Potential Impact of Copper Mining on Groundwater and Surface Water in Cape Breton Regional Municipality, Nova Scotia, Canada

Steven H. Emerman, Ph.D., Malach Consulting, LLC, 785 N 200 W, Spanish Fork, Utah 84660, USA, Tel: 1-801-921-1228, E-mail: SHEmerman@gmail.com

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LIGHTNING SUMMARY

Nova Copper has been carrying out exploration of a sulfide ore body on 33 square kilometers of the Cape Breton Regional Municipality (CBRM) in Nova Scotia, Canada, out of which it has requested the purchase of 1002 acres (about four square kilometers) of CBRM surplus land. The surplus land has a mean annual precipitation of 1482 mm and overlaps with the Bras d'Or Lake Biosphere Reserve, one of 19 UNESCO Biosphere Reserves within Canada. The surplus land is four kilometers from the shore of Bras d'Or Lake, in the vicinity of numerous wetlands, lakes, streams, drilled and dug wells, and 194 meters from private homes with wells. Since no sulfide ore mine has ever been operated or closed without environmental contamination, and since the wettest mine that has ever been proposed as having no environmental contamination had a mean annual precipitation of only 860 mm, it is highly likely that a Nova Copper mine would result in environmental contamination.

EXECUTIVE SUMMARY

Nova Copper has been carrying out exploration for copper mining on 33 square kilometers of the Cape Breton Regional Municipality (CBRM) in Nova Scotia, Canada. Out of the exploration area, the company has requested the purchase of 1002 acres (about four square kilometers) of CBRM surplus land. The objective of this report is to evaluate the potential impact on groundwater and surface water of copper mining at the site of the CBRM surplus land. To facilitate reading by non-specialists in mining, this report includes a tutorial on basic mining concepts.

The inevitability of environmental contamination is generally accepted throughout the literature on mining engineering and environmental contamination is generally regarded as the price that society pays in exchange for raw materials. At the same time, it should be noted that there is no literal "society" that is weighing the risks and benefits of mining, but that mining decisions result from interactions among political actors often with opposing interests and wide disparities in power. Environmental contamination is particularly acute in the case of sulfide ore bodies, in which the commodity of value occurs in the form of sulfide minerals. The reaction of sulfide minerals with oxygen converts the minerals into sulfuric acid with the release of heavy metals, which results in acid mine drainage when the reaction products are released into the environment. Acid mine drainage can result from exploration alone and the author has served as an expert witness in a court case in which a mining permit was revoked partly due to the environmental damage that had already occurred from exploration. A presentation by Nova Copper states that the ore body is a copper porphyry deposit, but does not clarify that all copper porphyry deposits are sulfide ore bodies.

In 1997 Wisconsin passed legislation that stated that no permits for sulfide ore mines could be granted until it had been demonstrated that, in either the USA or Canada, at least one sulfide ore mine had operated for 10 years without environmental contamination and at least one sulfide ore mine had been closed for 10 years without environmental contamination. As a consequence, no permits for sulfide ore mines were granted in Wisconsin and the impasse was broken only when the law was repealed in 2017. Every legislative session since 2021 a "Prove it First" bill has been introduced in the Minnesota legislature that would prohibit permits for sulfide ore mining until it had been demonstrated that at least one sulfide ore mine in the USA had been operated for 10 years and had been closed for 10 years without environmental contamination. In response to the Prove It First legislation in Minnesota and Wisconsin, ten mines have been formally or informally proposed as candidates for sulfide ore mines with no history of environmental contamination. However, all of those candidates were discredited and the evidence for environmental contamination by the ten candidates has been compiled in another report by the author. It is noteworthy that most of the candidate mines are in relatively arid locations, with the wettest being the Flambeau mine in Wisconsin with a mean annual precipitation of 860 mm.

Mine tailings are the wet and crushed rock particles that remain after the commodity of value has been removed. Tailings are typically permanently disposed of above ground behind a dam constructed out of the coarser fraction of tailings, waste rock (the rock that must be removed to reach the ore body), or rockfill or earthfill that is available on the mine site. One of the worst possible outcomes for a mining project is the catastrophic failure of the tailings dam with the release of the often toxic tailings into the environment, together with the possibility of fatalities if there are mineworkers or communities in the pathway of the tailings slide. Filtering the tailings to remove excess water followed by compaction of the tailings in a tailings disposal facility is regarded as a best practice to reduce both the likelihood and the consequences of tailings dam failure. In an interview with the media, the CEO of Nova Copper has referred to the technology as "dry stacking," and has stated that failure is impossible for filtered tailings and that filtered tailings do not require a dam, all of which demonstrate a poor understanding of filtered tailings technology. The tailings are not literally dry, but have geotechnical water contents in the range 15-20% with the consistency of a moist soil. All engineered structures have the potential for failure and a filtered tailings stack collapsed at the Pau Branco mine in Brazil in January 2022 as a result of heavy rainfall. Finally, current filtered tailings technology is not able to consistently produce tailings with the appropriate water content for compaction. Even so, in a wet climate, the tailings can be rewetted by precipitation even if the tailings leave the filter presses with the appropriate water content. The current solution is to construct a periphery of tailings with the appropriate water content for compaction that is called the structural zone, while the tailings with excessive water content are placed in the interior with either light or no compaction. This structural zone serves the exact same function as a dam and should meet tailings dam safety standards.

The permanent nature of tailings dams cannot be overemphasized. Unlike water retention dams that must be completely dismantled if they are no longer needed or cannot be maintained, tailings dams can never be dismantled. The document <u>Safety First: Guidelines for Responsible Mine Tailings Management</u> has called for the monitoring, inspection, maintenance and review of tailings dams either in perpetuity or until all credible failure modes have been eliminated. By contrast, Dr. Steven Vick, the author of the standard textbook on tailings dams, has argued that because of the multitude of things that can go wrong with sufficient time, even with perpetual maintenance, the probability of tailings dam failure is 50% after 100 years and 100% after several centuries, with the implication that tailings dams should not be constructed at locations where the future catastrophic failure would be unacceptable.

The objective of this report was addressed by mapping the protected lands, Indigenous lands, surface water bodies, wetlands, wells, and private homes in the vicinity of the Nova Copper exploration area and the CBRM surplus land that has been requested for purchase by Nova Copper. Numerous protected areas and Indigenous lands are located in the vicinity and within the primary watershed of the Nova Copper exploration area and the CBRM surplus land. Both the Nova Copper exploration area and the CBRM surplus land overlap with the Bras d'Or Lake Biosphere Reserve, which is one of only 19 UNESCO Biosphere Reserves within Canada. The shore of Bras d'Or Lake is 4.0 kilometers and 2.3 kilometers south of the CBRM surplus land and the Nova Copper exploration area, respectively. The CBRM surplus land is located on a hill that is the headwaters of three secondary watersheds. Numerous lakes, streams and wetlands are found within those secondary watersheds, and even more are found within the primary watershed that encompasses nearly all of the CBRM. For example, the CBRM surplus land is 2.1 kilometers from Blacketts Lake and 1.0 kilometers from Macdonalds Lake. The CBRM surplus land is in the vicinity of numerous well log sites (which correspond to the positions of drilled wells), including one well log site within the surplus land and 19, 36, and 125 well log sites within 1, 2, and 3 kilometers of the CBRM surplus land, respectively. The map of well log sites does not include the hundreds of shallow, dug wells in the area and it should not be assumed that well logs have been filed for all drilled wells. In addition, the CBRM surplus land is within 1.5 kilometers of potential surficial aquifers and 6.5 kilometers from the Howie Centre municipal well. The CBRM surplus land is located within 194 meters of private homes with wells along Beechmont Road. Although China is often regarded as a country with weak environmental standards for mining, even Chinese regulations prohibit the placement of mine tailings within 1000 meters of populated areas. The mean annual precipitation at Sydney in the CBRM is 1482 mm. Because no sulfide ore mine has ever been operated or closed without environmental contamination, because the wettest mine that has ever been proposed as having no environmental contamination had a mean annual precipitation of only 860 mm (although the proposed mine actually did have an extensive record of environmental contamination), and because of the numerous lakes, wetlands, wells, and private homes within the vicinity of the requested land purchase, it is highly likely that a Nova Copper mine would result in environmental contamination.

Nova Copper has estimated the size of the ore deposit as 220,000 metric tons with a grade of 2.2%, so that the copper production could be 484 metric tons per year for a 10-year project. Since the world copper production was 22 million metric tons in 2022, a Nova Copper mine could produce 0.0022% of the world production. Whether there is an actual shortage of copper is beyond the scope of this report. However, a Nova Copper mine could not be regarded as making a substantial contribution to solving a world copper shortage.

In a message to the Mayor and Council of the CBRM, the CEO of Nova Copper stated, "Communities that do not welcome safe, responsible copper mining will be abdicating their responsibility to act on climate change." The argument by the CEO is neither scientific nor economic, but is quasi-religious in nature in stating that all communities with copper ore deposits, no matter how small and no matter how great the environmental risks, are obligated to offer themselves as sacrifice zones to satisfy an alleged global shortage of copper. The author finds no basis for such an argument in any traditional religion. It is the opinion of the author that the people of the CBRM have the right to decide for themselves whether any possible benefits from copper mining outweigh the environmental risks.

The recommendation of this report is that the request for purchase of CBRM surplus land by Nova Copper should not be granted.

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OVERVIEW

Nova Copper has been carrying out exploration for copper mining on 33 square kilometers of the Cape Breton Regional Municipality (CBRM) in Nova Scotia, Canada (see Figs. 1-2). The boundary of the CBRM includes all of Cape Breton County except for the Eskasoni and Membertou First Nations (see Fig. 2). Out of the exploration area, the company has requested the purchase of 1002 acres (about four square kilometers) of CBRM surplus land (see Fig. 2). On August 22, 2023, the CBRM Director of Engineering and Public Works sought a motion from the CBRM Council to sell the surplus land for CAD 140,300 or slightly more than CAD 140 per acre. The motion was tabled and no action has yet been taken by the CBRM Council (Keep Coxheath Clean, 2023a-c). For clarification, the CBRM land under discussion does not currently have the status of "surplus land," but must be deemed as surplus before it can be sold (Keep Coxheath Clean, 2023d).

If a Nova Copper mine were to be constructed, it would be the first industrial-scale metallic mine on Cape Breton. A small underground mine was operated within the Coxheath copper-molybdenum-gold deposit during 1878-1891, 1899-1901, and 1928-1930 (Mindat, 2023). The facilities for the historic mine no longer exist. It is not possible to determine the footprint of the mine, but it was certainly much less than one square kilometer (Keep Coxheath Clean, 2023b).

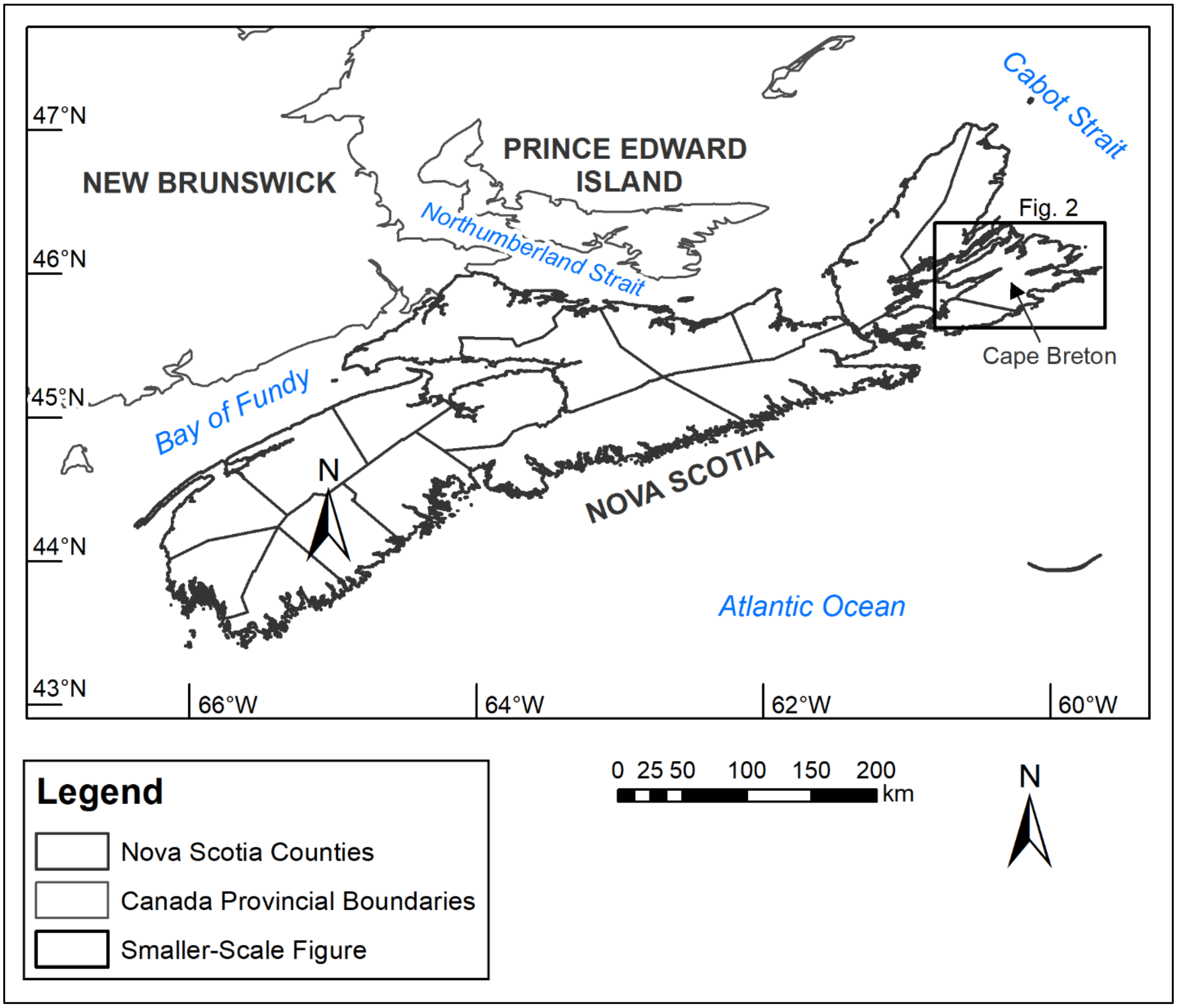

Figure 1. Nova Copper is carrying out exploration and has requested the purchase of surplus land from the Cape Breton Regional Municipality (CBRM) in Nova Scotia, Canada. The boundary of the CBRM includes all of Cape Breton County except for the Eskasoni and Membertou First Nations (see Fig. 2). County and provincial boundaries from ESRI (2023a-b).

