Technical Memorandum: Twin Metals Mining and the Boundary Waters Canoe Area Wilderness, Risk Assessment for Underground Metals Mining

Prepared for: Northeastern Minnesotans for Wilderness, Ely MN

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Twin Metals, Inc, which includes Duluth Metals, Franconia, and Beaver Bay, have acquired interests in federal subsurface mineral rights, including two 1966 leases. The two 1966 leases were issued prior to the enactment of the National Environmental Policy Act. Both expire on December 31, 2013, with opportunities to renew the leases. The BLM, the lessor on the leases, has decided to prepare and issue an Environmental Assessment of the two mineral leases prior to granting a renewal of the leases.

This technical memorandum assesses the risk of developing a sulfide ore mine within the watershed draining toward the Boundary Waters Canoe Area Wilderness (BWCA). It describes a conceptual model of flow and transport in the watershed, the likely potential mining of the ore deposits, and describes the risks to be expected from that mining. Because a mining lease can be interpreted as a right to mine, if the potential risks are substantial, the BLM should consider the risks in an environmental impact statement. This technical memorandum qualitatively outlines those risks.

A conceptual flow model (CFM) describes the flow paths through a watershed from precipitation to runoff, and from recharge to discharge in the aquifer. The CFM developed for the BWCA includes groundwater and surface water, including runoff processes, recharge (and seepage of waste), groundwater flow, and discharge to surface water. It discusses the relative magnitudes of flow but does not develop a detailed water budget. The CFM then imposes the potential mining into the flow model to consider the risks to the watershed.

There is no plan of operations for proposed mining, so the description of the probable mining would be based on information gleaned from Twin Metals' reports (Parker and Eggleston 2012; Cox et al. 2009). Other sources are hydrology studies completed by the US Geological Survey (USGS) and State of Minnesota.

Conceptual Flow and Transport Model

General Area

The Twin Metals leases lie south of the South Kawishiwi River. The South Kawishiwi River flows west from the BWCA and then joins with the Kawishiwi and flows back into the BWCA. The Kawishiwi watershed is in the Rainy River Headwaters watershed (http://www.dnr.state.mn.us/watersheds/map.html). The river system connects many lakes, some of which are manmade, with more than 40% of the channel length within lakes (Siegel and Ericson 1981). The area lies in two Minnesota groundwater provinces, the Arrowhead and Central Region, and in the fractured igneous or metamorphic bedrock province (http://www.dnr.state.mn.us/groundwater/provinces/index.html).

The BWCA is also considered an "outstanding resource value water" under the Minnesota statutes (MAR 7050.0180). The States policy regarding such waters is: "The agency recognizes that the maintenance of existing high quality in some waters of outstanding resource value to the state is essential to their function as exceptional recreational, cultural, aesthetic, or scientific resources. To preserve the value of these special waters, the agency will prohibit or stringently control new or expanded discharges from either point or nonpoint sources to outstanding resource value waters." (MAR 7050.0180 Subpart 1). Portions of the Kawishiwi River outside of the BWCA are classified as 1B, 2Bd, and 3C. Class 1B is the highest level of water quality assignable to surface waters, meaning that "with approved disinfection, such as simple chlorination or its equivalent, the treated water will meet both the primary and secondary drinking water standards …". Only groundwater can be classified higher because it is often usable without disinfection whereas surface water is not. Class 2Bd requires the quality be maintained as "to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associate aquatic life and their habitats. The waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable" (class 2Bd). Class 3C has to do with maintaining quality for industrial uses.

Hydrogeology

The mineral leases are hosted in the Duluth Complex, which is "composed of multiple discrete intrusions of mafic to felsic tholeiitic magmas that were episodically emplaced into the base of a comagmatic volcanic edifice between 1108 and 1098 Ma" (Miller et al. 2002, p 109). The complex dips southeastward with basement rock of Archaen age, which means it becomes deeper in that direction. The Duluth Complex has not been significantly deformed, but displacements due to reactivated basement faults and some cross faults have affected it (Miller et al. 2002). Faults trend north-northeasterly with the maximum offset being 400 feet.

