

# **Follow-Up Report: Acid Mine Drainage and other Water Quality Problems at Modern Copper Mines Using State-of-the-Art Prevention, Treatment, and Mitigation Methods**

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## **Introduction**

In 2014, Northeastern Minnesotans for Wilderness asked the Center for Science in Public Participation (CSP2) to assess current state-of-the-art mining practices and technologies to determine whether it was possible at this time to eliminate risks to water quality and other natural resource values in the immediate and downstream areas of sulfide ore mines, should they be developed next to the Boundary Waters Canoe Area Wilderness (BWCAW) and along lakes and rivers that flow directly into the BWCAW. That report examined several areas of mining practice and technology and concluded that while it was possible to reduce the risk of water contamination, it was not possible to eliminate the risks to local water resources such as lakes, rivers, and groundwater, and waters that flow to the BWCAW. In addition, the track record of copper mines in North America for containing contaminants, and even for preventing large-scale releases of contaminants, suggests that these events must be carefully considered in analyzing risk to water resources, especially risk to a water-intensive and significantly interconnected Lakeland national wilderness area.<sup>1</sup>

Campaign to Save the Boundary Waters asked CSP2 to follow-up on that report to answer new questions and to provide more detail about mitigation and related matters. Assumptions from Dr. Chambers' 2014 Report that continue to apply include, but are not limited to:

The report is focused on copper mining, and the water quality problems that are typically encountered in the mining and concentration of copper ores. Descriptions of mine processes assume current best practices for environmental protection. Copper mining and concentrating operations are assumed to use either underground and/or open pit mining and copper concentration via flotation processing. It is further assumed that the ore being mined comes from a disseminated orebody with little acid-buffering capacity, generally leading to the need for water treatment if a discharge is required in a net precipitation area, such as northeastern Minnesota. Waste disposal is also an important issue to consider, since a significant portion of the mining waste is potentially acid-generating. Mining waste typically constitutes over 99% of all the material that is mined, and will remain permanently on the minesite.<sup>2</sup>

Like its predecessor report, this report draws heavily on existing public sources of information on copper deposits and copper mining technologies. As such, this is not an original piece of

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<sup>1</sup> See Dave Chambers. The Potential for Acid Mine Drainage and other Water Quality Problems at Modern Copper Mines Using State-of-the-Art Prevention, Treatment, and Mitigation Methods, A Report by the Center for Science in Public Participation November 20, 2014.

<sup>2</sup> *Id.*

research, but a compilation of information from a number of existing sources, which are referenced in this document.

## Background

Northern Minnesota has a history of iron mining. Today the iron ore mined is almost entirely taconite. In recent years, minerals exploration has moved from iron mining to sulfide deposits containing disseminated copper and nickel. These are low-grade, high volume deposits. The change in mining brings with it a change in threats posed by mining to human health and the environment - notably to water quality. This form of mining has never been demonstrated or conducted in the Boundary Waters area or elsewhere in Minnesota.

On December 14, 2016, the US Forest Service declined to renew the only two federal mineral leases in the watershed of the BWCAW. On January 13, 2017, the Forest Service published a Federal Register notice of its application to the Secretary of the Interior to withdraw from mineral leasing 234,328 acres of federal land minerals in the BWCAW watershed. This proposed Forest Service action was founded on the recognition that sulfide-ore copper mining in the headwaters would likely imperil the BWCAW and that permitting such mining activities would violate the Forest's statutory obligations and the requirements of the BWCAW. The Forest Service stated:

As previously noted, the 234,328 acres of Federal land for which the Forest Service requests withdrawal are located within the Vermillion and Rainy Headwaters sub-watersheds of the Rainy River watershed in the Superior National Forest and are adjacent to the BWCAW and MPA. There is known interest in the development of hardrock minerals that have been found-and others that are thought to exist in sulfide-bearing rock within this portion of the Rainy River watershed. **Any development of these mineral resources could ultimately result in the creation of permanently stored waste materials and other conditions upstream of the BWCAW and the MPA with the potential to generate and release water with elevated levels of acidity, metals, and other potential contaminants.** Additionally, any failure of mitigation measures, containment facilities, or remediation efforts at mine sites and their related facilities located upstream of the BWCAW and the MPA could lead to irreversible impacts upon natural resources and therefore, render the Forest Service unable to meet the purposes for the designation of the BWCAW and the MPA specified by Sec. 2 of Pub. L. 95-495, 92 Stat. 1649 (1978). **These concerns are exacerbated by the fact that perpetual maintenance of waste storage facilities along with the perpetual treatment of water discharge emanating from the waste storage facilities and the mines themselves would likely be required to ameliorate these adverse effects, yet it is not at all certain that such maintenance and treatment can be assured over possibly infinite timeframes.** [Emphasis added]<sup>3</sup>

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<sup>3</sup> Application for Withdrawal, Superior National Forest, Cook, Lake, and Saint Louis Counties, Minnesota. January 12, 2017. Available at: [http://a123.g.akamai.net/7/123/11558/abc123/forestservic.download.akamai.com/11558/www/nepa/105871\\_FSPLT3\\_3924868.pdf](http://a123.g.akamai.net/7/123/11558/abc123/forestservic.download.akamai.com/11558/www/nepa/105871_FSPLT3_3924868.pdf).

Given the poor historical record of sulfide-ore copper mines/mining industry to prevent spills, leaks, and contamination to natural resources, sulfide-ore copper mining in the BWCAW watershed would pose a significant threat of contamination of the water and other natural resources – and the diminishment of the wilderness character and recreational values of the BWCAW.

