Climate Change, the Great Lakes, and Kennecott's Eagle Mine

September 2011

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Cover Image: SeaWiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE; http://visibleearth.nasa.gov/view_rec.php?id=1244

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Introduction

Global warming is already contributing to regional climate change in the Great Lakes region. Generally, the regional climate is becoming wetter and warmer, with most warming and precipitation occurring during the cold season. This has already been seen with the onset of warmer winters; earlier spring melts, and lower surface water levels in summer and fall. These changes, if not adapted to, have the potential to negatively affect the mining industry, as well as other energy and water intensive users.

Yellow Dog Watershed Preserve (YDWP), a watershed protection group, based in Big Bay, Michigan, solicited this report. Though not meant to be comprehensive, this report reviews much of the available relevant literature to determine how regional climate change can be projected to affect the mining industry, the environment, and humans in the Great Lakes region, and potentially affect Kennecott Eagle Minerals Company's Eagle Mine, in Marquette County, Michigan.

YDWP, through a grant with Freshwater Future, sought to determine what problems Kennecott might face as the result of projected regional climate changes. Kennecott did not noticeably consider climate changes in their Eagle Mine design. YDWP expects to approach regulators with this information in order to influence them into encouraging Kennecott to revise its environmental protection plans. YDWP hopes that improvements to the mine plan that would help to safeguard the watershed would result from these efforts.

This report first defines global warming, locates its causes, and outlines projections for regional climate change in the Great Lakes as the result of global warming. The report then moves into assessing how global climate change is affecting the mining industry. Then, it briefly discuss the potential for an extensive hardrock mining district in the northern Great Lakes before looking more specifically at how Kennecott's Eagle Mine, the most advanced of recent proposals, may react to regional climatic changes. Finally, it concludes the results of this review and offer recommendations to groups interested in protecting the environment and human health from the regional effects of global warming.

Global Warming[1]

Current global warming is the result of an increase in levels of greenhouse gases, such as carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) in the atmosphere. This unnatural increase in greenhouse gases has largely happened from burning fossil fuels, like coal, oil and natural gas; burning forests to create pasture for grazing or to grow food crops; constructing landfills; and certain agricultural practices.

Naturally, the sun warms the earth and, while some of that heat escapes back into space, the rest—known as infrared radiation—is trapped by atmospheric gases, such as CO_2, and water vapor, most often in the form of clouds, thus heating the Earth's surface. Without this natural process, known as "the greenhouse effect," our planet would be 60°F (33°C) cooler and would not support life as we know it.

Typically, greenhouse gases are emitted into the atmosphere as the result of volcanic eruptions, forest fires, and other natural events. Changes in the Earth's orbit and the amount of energy released from the sun have also contributed to long-term global warming over the millennia. However, since the onset of the Industrial Revolution in the late 19th century, the amount of CO_2 entering the atmosphere has dramatically increased, creating problems that can no longer be absorbed by natural processes. This anthropogenic effect has created a warming many times more rapid than has occurred during any known period in the Earth's history. Because CO_2 can remain in the atmosphere for centuries, the problem becomes worse over time. The high levels of CO_2 we are currently emitting into the atmosphere may not produce noticeable effects for many decades.

Over the past century global average temperature has increased by about 1.3°F (0.7°C), with the past decade being the warmest since reliable records were first kept in 1880. According to the National Oceanic and Atmospheric Administration (NOAA), seven of the eight warmest years on record have occurred since 2001. Over the last three decades the rate of warming has been three times greater than warming over the past 100 years. If humans continue to emit greenhouse gases at or above the current pace, the Earth's average temperature is expected to increase between 3 and 7°F (1.7 to 3.9°C.), with even larger increases possible over land and at the poles. Even reducing greenhouse gases to 2000 levels would increase average global temperature by at least another 1°F (0.56°C) over the next 100 years.

While average global temperatures are increasing, this warming is not even, with some areas warming faster than others. In addition to temperature increases, this warming planet may also see changes in rain and snowfall patterns; an increase in droughts and extreme precipitation events; reduced ice cover over lakes; increased melting of glaciers and polar ice shelves, thus an increase in sea

[1] Sources for this chapter: Blunden, et. al., 2011; EPA, 2009; IPCC, 2007; McKibben, 2010; Oreskes & Conway, 2010; UCS, 2011; EPA, undated

levels; and an altered ability for many plants and animals to adapt to a changing climate.

While there has been considerable controversy over global warming, ranging from debate over specific projections to denying that global warming is happening or that humans are not contributing significantly to global warming, this controversy has been largely political and not based in science. Peer-reviewed, established science is now unequivocal that the planet is warming and that humans are contributing significantly to this warming.

Having established anthropogenic global warming as scientific fact, much of the current research on global warming has broadened to consider specific implications for humans and ecosystems, as well as identifying options for adaptation.

Climate Change in the Great Lakes

According to the 2009 State of the Great Lakes report[2] – a partnership between the Canadian and United States' governments – some of the major stressors that currently are and will be affecting Lake Superior are climate change and mining. Both of these stressors are expected to increase in the near future.

The effects of global warming are already being felt in the Great Lakes region. According to scientists, warmer winters, drier summers, and alternating patterns of extreme precipitation and drought may become the new normal for the region. While there are many influences already stressing environmental quality in the Great Lakes, regional climate change will further exacerbate these problems, especially as they relate to water quality.

While global warming, and man's role in causing it, is undeniable, specific localized and regional effects are more difficult to predict than general global changes. There remains considerable scientific uncertainty as to specific changes that will take place in the future related to global, let alone regional or localized warming. Thus, to determine what these future changes will be on a project-by-project basis would be exceedingly risky to perform and would largely be speculative.

Nonetheless, uncertainty as to the specific localized effects of global warming should not prevent the implementation of common sense measures that will protect the regional environment and economy regardless of the exact changes that will be caused by global warming. According to a report produced by the International Joint Commission[3], a collaboration between Environment Canada and the Environmental Protection Agency (EPA), while there is uncertainty about specific future climate changes and effects on the Great Lakes, "failure to invest in adaptation may leave the region poorly prepared to cope with adverse changes and increases the probability of severe consequences."

Projections for climate change in the Great Lakes[4]

With the above in mind, here is what is known, with relative certainty, will happen to the Great Lakes regional climate as the result of global warming:

- Air temperatures are likely to increase by 5 to 12°F (3 to 7°C) in winter and 5 to 20°F (3 to 10°C) in summer.
- Surface water temperatures likely to increase, along with air temperatures.
- The lakes' water levels are expected to fall due to evaporation.
- Increase in precipitation, with an increasing percentage of precipitation falling as rain, rather than snow.
- There will be likely reduced ice cover over the lakes in the winter.

