After an introductory question, asking the subject to briefly describe their organization, we read each interviewee a short description of PHES, including the fact that PHES is a means of storing energy, and describing the possible use of old mine pits. In this description we deliberately did not say that PHES could enable intermittent renewables, because we wanted to determine whether stakeholders made this association on their own. The full PHES description is included in the appendix. After reading the PHES description we asked the following questions:

1. Tell me what you think about pumped hydro energy storage.
2. More specifically, what do you see as the challenges and opportunities for pumped hydro energy storage? If they focus on challenges then ask about opportunities and vice versa.
3. (Follow up from above) How do you think these issues would play out on the MIR?
4. If they haven’t mentioned renewable energy, then ask, Do you think pumped hydro energy storage would play any role related to renewable energy? and
5. Is there anything else you’d like to add about pumped hydro energy storage?

Data analysis was conducted in two steps. In the first step, we noted which topics interviewees mentioned using a list of topics that are generally of interest to stakeholders regarding large projects. In coding this step we tabulated whether an interviewee mentioned a general topic, not how many times it was mentioned. Regulatory and aesthetic issues, frequently a concern for new energy technologies, were infrequently mentioned, so they were not analyzed further in this study (Table 4.1-2). In the first stage of analysis, we also noted whether interviewees’ first statements about PHES in the interview focused on opportunities or on challenges, and whether they spontaneously associated PHES with renewable energy (without being prompted by the interviewer). During the first step, we also identified themes that frequently emerged related to each general topic. In the second step of analysis, we coded the incidence of subjects mentioning these themes, arriving at a list of key themes, defined as those that were mentioned by three or more interviewees.

**Results**

The number of interviewees that raised each general topic is summarized Table 4.1-2. Table 4.1-3 details the key themes that emerged regarding each topic and shows how often they were mentioned.
Table 4.1-2. Incidence of general topics related to PHES.

<table>
<thead>
<tr>
<th>Topic</th>
<th>Incidence (out of 16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reuse of mine pits</td>
<td>16</td>
</tr>
<tr>
<td>Renewable energy</td>
<td>12</td>
</tr>
<tr>
<td>Electricity supply or price</td>
<td>11</td>
</tr>
<tr>
<td>Public acceptance</td>
<td>9</td>
</tr>
<tr>
<td>Environmental issues</td>
<td>8</td>
</tr>
<tr>
<td>Economic development</td>
<td>7</td>
</tr>
<tr>
<td>Regulatory issues</td>
<td>5</td>
</tr>
<tr>
<td>Aesthetic issues</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 4.1-3. Key stakeholder themes about PHES.

<table>
<thead>
<tr>
<th>General Topic</th>
<th>Stakeholder theme</th>
<th>Incidence (out of 16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept of PHES</td>
<td>PHES is energy storage/peaking power</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>PHES creates energy</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>PHES not energy efficient</td>
<td>4</td>
</tr>
<tr>
<td>Renewable electricity</td>
<td>Unprompted association of PHES and renewables</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>PHES enables intermittent renewables</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>PHES is renewable because it uses water</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Need for more renewable electricity</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Wind turbines for PHES should be located on the MIR</td>
<td>3</td>
</tr>
<tr>
<td>Reuse of mine pits</td>
<td>PHES would be a constructive use for old pits</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>PHES would jeopardize future mining. Difficult to get land and mineral rights</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Concerned about pit or mine stability or erosion</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>MIR hydrology is poorly understood/ PHES could interfere with water supplies</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Concerned about interference between PHES and mine dewatering</td>
<td>4</td>
</tr>
<tr>
<td>Electricity Supply and Price</td>
<td>Mesabi Iron Range needs power for industry</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Will PHES projects be owned by utilities or mining companies?</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Who will use electricity produced by PHES?</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Would support PHES if it lowers electricity price</td>
<td>4</td>
</tr>
<tr>
<td>Anticipated public reaction</td>
<td>Public will be polarized</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Public will favor</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Mentioned Excelsior Energy’s Mesaba Project</td>
<td>4</td>
</tr>
<tr>
<td>Environmental issues</td>
<td>Water quality concerns</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Don’t think PHES will have major environmental problems</td>
<td>4</td>
</tr>
<tr>
<td>Economic development</td>
<td>Good if PHES creates jobs</td>
<td>7</td>
</tr>
</tbody>
</table>
Even in this group of reasonably knowledgeable stakeholders, many find it hard to grasp the concept of energy storage and to link the electricity created by PHES back to the original source of the energy (wind, coal, nuclear, etc.). Despite having just been told that PHES is an energy storage technology, 7 of 16 stated that PHES creates energy, and 6 said it produces renewable electricity because it uses water. Several also voiced concerns about the efficiency of PHES, for example:

“It seems like wasting power to pump [the water] back up.”

Only a minority understands that energy storage could enable use of more renewable resources. Less than half (7 of 16) associated PHES with renewable energy without a prompt, and only 6 mentioned that it could enable deployment of more intermittent renewable energy sources like wind and solar.

Reuse of the mine pits was the most frequently mentioned topic and the topic with the most strongly stated and diverse concerns. While most stated that they think PHES would be a constructive use for old pits (11 of 16), 7 spoke at length about concerns that PHES would jeopardize future mining prospects and that it would prove difficult or impossible to get the necessary land and mineral rights to build a PHES project. Several quotes illustrate these concerns:

“[PHES is] a good idea. I just don’t think it’s a good idea to do it on the Mesabi Iron Range, because there’s vast mineral deposits which still remain that will be mined in the future, and putting infrastructure on the Mesabi Iron Range could deter mining.”

“They’re going to be very hesitant to jeopardize any future mining opportunity by installing something else.”

“Most people who’ve held mineral rights this long aren’t interested in selling, because if they were, they would have.”

Interviewees holding this viewpoint spoke of the resurgence of the iron ore market, driven by the Chinese demand for steel, with perhaps enough iron deposits remaining to support another century of mining on the MIR. Another potential incompatibility between PHES and mining was voiced by four subjects who foresaw conflicts between PHES and mine dewatering. Interestingly, subjects who made statements about ongoing mining as an impediment to PHES came from all organization types except those associated with mining. This point deserves further study.

Other concerns regarding PHES in mine pits on the MIR included issues about pit or mine instability or erosion due to fluctuating water levels (5 of 16), and general cautions about the fact that the hydrology of the MIR is poorly understood, so PHES risks interfering with community water supplies (4 of 16).

Several interesting themes emerged on the topic of electricity supply. While not directly related to PHES, seven interviewees mentioned that MIR industries need a lot of power. The issue of ownership also proved important. Seven subjects questioned who would use the electricity produced by PHES, and five asked whether PHES projects would be owned by utilities or by companies.

The majority of interviewees volunteered their opinion on how the public would react to a PHES project, roughly split between those who anticipate the public would favor PHES and those who anticipate that the public would be polarized (5 and 4 subjects, respectively.) The relatively high incidence of statements about public acceptance may be related to the history of controversy regarding other major projects in the area, such as the copper-nickel mining proposals and the proposal for a new coal-fired
power plant. In fact, four interviewees associated the concept of PHES with the Excelsior Energy’s proposed Mesaba project, for example:

“Is there a need and a demand for [PHES], or is it just somebody’s idea of a neat idea and they have connections to be able to get funding for it?”

Associations regarding environmental issues and economic development were generally unremarkable, perhaps more subdued than would be expected for an infrastructure project of this scale. Only half the interviewees (8 of 16) mentioned environmental issues, and of these, 4 stated they doubted that PHES would have major environmental problems. Four mentioned concerns about water quality, but statements were typically moderate, for example:

“I would be concerned that water quality issues be addressed and that we not be spreading water quality problems.”

Surprisingly, less than half mentioned potential economic development benefits of PHES, and in most cases the statements were made in passing. This could be because the current boom in the iron and minerals markets has taken the edge off unemployment concerns.

DISCUSSION

Because we interviewed people who are knowledgeable about environmental and energy issues specific to the Mesabi Iron Range, but not necessarily experts about electrical power, results must be carefully interpreted. Results regarding topics in which these interviewees are not experts, such as the concept of PHES, renewable electricity, and electricity supply and price, are best used to inform materials for future PHES community engagement. They indicate what background material would be helpful as a foundation to help stakeholders evaluate PHES and suggest what types of questions and concerns local communities might raise. Results regarding local issues, about which interviewees are experts, can provide guidance regarding the potential for deployment of PHES on the MIR.

Concerns over potential incompatibilities between PHES and mining emerged as the most significant finding of these interviews. Local stakeholders strongly cautioned that obtaining the surface and mineral rights to construct a PHES project would likely be very difficult and costly. This issue deserves further study. A positive regarding deployment on the MIR, however, is that the concept of PHES did not appear to trigger strong environmental concerns, partly due to the fact that the local landscape is already highly altered.

Results demonstrate that the concept of PHES is hard for non-experts to understand. Materials designed for community engagement regarding PHES should provide basic knowledge about electricity demand, the types of generation used to meet varying levels of demand, and the role of transmission. Information should emphasize the fact that PHES stores energy and does not create energy, and furthermore, it should introduce the idea that the environmental attributes of the energy stored by PHES mirror those of the grid-supplied electricity used for pumping.

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1 Excelsior Energy received $36 million in DOE funding to develop a 600 MW integrated gasification combined cycle coal plant to be located on the MIR that could capture carbon emissions for geologic sequestration in the Williston basin.
Anyone undertaking community engagement for PHES on the MIR should be prepared to answer questions regarding the following issues:

- How would a PHES project affect future mining prospects?
- Why is PHES needed? What problem does it solve?
- Who benefits from PHES? Who will own the project and who will use the power?
- How will PHES affect the price and supply of electricity on the MIR?
- Will wind turbines on the MIR provide the pumping power for PHES? and
- Where would the water for PHES come from, and would PHES affect water quality?

At the point that a specific PHES project was proposed, community engagement efforts should also be prepared to answer questions regarding:

- Mine pit stability and erosion;
- How fluctuating PHES water levels might affect public water supplies; and
- How PHES and mine dewatering would interact.
SECTION 4.2:

Policy and Economic Issues of PHES Compatibility with Mining

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University of Minnesota
Minneapolis MN
COMPATIBILITY OF PUMPED HYDRO ENERGY STORAGE WITH PRESENT AND FUTURE MINING ON THE MESABI IRON RANGE

Compatibility with present and future mining is a key objective in siting and designing a pumped storage energy (PHES) project on the Mesabi Iron Range (MIR). The MIR offers many advantages for a PHES project, including preexisting pits that could be used as reservoirs, sufficient differences in elevation, and communities accustomed to living alongside industry. The MIR also presents challenges because widespread mineral deposits make land valuable, and mining operations can affect large areas. This paper outlines a framework for assessing the compatibility of potential PHES sites with present and future mining. The premise is that: 1) PHES plants would need to be insulated from the effects of current and future mining; 2) engineering techniques are available that could achieve this insulation in many cases; and 3) building a PHES project that can coexist with mining will require additional land and engineering beyond what’s needed for power production.

Nearby mining could harm a PHES project primarily through blasting or dewatering, presenting dam safety issues, requiring costly repairs, or affecting the water levels in the PHES reservoirs. Permitting processes will likely require that these types of potential impacts be addressed. Should such damages occur, legal remedies could be sought, but lawsuits are costly and holders of mineral rights typically have precedence. Selecting a site that would never fall within the area of influence of current or future mining would be ideal, but this is unrealistic on the MIR because mineral deposits are widespread, and mine dewatering operations can affect water levels two miles or more from the pit (R. Wuolo, pers. comm.). A more feasible and secure approach is to site and design the plant so it is insulated from nearby mining.

Geo-engineering to insulate a PHES project from blasting and dewatering would be site specific, with two focuses. Minimizing blast vibration damage might be achieved through inclusion of a blast buffer (sized according to the geologic properties of the site). Blast buffers on the range of 2,000 to 3,000 feet are reported in the LVP (Laurentian Vision Partnership, 2002). Where active mining or future mining could approach closer than the necessary buffer, techniques such as pre-splitting could be utilized, as was proposed in Barr Engineering’s (1999) Giant’s Ridge Report. Isolating the upper and lower reservoirs from water level fluctuations caused by mine dewatering might be achieved through a variety of seepage control techniques, including liners and grouting. Leakage control will be a factor in project design regardless of mine dewatering because the hydraulic gradient between reservoir water levels and local aquifers will induce leakage out of the upper reservoir and leakage into the lower reservoir. Potential water level fluctuation due to dewatering could significantly alter static conditions and, therefore, must be assessed when determining the construction requirements to minimize reservoir leakage.

The site-specific options for insulating a plant from blasting and dewatering will determine the additional costs associated with designing a PHES project to coexist with mining on the MIR. Two categories of additional costs must be estimated, both based on the preferred geotechnical options to minimize impacts from blasting and dewatering: 1) the costs of additional design and construction work (described above); and 2) the costs of additional property acquisition. PHES projects on the MIR will need to buy or lease surface and mineral rights for both for the project footprint, encompassing the reservoirs and surface facilities, and, for a buffer zone, needed to insulate the project from current or future mining. The size of the buffer will be site specific, determined by proximity to mineral deposits and by the geo-engineering options chosen to prevent damage to the PHES project from blasting and dewatering.
To meet the objective of compatibility with present and future mining, preference should be given to PHES sites with the following characteristics:

- Feasible engineering solutions exist to insulate the PHES project from blasting and dewatering at nearby mines;
- Engineering options minimize cost and uncertainty;
- Required buffer area is minimized;
- Project footprint and buffer area overlie a minimum of mineral deposits that could potentially be mined within the next 50 to 100 years;
- Project boundaries are as distant as possible from active mines or mineral deposits which could potentially be mined within the next 50 to 100 years; and
- Property owners within project footprint and buffer are willing to sell or lease surface and mineral rights to PHES operator.

REFERENCES

SECTION 4.3:

PHES Policy and Economics LCA Parameters

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PARAMETER IDENTIFICATION FOR FUTURE PHES LIFE CYCLE ANALYSIS

Future assessment of a proposed PHES project on the MIR could include a life cycle assessment (LCA) of the project’s potential energy and environmental performance. Here we outline principles related to LCA methodology for PHES and discuss potential impact categories.

Life cycle assessments can take many forms, depending on their objectives (Scientific Applications International Corporation, 2006). The most likely purpose of an LCA for a PHES project would be to compare the environmental attributes of PHES with other forms of electrical generation. Therefore, the basis for comparison (the functional unit) should be the kilowatt-hour. The ideal scope would be cradle-to-grave; in other words, an assessment of inputs and outputs related to the construction, operation, and decommissioning of the pumped hydro storage facility.

The environmental attributes of the PHES project will be largely determined by the environmental attributes of the electricity purchased for pumping. Previous LCA studies of PHES address this by specifying both fixed and variable LCA parameters, with fixed parameters stemming from PHES project construction and decommissioning, and variable parameters derived from PHES operations, primarily input of electricity for pumping (Denholm and Kulcinski, 2004). While one of the drivers behind deployment of PHES is integration of intermittent renewable energy sources, the electricity input for pumping will come from a combination of sources, and the makeup of that mix will vary both in the short-term, as various current generation sources are dispatched, and over longer time periods, as new generation sources are added and older plants decommissioned. An LCA methodology for PHES must account for the variable environmental attributes of the “fuel mix.”

Two considerations drive selection of impact categories for a PHES LCA. The first is consideration of the types of potential environmental impacts specific to PHES on the MIR, for example, impacts related to creating a reservoir, or groundwater quality changes due to fluctuating water levels. The second is consideration of the impact categories assessed for other methods of generating electricity. While there are dozens of impact categories used in the LCA field (Scientific Applications International Corporation, 2006), the following are potentially applicable for a life cycle assessment of a PHES project:

- Energy use;
- Greenhouse gas emissions;
- Acidification;
- Eutrophication;
- Aquatic toxicity; and
- Water Use.

Of these, only the first three are routinely assessed for electrical power projects, so if the goal of the PHES LCA is to facilitate technology comparison, the preferred impact categories to include would be energy use, greenhouse gas emissions, and acidification.

After deciding on the impact categories for a PHES LCA, the next step will be to identify the parameters to quantify. LCA parameters for PHES would include inputs and outputs related to plant construction, operation and decommissioning. LCA parameters during PHES plant construction should include inputs and outputs related to:

- Concrete manufacturing and transport;
- Installation of any rock fill, earth, and/or concrete dams;
• Construction, transport, and installation of pump turbines, generators, other electrical equipment, etc.;
• Construction of all surface and subsurface facilities; and
• Reservoir carbon emissions - This item is not an issue if project uses existing mine pits for the upper and lower reservoirs. If land is flooded to create the upper reservoir, there will be carbon emissions associated with the decay of biomass under the flooded area.

LCA parameters during PHES plant operation should include:

• Storage system efficiency – use a measure of the round-trip efficiency, which is the KWh required to fill the upper reservoir divided by the KWh generated from completely discharging the reservoir;
• Transmission losses – energy storage requires additional transmission components – additional step-up and step-down phase; and
• Total system generation – quantity delivered directly by the intermittent renewable energy and the quantity stored and then delivered.

LCA parameters during PHES plant decommissioning should include inputs and outputs related to:

• Facility demolition and disposal; and
• Land reclamation.

REFERENCES

SECTION 4.4:

Policy Environment for Pumped Hydro Energy Storage on the Mesabi Iron Range

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The policy environment for pumped hydro energy storage (PHES) is interactive: PHES could play a role in achieving certain policy goals (such as increasing the percentage of renewable power in Minnesota), and policy would play a role in whether PHES projects are built and how they are operated. Regulations would strongly influence whether PHES is chosen as the least cost alternative for a utility to meet its reliability, quality and environmental objectives. It would also influence site selection, design, and operation of a PHES project. To explore these inter-relationships, Section One presents an overview of the regulatory environment for PHES in Minnesota and Section Two outlines policy goals related to PHES and gives a screening assessment of PHES’ ability to further them. Section Three identifies policy barriers to implementation and opportunities for promoting PHES.

OVERVIEW OF REGULATORY ENVIRONMENT

Generally, a PHES project would be subject to four general types of regulation: 1) rules governing electric utilities established by the Minnesota Public Utilities Commission (MPUC) and the Midwest Independent Systems Operator (MISO); 2) dam safety rules established by the Federal Energy Regulatory Commission (FERC); 3) environmental rules set by state and federal agencies; and 4) worker health and safety rules administered by the Occupational Safety and Health Administration (OSHA). Previous reports have detailed the environmental, health, and safety rules that would apply, and the types of permits that would be required for a PHES project that constructed an upper reservoir with dikes and used a mine pit as the lower reservoir (Barr Engineering Co., 2009). Details would vary with alternate reservoir configurations, for example if both reservoirs were mine pits, or if the lower reservoir was created from an underground mine. This section focuses on regulations that will most affect the design and profitability of a PHES project with any reservoir configuration – namely, electric utility regulation and FERC rules.