Hydrogeologically, the Duluth Complex is a low-permeability intrusive formation with a very low conductivity except possibly near some of the infrequent faulting. There is little data available concerning the hydrogeology of the faults.

There are two aquifers over the area. The surficial aquifer, consisting of either glacial till or sand and gravel, is very thin, generally less than 10 feet thick but with some areas especially in the west end of the area being 20 feet or slightly more thick (Mast and Turk 1999). Underlying the surficial aquifer is bedrock generally of the Duluth Complex.

Well yields throughout the Kawishiwi watershed are less than 10 gpm (Siegel and Ericson 1981) which reflects the very thin to nonexistent surficial aquifers and the low permeability bedrock, which transmits very little groundwater except in fractures. The aquifer along the river is not a target for production water pumping because it is too thin (Siegel and Ericson 1981). The Duluth Formation is relatively fractured for the upper two to three hundred feet, but the well yields range from 5 to 15 gpm, especially in the South Kawishiwi intrusion which hosts the nickel/copper ore body (Cox et al. 2009; Siegel and Ericson 1981). The best bedrock aquifer of the province is the Biwabik formation, in which most of the area iron mines were developed.

Conceptual Flow Model

The CFM through the South Kawishiwi watershed is that precipitation segregates into evapotranspiration (ET), runoff or infiltration into the ground. ET includes direct evaporation of surface water and precipitation intercepted by vegetation and transpiration of soil water through the vegetation. River flow is either direct runoff from the surface, interflow, or groundwater discharge of recharge. Interflow is flow through the soils and unsaturated zone above the water table to rivers. Wintertime precipitation is frozen along with the soils so little direct runoff or recharge occurs.

Annually, about a third of the precipitation in the Kawishiwi River watershed (above Winton and north of the South Kawishiwi River watershed) becomes runoff and the remainder ET (9.4 inches runoff and 18.1 inches of ET) (Siegel and Ericson 1981) based on the 1955 through 1976 time period. These authors did not estimate the groundwater discharge portion of river flow. Their budget calculations assume steady state which means there is no change in basin water storage. Runoff at the Kawishiwi River near Ely gage (USGS gage 05124480) for 1966 through 2012 is 10 in/y. Except for climate change, to be addressed below, there is no reason to expect that the current water budget has changed significantly because the watershed is predominantly undeveloped within wilderness.

One estimate of recharge to surficial aquifers in the Kawishiwi watershed is 20 to 30 cm (Delin et al. 2007), or 8 to 11 in/year (rounding off the ends of the range). This estimate is based on baseflow recession indices, or the rate that the flow rate decreases after a flood peak, determined around Minnesota (Lorenz and Delin 2007). This estimated recharge is close to the total runoff as estimated by Siegel and Ericson (1981) which reflects inaccuracies in the methodologies.

Siegel and Ericson (1981) noted that 60 percent of the runoff occurs during snowmelt from April through June whereas less than 11 percent occurs from December through March. It is common to assume that baseflow rates equal groundwater recharge over the basin (Scanlon et al. 2002), but in the Partridge River basin, just west of the Laurentian Divide, Myers (in preparation) has found that the lowest baseflow cannot equal the average recharge because of the long time period since recharge would have occurred (the previous snowmelt period) and the short travel time through the aquifers due to the high conductivity and thinness of the surficial aquifers. Recharge cannot occur when the precipitation and soils are frozen, so early spring baseflow can represent only the recharge that occurs more than about 5-month travel time from the stream.

During the spring snowmelt, flow from the watershed reaches a peak and there is a significant wetting of the aquifers due to recharge. Average monthly river flow at the Kawishiwi River near Ely gage peaks at more than 30 in/y during May just two months after the low flow of less than 3 in/y recorded in March (Figure 1). Much recharge would likely occur during this snowmelt freshet flood because there is water running on the ground surface and river and stream levels are high which creates a gradient for flow into the streambanks near the river. No groundwater level data is published by the US Geological Survey for this area but studies in support of mining in the Partridge River watershed just west of the Kawishiwi River includes data showing that groundwater levels fluctuate up to six feet during the spring (Polymet 2013).