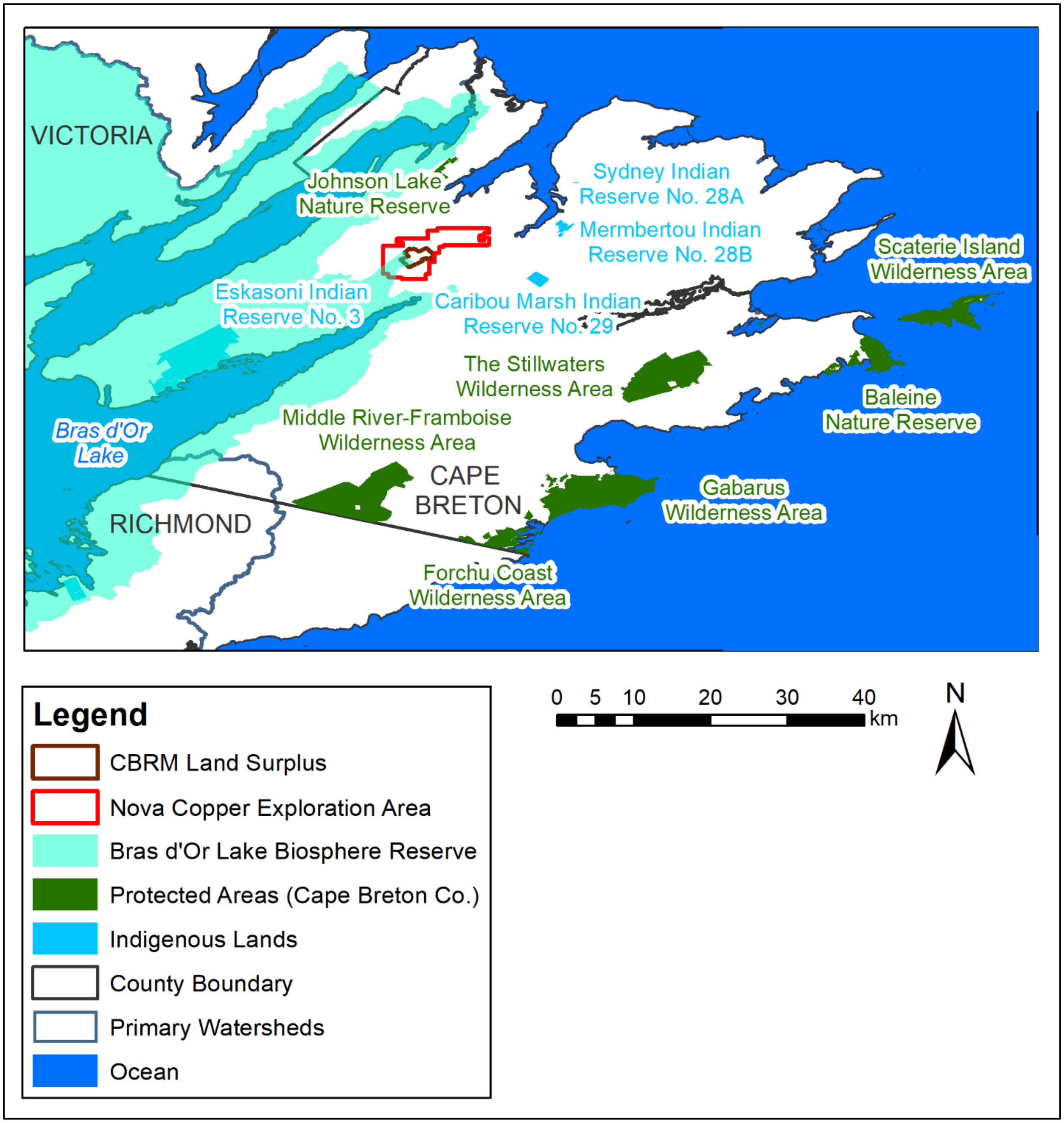

Figure 2. The Nova Copper exploration area covers 33 square kilometers, while the requested purchase of surplus land from the Cape Breton Regional Municipality (CBRM) covers four square kilometers. The boundary of the CBRM includes all of Cape Breton County except for the Eskasoni and Membertou First Nations. Numerous protected areas and Indigenous lands are located in the vicinity and within the primary watershed of the Nova Copper exploration area and the CBRM land surplus. Both the CBRM land surplus and the Nova Copper exploration area overlap with the Bras d'Or Lake Biosphere Reserve, which is one of 19 UNESCO Biospheres within Canada. The shore of Bras d'Or Lake is 4.0 kilometers south of the CBRM land surplus. Perimeters of the CBRM land surplus and Nova Copper exploration area from Keep Coxheath Clean (2023c). County boundaries, protected areas within Cape Breton County, and Indigenous lands from ESRI (2023a, c and d). Boundaries of Bras d'Or Lake Biosphere Reserve and primary watersheds from Nova Scotia Canada (2023a-b).

The concerns of the Cape Breton community regarding the possibility of the initiation of industrial-scale metallic mining include impacts on surface water and groundwater, in addition to impacts on endangered and at-risk species, such as the little brown bat, yellow lampmussel, Atlantic salmon, and Canada lynx. The potential impacts on groundwater are of particular concern, since residents in the vicinity of the CBRM surplus land all rely on well water and there are hundreds of shallow, dug wells (Dyment, 2023; Keep Coxheath Clean, 2023b; Lazovskis, 2023; Nathanson, 2023). There are also concerns regarding the lack of consultation and the general impacts on the way of life on Cape Breton. According to Marshall (2023), "My name is Albert Marshall and I am an elder and knowledge keeper from Unama'ki [Cape Breton]. I represent the elders of this island when it comes to environmental matters … As you know, the government is legally and morally required to consult with First Nations communities about the transfer of land that rests on the traditional and unceded territory of the Mi'kmaq … The pollution that would occur from mining would have a devastating effect on all nearby populations. It would also negatively impact our ability to engage in traditional activities such as hunting, trapping, fishing, and medicine-gathering, to name a few … The proposed copper/metals mine does not fit with our beliefs or hopes for the future of Unama'ki."

Keep Coxheath Clean (2023b) proposed three potential alternative uses for the surplus land. The proposed alternative uses were:

1) Transfer of the land to First Nations for conservation and land-based education and training, as well as traditional use
2) Transfer of the land to the Province for conservation
3) Opening the purchase of land to private parties specifically for conservation.

Keep Coxheath Clean (2023b) added that three distinct potential buyers had already been identified.

The objective of this report is to evaluate the potential impact on groundwater and surface water of copper mining at the site of the CBRM surplus land. The intention is that this report should be accessible to the Cape Breton public and the Mayor and Council of the CBRM. For that reason, the subsequent section is a tutorial on basic mining concepts to facilitate reading by non-specialists. Further information about Nova Copper and the copper deposit under exploration will be provided in the following sections.

TUTORIAL ON MINING CONCEPTS

Inevitability of Environmental Contamination

Despite the abundance of tools for the prevention of mining-related pollution, some degree of environmental contamination has, thus far, been inevitable simply because there are so many ways for environmental contamination to occur. For example, liners can leak, pipelines can burst, and storage ponds can overflow. As part of a review of the Flambeau copper-gold-silver mine, Moran (2019) summarized, "I know of no metal-sulfide mines anywhere in the world that have operated without degrading the original water quality, long-term – even those employing modern technologies." The concept of metal-sulfide or sulfide ore mining will be explained in the next two subsections. Nevertheless, this inevitability of environmental contamination has been applied to all mining, not just to sulfide ore mining. According to Safety First: Guidelines for Responsible Mine Tailings Management, "It is important to recognize that mining is a fundamentally destructive industry, meaning that a goal of zero harm to the environment is impossible to achieve. Nevertheless, operating companies must do all that they can to minimize environmental harm everywhere. In particular, they must limit any environmental harm that inevitably occurs to within the mine site … A mine site is the area of surface disturbance necessary to conduct a mining operation. This includes extraction, processing, and waste disposal facilities, and roads. A mine site does not necessarily include the entire area as defined by the mine permit or claim" (Morrill et al., 2022).

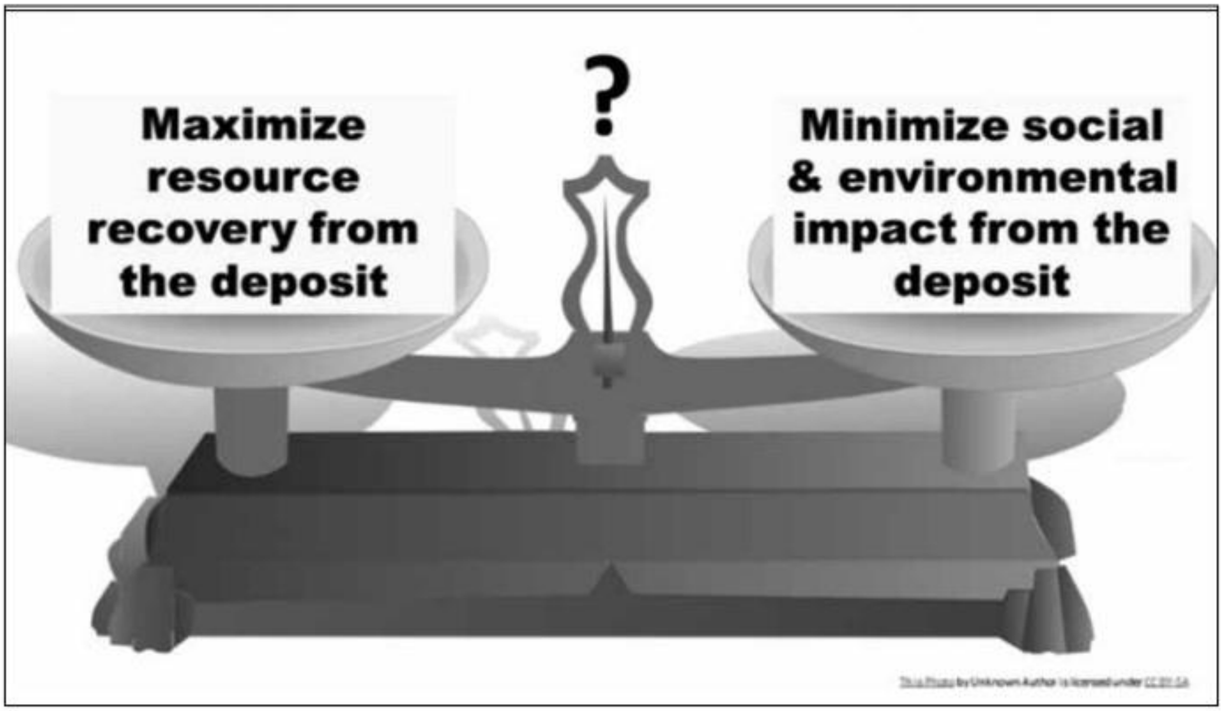

Figure 2 - Balancing resource recovery with social and environmental impact mitigation.

Figure 3. Abbott (2020) used the above figure to emphasize the inevitability of some degree of environmental degradation from any form of mining. According to Abbott (2020), "Figure 2 [the figure above] presents the need to balance maximum resource recovery with minimizing the adverse social and environmental impacts of mining … Dialog among the mining industry and these stakeholders is the key to finding the appropriate balance for each mineral deposit shown in Figure 2. However, the discussion among the various stakeholders about a particular deposit should also recognize society's need for mineral products including acceptance of some level of adverse impacts." Figure from Abbott (2020).

The concept that mining involves inevitable environmental contamination is widely assumed in the mining engineering literature. In fact, the assumption runs so deep that it is usually not even mentioned except in the context of making some other point. For example, in the context of critiquing one of the Fundamental Values of Geoethics (Di Capua et al., 2017), Abbott (2020) wrote, "The costs for environmental and social impact mitigation increase the cut-off grade, the minimum grade that allows for profitable extraction. Dialog between the mining industry and the various environmental and social impact stakeholders is the key to finding the unique appropriate balance for each mineral deposit. The dialog among the various stakeholders about a particular deposit should recognize society's need for mineral products as an important, socially desirable goal … Figure 2 [see Fig. 3 in this report] presents the need to balance maximum resource recovery with minimizing the adverse social and environmental impacts of mining." Abbott (2021a) continued, "The facts that future generations will need newly mined mineral products and that extraction of individual mineral deposits is not a sustainable activity are things about which the mining industry must educate the general public. Public education about the need to balance the costs of the environmental and social impacts of mining with the need for future generations' need for minerals is required for the sustainability of the mining industry."

In the context of arguing for the inevitability of the creation of post-mining ghost towns, Abbott (2021b) explicitly assumed the inevitability of environmental contamination as a "fact." According to Abbott (2021b), "This article is based on four facts: … 4. Exploitation of individual mineral deposits or occurrences involves environmental degradation … Ensuring future generations' supply of mineral products requires balancing mineral product recovery with an acceptable amount of environmental degradation at the deposit … Exploitation of mineral deposits results in widely varying social impacts and environmental degradation. Various mitigation measures can reduce, but not fully eliminate, the negative impacts of this exploitation. The costs of complete remediation of a mine site will eliminate the possibility of profitable extraction, yet society's need for mineral products requires that exploitation of mineral deposits will continue into the future."

The inevitability of environmental degradation is so deeply assumed in the mining literature that environmental protection is often discussed not as a real issue, but only as a show that must be carried out in order to appease certain voting blocs. For example, following the election of President Biden in the USA, in a passage that is difficult to follow through the twists of sarcasm, the President of the Society for Mining, Metallurgy and Exploration (SME) wrote, "It will be very challenging for the government to promote sustainable electrical energy sources (wind, solar, hydro, nuclear, geothermal) and their transmission and energy storage (all of which require our products [from mining]) without rejecting some of the demands of environmental preservationists. And despite the movement toward green energy, there will still be a need for coal … That will be the political rub. How will the Biden administration promote the megadevelopments of a clean-energy economy while simultaneously encouraging governmental regulatory agencies to tighten environmental oversight and deny development permits in areas preservationists consider off-limits to keep Biden's constituency happy? All the while the new administration collectively knows it needs to satisfy the demands for goods and services and advance the values and comforts of First World societies to maintain its leadership position in future elections" (Schafer, 2021). As an alternative, Schafer (2021) called for a "BIG compromise" (capitalization in original) in which the "environmental preservationists" would be pushed aside for the purpose of promoting an energy transition.

In summary, nearly all sides see some degree of environmental contamination as a necessary sacrifice that society makes in order to obtain metals and other commodities from the Earth. One caution is that the concept of society making sacrifices is profoundly apolitical. There is no "society" that is collectively making decisions as to whether to accept the risks of mining in exchange for the benefits. These decisions result from the interaction of political actors with more or less access to power and resources. In their book about the development of the Global Industry Standard for Tailings Management and using the high fatality rate of rail workers as an example, Hopkins and Kemp (2021) wrote, "Risk analysts do not normally consider whether the risk is acceptable to those on whom the risk is imposed. Rather the question is whether the risk is acceptable to 'society.' This does not make much sense. Society is not in a position to accept risk; governments might, on behalf of society, but society is not an entity that can make these normative judgements … However, we believe that rather than seeing the existing distribution of risk as a result of some kind of value consensus, it is better to see it as the outcome of a political process, the result of a contest between unequal political forces. Rail track workers would clearly like to have a workplace that was 10 times safer, but they are not a politically influential group, and given existing resources and rail track priorities, this is quite beyond their reach." In a sense, the discussion by Hopkins and Kemp (2021) is not much different than the call for "dialog" by Abbott (2020, 2021a-b) and for "compromise" by Schafer (2021), except that the mining literature rarely recognizes the power differentials among the various political actors. This point will be further addressed in the Discussion section.

Acid Mine Drainage

Acid generation occurs when sulfide minerals from beneath the surface are excavated and exposed to oxygen and water on the surface, so that the reaction with oxygen and water (called oxidation) converts the sulfides into sulfuric acid. The conversion of sulfide minerals to sulfuric acid is promoted both by crushing the sulfide minerals, which increases the surface area that is exposed to oxygen and water, and by the permanent aboveground disposal, which allows for an extended time over which the acid-generating reactions can occur. Acid generation can result from the aboveground disposal of any mine waste, which can be referred to as either non-acid generating (NAG) or potentially acid generating (PAG), depending upon the concentrations of sulfide minerals, especially in comparison to other minerals, such as carbonate minerals, that could neutralize acid generation. Acid generation can even result from the exposure of the walls of open pits or underground workings if the host rock has a sufficient concentration of sulfide minerals.

Mine waste falls into two main categories, which are waste rock and tailings. Waste rock is the rock that must be removed to reach the ore body. Tailings are the wet, crushed rock particles together with water, reagents, and the by-products of ore processing that remain after the commodity of value has been extracted. Typically, waste rock is disposed of in a free-standing pile called a waste rock dump. Because of their fine-grained nature, tailings must be disposed of behind a tailings dam, which is typically constructed out of the coarser fraction of tailings, waste rock, or rockfill or earthfill that is available on the mine site. On a global basis, for copper mining, 1.86 metric tons of waste rock are removed for every metric ton of copper ore. Considering a typical ore grade of 0.64% and typical concentrator and smelter/refinery recovery rates, 513 metric tons of mine waste (both tailings and waste rock) are generated for every metric ton of refined copper. In the case of gold mining, 3,046,349 metric tons of mine waste are generated for every metric ton of refined gold, which is the largest rock-to-metal ratio for any common mined commodity (Nassar et al., 2022a-b). The disposal of mine tailings will be discussed further in the subsection "Filtered Tailings Technology."

The general acid-generating reaction can be written as a balanced chemical reaction as

$$2FeS_2 + 7O_2 + 2H_2O \rightarrow 2Fe^{+2} + 4SO_4^{-2} + 4H^+$$

or in words as

$$\text{pyrite + oxygen + water} \rightarrow \text{dissolved iron + sulfuric acid}$$

Pyrite (iron sulfide) is the most common sulfide mineral, but many other metallic elements form sulfides, such as chalcopyrite (copper-iron sulfide or $CuFeS_2$), bornite (copper-iron sulfide or Cu_5FeS_4), galena (lead sulfide or PbS), and sphalerite (zinc sulfide or ZnS). Based on the above reaction, a by-product of acid generation is the mobilization of heavy metals into the dissolved form. The oxidation of pyrite results in the mobilization of dissolved iron. However, most sulfide minerals include a variety of other heavy metals that can substitute for the primary metal (such as substitutes for iron in the mineral pyrite), so that the oxidation of pyrite can result in the mobilization of a wide range of other heavy metals.

