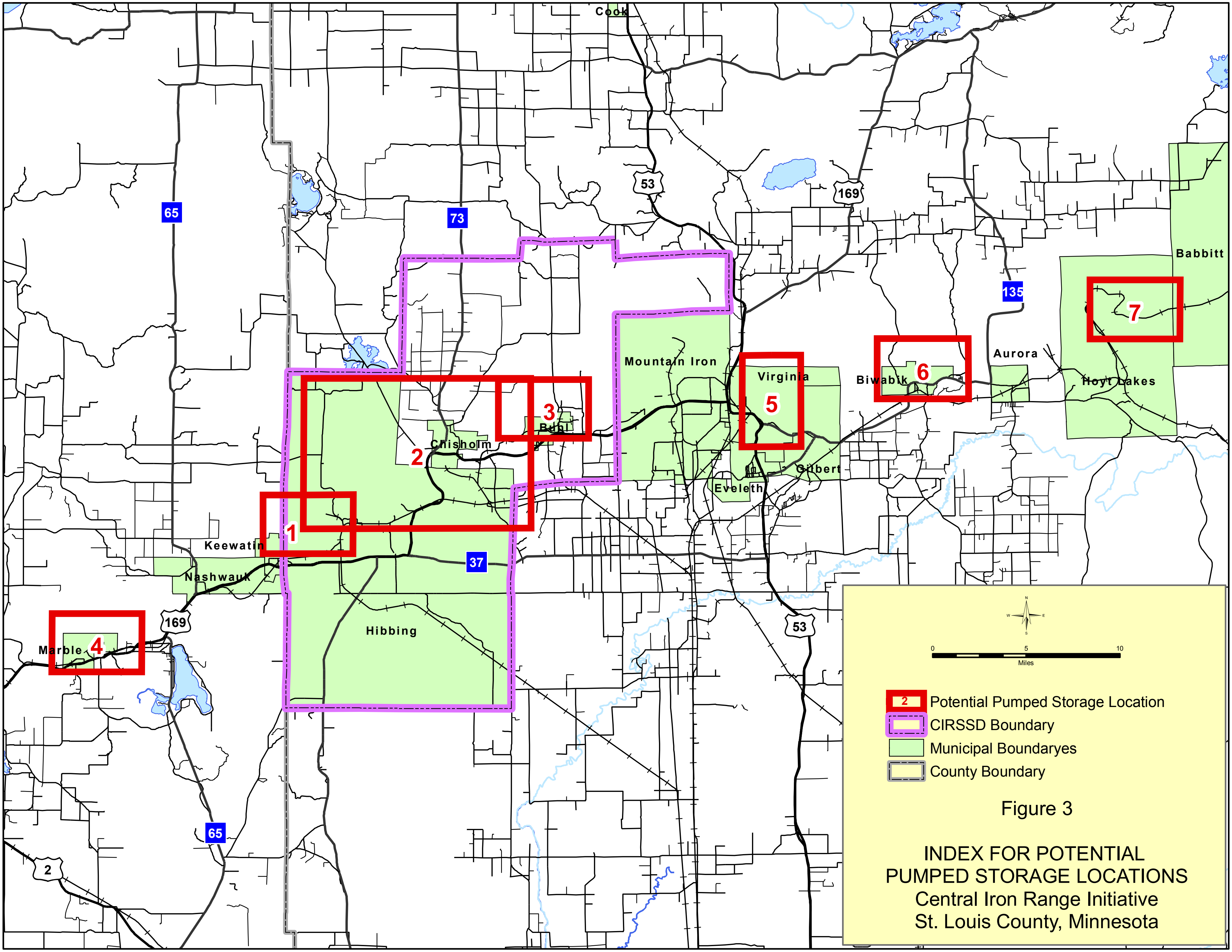


Figure 3

INDEX FOR POTENTIAL PUMPED STORAGE LOCATIONS
Central Iron Range Initiative
St. Louis County, Minnesota

Figure 4

POTENTIAL PUMPED STORAGE LOCATION 1:
KEEWATIN SITE
Central Iron Range Initiative
St. Louis County, Minnesota


Existing Hibbing Taconite Tailings Basin Phase II Upper Reservoir Normal Pool Elevation 1520
Hibbing
Chisholm
Buhl
Biwabik
Hartley
Grant
Fraser
Sherman
Twin City
Pillbury/Glen
Upper Reservoir Possible Operating Range: Elevation 1460-1475
Proposed Dams
Channel
Albany
Powerhouse
Phase II Lower Reservoir Pit Bottom ~ Elevation 1040 869.3 Acres
Phase 1 Lower Reservoir Possible Operating Range Elev. 1060-1180 283.8 Acres
0 2,000 4,000 6,000 8,000 10,000
Feet
Taconite Pits
Figure 5
POTENTIAL PUMPED STORAGE LOCATION 2: HULL-RUST SITE
Central Iron Range Initiative
St. Louis County, Minnesota

Figure 6

POTENTIAL PUMPED STORAGE LOCATION 3:
BUHL SITE
Central Iron Range Initiative
St. Louis County, Minnesota