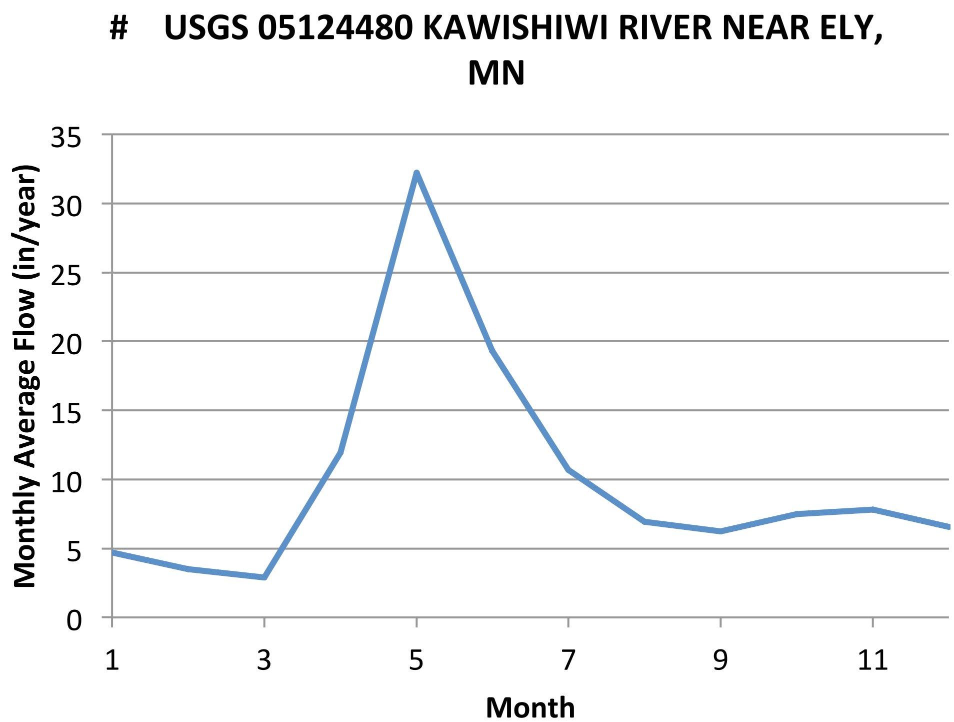


Figure 1: Average flow by month (1=January, 12=December) in inches per year for the Kawishiwi River near Ely, MN.

Some authors suggest that long-term drainage from surface storage in areas with a lot of lakes supports long-term baseflow which complicates the calculation of recharge (Sophocleous 2002). The watershed is a system of connected local flow systems defined by microscale topography embedded within a larger flow system (Winter 1998). The recession index, defined as the time for a flood hydrograph to recede one logarithmic interval (base 10), for the Kawishiwi River was 63.75 days (Lorenz and Delin 2007). This was relatively long compared to other Minnesota basins (Lorenz and Delin 2007) and reflects the elongated recession caused by slow drainage from extensive surface storage. Water storage in the Kawishiwi River basin includes surface storage such as wetlands and small lakes and subsurface storage temporarily in the unsaturated zone and groundwater. Because water release from small-scale surface storage resembles release from groundwater, the methods of Lorenz and Delin (2007) and Delin et al. (2007) may overestimate recharge for this area by not distinguishing slow surface water release and interflow from true groundwater baseflow. This means the amount of water reaching the bedrock aquifers is limited, as expected due to the low bedrock conductivity.