[2] EPA & Environment Canada, 2009
[3] Mortsch & Alden, 2003
[4] Sources for this subsection: Anderson, 2011; Dempsey, et. al., 2008; EPA & Environment Canada, 2009; IPCC, 2007; Kling, et. al., 2003; Kling & Wuebbles, 2005; Mortsch & Alden, 2003

- Likelier earlier spring melts (freshet).
- The timing of hydrologic flows is likely to change.
- Likely to be an increased variability in timing frequency and duration of weather disturbances.
- Increase in invasions of non-native aquatic and terrestrial species.
- Distribution patterns of fish species and other aquatic organisms likely to change.
- Many types of wetlands could be reduced by 50% within the next 50 years.
- Competition for Great Lakes water expected to increase.

Some other changes that may happen, but can be predicted with less certainty:

- Precipitation increases in winter and spring with declines in summer and autumn.
- Levels of surface water, groundwater, and soil moisture expected to drop in summer.
- Increase in extreme rain events lasting 24 hours to 7 days that could increase flooding.
- Fewer safe breeding sites for amphibians, migratory shorebirds, and waterfowl.
- The timing and extent of migration for waterfowl to change.
- Migratory birds, such as warblers, and other songbirds likely to be affected by climate change as the boreal forest retreats north. This will lead to less seed dispersal and insect control, as birds die off, and would also affect a multi-billion dollar industry in wildlife watching in the northern tier of Great Lakes states.
- Waterfowl expected to decline, along with aquatic plants.

Many expected regional climate changes should be of serious concern in the Upper Peninsula of Michigan, as well as other northern areas that feature an abundance of still high-quality surface and groundwater supplies. Headwaters streams, which are often more than 75% of the river miles in a watershed are expected to be the most vulnerable of aquatic ecosystems as the regional climate becomes warmer and drier.

Some projected effects that may be exacerbated by an increase in regional mining activity:

- When exposed to acidic precipitation there may be an increase in the level of metals such as cadmium, copper and lead that are released into wetlands downstream of industrial effluents, such as treated mine wastewater. Lower surface water levels in these areas would likely lead to a further concentration of contaminants.

- Periodic droughts, particularly in the summer and fall, will likely allow sulfates and acidity to mobilize once precipitation continues, delivering a strong acidic shock to surface waters. As a result, some ecosystems

already affected by acid rain may be slower to recover, or may fail to recover fully.

- Lower oxygen levels in lakes as the result of an increase in bacterial decomposition may lead to an increase in the biotic uptake of contaminants such as mercury and other heavy metals that become more soluble in the absence of oxygen.

- An increase in acid mine drainage and heavy metal contamination resulting from new mining exploration and extraction in host rock containing high amounts of sulfides could increase the pollution effects already occurring and expected to increase in the future from regional climate change.

- While surface water temperatures are expected to increase, cool groundwater seeps may help to maintain lower water temperatures in some areas. This effect would be negated with a decrease in forest cover resulting from increased logging, road construction, and mining.

Climate changes already noticed in the Great Lakes[5]

The Michigan State Climatologist's Office concurs that the Great Lakes region faces a warmer and wetter future, which are the two major trends expected to impact the region.

Of twenty some regional climate models performed to date there is variability in predictions for regional climate change, yet every model suggests warming of the regional climate; projected increases are expected to be between 3 and 10°F (1.7 to 5.6°C).

The State Climatologist agrees with climate scientists that most of the increased precipitation will occur during the colder season months in spring and winter; similarly the greatest temperature increases will occur during the cold season.

In fact, most of these projected effects are already happening. Although many northern areas, including the Yellow Dog River watershed, have been experiencing drought conditions for at least several years, the long-term trend points to a wetter and much warmer region than we've had in the past.

Some trends already show global warming's impact on the Great Lakes region:

- Long-term changes in average annual temperatures have been clearly noticed, with the greatest increase during the cold season and, specifically, at night; La Niña has been an influence to slow or temporarily reverse this trend.[6]

[5] This subsection sourced from: Anderson, 2011

[6] According to the National Oceanic & Atmospheric Administration (NOAA), La Niña-type events are "characterized by unusually cold ocean temperatures in the Equatorial Pacific," the inverse of El Niño-type events; http://www.pmel.noaa.gov/tao/elnino/la-nina-story.html

- Over the past century a 1°F (0.55°C) increase has been noticed, despite a 1940-1980 cooling trend; since 1980 average annual temperatures have increased 2°F (1.1°C).

- Spring happens earlier in the Great Lakes region, with most of Michigan experiencing the onset of the spring melting season an average of 7-10 days earlier than in the past.

- Despite periods of dryness, such as the 1930s, part of the 1990s, and the past several years, the long-term trends show an increase in precipitation.

- There has been somewhat of an increase in extreme precipitation events, a trend that is noticeable regionally.

- There has been a 10-15% increase in precipitation over the last half-century, an increase of roughly 4" in precipitation per year, the result of increasingly wet and cloudy days.

- The frequency of precipitation events has increased; the number of wet days in the 1930s was 1 in 4, now it is 1 in 3.

- While precipitation has increased since the dry 1930s, relevant records do show that, while the late 19th century was wetter than in the 1930s, today's climate is still wetter than this earlier period.

According to the State Climatologist, municipalities are currently facing challenges in planning for future water use in relation to regional climate change. Uncertainties in specific future climate projections allow only for planning for broad projections, but municipalities, as heavy water users, are beginning to make prudent planning changes in response to regional climate change.

It is reasonable to assume that industrial users of large quantities of water, such as the mining industry, will have to account similarly for regional climate change projections in their operations plans and long-term outlook in order to secure their own business certainty and protect water quality and quantity for the region's citizens and wildlife.[7]