Minnesota Public Utilities Commission roles and responsibilities

The MPUC is the regulatory body with the most influence over a company’s portfolio of generation sources. It oversees electric utilities’ resource plans to serve Minnesota customers and approves proposals to construct large energy facilities in the state. In determining whether to grant a Certificate of Need for a new energy facility such as a PHES project, the MPUC considers how the project would affect the reliability, adequacy, and efficiency of the energy supply, whether a more reasonable and prudent alternative is available, and what effects the project would have on natural and socioeconomic environments (MN Rules 7849.0120). The MPUC considers the cost of the proposed plant as well as the cost of energy it would supply in comparison with alternatives. In the case of PHES, the MPUC would probably consider a combined cycle gas turbine (CCGT) plant as a reasonable alternative to PHES. The MPUC also implements the Renewable Energy Standard (RES) passed by the legislature in 2005 and tracks utilities’ compliance with the RES requirements. The MPUC would make a determination as to whether and to what extent PHES is an eligible energy technology for the purpose fulfilling the RES requirements, and consider the role of PHES in integrating more intermittent wind power into a company’s overall resource portfolio.

MISO regulations

The Midwest Independent System Operator (MISO) sets and administers wholesale electricity market rules as well as the rules and rates (tariffs) for transmission services. It manages the energy markets
including day-ahead energy, real-time energy, and ancillary services. MISO also manages generator interconnection to ensure reliability. MISO rules would influence the operating strategy and profitability of a PHES facility and determine how the costs of new transmission to connect a PHES facility to the grid would be distributed between the facility’s owner and customers. MISO rules also influence the value of energy storage in that they control the interconnection of intermittent renewable resources to the grid. MISO is actively studying the role of energy storage, with a study initiated in June, 2011 to explore in detail the reliability and planning benefits that storage projects may offer to the MISO area.

A PHES facility would make money by selling electricity into the competitive energy markets and participating in the ancillary services markets. MISO has markets for three different ancillary services products: spinning, supplemental, and regulation reserves. Supplemental reserve is generating capacity that is currently not synchronized to the transmission grid but is capable of coming online in a short amount of time. Spinning reserve is generating capacity that is synchronized to the grid. Regulation reserve is generating capacity that is capable of balancing supply and demand on a moment-to-moment basis. The highest quality (and highest price) ancillary service is regulating reserve, for which PHES is an ideal technology, as discussed in Section 4.2.1. There are day-ahead and real-time markets for both energy and ancillary services. The day-ahead markets are cleared on an hourly basis, and the real-time markets are cleared on a co-optimized, five-minute basis.

A PHES facility would rely on transmission services to get power to market, and also to procure its fuel (to pump water to the upper reservoir). At a local level, it might require new or upgraded transmission lines to connect to the grid or to accommodate the increased flow of electricity, which MISO regulates by setting rules for how the costs of Generator Interconnection Projects (GIPs) are allocated between generators and customers. Traditionally, this cost allocation methodology reflected the notion that the generator seeking interconnection caused the need for the new transmission and should pay for it. This is complicated by the fact that GIP transmission upgrades may also provide local and or regional benefits. The GIP cost allocation was changed in 2009 so that 90 percent of the interconnection costs related to the construction of 345 kV lines or larger are allocated to the interconnecting generator and 10 percent are allocated regionally. One hundred percent of the interconnection costs for transmission build-outs smaller than 345 kV are allocated to the interconnecting generator.

MISO also conducts regional transmission expansion planning on an annual cycle, which produces the MISO Transmission Expansion Planning (MTEP) report. In this capacity MISO exerts substantial influence over the system-wide integration of both energy storage and renewable energy projects. The MTEP reports designate five different categories of transmission projects: Baseline Reliability Projects, Transmission Access Projects, Regionally Beneficial Projects, Multi-Value Projects (MVP), and projects not eligible for MTEP cost allocation. These categories determine the percent of project cost that is allocated to local customers, to sub-regional consumers, and to customers across the entire MISO footprint. The costs of an MVP are allocated to all loads in the MISO footprint. A project is designated as having multiple values if it supports reliability, provides multiple types of economic benefits and economically furthers an energy policy, criteria a PHES project would likely satisfy.
**FERC dam safety regulations**

Any PHES facility connected to the interstate grid is subject to FERC’s jurisdiction for safety regulation during construction and operations. Dam safety is the most important component of FERC efforts to minimize overall damage to the environment from PHES projects. FERC regulators must approve the PHES project design, and they would also monitor the construction and operational phases of pumped hydro energy storage projects. One of the key concerns unique to PHES projects is water level management to prevent reservoir overtopping. In response to overtopping incidents, FERC issued guidance to pumped storage owners for assessment of safe operation of PHES facilities (FERC, 2007).

**POLICY OBJECTIVES RELEVANT TO PHES**

The desire to promote energy security and achieve climate change goals has led to the adoption of renewable energy standards in Minnesota and many other states. The Next Generation Energy Act of 2007 (Chapter 136, Laws of Minnesota for 2007) articulates two state policy objectives particularly relevant to PHES:

- Derive 25 percent of the total energy used in the state from renewable energy resources by the year 2025 (Article 1 Section 2); and
- Reduce statewide greenhouse gas emissions to a level at least 15 percent below 2005 levels by 2015, to a level at least 30 percent below 2005 levels by 2025, and to a level at least 80 percent below 2005 levels by 2050 (Article 5, Section 2).

Other state policy objectives relevant to energy facilities are found in the statutes implementing the Next Generation Energy Act. (Minn. Stat. §216B.1691). New projects should increase renewable electricity and decrease greenhouse gas emissions in a manner that:

- minimizes cost impacts on ratepayers;
- maintains the reliability of the state’s electric power grid; and
- promotes economic development in rural areas.

In addition to statewide policy objectives, local goals are also important for a potential PHES project, such as economic development, productive reuse of mined land, and integration with local long-term planning efforts like those of the Laurentian Vision Partnership.

**Increasing renewable electricity**

The challenges of increasing renewable electricity and the ways that PHES could contribute to meeting those challenges are best understood in the context of how the electrical system currently works. The power system is operated to match the supply of electricity with demand. Demand exhibits a predictable daily pattern, with a minimum “baseload” level of demand at all times and two demand peaks during the day, a smaller peak in the morning, and a larger peak in the late afternoon through early evening. Utilities typically use nuclear and coal plants to supply base-load demand because they have high capital costs and low variable costs, which makes them economical to operate continuously. Natural gas plants and hydroelectric plants are typically used to meet peak demand. The more predictable daily variations in demand are managed through MISO’s day-ahead energy market.
The system must also balance less predictable short-term variations in power supply and demand, caused, for example, by extreme weather or mechanical problems. Short-term demand spikes or supply interruptions are typically balanced by increasing generation from natural gas plants or hydroelectric facilities. Natural gas plants are fast-ramping resources. From a cold start, CCGT's need about one hour to operate at best efficiency. Technical constraints and economic considerations limit the capability of coal or nuclear plants to quickly adjust their level of power output. Coal plants may take anywhere from 6-12 hours to reach rated output from a cold start. Therefore, coal is not suited for variable operation. Coal plants usually operate at best efficiency when they produce power at their rated output. Coal plants are used to follow load, but cycling a coal plant reduces efficiency, increases pollution, and creates mechanical issues. The less predictable short-term variations in demand are managed through MISO’s real time energy and ancillary services markets.

Increasing wind generation adds complexities to the process of matching electricity supply with demand. Wind power presents three main technical challenges. First, wind supply in the upper Midwest is typically highest during time periods when electricity demand is lowest, and vice versa. Second, wind resources can be highly variable in the short term, producing either significantly more or less power than expected. Figure 4.4-1 illustrates both of these effects. Third, wind supply is often located far from electricity demand centers. Increasing the supply of wind power can result in congestion on existing transmission lines and create the need for new transmission.

![Figure 4.4-1. Wind supply versus electricity demand in MISO region, Oct 11, 2011. Figure shows the inverse relation between wind supply and electricity demand, with wind supply lowest during the day when electricity demand is highest. It also illustrates the variability and difficulty of predicting of wind supply, with the actual wind generation deviating significantly from forecast levels.](image)

Energy storage technologies could be used to bridge the mismatch between the typical daily patterns of wind supply and energy demand by capturing wind energy produced during off peak periods and making it available during peak periods. The current electrical system, without energy storage, has several ways to deal with excess off-peak wind supply. First, if demand exists in other regions and transmission resources are adequate, the wind power can be exported. Second, base load coal power generation can be backed down to make room for the wind power, but this is economically and mechanically inefficient.
Third, wind power can be curtailed (turned off), an option that runs contrary to the goal of increasing the amount of wind energy in the system.

To ensure reliability, the system must have other generation resources that can be adjusted quickly to balance supply and demand when wind generation deviates from forecast levels. Energy storage technologies such as PHES are ideally suited to provide regulation service – balancing short-term fluctuations in supply or demand. They are able to respond to control signals nearly instantaneously, providing faster and more accurate regulation service than conventional power plants (Kirby, 2006). Despite the superior regulation service performance of energy storage technologies in general, the ability of any particular energy storage project, such as a PHES plant on the MIR to provide regulation services in response to supply variations caused by wind generation would depend on the location of the wind resources and of the storage facility, as well as the characteristics of the transmission system connecting them.

The role of PHES in transmission issues related to increasing wind power is complex and highly dependent on the relative locations of the PHES facility and the wind generation. The current electricity system, without energy storage, has two ways of dealing with transmission congestion created by increased wind generation: build more transmission lines or curtail the wind generation. Transmission congestion in Minnesota is not currently as significant a problem as it is in other portions of the MISO region (Figure 4.4-2), suggesting that transmission resources are adequate to handle the current wind supply which amounts to 10% of state power supply. Introducing more wind power into the system to meet the RES goal of 25% may increase curtailment, as demonstrated by the experience in Iowa, where wind supplies 15.4 percent of in-state generation (Wiser and Bolinger, 2011), and curtailments are significantly higher.

![Figure 4.4-2. Wind Curtailment in the MISO region](image)

**Figure 4.4-2.** Wind Curtailment in the MISO region (Source: Midwest ISO Real-Time Operations Department, April 2011 Wind Curtailment Report). In the MISO region, wind curtailments are highest in Iowa, where wind provides 15.4% of in-state generation (Wiser & Bolinger, 2011).

New transmission will be needed to move wind power to demand centers, and planning for this is under way through a consortium of Midwestern utility companies (CapX2020) and the MISO transmission planning process. However, storage could be considered as a possible solution to specific congestion
bottlenecks that may occur during some peak wind production periods. PHES located on the MIR may be well positioned to support wind power imported from North Dakota over Minnesota Power’s DC transmission line feeding the Arrowhead Substation near Duluth. This line is scheduled to begin transmitting approximately 300 MW of wind by 2010 (Minnesota Power, 2011). Additional transmission studies would be needed to determine the extent to which a PHES facility on the MIR would affect transmission congestion due to wind power generated in the southwest portion of the state.

**Decreasing greenhouse gas emissions**

The impact of PHES on greenhouse gas (GHG) emissions is complex to project. The availability of storage could cause GHG emissions to decrease or to increase, depending on the existing generation mix, the extent of wind penetration, the capabilities of the transmission system, the operating strategy of the PHES plant (driven largely by MISO rules), and the type of generation that PHES displaces while providing peak power.

The “fuel” consumed by PHES is electricity in the system, so the environmental attributes of power generated by PHES are roughly equal to the system-wide averages increased by the efficiency factor (the inefficiency) of the pumped hydro energy storage facility. So, for example, the average CO2 intensity of electricity in the MISO region was approximately 0.83 tons per MWh in 2009 (MISO, 2009). Purchasing this electricity to pump, a pumped hydro storage plant with an efficiency factor of 0.80 would have emissions of 1.04 tonnes per MWh. With increasing levels of renewable generation, the emissions attributable to a PHES facility could decrease as the average emissions of system-wide power decreases. In high wind penetration scenarios, the PHES power would be “cleaner” because most of the power used for pumping is wind power that would otherwise be wasted through curtailment (Tuohy and O’Malley, 2011). As a producer of peak power, a PHES plant would displace Natural Gas Combined Cycle generation, which emits approximately 0.50 tonnes CO2 per MWh, so the net impact on system GHG emissions would depend on whether the emissions attributable to the PHES plant were higher or lower than this level.

The operating strategy of a PHES facility (driven largely by the pattern of electricity price variations, by MISO rules, and by the ownership structure of the facility) would also influence the effect of the facility on net system GHG emissions. In a scenario with a low level of wind penetration (and curtailment), the operation of a PHES plant would be driven mainly by demand and the pattern of electricity price variations. The PHES plant would pump during the off-peak period (when prices and demand are low) and generate during the peak period (when prices and demand are high). In this scenario, the introduction of PHES could allow coal plants to operate constantly at their rated capacity during the off-peak period, producing more output, which increases GHG emissions (Tuohy and O’Malley, 2011).

However, as more wind is installed and curtailment becomes a significant problem, the availability of PHES could reduce GHG emissions per MWH. In this scenario, PHES operation could be increasingly driven by the excess wind on the system, the PHES facility could pump during periods of excess wind supply to limit curtailments, and, as a result, wind power would not be wasted and the emissions attributable to the PHES facility would decrease. Pumping and generation curves would smooth and impacts on output of conventional plants lessen, so emissions from coal plants would decrease because they could operate at their best efficiency. Furthermore, PHES could displace natural gas plants at the top of the dispatch stack to produce lower-carbon peak power.
Impact of PHES on electric power system reliability and costs

PHES would also have impacts on the policy goals of minimizing costs to ratepayers and maintaining system reliability. The availability of PHES clearly improves the reliability of the overall system, as discussed above, by acting as a flexible, instantaneously available resource that can provide either supply during peak periods or demand when there is excess supply of renewable generation. This flexibility and the high quality regulation services PHES provide would strengthen the reliability of the system.

The impact of PHES on system costs is more complex to evaluate. The adoption of energy storage technologies like PHES will be dependent on the economic merits of the storage technologies compared to alternatives. Currently, the main alternative to PHES is using NGCC to balance wind, cycling coal plants, and curtailing or exporting excess wind.

Much of the existing literature concentrates on whether the introduction of PHES reduces overall system costs and finds that storage can become economical when wind curtailment becomes a significant problem, for example, when wind provides more than 40 percent of total system generation (Tuohy and O’Malley, 2011). Wind curtailments are costly in several ways. Power purchase agreements between wind generators and utilities typically specify that the utility must pay for a set amount of wind power regardless of whether system constraints force them to curtail it. Furthermore, when a utility curtails wind, they must also pay the wind generator the value of the producer tax credit, currently $0.022/kWh (AWEA, 2011), so, ironically, curtailed wind power costs a utility more than wind power that enters the transmission system. Curtailments also undermine utilities’ efforts to meet renewable energy standards.

Introducing PHES into a scenario with low or moderate levels of wind generation will increase system operation costs due to the fact that storage consumes a portion of energy to pump water from the lower reservoir to the upper reservoir. Total system costs will also increase because PHES capital costs greatly exceed those of natural gas plants. Pumped hydro energy storage projects vary widely in cost depending on the civil works, topography, etc. The base capital costs for a PHES plant at the Giants Ridge location exceed $2000/kW, not including escalation and AFUDC (Barr, 2009). This is at least double the typical capital costs for a new NGCC plant, which are estimated at $850−$1000/kW (Burns and McDonnell, 2011). Furthermore, attaching prices to greenhouse gas emissions would actually increase total system costs, because coal plants could increase their output.

In high wind penetration scenarios, the availability of PHES could decrease total system costs. First, it could reduce costs due to curtailment. Second, PHES could help system operators avoid backing down coal plants during periods of excess wind. This would allow coal plants to be run more efficiently, decreasing their CO2 emissions per kWh. Third, in scenarios where wind curtailment is significant problem during a limited number of hours, PHES may be a more cost effective solution compared to transmission upgrades and build-outs (McDowall, 2006). Finally, if prices were attached to greenhouse gas emissions, the total costs for a system that includes PHES would be lower than for a system without PHES because overall GHG emissions are reduced, as described in Section 4.4 (Decreasing greenhouse gas emissions).

There are several factors and future developments that could make storage technologies, like PHES, more economically attractive within the overall system (see full discussion in Section 4.5):
• Technological advances could improve the efficiency and flexibility of turbines. For example, advances in variable speed technology and control systems allow for power control when the PHES facility is in pumping;
• Increasing prices for coal and natural gas also improve the economic merits of storage compared to alternatives;
• MISO ancillary service market rules could be modified to reward the response speed for fast-ramping PHES; and
• Markets could adopt rules that reward PHES’s contributions to improving power quality and system reliability.

POLICY BARRIERS AND OPPORTUNITIES FOR PROMOTING PUMPED HYDRO ENERGY STORAGE

Despite PHES technologies having the potential to create benefits for the power system, there are currently numerous barriers to their deployment. Price is clearly a barrier, with PHES technologies significantly more expensive than the alternatives that are currently in use, but there are also regulatory barriers that could be addressed to incentivize deployment of pumped hydro energy storage. Some of these potential regulatory changes, such as creating electricity markets where price is a function of power quality, as well as power quantity, are longer term issues, but there are other regulatory barriers to storage that could be addressed now.

Pumped hydro energy storage could be made eligible to receive renewable energy credits under Minnesota’s Renewable Energy Standard, similar to its treatment in Michigan. Michigan grants 20 percent of a renewable energy credit for each MWh of electricity that is generated from a renewable energy system during off-peak hours, stored by a PHES facility, and resold during peak hours (MI Clean, Renewable, and Efficient Energy Act, Section 460.1039). This renewable energy credit incentive reflects the mixed impact of pumped hydro energy storage on greenhouse gas emissions. Pumped hydro energy storage in some scenarios could reduce the cost of integrating large amounts of wind resources into the power system and displace natural gas. However, PHES enables coal plants to run more often at rated capacity. Therefore, only a portion of the stored energy has "green" attributes. This change would likely require legislative action, and support is uncertain because it is potentially problematic to open the RES for amendment in the current economic climate.

There are a number of changes that MISO could make that would incentivize PHES. MISO could adopt rules similar to those of the NE ISO ancillary service market that make payments on the basis of the response speed of a regulating resource. This would provide more compensation for faster-ramping resources such as pumped hydro energy storage. MISO could also make payments based on the accuracy of the performance. Pumped hydro energy storage is capable of providing frequency regulation service with a very high degree of accuracy – a valuable service, as it supports the high quality power increasingly necessary for digital devices. To date, no other ISO has incorporated accuracy into its ancillary services market. Finally, MISO could consider the impact of energy storage facilities when doing transmission planning studies and treat PHES on a comparable basis with transmission build-outs for purposes of qualifying for transmission price incentives and participation in regional transmission plans. Pumped hydro energy storage projects might also be classified as Multi Value Projects in the transmission planning process, which would give them advantages in cost allocation for grid interconnection.

The future viability of pumped hydro energy storage, such as PHES, will depend on the extent to which public utility commissions and electricity market operators establish rules that internalize system-wide costs, looking at PHES as a part of a resource portfolio that serves a range of valuable functions.
REFERENCES

SECTION 4.5:

The Economics of Pumped Hydroelectric Energy Storage

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The economics of pumped hydro energy storage depend on factors related to the overall electrical power system (e.g., percent of generation by variable renewable resources, transmission availability, electricity prices and price patterns), the facility site (e.g., land acquisition costs, engineering specifics), and regulation (e.g., market rules, rate decisions). Furthermore, the viability of PHES will be dependent on its relative economic merits compared to alternative means of providing the same energy services. Some of the energy services that PHES can provide, such as peaking power and load balancing services, are valued in the competitive wholesale electricity market operated in Minnesota by MISO, as described in Section 4.4 (MISO Regulations). However, there is no market for some of the other energy services PHES offers, such as improved power quality, reduced wind curtailment, and operational flexibility, so comparisons with alternatives will tend to undervalue energy storage.