Acid mine drainage (AMD) results when the dissolved metals and sulfuric acid are introduced into surface water or groundwater, which can have detrimental impacts on public water supply and aquatic life. Acid mine drainage in streams is typically characterized by strong colors in the range of red, brown and yellow, which result from the oxidation of dissolved metals to form very fine-grained particles of metal oxides or metal oxyhydroxides that are transported with the stream flow (see Figs. 4a-b and 5a-d). Under some circumstances, metal leaching (introduction of dissolved metals from mining by-products into surface water or groundwater) from sulfide minerals can also occur in the absence of acidity or even under alkaline conditions. Thus, streams affected by neutral (non-acidic) metal leaching can have the same colors as those affected by acid mine drainage. The literature on acid mine drainage and its impacts on human health and the environment is vast and a good starting point is Maest et al. (2005).

Acid mine drainage can induce a positive feedback in that the downstream load of dissolved metals can greatly exceed the dissolved metals that result from the oxidation of the exposed sulfide minerals. Stream sediments typically include clay minerals, whose surfaces have negatively-charged sites that bind cations (positively-charged ions). Most dissolved metals are cations, although there are some exceptions, such as arsenic (actually a metalloid), molybdenum and uranium, which occur in dissolved form as oxyanions (polyatomic negatively-charged ions that include oxygen). When acidic water interacts with these stream sediments, the hydrogen cations in the water displace other cations (such as metallic cations) from the negatively-charged sites on stream sediments, so that metals are no longer fixed onto sediment, but are mobilized in the stream column as dissolved metals. Stream beds can also include tailings from previous episodes of mining that have heavy metals attached to surface sites. As above, these heavy metals can be mobilized by the introduction of new acid mine drainage into streams or by other anthropogenic increases in stream acidity. For this reason, mine tailings in stream beds are often referred to as a “chemical time bomb.” In this regard, it should be noted that there does not appear to be research into where either the tailings or the waste rock from the historic Coxheath mine were disposed of.

A wide range of tools have been developed for the mitigation of acid mine drainage and metal leaching from mining that involves the excavation of sulfide minerals. For example, soil or clay covers on tailings disposal facilities can minimize the contact of tailings with oxygen and rainfall, while stormwater diversion channels around the facilities can minimize the contact with surface water. Crushed limestone can be mixed with mine waste to neutralize any acidity that is generated. Impermeable liners can be placed beneath tailings disposal facilities to prevent seepage into groundwater. Wells can be placed around tailings disposal facilities for the capture and treatment of any acid mine drainage that escapes into groundwater. Water from tailings disposal facilities can be treated for removal of acidity and dissolved metals prior to release into surface water. In fact, most of the above tools should be used at any mine site that carries out excavation of sulfide minerals and there should be no reliance on a single tool, such as a liner.

Despite the abundance of tools, some degree of either acid mine drainage or metal leaching always occurs from sulfide ore mining, simply because of the great variety of things that can go wrong, as mentioned in the previous subsection. For example, the author observed the characteristic reddish-brown color of acid mine drainage in the discharge from the Santo Antônio tailings disposal facility at the Kinross Gold Morro do Ouro mine in Paracatu, Minas Gerais, Brazil (see Fig. 4a). In this case, the effluent from the tailings disposal facility was treated with crushed limestone to neutralize the acidity before it was discharged into a stream. A likely explanation for the observation of acid mine drainage is that some of the effluent had found a pathway to circumvent the crushed limestone. After the addition of bleach, the same reddish-brown color was observed in water from a shallow, dug well that was downstream from the tailings disposal facility (see Fig. 4b). The effect of bleach was to oxidize the dissolved metals, resulting in the formation of very fine-grained metal oxides and metal oxyhydroxides.

Figure 4a. Acid mine drainage is evident in the reddish-brown color in the discharge from the Santo Antônio tailings disposal facility at the Kinross Gold Morro do Ouro mine in Paracatu, Minas Gerais, Brazil, even after water treatment to remove the acidity. The pipe in the background is a culvert under the highway. The stream on the other side of the highway receives the discharge from the tailings disposal facility. The reddish-brown color results from fine-grained particles of metal oxides and oxyhydroxides. Photo taken by the author on May 7, 2019.

Figure 4b. After addition of bleach, the same reddish-brown color (see Fig. 4a) is visible in water from a dug well in the village of Santa Rita, downstream from the Santo Antônio tailings disposal facility at the Kinross Gold Morro do Ouro mine in Paracatu, Minas Gerais, Brazil. The bleach re-oxidizes the dissolved metals to form fine-grained particles of metal oxides and oxyhydroxides. Photo taken by the author on May 6, 2019.

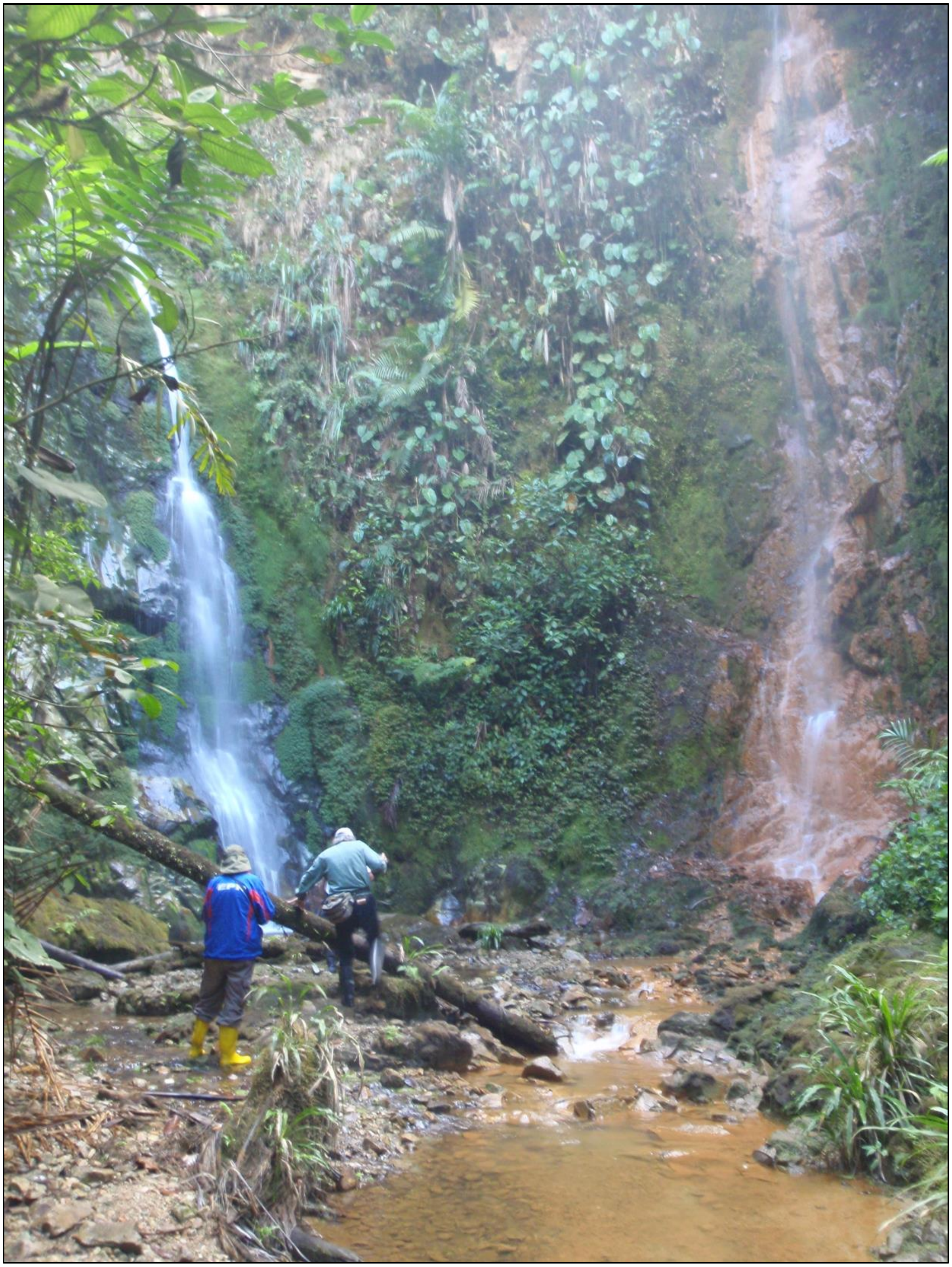

Figure 5a. Paired waterfalls ("Cascadas las Gemelas") in the province of Imbabura, Ecuador, show the effect of drilling for copper exploration in the source of the waterfall on the right, but not on the left. The reddish-brown color indicates acid mine drainage and results from fine-grained particles of metal oxides and oxyhydroxides. Photo taken by the author on October 28, 2018.

Figure 5b. Acid mine drainage is evident in the stream that results from the union of twin waterfalls, one of which has its source in an area with drilling for copper exploration (see Fig. 5a). The reddish-brown color results from fine-grained particles of metal oxides and oxyhydroxides. View looking upstream toward the waterfalls. Photo taken by the author on October 28, 2018.

Figure 5c. Acid mine drainage is evident in the stream that results from the union of twin waterfalls, one of which has its source in an area with drilling for copper exploration (see Fig. 5a). The reddish-brown color results from fine-grained particles of metal oxides and oxyhydroxides. View looking downstream away from the waterfalls. Photo taken by the author on October 28, 2018.

It is important that acid mine drainage can result from the drilling involved in mineral exploration, even before the construction of a mine or the disposal of tailings or waste rock. In particular, acid mine drainage has been documented as a consequence of the oxidation of the drilling waste that has been disposed of on the surface or into ponds. Acid mine drainage can also develop from artesian water that is encountered during drilling and which spills into the environment (Chambers and Zamow, 2019; Zamow and Chambers, 2019). The author was an expert witness in a court case in the province of Imbabura, Ecuador, in which drilling for copper exploration had released acid mine drainage into surface water. In that case, paired waterfalls ("Cascadas las Gemelas") showed the effect of drilling for copper exploration in the source of the waterfall on the right looking upstream (with the characteristic reddish-brown color indicative of acid mine drainage), but not on the left looking upstream (with clear blue water) (see Fig. 5a). Once the waterfalls mixed, the entire downstream waterway showed the impact of acid mine drainage (see Figs. 5b-c). At a nearby location, acid mine drainage was still evident in surface waters next to wells that were drilled for copper exploration more than 30 years ago (see Fig. 5d). Acid mine drainage was not evident in the surface waters that flowed only five meters from a well that was drilled for copper exploration 30 years ago (see Fig. 5e), thus indicating the connection between acid mine drainage in streams and exploration wells. In response to the environmental damage that had already occurred from exploration alone, as well as the lack of respect for the right of the community to consultation and for the "Rights of Nature," the Imbabura Provincial Court canceled the mining licenses on March 29, 2023 (Kimbrough, 2023). Note that the determination of acid mine drainage requires that visual observations of color (see Figs. 4a-b and 5a-d) be supported by measurements of acidity and heavy metal concentrations, which was done in the cases previously mentioned in Brazil and Ecuador.

Figure 5d. Acid mine drainage is still evident in surface waters in the province of Imbabura, Ecuador, next to wells that were drilled for copper exploration more than 30 years ago. Photo taken by the author on October 28, 2018.

Figure 5e. Acid mine drainage is not evident in the surface waters that flow only five meters from a well that was drilled for copper exploration 30 years ago (see Fig. 5d), thus indicating the connection between acid mine drainage in streams and exploration wells. Photo taken by the author on October 28, 2018.

Lessons from Prove it First Legislation in Wisconsin and Minnesota

In response to the preceding widely-accepted concerns, in 1997 the Wisconsin legislature enacted Statute 239.50 entitled "Moratorium on Issuance of Permits for Mining of Sulfide Ore Bodies" (National Wildlife Federation, 2012). The statute defined "a sulfide ore body" as "a mineral deposit in which nonferrous metals are mixed with sulfide minerals" (Wisconsin Statutes Archive, 2023). The statute then stated, "Beginning on May 7, 1998, the department [Department of Natural Resources] may not issue a permit under s. 293.49 for the purpose of the mining of a sulfide ore body until all of the following conditions are satisfied: (a) The department determines, based on information provided by an applicant for a permit under s. 293.49 and verified by the department, that a mining operation has operated in a sulfide ore body which, together with the host nonferrous rock, has a net acid generating potential in the United States or Canada for at least 10 years without the pollution of groundwater or surface water from acid drainage at the tailings site or at the mine site or from the release of heavy metals. (b) The department determines, based on information provided by an applicant for a permit under s. 293.49 and verified by the department, that a mining operation that operated in a sulfide ore body which, together with the host nonferrous rock, has a net acid generating potential in the United

States or Canada has been closed for at least 10 years without the pollution of groundwater or surface water from acid drainage at the tailings site or at the mine site or from the release of heavy metals" (Wisconsin Statutes Archive, 2023). In other words, the Wisconsin statute implicitly recognized the theoretical possibility of sulfide ore mines that had either operated or been closed without environmental contamination, but also implicitly insisted that Wisconsin should not be the testing ground. Another implicit implication was that any successful proposal for a sulfide ore mine in Wisconsin should demonstrate how it would incorporate the lessons from any previous sulfide ore mines that had been free from environmental pollution, as well as the myriad of sulfide ore mines that had resulted in environmental pollution.

Over the next two decades, despite the generally-recognized inevitability of environmental contamination by sulfide ore mining, eight candidates were formally or informally put forward as model sulfide ore mines that met the requirements of the Wisconsin statute (see Table 1 and Fig. 6). Each of the eight candidates were rebuffed because, in fact, they each had extensive records of environmental contamination. As a consequence, no sulfide ore mines were approved in Wisconsin during the tenure of the statute (National Wildlife Federation, 2012). The impasse was broken in favor of the mining industry when the statute was repealed in 2017 with effect in 2018 (Frye, 2018).

Each year since 2021 a bill for a similar statute has been introduced into the Minnesota legislature entitled 93.2501 "Moratorium on Issuing Permits for Nonferrous Sulfide Ore" and popularly known as the "Prove It First Bill." The bill defines "nonferrous sulfide ore" as "any ore, other than iron ore, consisting of sufficient sulfide minerals to generate acid mine drainage" (Minnesota Legislature, 2021). According to the bill, "The commissioner [of Natural Resources] may not issue a permit required to mine nonferrous sulfide ore unless the commissioner and the commissioner of the Minnesota Pollution Control Agency both determine, based on published, peer-reviewed scientific information and public records, that a mine for nonferrous sulfide ore has operated commercially for at least ten years and has been closed for at least ten years without resulting in a release of a hazardous substance, hazardous waste, or pollutant or contaminant as defined under section 115B.02. The mine must have operated in the United States in a similar environment to the mine for which the permit is sought and must have used reclamation techniques substantially similar to those proposed in the permit application. The applicant for a permit required to mine nonferrous sulfide ore bears the burden of demonstrating each of the conditions necessary for a determination under this paragraph that a permit may be issued" (Minnesota Legislature, 2021). "Similar environment" is defined as "a location with similar abiotic ecological features, such as average annual precipitation and average monthly temperature, and in which the proximity of surface water and groundwater to mining operations is similar to the proximity of surface water or groundwater to the Minnesota site or sites for which the permit is sought" (Minnesota Legislature, 2021). The Prove it First bill refers to "nonferrous sulfide ore" presumably because it is unheard of to exploit sulfide ores for iron due to the possibility of acid mine drainage, a variety of processing challenges, and the remaining abundance of iron oxide ore bodies in the world.

In some ways, the Minnesota bill is more conservative than the repealed Wisconsin statute, meaning that it is more protective of people and the environment. The Wisconsin statute allowed for the consideration of sulfide ore mines anywhere in the USA or Canada, whereas the Minnesota bill would allow for consideration of mines only in the USA and only in an environment similar to the proposed mine site. The Wisconsin statute allowed for consideration of one mine that had operated for 10 years and a possibly totally different mine that had been closed for 10 years. The Minnesota bill would allow for consideration of only a single mine that had been operated for at least 10 years and then closed for at least 10 years. In other words, the only mines that could be considered for comparison would have opened no later than 2003 and closed no later than 2013 (assuming that the bill would take effect in 2023). Thus, the Minnesota bill is even more insistent that Minnesota is not the testing ground for the possibility of sulfide ore mining without environmental contamination.