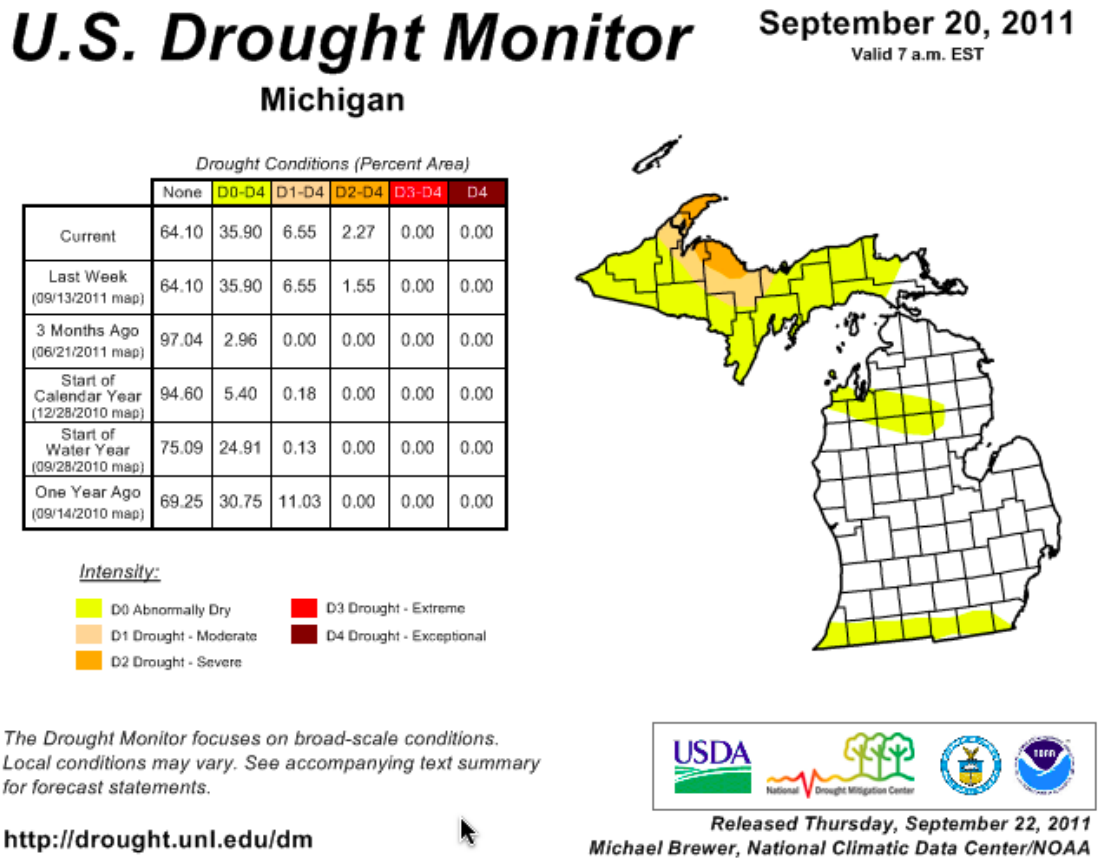
Drought in the northern Great Lakes[8]

Much of the northern Great Lakes region has been experiencing seasonal drought conditions, a trend that has lasted for at least several years, according to the Michigan State Climatologist's Office.

[7] Attempts were made to contact relevant personnel at several local mining and exploration companies; these attempts, unfortunately, did not yield productive information that could be included in this report. It is unclear at this point if active mining operations in the area are already accommodating the effects of regional climate change or are planning for future changes.
[8] NOAA, 2011

The National Weather Service's office in Marquette, Michigan, notes:

> "From June 23rd to August 31st, only 2.05 inches of rain fell at the National Weather Service office in Negaunee Township, resulting in the driest June 23rd to August 31st period on record. . . Continued dry weather into September has kept the NWS office on pace to have the driest July-September on record."



As of the middle of September, 2011, northern Marquette County and northeastern Baraga County are currently considered to be in the midst of a "severe drought" [*see above graphic*]. This drought area encompasses much of the Yellow Dog River watershed and Huron Mountains region where the greatest amount of new mining exploration in the Upper Peninsula is occurring.

As the result of this pronounced drought, baseline monitoring conditions of water quality and quantity collected by companies in the area as a requirement under Michigan's "Part 632" nonferrous mining regulations could potentially be misleading.

Decreased stream flows and groundwater levels may have already led to a concentration in levels of acidity, heavy metals, and other contaminants in the regional water supply. If hydrologic conditions return to normal – or what is

becoming the new normal as the result of regional climate change – skewed baseline data could potentially serve to inadvertently mask lower than normal water levels and increased contamination as the result of mine dewatering and wastewater treatment.

Hydrology and Michigan's "Part 632" mining law

The Part 632[9] mining permit process requires, among other things, baseline information on hydrology in the mining area:

> "An environmental impact assessment for the proposed mining operation that describes the natural and human-made features, including, but not limited to, flora, fauna, hydrology, geology, and geochemistry, and baseline conditions in the proposed mining area and the affected area that may be impacted by the mining, and the potential impacts on those features from the proposed mining operation…"

Additionally, an applicant's water monitoring regime is required to be designed based upon assessments of local hydrology:

> "Water monitoring shall include the collection of water quality samples from groundwater and surface water, groundwater levels, and surface water levels and discharge rates. The design of the water monitoring systems shall be based on. . . The local geology and hydrology."

Part 632's requirement for a two-year flora and fauna study does not specify what time frame the study must be performed in, nor stipulate that such a study be performed in the area surrounding the proposed mine site. The mine plan is required to have an assessment of:

> "Species and abundance of aquatic and terrestrial flora and fauna, and predicted variations in their occurrence based on at least 2 years of relevant information. Relevant information may include records of pertinent data at other sites having documented similar conditions or credible regional studies from acknowledged sources, but shall include at least 1 year of site-specific data."

As indicated in their environmental impact assessment (EIA)[10] for the Eagle Mine, Kennecott did begin water quality monitoring, including analysis of stream flows in 2002. Their monitoring regime may have been implemented when baseline hydrologic conditions could have been considered "normal" and may have detected changes both in ground and surface water levels and contamination levels as drought began to occur and progress in later years. Ensuring that Kennecott planned for higher average levels of precipitation in

[9] MDEQ, 2006
[10] Foth & Van Dyke, 2006

spring and winter (and, concurrently, lower levels in summer and fall) than are currently occurring, would be essential in efforts to protect stream, wetland, and groundwater quality to the fullest extent possible.

If it has not already been done, further information as to the dates of baseline water quality monitoring in the area surrounding the Eagle Mine should be sought to infer whether or not baseline data included in the company's mine permit application, including its EIA, list lower than normal water levels and higher contamination concentrations as historic baseline levels. A more accurate view of baseline environmental conditions would likely consider the current drought an anomaly in a long-term trend toward increasing precipitation.

Mining in the Great Lakes

The upper Great Lakes region is already enduring stresses associated with mining development. The region has hosted numerous large-scale iron ore mining operations for decades – current operations are located in northeastern Minnesota and the central Upper Peninsula – as well as non-ferrous mining and smelting operations in Ontario.

According to the latest State of the Great Lakes report (2009) – published jointly by the United States and Canadian governments – environmental quality in the Lake Superior basin is already threatened by current mining operations. While air quality is affected by mining operations, including associated power production and transportation, it is regional water quality that has suffered most noticeably as the result of mining activity.