Section 4.5 (Model explanation) describes a dynamic optimization model we developed to project hypothetic economic outcomes for a PHES facility on the MIR operating in a competitive electricity market, providing a brief explanation of the model inputs and assumptions. Section 4.5 (Results and Discussion) discusses key findings and insights from using the model to explore a number of scenarios. It is important to note that the model results represent estimates of the arbitrage value of storage that are based on the model’s assumptions. Site-specific factors and future prices will change the results. Discussion of the results is intended to highlight key economic issues that deserve consideration rather than putting hard numbers on the value of pumped storage. Finally, Section 4.5 (Impact of PHES on total system costs) places the economics of a PHES facility in the context of total electric power system costs.

MODEL EXPLANATION

The purpose of the model is to estimate the profit-maximizing operating schedule and bidding strategy for a PHES facility; in other words, the most profitable way to sell electricity and ancillary services and to buy electricity to pump. In real life, the operating strategy of a PHES facility would be influenced by its ownership structure. An independent power producer (IPP) would optimize at the level of the PHES facility, with generation and pumping times driven by price and load patterns to maximize the arbitrage value of storage. A regulated utility will also take advantage of price spreads, but, to the extent that the utility bears a financial risk of wind curtailment, operations will be driven less by load and more by excess wind on the system (Hill et al., 2010).

The model is constructed to examine the economics of a PHES facility from the perspective of an Independent Power Producer (IPP) because it simplifies the problem and allows for an analysis of several important cost factors and operating issues. This analysis is still relevant to a facility responding to more complex incentives, as these cost factors do not change so much as they are complicated by the introduction of other considerations such as wind curtailment. The model assumes the introduction of a small-scale PHES system that will not change the price of electricity. The objective of the model is to maximize profit by arbitraging electricity prices. The model simulates bids into the day-ahead energy and the ancillary services markets according to MISO rules. Historical prices for day-ahead energy, regulation reserve, and spinning reserve at the MP.HVDCE node on the Minnesota Iron Range (MIR) are used. An important assumption is that the owner-operator has complete foresight. This assumption is reasonable since operations are driven by predictable historical price and load patterns (Sioshansi et al., 2009).

PHES facility characteristics and capital costs are based on detailed plans for a PHES facility on the MIR (Barr Engineering Co., 2009) and supplemented by the engineering work conducted for this project (see
engineering Sections 3.2-3.3) Table 4.5-1 gives key facility characteristics. Table 4.5-2 shows key economic assumptions. We also assume project cost escalation over the permitting and construction period at a 7 percent annual rate. Escalation costs are based on Black and Veatch estimates. Indirect costs are accounted for, which include costs for training employees, among other costs. The AFUDC represents the cost of financing the project during the construction period. The total capital cost is levelized over the lifetime of the project and added to annual operations and maintenance expenses to derive the levelized annual revenue requirement.

Table 4.5-1. Modeled PHES facility characteristics.

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output at best efficiency head (MW)</td>
<td>200</td>
</tr>
<tr>
<td>Design head height (m)</td>
<td>97.46</td>
</tr>
<tr>
<td>Maximum head height (m)</td>
<td>104.8928</td>
</tr>
<tr>
<td>Minimum head height (m)</td>
<td>86.3</td>
</tr>
<tr>
<td>Turbine efficiency at full gate at best</td>
<td>0.89</td>
</tr>
<tr>
<td>efficiency head</td>
<td></td>
</tr>
<tr>
<td>Pump efficiency at best efficiency head</td>
<td>0.915</td>
</tr>
<tr>
<td>Pump Discharge at best efficiency head (m$^3$/s)</td>
<td>191.52</td>
</tr>
<tr>
<td>Turbine discharge at full gate at best</td>
<td>232.57</td>
</tr>
<tr>
<td>efficiency head (m$^3$/s)</td>
<td></td>
</tr>
<tr>
<td>Area of lower reservoir (m$^2$)</td>
<td>480,850</td>
</tr>
<tr>
<td>Area of upper reservoir (m$^2$)</td>
<td>1,678,331</td>
</tr>
<tr>
<td>Maximum Power Output (MW)</td>
<td>245</td>
</tr>
<tr>
<td>Peak pumping input (MW)</td>
<td>200</td>
</tr>
</tbody>
</table>
Table 4.5-2. Financial assumptions.

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic life</td>
<td>30 years</td>
</tr>
<tr>
<td>Commercial operation date</td>
<td>1-Jan-2011</td>
</tr>
<tr>
<td>Annual escalation rate</td>
<td>7%</td>
</tr>
<tr>
<td>Present worth discount rate</td>
<td>10.00%</td>
</tr>
<tr>
<td>Levelized annual fixed charge rate</td>
<td>10.61%</td>
</tr>
<tr>
<td>AFUDC rate</td>
<td>25%</td>
</tr>
<tr>
<td>Construction period</td>
<td>4 years</td>
</tr>
<tr>
<td>Capital Cost</td>
<td>$245,336,000</td>
</tr>
<tr>
<td>Escalation 7%, 4 years</td>
<td>$262,509,520</td>
</tr>
<tr>
<td>Escalation 7%, 4 years</td>
<td>$280,885,186</td>
</tr>
<tr>
<td>Escalation 7%, 4 years</td>
<td>$300,547,149</td>
</tr>
<tr>
<td>Escalation 7%, 4 years</td>
<td>$321,585,450</td>
</tr>
<tr>
<td>Escalation 7%, 4 years</td>
<td>$76,249,450</td>
</tr>
<tr>
<td>Direct Cost</td>
<td>$321,585,450</td>
</tr>
<tr>
<td>Indirect Costs</td>
<td>$25,726,836</td>
</tr>
<tr>
<td>AFUDC</td>
<td>$80,396,362</td>
</tr>
<tr>
<td>Total Capital Cost</td>
<td>$427,708,648</td>
</tr>
<tr>
<td>Fixed Charges</td>
<td>$45,371,012</td>
</tr>
<tr>
<td>Annual Operating Cost</td>
<td>$8,773,232</td>
</tr>
<tr>
<td>Total levelized annual cost</td>
<td>$54,144,244</td>
</tr>
</tbody>
</table>

The model uses stochastic dynamic programming methods to optimize the bidding schedule over a one-week period. We optimized over a one-week period because this allows the facility to take advantage of both diurnal and week-day/weekend patterns. A Markov probability matrix is used to model stochastic instructions to ramp up or down to provide regulation services. Backwards recursion is used to solve the model. Carry-over values are assigned to stored energy at the end of the one-week period because it is not realistic to constrain the terminal amount of energy stored to equal the initial amount of energy stored. The model accounts for variable head, variable discharge, start and stopping costs, stochastic instructions to ramp up or down on a 4 sec periodicity when providing regulation services, and cycle efficiencies.

RESULTS AND DISCUSSION

Model results provide insight into the potential operating profit of a hypothetical PHES facility operating on the MIR. They also estimate the total revenue requirements to construct and operate this hypothetical PHES facility, from which the levelized cost of electricity (LCOE) can be calculated for
several different scenarios. The LCOE projections for PHES are limited in that future prices and site-specific factors could produce very different results. Capital costs, which are a major factor in the LCOE, are very sensitive to site selection and engineering requirements. We simulate a range of costs of acquiring mineral rights, but future research should simulate uncertainties around the costs of constructing earth embankment dams, lining reservoirs, permitting and construction lead times, etc.

**Operating profit**

Using historical prices from the node nearest the MIR (MP.HVDCE node), operating profit is $309,000 for the week January 1 to January 7, 2010. Revenue from the regulation services market makes up 20% of this profit. Figure 4.5-1 shows the modeled operations profile, which is driven by load with pumping occurring during the traditional off-peak period and generation occurring during the peak period. It is important to note that discharge and recharge times are different from day-to-day reflecting the importance of inter-day arbitrage and a weekly operating schedule.

![Weekly PHES operations profile January 1-6, 2010.](image)

**Figure 4.5-1.** Weekly PHES operations profile January 1-6, 2010.

The profitability of a PHES facility is strongly linked to the volatility of electricity prices, which change over time (seasonally and through the decades), and with location on the electric grid. The PHES facility captures arbitrage value by storing low-cost energy and selling that energy during the high-price peak demand periods. The arbitrage value of storage depends on the price spread and the efficiency of the PHES facility. We modeled the effects of the price spread by calculating the arbitrage value of storage over each one week period during the first six months of 2010. Terminal values were established by starting the optimization at the end of the six-month period and working backwards one week at a time. The terminal values reflect the value of stored electricity at the end of each one-week planning period. Without the terminal values, the operator would completely discharge the upper reservoir at the end of each one-week planning period.
Figure 4.5-2 plots the modeled arbitrage value of storage as a function of electricity price volatility for each of the 26 weeks, showing a strong correlation between weekly volatility in day-ahead electricity prices and the arbitrage value of each MWH stored. This illustrates how higher price spreads offer better arbitrage opportunities for storage. This analysis also shows that the first week of January was one of the more volatile and most profitable of this six month period, with the second highest arbitrage value of storage.

A number of factors would affect the arbitrage value available to a PHES facility, for example, trends in the price of natural gas will impact the arbitrage value of storage due to the fact that natural gas sets the price during peak periods. Also, changes in the generation mix will impact price spreads. The integration of more wind into the power system and the retirement of coal plants will increase price volatility and produce more arbitrage opportunities for storage.

The model also demonstrates that the particular rules of the ancillary market have a large impact on profitability. For example, the ancillary services market rules of the New England ISO (NE ISO) pay regulating resources according to the speed of their response when they are called on. The model shows that the profits of the same hypothetical PHES facility for the same time period would be 75% higher under the NE ISO rules than under the MISO rules ($627,000 instead of $390,000). This suggests that the current pricing rules for regulation services in the MISO significantly undervalue the regulation services provided by fast-ramping energy storage resources such as PHES.

![Figure 4.5-2. Weekly arbitrage value of storage as a function of price volatility showing the amount of weekly operating profit per MWh stored versus the weekly variance of the LMP at the MP.HVDCE node on the Minnesota Iron Range for the weeks from January 1 to June 30 2010. The week of January 1-6 was a week of high price volatility, with the second highest arbitrage value of storage, at $266/MWh).](image)

**PHES total revenue requirements**

The total annual revenue requirements depend on the total capital and variable costs. As detailed in Section 4.5 (*Model explanation*), capital costs are based on a specific project proposed for the MIR. The model assumes the cost of purchasing power to pump water from the lower reservoir to the upper
reservoir is the only variable cost. In reality, maintenance costs associated with stopping and starting the facility should also be considered. However, based on conversations with BARR and SAFL engineers, variable operations and maintenance costs are assumed to be trivial. The cost of purchasing electricity is calculated based on the modeled optimal pumping schedule.

The LCOE is total levelized annual cost divided by the annual energy output, so it is very sensitive to the cost of electricity and the operating schedule. To explore the LCOE range for the modeled PHES facility on the MIR, we varied electricity prices and pumping times. Electricity prices were selected based on trends in the day-ahead price for electricity in MISO over the year 2010. The low price is representative of the cost of pumping during the late spring/early summer months and the Fall season. The high price is representative of the cost of pumping during the peak summer months and winter months. The price spreads exhibit six month seasonal variations, which impacts self-scheduling into the markets. When price spreads narrow, the pumping time is reduced. The high low estimates for pumping times are based on optimizing operations over weeks with high and narrow price spreads. The low pumping time is representative of pumping times during weeks with narrow price spreads. The high pumping time is representative of pumping times during weeks with high price spreads. Results show the LCOE varying between $237 and $378 per MWh (Table 4.5-3).

Table 4.5-3. LCOE estimates for different scenarios (per MWh).

<table>
<thead>
<tr>
<th>Pumping duration</th>
<th>Electricity price (per MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (2496 hrs)</td>
<td>$366</td>
</tr>
<tr>
<td>High (3328 hrs)</td>
<td>$237 $273</td>
</tr>
</tbody>
</table>

Note: These LCOE projections for PHES are limited in that future prices and site-specific factors could produce very different results.

The LCOE is useful for comparing the cost of a PHES facility to other peaking plants such as combined cycle gas turbines (CCGT). It should be noted that the LCOE is very sensitive to the capacity factor. Estimates of the LCOE cost for CCGT plants vary widely due to different assumptions about the CCGT capacity factor and gas prices. In a 2002 study, EPRI used a 25 percent factor and calculated the LCOE of a CCGT plant to be $176/MWH. Moreover, gas prices have declined since the EPRI study was completed. However, PHES could be competitive with natural gas in high gas price scenarios.

For a PHES facility on the MIR, the cost of acquiring the necessary mineral rights represents one of the largest sources of uncertainty regarding total capital cost. The mineral rights accounted for about 15 percent of the total capital cost in the Barr Engineering study of the Giants Ridge PHES facility, where mineral rights would only need to be acquired under the lower reservoir (BARR Engineering, 2009), but the cost of acquiring mineral rights could be significantly higher. Many potential PHES sites on the MIR would require acquisition of mineral rights under both reservoirs, as well as around them, to create a buffer zone from blasting. Furthermore, the price of acquiring mineral rights has doubled in recent years from what Barr assumed in its study, and prices are expected to continue to increase, driven by global demand for iron ore. Figure 4.5-3 shows the sensitivity of the LCOE to increases in the cost of acquisition.
of mineral rights. If the cost of acquiring mineral rights increases by four times the cost assumed in current model (roughly a scenario in which mineral rights need to be acquired under both reservoirs at 2011 prices), LCOE could increase by 59 percent, and total revenue requirements could increase by as much as 36 percent.

Figure 4.5-3. Impact of Mineral Rights on LCOE.

**IMPACT OF PHES ON TOTAL SYSTEM COSTS**

Ultimately, the value of energy storage technologies must be judged at both the facility scale and for their impact on total system costs. As described in Section 4.4 (Impact of PHES on electric power system reliability and costs), the impact of PHES on total system costs would be a function of the level of wind deployment, curtailment patterns, and whether or not there is a climate policy that places a price on greenhouse gas emissions. Within the system as a whole, the impact of energy storage technologies like PHES will depend on the value of the energy services they provide compared to alternatives, and there is currently no way to make a fair comparison because existing markets and rules do not monetize many of the benefits that storage adds to the system such as increased power quality and operational flexibility.
REFERENCES

Barr Engineering, 2006, Resource assessment and site selection: Wind power development and pumped energy storage on Minnesota's iron range.
Barr Engineering, 2009, Giant's Ridge Pumped Storage Project.
CHAPTER 5:

EVALUATION OF ENVIRONMENTAL IMPACTS OF PHES ON THE MESABI IRON RANGE INCLUDING UNDERSTANDING OF ENVIRONMENTAL IMPACT ASSESSMENT PARAMETERS

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Synopsis

Chapter 5 concentrates on reviewing various environmental issues that will need to be studied in more detail for implementation of PHES at a selected site. In addition, a draft environmental impact report was developed to outline specific parameters that need to be addressed to provide public, governmental, and other interested parties with information about the specific impacts that PHES implementation may cause using existing mine pits. Significant environmental impacts include soil erosion and surface water quality changes that likely can be mitigated with sound erosion control practices. Further investigation is necessary to develop site-specific information regarding water balance, release of mineral and other agents to the water, groundwater quality and availability, surface water bodies, and the impacts of the technology implementation on cultural and aesthetic resources. In developing the environmental picture for the Mesabi Iron Range, various stakeholders were interviewed, and the feedback obtained is summarized in this chapter. Additionally, a summary of permitting requirements including the process for permitting is presented. Also, various evaluation methods and models are presented to help evaluate prioritized environmental concerns. Finally, the level of significance of PHES for various environmental impacts is assessed, and various potential mitigation measures are discussed for each impact.
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EXECUTIVE SUMMARY

This report on a Mesabi Iron Range Pumped Hydro Energy Storage (proposed project) draft environmental impact report (EIR) was prepared to provide the public, governmental and/or responsible agencies, and other interested parties with information about the environmental effects of PHES implementation in northeastern Minnesota using existing mine pits.

This EIR was scoped on possible effects caused by the proposed project in terms of geology and soil, water quality, surface water, groundwater, biological resources, and other common issues that are often mentioned in most environmental impact reports for new project development such as agricultural resources, cultural resources, aesthetic resources, population and housing, air quality, and noise. These possible impacts are briefly summarized in Section 5.1. In Section 5.2, three issues: groundwater impact, release of mineral dissolution, and water balance, which were deemed as critical and somewhat unique to the proposed project, are analyzed in detail by providing conceptual models and analytical methods. The possible impacts caused by an effort of enhancing the efficiency of the whole project by increasing the net head from upper reservoir to lower reservoir is also analyzed in Section 5.2. The analytical methods of determining the radius of influence area and possible effects to the surrounding surface water bodies by decreasing natural or steady state hydraulic head is demonstrated. In Section 5.3, the environmental impacts caused by the proposed project are synthesized and tabulated with impact assessments and possible mitigation measures for those issues deemed as significant. For those issues for which further information is needed to evaluate at a specific project site, the missing data and information are identified.

Significant environmental impacts caused by the proposed project include soil erosion and surface water quality during the construction phases. The possible mitigation measures include implementation of sound erosion control practices. Possible significant issues that require further investigation and information for insightful evaluation after a specific site is determined include water balance, release of mineral and sulfate solutions, groundwater quality and availability, surface water bodies, and cultural and aesthetic resources.

As a part of the evaluation of environmental impacts, meetings were held with various stakeholder groups including regulatory agencies, tribes, and other interested parties. These stakeholder interviews provide an opportunity for the project team to receive feedback from parties having vast experience with environmental issues in northeastern Minnesota. Their comments are summarized in Section 5.4 and are incorporated into the synthesis table of Section 5.3. A summary of the permitting requirements for the implementation of a PHES facility on the Mesabi Iron Range is included in Section 5.5.

This EIR serves as an informational document which informs public agency decision makers and the public generally of the significant environmental effects of the proposed project, presents preliminary conceptual models and tools to evaluate high-priority environmental impacts, identifies possible ways to minimize the significant effects, and synthesizes required permitting information. While the scope of this EIR does not allow for a detailed evaluation of the environmental impacts for the proposed project at a specific site, it provides a framework on which future evaluations of environment impacts caused by developing and operating a Pumped Storage Hydroelectric Energy Storage project at the Mesabi Iron Range area can be based.
SECTION 5.1:

General Environmental Issues and Concerns for PHES Project

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The proposed project facility and components include: upper dams and reservoir, lower reservoir, spillways, conduits, powerhouse, access tunnel, water supply, land conveyance pipelines, and transmission lines. The general environmental concerns of this proposed project include: geology and soil, surface water, groundwater, agricultural resources, biological resources, aesthetic resources, cultural resources, recreation, population and housing, air quality, and noise. Each general category of environmental concerns is described briefly in Section 5.1. Section 5.2 focuses on a more detailed description of groundwater and surface water related impacts from implementing PHES in the abandoned mine pits. Section 5.3 presents an overall summary and assessment of the potential environmental impacts from PHES development on minelands in northern Minnesota. Section 5.4 has results from stakeholder interviews.

**GEOLOGY AND SOIL**

Construction activities of dams and reservoirs, along with water conveyance corridor and transmission line corridor, as well as operations of the project may potentially impact the geological and soil resources at the project site. The Mesabi Iron Range (MIR) is bounded on the north by Giants Ridge, which is the major topographic high in the area. According to Winter (1973), this long, linear ridge consists of mostly Precambrian granite, towering more than 400 feet above the land immediately to the south.