Since the opening of the public discussion over the Minnesota Prove it First Bill, again despite the generally-recognized inevitability of environmental contamination by sulfide ore mining, ten candidates have been informally put forward as model sulfide ore mines that would meet the requirements of the Minnesota bill. The proposals for model mines have been informal, such as in communications from elected officials or blogs or letters to the editor since there is not yet any formal process. The irony is that, out of the ten candidates that have been put forward as model sulfide ore mines that would meet the requirements of the Minnesota Prove It First Bill, eight are the exact same candidates that were put forward and rebuffed during the tenure of the Wisconsin statute, the only new candidates being the Musselwhite gold mine in Ontario and the Rainy River gold-silver mine in Ontario (see Table 1 and Fig. 6). The fact that only two new potential candidates for model mines have emerged over the past 25 years is the best evidence of all that there has never been a sulfide ore mine that did not result in environmental contamination. The evidence for actual environmental contamination by each of the ten candidates for sulfide ore mines without environmental contamination was compiled in an earlier report by the author (Emerman, 2023).

Table 1. Candidates for model sulfide ore mines with comparison to precipitation in Cape Breton Regional Municipality[1]

Mine	Location	Principal Commodities	Opening – Closure	Mean Annual Precipitation (mm)
Bagdad	Arizona (USA)	Copper	1928-2101	424.4
Cactus	Arizona (USA)	Copper, silver, gold	1972-1984	235.5
Cullaton Lake	Nunavut (Canada)	Gold	1976-1985	244.0
Eagle	Michigan (USA)	Nickel, copper	2014-2026	739.9
Flambeau	Wisconsin (USA)	Copper, gold, silver	1993-1997	860.3
McLaughlin	California (USA)	Gold	1985-2002	798.1
Musselwhite	Ontario (Canada)	Gold	1997-2029	717.4
Raglan	Quebec (Canada)	Nickel	1997-2027	401.0
Rainy River	Ontario (Canada)	Gold, silver	2017-2032	709.5
Stillwater	Montana (USA)	Palladium, platinum	1986-2055	458.5
Sydney (Cape Breton Regional Municipality)[2]				1481.6

[1]Table adapted from Emerman (2023)
[2]Government of Canada (2023b)

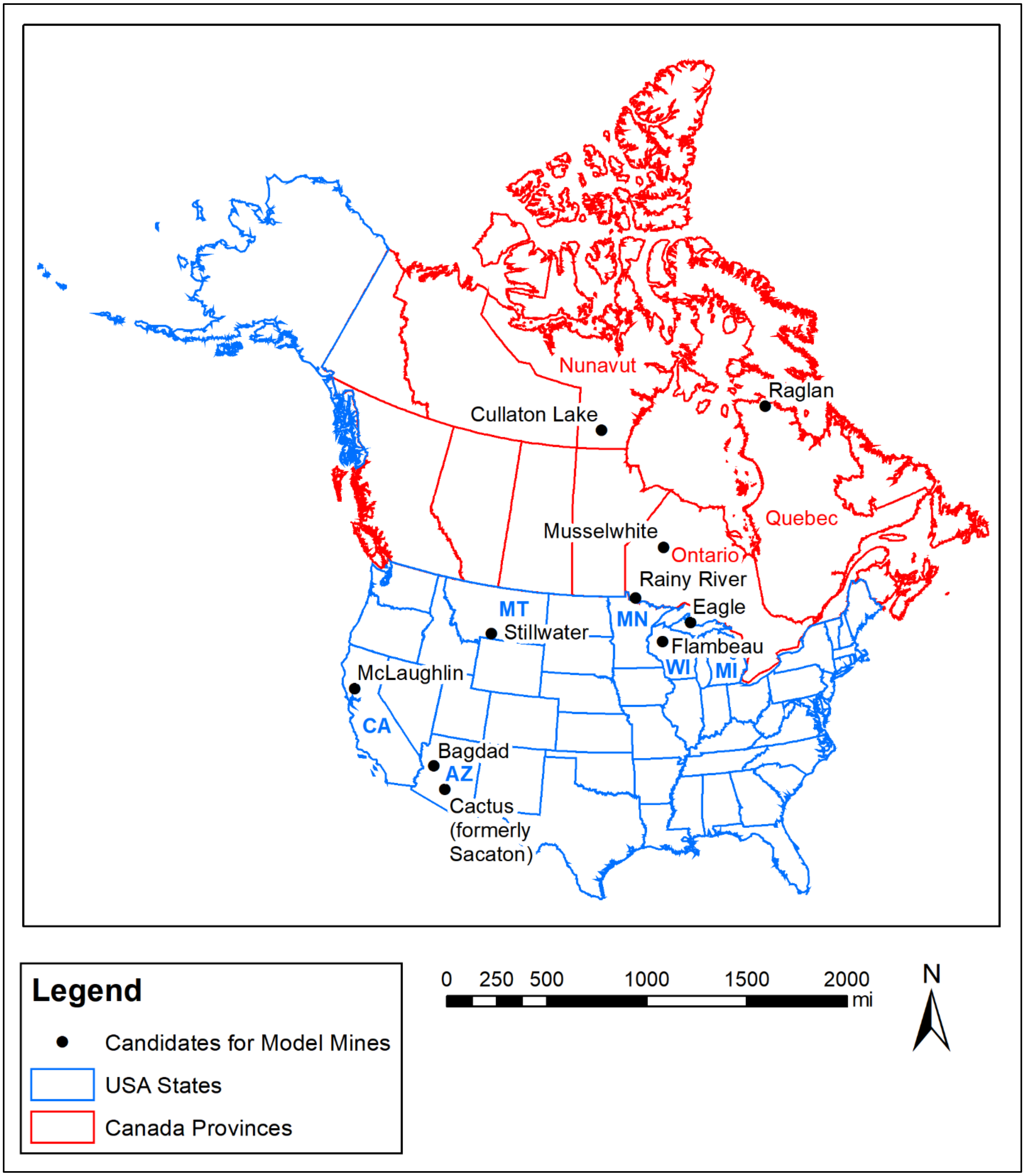

Figure 6. In response to the Prove It First legislation in Wisconsin and the proposed Prove It First legislation in Minnesota, ten mines were put forward as candidates for model sulfide ore mines with no history of environmental contamination (see Table 1). However, all ten candidates have been discredited since they actually do have records of environmental contamination. The mean annual precipitation for the ten mines range from 235.5 to 860.3 mm. Since the Sydney weather station on Cape Breton has a mean annual precipitation of 1481.6 mm and because of the numerous surface water and groundwater resources in close vicinity to the CBRM surplus land, it is highly unlikely that a sulfide ore mine at the site of the CBRM surplus land could operate and be closed without environmental contamination. Figure adapted from Emerman (2023).

Filtered Tailings Technology

One of the worst possible outcomes for a mining project is the catastrophic failure of the tailings dam with the release of the often toxic tailings into the environment, together with the possibility of fatalities if there are mineworkers or communities in the pathway of the tailings slide. Filtered tailings technology seeks to mitigate this worst possible outcome by partially dewatering the tailings, so that they can be compacted in the tailings disposal facility. Filtered tailings technology is regarded as a Best Available Technology (BAT) because it reduces both the probability and the consequences of tailings dam failure. According to the expert panel report on the failure of the tailings disposal facility at the Mount Polley mine, "BAT [Best Available Technology] has three components that derive from first principles of soil mechanics: 1. Eliminate surface water from the impoundment. 2. Promote unsaturated conditions in the tailings with drainage provisions. 3. Achieve dilatant conditions throughout the tailings deposit by compaction … Filtered tailings technology embodies all three BAT components … There are no overriding technical impediments to more widespread adoption of filtered tailings technology" (Independent Expert Engineering Investigation and Review Panel, 2015). Safety First: Guidelines for Responsible Mine Tailings Management also mandates "the use of Best Available Technology for tailings, in particular filtered tailings" (Morrill et al., 2022). The use of filtered tailings technology is required in the state of Maine (Maine Metallic Mineral Mining Act, 2021).

In a radio interview with CBC (Canadian Broadcasting Company) Mainstreet (Keep Coxheath Clean, 2023e), Harry Cabrita, CEO of Nova Copper, personally committed himself to the use of filtered tailings technology, at the same time that he showed a poor understanding of the technology. According to Mr. Cabrita, "For us, I have always pledged to every stakeholder in Sydney that I would never build a tailings pond and we are not going to build a tailings pond under my watch … there will never be a tailings pond in Beechmont … Copper mines aren't allowed to build tailings ponds anymore … There's moisture levels and then there would be dry stacking so there's a well-known process now called dry stacking where what you're doing is you're not having a pond that can eventually or has potential like when an earthquake or something to migrate, dry stacking is solid … there's no dam." In the preceding quote, "tailings ponds" refer to tailings disposal facilities in which the tailings are not dewatered, so that the tailings are saturated and there is a surface cover of water over the tailings.

The first misunderstanding is that it is not correct to state that copper mines are not allowed to construct tailings ponds. That is the law in Maine, but there is certainly no such law in Nova Scotia. The second misunderstanding is that in stating "you're not having a pond that … has potential … to migrate, dry stacking is solid," Mr. Cabrita seems to imply that failure of a filtered tailings stack is impossible. Failure is possible for any engineered structure and denying the possibility of failure is typical grounds for rejection of a project. In fact, a filtered tailings stack collapsed after heavy rainfall at the Pau Branco mine in Brazil in January 2022 (see Fig. 7) (Angelo, 2022; Morrill, 2022, Petley, 2022).

Figure 7. A 48-meter-high filtered tailings stack at the Pau Branco iron-ore mine in Brazil collapsed on January 8, 2022, due to heavy rain. Although filtered tailings are regarded as the Best Available Technology at the present time (Morrill et al., 2022), the failure of a filtered tailings stack should not be regarded as impossible, especially in areas with high precipitation. Photo from Angelo (2022).

The third misunderstanding is that, although Mr. Cabrita refers to “dry stacking,” this is non-standard terminology and is essentially a marketing or public relations expression. Typical geotechnical water contents (ratio of mass of water to mass of solids) for filtered tailings are in the range 15-20%, so that they have the consistency of a moist soil. The tailings are not literally dry and, if they were, it would be impossible to properly compact them for safe disposal. On their website, the mining consulting company Knight-Piésold includes a publication by employees of Knight-Piésold that states, “Regarding terminology, the rather misleading term dry stack is generally not a good engineering term since the target moisture content coming from the filter plant is typically desired to be somewhere around the optimum moisture content based on the Proctor compaction procedure … Geotechnical engineers associate the optimum moisture content with moisture levels just below full saturation after compaction, thus terming such a facility as a dry stack is a misnomer. The present authors would encourage practitioners to abandon the use of the term dry stacking in favor of the more straightforward term, ‘filtered tailings.’ It is not desirable to unintentionally mislead the public at large with an industry term that is noticeably misused” (Ulrich and Coffin, 2017). With regard to the proposed Twin Metals mine in Minnesota, for which the mineral lease has since been canceled, the Minnesota Department of Natural Resources (2021) asked, “Is characterizing the tailings filter cake as being ‘dry’ a common terminology for a product exhibiting a 13% to 16% moisture content?” Finally, the SME (Society for Mining, Metallurgy and Exploration) Tailings Management Handbook confirms that “The term dry stacking … is somewhat of a misnomer. Stacked tailings must be sufficiently dry to allow placement in stable and trafficable piles, but not so dry as to result in dust generation from prevailing wind” (Reemeyer, 2022).

The fourth and most important misunderstanding is that filtered tailings stacks actually do require a dam. Most typically, filtered tailings stacks are constructed with an outer shell of compacted tailings (sometimes called the "structural zone") surrounding an inner core of uncompacted or lightly compacted tailings (see Fig. 8). The structural zone fulfills the exact same function as a dam, that is, it is an engineered structure that prevents the flow of water or waste materials containing water. Klohn Crippen Berger (2017) has also emphasized that a filtered tailings facility "still requires 'structural zones' (which perform like dams), made of compacted tailings for confinement" and "if filtered tailings are placed in a stand-alone facility (pile/stack), the outer slopes must maintain structural stability (similar to a dam or a waste dump), particularly under seismic loading conditions." Finally, according to Safety First: Guidelines for Responsible Mine Tailings Management, "Because they [filtered tailings stacks] still require a structural zone (which is a type of dam) for containment, they must be treated as an engineered tailings facility (i.e. tailings dam) from a regulatory standpoint … The structural zone of a filtered tailings facility serves the same function as a dam" (Morrill et al., 2022). In other words, the structural zone of a filtered tailings stack should comply with all tailings dam safety standards.

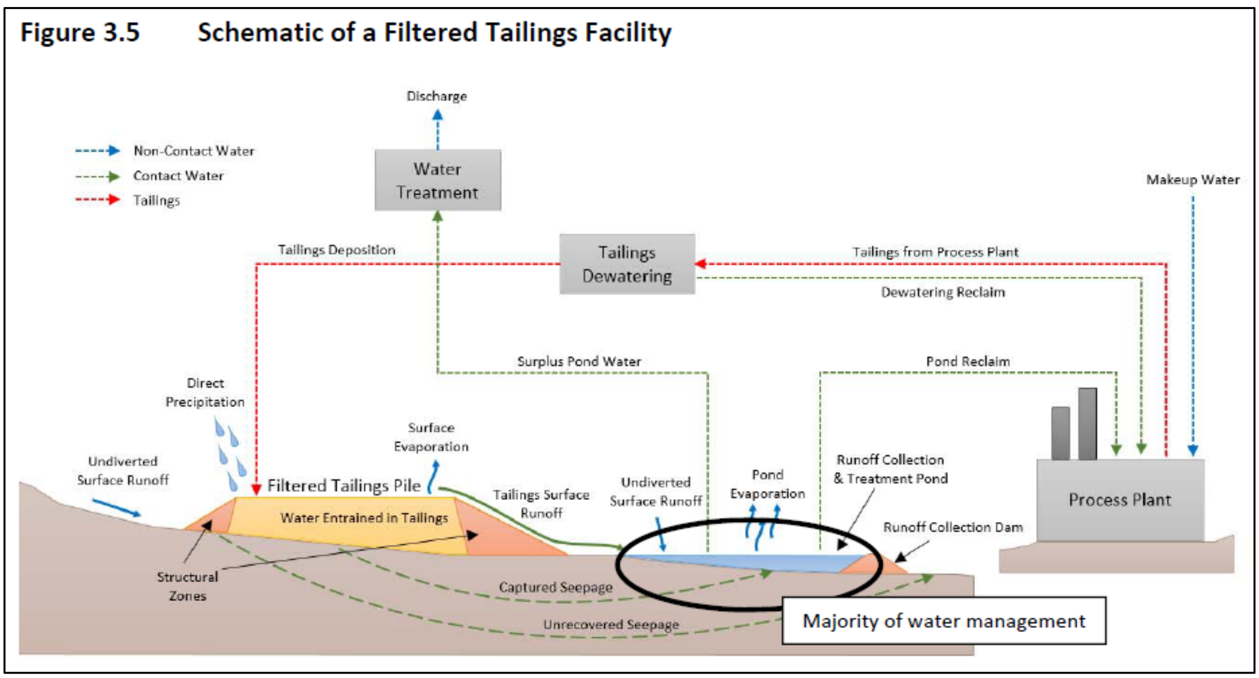

Figure 8. Current filter press technology does not consistently produce filtered tailings with the appropriate geotechnical water content for adequate compaction. Even if tailings do leave the filter presses with the appropriate water content, they can be rewetted by precipitation. The standard solution for filtered tailings stacks is to place the tailings that are too wet or too dry for adequate compaction in the center of the facility in a non-structural zone, in which the tailings are either uncompacted or lightly compacted. The tailings with the appropriate water content for adequate compaction are then placed on the periphery, where they can be compacted to form a structural zone. The structural zone serves the same function as a dam for the non-structural zone. Figure from Klohn Crippen Berger (2017).