The EPA lists a number of "Great Lakes Areas of Concerns" (AOC) on its website[11]. Some of these areas are associated with past mining operations, including Torch Lake and Deer Lake in Michigan. In the United States, the St. Louis River and Bay, and Menominee River AOCs are located in areas that will face additional stresses if planned mining projects move forward in these watersheds.

As the result of industry-friendly mining regulation introduced in Michigan (2005)[12] and high metal prices, the Upper Peninsula has been inundated with new mineral exploration and mining proposals. Similarly, in Minnesota and Wisconsin, politicians ideologically and financially attached to the mining industry are working to introduce legislation aimed at fast-tracking the development of new mining projects.

In Wisconsin, although a "prove it first" law exists requiring a mining company to prove it can mine safely before doing so, the "Jobs for Generations Act" would fast-track the permitting process specifically for Gogebic Taconite to open a vast open-pit iron ore mine, near Ashland, as well as limit public participation in the process.[13] It is conceivable that additional industry-friendly legislation may be passed in the future to assist in the development of other mining deposits.

While this report looks more specifically at Kennecott's Eagle Mine, in the central Upper Peninsula, a number of other proposed mining projects (in addition to current mining projects) could have as great or a greater impact on environmental quality in the region.

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[11] EPA, 2011

[12] A Great Lakes Media and Research project on Aquila/HudBay's Back Forty zinc-gold mine (Bertossi & Caplett, 2010) highlighted documented industry perspectives from a number of mining companies operating in Michigan that Part 632 is more industry friendly than environmentally protective, despite widespread claims to the contrary.

[13] Gedicks, 2011

Some of the new primary mineral exploration and mining development projects in the region are listed below.

- Kennecott Eagle Minerals Company: Eagle Mine (underground nickel and copper mine); mining permits approved by the Michigan Department of Environmental Quality (MDEQ) in 2007
- Orvana Minerals: Copperwood Project (underground copper mine); mining permit submitted to the MDEQ on September 26, 2011[14]
- Aquila Resources/HudBay Minerals: Back Forty Project (underground and open-pit zinc and gold mine), permit application anticipated early 2012
- Gogebic Taconite: (open pit iron ore mine)
- PolyMet Mining Company: NorthMet (open pit copper mine)
- Twin Metals (Duluth Metals & Antofagasta): Nokomis Project (underground copper, nickel and PGM mine)
- Franconia Minerals: Birch Lake Project (underground copper, nickel, PGM mine)
- Numerous exploration and development projects in Ontario

Numerous other companies have been actively exploring the region for well over a decade; these exploration projects are primarily focused on locating profitable platinum group metal (PGM) deposits, as well as copper, nickel, uranium, iron ore and other mineral resources. Companies with presumably viable projects, such as Aquila/HudBay and Kennecott have additional exploration projects in the region. Aquila is exploring the Reef deposit, in northeastern Wisconsin, while Kennecott has been actively exploring the Tamarack deposit, in eastern Minnesota, as well as projects spanning a rough horizontal band from its Eagle Mine location, in Marquette County, Michigan, to the western Upper Peninsula.

Many of these projects are located directly next to or underneath valuable freshwater resources in the region:

- In Minnesota: Franconia Minerals' Birch Lake project is directly underneath the eponymous Birch Lake, which feeds into the Boundary Waters Canoe Area Wilderness. The Twin Metals project is even closer to the Boundary Waters, while PolyMet's NorthMet project would affect both the Boundary Waters' system and Lake Superior.

- In Michigan: The Back Forty project is located on the banks of the Menominee River, while the ore deposit extends underneath the river. Kennecott's Eagle Mine would operate underneath the Salmon Trout River, while its proposed ore hauling road (County Road 595) would cross numerous rivers and creeks, including the Yellow Dog River, a National Wild and Scenic River. Kennecott's ore processing mill would potentially affect the Escanaba River watershed, part of the Lake Michigan basin.

[14] Broman, 2011

Orvana's Copperwood Project is located within a couple miles of Lake Superior, the Presque Isle River, and the Black River.

- In Wisconsin: Gogebic Taconite's project would affect the Bad River watershed, where wild rice is a critical part of the local economy.

Mining and Global Warming[15]

In general, the mining industry has been slow to recognize the necessity of adapting to global climate change. A majority of industry representatives seem hesitant to realize that adapting to climate change should be a major operational concern, especially as it relates to post-closure activities.

A failure to adapt to projected climatic changes will likely further expose the industry to negative economic effects, harm its public image and, more critically, increase pressures on the environment and human society. A lack of adaptation will also likely have negative economic effects on communities dependent on mining employment. Indeed, according to the Stern report on the Economics of Climate Change, failing to proactively plan for global climate change could cost the global economy 20% of GDP by 2050.[16]

Mining, like forestry, agriculture, and fishing, is a primary industry heavily dependent on the natural environment for its existence. Despite its susceptibility to global climate change, little research has been conducted on the relationship between mining and global warming. While global warming is slowly becoming a major concern for the mining industry, little has been done in the way of adapting to or planning for future changes, largely due to a perceived uncertainty in specific projections for regional and local climate change, as well as short-term costs involved in proactively adapting to these changes. As a result, most responses to negative climate change effects have involved reactively mitigating effects, rather than adopting preventative measures. In Canada, industry measures have largely been limited to reducing greenhouse gas emissions and improving energy efficiency.

Political responses to global warming appear to worry the industry most, especially heavy greenhouse gas emitters, like coal and smelting operations. Legislation limiting greenhouse gas emissions can harm companies that have done little to adapt to these changes. Efforts such as the Kyoto protocol and cap-and-trade legislation have been actively opposed by emissions-heavy industry.

Yet already the industry, and Rio Tinto – because of the company's global reach – in particular, has been seriously affected by global warming. In 2006, a study conducted by the banking and investment company Citigroup said that mining

[15] Unless otherwise noted, this chapter sourced from: Pearce, et. al., 2010; Pearce, et. al., 2009; Ford, et. al., 2007
[16] Stern, 2007

giants, such as Rio Tinto and BHP-Billiton, were among Australian companies most at risk from the effects of global warming.[17]

In Queensland, Australia, Rio Tinto's massive coking coal operations were forced to close for weeks, and incurred severe property loss, due to torrential rainfall and resulting flooding in 2010.[18] In the Arctic, the company's diamond mining operations rely on cold winter weather in order to transport fuel, materials, and product on seasonal ice roads; these roads have faced pressures from a rapid increase in temperatures that has shortened the ground transportation season in many areas.