## General Sources of Mine Contamination

Mines create many sources of contamination. These have been extensively documented and are only briefly summarized here. Proximity to surface water and ground water is associated with higher rates of acid, heavy metals, and other contamination of those waters.<sup>4</sup>

**Waste Rock.** Ore material that has insufficient mineral value to be processed economically is removed as waste rock to expose economically processable ore. The primary environmental risk associated with waste rock is through the oxidation of waste-rock material and subsequent seepage, which would result in contamination of either groundwater or surface water.<sup>5</sup> The oxidation of sulfide minerals produces sulfuric acid, which when wetted can dissolve and mobilize heavy metals and related elements from associated sulfide, silicate, and carbonate minerals.<sup>6</sup>

**Pits/Underground Workings.** Ore is accessed/removed by first removing waste rock and then removing ore - most commonly either via an open pit or underground workings. Underground and open pit mine workings can be fractured by blasting and mining activities and therefore can have extra spaces for air and water to mix with minerals to form acid mine drainage or other compounds - and to convey water and soluble contaminants through these fractures. As a result, mine workings can act as both sources and conveyances for contaminants as water collects in and/or passes through contaminated materials and leaches/transport contaminants. Pits also intercept/draw-down/alter surface and ground water patterns/flows and volumes. Underground mine facilities are more out of sight which can hide their impacts to water quality and water patterns and volumes - but these impacts still occur. Underground mine facilities also can cause subsidence and related surface deformations.<sup>7</sup>

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<sup>4</sup> See Maest, A.S., Kuipers, J.R., Travers, C.L., and Atkins, D.A., 2005. Predicting Water Quality at Hardrock Mines: Methods and Models, Uncertainties, and State-of-the-Art. Available at: [http://www.ceaa-acee.gc.ca/050/documents\\_staticpost/cearef\\_3394/hearings/SM09.pdf](http://www.ceaa-acee.gc.ca/050/documents_staticpost/cearef_3394/hearings/SM09.pdf) and Kuipers, J.R., Maest, A.S., MacHardy, K.A., and Lawson, G. 2006. Comparison of Predicted and Actual Water Quality at Hardrock Mines: The reliability of predictions in Environmental Impact Statements. The authors compared EIS water quality predictions with actual ground and surface water pollution to conclude that most EIS' underestimate pollution and the ability to mitigate pollution.

<sup>5</sup> Seal, Robert R, Geologic and Environmental Characteristics of Porphyry Copper Deposits, with Emphasis on Potential Future Development in the Bristol Bay Watershed, Alaska, US Geological Survey, April 2012.

<sup>6</sup> *Id.*

<sup>7</sup> Miner's Lake, near Ely, MN, was created when underground workings collapsed. See e.g. [http://www.virginiamn.com/mine/pioneer-mine/article\\_319b5264-f967-11e2-abc4-0019bb2963f4.html](http://www.virginiamn.com/mine/pioneer-mine/article_319b5264-f967-11e2-abc4-0019bb2963f4.html)

**Processing and Mill Facilities.** Ore is processed and concentrated by various on-site methods. The primary risk associated with milling and processing facilities is leaks and spills. Because the Duluth Complex minerals are low grade it likely would be necessary to process the ore on-site before shipping materials offsite for further concentrating/smelting. This is proposed at the NI 43-101 for the Twin Metals Minnesota series of mines. Processing facilities house and employ various chemical and physical methods that include floatation of finely ground ore with mixes of hazardous and toxic materials known as beneficiation chemicals, in a process that leaves behind significant wastes (tailings). Ore is the valuable commodity at a mine so mines are designed to contain these materials/facilities, but spills and leaks still occur that can contaminate surface and groundwater. After mine closure, economically valuable processing/milling machinery and components are generally removed, and the remaining machinery/facilities/foundations are left in-situ or buried, depending on the site's closure plans.

**Tailings.** Tailings impoundments/ponds are constructed facilities intended to contain tailings and waste materials forever. They can be designed to contain both wet and dry wastes. They generally incorporate a combination of depressions (excavations) and berms that “dam” tailings materials and are often constructed of non-reactive waste rock, compacted earth, and/or synthetic liners. The primary risk associated with tailings facilities is leaks to surface or ground water resources. These can occur from the facilities themselves (such as cracks or piping through materials or liner rips/punctures); from pipelines, conveyors, or other transport mechanisms that will move tailings and wastes from the processing facilities to their storage or treatment facilities; or from the final repositories (or holding facilities in the event that materials will later be deposited underground or in pits). These processing wastes generally contain hazardous and/or toxic products and byproducts.

**Tailings Storage.** Tailings storage facilities act as contaminant sinks and therefore are a special risk for release. In cases where tailings are processed to produce “dry” tailings, those tailings, if not maintained as dry, may leak and/or seep contaminants into or through adjacent surface and ground waters. Acid-producing tailings may be kept under a layer of water to prevent oxidation to sulfuric acid, but this then poses the in-perpetuity risk of failure, either through collapse of the structure containing the water, loss of the water cap itself, or leaking/seeping/leaching.<sup>8</sup> Any failure that exposes acid or acid generating materials<sup>9</sup> to air and water may cause leaching and contamination. Mischaracterization of materials (missing acid generating or leaching potential), unintentional exposure to water (or water and air), mishandling of materials, or imperfections or upsets in transport/storage facilities all can lead to leaching and water and/or soil contamination.

**Materials transportation.** Materials must be transported on-site between major facilities (waste rock from the pit to waste rock piles; ore to the mill; tailings to the tailings impoundment;

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<sup>8</sup> If tailings are disposed in the mine's pit with the intent of being kept underwater there is always the possibility that the tailings could leach contaminants into the pit's waters and any waters to which that water flows. Further, if the tailings are acid producing then during the period it takes for the pit to fill with water (which may take years) and if the water level fluctuates to expose the acid producing tailings to air then these tailings could produce AMD which could leach or flow from the pit.

<sup>9</sup> See Environmental Protection Agency (EPA), 1994. Technical Document: Acid Mine Drainage Prediction. Office of Solid Waste, Special Waste Branch, Washington, DC.

etc.). This can occur by many methods such as slurry, conveyor, truck, tunnel, or rail. Leakage during transport can create linear zones of soil and water contamination and accumulations due to major spills or long steady accrual of contaminants that can cause localized problems and/or further leach/transport pollutants elsewhere in the environment. As Gestring demonstrated, accidental releases of contaminated materials such as sulfuric acid, process water, tailings slurry, copper sulfate, tailings, and/or leachate are not infrequent occurrences, and that it is common for mines to suffer multiple failures. These can come from many things, such as cracks, breaks, ruptures, and valve failures; power failures; indicator failures; water collection and/or treatment failures; and tailings dam failures.<sup>10</sup> As documented by Kuipers, et al., design and construction failures, operator errors, false assumptions, and other factors can occur in practice - thereby making mine project-specific environmental review documents including Environmental Impact Statements (EISs) unreliable at predicting surface and groundwater contamination, water exceedences, and permit violations.<sup>11</sup> Contamination released from materials transportation infrastructure can contaminate ground and surface waters. Further, dust and fine particulates can become airborne and blow offsite (and within the site), spreading particulates and/or contamination.