The inner core of a filtered tailings stack is, in fact, a requirement for the storage of tailings that leave the filter presses with too much water for adequate compaction. Crystal et al. (2018) have emphasized that target water contents for filtered tailings are rarely achieved. According to Crystal et al. (2018), "Commonly, projects are specifying (or promising) a target filter-cake moisture at the limit of the filter performance (including at the limit of the thickener's ability to deliver feed at the required solids ratio). This has caused numerous examples where the operating performance does not consistently meet the target … Essentially, irrespective of site, ore body type, or filter press manufacturer, a 15% moisture content remains a typical target, while tracking of day-in and day-out moisture contents of filter cakes demonstrates that achievable moisture contents are often in the range of 17 to 18% when things are running smoothly and can be up to 20 to 23% when off-spec … 'Targets' may be cited or promised, but achievable filter cake moisture contents and the variability of the process are not generally within the tailings engineer's control." For example, Mexican gold and silver mines that use filtered tailings technology have achieved geotechnical water contents in the range 14-19% (Espinosa-Gomez et al., 2018). Cacciuttolo and Pérez, 2022) list 28 filtered tailings disposal facilities with geotechnical water contents ranging from 12 to 20%, although without clarifying whether these are target or achieved water contents. Even if the tailings leave the filter presses with the target geotechnical water content, they can still be rewetted by precipitation. Thus far, these filtered tailings disposal facilities have mostly been small and mostly constructed in areas with arid climates (Klohn Crippen Berger, 2017). The partial restriction to arid regions has partly been motivated by the greater need to recycle water in regions with high water scarcity. However, an additional factor has been the challenges in achieving the appropriate water content for adequate compaction in wet climates. At the present time, the standard solution in both arid and wet climates is to set aside an inner core (a region away from the outer slopes) for placement of tailings that cannot be adequately compacted. Crystal et al. (2018) continue, "The tailings engineer can, however, specify acceptable moisture contents for different areas … For example, external structural zones may have more stringent criteria than non-structural zones, for which reduced constraints may be allowed."

The final point is that it is entirely unclear as to the status of the personal commitment made by the CEO of Nova Copper. On its website, Nova Copper describes itself not as a mining company, but as a "privately held junior exploration company" (Nova Copper, 2023). Typically, the exploration company obtains the mining permit, which it then sells to a much larger company that has the resources to carry out the mining project. Thus, it is entirely unclear as to how Mr. Cabrita can make commitments on behalf of whatever company would eventually design, construct and operate the tailings disposal facility, especially considering that the use of filtered tailings technology is not required in Nova Scotia. Even so, it is not clear how a personal commitment by the current CEO of Nova Copper constitutes a permanent commitment by the company Nova Copper.

Mine Tailings are a Permanent Threat to the Environment

It was mentioned in the previous subsection that one of the worst possible outcomes for a mining project is the catastrophic failure of the tailings dam. It cannot be overemphasized that the threat of the worst-case scenario is permanent, which is the essential difference between tailings dams and water-retention dams, such as dams for hydropower, flood control or irrigation. At the end of its useful life, or when it is no longer possible to inspect and maintain the dam, a water-retention dam is completely dismantled. A water-retention dam cannot simply be abandoned or it will eventually fail at an unpredictable time with consequences that are difficult to predict. On the other hand, a tailings dam cannot be dismantled unless the tailings can be moved to another location, such as an exhausted open pit. Typically, a tailings dam is expected to confine the often toxic tailings in perpetuity, although normally the inspection, monitoring, maintenance, and review of the dam cease at some point after the end of the mining project.

The need for perpetual maintenance of a tailings dam, as well as the realism of such a prospect, was discussed in Safety First: Guidelines for Responsible Mine Tailings Management. According to Morrill et al. (2022), "It is imperative that the reclamation and closure of tailings facilities be a factor in their initial design and siting … A tailings facility is safely closed when deposition of tailings has ceased and all closure activities have been completed so that the facility requires only routine monitoring, inspection and maintenance in perpetuity or until there are no credible failure modes … Currently, there is no technology to ensure that an active tailings facility can be closed in such a way so as to withstand the PMF [Probable Maximum Flood] or MCE [Maximum Credible Earthquake] indefinitely without perpetual monitoring, inspection, and maintenance ... Given that operating companies will not exist long enough to accomplish perpetual monitoring, inspection, maintenance, and review, the operating company's ability to eventually eliminate all credible failure modes must be a key consideration during the permitting process. If a regulatory agency does not believe an operating company can carry out perpetual care and financial responsibility, or eliminate all credible failure modes, they must not approve the facility."

According to the Global Industry Standard on Tailings Management, "The term 'credible failure mode' is not associated with a probability of this event occurring" (ICMM-UNEP-PRI, 2020). Thus, a credible failure mode is "a physically possible sequence of events that could potentially end in tailings dam failure" (Morrill et al., 2022), no matter how unlikely. It should be noted that there are not many ways to eliminate all physically possible failure modes, aside from transferring the tailings to another location, such as an exhausted open pit. Since, as mentioned in the previous subsection, Mr. Cabrita has made a personal commitment to filtered tailings technology (Keep Coxheath Clean, 2023e), it is worth asking whether he is also making a personal commitment to the perpetual monitoring, inspection, maintenance, and review of the filtered tailings disposal facility or until all credible failure modes have been eliminated.

On the other hand, Dr. Steven Vick, the author of the standard textbook Planning, Analysis, and Design of Tailings Dams (Vick, 1990) has argued that tailings dam failure is inevitable, simply due to the multitude of things that could go wrong even if maintenance were carried out in perpetuity. In a conference presentation, Vick (2014a) concluded that "System failure probabilities much less than 50/50 are unlikely to be achievable over performance periods greater than 100 years … system failure probability approaches 1.0 after several hundred years." Vick (2014a) continued, "For closure, system failure is inevitable … so closure risk depends solely on failure consequences." In the accompanying conference paper, Vick (2014b) elaborated, "Regardless of the return period selected for design events, the cumulative failure probability will approach 1.0 for typical numbers of failure modes and durations. This has major implications. For closure conditions, the likelihood component of risk becomes unimportant and only the consequence component matters … This counterintuitive result for closure differs so markedly from operating conditions that it bears repeating. In general, reducing failure likelihood during closure—through more stringent design criteria or otherwise—does not materially reduce risk, simply because there are too many opportunities for too many things to go wrong. In a statistical sense, all it can do is to push failure farther out in time. System failure must be accepted as inevitable, leaving reduction of failure consequences as the only effective strategy for risk reduction during closure." Although not explicitly stated, the obvious implication is that tailings disposal facilities should not be constructed at any location at which the future failure of the facility would be unacceptable.

COXHEATH COPPER DEPOSIT AS SULFIDE ORE DEPOSIT

In a presentation to investors, Nova Copper (2023b) describes the Coxheath copper deposit under exploration as a "porphyry-epithermal system," but does not clarify that all such ore bodies are sulfide ores. The briefest explanation is that porphyry copper deposits form when hydrothermal fluids are released from sulfur-rich magmas into the surrounding host rock. As these hydrothermal fluids cool, they precipitate copper in the form of various sulfides (see Fig. 9). The difference between porphyry and epithermal deposits is that epithermal deposits precipitate the copper sulfides at shallower depths and lower temperatures. According to Richards (2021), "Porphyry Cu deposits are characterized by concentrations of Cu-Fe-sulfide minerals (mainly chalcopyrite, $CuFeS_2$), along with pyrite (FeS_2) and variable quantities of molybdenite (MoS_2), precipitated in quartz veins and as disseminations in hydrothermally altered wall rocks." According to Meng et al. (2021), "Most known porphyry Cu deposits formed in the Phanerozoic and are exclusively associated with moderately oxidized, sulfur-rich, hydrous arc-related magmas derived from partial melting of the asthenospheric mantle metasomatized by slab-derived fluids."

The sulfidic nature of the Coxheath copper deposit is abundantly clear in consulting reports for Nova Copper and its predecessors Silvore Fox Minerals Corporation and Silvor Foxx Capital Corporation. For example, according to a selection from O'Sullivan and Hannon (2017), "There are other showings in the east of the property with intense sulphide and sericite alteration in felsic volcanics which show potential for Volcanogenic Massive Sulphide deposits … One hole (DDH MM 35) drilled near the No. 5 Shaft, intersected three silicified and sulphide bearing zones, one 10.5 feet to 21 feet (3.2m) grading 1.1 % Cu and another 5 feet (1.52m) of .92% Cu and a third of 4 feet (1.21 m) of 5.62% Cu … Mineralization found on the Coxheath Property is primarily chalcopyrite [copper-iron sulfide] and pyrite [iron sulfide] associated with shear zones in diorites, in a mixed sequence of intrusive rocks in a volcanic country rock sequence … The mineralization occurs in northeast-southwest trending, steeply dipping shear zones that contain a stockwork of tourmaline-sulphide veins … Vein density is up to 150-200 per meter with some veins up to 20 cm wide, that are composed primarily of sulphides … The sulphides generally show a spatial relationship with the tourmaline and consist primarily of pyrite with subordinate chalcopyrite and bornite [copper-iron sulfide]. The sulphides are coarse textured and occur both as intimate intergrowths with the tourmaline and as isolated massive pods … Its mineralization consisted of vertically dipping, north trending zones of thin sheeted quartz, chlorite and chalcopyrite veinlets and sulphide coatings along thin fractures within potassic altered diorite … The Copper Brook area mineralization consists of four NE-SW steeply dipping, sub parallel shear zones within the Coxheath Hills diorite which contain a stockwork of tourmaline-sulphide veins with an enrichment of barium of up to 4.5 wt % BaO." According to O'Sullivan (2012), "The exploration objective of the Titan 24 DCIP & MT [Direct Current Induced Polarization & Magnetotelluric] survey at Nova Scotia Project was to extend the existing mine and to expand the exploration by detecting and delineating zones and structures related to the emplacement of sulphide mineralization to depths of up to 750 meters with IP Chargeability and DC resistivity and to depths of up to 1500 meters with MT resistivity. Titan 24 should provide the following benefits: Locating potential sulphide rich zones and/or associated alteration." Finally, according to Jensen (2019), "Zones of intensive argillic alteration have been located in the Mill Brook area containing abundant pyrophyllite, minor diaspore and kaolinite indicating the preservation of a high sulphidization system in this locality. Kontak et al. 2003 postulates a genetic link to the Cu/Mo/Au porphyry mineralization westward in the Beechmont Road area due to the fact both the pyrophyllite and the potassic feldspar alteration associated with the sulphide rich zones there have elevated levels of barium."

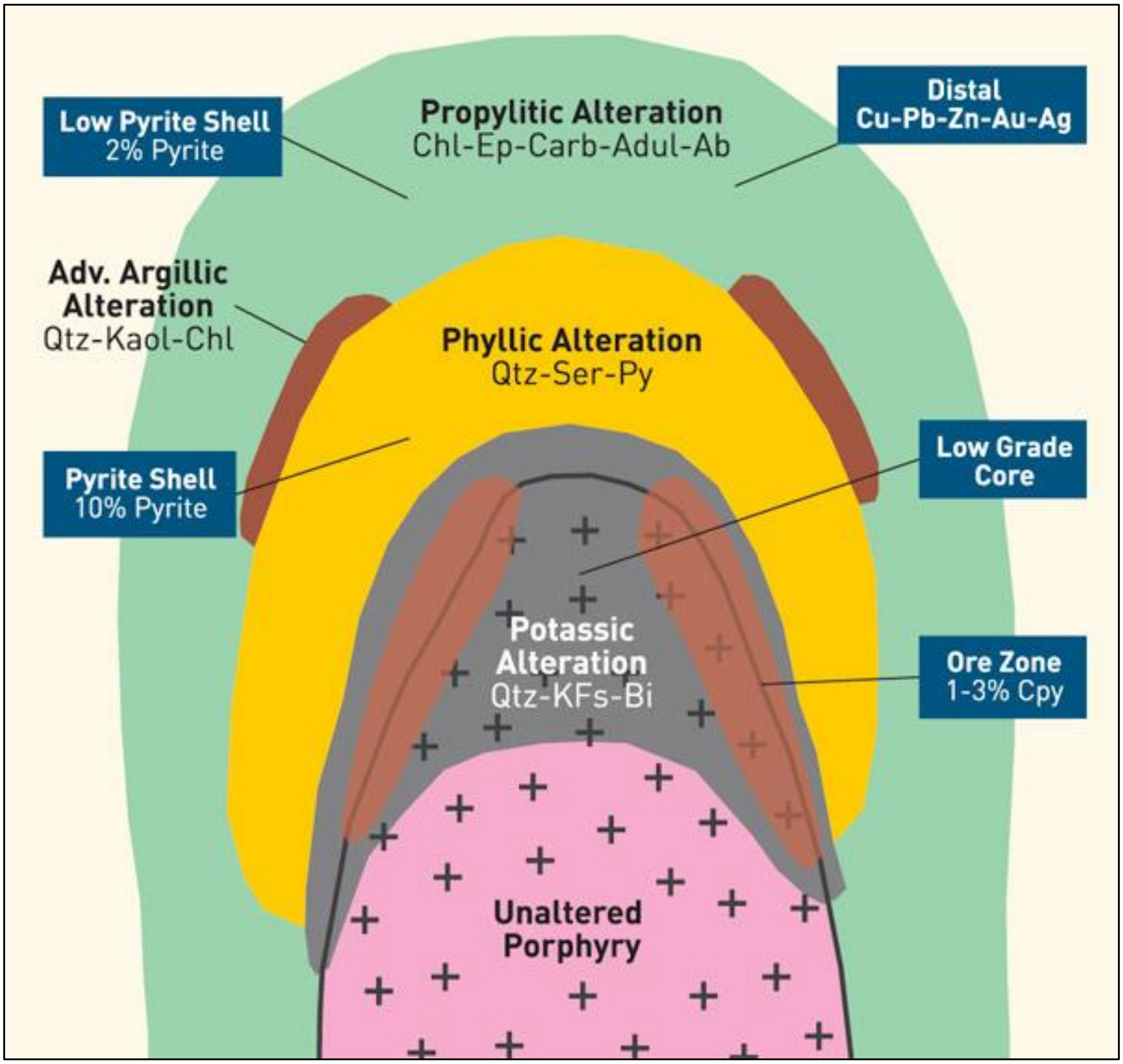

Figure 9. The copper deposit on Cape Breton is a type of copper porphyry. All copper porphyry deposits are types of sulfide ore deposits and, thus, susceptible to acid mine drainage. The diagram indicates the high percentage of pyrite (iron sulfide) that tends to be associated with copper porphyry deposits. Figure from Geology Science (2023).

METHODOLOGY

Based upon the preceding sections, the objective of this report can be subdivided into the following questions:

1) What is the vicinity of the Nova Copper exploration area and the CBRM surplus land to protected areas and Indigenous lands?
2) What is the vicinity of the Nova Copper exploration area and the CBRM surplus land to surface water bodies?
3) What is the vicinity of the Nova Copper exploration area and the CBRM surplus land to private and municipal wells?
4) What is the vicinity of the Nova Copper exploration area and the CBRM surplus land to private homes and communities?

The questions were addressed by comparing the boundaries of the Nova Copper exploration area and the CBRM surplus land (Keep Coxheath Clean, 2023c) with digital spatial datasets available from ESRI (2023a-g), Government of Canada (2023a), and Nova Scotia Canada (2008, 2014, 2022, 2023a-b). All maps were created using ESRI ArcGIS ArcMap v. 10.8.2.

RESULTS

Vicinity to Protected Areas and Indigenous Lands

Both the Nova Copper exploration area and the CBRM surplus land overlap with the Bras d'Or Lake Biosphere Reserve (see Fig. 2), which is one of only 19 UNESCO Biospheres within Canada and one of two UNESCO Biospheres within Nova Scotia (Government of Canada, 2023a). The shore of Bras d'Or Lake is 4.0 kilometers south of the CBRM surplus land and 2.3 kilometers south of the Nova Copper exploration area (see Fig. 2). Numerous protected areas and Indigenous lands are located within the same primary watershed as the Nova Copper exploration and the CBRM surplus land. The primary watershed includes nearly all of Cape Breton County (see Fig. 2). The Eskasoni First Nation is 15.4 and 17.7 kilometers southwest of the Nova Copper exploration area and the CBRM surplus land, respectively (see Fig. 2).

Vicinity to Surface Water Bodies

The CBRM surplus land is located on a hill that is the headwaters of three secondary watersheds (see Fig. 10). Numerous lakes, streams and wetlands are found within those secondary watersheds, and even more are found within the primary watershed that encompasses nearly all of Cape Breton County (see Fig. 2 and 10). Mapped wetlands within the CBRM surplus land include marshes, swamps, either bogs or fens, and wetlands of unknown type (see Fig. 10). There are small lakes within the CBRM surplus land and the CBRM surplus land is 2.1 kilometers from Blacketts Lake and 1.0 kilometers from Macdonalds Lake (see Fig. 10). The Nova Copper exploration area includes numerous small lakes as well, overlaps with Gillis Lake and includes all of Macdonalds Lake (see Fig. 10). (According to ESRI (2023e), there is both a western and an eastern Gillis Lake (see Fig. 10)). The Nova Copper exploration area is 1.7 kilometers from Blacketts Lake and 0.9 kilometers from the Sydney River (see Fig. 10).