There are largely four areas where climate change is already affecting mining operations, and is projected to continue to have an increasingly negative impact:

- Transportation (especially road and rail): Seasonal ice roads in the Arctic are under pressure from increasing temperatures. However, transportation routes elsewhere are also prone to weakening, and ultimate failure, as the result of an increased frequency in extreme weather events and drastic variations in climate. The City of Greater Sudbury, an area heavily dependent upon the metal mining and smelting industry, has recognized "potentially major vulnerabilities" in road drainage infrastructure and the need to accommodate regional climate change projections into transportation planning.

- Mining infrastructure: Mining facilities are likely to be increasingly affected by climate changes such as permafrost thaw, rising temperatures, altered ground and surface water levels, changes in ice cover, and extreme precipitation events.

- Mineral processing: Mineral processing, like much mining, especially metal mining, is heavily dependent upon water resources. Water scarcity as the result of increasing temperatures, and resulting evaporation, as well as periods of drought can limit production rates and limit the ability to suppress dust and cover tailings. Passive wetland filtration systems would also be affected by the drying of ground cover that exposes metals and contaminants that would otherwise be "locked" under water.

- Mining, post-closure: Tailings ponds, waste rock piles and other mine infrastructure left at the site following closure can fail if not designed to withstand changing climatic conditions long after mine operations cease. Little research appears to exist on effectively closing mine operations while considering long-term climatic changes.

Effects of regional climate change in Marathon, Ontario[19]

[17] Marx, 2006
[18] Bartholomeusz, 2010
[19] This subsection sourced from: Brown, et. al., 2006

While the effects of climate change on mining operations elsewhere, including in the Lake Superior region, are not as pronounced as in the Arctic and other more extreme environments, they are being noticed, even if measures to adapt to these changes have yet to be seriously implemented, or even considered.

In 2005 a number of mines in the Marathon, Ontario region (northeast Lake Superior) were forced to reduce intakes of water and find alternative sources after severely dry and warm weather reduced water levels in the watershed.

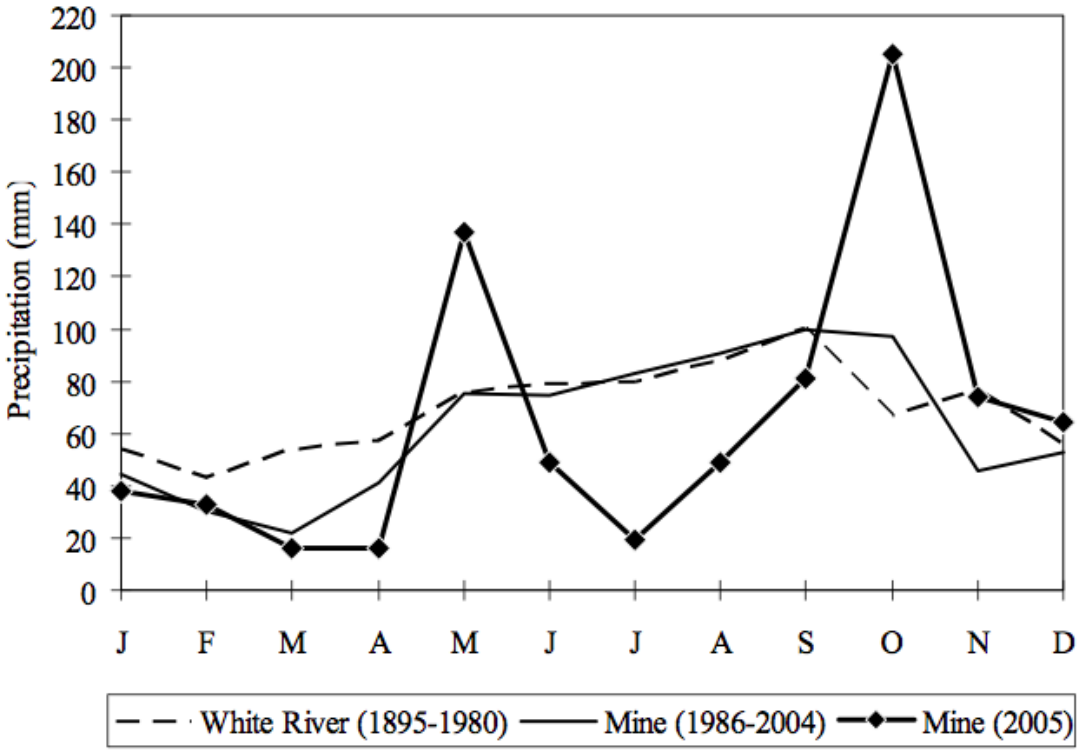
The Ontario Ministry of the Environment stipulates that minimum water levels downstream of three Hemlo mining operations must be maintained based on the Cedar Creek's 7-day flow with a return period of 20 years. The three Hemlo mines (as well as Newmont Canada's Golden Giant Mine) draw water from Cedar Creek for process and drinking water.

While major rain events were experienced in the area in May and October of 2005, warm, dry summer weather caused water levels in nearby Theresa Lake to drop to its lowest recorded level – 38.6% of the lake's capacity. Watershed-wide, water levels were reduced and the minimum stream flow limit for Cedar Creek was nearly reached numerous times.

All three Hemlo mining operations responded by reducing intakes of water from Cedar Creek. Response steps included recycling of process water; introduction of alternative water sources for emergency use; building of infrastructure to move treated water from a tailings pond to the David Bell Mine for underground usage; and utilizing water from pits at the Williams and Golden Giant mines.

According to researchers, historical climate data show that monthly precipitation is more sporadic in this one mining area.

Torrential rains in August 2008 forced Sherwood to release about 350,000 cubic meters of untreated water from its wastewater treatment plant into the Yukon River. The release dramatically exceeded provincial water quality standards and also washed out four kilometers of Sherwood's mine haul road. The company, after failing to make changes, was forced to again release untreated water into the Yukon River in 2009. In the summer of 2009 Sherwood applied to the Yukon Water Board for an emergency permit to discharge 10,000 cubic meters of runoff and waste water every day in order to prepare for potentially heavy summer rains. In 2010 the subsequent mine owner, Capstone Mining Corporation, requested permission from the water board to discharge more untreated waste water into the river.