Interflow is both unsaturated and saturated flow to streams that occurs during and just after a storm, with saturation causing temporary perched zones (Sophocleous 2002). Because of the shallowness and flatness of the groundwater table in this watershed, especially in wetland areas, interflow should be limited and should soon discharge to the ground surface and become overland flow among the wetlands. Another possible short-term shallow groundwater discharge to the rivers may be caused by groundwater ridging which causes a rapid conversion of the capillary zone to atmospheric pressure which would rapidly increase the groundwater head and significantly increase the gradient for flow to surface drainages over the short-term (Sophocleous 2002). Both processes may in reality represent groundwater recharge.

Filson Creek is a 25.2 km^2 tributary described by Siegel (1981) as having two significant lakes and being 60% covered by upland forest, 30% covered by wetlands and lakes, and the remainder by stands of pine. The watershed has less than one meter of drift covering the bedrock which outcrops over about 10% of the watershed (Id.). Under the wetlands, there is a layer of peat with thickness up to 15 meters (Id.). Peat generally has very low permeability (Siegel et al. 1995) and wetlands underlain by peat are usually perched, so that little recharge through the wetlands occurs.

Groundwater Chemistry

Groundwater in sand and gravel is a magnesium bicarbonate type typical of groundwater that has either a short residence time or has been collected in a recharge zone (Siegel and Ericson 1981). In till, the groundwater is either calcium magnesium bicarbonate or calcium magnesium sulfate; the later occurs near mineralized zones where oxidation may occur (Id.). The till has a smaller particle size and therefore larger surface area to volume ratio which leads to more dissolution and chemical reaction times and therefore higher concentrations of various constituents (Id.). For example, "mean values of major dissolved constituents are significantly higher for water from till than from sand and gravel. Mean and median concentrations of the major ions, specific conductivity, and hardness in water from till are about twice that found in sand and gravel" (Id., p 19). The same is not true for nitrate, phosphorus, total organic carbon, silica, and chemical oxygen demand. Concentrations of copper, cobalt, and nickel can exceed 100 ug/l in surficial material above the mineralized zone because of the oxidation of sulfide ore at the contact (Id.). This indicates there is an exchange of groundwater between the surficial and bedrock aquifers or an upward flow gradient in these areas. Higher concentrations of copper and nickel extend over an area of 5 to 10 miles from the center of the contact zone. Iron concentrations are sometimes very high.

In the bedrock, concentrations are highly variable because they reflect localized concentrations in fracture zones and sometimes increase with depth. Duluth Complex water is either sodium chloride or sodium bicarbonate and Biwabik Iron and Virginia Argillite water is a calcium magnesium bicarbonate type similar to the overlying surficial materials. Metals concentrations are generally lower than in the surficial aquifer near the contact zone. This may relate a lack of oxygen for oxidation rather than a lack of the presence of metals at depth.

Surface Water Chemistry

Surface water sediment transport is generally low in the Kawishiwi River, at about 5 tons/year/mi^2; this is less than half that found in the Partridge River and Embarrass River basins (Siegel and Ericson 1981). There is no evidence regarding a hydrograph of sediment concentration although presumably the peak load occurs during spring runoff. There was also no data related to contaminant loads on the sediment.

Between 1967 and 1977, water temperature at the Kawishiwi River near Ely gage peaked at near 20°C during July and August based on a 1967 to 1977 average (Siegel and Ericson 1981). Interestingly, the air temperature averaged several degrees lower than the water temperature. The significant wetland area probably causes the higher summer water temperature due to higher insolation over the large surface water area.

Electrical conductivity, a surrogate for total dissolved solids, generally is less than 80 umhos/cm when river flow includes surface runoff. Surface runoff has less salt because it has less contact time with the surficial aquifer during which salts would be dissolved. At less than 1.5 cfs/mi^2, the EC increases significantly which probably reflects the transition from runoff to groundwater discharge to the rivers including interflow through the surficial aquifers.