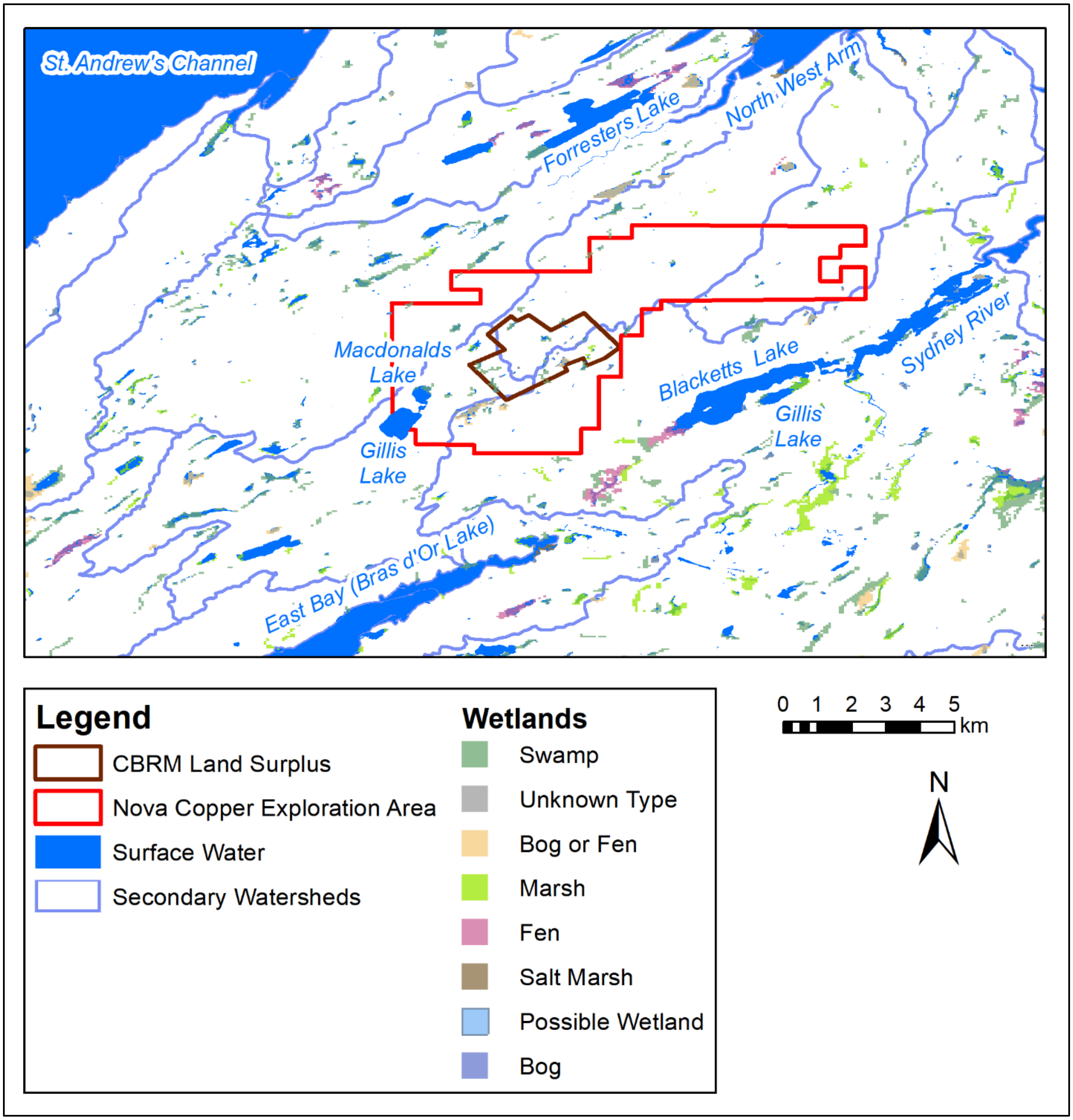

Figure 10. The CBRM land surplus is located on a hill that is the headwaters of three secondary watersheds. Numerous lakes, streams and wetlands are found within those secondary watersheds, and even more are found within the primary watershed that encompasses nearly all of Cape Breton County (see Fig. 2). In particular, the CBRM land surplus is 4.0 kilometers from the shore of Bras d'Or Lake, part of a UNESCO Biosphere Reserve, 2.1 kilometers from Blacketts Lake, and 1.0 kilometers from Macdonalds Lake. Perimeters of CBRM land surplus and Nova Copper exploration area from Keep Coxheath Clean (2023c). Watersheds from Nova Scotia Canada (2023b). Surface water bodies and wetlands from ESRI (2023e-f).

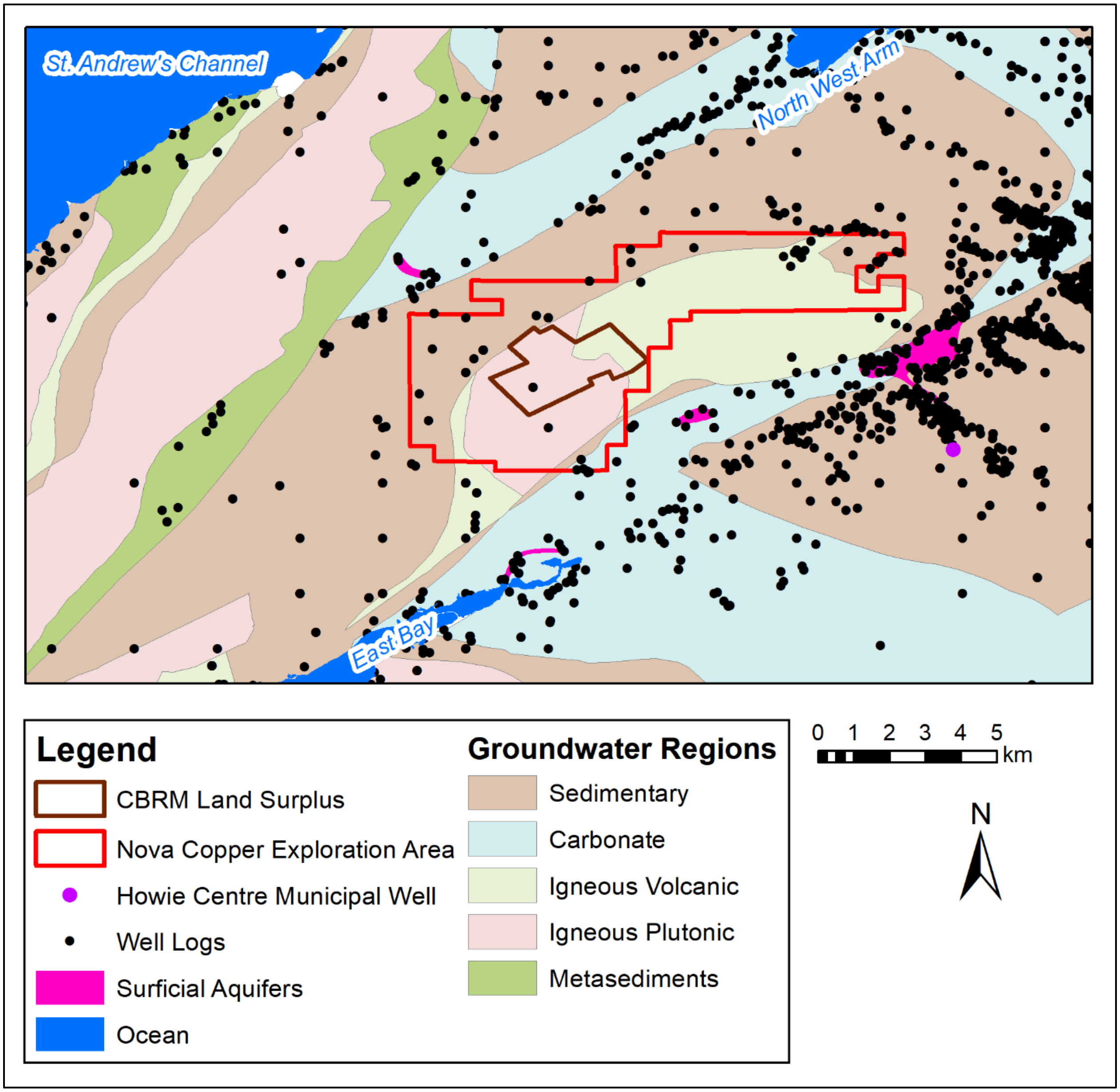

Figure 11. The CBRM land surplus is in the vicinity of numerous well log sites (which correspond to the positions of drilled wells), including one well log site within the land surplus. The map does not include the hundreds of dug wells in the area and it should not be assumed that well logs have been filed for all drilled wells. In addition, the CBRM land surplus is within 1.5 kilometers of potential surficial aquifers and 6.5 kilometers from the Howie Centre municipal well. Perimeters of CBRM land surplus and Nova Copper exploration area from Keep Coxheath Clean (2023c). Municipal wells from ESRI (2023g). Well logs, surficial aquifers, and groundwater regions from Nova Scotia Canada (2022), Nova Scotia Canada (2014), and Nova Scotia Canada (2008).

Vicinity to Groundwater Sources

A well log is the description of the earth materials with their depth ranges that are encountered during drilling and it is typical for well logs to be filed with a regulatory agency. The CBRM surplus land is in the vicinity of numerous well log sites, including one well log site within the surplus land (see Fig. 11). Each well log site should correspond to a single drilled well, but it should not be assumed that the driller of each drilled well has properly filed the well log with the appropriate regulatory agency. The map (see Fig. 11) does not include shallow, dug wells, but media articles have stated that there are hundreds of dug wells in the vicinity of the CBRM surplus land (Dyment, 2023; Keep Coxheath Clean, 2023b; Lazovskis, 2023; Nathanson, 2023). Within 1, 2, and 3 kilometers of the CBRM surplus land, there are 19, 36, and 125 well log sites (see Fig. 11). There are 55 well log sites within the Nova Copper exploration area (see Fig. 11). Outside of the Nova Copper exploration area, there are 121, 376, and 769 well log sites within 1, 2 and 3 kilometers of the exploration area (see Fig. 11). The Howie Centre municipal well is 4.0 kilometers from the Nova Copper exploration area and 6.5 kilometers from the CBRM surplus land (see Fig. 11). Finally, the CBRM surplus land is 1.5 and 2.5 kilometers from two potential surficial aquifers, while the Nova Copper exploration area is 770, 850, 960 meters from three potential surficial aquifers (see Fig. 11). A potential surficial aquifer should be understood both as an optimum location for a shallow, dug well and as a surficial region through which mining-related contaminants could be rapidly transmitted.

Vicinity to Communities

The CBRM surplus land is within the vicinity of numerous private homes, all of which rely on groundwater (see Fig. 12a). Homes along Beechmont Road are inside of the Nova Copper exploration area and within 194 meters of the CBRM surplus land (see Fig. 12b). Homes along an unnamed road are 918 meters from the CBRM surplus land and 306 meters outside of the Nova Copper exploration area (see Fig. 12c). Homes along Coxheath Road are within 1763 meters of the CBRM surplus land and either inside of or only tens of meters outside of the Nova Copper exploration area (see Fig. 12d). Numerous homes are visible within the Nova Copper exploration area from Google Earth imagery and no attempt was made to document all of those homes.

At this point it is appropriate to inquire as to the proper distance between a mine site and a community. The author is not aware of any jurisdiction in Canada that sets such a minimum distance. Each proposed mine permit takes into consideration many factors, including, for example, groundwater pollution, noise pollution, light pollution, and traffic. There are international regulations regarding minimum distances between tailings disposal facilities and communities. Of course, Nova Copper has not stated that they intend to construct the tailings disposal facility on the CBRM surplus land. However, unless they come up with some other solution for the disposal of mine tailings, they or the mining company that constructs the mine will need to construct a facility somewhere on land that they own or otherwise control.

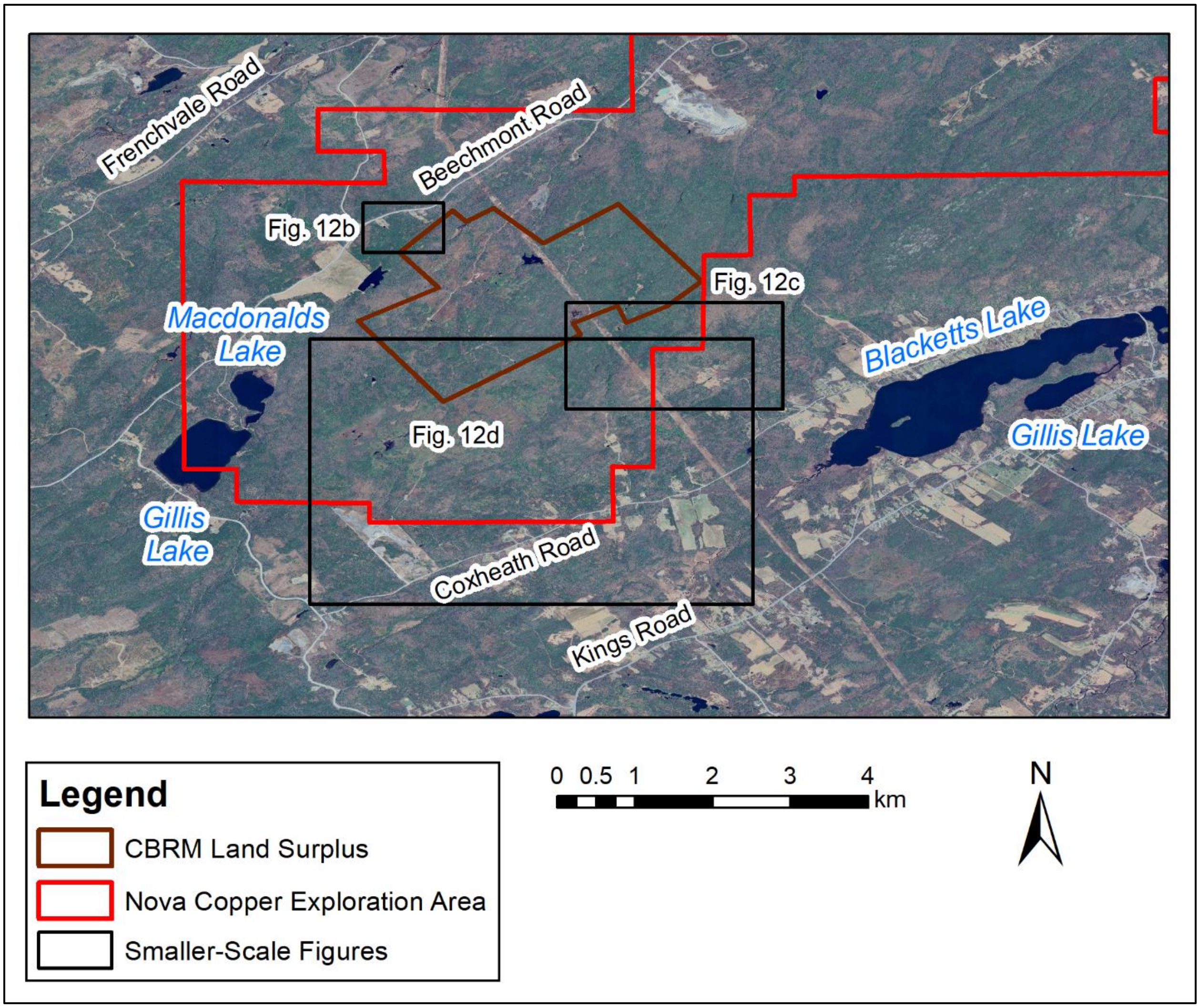

Figure 12a. There are numerous private homes with wells within the vicinity of the CBRM land surplus. Smaller-scale maps are shown in Figs. 12b, 12c and 12d. Perimeters of CBRM land surplus and Nova Copper exploration area from Keep Coxheath Clean (2023c). Background is Google Earth imagery from July 12, 2019, January 28, 2023, and April 27, 2023.