**Surface Transportation.** Materials and workers must also be transported to and from the mine site. This is commonly by road and railroad. As with on- and inter- site transport, this can create linear and downwind contaminant zones (such as a rail or road vehicles transporting concentrated ore for off-site concentration/smelting). If waste rock or tailings are proposed for off-site disposal then these slurry pipeline, conveyor, truck, or rail corridors can also become contaminated or suffer spills, leaks, accidents, etc.

**Reclamation.** Mine reclamation (or rehabilitation) is the process of rehabilitating the post-mine environment into its post-mine land form. Ideally, general goals should include specific plans for all mine disturbances (waste rock piles, pit, tailings impoundments, mill facilities, etc.) and restoring land to a stable form (free from erosion), revegetating disturbed areas suitable to a self-sustaining post mine land use, storing mine contaminants so that they do not contaminate the environment, protecting water quality from degradation, etc. These idealized goals are rarely met and/or practical.<sup>12</sup> Financial, social, or other factors – including simple impossibility or impracticability – render them unlikely. Reclamation failures are often significant source of contamination. Failure of any major component - such as a tailings impoundment or acid mine drainage formation in a waste rock pile contaminating surface and/or ground waters - is a failure of reclamation. Contamination also occurs from multiple minor deficiencies (or failures) that cumulatively are capable of considerable harm.

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<sup>10</sup> See The Track Record of Water Quality Impacts Resulting from Pipeline Spills, Tailings Failures and Water Collection and Treatment Failures, Gestring, B, Earthworks, July 2012.

<sup>11</sup> See Kuipers, J.R., Maest, A.S., MacHardy, K.A., and Lawson, G. 2006. Comparison of Predicted and Actual Water Quality at Hardrock Mines: The reliability of predictions in Environmental Impact Statements.

<sup>12</sup> As a practical matter land may be “greened” (grow something) but genuine alpha and beta biodiversity, water pathways, wildlife establishment, and a genuine return to former conditions are improbable within human lifespans. Soil structure, soil flora and fauna, and hydrology that established over centuries or thousands of years are generally not replicable in a practical mine reclamation’s time scale.

## Other Risks Associated with Sulfide-ore Copper Mines

### Air

Air contaminants are often measured based on size gradients: PM<sub>2.5</sub> refers to particulate matter that is 2.5 micrometers or less in size and PM<sub>10</sub> refers to particulate matter that is 10 micrometers or less in size. The risk from both sizes is that they are small enough to be inhaled, often deep into the lungs, and are associated with an increased risk of several health problems and are among the top causes of premature death in America.<sup>13</sup> PM<sub>10</sub> emissions are predicted for various parts of mining process: dust generated during overburden, waste rock and ore removal as well as operation of vehicles on unpaved roads; emissions from operation of vehicles and heavy equipment (e.g., mining shovels or excavators, conveyors, crushers and grinders, and generators); and mine ventilation systems.

### Dust

Dust is created at all stages of the mining process, including land clearing, road construction, excavation, blasting, crushing and grinding, dumping and transportation, and ventilation from underground mines. Tailings beaches and dry stack tailings can also be significant sources of dust (in reality, any tailings surface with dry particulates can allow for dust mobilization). Despite the best attempts to control dust, there are areas in any mining operation where there will be elevated dust concentrations. A large portion of dust is made up of large particles, with diameters *greater* than 10 microns. This coarse dust usually settles gravitationally within a few hundred meters of the source. The smaller particle size fractions (PM<sub>10</sub>), however, can be carried by wind in dust clouds for great distances and may be deposited on or near surface and ground water resources. The dust-related contaminants will enter water where it lands or is carried by rain and storm flows. It may also be inhaled and cause health impacts.<sup>14</sup>

During wet periods it is reasonable to expect dust to be low, except possibly from dust ejected aboveground into the air from underground ventilation systems. However, during dry periods, including extreme cold such as is encountered in northern Minnesota for six months or more per year (when sprinkler systems are likely ineffective), it will be difficult or impossible to eliminate dust.

### Emissions from Vehicles, Mining Equipment, Heating Systems, and Electric Power Generation Required by Mines.

Particulate and gaseous air pollutant emissions are the result of vehicle and equipment exhaust (and may also include dust emitted by equipment operations). Particulate emissions (PM<sub>2.5</sub>, PM<sub>10</sub>, etc.<sup>15</sup>), carbon monoxide, unburned hydrocarbons (volatile organic compounds), nitrogen oxides and sulfur dioxide result from fuel combustion in vehicles, heavy equipment (including crushers and grinders), and smaller on-site electric generators, and larger power plants associated with mining. Milling facilities may produce stack emissions (see below). For underground

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<sup>13</sup> See <https://www.epa.gov/pm-pollution/particulate-matter-pm-basics>.

<sup>14</sup> See <https://www3.epa.gov/region1/airquality/pm-human-health.html>.

<sup>15</sup> See e.g. <https://www.arb.ca.gov/research/diesel/diesel-health.htm>.

operations, exhaust gases released by vehicles and mining equipment as well as blasting gasses and blast particulates vented to the surface may enter the environment.

### ***Organic and Chemical Fumes and Gases, and Hydrometallurgical Residues.***

Hydrometallurgical beneficiation is the chemical processing and treatment of ore (usually milled first) to isolate desired minerals/materials. These processes can create large quantities of sulfur dioxide, carbon monoxide, and organic and chemical fume emissions. Further, many mining techniques require the use of a variety of hazardous chemicals for ore processing such as acids and reagents, which, in the event of an accidental spill can result in fumes which would be released into the environment. Further fumes and gases would be released by thermal processes such as autoclaves, roasters, and carbon regeneration kilns.<sup>16</sup>

***Smelter Emissions.*** Smelting refers to extracting metals from ore by heating and melting processes. Smelting produces a large amount of wastes (slag, dross) that include particulate matter and heavy metals that can cause contamination if released/leached into the environment.