Historical vs. 2005 equivalent precipitation in the Hemlo mining area; Brown, A.; et. al., 2006

Other problems with inadequate mine planning

In most cases mines have been constructed based upon projections that local climatic conditions will remain stable during the life of the mine and for years following closure. Many of these mines plan for a once in 100-years flood event. As a result, an increase in extreme weather events not accounted for can overwhelm mine infrastructure, especially tailings and other waste rock impoundments and wastewater treatment and discharge systems. Such scenarios most often lead to releases of untreated or partially-treated water containing acidic mine drainage, heavy metals, and other contaminants that enter ground and surface water, affecting aquatic species, such as fish, as well as local drinking water supplies.

Indicative of the mining industry's penchant for generally managing extreme climatic events as they happen, rather than proactively planning for them, is the Sherwood Copper Corporation's Minto copper-gold mine in the Yukon Territory. The Minto mine was not designed to accommodate global warming projections and, even after failures of mine infrastructure, the company neglected to adapt to climatic changes [*see sidebar*].

Regulation of and industry attitudes toward global warming

While global warming is increasingly being recognized as a concern affecting mining operations, a persistent negative attitude and ignorance toward established climate science could represent a major impediment in holding the mining industry to account regionally. Indeed, some industry stakeholders still argue that humans are not contributing substantially to global warming. General knowledge of climatic change, its severity, and imminence is limited in the industry, especially as it relates to regional changes. Even mine plans that assess climate change often do not translate into local mine employees having knowledge on the subject.

A number of trade groups, including the International Council on Mining and Metals, and many individual companies, now generally recognize global warming as an economic and environmental issue.[20] While companies like Rio Tinto pay some attention to global warming and the need to reduce greenhouse gas emissions and improve energy efficiency[21], this visible attention rarely seems to trigger comprehensive reviews of how global warming will create tangible, on-the-ground changes to existing and abandoned mining operations, and what options exist to best avoid negative consequences. As a whole the industry has yet to implement even those measures that prove economically and environmentally beneficial regardless if any future climate changes occur or not.

There is currently no known regulation specifically requiring companies to consider global warming in mine planning, operation, and closure in the Great Lakes. Even globally, measures in place relating to adapting to climate changes are largely voluntary. This lack of clear regulatory direction, along with antiquated attitudes that global warming presents only minor problems and are too costly to remedy, could mean that adaptations to the effects of regional climate change may continue to be limited to reactive measures that attempt to correct pollution problems after-the-fact, rather than during the planning stages.

In this paper's previously noted limited review of local mining industry perceptions of global warming, communication that was achieved reflected broader industry perceptions noted in other research. Communication here was initially openly hostile to suggestions that mining is a leading culprit in creating global warming, that anthropogenic global warming even exists, and that industry should adapt to projected changes anymore than individual citizens.[22]

It would be interesting to obtain the perspective of a number of regional industry stakeholders involved in longer-term projects, such as Cliffs Natural Resources' iron mining complex in central Marquette County, and contrast this perspective with the perspectives of potential operators of short life span projects, such as Kennecott's Eagle Mine. Many new exploration projects in the Great Lakes

[20] ICMM, 2011
[21] Rio Tinto, 2011
[22] Gardner, 2011

region are locating ore bodies that would likely have a brief operational life span. This short duration may make it more difficult to encourage industry stakeholders resistant to progress and change to consider the effects of global warming as effects are often perceived as being of little near-term significance.

Global Warming and Kennecott's Eagle Mine

The role increased mining could play in further exacerbating the effects of regional climate change in the Great Lakes is clear. Many new mining development projects would take place in areas with high sulfide content and abundant water. The introduction of acidic mine drainage and heavy metals into local ground and surface water from mining would be an added stressor on hydrologic systems already affected by acidic precipitation and the concentration of heavy metals and acidic water caused by reduced water levels.

Unfortunately, for the purposes of influencing state and federal regulators, scientific interpretations of the effectiveness of Kennecott's wastewater treatment plant, its treated wastewater infiltration system (TWIS), and other elements of the company's Eagle Mine design relating to water quality protection differ dramatically.

As expected, Kennecott's own interpretations, as well as those outsourced by the company, tend to be quite optimistic, placing mine water inflow rates, the ability of the system to handle heavy precipitation and snow melt, as well as difficult-to-remove contaminants, and other scenarios, well within the range its wastewater treatment plant can handle.[23]

[23] Attempts to convey questions to the company for the purposes of this review were consistently rebuffed by Kennecott's media relations personnel. In light of this interaction it is unlikely, but possible, that even a marginally constructive conversation with knowledgeable company staff may help in efforts to better understand the extent to which the company's current wastewater treatment system design (changed as recently as August 11, 2011) will be protective of ground and surface water quality.

According to reviews performed by an independent contractor working for the EPA during review of the Eagle Mine's TWIS[24], the facilities were expected to handle frequent precipitation events. Additional reviews by Keweenaw Bay Indian Community and National Wildlife Federation show that there are numerous concerns needing to be addressed, particularly in regards to water levels, preparedness for extreme weather events, etc. To further confuse the issue, much of Kennecott's original Eagle Mine project plan has been changed from the original[25], and independent reviews likely have not been performed on these new changes.

Nonetheless, below are some concerns highlighted by legal opponents of Kennecott's original Eagle Mine plans that could potentially be further exaggerated by the effects of regional climate change[26]:

- Kennecott underestimated the drawdown of wetlands at the mine site, which could be up to 12'.
- There will be reduced flow of the Salmon Trout River.
- Highly acidic drainage will lead to increased toxicity levels of heavy metals and increased acidification, especially during low stream flow in summer/fall.
- Inflow of mine water due to fractures in bedrock and the mine's crown pillar is underestimated and will overwhelm the wastewater treatment plant.
- A thick crown pillar means there will be more reactive ore exposed to water entering the mine workings.
- Concentrations of sulfates and metals that exceed water quality standards exist in the underground mine.
- Leakage of acidic and metal-contaminated water from the temporary development rock storage area (TDRSA) will enter ground and surface water.
- The wastewater treatment plant was not designed to accommodate extreme precipitation events followed by normal/average precipitation pollution from mine, coarse ore storage areas, fine ore bins, etc.

[24] Cadmus Group, 2009 & 2010
[25] Kennecott, 2011
[26] The following from: NWF, 2007; Maest & Prucha, 2008 & 2009; Maest & Ritter, 2007; Wittman Hydro, 2007

- More surface water impacts than predicted to the East Branch of the Salmon Trout River because groundwater flow to seeps and springs will be quicker than anticipated.

- Development rock, wastewater, reverse osmosis concentrate, contact water basin solids, etc., will be used in the backfill of the mine and will present heavy metal and acid mine drainage pollution concerns.