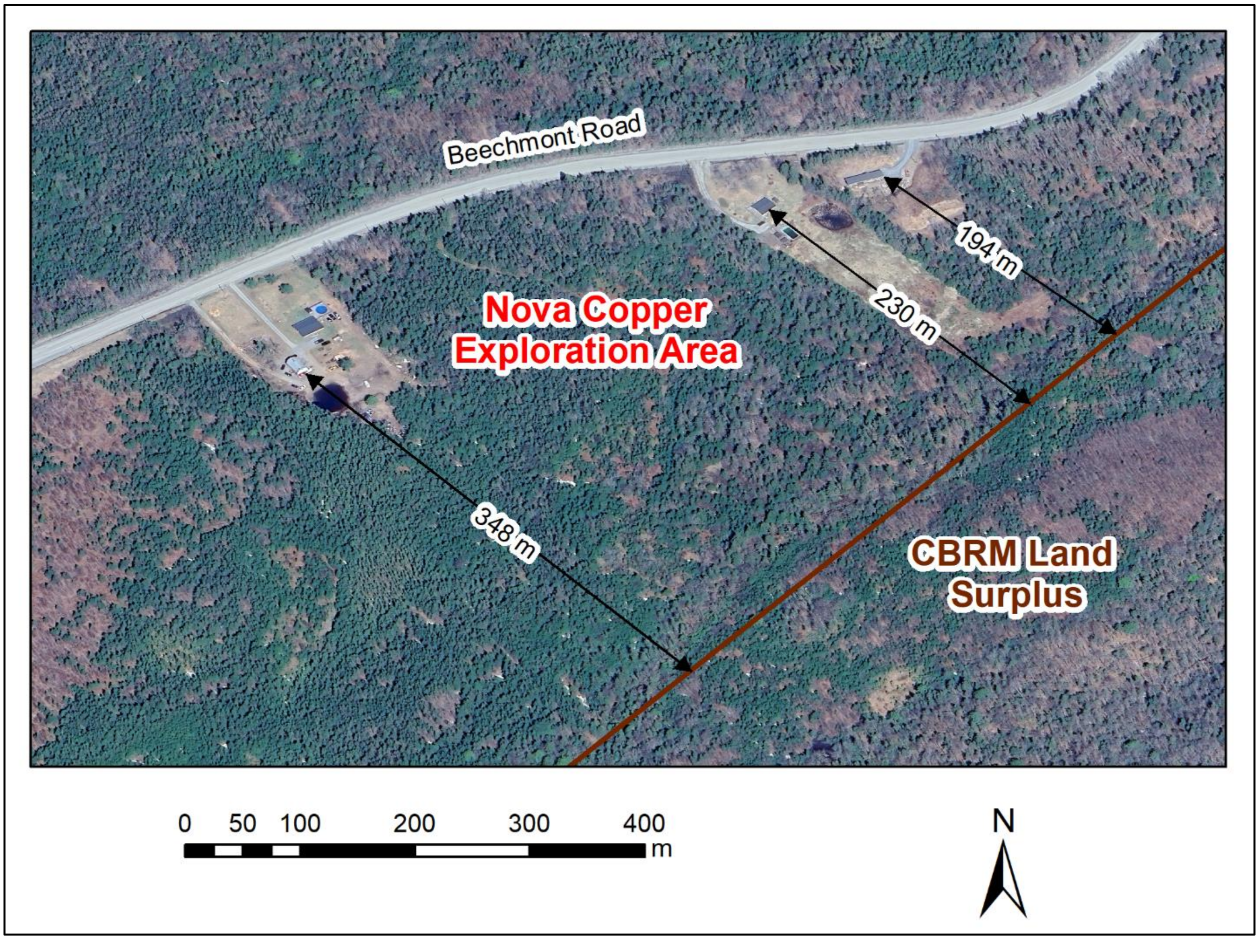

Figure 12b. The CBRM land surplus is located within 194 meters of private homes with wells along Beechmont Road (see larger-scale map in Fig. 12a). Although China is often regarded as a country with weak environmental standards for mining, Chinese regulations prohibit the placement of mine tailings within 1000 meters of populated areas. Perimeter of CBRM land surplus from Keep Coxheath Clean (2023c). Background is Google Earth imagery from April 27, 2023.

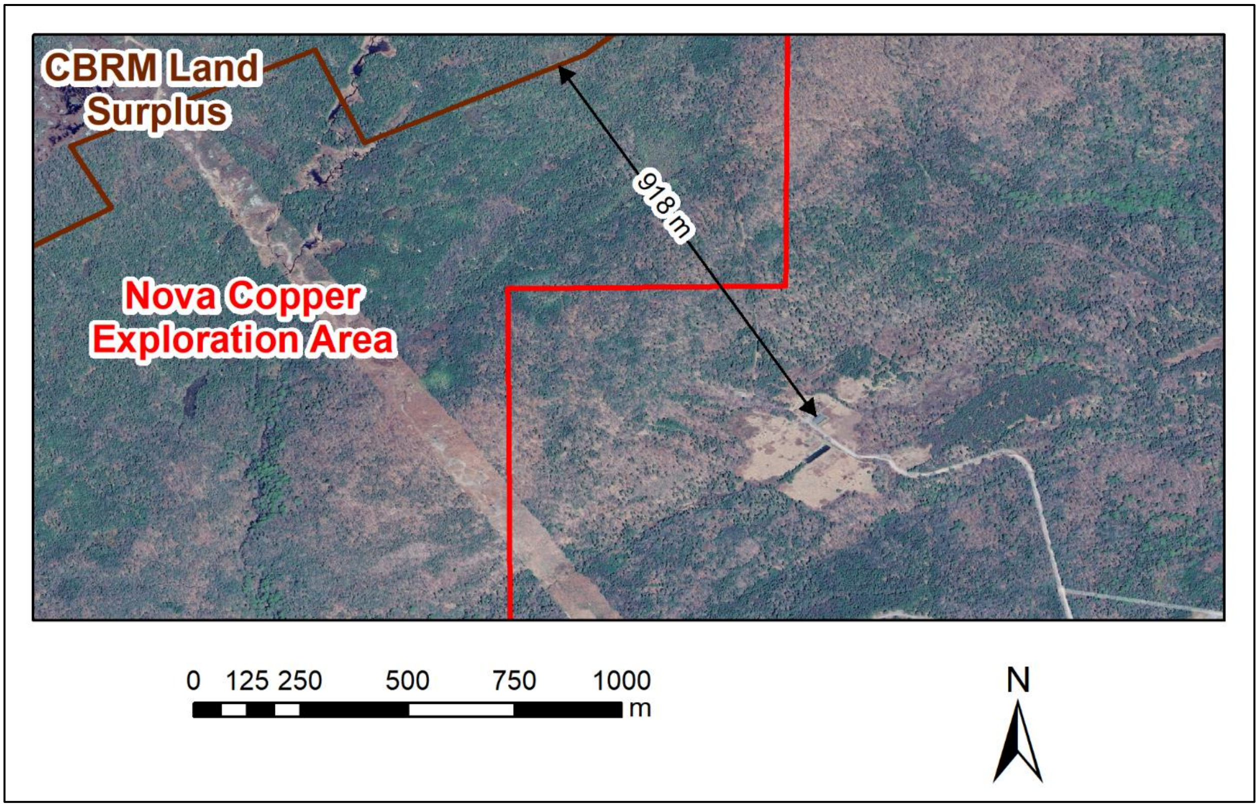

Figure 12c. The CBRM land surplus is located within 918 meters of private homes with wells along an unnamed road (see larger-scale map in Fig. 12a). Although China is often regarded as a country with weak environmental standards for mining, Chinese regulations prohibit the placement of mine tailings within 1000 meters of populated areas. Perimeter of Nova Copper exploration area and CBRM land surplus from Keep Coxheath Clean (2023c). Background is Google Earth imagery from April 27, 2023.

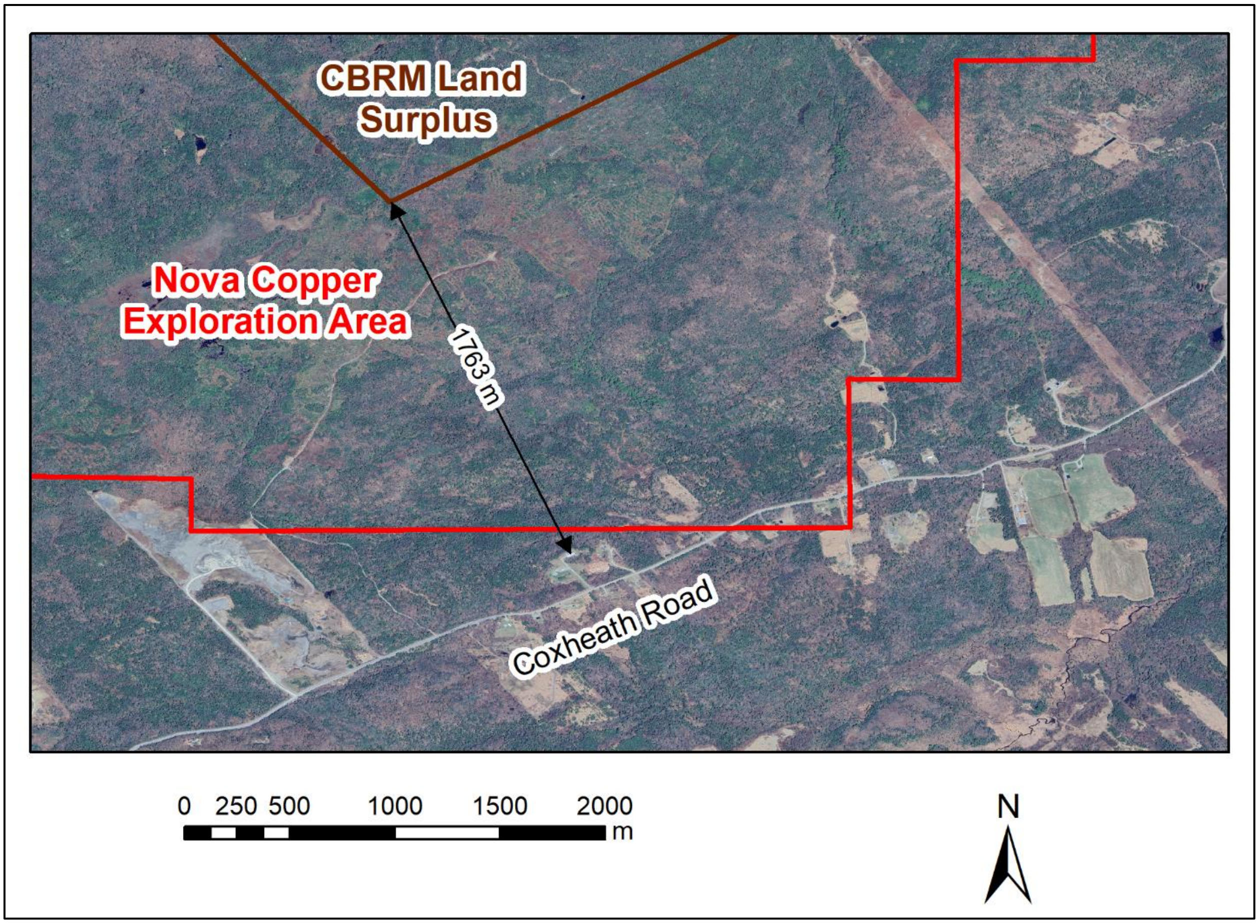

Figure 12d. The CBRM land surplus is located within 1763 meters of private homes with wells along Coxheath Road (see larger-scale map in Fig. 12a). Perimeter of Nova Copper exploration area and CBRM land surplus from Keep Coxheath Clean (2023c). Background is Google Earth imagery from April 27, 2023.

As an example, the state of Minas Gerais in Brazil sets a minimum distance of 10 kilometers between tailings dams and communities, which can be increased up to 25 kilometers depending upon the population density and the natural and cultural heritage of the area. According to Assembleia Legislativa de Minas Gerais [Legislative Assembly of Minas Gerais] (2019), "*Fica vedada a concessão de licença ambiental para construção, instalação, ampliação ou alteamento de barragem em cujos estudos de cenários de rupturas seja identificada comunidade na zona de autossalvamento. § 1º – Para os fins do disposto nesta lei, considera-se zona de autossalvamento a porção do vale a jusante da barragem em que não haja tempo suficiente para uma intervenção da autoridade competente em situação de emergência. § 2º – Para a delimitação da extensão da zona de autossalvamento, será considerada a maior entre as duas seguintes distâncias a partir da barragem: I – 10km (dez quilômetros) ao longo do curso do vale; II – a porção do vale passível de ser atingida pela onda de inundação num prazo de trinta minutos. § 3º – A critério do órgão ou da entidade competente do Sisema, a distância a que se refere o inciso I do § 2º poderá ser majorada para até 25km (vinte e cinco quilômetros), observados a densidade e a localização das áreas habitadas e os dados sobre os patrimônios natural e cultural da região*" [It is forbidden to grant an environmental license for the construction, installation, expansion or elevation of a dam for which studies of rupture scenarios identify a community in the self-rescue zone. § 1 – For the purposes of the provisions of this law, the portion of the valley downstream of the dam in which there is not enough time for intervention by the competent authority in an emergency situation is considered a self-rescue zone. § 2 – For the delimitation of the extent of the self-rescue zone, the greatest between the following two distances from the dam will be considered: I – 10 km (ten kilometers) along the course of the valley; II - the portion of the valley that can be reached by the flood wave within thirty minutes. § 3 - At the discretion of the competent body or entity of SISEMA, the distance referred to in item I of § 2 may be increased to up to 25 km (twenty-five kilometers), taking into account the density and location of the inhabited areas and the data on the region's natural and cultural heritage]. The phrase "self-rescue zone" should be a chilling expression.

Ecuador has followed the lead of Minas Gerais, but without the provision to increase the minimum distance to 25 kilometers. According to Ministerio de Energía y Recursos Naturales No Renovables [Ministry of Energy and Non Renewable Natural Resources] (Ecuador), 2020), "*Se prohíbe el diseño y construcción de depósitos de relave en los casos que se identifique una zona poblada ubicada aguas abajo del mismo que pudiera ser afectada por la onda de inundación, la cual queda limitada por la mayor de las dos distancias: • A diez (10) kilómetros de distancia aguas abajo del pie de la presa a lo largo del curso del valle, o; • La porción de territorio que sea alcanzada por la onda de inundación en un plazo de 30 minutos*" [The design and construction of tailings deposits is prohibited in cases where a populated area located downstream of the same is identified that could be affected by the flood wave, which is limited by the greater of the two distances: • Up to ten (10) kilometers downstream from the toe of the dam along the course of the valley, or; • The portion of territory that could be reached by the flood wave within 30 minutes].

The People's Republic of China is often regarded as a country with exceptionally weak environmental standards, although that is not entirely justified. The Chinese tailings regulations define "overhead ponds" [头顶库] as "初期坝坡脚起至下游尾矿流经路径 1 公里范围内有居民或重要设施的尾矿库" [tailings ponds with residents or important facilities within 1 km from the toe of the embankment of the starter dam along the downstream tailings flow path] (Department of Basics for Production Safety, 2020). The regulations then clarify that it is prohibited to construct new tailings dams within 1000 meters of populated areas ("overhead ponds"). It is also prohibited to construct new tailings dams or to modify or expand existing tailings dams within 1000 meters of important tributaries. According to Department of Basics for Production Safety (2020), "严禁新建"头顶库", 总坝高超过 200 米的尾矿库, 严禁在距离长江和黄河干流岸线 3 公里, 重要支流岸线 1 公里范围内新（改, 扩）建尾矿库" [It is strictly forbidden to build new "overhead ponds" and tailings ponds with a total dam height of more than 200 meters. It is strictly forbidden to build new (or modified or expanded) tailings ponds within 3 kilometers from the banks of the main streams of the Yangtze River and the Yellow River, and 1 kilometer from the banks of their important tributaries]. English-language media articles on Chinese tailings regulations are available in Zhang and Daly (2020) and Zhang and Singh (2020). In summary, the short distances between communities and a prospective mine site on the CBRM surplus land (see Figs. 12a-c) would be highly questionable even in the People's Republic of China.

DISCUSSION

Copper Mining on Cape Breton without Environmental Contamination is Unlikely

It is now appropriate to return to the ten candidates for sulfide ore mines that have operated or been closed without environmental contamination (see Table 1 and Fig. 6). Note that the evidence that all of these candidate mines actually do have extensive records of environmental contamination has been compiled by Emerman (2023). Out of the ten candidate mines, two are in arid regions (annual precipitation less than 250 mm), while three more are in semi-arid regions (annual precipitation between 250 and 500 mm) (see Table 1). The candidate mine in the wettest climate is the Flambeau mine in Wisconsin with a mean annual precipitation of 860.3 mm (see Table 1 and Fig. 6). By contrast, the weather station at Sydney in the CBRM has a mean annual precipitation of 1481.6 mm (Government of Canada, 2023b; see Table 1). Three of the candidate mine sites in Wisconsin and Ontario (Flambeau, Musselwhite, Rainy River) are wetter than Sydney during the summer months, while the McLaughlin mine site in California is wetter in January (see Figs. 6 and 13). However, the Sydney site lacks the marked seasonality of the other sites and is consistently wet throughout the year (see Fig. 13).