During 1976, the USGS collected 16 samples for water chemistry at the South Kawishiwi River above White Iron Lake near Ely gage (#05126210). The records show very high quality water, with low total dissolved solids concentration that peaks around 35 mg/l during baseflow. Carbonate is nondetect which along with there being almost no carbonate rock in the watershed indicates a very low acid buffering capacity. Buffering is the ability of the water to absorb an acid without the acidity increasing. In this river system, the addition of an acid would significantly increase the acidity.

Mercury contamination is a current issue in the Kawishiwi watershed area, with the river, Birch Lake, and many other streams and ponds listed under section 303d of the Clean Water Act as impaired for mercury (http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/impaired-waters-list.html, accessed 12/3/13). The impairment is often "mercury in fish tissue" rather than a water column measurement. This reflects the tendency for mercury to be bound in sediment where it affects fish feeding on it. Mercury likely moves through the watershed adsorbed to sediment during high flows, especially during the spring.

The spring snowmelt peak also corresponds with a spike in contaminants reaching the stream system (Siegel 1981). Although direct runoff often has low dissolved solids, the high proportion of interflow and high baseflow discharge increases the dissolved solids discharge, in addition to a likely peak in suspended sediment.

Climate Change

A general rule of thumb regarding climate change is that wet areas will become wetter and dry areas will become drier. Northern Minnesota is projected to have a small increase in annual runoff due to climate change (IPCC 2007). Increased precipitation and temperature can have variable effects depending on the relative and seasonal changes, with increased ET decreasing runoff at some parts of the year while increased precipitation can increase runoff at other times.

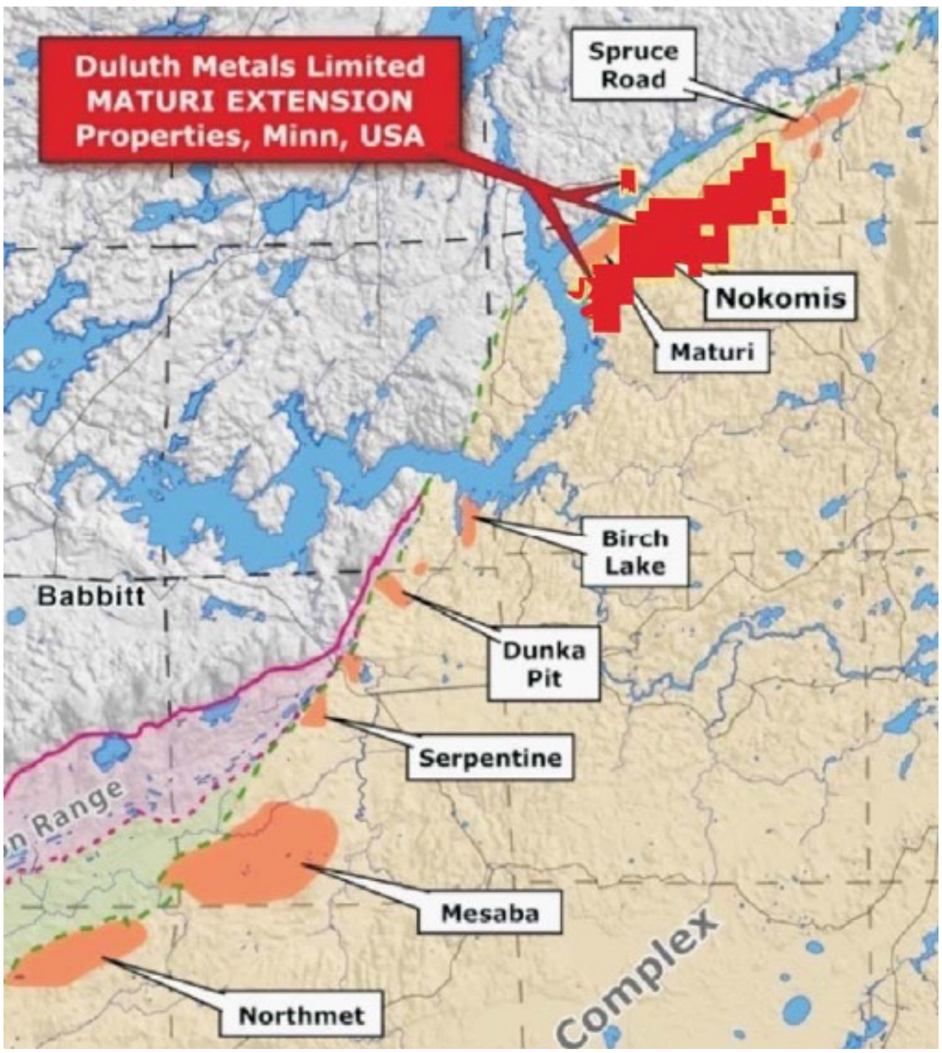
Minnesota streamflow has a linear relationship with non-winter precipitation and summer temperatures (Nichols and Verry 2001). Historic stream flow data shows that summertime rainfall runoff peaks have increased as have summertime baseflows (Novotny and Stefan 2007). This is primarily due to increased precipitation, which manifests as heavier individual events rather than more storm events. Because the additional precipitation would occur primarily in summer, increased recharge may not be expected due to its coincidence with increased ET. Increased precipitation in general would increase the moisture accessing the unsaturated zone, including in an above ground waste or tailings impoundments.