Airborne contaminants from the above sources could likely reach waters in, or that flow into, the BWCAW either by direct deposition to water or by being washed into surface waters or ground water. The extent of this deposition and contamination would depend on a range of factors, some of which, like localized meteorological conditions, would not be within the control of a mining company.

### **Noise & Light**

Impacts from noise and light may be overlooked but their impacts can uniquely threaten wilderness resources and values. These impacts often focus on human experiences but can also impact wildlife (such that it may impact the wildlife but also the wildlife resources and values that are a critical, intrinsic part of the wilderness experience).

“Noise pollution” refers to disturbing noise that impacts human or wildlife activities. Many mining processes can create significant noise (or vibration), such as from blasting, large truck traffic, machinery operations (e.g. crushers), train and conveyor operations, etc. Studies demonstrate links between noise and human health and noise can impact wildlife.<sup>17</sup> Some noise can be moderated, such as through berms mufflers, etc., but can rarely be eliminated.

“Light pollution” refers to the presence of human-caused light in the night environment that impacts human or wildlife activities.<sup>18</sup> In the wilderness setting this most notably could impair the use and enjoyment of the natural (as compared to anthropogenic) world and reduction of the visibility of the celestial sky.

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<sup>16</sup> The waste products from these processes can further contaminate water and other resources if released/leached into the environment.

<sup>17</sup> See e.g. US EPA Noise Pollution Clearinghouse website: [www.nonoise.org/epa.htm](http://www.nonoise.org/epa.htm); World Health Organization website: [www.euro.who.int/en/health-topics/environment-and-health/noise/publications](http://www.euro.who.int/en/health-topics/environment-and-health/noise/publications).

<sup>18</sup> See e.g. <http://www.darksbiesawareness.org/faq-what-is-lp.php>.

## Mine Dewatering and Ground Water Drawdown

The effects of dewatering a fracture zone could be substantial.<sup>19</sup> Dewatering combined with mine impacts, such as fracturing caused by blasting, could expand hydraulic conductance/connectivity within and between surface and shallow or deep ground water.<sup>20</sup>

Mine dewatering refers to pumping and diversion to keep working areas of the mine dry. This is needed whether mining is by open pit or underground or a combination of both. Mine dewatering can draw down the water table and/or create a localized “cone of depression” where water flows towards the now-dewatered zone because it has become a new “sink.” Drawdowns can negatively affect both surface and ground waters (increasing flow and direction of flow towards the dewatering point(s)) by reducing or interrupting flows and could exacerbate or create unforeseen consequences where faults or other geologic or hydrologic features are encountered. Ground water depletion from dewatering may take decades to replenish after mining - and ground water levels and directions of flows could be altered permanently. Depending on the localized hydrology these impacts would negatively impact surface and ground waters in and adjacent to the BWCAW.

Production water development provides the water necessary for mining activities. These will include, but are not limited to, mining activities such as milling and minerals processing; materials transport such as slurring tailings or concentrates; water contained or entrained in concentrates and tailings that is carried to the tailings impoundment and next-processing facilities (independent of the transport water, which may or may not be reused); and dust suppression. Removal of production water from the natural system could affect surface and ground water availability and flows, particularly during low-flow times of the year.<sup>21</sup> The diminishment of flows at low-flow times could increase contaminant concentrations, increase water temperatures, decrease dissolved oxygen levels, and otherwise impair receiving waters in ways that negatively affect stream health and aquatic habitats.

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<sup>19</sup> Id.

<sup>20</sup> These changes to ground flows can further impact water quality. Examples may include such things as decreased (or increased) contaminant concentrations caused by reduced flows and by increased acid mine drainage caused by introducing air to underground spaces that were saturated before dewatering.

<sup>21</sup> Water management is of course very important. At the Resolution Mine in Arizona the mine company sank a shaft and had prepared to handle 80 gallons per minute of water (based on core sample predictions from 30 feet away) but at its peak water flowed at 580 gallons per minute and it took a year for the mine to figure out how to pump out that much water so as to continue working at the location. A mine project manager stated that “We never gave up, but there were times we worried if we could do it or not.” [http://tucson.com/news/resolution-copper-mine-venturing-feet-below-earth-s-surface/article\\_44ca18f8-7a29-5562-9833-dd6611c968fc.html](http://tucson.com/news/resolution-copper-mine-venturing-feet-below-earth-s-surface/article_44ca18f8-7a29-5562-9833-dd6611c968fc.html). This uncertainty could be devastating for a fragile environment such as the BWCAW and demonstrates how the best plans can go awry when dealing with the real, natural world. While it is a different environment, it highlights that mine certainty is not always realistic and that consequences can be substantial (and potentially catastrophic). For example, predictions that are off by a small amount (such as a few gallons per minute) would add up to potentially millions of gallons per year.

Among the primary risks from mining near the BWCAW are threats to water quantity.<sup>22</sup> Mine dewatering and drawdown could impact and alter both surface and ground waters and their features (flow, direction, etc.). These alterations could further impact the local hydrograph (including low and high flows) and surface features for wetlands, streams, rivers, lakes, etc. Fracture zones can be regional flow paths and connect and convey pollution from the mine area with distant discharge points.

## Contaminant Transport

In the BWCAW region mine leaks may have negative consequences on the region's interconnected waterbodies.

These results show that leaks from mines in the watershed leading to the BWCAW could have substantial effects on the wilderness. Catastrophic spills were not considered but the impacts would be much more significant. Spills would not likely transport through the groundwater, so the potential concentrations would simply be the load divided by the flow rate (dilution).

This discussion focuses on the peak impact of a spill, but an important point is that leaks, even when stopped within a short time period, will continue discharging to the rivers for many years, sometimes as long as centuries due to dispersion during transport through the groundwater. A leak is not a simple thing to remediate, so it is critical to prevent leaks, which has historically been shown to be almost impossible. If mineral deposits in the Rainy Headwaters are developed, it is not a question of whether, but when a leak will occur that will have major impacts on the water quality of the Boundary Waters Canoe Area Wilderness.<sup>23</sup>

Contaminants could also enter sediment, and become part of a cycle of moving between sediment and the water column, and move downstream during storm transport of bedload sediment. Contaminants in sediment could also be bioavailable to benthic fauna and to fish.