EPA review of the Eagle Mine[27]

It may be useful to review some of the work conducted by the Cadmus Group, which acted as an independent consultant to the EPA on issues surrounding Kennecott's wastewater treatment and discharge systems. As the only truly independent reviewer of this information (presumably not under contract with an entity having a stake in the eventual outcome of the mine permitting process) the Cadmus Group's review and recommendations are noteworthy.

A report from the Cadmus Group to the EPA, dated March 2010, contained a vague reference to the potential for illegal releases of mercury from Kennecott's wastewater treatment plant: ". . . the study [by a consultant to Kennecott] revealed a possible issue with mercury that should be further examined." The Cadmus Group cited "laboratory error" and the lack of a treatability study at the time Kennecott submitted its Underground Injection Control permit to the EPA, as reasons for the discrepancy.

The Cadmus Group also pointed to the potential for certain contaminants that are difficult to remove during the wastewater treatment process, such as boron, to escape state regulatory notice:

> "The MDEQ discharge permit for the WWTP effluent does not have numeric effluent limits for key contaminants that are difficult to remove. The MDEQ discharge permit limits are outside of federal authority; however, Cadmus recommends that EPA consider including limits in their permit for the federally-regulated contaminants."

These suggestions were never able to be acted upon however. KEMC withdrew their application for a permit to discharge wastewater into the ground under the Underground Injection Control program. Additionally, the Cadmus group determined the design to be consistent with existing state law.

It is predicted that there will be an increase in precipitation, although summer and fall months are expected to be drier than usual. If looking at the effects of precipitation and runoff on the Eagle Mine's wastewater treatment plant, the effects of a more pronounced spring runoff (freshet) and extreme rain events seem to be the most likely scenario for increased stresses on the ability of the wastewater treatment plant to handle temporary excess capacity.

[27] Unless otherwise noted, this subsection sourced from: Cadmus Group 2009 & 2010

The Cadmus Group considered it an unlikely possibility that mine inflows, combined with heavy precipitation and/or snowmelt, would overwhelm the capacity of the wastewater treatment system to store and treat wastewater:

Part 632 and the Eagle Mine

While planned-for scenarios do look better on paper than in the real world, it seems that community's ability to influence state and federal regulators to require changes to Kennecott's wastewater treatment system to accommodate the projected affects of regional climate change may be challenging because these specific effects are still relatively unclear, Kennecott has already obtained relevant mining permits, and because the company has already designed and is constructing its wastewater treatment system to handle rainfall and snowmelt in excess of current regulatory requirements.

Interestingly, Part 632 does require a mining applicant to consider the effects of extreme weather events in its mining plan as it relates to the potential for acid mine drainage draining from reactive ore, waste rock, overburden, and tailings at the mine site, the primary environmental and health concern of metallic sulfide mining:

> "The treatment and containment plan required. . . shall account for the volume, rate, and movement of leachate that may be generated, and the influence of weather on the generation of leachate, including any adverse impacts from severe or extreme weather events."[28]

While regulatory guidelines have been followed, the law does not require implementation of direct climate change considerations. A failure to proactively adapt to the projected effects of climate change have been shown to have the potential to create pollution problems during mining operations and following, regardless of how well a company designs its project to conform with existent regulatory requirements.

Water quality is already a severe mining problem[29]

It is instructive to note that a study performed by Kuipers & Associates and Buka Environmental shows a general failure of mining companies to accurately predict water quality damages in pre-mining environmental impact statements.

At the Zortman-Landusky open pit gold mine in Montana, major surface water pollution was caused by multiple precipitation events exceeding once in 100-year storm event criteria:

> **"**Surface water impacts were associated with storm events exceeding the 100-year design criteria. During the past 25 years, at least four storm events have exceeded the predicted 100-year storm event. In addition to

[28] MDEQ, 2006
[29] This subsection sourced from: Kuipers, Maest, et. al., 2006

> improper design criteria for the mine units and the lack of run-on ditches to prevent upgradient additions to storm events, this suggests that the extent of hydrologic characterization in terms of storm frequency and strength (i.e. amount of rainfall) prediction was inadequate to properly design mine units."

According to the report mines can lessen impacts to water quality by offering conservative assessments of expected water quality and quantity:

> "Hydrological characterization failures are most often caused by over-estimation of dilution effects, failure to recognize hydrological features (e.g., springs and shallow or perched groundwater) and underestimation of water production and stormwater quantities. Requiring adequate hydrological investigations as well as making conservative assumptions about water quality and quantity can address hydrological failures."

Eagle Mine's crown pillar[30]

One serious concern related to Kennecott's Eagle Mine has been the possibility, however remote, for the mine's crown pillar to collapse or seriously fracture. While Kennecott has offered assurances it will continuously monitor the area for ground subsidence, information obtained, and allegedly suppressed, by the Michigan Department of Environmental Quality (DEQ) from an independent consultant raises serious concerns about the stability of the crown pillar.

In a series of reports David Sainsbury, a rock mechanics consultant hired by the DEQ, maintained that Kennecott's mine plan, especially relating to the integrity of the crown pillar, was "not considered to be defensible" and does "not reflect industry best practice." Even in a final report on the subject Sainsbury maintained Kennecott's mine could collapse, but recommended regular monitoring of the site and a thicker crown pillar as potential solutions to the problem.

A crown pillar collapse or serious fracturing would dramatically increase the rate at which ground (and possibly surface) water enters the mine workings and, in the event of a collapse, could have serious environmental consequences for local surface water in the vicinity of the mine site.

Potential water protection action at the Eagle Mine

Communities may want to seek further information as to what contaminants are currently addressed under state monitoring requirements. If certain contaminants that are difficult to remove lack appropriate limits or regulation by the state, as the Cadmus Group suggests, this may be an issue to pursue in order to prevent as much inflow of heavy metals and other contaminants as possible into local ground and surface water.

[30] This subsection sourced from: Parker, 2010; Sainsbury, 2006 & 2007

Additionally, concerns with filling abandoned mine workings, post-closure, with treated waste and other materials have yet to be fully addressed.

Also, the potential for acidic mine wastes and heavy metals to leach into groundwater through the TDRSA exist.[31] These wastes will be separated by a composite liner system consisting of clay and synthetic membrane layers. Liquid wastes making their way through this system are intended to be collected by a leachate collection system. However, there is the potential for these systems to fail. Consistent and accurate monitoring of groundwater areas downgradient of the TDRSA would be essential to addressing contamination problems as quickly as possible after they arise. While this type of monitoring would be very unlikely to lead to closure of the mine, it would (along with other monitoring) help establish culpability in possible efforts to require company payment for eventual mine clean-up.