The rest of the area consists of landforms resulting from glacial deposits from over 10,000 years ago. Bedrock underlying the Mesabi Iron Range (MIR) includes granite, quartzite, iron-formation, argillite, and gabbro of Precambrian age. Conglomerate, sandstones, and shales of Cretaceous age overlie the Precambrian rocks in the western half of the area. Glacial drift in the Mesabi Iron Range area consists of three major till units - basal till, boulder till, and surficial till. Total thickness of all drift units ranges from zero along the base of the Mesabi Iron Range to 250-300 feet in the southeastern MIR while in most of the area the drift is greater than 100 feet thick (Winter, 1973).

**Soil Erosion**

We assumed that soil erosion will likely only occur during construction processes of this project. Soil erosion and sedimentation control plans aiming to minimize soil particles movement from the disturbed land caused by raindrop splash and surface runoff should be included and implemented during the development of the project. Control plans should specifically be implemented for the areas of cleared and graded for minor cuts and fills and that have permanent or temporary structures.

**Landslides**

During site investigation and preparation of construction, areas within the upper and lower pits that have potentially unstable slopes caused by mining fracture sets on the pit wall should be carefully identified and repaired to avoid potential slope raveling and localized slope failures and rock falls.
Seismicity

Concerns to the project include regional seismicity that may affect the project’s safety, and the potential for increasing the risk of an earthquake triggered by the increase of water weight in project reservoirs. Historical earthquakes affecting Minnesota are summarized in Table 5.1-1 (USGS, 2009). It is generally accepted that only a small percentage of reservoirs impounded by large dams have triggered known seismic activity (Gupta, 2007). Since the mine pits in the Mesabi Iron Range are relatively small in size and earthquakes infrequent, the potential for reservoir triggered seismicity at the proposed scale of project being considered, is likely to be insignificant. However, a detailed evaluation of project safety regarding earthquake hazards should be carefully conducted when/if a project site is identified.

Table 5.1-1a. Recorded historical earthquakes affecting Minnesota (adapted from USGS, 2009).

<table>
<thead>
<tr>
<th>Date</th>
<th>Severity of the Shock</th>
<th>Quake Center</th>
<th>Area affected in Minnesota</th>
</tr>
</thead>
<tbody>
<tr>
<td>1860</td>
<td>Fairly strong</td>
<td>Central Minnesota, US</td>
<td>Entire state</td>
</tr>
<tr>
<td>Sept. 3, 1917</td>
<td>Intensity VI</td>
<td>Central Minnesota, US</td>
<td>Entire state</td>
</tr>
<tr>
<td>Nov. 15, 1877</td>
<td>Strong shock</td>
<td>Eastern Nebraska, US</td>
<td>SW Minnesota</td>
</tr>
<tr>
<td>May 26, 1909</td>
<td>Intensity VII</td>
<td>Illinois, US</td>
<td>SE Minnesota</td>
</tr>
<tr>
<td>Feb. 28, 1925</td>
<td>--</td>
<td>Quebec, Canada</td>
<td>Slightly felt in Minneapolis, MN</td>
</tr>
<tr>
<td>Nov. 1, 1935</td>
<td>Strong</td>
<td>Timiskaming, Canada</td>
<td>Slightly felt in Minneapolis</td>
</tr>
<tr>
<td>Nov. 9, 1968</td>
<td>Intensity I-IV</td>
<td>South-central Illinois, US</td>
<td>Austin, Glencoe, Mankato, Minneapolis, Rochester, MN</td>
</tr>
</tbody>
</table>
Table 5.1-1b. Additional historical earthquakes affecting Minnesota (Chandler, 1994, and pers.comm., Nov. 8, 2011).

<table>
<thead>
<tr>
<th>#</th>
<th>Epicenter (nearest town)</th>
<th>County</th>
<th>Mo./Day/Yr.</th>
<th>Lat. (deg.)</th>
<th>Long. (deg.)</th>
<th>Depth (km)</th>
<th>Km²</th>
<th>Intensity</th>
<th>Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Long Prairie</td>
<td>Todd</td>
<td>1860-61</td>
<td>46.10</td>
<td>94.90</td>
<td>---</td>
<td>---</td>
<td>VI-VII</td>
<td>5.0</td>
</tr>
<tr>
<td>2</td>
<td>New Prague</td>
<td>Scott</td>
<td>12/16/1860</td>
<td>44.60</td>
<td>93.50</td>
<td>---</td>
<td>---</td>
<td>VI</td>
<td>4.7</td>
</tr>
<tr>
<td>3</td>
<td>St. Vincent</td>
<td>Kittson</td>
<td>12/28/1880</td>
<td>49.00</td>
<td>97.20</td>
<td>---</td>
<td>---</td>
<td>II-IV</td>
<td>3.6</td>
</tr>
<tr>
<td>4</td>
<td>New Ulm</td>
<td>Brown</td>
<td>2/5-2/12/1881</td>
<td>44.30</td>
<td>94.50</td>
<td>---</td>
<td>v. local</td>
<td>VI</td>
<td>3.0-4.0?</td>
</tr>
<tr>
<td>5</td>
<td>Red Lake</td>
<td>Beltrami</td>
<td>2/6/1917</td>
<td>47.90</td>
<td>95.00</td>
<td>---</td>
<td>---</td>
<td>V</td>
<td>3.8</td>
</tr>
<tr>
<td>6</td>
<td>Staples</td>
<td>Todd</td>
<td>9/3/1917</td>
<td>46.34</td>
<td>94.63</td>
<td>---</td>
<td>48,000</td>
<td>VI-VII</td>
<td>4.3</td>
</tr>
<tr>
<td>7</td>
<td>Bowstring</td>
<td>Itasca</td>
<td>12/23/1928</td>
<td>47.50</td>
<td>93.80</td>
<td>---</td>
<td>---</td>
<td>IV</td>
<td>3.8</td>
</tr>
<tr>
<td>8</td>
<td>Detroit Lakes</td>
<td>Becker</td>
<td>1/28/1939</td>
<td>46.90</td>
<td>96.00</td>
<td>---</td>
<td>8,000</td>
<td>IV</td>
<td>3.9-3.9</td>
</tr>
<tr>
<td>9</td>
<td>Alexandria</td>
<td>Douglas</td>
<td>2/15/1950</td>
<td>46.10</td>
<td>95.20</td>
<td>---</td>
<td>3,000</td>
<td>V</td>
<td>3.6</td>
</tr>
<tr>
<td>10</td>
<td>Pipestone*</td>
<td>Pipestone</td>
<td>9/28/1964</td>
<td>44.00</td>
<td>96.40</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>3.4</td>
</tr>
<tr>
<td>11</td>
<td>Morris*</td>
<td>Stevens</td>
<td>7/9/1975</td>
<td>45.50</td>
<td>96.10</td>
<td>---</td>
<td>82,000</td>
<td>VI</td>
<td>4.8-4.6</td>
</tr>
<tr>
<td>12</td>
<td>Milaca*</td>
<td>Mille Lacs</td>
<td>3/5/1979</td>
<td>45.85</td>
<td>93.75</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>1.0</td>
</tr>
<tr>
<td>13</td>
<td>Evergreen*</td>
<td>Becker</td>
<td>4/16/1979</td>
<td>46.78</td>
<td>95.55</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>3.1</td>
</tr>
<tr>
<td>14</td>
<td>Rush City*</td>
<td>Chisago</td>
<td>5/14/1979</td>
<td>45.72</td>
<td>92.90</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>0.1</td>
</tr>
<tr>
<td>15</td>
<td>Nisswa*</td>
<td>Crow Wing</td>
<td>7/26/1979</td>
<td>46.50</td>
<td>94.33</td>
<td>---</td>
<td>v. local</td>
<td>III</td>
<td>1.0</td>
</tr>
<tr>
<td>16</td>
<td>Cottage Grove</td>
<td>Washington</td>
<td>4/24/1981</td>
<td>44.84</td>
<td>92.93</td>
<td>---</td>
<td>v. local</td>
<td>III-IV</td>
<td>3.6</td>
</tr>
<tr>
<td>17</td>
<td>Walker</td>
<td>Cass</td>
<td>9/27/1982</td>
<td>47.10</td>
<td>97.60</td>
<td>---</td>
<td>v. local</td>
<td>II</td>
<td>2.0</td>
</tr>
<tr>
<td>18</td>
<td>Dumont*</td>
<td>Stevens</td>
<td>6/4/1993</td>
<td>45.67</td>
<td>96.29</td>
<td>---</td>
<td>69,500</td>
<td>V-VI</td>
<td>4.1</td>
</tr>
<tr>
<td>19</td>
<td>Granite Falls*</td>
<td>Yellow Medicine</td>
<td>2/9/1994</td>
<td>44.86</td>
<td>95.56</td>
<td>---</td>
<td>11,600</td>
<td>V</td>
<td>3.1</td>
</tr>
<tr>
<td>20</td>
<td>Alexandria*</td>
<td>Douglas</td>
<td>4/29/2011</td>
<td>45.99</td>
<td>95.53</td>
<td>15.6</td>
<td>---</td>
<td>---</td>
<td>2.5</td>
</tr>
</tbody>
</table>

* Asterisks denote earthquakes that were recorded instrumentally.

WATER QUALITY

Because water is the primary resource and energy transport vehicle for a PHES project, and because of Minnesota’s strong regulatory protection of water resources, negligible impacts on water quality and quantity are critical goals for the design of a PHES system. Moreover, both the water quality and hydrology of the pit used for PHES could potentially be altered by project activities during and after construction, as could surface and groundwater in their vicinity. Key pathways whose modification might affect water quality include: evaporative water losses, soil erosion leading to increased nutrient runoff and potential eutrophication as well as direct ecological effects due to increased suspended sediment, elevated metals concentrations, elevated salt levels in runoff and pit lake discharge (sulfate in particular), and acidification of pit lake water.

Water balance from evaporative loss during operation processes and water gain from precipitation and runoff should be determined for specific pits chosen for the proposed PHES project. Average precipitation on the Northeastern Minnesota Iron Range is approximately 28.3 inch (71.9 cm)/year and annual surface runoff in this region is estimated to be approximately 8-10 inches (20.3 – 25.4 cm) (Herr and Gleason, 2007). Evaporation rates will differ from pit to pit depending on their rim areas, slopes and orientation to the sun, plus water elevation. A water losing reservoir could not only decrease the energy
efficiency of the proposed PHES project, but also potentially result in increased salt, nutrient, and acid concentrations in the system water. In the case of severe evaporative water loss, make up water would be required.

Eutrophication is a process involving the nutrient enrichment of a water body, such as lakes, estuaries, or slow-moving streams, where excessive plant growth of algae, periphyton (attached algae), and nuisance higher plants (“weeds”) results from this excess fertility. Negative impacts that most commonly occur involve obnoxious growths of algae and plants that smother habitat, modify food webs, deplete dissolved oxygen in the water, and cause taste, odor, and sometimes algal toxin problems. Nutrients normally come from sources such as fertilizers applied to agricultural fields, golf courses, and suburban lawns; deposition of nitrogen from atmosphere, soil erosion and runoff containing nutrients, and sewage treatment plant discharges (GEI Consultants Inc., 2010; Axler et al., 1996). Because the water in a PHES project system would be designed to be cycled between upper and lower reservoirs, no direct nutrient sources would be introduced during routine operation. The proposed sites are at disturbed mined lands where there are no agricultural fields or golf courses within the drainage areas. Furthermore, there are no sewage-related discharges to those abandoned mine pit lakes. Therefore, eutrophication impacts from external nutrient loading are likely to be insignificant.

According to preliminary site investigations conducted by the project team using available map (GIS) data, most mine pits are surrounded by fracture dominated rocks left from prior mining activities. Exposed oxide (primarily iron oxide) and sulfide minerals are presumed to be contained within the fractured pit walls (Fetter, 2001). Fluctuation of water level in the pits during PHES operations would enhance the availability of oxygen to those minerals that accumulated on the weathered bedrock surface during mining and during the early period post-mining flooding. Repeated cycles of flooding and exposure to the atmosphere will speed the oxidation of ferrous iron and reduced sulfur compounds and potentially increase the release of iron and sulfate salts and acid from pit walls to system water (Berndt, 2003). Figure 5.1-1 shows a conceptual model of the interaction between pit water, minerals, and solutes from pit walls caused by fluctuating water level and depicts the exchanges between the groundwater and pit water during PHES operation.

For a specific project site, the mineralogy of the geologic units in the vicinity of the pit should be carefully investigated so that the nature and magnitude of changes in water quality can be estimated. If increased release of solute mineral and/or acid are demonstrated to be detrimental to either the safety of power generation equipments, as well as down stream beneficial uses of the water, then in situ or off-site treatment of the pit water may be required. Section 5.2 of this report details test methods of in pit sulfate/mineral concentration. Alternative mitigation measures to reduce potential adverse effects to system equipment is to apply rust protection for project equipments such as turbine, pumps, and water conduits.

One final consideration, though perhaps unlikely to be significant, is the change in water column thermal and chemical stratification that would result from turbulent mixing associated with large water volumes being cycled relatively frequently between the two reservoirs (time periods < 1 day). Some mine pit lakes on the Mesabi Iron Range (MIR) have previously been discovered to be meromictic, i.e., exhibiting a strong vertical chemical stratification for much of the year if deep enough (guestimated at > 60 meters or so), but dependent on basin fetch and wind sheltering by the cliff walls of the pit lakes (Axler et al., 1992, 1996; Axler, unpubl. data). Such pit lakes are characterized by strong hypolimnetic anoxia during much if not all of the ice free growing season and strong reducing conditions in this stagnant monimolimnion (cf. Cole, 1994).
Figure 5.1-1. Schematic of exchange between groundwater and pit water during operation of a PHES facility.

GROUNDWATER

Previous studies have shown that the most productive aquifers on the Mesabi Iron Range are the Precambrian Biwabik Iron Formation (BIF) and the stratified glacial drifts. Ground water movement in the BIF is generally through fractures, faults and joints. Recharge to the BIF is generally through infiltration of the overlying glacial drift deposits. The general ground water movement in the Mesabi Iron Range tends to be south and southeast from the Laurentian Divide (Herr and Gleason, 2007).

Tests have been performed by previous researchers (Herr and Gleason, 2007) to determine the critical hydrological parameters for the Mesabi Iron Range. However, even though those studies only focused on a few relatively small areas, much more specific hydraulic conductivity data is needed to estimate local and regional groundwater flows for assessing the suitability of potential sites. Table 5.1-2 lists the hydraulic conductivities of some aquifers of potential sites and should be used as a reference to describe the regional flow regime.

According to PHES facility design, the fluctuation distance between high and low water level in pits is likely to be about 30 ft (9 m), and the processes of pumping and releasing cycles normally occur within 48 hours. Since low values of hydraulic conductivity for the rocks surrounding the pit lakes that have previously been studied, the exchange between groundwater and pit water is considered likely to occur within a very short distance from the pit walls (see Figure 5.1-1).
Table 5.1-2. Hydraulic conductivity of the local aquifers in feet per day (adapted from Herr and Gleason, 2007).

<table>
<thead>
<tr>
<th>Aquifers</th>
<th>Test Performed</th>
<th>Hydraulic Conductivity (K) ft/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duluth Complex</td>
<td>single-well aquifer test</td>
<td>$10^{3.6}$ to $10^{2.6}$</td>
</tr>
<tr>
<td>Virginia Formation</td>
<td>4 pumping and 5 observation wells</td>
<td>$10^{2.6}$ to 1</td>
</tr>
<tr>
<td>Biwabik Formation</td>
<td>specific capacity test</td>
<td>$10^{0.05}$</td>
</tr>
<tr>
<td>Between Buhl and Chisholm</td>
<td>various slug tests</td>
<td>$10^{3.5}$ to $10^{-0.5}$</td>
</tr>
</tbody>
</table>

Although a specific site has not been determined for the proposed PHES, general considerations about regional ground water can be discussed based on the anticipated design configuration for the proposed project. Two preliminary scenarios: (1) using existing pits for lower and upper reservoirs; and (2) using an existing pit as lower reservoir and constructing an upper reservoir, are discussed below. The groundwater interactions should be similar for the lower reservoir in both scenarios; however, the extent to which the upper reservoir interacts with local and regional groundwater will depend on the characteristics of the specific site.

In the case of using existing pits with stable water level as an upper or lower reservoir, the interaction between pit water and ground water surrounding the pits will likely occur within a limited area, as shown in Figure 5.1-1. One major concern relates to soluble iron and sulfate (and possibly manganese) release from pit walls to the system water due to the oxidation of rock minerals associated with water level fluctuation. This oxidation could result in a net release of these compounds to either down gradient groundwater or surface waters if discharged. As noted in the water quality session, the interaction between groundwater and the water in the reservoir will be limited during the PHES operation. The impact to groundwater quality within the vicinity of the selected mine pits is expected to be small, or negligible.

In cases where an upper reservoir is constructed, the walls and bottom of the upper reservoir could be carefully lined so as to minimize hydrologic interaction between the upper reservoir and its surrounding water system.

Another concern regarding groundwater is the impact caused by project operation on local groundwater movement that could affect the availability of groundwater to municipal, industrial, and private wells, wetlands, rivers, and lakes in the surrounding area. However, since the interaction between groundwater and pit water during the operation of a PHES will occur over a relatively small area, this potential impact is likely not to be significant.

**SURFACE WATER**

PHES impacts to surface water are based on both a construction phase and an operation phase. By implementing proper runoff, soil erosion, and sedimentation control practices, the impact(s) during the construction of the powerhouse, upper reservoir, and power line corridor to surface water bodies can be effectively mitigated. During the operation processes, there are two possible means through which the water in reservoirs can impact surface water: (1) exchanges between pit water and groundwater and between groundwater and surface water; and (2) discharge of water from reservoir to the surface water bodies if precipitation and surface runoff associated with storm events flood the reservoir system and
water levels require reduction. While the likelihood of impact through the first pathway is small, as discussed previously, the possibility of impacts to surface water via direct discharges will depend on the quality of the water in the reservoir (both the legacy contamination and increased sulfate and iron in solution resulting from operation processes), the drainage area of the selected mine pits, and the magnitude of the potential discharge.

Increased stormwater would be produced from the PHES facility due to increased impermeable surface area. Its potential effects to the downstream watershed include greater potential for erosion and sedimentation, increased pollutant concentrations in stormwater washing through surfaces within the PHES facility, and potential need for culvert upgrading. Magnitude of this effect will depend on the size and management strategies of the proposed project.

BIOLOGICAL RESOURCES

Biological resources include plant communities, wildlife communities, fishery resources, and sensitive species and sensitive habitats. Concerns of this project to the biological resource include substantial adverse effects, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special status species in local or regional plans, policies, or regulations.