Potential Twin Metals Nickel/Copper Mining

Twin Metals proposes mining at four mineral deposits – Nokomis, Maturi, Spruce Road, and Birch Lake - located 10 miles east of Babbitt, MN and 15 miles southeast of Ely MN. All four deposits are in the watershed of and lie south of the South Kawishiwi River (http://www.twin-metals.com/about-the-project/project-facts/, accessed 10/23/13) (Figure 2). Each deposit would be accessed with underground methods (Parker and Eggleston 2012; Cox et al 2009) and Twin Metals suggests that some tailings could be deposited underground. The letter prepared by Twin Metals (Williamson 2012) regarding "State Hydrogeologic Field Activities" lists the leases for which hydrogeologic data would be collected. The leases span all four of the deposits.

The Maturi, Birch Lake, and Spruce Road deposits are all hosted in the Duluth Complex, a composite intrusion, in the basal portion of the South Kawishiwi intrusion. The mineralized zone is as much as 1000 feet thick in locations. All deposits are magmatic nickel-copper-platinum group element deposits which are mostly considered sulfide deposits (Parker and Eggleston 2012). They occur in localized areas along the basal zone of the South Kawaishiwi at the contact (Miller et al. 2002, p 167). The sulfide content of the Spruce Road deposit is 2 to 5% by volume and 3 to 4% by weight, with chalcopyrite being the primary copper sulfide; it is the only deposit with sulfide content specified.

The Maturi deposit extends to as much as 4500 feet below the ground surface. The depth of the Spruce Road deposit ranges from the ground surface to about 1500 feet bgs. The Birch Lake deposit ranges to about 4000 feet below ground surface[1]. The Birch Lake deposit contains up to eight possible significant faults, which are identified as significant issues which will potentially affect the underground mining operations and the location of high grades of mineralization.



[1] The source for this information is Figure 7-7 in Parker and Eggleston (2012) which does not have units specified on the vertical axis. The ground surface shows at a little less than 500 which if meters would be near 1500 feet, the ground surface elevation. The depth ranges to about 900 below ground surface, which if meters would be near 3000 feet.

Figure 2: Snapshot from Figure 15-1 in * showing the location of the Birch Lake, Maturi, Nokomis, and Spruce Road deposits. Scale is provided by the squares which are approximate townships.**

Mine production for the Nokomis deposit would occur at 40,000 tpd, after an initial three-year period of slower production (Cox et al 2009). A tailings impoundment may be constructed at the Dunka Mine site, with some tailings backfilled into the abandoned open pit (Cox et al 2009). Cox et al (2009) suggests that about 283,000,000 tons of tailings would be deposited at that mine, which is in the South Kawishiwi watershed. There is little discussion of actual mining for the other deposits, other than mention that run-of-mine material will be fed to the grinding circuit also at 40,000 tons per day (Parker and Eggleston 2012). In their recent financial update for Duluth Metals, Edison (2013) prepared an "upside case evaluation" indicating that throughput would be 80,000 tons per day. It is not specified whether mining would occur simultaneously at more than one deposit or where the tailings would be impounded.