Due to the ubiquity and proximity of water resources, sulfide-ore copper mining in the BWCAW watershed could lead to contamination of groundwater and surface waters. Such flows into and between groundwater and surface waters could make remediation particularly complex and improbable.

### **Sulfide-Ore Copper Mines Degrade Water Quality**

At most if not all mines, water contamination is a matter of “when” - not “if”. Mines in wet regions, such as the Boundary Waters region, are highly likely to have a spill, leak, seep, failure, unanticipated impact, human error, and/or other unintended event that results in an irrecoverable release of contaminants to ground water and/or surface waters.<sup>24</sup> Acid mine drainage, which is

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<sup>22</sup> Technical Memorandum: Twin Metals Mining and the Boundary Waters Canoe Area Wilderness, Risk Assessment for Underground Metals Mining. Tom Myers, Ph.D. December 3, 2013.

<sup>23</sup> Id.

<sup>24</sup> It should be noted that releases may be *off-site*, meaning outside of the permitted area/boundary, or they may be *on-site*, meaning within the permitted area/boundary. While on-site releases are often characterized as something less than a contaminant release (presumably because they are within the permit area) they are nonetheless a failure

formed when sulfide metals oxidize (mix with air and water), is a particular risk, because the sulfur/sulfide-bearing rock of the Duluth Complex is known to be acid-generating.<sup>25</sup>

A review of the track record of water quality impacts from sulfide-ore copper mines found severe impacts to water, contamination of farmland, contamination, loss of fish and wildlife and habitat, and risks to public health.<sup>26</sup> In some cases, acid mine drainage will generate water pollution in perpetuity.<sup>27</sup> The Earthworks (2012) report examined fourteen copper mines then operating in the U.S., and which had been in operations for at least five years, and demonstrated that all of the mines in the study experienced failures that led to pollution spills that contaminated water; most of the mines experienced multiple failures:<sup>28</sup>

- Each of the mines had pipeline spills or other accidental releases. These included pipeline spills that washed tailings into rivers, pipeline spills that washed sulfuric acid into a creek, and major process and other water spills.
- Thirteen of fourteen of the mines had failed water collection and treatment systems resulting in uncontrolled contaminated mine seepage.
- Acid mine drainage was associated with the most severe and lasting impacts.
- Tailings spills occurred at nine of the mines.
- Partial failure of tailings impoundments occurred at three mines.

Many currently operating or recently operated US copper mines are located in arid environments that have less extensive surface water resources and volumes, and typically different groundwater volumes and proximity than likely would be the case in the BWCAW headwaters. The BWCAW is a comparatively wet climate with abundant surface and ground waters and relatively shallow groundwater. The wet environment increases the likelihood that the mines in the area will have contamination and containment problems. These problems - notably water collection and treatment failures - will probably get worse after mining ends and groundwater pumps are no longer keeping the mine area/workings dewatered.<sup>29</sup>

### **Mining Impacts and Mitigation**

There is a long history with many examples of mining projects that have been permitted subject to substantial environmental review/environmental impacts statements that failed to predict pollution problems that occurred during operations and/or after mine closure, despite mitigations

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of primary containment and a variance from the mine plan and/or permit. In an interconnected watershed they are also likely to lead to off-site contamination through air or surface or ground water transport. Either way, they are a loss of materials. This is an important matter for public lands - where the notion that a release that is on the minesite somehow is not a problem because it is within the permit boundary. It is still a release and is still a potential long-term contaminant and threat to onsite and adjacent resources.

<sup>25</sup> Environmental Protection Agency (EPA), 1994. Technical Document: Acid Mine Drainage Prediction. Office of Solid Waste, Special Waste Branch, Washington, DC.

<sup>26</sup> The Track Record of Water Quality Impacts Resulting from Pipeline Spills, Tailings Failures and Water Collection and Treatment Failures, Gestring, B, Earthworks, July 2012.

<sup>27</sup> Id.

<sup>28</sup> Id.

<sup>29</sup> The Track Record of Water Quality Impacts Resulting from Pipeline Spills, Tailings Failures and Water Collection and Treatment Failures, Gestring, B, Earthworks, July 2012.

provided for in the EISs. In their 2006 report, Kuipers and Maest<sup>30</sup> reviewed the environmental review documents prepared for 25 hard rock mines<sup>31</sup> to compare the EIS predictions for water quality with the actual water quality observed in surface and ground water resources. Their review shows that mine project-specific EISs often do a poor job at predicting water quality impacts from hardrock mining, that EISes assume incorrectly that proposed mitigations will function as described, and that mitigations will prevent contamination of surrounding water resources:

- Overall, 21 of the 25 case study mines (84%) had exceedences of water quality standards in either surface water or groundwater or both.<sup>32, 33</sup>
- As of the report's date, nine case study mines (36%) had developed acid drainage on site. More importantly, of these 9 mines 8 (89%) had environmental documents that predicted low acid drainage potential or had no information on acid drainage potential.
- Nineteen (76%) had mining-related exceedences in surface water or groundwater. More importantly, almost half of the mines with exceedences (8/19; 42%) predicted low contaminant leaching potential in their EISs.
- Eight mines predicted low contaminant leaching potential but after mining started five of the eight mines (63%) had exceedences of standards in surface water, ground water or both.<sup>34</sup>
- Failure of mitigation to perform was identified as a contributing factor to water quality impacts at 16 of the 25 mines evaluated.
- Based on all these numbers, nearly half of the mines that had exceedences of water quality standards had underestimated or ignored the potential for contaminant leaching potential in their respective EISs. The constituents that most often exceeded standards or that had increasing concentrations in groundwater or surface water included toxic heavy metals.<sup>35</sup>

A critical observation is that these (poor) results occurred despite the mines' use of mitigation measures. This report underscores the over-optimistic and unrealistic predictions of environmental review documents, permit limits, and mitigation measure efficacy. Regarding ground water, the report's results indicate that mines with proximity to groundwater had higher rates of pollution - although even pits above ground water levels could cause ground water

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<sup>30</sup> Kuipers, J.R., Maest, A.S., MacHardy, K.A., and Lawson, G. 2006. Comparison of Predicted and Actual Water Quality at Hardrock Mines: The reliability of predictions in Environmental Impact Statements.