According to cursory site investigations conducted by the project team and the GIS data obtained from the Laurentian Vision Partnership (2002), the vicinity of the pits potentially selected for this project is heavily-disturbed mined land and rare plant species are unlikely to be present (Felleson, 1999). Therefore, the impact to sensitive on-site plant communities for this project is unlikely to be significant. Regional forest-sensitive wildlife in northeastern Minnesota includes: Peregrine falcon, Great Gray owl, Boreal owl, and Female Nabokov’s blue butterfly. Regional forest sensitive plant species of particular concern in northeastern Minnesota include: *Moehringia macrophylla*, *Litoria auriculata*, *Pyrola minor*, and *Waldsteinia fragarioides* (USDA, 2008). In an EIS prepared for PolyMet NorthMet mine site, nine State-listed Endangered, Threatened or Special Concern (ETSC) plant species were identified (PolyMet Mining Inc., 2009). Seven federal and state-listed ETSC wildlife species were also identified as outlined below:

1. ETSC plants: Prairie moonwort, pale moonwort, ternate grape-fern, least grapefern, flooting mash ary gold, neat spike rush, lapland butter cup, clustered bur-reed, torrey’s manna grass; and
2. ETSC wildlife: Canada lynx, grey wolf, bald eagle, wood turtle, heather vole, yellow rail, and tiger beetle.

The Minnesota Department of Natural Resources (MN DNR) and U.S. Forest Service (USFS) developed the Ecological Classification System (ECS) that has been used to identify and describe unique features. The majority of the Mesabi Iron Range lies in the ECS subsection of Nashwauk Uplands, where 38 rare species were identified (MN DNR, 2010). Because the prior mining activities have already destroyed the habitat of these species at the mine pit areas, they are not likely to be directly impacted by this proposed project; however, a PHES project can potentially prevent the remediation of a site that provides a viable, useable habitat for wildlife. Therefore, in the phase of determining a specific site(s) for a PHES facility, the U.S. Fish and Wildlife Service (USFWS) should also be contacted and consulted to determine additional measures that could be implemented wildlife protection.

Selected fish species stocked in some of Mesabi Iron Range (MIR) pit lakes include Lake Trout, Rainbow Trout, White Sucker, and Brook Trout (MN DNR, 2011). Major concerns of PHES to fish include increased water temperature and fish being killed or wounded by being transported through the pump/turbine
machinery (Kleinschmidt, 2009). According to the Ludington PHES staff in Michigan, temperature increases were negligible (less than 0.02°C) between the upper and lower reservoir (Consumers Energy, 2006). Since the heating from the project is small and the reservoirs are open to the atmosphere, the water temperature will quickly equilibrate, and resultant potential impacts are small. However, fish killed or damaged by turbines can be a major concern for the pits with fish in them because of direct damage to the fishery, and indirect effects to fish-eating wildlife, even if the pit lake fishery is not a natural community and not managed directly by MN DNR. Therefore, protection efforts must be implemented at the intakes of water conduits at both upper and lower reservoirs. In most PHES facilities, interactions exist with fisheries populations and mitigation needs to occur so that these populations are not damaged (GEI Consultants Inc., 2010).

**IMPACTS COMMON TO LARGE FACILITY /RESERVOIR/DAM CONSTRUCTION**

**Agricultural Resources**

Agriculture activities in northern Minnesota are primarily pasture and hay crop farming. Along the Mesabi Iron Range itself, the landscape is heavily disturbed from historical mining, and there are probably no specific agricultural resources at risk in the immediate vicinity of the pits potentially chosen as upper or lower reservoirs. Therefore, the impact of this proposed project to agriculture resources is considered to be insignificant.

**Cultural Resources**

Early consideration of historic resources helps preserve the state’s rich historic heritage while eliminating and reducing project delays (Minnesota Historical Society, 2011). Concerns about cultural resources to this proposed PHES project center on the potential impact of new construction of an upper and/or lower reservoir, dams, power line corridors, new roads, and any structures, buildings, or other features that could overlie or constitute historic or prehistoric resources. Prior to deciding on a specific site, federal, state and local agencies, tribal governments, the Minnesota State Historic Preservation Office (SHPO), and other stakeholders should be consulted to ensure that potential impacts to Minnesota and tribal historical and cultural/spiritual resources are considered early and avoided entirely or mitigated to stakeholder satisfaction.

**Aesthetic Resources**

Causes of potential impacts to aesthetic and visual resources by PHES are expected to be primarily from construction of the power lines and the upper and/or lower reservoir. The severity of these impacts will depend on the visual character and scenic quality surrounding the selected site.

**Recreational Resources**

The proposed project will primarily occupy abandoned mine pits and minelands that are commonly considered to have low recreational value. However, the potential impact will depend on the actual site chosen, and therefore regulatory and economic development agencies, along with a long list of non-
governmental organizations (NGOs) associated with natural resource conservation and recreation, will need to be consulted early in the siting process.

**Population and Housing**

A project will bring significant impact to population and housing if it does one of the following (GEI Consultants Inc., 2010):

1. Induce substantial population growth in the area, either directly or indirectly; and/or
2. Displace substantial numbers of people or existing housing, necessitating the construction of replacement housing elsewhere.

According to its characteristics, the implementation of the proposed PHES project is not likely to significantly increase or decrease population at the area. Therefore, the impacts to population and housing are not likely to be significant.

**Air Quality and Noise**

The primary operation of a PHES facility is pumping and releasing water between upper and lower reservoirs, which impacts air quality and noise. The most likely air quality impact is the release of fugitive dust within a limited area during construction of dams, reservoirs, roads, power line corridors, and other facility buildings. This possible impact to air quality can be effectively prevented by implementing appropriate dust control efforts during the construction processes.

**Greenhouse Gas Emissions**

Greenhouse gas emission issues would be primarily associated with the life cycles of the materials used for the PHES facility during the phases of construction, transportation, and maintenance. Magnitude of this impact depends on the scale of the proposed project.

**Hazardous Materials**

Hazardous materials would primarily be released during the construction and maintenance phases of a PHES facility. The magnitude of this impact would depend on the scale of the project and its long-term management strategies.

**Indirect Impacts Associated with PHES**

PHES is essentially an enabling technology in support of wind energy generation and, at this point in time, to a lesser degree, solar power or other fluctuating power generation technologies. Indirect environmental impacts from these off-site power generation facilities, whether they currently exist (e.g., North Dakota wind power) or not have not been addressed in this study. No new alternative power generation facilities besides PHES are being proposed as part of the current study. However, a number
of issues should be considered as associated with wind energy as part of the overall scoping process for the next phase of a project (e.g., bat, bird, and noise issues in particular).
SECTION 5.2:

Preliminary Evaluation Methods for Prioritized Environmental Concerns

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During the process of researching the environmental impacts summarized in Section 5.1 and outlined in Section 5.3, several potential concerns were identified as priority due to their likelihood of occurrence and the magnitude of the potential impact. These “priority impacts” were also frequently mentioned in conversations with regulatory staff and other interested parties. Because these impacts are most likely to influence decisions about the choice of specific PHES site, additional time was spent researching priority environmental impacts, including alterations to groundwater movement, accelerated mineral dissolution, and surface water discharges. A conceptual model and more detailed analysis and literature review for each is presented here in Section 5.2.

GROUNDWATER MOVEMENT

Net head from upper to lower reservoir is the key factor determining the efficiency and capacity of a PHES project, thus increasing the net head will significantly increase the capacity of power generation. While the proposed project sites were chosen based on the existing elevation differences between the potential upper and lower reservoirs assuming a minimum net head of about 300 feet (90 m), the environmental assessment team investigated the potential impacts of dewatering and maintaining a lower reservoir at a certain level during long term operation. This could improve the net head and thus enhance the efficiency of a PHES project. Major concerns involve the potential impacts to the availability of groundwater resources in the vicinity of the dewatered reservoir and to the quality and quantity of surface water bodies caused by drawdown of the water table within the affected area.

According to the MN Health Department (MDH), approximately 70 percent of all Minnesotans rely on groundwater as their primary source of drinking water, and one million Minnesotans rely on private wells (Minnesota Department of Health, 2011). Mesabi Iron Range communities have a diverse array of source waters for their clients, including several pit lakes (see Section 5.5), deep bore holes and abandoned mine shafts associated with historical mining, and shallow to moderately-deep wells (MDH, 2011). In addition, there are hundreds to thousands of rural wells presumed to be relatively shallow in the region. Because surface water bodies are important resources to human and wildlife habitat, it is crucial to investigate the impacts to surface water bodies due to such a rapid decrease of water level in a lower reservoir. Determining the radii of the affected area of a dewatering pit and the drawdown of water table within the influence area are key elements to estimate the potential effects surface water resources caused by dewatering and holding a low water level in a mine pit.

Groundwater Movement Conceptual Model

Figures 5.2-1 and 5.2-2 depict the initial analysis of the long-term effect of water table drawdown caused by dewatering and maintaining a certain low water level in a pit. This conceptual model is adapted from the simple analytical equations for estimating groundwater inflow to a mine pit reported by Marinelli and Niccoli (2000). In this method, the pit is treated as a well, and the long-term pumping is considered as steady state discharge. Assumptions of applying this method include:

- The pit walls are approximated as a right circular cylinder;
- The water table is approximately horizontal;
- Recharge is uniformly distributed across the influenced area;
- All recharge within the influenced area of the pit is assumed to be captured by the pit; and
- Groundwater flow toward the pit is axially symmetric.
Figure 5.2-1. Schematic of groundwater movement due to dewatering a reservoir.

Figure 5.2-2. Conceptual model of groundwater inflow (adapted from Marinelli and Niccoli, 2000) caused by dewatering an existing pit.

Q₁: The pit inflow rate from zone 1, or from the pit wall
Q₂: The pit inflow rate from zone 2, or through the pit bottom
W: The distributed recharge flux
r_p: Effective pit radius
r₀: Radius of influence (maximum extent of the cone of depression)
h_p: Saturated thickness above the base of Zone 1 at r_p (i.e., Saturated thickness at the pit wall)
h₀: The initial saturated thickness above the base of Zone 1
**Analytical solutions**

The radius of influence \( r_0 \) can be determined using the equation (1) by iteration (Marinelli and Niccoli, 2000):

\[
\hat{h}_0 = \left( \hat{h}_0^2 + \frac{W}{Kh_1} \left[ r_0^2 \ln \left( \frac{r_0}{r_p} \right) - \frac{(r_0^2 - r_p^2)}{2} \right] \right)^{1/2}
\]

(1)

The inflow from the pit walls can be determined by equation (2):

\[
Q_{11} = W \pi (r_1^2 - r_0^2)
\]

(2)

The hydraulic head contours (the cone of depression) can be expressed using equation (3):

\[
H_1 (r) = H_0 - h_0 + \sqrt{(h_p^2 \pi \ln (r/r_p^2) - ((r_0^2 - r_p^2)/2))}
\]

(3)

\( H_0 \) : The initial water table elevation (pre-dewatering)

\( H_1 \) : The steady-state hydraulic head elevation (post-dewatering)

The inflow through the pit bottom will be determined using equations (4) and (5):

\[
Q_2 = 4 \pi r_p \left( \frac{K_{h2}}{m_2} \right) (h_0 - d)
\]

(4)

\[
m_2 = \sqrt{\frac{K_{h2}}{K_{r2}}}
\]

(5)

For the general model, it is assumed that the initial water level in the pit is the same as the piezometric surface in the aquifer at level \( h_0 \), and that the water level in lower reservoir is decreased to \( h_p \) abruptly at time zero and is held at this level during the routine operation of this project.

**Example Applications**

An imagined mine pit in the Mesabi Iron Range with radius of 257.8 meters has been used to demonstrate the application of this model. The relevant parameters used to estimate the impacts are:
1. Hydraulic conductivity: \( K = 5.0\times 10^{-7} \text{ m/s} \)
2. Approximated pit radius: \( r_p = 257.8 \text{ m} \)
3. Steady lower pit water level: \( h_p = 10 \text{ m} \)
4. Recharge within the system: \( w = 2.1\times 10^{-9} \text{ m/s} \)
5. Initial pit water level: \( h_0 = 60 \text{ m} \)
6. The elevation change of pit water level: \( h_0 - h_p = 50 \text{ m} \)

Iteration of equation (1) indicated that the radius of influence \( (r_0) \) is 1291 m. Figure 5.2-3 shows the relationship between the radius of influence area and the targeted decrease of water level in the pit. The greater the water level decrease targeted for the lower pit, the greater will be the radius of the affected area. Hydraulic heads at various radial distances from the pit center have been calculated using equation (3), assuming the pit’s water level decrease is 50 m. Figure 5.2-4 shows the steady state water table within the affected area.

![Figure 5.2-3](image1.png)

**Figure 5.2-3.** Relationship between the radius of influence and the elevation change of pit water level.

![Figure 5.2-4](image2.png)

**Figure 5.2-4.** Change of hydraulic head with radial distance from the pit center.
Potential Effects at Proposed Sites

For the proposed PHES project, out of the 20 potential sites proposed by the project team, 5 were identified as the most likely sites: Alpena Minorca, Morton Agnew area, Minntac East area, Hibtac area, and Keetac North area. These were investigated in more detail to illustrate how potential impacts caused by decreasing the water level elevation might be estimated. As wetlands are a highly valued water resource for many plant and wildlife species in northeastern Minnesota (Barr Engineering, 2009; Berndt, 2003), for flood control and for other reasons, more attention has been paid to the potential impacts to wetlands. The focus of this investigation is on the size of the affected area and the potential impacts to the water resources (wells, wetlands, streams, lakes, aquifers) within the affected area. Assumptions for each pit are similar to those from the previous exercise:

1. Initial water level: 90 meters;
2. Steady water level: 60 meters;
3. Water level drawdown: 30 meters;
4. Hydraulic conductivity: $5.0 \times 10^{-7}$ m/s; and
5. Recharge within the system: $2.1 \times 10^{-5}$ m/s.

Table 5.2-1. The physical characteristics of the five prioritized potential pits and water resources within the influence areas, assuming 100 feet (30 meters) of water level drawdowns in the lower pit.

<table>
<thead>
<tr>
<th>Potential sites</th>
<th>Area of lower pit, $m^2$</th>
<th>Equivalent radius of lower pit, m</th>
<th>Radii of influence area, m</th>
<th>Protected water resources within affected area, $m^2$</th>
<th>Wetlands within affected area, $m^2$</th>
<th>Streams within affected area, m</th>
<th>Wells within affected area, #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpena Minorca</td>
<td>208,687</td>
<td>257.8</td>
<td>1,448</td>
<td>179,503</td>
<td>806,522</td>
<td>3,058</td>
<td>0</td>
</tr>
<tr>
<td>Morton-Agnew</td>
<td>440,470</td>
<td>374.5</td>
<td>1,423</td>
<td>0</td>
<td>568,235</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Minntac East</td>
<td>425,423</td>
<td>368.1</td>
<td>1,424</td>
<td>0</td>
<td>915,053</td>
<td>4,897</td>
<td>7</td>
</tr>
<tr>
<td>Hibtac (within pit)</td>
<td>448,583</td>
<td>378.0</td>
<td>1,422</td>
<td>0</td>
<td>727,689</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Keetac North</td>
<td>172,592</td>
<td>234.4</td>
<td>1,452</td>
<td>115,596</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
</tbody>
</table>

Figures 5.2-5 to 5.2-9 depict the influence areas and their geological coverage surrounding those five proposed pits. In those figures, the bright blue polygons are the pits chosen as proposed lower reservoirs, while light green circles surrounding the pits are the influence areas, purple spots indicate wetlands, green/blue lines are streams, and the red/green dots are wells. While the physical connections between groundwater resource to the listed surface water bodies and wells in Table 5.2-1 need to be further investigated, the severity of potential impact among the top five potential sites can be estimated. Based on the data in Table 5.2-1, the Morton-Agnew and Keetac areas seem to have fewer potential impacts compared to the other three sites because less surface water area is located within their affected areas as compared to the other potential sites.
Figure 5.2-5. Influence of Alpena-Minorca.

Figure 5.2-6. Influence of Minntac East area.
Figure 5.2-7. Influence of Hibtas area.

Figure 5.2-8. Influence of Morton-Agnew area.
MINERAL DISSOLUTION AND WATER QUALITY

An important impact of the proposed project is mineral dissolution that may be accelerated due to frequent fluctuation of water level during the operation of PHES. The wetting and drying of minerals, especially those with a large surface area such as rocks or tailings disposed of in-pit, is known to accelerate dissolution and, although mitigation by site selection and engineered measures may be possible, this concern will need to be addressed in detail. As prioritized topic, mineral dissolution reaction processes, test methods, and conceptual model are described herein.

Description of Dissolution Tests

Many mine deposits in the Mesabi Iron Range have sulfidic minerals within their rock matrices (Lapakko, 1991). A few examples of sulfidic minerals that are quite common are pyrite (FeS₂), pyrrhotite (Fe₁₋ₓS), and marcasite (FeS₂) (EPA, 1994). All of the aforementioned minerals are capable of producing acidic leachate if exposed to atmospheric oxygen or oxygenated waters, with pyrite having the fastest oxidation rates (Kwong and Ferguson, 1990). At pH lower than 4.5, Fe³⁺ is the primary oxidant, which is mediated by iron oxidizing bacteria (Eqn. 7) (Singer and Stumm, 1970; Baker, 2003). The microbially catalyzed ferric iron is then used to oxidize S²⁻ to produce acid mine drainage (AMD) (Stumm and Morgan, 1996; Eqn. 8). The oxidation of sulfur containing minerals have two main outcomes (other resultant biogeochemical changes are of less importance relative to this report), decreasing pH and increasing sulfate concentrations of the water body that receives the drainage. While understanding the
The basic geochemistry of AMD is important, a means of managing and predicting AMD is required to gain knowledge of a site's acid producing capacity.

\[
\begin{align*}
\text{Fe}_2\text{S}_2(s) + 7\text{O}_2(aq) + \text{H}_2\text{O} & \rightarrow \text{Fe}^{2+} + 2\text{SO}_4^{2-} + 2\text{H}^+ \\
\text{Fe}^{2+} + \frac{1}{4}\text{O}_2 + \text{H}^+ & \rightarrow \text{Fe}^{3+} + \frac{1}{2}\text{H}_2\text{O} \\
\text{Fe}_2\text{S}_2 + \text{Fe}^{3+} + 8\text{H}_2\text{O} & \rightarrow 15\text{Fe}^{2+} + 2\text{SO}_4^{2-} + 16\text{H}^+ \\
\text{Fe}_{1-x}\text{S}(s) + ([9-3x]/4)\text{O}_2 ([5-3x]/2)\text{H}_2\text{O} & \rightarrow (1-x)\text{Fe(OH)}_3(s) + \text{SO}_4^{2-}(aq) + 2\text{H}^+(aq)
\end{align*}
\]

There are two main predictive methods for characterizing potential acid mine drainage (AMD) in mine waste rock and exposed geologic material. Static and kinetic tests (Lapakko, 1991). Static tests are meant to describe a material's total capacity to produce acid (or neutralize acid) while kinetic tests measure the rate at which a material may produce acidic leachate. Many common and less common static and kinetic tests are outlined below, with some rarely used tests being omitted due to the limited scope of this literature review. In addition to kinetic and static testing, mineralogical/chemical makeup of rock samples is routinely measured using techniques such as X-Ray Flocculence (XRF), X-Ray Diffraction (XRD), scanning electron microscopy, and total elemental analysis (coulometry or colorimetry) (Lapakko, 2002). Although there are many methods to describe the acid production/neutralization potential, various kinetic rates, and composition available, the scope of this literature review is to gain an understanding of what static and kinetic methods are commonly used and readily available.