If a sulfide ore mine were to be operated and then eventually closed at the site of the CBRM surplus land or anywhere else within the CBRM, it would be the first example of a sulfide ore mine that had operated or been closed without environmental contamination. According to Mr. Cabrita, "And nowadays in modern mining the water that goes into the plant comes out the other side cleaner" (Keep Coxheath Clean, 2023e). The CEO of Nova Copper does not offer any examples, nor is the author aware of any such examples. It has already been noted that the site of the CBRM surplus land has the following meteorologic, hydrologic and social characteristics:

1) high mean annual precipitation (1482 mm)
2) overlap with the Bras d'Or Lake UNESCO Biosphere Reserve
3) 4.0 kilometers from the shore of Bras d'Or Lake
4) location at the head of three secondary watersheds
5) numerous wetlands within the site and in the vicinity of the site
6) small lakes within the site
7) 2.1 kilometers from Blacketts Lake and 1.0 kilometers from Macdonalds Lake
8) one drilled well within the site and 19, 36, and 125 drilled wells within 1, 2, and 3 kilometers of the site
9) hundreds of unmapped dug wells in the vicinity of the site
10) private homes with wells within 194 meters of the site

Based on the preceding characteristics, it seems highly unlikely that a Nova Copper mine could be the first example of a sulfide ore mine without environmental contamination. Certainly there is no discussion in documents from Nova Copper as to what technology or site characteristics would separate a Nova Copper mine from every other sulfide ore mine.

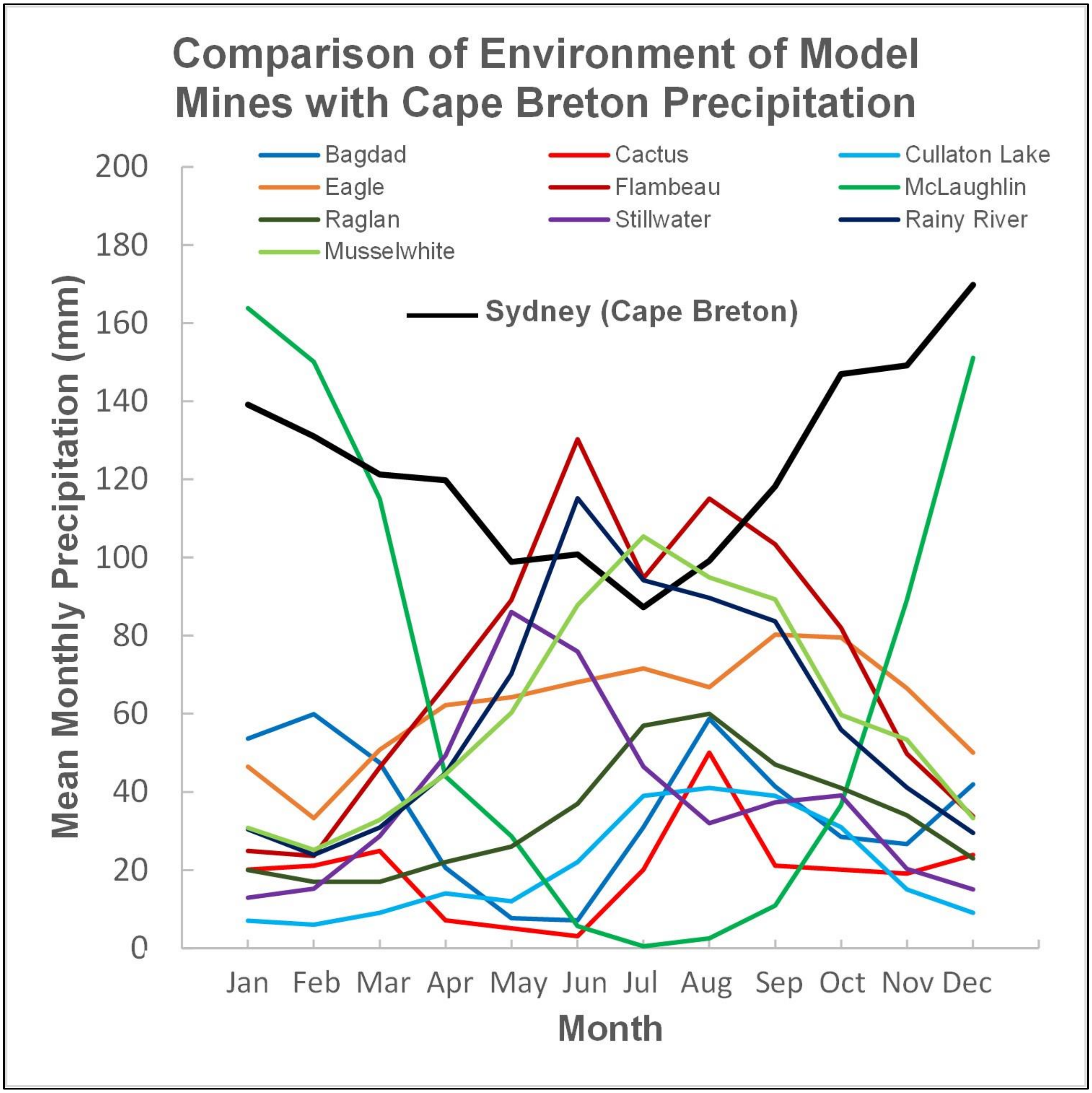

Figure 13. In response to the Prove It First legislation in Wisconsin and the proposed Prove It First legislation Minnesota, ten mines were put forward as candidates for model sulfide ore mines with no history of environmental contamination (see Table 1 and Fig. 6). However, all ten candidates have been discredited since they actually do have records of environmental contamination. The mean annual precipitation for the ten mines ranges from 235.5 to 860.3 mm. Since the Sydney weather station on Cape Breton has a mean annual precipitation of 1481.6 mm and because of the numerous surface water and groundwater resources in close vicinity to the CBRM land surplus, it is highly unlikely that a sulfide ore mine at the site of the CBRM land surplus could operate and be closed without environmental contamination. Figure adapted from Emerman (2023).

Copper on Cape Breton is a Miniscule Fraction of World Production

Nova Copper has stated that there is a global shortage of copper and that the Coxheath copper deposit is the last hope for addressing the shortage without the destruction of wilderness. According to Mr. Cabrita, CEO of Nova Copper, “This is probably one of the last copper projects that can be low impact, as environmentally friendly as possible … This is probably one of the last ones in Canada … Copper is deemed the most critical mineral for the green transition … It doesn't get any sweeter than this. And when I say one of the last great deposits in Canada that can be done like this, if we don't do it here, in our backyard, then we do have to go and displace the wilderness" (Keep Coxheath Clean, 2023e). Mr. Cabrita also informed the Mayor and Council of CBRM that "The fight against climate change depends on copper. Electric vehicles, wind turbines, solar panels – many of the major tools to address the climate emergency rely on copper. There is a global shortage of copper" (Cabrita, 2023). It is not clear as to how a Nova Copper mine could constitute an alternative to the displacement of wilderness, since the CBRM surplus land that has been requested for purchase by Nova Copper overlaps with a UNESCO Biosphere Reserve (see Fig. 2). The discussion as to whether there is an actual global shortage of copper is beyond the scope of this report. However, it is worth considering whether a Nova Copper mine could make a significant contribution toward addressing a global copper shortage, even if such a shortage did exist.

In a presentation to investors, Nova Copper (2023b) estimated a Phase I production of 60,000 metric tons of ore and a Phase II production of 160,000 metric tons of ore, for a total of 220,000 metric tons. For both phases, Nova Copper (2023b) estimated the ore grade at 2.2% copper for a total of 4840 metric tons of refined copper. Nova Copper (2023b) even described the project as "small scale mine production." The most recent estimate represents a downgrading of previous estimates, since O'Sullivan (2007) reported a "potential tonnage" of 410,000 metric tons with a grade of 3.145%, or 12,895 metric tons of refined copper. There is no estimate of the duration of the proposed mine, but if a Nova Copper mine operated for 10 years, based on the latest estimate of total production, it would be producing an average of 484 metric tons of copper per year.

In 2022 the global production was 22 million metric tons of refined copper (Statista, 2023). Thus, a production of 484 metric tons per year by a Nova Copper mine would represent 0.0022% of the global production and even less if the global production increased (which should be expected as a response to global shortage). In other words, a Nova Copper mine could make only a miniscule contribution toward addressing a global shortage of copper, whether such a shortage does or does not exist. It is difficult to reconcile the possible minuscule contribution with the assertion by Mr. Cabrita that the Coxheath copper deposit is "one of the last great deposits in Canada" (Keep Coxheath Clean, 2023e).

Arguments Advanced by Nova Copper are Quasi-Religious

In an email to the Mayor and Council of the CBRM on November 14, 2023, on the day of a presentation to the CBRM Council by Keep Coxheath Clean Association (2023b), Mr. Cabrita wrote, "Communities that do not welcome safe, responsible copper mining will be abdicating their responsibility to act on climate change" (Cabrita, 2023). The argument by the CEO of Nova Copper is neither scientific nor economic. The argument is, in fact, quasi-religious in nature in stating that all communities with copper ore deposits, no matter how small and no matter how great the environmental risks, are obligated to offer themselves as sacrifice zones to satisfy an alleged global shortage of copper. The author finds no basis for such an argument in any traditional religion.

The preceding declaration by the CEO of Nova Copper represents a considerable upgrading of rhetoric on the part of the mining company. On August 26, 2023, the company stated in a more muted way, “The world needs copper now for energy transition and to combat climate change. Let’s all do our part” (Nova Copper, 2023c). Even so, the same web page under the “Community” tab backs up the more subdued rhetoric with the false fact that “China produces the majority of the world’s copper … it is vital to source the copper we need for renewable energy projects here at home” (Nova Copper, 2023c). In fact, in 2021, China accounted for only 8% of world copper production (Visual Capitalist, 2022).

It is the opinion of the author that the people of the CBRM have the right to decide for themselves whether any possible benefits from copper mining outweigh the environmental risks. The benefits might be revenue from employment and taxes. It should go without saying that, in terms of the availability of copper, the people of the CBRM can equally benefit from copper that is mined and processed outside of Cape Breton. Whether there is or is not a global shortage of copper, the shortfall cannot be met by the very small amount of copper that seems to be available on Cape Breton and meeting a shortfall certainly does not depend on any type of special copper that is available only on Cape Breton. Thus, the balance of risks and benefits is a balance between money and a clean environment, including the availability of clean water for drinking, cooking and other domestic uses. At the same time, it should be noted that copper mining in the CBRM can preclude other economic activities and can impact the economic value of wetlands and other ecosystems.

It is the most basic principle of justice that one party cannot receive the benefits, while another party suffers the risks or the damages. This is the point that was made in the “Overview” section in stating that, while discussions regarding mining often involve calls for “compromise” and “dialogue,” the decisions that are made typically result from the interactions among political actors with profound differentials in power. Justice requires that discussions regarding risks and benefits take place within the group of people who will both reap the potential benefits and suffer the potential consequences. In this regard, it should be noted that Nova Copper has in no way indicated their willingness to make sacrifices or to accept risks. In fact, the CEO of Nova Copper has done quite the opposite in demanding certainty from the CBRM Council. In his email to the Mayor and Council on November 14, 2023, Mr. Cabrita wrote, “We are confident that Cape Breton Regional Council will do the right thing, support action on climate change and provide the clarity and certainty that we need …” (Cabrita, 2023).

Any sulfide ore mine that operated on Cape Breton without environmental contamination would be the first such sulfide ore mine anywhere in the world. Although Nova Copper has not mentioned any new technology that would enable them to be the first sulfide ore mine without environmental contamination, there is no principle of justice that would require the people of the CBRM to be the testing ground for new technologies for sulfide ore mining. Being the testing ground means accepting not only risks, but unknown risks. There is no principle that should require any jurisdiction to be the testing ground, although the people of some jurisdiction might choose to do so for whatever reasons they choose. Even when choices are made to accept sulfide ore mining or new technologies for sulfide ore mining, due attention should be paid to possible power differentials among the stakeholders and the possible separation of risks and benefits. In summary, no jurisdiction, not the Cape Breton Regional Municipality, and not anywhere, should have the obligation to be the sacrifice zone so that the rest of the world can have copper.

CONCLUSIONS

The chief conclusions of this report can be summarized as follows:

1) Numerous protected areas and Indigenous lands are located in the vicinity and within the primary watershed of the Nova Copper exploration area and the CBRM surplus land.
2) Both the Nova Copper exploration area and the CBRM surplus land overlap with the Bras d'Or Lake Biosphere Reserve, which is one of only 19 UNESCO Biosphere Reserves within Canada. The shore of Bras d'Or Lake is 4.0 kilometers and 2.3 kilometers south of the CBRM surplus land and the Nova Copper exploration area, respectively.
3) The CBRM surplus land is located on a hill that is the headwaters of three secondary watersheds. Numerous lakes, streams and wetlands are found within those secondary watersheds, and even more are found within the primary watershed that encompasses nearly all of the CBRM. For example, the CBRM surplus land is 2.1 kilometers from Blacketts Lake and 1.0 kilometers from Macdonalds Lake.
4) The CBRM surplus land is in the vicinity of numerous well log sites (which correspond to the positions of drilled wells), including one well log site within the surplus land and 19, 36, and 125 well log sites within 1, 2, and 3 kilometers of the CBRM surplus land, respectively. The map of well log sites does not include the hundreds of dug wells in the area and it should not be assumed that well logs have been filed for all drilled wells.
5) The CBRM surplus land is within 1.5 kilometers of a potential surficial aquifer and 6.5 kilometers from the Howie Centre municipal well.
6) The CBRM surplus land is located within 194 meters of private homes with wells along Beechmont Road.
7) The mean annual precipitation at Sydney in the CBRM is 1482 mm.
8) Because no sulfide ore mine has ever been operated or closed without environmental contamination, because the wettest mine that has ever been proposed as having no environmental contamination had a mean annual precipitation of only 860 mm (although the proposed mine actually did have an extensive record of environmental contamination), and because of the numerous lakes, wetlands, wells, and private homes within the vicinity of the requested land purchase, it is highly likely that a Nova Copper mine would result in environmental contamination.
9) Nova Copper has estimated the size of the ore deposit as 220,000 metric tons with a grade of 2.2%, so that the copper production could be 484 metric tons per year for a 10-year project. Since the world copper production was 22 million metric tons in 2022, a Nova Copper mine could produce 0.0022% of the world production, so that a Nova Copper mine could not be regarded as making a substantial contribution to solving a world copper shortage.
10) In a message to the Mayor and Council of the CBRM, the CEO of Nova Copper stated, "Communities that do not welcome safe, responsible copper mining will be abdicating their responsibility to act on climate change." The argument by the CEO is neither scientific nor economic, but is quasi-religious in nature in stating that all communities with copper ore deposits, no matter how small and no matter how great the environmental risks, are obligated to offer themselves as sacrifice zones to satisfy an alleged global shortage of copper. The author finds no basis for such an argument in any traditional religion. It is the opinion of the author that the people of the CBRM have the

right to decide for themselves whether any possible benefits from copper mining outweigh the environmental risks.

RECOMMENDATIONS

The recommendation of the report is that the request for purchase of CBRM surplus land by Nova Copper should not be granted.

ABOUT THE AUTHOR

Dr. Steven H. Emerman has a B.S. in Mathematics from The Ohio State University, M.A. in Geophysics from Princeton University, and Ph.D. in Geophysics from Cornell University. Dr. Emerman has 31 years of experience teaching hydrology and geophysics, including teaching as a Fulbright Professor in Ecuador and Nepal, and has over 70 peer-reviewed publications in these areas. Since 2018 Dr. Emerman has been the owner of Malach Consulting, which specializes in evaluating the environmental impacts of mining for mining companies, as well as governmental and nongovernmental organizations. Dr. Emerman has evaluated proposed and existing mining projects in North America, South America, Europe, Africa, Asia and Oceania, and has testified on issues of mining and water before the U.S. House of Representatives Subcommittee on Indigenous Peoples of the United States, the European Parliament, the United Nations Permanent Forum on Indigenous Issues, the United Nations Environment Assembly, and the Permanent Commission on Human Rights of the Chamber of Deputies of the Dominican Republic. Dr. Emerman is the Chair of the Body of Knowledge Subcommittee of the U.S. Society on Dams and one of the authors of Safety First: Guidelines for Responsible Mine Tailings Management.

Steven H. Emerman

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