<sup>31</sup> Operating and closed at the time of their report.

<sup>32</sup> It is worth noting that at the time of the report half of the mines studied were still in operations and therefore further pollution could have resulted after the study was completed. In addition, water pollution problems occurring at many of the mines did so with mitigation measures in place, showing those measures to be partially or completely ineffective.

<sup>33</sup> The exceedences at two of these mines may be related to baseline conditions.

<sup>34</sup> The three that predicted low contaminant leaching potential and actually had no exceedences of water quality standards were mines located in arid areas.

<sup>35</sup> These included, but were not limited to, copper, cadmium, lead, mercury, nickel, or zinc (12/19 or 63% of mines), arsenic and sulfate (11/19 or 58% of mines for each), and cyanide (10/19 or 53% of mines).

contamination.<sup>36</sup> These results are particularly important for the BWCAW watershed due to its generally high water table, and vast and massively interconnected network of lakes and rivers.

Mining environmental reviews generally make two types of water quality predictions. The first is the “potential” water quality which does not take mitigation into account and which therefore tends toward worst-case water quality. The second is “predicted” water quality which does take mitigation into account. The Kuipers and Maest report shows, among other things, that actual water quality impacts are closer to the potential/pre-mitigation impacts than the predicted/post-mitigation impacts in EISs (they exceed the mine’s predicted pollution potential).<sup>37</sup>

Myers and Chambers both demonstrate some of the threats that disseminated sulfide copper mining poses to the BWCAW.<sup>38</sup>

## Mitigation Measures

Mitigation measures are employed to protect human health and the environment from predicted impacts. Because of the complexity of the BWCAW watershed it would be functionally impossible to avoid significant damage/contamination from mining. With its highly interconnected waters, very high quality, low sulfates, and limited acid-buffering capacity, the BWCAW would be especially vulnerable to sulfide-ore copper mining contamination, and it would be difficult if not impossible to contain and/or treat that contamination.

## Mitigation Technologies

Three primary factors would come into play: containment, interception, and treatment. Each would have various strengths and weaknesses in terms of effectiveness in the geology and hydrogeology of the BWCAW area. Ultimately, it is important at the outset to recognize that because of the complexity of the BWCAW ecosystem, its geology, hydrogeology, wilderness status, etc.; it would likely be impossible to fully “undo” mining pollution that entered the surface or ground waters of the BWCAW watershed.

**Containment Technologies.** Examples of common containment technologies include natural and synthetic liners and covers (e.g. compacted clay and geomembrane liners), slurry walls, and grouting (injecting grout to contain contaminants from moving beyond the grouted area). These

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<sup>36</sup> Kuipers, J.R., Maest, A.S., MacHardy, K.A., and Lawson, G. 2006. Comparison of Predicted and Actual Water Quality at Hardrock Mines: The reliability of predictions in Environmental Impact Statements.

<sup>37</sup> Maest, A.S., Kuipers, J.R., Travers, C.L., and Atkins, D.A., 2005. Predicting Water Quality at Hardrock Mines: Methods and Models, Uncertainties, and State-of-the-Art. Available at: [http://www.ceaa-acee.gc.ca/050/documents\\_staticpost/cearef\\_3394/hearings/SM09.pdf](http://www.ceaa-acee.gc.ca/050/documents_staticpost/cearef_3394/hearings/SM09.pdf).

<sup>38</sup> See Acid mine drainage risks – A modeling approach to siting mine facilities in Northern Minnesota USA. Tom Myers, Journal of Hydrology 533 (2016) 277–290. Dave Chambers. The Potential for Acid Mine Drainage and other Water Quality Problems at Modern Copper Mines Using State-of-the-Art Prevention, Treatment, and Mitigation Methods, A Report by the Center for Science in Public Participation November 20, 2014. Technical Memorandum: Twin Metals Mining and the Boundary Waters Canoe Area Wilderness, Risk Assessment for Underground Metals Mining. Tom Myers, Ph.D. August 8, 2014. Technical Memorandum: Twin Metals Mining and the Boundary Waters Canoe Area Wilderness, Risk Assessment for Underground Metals Mining. Tom Myers, Ph.D. December 3, 2013.

technologies may lend themselves to a small site but are not likely to be particularly practical or effective at a mine in the Duluth Complex because of a mine's significant breadth of surface and ground disturbances (both underground and surface (open pit) mines will disturb significant surface and ground resources, even though underground mines tend to have a smaller surface footprint).

***Interception Technologies.*** Examples of interception technologies include trenches, French drains, seepage collection ponds, and well fields, often used in combinations with each other or containment systems. The effectiveness of each will vary significantly based on local geology, hydrology, climate, etc. To be effective in a varied environment it may be necessary to employ multiple technologies to attempt to capture contaminants. It is unlikely that interception would stop and/or capture all contamination. This is especially true in a wet environment, such as the BWCAW watershed, which is further complicated by being a highly fractured bedrock environment (without the effects of blasting). The ability to intercept contaminated water is likely to be further limited by the existence of any deep regional flow patterns that may not necessarily be connected to upper aquifers or follow topography – yet daylight at some point downgradient. It would be impossible to study or fully understand these flow patterns because the types of exploration required are likely incompatible with maintaining the wilderness character in the BWCAW (e.g. hydrogeological drilling is likely prohibited in the BWCAW).

Further, it would be impossible to intercept and capture all contaminants that enter surface waters flowing to the BWCAW. Moreover, if interception were possible it probably still could not be attempted without causing significant surface and ground disturbances within or adjacent to the BWCAW.

Stopping contamination from entering the BWCAW could effectively require cutting-off - to the extent possible - flows entering the BWCAW from a region down gradient (surface and ground water) from the mine site. This is not only impractical, but any techniques employed to attempt it also would likely be impermissible due to severe impacts to flow patterns and surface and ground water levels because intercepted waters would no longer reach the BWCAW.