Before samples can be tested, a representative sample must be obtained. A detailed procedure for field sampling is outlined in Field and Laboratory Methods Applicable to Overburdens and Minesoils (Sobek, 1978), if a sampling outline is required. Since this project may deal with intact lithology or mine waste piles, multiple methods may need to be used, which could include many different types of sampling (coring, grab samples, etc.; Sobek, 1978; MEND, 2008). Samples must represent the volume and type of rock that will be exposed during oxidative processes (EPA, 1994). Detailed sampling procedures can be found in multiple sources and should be consulted to fully understand proper protocol (B.C. AMD Task Force, 1989; Sobek, 1978) followed by consultation with MN DNR Minerals Division scientists and other relevant experts as indicated by stakeholder input to ensure scientific consensus on test methodologies and sampling and analytical procedures.

The least expensive and time intensive predictive tests that can be conducted are static tests (Adam et al., 1997). One result from static tests is the acid production potential usually reported as mass acidity (mass Si per mass of a given rock sample) formed by the oxidation sulfur containing minerals, generally pyrrhotite and pyrite (Stumm and Morgan, 1996; Eqns. 6 and 7 above). The other result from static tests is the neutralization potential, which usually represents carbonate minerals in a sample (Eqns. 9 and 10) and is also given in units of mass CaCO3 per mass of a given rock sample (EPA, 1994). While static testing can predict the theoretical acid potential and neutralization potential, they are not meant to be a quantitative measure of a rock sample's ability to potentially create acid mine drainage.

\[
\begin{align*}
\text{MgCO}_3 + 2\text{H}^+ & \rightarrow \text{H}_2\text{CO}_3^+ + \text{Mg}^{2+} \\
\text{CaCO}_3 + 2\text{H}^+ & \rightarrow \text{H}_2\text{CO}_3^+ + \text{Ca}^{2+}
\end{align*}
\]
Acid base accounting is a commonly used static test (Sobek, 1978), which requires little specialized equipment and can be done in a short period of time. This test involves two steps to determine acid production potential (APP) and neutralization potential (NP). The APP is calculated by determining the total sulfur (Stot) content of a given rock sample, which can be measured using a combustion furnace to measure the total sulfur dioxide, which is assumed to be the total pool of sulfur that can be oxidized to H₂SO₄ (strong acid). The Stot is then converted to kg CaCO₃/ton sample to estimate the corresponding amount of base needed to neutralize it (Sobek et al., 1978). The second metric calculated in the ABA test is neutralization potential (NP), which is determined by adding a known concentration of HCl (strong acid) to the rock samples past their ability to neutralize the added acid. The sample is then titrated using NaOH to determine the amount of HCl that was unreacted to ultimately estimate the NP of the sample (Sobek et al., 1978). Subtraction of the AP and NP gives the Net Neutralization Potential (NNP), which gives an estimate of the rock sample’s likelihood to be acid generating in the field (Adam et al., 1997). The ABA has been modified into several other static tests such as the Modified ABA (Lawrence, 1990) or the B.C. Research Initial Test (Duncan and Bruynesteyn, 1979). ABA methods can also be found in The American Society of Testing and Materials (ASTM), which include tests ASTM E-1019, ASTM E-395-70, and ASTM E-1915. The other type of static tests commonly found in the literature is the Net Acid Generation (NAG) (Miller, 1990) and Net Acid Production (NAP) test (Coastech, 1989). Both of these methods add a quantitative volume of H₂O₂ as a strong oxidant to a measured rock sample, and allowed to react for a given period of time. The final sample is then titrated back to a given endpoint to calculate the H₂SO₄ that was released from the rock (Stewart et al., 2006; Lapakko, 2002). These tests are particularly useful since they do not require large equipment, compared to other static tests which require combustion ovens or elemental analyzers.

The second category of AMD testing is Kinetic Testing, which includes many different methods that can determine rates of acid and neutralization potential for further investigating a site after a static test has been conducted (MEND, 2008). Although these tests supply more information, they generally cost more and have larger time scales relative to static test methods. While each test may yield a rate of acid production, each must be interpreted differently because each method measures weathering processes slightly differently (EPA, 1994). Most kinetic tests run for a long period a time (multiple months) relative to static tests (days) (Lapakko, 1991). Usually, kinetic testing is used after a static test has determined whether there is significant potential for acid production from a given sample (Lapakko, 1991; EPA, 1994; MEND, 2008).

A very common Kinetic Test used in North America is the humidity cell test (MEND, 2008; Lapakko, 2002). This test consists of crushing sample into ~ 2 mm particle size, placing the sample in a container, and exposing it to humid versus dry conditions to obtain rates of acid generation (Sobek, 1978). The humidity cell test is widely used and can model wet and dry weathering cycles, but has the disadvantage of taking a relatively long time period to carry out (Lapakko, 1991). In addition to the humidity cell, the “modified” humidity cell has a similar procedure and time length, but has a larger setup (Lawrence, 1990). Another common kinetic test is the column test, which consists of a column (various sizes and materials used) that contains the desired sample crushed to the desired particle size (Bruynesteyn and Hackle, 1982). Periodically, water is washed through column, where leachate is collected and analyzed for various parameters, depending on the study. Column tests have little standardization relative to humidity tests, which means a specific test can be tailored to a given project (EPA, 1994) to more accurately simulate highly variable field conditions. While both of these tests are commonly used in AMD literature, they can take a long period of time to run (>20 weeks), although costs are relatively low (Lapakko, 1993). Other kinetic tests that are used less frequently make use of Soxhlet extraction and/or shaker flasks. Soxhlet extraction involves putting a 0.05 mm grain size sample into a thimble, which is then heated to create a leachate (hot/warm water used as the extractant) (Singleton and Lavkulich,
The shaker flask (or batch reactor) test simply involves putting a sample in an Erlenmeyer flask containing water or other extractant (Halbert, 1983) and then shaking for a standardized period of time at a standardized shaker speed. Periodically, parameters are measured from subsamples of leachate to gain an understanding of how the leachate is changing over time. The parameters that are measured may include pH, conductivity, alkalinity, sulfate and various other analytes as needed. More information can be obtained about these tests and others in detailed reviews conducted by multiple different governmental agencies and researchers (MEND, 2008; Lapakko, 1991; EPA, 1994).

Kinetic tests attempt to estimate the rate in which acid rock drainage is produced by a given rock sample. Although they attempt to measure the rate at which a natural system would produce acidic leachate, no single test can reproduce in situ results. Although kinetic tests do not perfectly replicate in situ conditions, an estimate of the rate sulfide mineral oxidation can be determined. For example, the humidity cell test provides graphical results of parameters over time (i.e., SO₄²⁻), which are used to calculate a kinetic rates for a given sample. These oxidation rates can be used as the kinetic rate of dissolution (R1diss or R2diss) in the model described in this report. The use of multiple tests in conjunction with detailed knowledge of the actual field conditions may result in more accurate interpretation of kinetic tests results. It must be understood that although these tests are informative; each test results are unique and require expert interpretation.

**Mineral Dissolution Conceptual Model**

The major processes with potential to contribute to mineral accumulation in system water include: surface water runoff, groundwater inputs, direct dissolution in pit walls. Precipitation and settling, degassing, or biological tranformations are all processes that could remove minerals from the system. Each of these processes has been formalized and depicted in terms of rates of mineral transfer (grams/day) and water flows (m³/day) in Figure 5.2-10. While groundwater inputs to the PHES system could be important from a hydrologic impact standpoint, mineral dissolution during transport through the very low surface area of fractured rocks is unlikely to present a major issue. Dissolution from stockpiles or tailings disposed of below the water surface that would be subsequently exposed to oxygen during PHES construction or operation are a much more likely source of significant minerals within pits with frequent and large-magnitude water fluctuations. While the conceptual model presented in Figure 5.2-10 is not specific to any one chemical, the most frequent minerals encountered at undesirable concentrations in pit waters include sulfate, some heavy metals, and hardness (primarily magnesium).
Figure 5.2-10. Conceptual model of mineral dissolution in a mine pit caused by pit water fluctuation.

Assumptions:

1. Entire volume of both pits is represented as one well-mixed body of water;
2. Rate of removal via precipitation is first order with pit concentration;
3. Rate of dissolution is constant; and
4. Steady state.

\[
V \frac{dC}{dt} = Q_{1SW} c_{1SW} + Q_{1GW} c_{1GW} + Q_{2SW} c_{2SW} + Q_{2GW} c_{2GW} + R_{\text{Diss}} + R_{\text{Prec}} - C R_{\text{Prec}} V - Q_{\text{Disch}} C
\]

\[
C_{SS} = \frac{(Q_{1SW} c_{1SW} + Q_{1GW} c_{1GW} + Q_{2SW} c_{2SW} + Q_{2GW} c_{2GW} + R_{1\text{Diss}} + R_{2\text{Diss}})}{R_{\text{Prec}} V + Q_{\text{Disch}}}
\]

ON-SITE WATER BALANCE

Another concern of dewatering and holding a low water level in a pit is water balance. Figure 5.2-11 shows the key elements of the hydrologic water balance in a dewatered pit. Inflow water is largely from groundwater that is recharged by infiltration from precipitation. Water loss is primarily due to surface evaporation and enhanced evaporation due to pumping and releasing processes between the upper and lower reservoirs. The need to add make-up water depends on the climate, soil characteristics, and hydrogeological conditions at the specific sites. If it was necessary to pump water out of a pit to maintain the target low water level, a permit to discharge pit water to specified receiving water bodies might be required (Minnesota State Discharge Permit [SDS], National Pollutant Discharge Elimination System [NPDES]). The permit would require a rigorous assessment of the potential impact of the
discharge on the water quality, biological communities, and habitat in the receiving water bodies throughout the year. An alternative to discharge to a water body external to the system would be to discharge pit water to an on-site infiltration basin. If an infiltration basin with sufficient capacity could be constructed within the cone of depression of the drawdown for a lower pit, the need for off-site discharge could potentially avoided. An evaluation of the effects of this type of system would need to consider the effects of the recharged water on groundwater inputs to the lower pit and the potential for increased mineral transport to pit waters. Although a thorough water balance conceptual model was not developed as a part of this study, the potential of minimizing interactions with off-site surface water discharges should be considered in subsequent evaluations utilizing a holistic view of water flows to and from pits, as well as on and off site.

Figure 5.2-11. Schematic of water balance in a dewatered pit.
SECTION 5.3:

Environmental Impact Assessment Summary

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Table 5.3-1 summarizes the potential impacts of developing and operating a PHES facility using abandoned mine pits and related mine lands on the Mesabi Iron Range in northeastern Minnesota. Potential environmental impacts are divided into three groups:

1. impacts specific to the development of a PHES project based on the abandoned mine pits that involve effects common to hydroelectric, mining, or this unique combination of both;
2. impacts common to most large-scale construction projects that are commonly addressed and frequently mitigated effectively; and
3. impacts caused by decreasing the water level in the lower pits to increase the steady, natural water table for the purpose of increasing the efficiency (and capacity) of the PHES project.

The preliminary level of significance is estimated using best professional judgment based on the available information and resources and ranked as “significant” for which mitigation measures would likely be required, “not significant” for which the impact is determined to be negligible, and “maybe” for which further information is needed before assessing the potential impact of a PHES facility at a specific site.

**Table 5.3-1.** Summary of potential environmental impacts of a PHES project develop at Minnesota Mesabi Iron Range using abandoned mine pits.

<table>
<thead>
<tr>
<th>Potential Environmental Impacts</th>
<th>Level of Significance</th>
<th>Potential Mitigation Measures</th>
<th>Missing Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impacts to Geology and Soil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil erosion</td>
<td>Significant</td>
<td>Implementation of sound runoff, soil erosion and stormwater management practices, such as silt fences and Roll Erosion Control Product on disturbed areas during the construction phase.</td>
<td>None</td>
</tr>
<tr>
<td>Landslides</td>
<td>Maybe</td>
<td>Site specific</td>
<td>Site geotechnical for slopes</td>
</tr>
<tr>
<td>Seismicity triggered by the reservoirs</td>
<td>Not Significant</td>
<td>None likely</td>
<td>Site geotechnical</td>
</tr>
<tr>
<td>Impact to Water Quality in PHES Surface Water Reservoirs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Release of iron, sulfate, and acid by mineral dissolution</td>
<td>Maybe</td>
<td>1. System design and operation, site selection; and 2. Shoreline sealing and armoring.</td>
<td>1. Mineralogy of the geologic units in the vicinity of the selected mine pit; and 2. Chemical and physical properties of the pit walls.</td>
</tr>
<tr>
<td>Potential Environmental Impacts</td>
<td>Level of Significance</td>
<td>Potential Mitigation Measures</td>
<td>Missing Data</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-----------------------</td>
<td>------------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Mixing of low oxygen, high nutrient, high metal, high sulfide bottom water into surface water</td>
<td>Maybe</td>
<td>1. Careful management of water column mixing at start-up if water mixing depth indicates meromixis–limited mixing of stagnant bottom water characterized by anoxia and high nutrients, metals, and hydrogen sulfide gas; and 2. Discharge system treatment if necessary.</td>
<td>Pit lake limnology (includes water quality) and groundwater quality</td>
</tr>
<tr>
<td>Evaporative water loss</td>
<td>Maybe</td>
<td>Consideration during design</td>
<td>Area of water surface of the chosen reservoirs</td>
</tr>
<tr>
<td>Eutrophication</td>
<td>Not significant</td>
<td>Runoff, erosion control</td>
<td>Pit lake water quality</td>
</tr>
</tbody>
</table>

### Impact to Water Quality in other Surface Water within PHES Facility Boundary

| Legacy contamination from on-site solid or liquid wastes | Maybe | Clean or treat impacted areas during construction | Locations of legacy contamination |
| Impacts due to facility/road construction | Maybe | Best construction practices | |
| Fluctuations in water table for on-site wetlands and lakes (e.g., habitat alteration, mercury methylation) | Maybe | Site selection | Hydrologic conductivity of surface waters/wetlands with local groundwater |

### Impact to Water Quality in Surface Waters Outside PHES Facility Boundary

<p>| Erosion and sedimentation | Significant | 1. Sound runoff, soil erosion, and sedimentation management during construction phase; and 2. Slope stabilization and/or sealing. | Site specific geotechnical |
| Impact through interaction with groundwater | Not significant | 1. Seal pit bottom and sides; and 2. Within-pit lake treatment. | Site specific hydrogeology |</p>
<table>
<thead>
<tr>
<th>Potential Environmental Impacts</th>
<th>Level of Significance</th>
<th>Potential Mitigation Measures</th>
<th>Missing Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact through discharge of water from reservoir to surface water (sulfate, mercury, wild rice, metals, hardness)</td>
<td>Maybe</td>
<td>Treatment system (e.g., sulfate, metals, hardness removal)</td>
<td>1. Detailed water balance and evaluation of discharge/infiltration requirements; 2. Chemical and physical characteristic of the pit walls and surrounding area; and 3. The drainage area of a selected reservoir.</td>
</tr>
<tr>
<td>Groundwater quality</td>
<td>Not significant (for scenario of natural water levels, see final section of this table)</td>
<td>Not needed</td>
<td>Site specific water tables and GW quality</td>
</tr>
<tr>
<td>Groundwater quantity: availability to wells, wetlands, rivers and lakes in surrounding area</td>
<td>Not significant (for scenario of natural water levels, see final section of this table)</td>
<td>Not needed</td>
<td>Site specific water tables and GW quality</td>
</tr>
<tr>
<td>General plant communities</td>
<td>Not significant</td>
<td>Facility design to minimize disturbance and protect wetlands</td>
<td>Site specific</td>
</tr>
<tr>
<td>Special Concern (ETSC) plant and wildlife species</td>
<td>Maybe</td>
<td>Facility design to avoid ETSC species</td>
<td>Site specific</td>
</tr>
<tr>
<td>Fish safety due to increase of water temperature caused by operation</td>
<td>Not significant</td>
<td>Not needed</td>
<td>None</td>
</tr>
<tr>
<td>Fish killing and food web disruption caused by destratifying potentially stagnant bottom water</td>
<td>Maybe</td>
<td>Careful management of mixing and de-watering prior to start-up</td>
<td>1. Site specific and seasonal limnology data (includes water quality); and 2. Local meteorology.</td>
</tr>
<tr>
<td>Potential Environmental Impacts</td>
<td>Level of Significance</td>
<td>Potential Mitigation Measures</td>
<td>Missing Data</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-----------------------</td>
<td>------------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Fish killing from turbines</td>
<td>Significant</td>
<td>1. Proper protection measure such as screening will need to be installed at inlets of penstock at both upper and lower reservoirs; and 2. Could contribute damages funds to MN DNR for other pit lake enhancement projects.</td>
<td>Site specific</td>
</tr>
<tr>
<td>Wildlife Corridors</td>
<td>Significant</td>
<td>Site selection and design to avoid exacerbation of limited wildlife corridors</td>
<td>Site Specific. Some useful information may be available from MN DNR and from U. of MN’s Statewide Conservation and Preservation Plan (2008) <a href="http://www.lccmr.leg.mn/statewideconservationplan/SCPP_FinalPlan.html">http://www.lccmr.leg.mn/statewideconservationplan/SCPP_FinalPlan.html</a></td>
</tr>
<tr>
<td>Impacts connected to enabling of wind power (birds, bats, etc.)</td>
<td>Maybe (“Connected actions” included in some EIS evaluations)</td>
<td>Design and post project mitigation measures likely to exist</td>
<td>Dependent upon regulations regarding PHES project responsibility for “connected actions”</td>
</tr>
</tbody>
</table>

**Impacts common to large facility/reservoir/dam construction**

<table>
<thead>
<tr>
<th></th>
<th>Level of Significance</th>
<th>Potential Mitigation Measures</th>
<th>Missing Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural resource</td>
<td>Not significant</td>
<td>Not needed</td>
<td>Site specific</td>
</tr>
<tr>
<td>Cultural resources</td>
<td>Maybe</td>
<td>Site specific</td>
<td>Site and design specific</td>
</tr>
<tr>
<td>Aesthetic resources</td>
<td>Maybe</td>
<td>Site specific</td>
<td>Site and design specific</td>
</tr>
<tr>
<td>Population and housing</td>
<td>Not significant</td>
<td>Not needed</td>
<td>None</td>
</tr>
<tr>
<td>Water treatment from facilities operation</td>
<td>Maybe</td>
<td>Implement effective treatment systems</td>
<td>1. Possibly depending upon project discharge permitting required; and 2. Site specific.</td>
</tr>
<tr>
<td>Air quality and noise</td>
<td>Not significant</td>
<td>Management during construction and operational assessment dependent on link to wind power generation</td>
<td>Noise from wind turbines if determined to be an issue via “connected action”</td>
</tr>
<tr>
<td>Dam Safety</td>
<td>Significant</td>
<td>Proper design and operation</td>
<td>Site and design specific</td>
</tr>
<tr>
<td>Greenhouse gas emissions (construction &amp; operation)</td>
<td>Maybe</td>
<td>Management during construction, assessment during design</td>
<td>Unknown</td>
</tr>
<tr>
<td>Potential Environmental Impacts</td>
<td>Level of Significance</td>
<td>Potential Mitigation Measures</td>
<td>Missing Data</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-----------------------</td>
<td>------------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Hazardous materials</td>
<td>Maybe</td>
<td>Management during construction</td>
<td>Project design</td>
</tr>
</tbody>
</table>

**Special environmental concerns caused by lowering water level at the lower reservoir**

<table>
<thead>
<tr>
<th>Groundwater resources</th>
<th>Maybe</th>
<th>Site selection and design to avoid potential impacts to known groundwater users</th>
<th>1. Final determination of the mine pits selected for the project; 2. Reasonably accurate hydraulic conductivity values for proposed sites; and 3. Site specific water tables and GW quality.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface water bodies</td>
<td>Maybe</td>
<td>As needed</td>
<td>1. Hydrogeological information for the potential sites to determine the connection status of the surface water bodies and the groundwater within the affected area; and 2. Water balance investigation for the specific dewatered pits.</td>
</tr>
</tbody>
</table>
SECTION 5.4:

Environmental Assessment Stakeholder Input Interviews

Dr. Nathan Johnson, Civil Engineering UMD
Dr. Xianben Zhu, Civil Engineering UMD
Dr. Rich Axler, NRRI
Mr. Kurt Johnson, NRRI
Mr. Brian Beck, UMD (MS Student)
Mr. Jerry Henneck, NRRI
University of Minnesota Duluth
Duluth MN 55812
This element of the project was intended to serve three main goals: (1) provide additional “brainstorming” regarding potential environmental impacts of PHES on reclaimed minelands and information gaps that would likely be necessary to address; (2) provide an initial “advanced notification” to technical staff from local, state, federal, and tribal agencies that a PHES project was being considered and to do this in a setting that would be perceived as being informational, without specific “regulatory overtones”; and (3) identify additional technical expertise (organizations and individuals) who could be helpful during the initial scoping process, and/or would likely become officially involved should a specific site be identified and a PHES project developed.