Regional climatic projections of lower surface water levels and negative affects on migratory birds may also impact threatened species such as the Coaster brook trout and the Kirtland's warbler. The Salmon Trout River houses the last naturally spawning population of Coaster brook trout on the southern shore of Lake Superior.

It is important to understand that any pollution-related concerns with mining in relation to regional climate change are concerns that should already be considered to be potentially serious and common mining related problems.[32] While global warming's regional effects may exacerbate pollution problems, these largely water-pollution related problems should already be of significant enough concern that addressing them even without considering regional climate change predictions would in itself be a prudent course of action.

[31] Wittman Hydro, 2007
[32] Chambers, 2011

Recommendations

Monitoring of groundwater and surface water areas downgradient of the treated wastewater infiltration system (TWIS), the temporary development rock storage area (TDRSA), contact water basins, and the mine workings themselves is initially the most logical next step in assuring the watershed is protected. A productive action for mitigating the effects of specific mining projects may be for communities to secure long-term funding in order to perform this monitoring work and to work with regulators to ensure adequate access to relevant monitoring locations during mining operations and post-closure. While such monitoring is unlikely to lead to mine closure, consistent and accurate monitoring could have the effect of pinpointing culpability in the event that pollution from the mine enters the area water supply during mining or post-closure.

It would likely be even more useful for groups to work with regulators (along with other interests, including tribal entities) to ensure a more active and influential role in determining appropriate technologies, monitoring regimes, and best practices to employ at potential future mining operations or expansions, such as the Eagle East exploration site immediately east of the Eagle Mine, and potential development projects further west.

While difficult, reform of Michigan's mining laws (including "Part 632") to consider implications of global warming might also be effective, and a longer-term, way of achieving desired changes. But, it is important to consider mining companies can fairly easy apply pressure on legislators to reform mining laws too, or deploy vast resources in efforts to reverse legislative gains made by industry critics.

By 2005 in the Kennecott Eagle Mine battle, citizen efforts to require the company to fund a regional hydrology study were initiated that garnered support from a number of local units of government, including the Marquette County Board of Commissioners and a number of local townships, as well as the Michigan Department of Environmental Quality, and former Michigan Senator Mike Prusi.[33]

There is still a need for this type of study to determine the potential effects from a hardrock mining district in the western Upper Peninsula. Communities may be interested in reviving once-popular efforts for a hydrology study in order to protect water quality in Lake Superior and beyond Kennecott's Eagle Mine.

Efforts to stop construction of Kennecott's planned "County Road 595" ore hauling road that would start at the Eagle Mine and end at the company's Humboldt processing facility should also be pursued. As the EPA suggested in communication related to this road (formerly called "Woodland Road") in March 2010[34], this ore hauling road would likely increase the potential for additional

[33] Marquette County Board of Commissioners, 2005
[34] EPA, 2010

mining projects in the area, increasing stresses on water quality in multiple watersheds and, ultimately, Lake Superior. Additionally, if global warming will have a regional effect of reducing the number of wetlands available for aquatic species and waterfowl to live and reproduce, the ore hauling road's immediate impact on high-quality wetlands and resulting impacts on surface waters from increased logging and mining should make limiting the environmental effects of this road a priority. A thorough review of the planned crossings for County Road 595 should commence, as increases in seasonal precipitation could affect the road's influence on surrounding waterways.

Municipalities should consider how the availability of drinking water could be impacted if mining operations draw down water levels in conjunction with localized drought conditions. Communities would be wise to talk with their elected officials about this concern and make it a key priority in planning how their resources will be protected should a mining operation start in their area.

Additionally, communities have the option of working with the mining company itself to implement several safeguards:

- Develop a standard for downstream water levels
- Design steps for reducing water intake should drought conditions occur
- Have company run modeling with worst case scenario climate change predictions

Further, with the effects of global warming being felt regionally, environmental protection is evolving to take a broader global view. In the past, environmental efforts largely revolved around protecting isolated tracts of wilderness, bodies of water, or wildlife species. Global warming is quickly making it necessary for any environmental group to consider destructive factors originating hundreds, or thousands of miles away as a key consideration in efforts to protect local and regional ecosystems.

Conclusions

Anthropogenic global warming has been established, unequivocally, as a scientific fact. The Earth is currently warming at an unprecedented rate and is expected to continue to warm well into the future. This unnatural warming, largely caused by the burning of fossil fuels, has created regional climatic shifts that include extreme weather events, such as alternating periods of extreme droughts and heavy precipitation.

Even meaningful efforts to drastically reduce human-caused greenhouse gas emissions now will not prevent significant warming in the future. However, inaction, or inadequate action, will more than likely lead to warming at a level

that we, and the natural environment, may not be able to withstand in a way that supports current life on this planet.

In the Great Lakes global warming is already making the regional climate warmer and wetter, with extended dry periods in summer and fall, and wetter and warmer periods in winter and spring. An increase in extreme precipitation events is being noticed at the regional level, while spring melts are occurring earlier than in the past.

While little research has been done on how these global and regional changes affect mining operations, the industry, although reluctant to recognize established global warming science, is beginning to come to terms with the effects new climatic changes are having on profit margins. While many industry stakeholders still view global warming as a minor, and distant, problem, some mining operations have already been noticeably affected by these changes, including mining areas in the Lake Superior region.

Currently, regulation is not known to exist in any Great Lakes' states that requires mining companies to include regional climatic projections in mining plans. In fact, globally most such action is limited to voluntary compliance by industry. As noted earlier, the mining industry is already failing to adequately cope with new climatic changes. A similar failure to do so in the northern Great Lakes could have dire consequences for the region's still high-quality water supply, human health, and economy. Clearly, regulation should address this need.

In relation to the development of Kennecott's Eagle Mine, which this report is largely limited to, it appears the opportunity for interested citizen stakeholders to influence regulatory decision-making related to the construction of the mine (specifically to wastewater treatment components of the mine) is limited. This, of course, does not prevent interested stakeholders from consistently monitoring Kennecott's Eagle Mine during operation, closure and post-closure and making attempts to ensure that regional climatic projections are considered in other potential mining operations in the watershed and surrounding area, including mining and transportation expansions to Kennecott's Eagle Mine project.

In closing, climate change is an issue that has not been entirely accepted by the global community as an immediate threat. Although enough research exists to support the relationship between increased burning of fossil fuels and changing weather patterns, political obstacles cloud the discussion. However, it is imperative for communities to consider climate change in their operations and planning. In particular, a new streak of mining operations in the Great Lakes basin have the potential to decrease the region's ability to cope with climate change by adding stressors to already stressed environments. Steps can be taken to reduce these stressors and it is the responsibility of local communities to ensure business and government are on board.

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