***Treatment Technologies.*** Some sources of contamination, such as acid mine drainage once it has begun, are effectively impossible to stop. Other contamination sources may be possible to limit or stop but it is usually impossible to completely “undo” pollution - although it may be possible to treat it in some places (though not likely within the BWCAW). Treatment needs to be considered under two scenarios: planned treatment and unplanned treatment. Planned treatment would include a water treatment plant or passive treatment designed to treat mine water routed to it through planned pipelines and ditches that capture waste rock seepage, surface runoff, and so forth. Such treatment may or may not be sufficient for the variations in year-round flows and chemistry encountered during mine life. This frequently requires “pump and treat” – either intercepting contaminated flow to route it to treatment or treating at the source, or a combination. Therefore, unplanned treatment is intimately tied to the effectiveness of interception technologies.

Treatment technologies may or may not be effective (though most tend to be expensive). As noted by Myers, “leaks, even when stopped within a short time period, will continue discharging

to the rivers for many years, sometimes as long as centuries due to dispersion during transport through the groundwater.”<sup>39</sup>

## Mitigation Failures and Limitations

A threshold problem with mitigation measures is that if they are being discussed they are trying to fix something that has already gone wrong or otherwise occurred. They are not preventative and indicate a failure to predict outcomes or other failures (not to mention the inability to control outcomes). When employed, mitigation measures regularly fail to meet predicted effectiveness. For example, seepage recovery, intercept walls, etc., have limited efficacy (meaning that contamination is not recovered/collected and therefore not treated). Moreover, all mitigation measures can be subject to failures. Even redundant or multiplied mitigation measures can and do fail. Pipelines/pumping systems leak, break, rupture, or fail in other ways; dewatering operations fail to dewater; dust control fail to control dust; storm water collection and diversion systems fail to divert or contain storm water; etc.

**Liners Fail.** Kuipers and Maest documented that mitigation measures intended to capture contaminants such as liners and tailing impoundments can fail and lead to negative groundwater and surface water quality impacts.<sup>40</sup> These included onsite and offsite impacts and included potential long-term water treatment. Groundwater capture and treatment (including perpetual treatment in severe cases) methods may have varying degrees of effectiveness<sup>41</sup> but underscore that contamination has already occurred and further such capture/treatment may not be possible in the BWCAW without compromising the Wilderness’ character or violating the law.

At the Arctic Gold and Silver Mine, Yukon, an abandoned tailings site near Carcross, Yukon, a low permeability cover was installed to limit air and water that were allowing acid mine drainage to form. Initial performance assessments of the low-permeability cover suggested that it was successfully functioning as an oxygen and infiltration barrier. About ten years after its installation another performance assessment was completed and found persistently high metals concentrations in groundwater beneath the covered tailings impoundment.<sup>42</sup>

**Mitigation and Company Failure.** When it was started in the late 1980s the Beal Mountain Mine (Montana)<sup>43</sup> was billed as a “state-of-the-art” facility that would neither leak nor contaminate the underlying or surrounding Forest Service lands. The mining company declared bankruptcy and the legacy of contamination persists, in part from failure of a liner. The Forest Service continues to pump and treat water from the abandoned heap leach pile to protect surrounding waters from cyanide and metals and to ensure the heap does not catastrophically fail (including groundwater). The waste rock dump leaches selenium so the Forest Service collects

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<sup>39</sup> Id.

<sup>40</sup> Kuipers and Maest, 2006.

<sup>41</sup> Kuipers and Maest, 2006.

<sup>42</sup> It may be notable that most liner manufacturers’ warranty their products for about 20-years. This does not suggest a product that should be relied on for centuries, let alone into perpetuity.

<sup>43</sup> <http://montanatu.org/wp-content/uploads/2014/06/The-Beal-Mountain-Mine1.pdf>;  
<http://www.hcn.org/articles/contaminants-montanas-clark-fork-river-superfund-river-cleanup-mercury-pollution-mines>.

and discharges storm water into the ground along the creek to dilute the selenium to levels not harmful to fish.<sup>44</sup> This cost the Forest Service - and taxpayers - half a million dollars a year (over \$19 million so far; 2/3 of it public funding). If a permanent solution is possible it is estimated to cost \$40 million.<sup>45</sup>

At the Mt. Nansen gold mine (Yukon) and Aitik copper mine (Sweden) dam stability and failure concerns resulted from designs that were touted as latest technologies, but the designs forced or allowed water to flow under the dams. At Mt. Nansen it caused melting permafrost and instability and ultimately the tailings had to be relocated to the pit. At Aitik it led to dam failure and contaminated rivers with copper.

A common means of dealing with potentially acid generating waste materials is to expressly mix or segregate them to neutralize (mix with neutralizing materials). Another is to isolate (segregate the acid generating materials). It is difficult if not impossible to conclude that either of these is effective at preventing acid generation/spreading. Not only is there a lack of data to show they are effective methods, but there can be practical problems to overcome. For example, if mixing potentially acid producing materials with net neutralizing materials, it is essential that the neutralizing potential be available in time and location with the acid that is produced. The neutralizing agent (e.g., lime if it is added) must yield its neutralizing capacity exactly where the acid will form or travel; it cannot coat or otherwise be or become unavailable, and it must be of sufficient volume to not become exhausted. This is a complex proposition when handling large quantities of materials as is common and essential in mining. The location of the materials and distance from the source to water resources may be a critical element. Kuipers and Maest concluded that “mitigation may depend more on climate and factors such as distance and geology affecting travel time and attenuation of contaminants.”<sup>46</sup> They further concluded that these problems may be addressed by requiring adequate geochemical and hydrologic characterization and ensuring that segregated wastes are placed away from potential water pathways. These are more preventative measures and in an area such as the BWCAW - which is dedicated to water resources - this may not be practical or possible.

**Air Mitigation.** Air contaminant control, like many mitigation measures, would only be as good as it is employed. Even best practices are not likely to be fully effective. However, particularly when magnified of a decades-long mine life, anything less than zealous control may result in problematic cumulative deposition. Ultimately, given the nature and complexity of a mine site and the nature and complexity of air control technologies it is reasonable to conclude that although air contaminants could be controlled, it is not possible to guarantee protection of air quality.

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<sup>44</sup> The mine's host drainage, German Gulch, hosts the most important population of genetically pure west slope cutthroats in the upper Clark Fork watershed of western Montana.

<sup>45</sup> See e.g. <http://www.thestate.com/news/local/article13897079.html>. It is unknown how long contamination, particularly selenium, will continue.