Twin Metals does not hold the only leases in watershed. Figure 3 shows a snapshot of a broader map of mining leases prepared by the Minnesota Center for Environmental Advocacy. The map shows the four Twin Metals sites, but also shows other sites. All are within the watershed that drains to the BWCA. Additional mining in the watershed simply increases the risk that spills or leaks will occur and increases the risks to the BWCA. The magnitude of risks at any given time depends on how many deposits are being developed simultaneously.

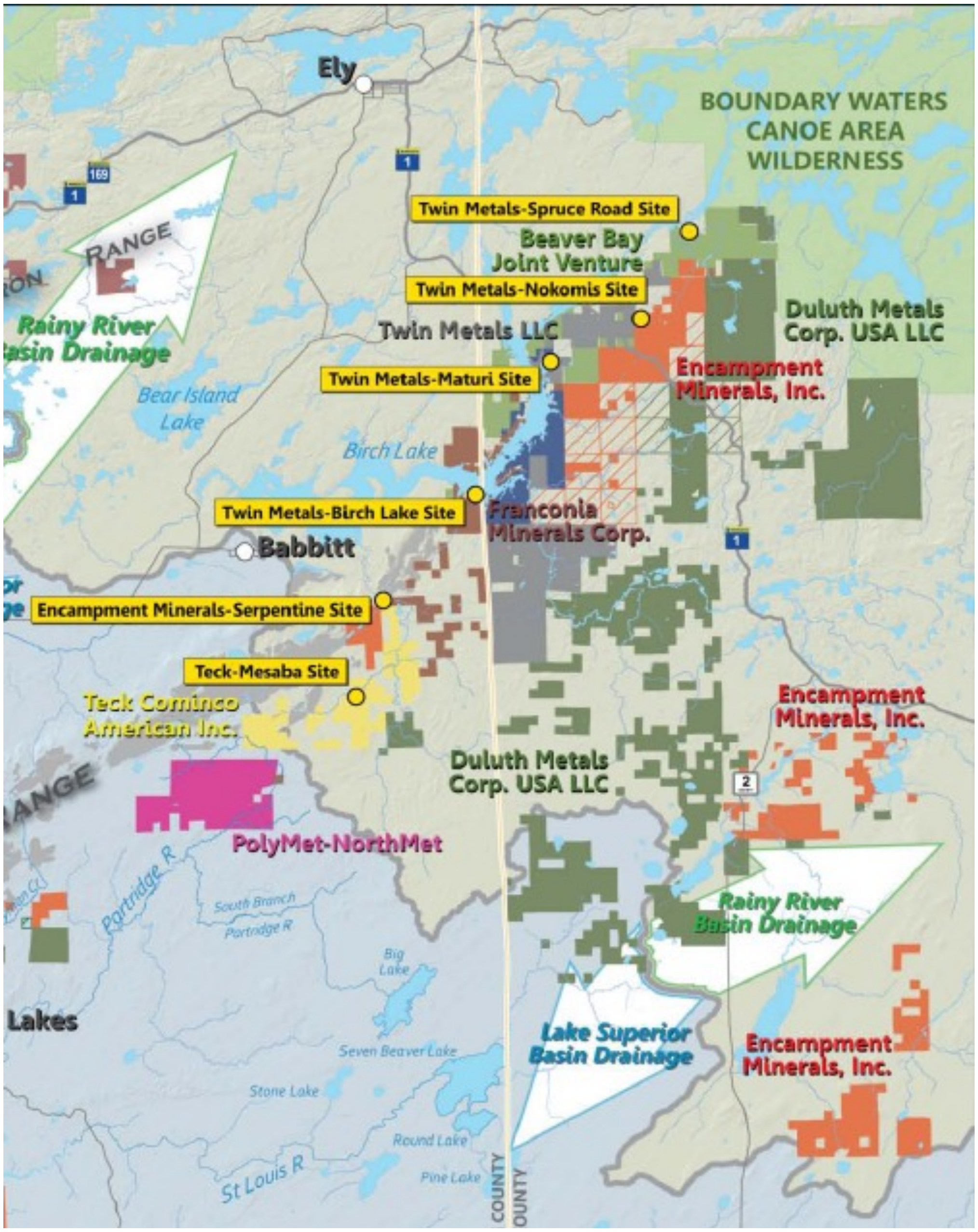


Figure 3: Snapshot of a mining lease map found at http://www.mncenter.org/Portals/0/Non_Ferrous_2013_Watershed.png

Risks of Mining in the South Kawishiwi River Basin

There are seven primary risks to water resources in the Kawishiwi River basin to the BWCA from the development of mines at the Twin Metals leases described herein. They are risks to water quantity from mine dewatering and production water development and risks to water quality from the development and seepage of acid mine drainage (AMD), seepage of tailings water, tailings impoundment failures, the runoff of sediment from the site due to stormwater, and wetlands disturbance.

Mine Dewatering

Mine dewatering is the lowering of the water table to prevent groundwater from discharging into the mine. An open cut through an aquifer will drain water into the cut until the water table drops to the bottom of the cut. Because the mine will lower the head relative to other portions of the aquifer including other discharge points, the flow toward the mine will divert flow from the other discharge points. The deposits potentially developed as described herein, as underground mines, would be deep in low conductivity bedrock so the amount of water diverted from discharge points would not likely be substantial unless the mine encounters major fracture zones. Fracture zones can be regional flow paths and could connect the mine area with distant discharge points. The effects of dewatering a fracture zone could be substantial.