Since the Policy team was also considering a series of stakeholder interviews, but with a focus on the policy and economic aspects of the project, the Environmental Assessment (EA) and Policy teams met near the start of the project to share ideas and develop a plan for conducting the interviews. Because the Policy team was from the University of Minnesota campus in the Twin Cities and was not a part of the Northern Minnesota network of water resources-related organizations, the EA team developed a pool of candidate agencies and individuals to be contacted and classified as Technical Assessment versus Policy. There was potential for overlapping of individuals and the groups that they represent that could have confounded the Policy Team’s intention to collect baseline information about current stakeholder understanding and perceptions of Pumped Hydroelectric Energy Storage (i.e., prior to being exposed to a presentation about PHES and Minnesota Power’s and Great River Energy’s interest in it). Therefore, the EA-related sessions were delayed until the Policy interviews were completed. Unfortunately, this created major scheduling problems because of the State budget shutdown followed by agency staff being immersed in both the administrative aftermath of the budget crisis, together with summer field sampling schedules. As a result, this task was only partially completed, though we intend to follow through with two more focus group meetings this Fall.

In order to reduce people’s reticence to discuss potential regulatory details or concerns about a statement being misconstrued, we developed four main groups of stakeholders, all being primarily technical staff that would ultimately be a part of assessing the technical environmental assessment aspects of a future site-specific PHES project:

1. Tribal agencies (Fond du Lac, Grand Portage, Bois Forte Bands of the Minnesota Chippewa Tribe, and the 1854 Treaty Authority);
2. MN Pollution Control Agency and MN Department of Health staff in Duluth, MN (with areas of expertise in watersheds, hydrology, TMDLs, water quality, non-point source permitting, and point source/industrial permitting);
3. MN Board of Soil & Water Resources, U.S. Army Corps of Engineers, U.S. Natural Resources Conservation Service, MN Department of Natural Resources (Fisheries) staff in Duluth; plus MN Sea Grant (UM-Duluth) water quality and stormwater extension educators; and
4. Central Iron Range region technical staff from the MN Department of Natural Resources Minerals Division (Hibbing), Fisheries Division (Grand Rapids), and Water & Ecological Services Division (Grand Rapids), the Iron Range Resources & Rehabilitation Board (Eveleth and Chisholm), the Laurentian Vision Partnership (Eveleth), Itasca Soil & Water Conservation District (Grand Rapids), North St. Louis Soil & Water Conservation District (Virginia).

GENERAL SUMMARY

- The first two meetings were very successful and indicated a need for us to follow up this Fall with two additional focus groups, one in Duluth and one on the MIR.
• No one was previously aware of the potential economic importance of an energy storage capability to wind energy power generation (or other sources of renewable energy for that matter), and we were able to provide new information to them about PHES, clarify what we had learned about Minnesota Power’s and Great River Energy’s interest in both PHES and wind energy in general, and provide historical background on the long history of Barr Engineering’s work on PHES potential using abandoned iron mining pit lakes and tailings basins. It is also noteworthy that the EA Team’s audience provided very different information from the Policy Team’s interviews with a focus on the technical aspects of potential water, land, and air impacts in the context of mineland reclamation and current and historical impacts associated with both ferrous and non-ferrous mining.
• Questions or comments regarding the suitability of using abandoned minelands for PHES, or whether such a project was “appropriate” for the Mesabi Iron Range (in the sense of a project jeopardizing future mining projects), were not raised.
• The fact that PHES could be viewed as an enabling technology that might reduce dependence on fossil fuels and associated greenhouse gas emissions and other air and water quality pollutants was viewed favorably.
• A number of additional technical staff from various agencies were recommended as people familiar with Mesabi Iron Range mineland issues to include in future technical discussions should the scoping process for suitable PHES sites be continued at the site-specific scale proposed in the original grant application.
• The discussions did not indicate any major new issues that might immediately be construed as “fatal flaws” but did highlight some of the same environmental issues that would appear to remain unresolved in regard to current permitting for non-ferrous mining in particular, and also new iron mining projects in Northeastern Minnesota.

SPECIFIC CONCERNS

1. There were strong feelings about the need to have an accurate local hydrology model that accurately predicts potential effects on headwater streams and wetlands. Although considerable progress has been made in terms of the general hydrology and hydrogeology of the Mesabi Iron Range since 2006 (via the MDNR’s LCMR-funded work associated with the Central Iron Range Initiative[CIRI]), the need for more detailed hydrologic models that include fine grained, site-scale hydrogeological information was stated to be critical to determining whether a PHES system would be truly a closed loop, and whether there could be indirect impacts to on-site and off-site wetlands (in particular) and area streams and lakes. The hydrologic model(s) would also need to incorporate the influence of groundwater cones of depression associated with nearby mine dewatering operations. Note that a framework for developing such a modeling tool was discussed previously in the EA section of this report (see Section 5.2);
2. There were strong feelings about the need to clean up existing tailings basins as part of using them as a component of PHES reservoirs. Continuing and historical pollutant discharges from the Mesabi Nugget and Minorca iron mines were highlighted, and it was suggested that we review Discharge Monitoring Reports (DMRs) from these mines. Tailings basins would need to be drained with attention to pollutant treatment to protect surface and groundwater from contamination and then lined with clay or other material(s) to ensure that local hydrology is not adversely affected;
3. The potential for drawing water levels down too far, and for fluctuating water levels in PHES reservoir(s) to exacerbate off-site sulfate transport, degrade wetlands, or cause other environmental impacts, was noted. This concern might be addressed via permit conditions, and/or by engineering design;
4. The potential for PHES to increase sulfate concentrations, and therefore potentially enhance mercury methylation and bioaccumulation and adversely affect wild rice, were highlighted as being important concerns that would need to be addressed. These are currently particularly controversial issues surrounding the permitting of both ferrous and non-ferrous mines and are both scientifically challenging issues, but with significant agency research efforts already in progress;
5. Potential metals effects from mining on water resources used for drinking water were noted, and we were told that the St. James pit lake, which is the raw water source for the City of Aurora, has had water sample(s) showing fathead minnow toxicity in standardized tests. Note that we have not confirmed this nor would it necessarily pose a threat to public health if true. However, it would be prudent to follow up on this information and determine its validity;
6. The fact that a MDNR study (possibly from 2006) had reported that there were only 13 remaining “intact” wildlife corridors on the MIR was mentioned, and it was suggested that this information be included as a GIS data layer as site selection studies proceed. Technical experts from the MN Department of Health and the U.S.G.S. were identified as good contacts;
7. Would this first PHES project lead to more wind power generation facilities coming on line in Minnesota? This question brought up discussions of the issue of Connected Actions and whether environmental impacts associated with wind energy would need to be addressed as part of the permitting process for a PHES facility. This is defined in the MN state environmental review guidance as "two or more projects that are related, interdependent parts of a larger whole." The PHES project would presumably not happen without the wind power generation in North Dakota; therefore, the wind power generation would be a "connected action" to the PHES project; and
8. The issues listed above were the focus of our discussions with agency staff, but do not represent an all-inclusive list of environmental impact concerns. The “more conventional” impacts were discussed in the previous sections of the EA section.

HANDOUTS DISTRIBUTED TO AGENCY PARTICIPANTS

1. Agenda outlining our preliminary list of environmental issues, questions for discussion, and proposed stakeholders (Figure 5.4-1); and
2. Slide presentation given at the start of each meeting to describe PHES in general, the purpose and scope of the entire IREE-funded study, the participants (including all collaborators) in the study, and the current (i.e., near-final) status of the study (Appendix 5.4-A).
Draft Agenda

Pumped Hydro Energy Storage – Environmental Assessment Brainstorm Meeting (~60-90 mins)

Project Description: A multidisciplinary team of researchers from UMD, with partners Great River Energy and Minnesota Power, is performing a preliminary investigation of whether geological and water resources (mine pits) on the Mesabi Iron Range could be suitable for implementing Pumped Hydro Energy Storage (PHES). If implemented, the PHES system would provide energy storage capacity to mitigate fluctuations in renewable energy sources, especially wind power.

Agenda
I. Purpose of meeting
II. Intro to Pumped Hydro (http://en.wikipedia.org/wiki/Pumped-storage_hydroelectricity)
III. Preliminary environmental issues identified
IV. Discussion

Preliminary list of issues

A) Conventional issues
   a. Mining Construction (tunnels/pits)
   b. Hydro & electric construction (dams, power lines)
   c. Other

B) Wind power – related issues
   a. Alternative energy issues
   b. Birds/bats/windmills
   c. Other

C) Unique, local issues (and “Hot Button”)
   a. Local hydrology, wells, cultural
   b. Asbestos
   c. Sulfate
   d. Mercury
   e. Wild rice
   f. Other

Questions for discussion:
- What are your general perceptions regarding wind energy and PHES?
- What do you think are the primary environmental concerns for this type of project?
- Are we missing any important issues that would be useful to identify before more site-specific evaluations are developed?
- Are we missing important stakeholder groups, or individuals (see course)?

List of stakeholder groups

A) Duluth Area
   a. Fond du Lac Band, 1864 Authority, Bois Forte Band, Mille Lacs Band, Grand Portage Band
   b. BWSR, USACE, St. Louis County, NRCS, Sea Grant
   c. MFCA, MDH

B) Central Iron Range
   a. DNR Minerals, Waters, Fisheries, Hydrology, Ecological Services
   b. Itasca County
   c. Barr Engineering, NTS/Prince Labs
   d. IRRRB
   e. Laurentian Vision / CRI

Figure 5.4-1. Agenda to guide discussions with agency stakeholders.
APPENDIX 5.4-A:

PowerPoint Presentation Used to Introduce the PHES on the Mesabi Iron Range Study to Agency Stakeholders
Renewable Energy Context

By the year 2025

Energy goal for Minnesota
25% of the total grid needs to be from renewable source by 2025

Signed “25” by “25” into law

Energy Alternatives

<table>
<thead>
<tr>
<th>Biomass</th>
<th>Geothermal</th>
<th>Solar</th>
<th>Wind</th>
</tr>
</thead>
</table>

- Wind most viable option for mid-latitudes
The necessity of Storage

Wind Generation

- Wind Power is a viable option for mid latitudes
- Wind varies in speed
- Daily
- Seasonally
- Geographically
- Electric load is uniform

Large quantities of renewable energy CANNOT be added efficiently to the grid without storage.

Mitigating Wind Fluctuations.

Energy storage systems:
(1) Bank energy when demand is low relative to supply and
(2) Provide energy when demand is high relative to supply.

Options for storage:

- Compressed Air (CAES)
- Pumped Hydro Storage
- NaS Battery
- Flow Batteries (ZnBr, VRB, PSB)
- High Energy Super Capacitors
- High Power Fly Wheels
- High Power Supercapacitors
- Li-ion
- Long Duration Fly Wheels
- Metal-Air Batteries
- Ni-Cd
- SMES (superconducting magnetic energy storage)
Pumped Hydro Energy Storage (PHES) Using Abandoned Mine Pits on the Mesabi Iron Range of Minnesota

Multidisciplinary Team

- Facilities team
- Environmental team
- Geotechnical team
- Policy team

Funded by:
**PHES - Engineering**

Pumped Hydro is a “water battery”
- Charge battery by pumping water up hill (when wind is blowing)
- Discharge battery by letting water down hill (when wind isn’t blowing)

Operating characteristics:
<10 minute start-up time
Efficiencies in excess of 80% per cycle
Operate as and fill role of peaking plant
Enter ancillary market (futures for energy)

**PHES - Engineering**

System requirements

- >300ft head requirement
- Low head fluctuation desirable (large surface area, ~5-20m fluctuation)
- ~50-150MW target (for MN Power, GRE in MN)
Marriage of PHES with mining-impacted water resources

Potential Benefits
- Less construction costs
- Make use of previously impacted resources

Potential Challenges
- Mineral rights issues
- Water Use issues
- Environmental impacts

Preliminary screening for essential system requirements on iron range

29 sites identified across iron range with sufficient head and volume requirements
Secondary screening for other system requirements on iron range

- Subsequent consideration of other potentially prohibitive factors (active/future mining, proximity to population centers, sensitive environmental areas)
- Narrowed list to top 5-10 for further consideration
- One example (not necessarily best option) will be presented to give a sense of what is involved

Example of one site for consideration

Example site just E. from Virginia
Consideration of Environmental Impacts

Conventional issues
• Mining Construction (tunnels/pits)
• Hydro & electric construction (dams, power lines)
• Other...

Consideration of Environmental Impacts

Wind power – related Issues
• Alternative energy issues
• Birds/bats/windmills
• Other
Consideration of Environmental Impacts

Preliminary Environmental Assessment

- Unique, local issues (and “Hot Button”)
  - Local hydrology, wells, cultural
  - Asbestos
  - Sulfate
  - Mercury
  - Wild rice
  - Other

Preliminary Environmental issues

Multidisciplinary Team

Funded by:
Federal Energy Regulatory Commission (FERC) Licensing

- The Federal Power Act authorizes FERC to license most nonfederal hydropower projects located on navigable waterways or federal lands, or connected to the interstate electric grid.
- Wind power from North Dakota requires PHES project in Minnesota to be connected to the interstate electric grid, therefore requiring FERC licensing.
- Includes environmental review.

FERC – Integrated Licensing Process
Other Federal Laws Affecting the Licensing Process

- National Environmental Policy Act
- Fish and Wildlife Coordination Act
- National Historic Preservation Act
- Endangered Species Act
- Clean Water Act
- Wild and Scenic Rivers Act
- Americans with Disabilities Act

Minnesota Public Utility Commission (PUC) Permits

- The Power Plant Siting Act authorizes the PUC to require a site permit to build a large electric power generating plant (LEPGP).
- A LEPGP is defined as a power plant operating at 50 megawatts or more.
- A PHES project in Minnesota will likely be 100 to 150 megawatts, therefore requiring a siting permit.
- Includes environmental review.
Other State Permits Required

- MN DNR - Water Appropriation Permit
- MN DNR - Dam Safety Permit
- MPCA - National Pollution Discharge Elimination System (NPDES) Permit

Local Permits

- Local permits and zoning requirements are generally superseded by state and federal permits.
SECTION 5.5:

Licensing and Permitting a Pumped Hydro Energy Storage Project

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  Dr. Rich Axler, NRRI
  Mr. Kurt Johnson, NRRI
Mr. Brian Beck, UMD (MS Student)
  Mr. Jerry Henneck, NRRI
University of Minnesota Duluth
  Duluth MN 55812
Introduction

Permitting a Pumped Hydro Energy Storage (PHES) project requires working with a number of federal and state agencies and compliance with a myriad of regulations. These detailed regulations are well documented in state and federal legislation. Rather than delving into the details of these laws, the goal of this document is to provide an overview of permitting and licensing procedures with references to regulatory documents that may be accessed for more detailed information. Most of the regulations concern hydropower generation on existing rivers and streams, and therefore may or may not pertain specifically to a PHES project.

The main federal agency responsible for licensing PHES projects is the Federal Energy Regulatory Commission (FERC). Other federal agencies that may become involved, especially for environmental issues include the U.S. Army Corps of Engineers (USACOE), the Environmental Protection Agency (EPA), and U.S. Fish and Wildlife Service (USFWS). In Minnesota, the primary state permitting agency for PHES projects is the Minnesota Public Utilities Commission (MPUC). Other state agencies that may be involved include the Minnesota Department of Natural Resources (DNR), Minnesota Pollution Control Agency (MPCA), and Minnesota Board of Water and Soil Resources (BWSR). Both federal and state permitting processes include environmental review to identify potentially harmful project impacts. Public and stakeholder review of the project will result in a list of potential impacts for further study. Environmental studies must be planned by the proposer in cooperation with the regulatory agencies to further define and evaluate potential impacts. These studies generally need to be conducted over a period of several years to achieve meaningful results (FERC, 2004).

Federal Licensing/Permitting

Federal Energy Regulatory Commission (FERC)

The Federal Energy Regulatory Commission (FERC) is authorized under the Federal Power Act to license non-federal hydropower projects located on navigable waters or federal land, or projects that are connected to the interstate electric grid. Proposers intending to develop a hydroelectric project should file a hydropower license application or a Declaration of Intention to determine if their project requires a FERC license (“Jurisdictional Determination”). FERC can issue an original hydropower license for a period of up to 50 years for project construction, operation and maintenance. When the license expires, the project may be turned over to the federal government, a permit may be reissued, or the project may be decommissioned. FERC has issued the “Handbook for Hydroelectric Project Licensing and 5 MW Exemptions from Licensing” (FERC, 2004) or “2004 FERC Handbook” to guide prospective developers and other interested parties through the licensing process. This document supersedes the previous 2001 document titled, “Hydroelectric Project Licensing Handbook.” The 2004 FERC Handbook has been revised in accordance with changes in hydroelectric licensing regulations issued in Order 2002 on July 23, 2003. Order 2002 established a new “integrated licensing process” (ILP) which provides “a predictable, efficient, and timely licensing process that continues to ensure resource protection.” Two previously allowed licensing processes, the “traditional licensing process” (TLP) and “alternative licensing process” (ALP) now require FERC approval, with the ILP being the default process. The three licensing processes are shown in Figures 5.5-1, 5.5-2, and 5.5-3. A summary the procedures common to all three licensing processes will be provided in this document. For more detailed information on each individual licensing process, please refer to the 2004 FERC Handbook. Although the 2004 FERC Handbook is a useful guide to the licensing process, it is recommended that proposers ultimately follow the implementing regulations in 18 CFR – Code of Federal Regulations – Title 18: Conservation of Power
and Water Resources, and seek supplemental legal assistance in preparing a license application (FERC, 2004).

Figure 5.5-1. FERC Integrated Licensing Process (FERC, 2004).

Figure 5.5-2. FERC Traditional Licensing Process (FERC, 2004).
Summary of the FERC Licensing Process

The TLP, ALP, and ILP licensing processes are all separated into pre-filing and post-filing stages. Cooperation with FERC staff and other regulatory and permitting agencies is recommended throughout the process to expedite licensing.