<sup>46</sup> Kuipers and Maest, 2006.

## Unproven Technologies

Every so often a new, sometimes hyped, claim emerges that promises a new/novel technology promised to somehow solve an ages-old mining problem. The great majority of these fail to live up to the hype.<sup>47</sup> This is not to say that new concepts and technologies should be ignored, but that they should be carefully examined, and that they are often limited to site-specific conditions which may be difficult to match with technologies before a mine is in operation.

For example, at the Tulsequah Chief mine, a past producing mine located adjacent to the Tulsequah River in British Columbia. Acid mine drainage has leached from the workings and waste rock piles since 1957. Constructed wetlands were built to treat seepage from abandoned tailings. The technology was supposed to treat water for safe release into the Tulsequah River and was intended for five years of operation until a new company was able to start mining and reprocessing, which was to include treatment of all historic and new water quality impacts. The new company went bankrupt, active treatment wasn't implemented, and the wetlands stopped working for even the limited flows that were present.<sup>48</sup>

More recently Teck Coal in British Columbia built a \$120 million treatment facility to remove selenium and other contaminants from its waste stream. Its waste stream degrades water quality and threatens waters important for threatened and endangered species and many human uses. However, the technology/facility not only failed but began making things worse: Teck data revealed that it was changing contaminant chemistry to create and release a more toxic chemical byproduct that was up to "100 times more likely to bioaccumulate in the aquatic environment."<sup>49</sup> Translated, the company degraded water quality, implemented a new technological plan it said

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<sup>47</sup> For example, in the early 1990s the latest "it" method was constructed wetlands, which were touted as solving mine contamination/effluent problems, perhaps most notably metals and acid mine drainage. As time has shown, they have a variety of good uses but are limited in actual scope and scale of reliable treatment. As the rate of water flow requiring treatment increases, so does the amount of land required, and distributing flow through the wetlands can be problematic. They may not work well during cold weather and require water to survive (and may not be suitable for environments with exceptionally high water quality), and can be ineffective or "wash out" if there is too much water. They require maintenance, monitoring, and periodic rebuilding, cleanup (and disposal of potentially hazardous materials), or overhaul. Moreover, in attempting to solve one problem, they can cause new problems, such as altering effluent conductance.

Similarly, at the time there was a lot of talk about surfactants, such as sodium laurel sulfate, used in shampoos, as a surfactant preventing microbes (*Thiobacillus ferrooxidans*) from magnifying acid mine drainage production. Biotreatment continues to be refined but no technology has proven to be widely successful.

The future will surely include new technologies and selective application of refined, new, and/or combined technologies. But it is important to see them for what they are - slow, ongoing potential evolution - and rarely as the hyped solution. As new methods are proven successful, they should be expanded incrementally to determine the limits of scale. Too often proposals are made to dramatically scale up a technology that has only been proven at a small scale or limited applicability.

<sup>48</sup> See <http://dnr.alaska.gov/commis/opmp/Canadian-Mines/tulsequah>; <https://www.desmog.ca/2017/08/04/new-b-c-government-inherits-toxic-legacy-tulsequah-chief-buyer-backs-away-abandoned-leaky-mine-0>; <http://vancouver.sun.com/news/local-news/conservationists-call-on-new-b-c-govt-to-act-on-tulsequah-chief-mine-cleanup>. A temporary water treatment plant was constructed in the fall of 2011 and operated from March 2011 to June 2012 and then was shut down and bypassed. Other companies have sought permits and funding to develop an underground copper, lead, zinc, silver, and gold project but recent reports suggest these may not move forward.

<sup>49</sup> <http://flatheadbeacon.com/2017/06/20/failure-water-treatment-plant-b-c-coal-mine-raises-downstream-concerns/>.

would fix its pollution flow, and in the process unknowingly made things far worse. Teck was forced to abandon the “fix.” Tech continues to mine and contaminated water continues to flow from the mine, degrading surrounding water quality.<sup>50</sup>

It should also be noted:

No fundamentally new water treatment technologies have been developed in the last several decades. There have been refinements of existing technologies, especially in the biotreatment field, in combining different treatment technologies to achieve lower contaminant discharge levels, and in the wider application of selective treatment technologies like arsenic and sulfate removal (e.g. see MEND [Manual Volume 5 – Treatment, MEND 5.4.2e, December 2000].<sup>51</sup>

Nothing has changed since 2014 when this was written to alter this conclusion. There remain no technological panaceas for the pollution containment, interception, and treatment problems posed by mining (or specifically, sulfide-ore copper mining).

New technologies should be specially screened- and avoided - in high-value areas, such as in or adjacent to wilderness, reserves and preserves, critical watersheds, etc.<sup>52</sup> This warning certainly applies to the BWCAW watershed.

## **Conclusions**

There are many mitigation technologies and measures available to employ at a copper/nickel mine in a sulfide ore body. However, these mitigation measures typically do not prevent pollution from occurring, particularly in situations where ground water and surface water resources are found in proximity to mining-related features and infrastructure. More importantly, many hyped technologies are experimental, unproven, or are not proven in an environment equivalent to northeastern Minnesota.

The BWCAW watershed includes vast, interconnected very high quality waters. In such a watershed existing mining and mitigation techniques cannot be expected to sufficiently reduce the risks to water quality (and other resources) posed by sulfide-copper mining. Were mining contaminants to reach waters flowing into the BWCAW it is highly unlikely that existing mitigation measures or technologies could effectively protect water quality and/or be consistent with the BWCAW’s wilderness character.

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<sup>50</sup> See <http://flatheadbeacon.com/2016/07/19/kooconusa-concentrations-exceed-new-selenium-standard/>.

<sup>51</sup> Dave Chambers. The Potential for Acid Mine Drainage and other Water Quality Problems at Modern Copper Mines Using State-of-the-Art Prevention, Treatment, and Mitigation Methods, A Report by the Center for Science in Public Participation November 20, 2014.

<sup>52</sup> Further, the burden of proving the efficacy of any new or novel treatment should fall on the mining proponent to satisfactorily demonstrate to regulators and the public its effectiveness (and lack of liabilities); regulators and the public should not have the burden to demonstrate the new technology’s lack of effectiveness or liabilities.