Preliminary Permit

A preliminary permit is first issued to an applicant to reserve a new project site while they complete their application. The permit is valid for a period of up to three years, does not require a dam or land ownership, and does not authorize any construction or land disturbance (“Hydropower Licensing”).

Pre-Filing Stage

The pre-filing stage consists of a number of steps that include an initial proposal, public notice and scoping, and development and implementation of study plans to be used in the license application. During public notice and scoping FERC requests input from the public; local, state and federal resource agencies; non-governmental organizations; and Native American tribes to identify potential environmental impacts and issues resulting from the project. Based on this input, study plans are designed and implemented to address these issues. The study phase of the process usually takes approximately two years. Study results are used to complete the project application that includes detailed descriptions of project facilities, operation, and maintenance; and potential environmental impacts and proposed mitigation strategies. The pre-filing stage ends when the complete license application is submitted to and accepted by FERC (“Hydropower Licensing”).

Post-Filing Stage

In the post-filing stage, FERC again seeks public input on the complete license application and incorporates comments into the environmental review required by the National Environmental Policy Act (NEPA). FERC then uses the environmental review documents to determine if the proposed project
should be approved for licensing, and if any additional operational or environmental requirements should be included in the license. Once the license is issued, it allows the licensee to construct and operate a hydropower project for a period up to 50 years with the conditions that they own or have an easement on the project land and waters, and comply with environmental requirements (“Hydropower Licensing”).

**Licensing Details: The Integrated Licensing Process**

All three licensing processes go through similar steps. For the purposes of this document the Integrated Licensing Process will be described in more detail. For more information on the specifics of the TLP and ALP licensing processes, refer to the FERC 2004 licensing handbook.

According to the 2004 FERC Handbook, the ILP is an improvement on the traditional and alternative licensing processes in that “It is designed to improve efficiency and timeliness of preparing and processing license applications by: combining an applicant’s pre-filing consultation with the Commission’s scoping pursuant to the National Environmental Policy Act (NEPA), rather than conducting these activities sequentially; increasing public participation in pre-filing consultation; improving coordination between the Commission’s processes and those of other participants; providing for increased staff assistance during the preparation of the application; and establishing schedules for all participants, including Commission staff.” FERC also issued a new Tribal Consultation Policy to improve consultation with Native American tribes.

The ILP consists of a number of steps that run both sequentially and concurrent. The key steps are as follows (FERC, 2004):

- Step 1: Decision to file and initial actions;
- Step 2: Consultation, scoping, and study plan development;
- Step 3: Studies and preliminary licensing proposal preparation;
- Step 4: Application filing;
- Step 5: Application processing and NEPA compliance;
- Step 6: Completion of the Section 10(J) process; and
- Step 7: License issuance and monitoring.

The following sections provide a brief summary of each of these steps taken from the 2004 FERC Handbook.

**Step 1: Decision to file and initial actions**

In Step 1 the applicant must inform FERC of its intention to file for an original hydropower license. This notice of intent (NOI) may be in letter form and contains information such as the licensee’s intention to file for a license, name and address, project location, plant installed capacity, names and addresses of potentially affected counties, cities, towns, and Native American tribes.

A pre-application document (PAD) must be filed concurrent with the NOI. The PAD contains all existing or known engineering, economic, and environmental information relevant to the project. The applicant is not expected to conduct studies to acquire this information, but the PAD should be sufficient to help
stakeholders determine potential information gaps and guide study development and implementation in the licensing process.

**Step 2: Consultation, scoping, and study plan development**

In addition to consulting with FERC staff, it is essential that the applicant also consult with the appropriate, state, federal, and interstate resource agencies, as well as affected Native American tribes and the public. Issues to be addressed include the project design, potential impacts, alternatives and required studies. A list of relevant agencies and tribes is available on the FERC web page. Communication between FERC staff and non-FERC personnel is subject to specific rules to ensure fairness in the process.

The goal of consultation is to provide a forum for participation in the scoping process and identify engineering, environmental, and economic issues that will be addressed in a scientifically valid study plan. Engineering studies usually include such things as project operations, facilities and equipment safety, and dam safety requirements. Environmental studies may include potential impacts to water quality, fisheries, wildlife, and recreation. Alternatives to minimize potential environmental impacts should be identified and explored. Economic studies should look at the cost of the project power versus alternatives, and operation and maintenance costs. To the extent possible, the study issues should be integrated as it is likely that they may be interrelated. For instance, environmental issues may affect engineering design. A more detailed listing of potential studies that may be required is presented in the FERC 2004 Handbook.

**Step 3: Studies and preliminary licensing proposal preparation**

Studies generally take from one to two years to complete. Once complete, the information obtained is incorporated into the license application in the form of environmental reports, design drawings and maps. The type of project and the different licensing processes (ILP, TLP, and ALP) used will define what is specifically required in the application. At the applicant’s request FERC may also allow a third party contractor to assist in completing the application, particularly the environmental report. More details on the specific application requirements and rules for use of a third party contractor are available in the FERC 2004 Handbook.

**Step 4: Application filing**

The original application and eight copies must be filed with the Secretary at FERC. One copy must also be given to the Regional Engineer at the FERC regional office, and one copy to each resource agency, Native American tribe, and public person consulted in the process. The applicant must publish a notice of filing their application twice in a local newspaper in the area where the project is located within 14 days of filing.

**Step 5: Application processing and NEPA compliance**

Application processing begins when FERC issues a notice of tendering of the application for filing. The notice will be published in the local newspaper, Federal Register and given directly to agencies and
Native American tribes. The notice will contain a preliminary application processing schedule. Within 30 days, FERC will notify the applicant of any deficiencies in the application and allow 90 days for correcting the deficiencies. FERC will notify the applicant by letter if the application has been accepted or rejected for filing. Additional information may also be requested.

If the application is accepted, FERC will then publish a ready for environmental assessment (REA) notice once it has determined that all studies are complete to conduct its environmental analysis. Comments, terms and conditions, recommendations, and prescriptions are then requested and must be received within 60 days of the REA notice.

FERC requires the applicant to file a copy of its 401 Water Quality Certification within 60 days of the REA notice.

Federal environmental review for hydropower projects is addressed in general as follows (FERC, 2004):

“The National Environmental Policy Act (NEPA) requires federal agencies to evaluate the effects of their actions on the environment, disclose those effects, develop possible protection, mitigation, and enhancement measures to minimize those effects, and make a finding that the action is:

- Not a major federal action significantly affecting the quality of the human environment; or
- A major federal action significantly affecting the quality of the human environment, and therefore requires an EIS.”

FERC will evaluate the application and determine how it will be processed based on scoping and comments received in response to the REA notice. A draft Environmental Assessment (EA) or Environmental Impact Statement (EIS) will be issued for comment and then a final EA or EIS will be prepared by FERC.

**Step 6: Completion of the Section 10(J) process**

According to the Federal Power Act (FPA) FERC is required under Section 10 (J) to include in any hydropower license requirements for the protection, mitigation, and enhancement of fish and wildlife resources potentially impacted by the project as recommended by fish and wildlife agencies.

**Step 7: License issuance and monitoring**

The license order which contains the terms and conditions for operation of the project is issued by FERC. The license order usually contains (FERC, 2004):

- “a description of the project works licensed;
- a description of the project operation;
- a discussion and findings of the issues raised in the proceeding;
- term of license;
- environmental conditions;
- engineering conditions; and
- administrative compliance conditions.”

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FERC conducts ongoing monitoring of the licensee’s compliance with license terms and conditions. FERC can issue formal orders directing compliance and can impose fines or revoke a license if the licensee is found to be in non-compliance (Division of Hydropower Administration and Compliance, 2004).

Other Federal Laws Pertaining to PHES Projects

In addition to the National Environmental Policy Act (NEPA), FERC must also comply with a number of other federal laws in regards to permitting Pumped Hydro Energy Storage facilities including the Fish and Wildlife Coordination Act (FWCA), National Historic Preservation Act (NHPA), Endangered Species Act (ESA), Clean Water Act (CWA), Wild and Scenic Rivers Act, and Americans with Disabilities Act (ADA). Details on how these laws affect Pumped Hydro Energy Storage permitting are listed in Appendix B of the 2004 FERC Handbook.

Dam Safety

FERC has the largest dam safety program in the United States including over 3,000 dams (“Dam Safety Program”). FERC engineers are involved in the design, construction, maintenance, and inspection of dams. FERC staff inspects projects, without notice, to examine dam safety and ensure compliance with license requirements. Licensees are required to develop emergency action plans to in preparation for potential catastrophic dam failure or other unexpected water releases. The plan must include procedures for reducing water levels and downstream flows, and notifying downstream residents and emergency management agencies. Plans must be frequently updated and tested to ensure emergency preparedness and minimize damage to human life and property in the event of a dam failure. More dam safety information can be found on the FERC website (“Regulations, Guidelines and Manuals”).

Potential Pumped Hydro Energy Storage FERC Licensing Issues

FERC licensing for a pumped hydro energy storage facility can take up to 5 years or more, thus hampering development schedules and adding significant costs to a project (Gilbert et al., 2011). This and other factors may have had a role in the fact that a new pumped hydro energy storage facility has not been licensed and built in the U.S. in the last 15 years.

This study is focusing on the use of abandoned mining features on Minnesota’s Mesabi Iron Range for pumped storage rather than natural lakes or rivers. As such, the design of a pumped storage system is more likely to be a “closed loop” with reduced impacts to natural waterways. According to FERC, license applications for closed loop pumped storage projects are on the rise (Figure 5.5-4). FERC’s jurisdiction over such projects that are not on navigable waters or federal land comes from the fact that they are most always connected to the interstate electrical grid. It has been suggested by some that the FERC licensing process should be streamlined for closed loop projects due to their reduced environmental impacts (Gilbert et al., 2011). To date, this has not been the case and continues to hamper pumped hydro energy storage development.
Figure 5.5-4. Trends for Open- and Closed- Loop PHES Projects ("Pumped Storage Projects").

There are a number of ways to expedite the pumped hydro energy storage FERC licensing process (Gilbert et al., 2011). It is essential to determine all other permitting and regulatory requirements early on to allow a coordinated effort towards attaining all needed approvals. Combining these efforts with the FERC licensing process will reduce duplication of effort and save time. Getting to know the state and local agency personnel responsible for permitting can also be helpful. A successful licensing and permitting strategy involves early contact and cooperation with all involved parties.

Setting up transmission line interconnection points requires cooperation and studies with associated utilities and can take up to a year or more to reach a decision. Therefore, it is important to start this process as soon as possible.

It is also necessary to get permission from landowners on the site to conduct the necessary studies required for the FERC licensing process, as at the time of licensing many developers do not yet own the property proposed for development. This is also important so that the timing of certain season dependent studies is not interrupted (Gilbert et al., 2011).

State Licensing/Permitting

**Minnesota Public Utilities Commission (MPUC)**

In Minnesota, the primary state permitting agency for PHES projects is the Minnesota Public Utilities Commission (MPUC). According to the MPUC website ("Siting & Routing"), "The Minnesota Legislature has established a state policy to locate large energy facilities in an orderly manner compatible with environmental preservation and the efficient use of resources. The legislature has directed the
Commission to designate sites and routes that minimize adverse human and environmental impact while ensuring continuing system reliability and integrity while fulfilling energy needs in an orderly and timely fashion.”

The Power Plant Siting Act (Minnesota Statutes 216E) authorizes the MPUC to require permits for electric power generating plants, transmission lines, and wind power generation plants. All of these may pertain to a PHES project. The MPUC may require a state Certificate of Need and/or a state route or site permit depending on the project.

The Power Plant Siting Act authorizes the MPUC to require a site permit to build a large electric power generating plant (LEPGP). An LEPGP is defined as a power plant operating at 50 megawatts or more. A PHES project envisioned for Minnesota’s Mesabi Iron Range will likely be in the range of 100-150 megawatts and therefore require a siting permit. The applicant must identify in the site permit application their preferred site and one alternative site. Environmental review consists of an Environmental Impact Statement (EIS) prepared by the Minnesota Department of Commerce and the Office of Energy Security. A contested case hearing is also held by an administrative law judge. The MPUC has one year from the time the application is accepted to make a permit decision (“Public Utilities Commission”). Rules pertaining to LEPGP site permits are found in Minnesota Statutes 216E and Minnesota Rules Chapter 7850.

The MPUC will require a route permit if the PHES project includes a High Voltage Transmission Line (HVTL) of 100 kilovolts or more according to Minnesota Statutes 216E and Minnesota Rules Chapter 7850. A diagram showing the HVTL routing and plant siting permitting process is presented in Figure 5.5-5.

Should the wind energy used for the PHES project originate in Minnesota, a Large Wind Energy Conversion System (LWECS) site permit will be required if the system is over 5 megawatts according to Minnesota Statutes 216F and Minnesota Rules Chapter 7854.

Certificate of Need

Large energy projects in Minnesota also require a Certificate of Need (CON) in addition to site or route permits (“The Certificate of Need Process”). In the CON process the applicant demonstrates that the proposed energy project is in the best interest of the state’s citizens and that it is the best alternative to provide the stated project goals. The applicant first submits a CON application to the MPUC. If the MPUC finds the application adequate it then passes it on to the Department of Commerce (DOC). The DOC then proceeds with environmental review of the project while the MPUC and the Office of Administrative Hearings (OAH) begin the contested case process. After a series of public meetings, hearings, and a comment period the MPUC will hold a final meeting to determine whether or not the CON will be issued. Rules pertaining to the CON are found in Minnesota Statutes 216B and Minnesota Rules Chapter 7849. A diagram showing the Certificate of Need process is presented in Figure 5.5-6.
Figure 5.5-5. Minnesota Public Utilities Commission full review permit process ("Full Review").
Minnesota Department of Natural Resources

The Minnesota Department of Natural Resources (DNR) Division of Waters requires a water appropriation permit for all users withdrawing greater than 10,000 gallons of water per day or 1 million gallons per year (“Water Use Permits”). Users are required to monitor monthly water use and are charged annual fees based on the amount of water use.

The DNR Division of Waters also requires a dam safety permit to “construct, alter, repair, remove, or transfer ownership of a regulated dam” (“Dam Safety - Permit Guidelines”). Regulated dams are those that are generally greater than 25 feet in height and impound greater than 50 acre-feet of water, unless they pose a potential for loss of life, in which case dams greater than 6 feet in height and impounding more than 15 acre-feet of water require regulation and permitting. Federally-owned dams and those deemed non-hazardous by the DNR are exempt from the DNR dam safety regulations.

Minnesota Pollution Control Agency

According to the Clean Water Act, any project requiring a federal permit and may result in a discharge to navigable waters will require a state Section 401 Water Quality Certification to ensure compliance with state water quality standards (“Clean Water Act Section 401”). The Minnesota Pollution Control Agency (MPCA) administers this permit in Minnesota. FERC issued permits, such as PHES licenses, are included in the list of federal permits requiring Section 401 Certification. The Section 401 Certification will be granted if the applicant demonstrates that their project will meet Minnesota water quality standards and not result in long-term or short-term detrimental impacts on water quality.

Another permit administered by the MPCA that may be required for a PHES project is the National Pollutant Discharge Elimination System (NPDES) permit. This permit is generally required for industrial wastewater discharges to lakes, streams, wetlands, and other surface waters (“Industrial National Pollutant”). If a PHES project is a completely “closed-loop” system, this permit may not be required. However, any discharge, including seepage from reservoirs, etc. will require monitoring, water quality limits, and management practices under the NPDES permit.
Figure 5.5-6. Minnesota Public Utilities Commission Certificate of Need Process Chart ("Certificate of Need").
**Wetland Issues and Regulations**

The ideal scenario for a PHES project on Minnesota’s Mesabi Iron Range is one in which the upper and lower reservoirs are both existing mine pits with little to no additional excavation or impacts occurring on natural ecosystems. However, the case may likely be that all or part of either reservoir may need to be excavated on previously undisturbed areas. This may impact wetlands. Federal and State “no-net-loss” wetland policies require compensatory mitigation for any unavoidable wetland impacts. Mitigation can consist of restoration, creation, enhancement of other previously impacted wetland sites or preservation of pristine sites to compensate for project related wetland impacts. Mitigation can be achieved by project specific replacement, where a mitigation wetland is developed specifically to compensate for a particular project impact, or mitigation credits can be purchased from an established wetland bank (U.S. Army Corps of Engineers, 2009). The goal is to replace lost wetland functions.

Wetlands impacts are regulated and permitted in Minnesota by the U.S Army Corps of Engineers (USACOE) through their Section 404 Permit, the Minnesota Department of Natural Resources through their Public Waters Work Permit Program, the Minnesota Board of Water and Soil Resources (BWSR) together with local governments through the Wetland Conservation Act (WCA), and the Minnesota Pollution Control Agency through their Section 401 Water Quality Certification (“Wetland Regulation in Minnesota”). Detailed regulations regarding wetland impacts and mitigation can be found in the publication, “St. Paul District Policy for Wetland Compensatory Mitigation in Minnesota” (2009) and on the BWSR website (“Wetland Regulation”).

According to a 2007 report by BWSR, potential wetland impacts due to mining projects, public road construction and residential/commercial development in northeastern Minnesota could total as much as 550 acres annually through the year 2012 (BWSR, 2007). This increased demand for scarce wetland mitigation sites and credits in NE Minnesota has raised the price of wetland credits. Voluntarily reported mean credit prices in northern Minnesota ranged from about $6,000/acre in Beltrami County to over $30,000/acre in St. Louis County from 2005 through 2008 (“Wetland Banking”). This can be a costly addition to a project budget depending on the extent of wetlands impacted. Project specific mitigation can also be expensive with land purchase, construction, and a minimum of five years of monitoring required by regulators. The USACOE generally prefers developers to purchase credits from an established bank rather than project specific mitigation due historically better success with wetland banks at replacing lost wetland functions. Due to potential wetland impacts and increased project costs, site selection to avoid wetlands should be considered.

**Summary**

Licensing and permitting a PHES project can be a lengthy and expensive undertaking. Consultation with all affected parties and extensive environmental, engineering, and economic studies are required by both federal and state agencies. The licensing and permitting process can take five years or more to complete. To date, at least at the federal level, there is no licensing advantage for closed-loop projects, such as those potentially proposed for the Mesabi Iron Range. Some licensing and permitting issues that may prove particularly difficult include Section 401 Water Quality Certification and wetland impacts. Compliance issues after the project has been approved and constructed such as operation, maintenance, and dam safety are also important and continue for the life of the project. Due to the extensive and complex nature of the licensing and permitting process for a PHES project, it is recommended that developers seek qualified legal assistance in addition to the resources listed in this report.
SECTION 5.6:
Mesabi Range Mine Pit Limnology and Water Quality

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This element of the project proved to be far more difficult than anticipated because only a small fraction of the limnological and water quality data that has been collected for mine pit lakes by various agencies is available in the MPCA’s water quality data base (i.e., STORET, EDA, Equis) or via the MDNR’s Lake Finder utility. Data is buried in reports and unpublished agency files that have been difficult to locate and retrieve. Nevertheless, we believe this is a worthwhile task to complete and, in fact, expect to finish it before December 1, 2011 at which time we will submit it to IREE. This section was not critical to the Phase 1 - Environmental Assessment funded as part of the current study but would be useful to further studies of potential PHES on the Mesabi Iron Range involving specific sites as proposed in the original grant application.
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