The rate of underground mining affects dewatering in two opposite ways. The area affected by drawdown increases as long as the water table is held at a certain depth, therefore mining quickly decreases the area affected by drawdown. Mining faster, however, means that more fracture zones may be open or dewatered at any given time so that more areas connected to fracture zones may be impacted. It also means that the company may have less ability to utilize best practices to minimize dewatering, such as grouting the fractures. Short-term dewatering impacts should be more significant if Twin Metals mines at the higher rate, but the system could recover more quickly if they would finish mining more quickly.

The EIS should consider all available borehole data for the presence of fracture systems. Additionally, fractures should be considered by examination of the pit walls in open pits developed in the Duluth Complex.

Production Water

Mine ore processing requires water. It is unlikely that Twin Metals will obtain sufficient water from groundwater sources because of the low well yields and sparse surficial aquifers (Siegel and Ericson 1981). The amount of water required for processing increases with the amount of ore being processed. An EIS considering renewal of the leases should include an analysis of water resources in the area. If water would be obtained from surface water sources, the EIS should consider the effect on flow especially during low-flow periods. If insufficient water is available, the EIS should consider from where water would be obtained, and what water conveyance structures would be necessary.

Acid Mine Drainage

The potential minerals found in sulfide ore bodies, which when exposed to air and water, may produce large amounts of acid which may leach metals into flow pathways. The volume percent of sulfide reported for the Spruce Road deposit is several times that found to produce significant acid mine drainage in Duluth Complex waste (Lapako 1988), so the potential for AMD at these sites must be considered high. The EIS should include an analysis of the potential for AMD and determination of the strategies that would have to be taken to prevent discharge to the river. At a minimum, the cuttings from boreholes drilled in and near the ore bodies should undergo static acid/base testing. If the static tests show cuttings to be potentially acid generating, they should be further subjected to kinetic testing. The streams are poorly buffered meaning that AMD and associated metals that reach the rivers would not be chemically attenuated. Once AMD into the BWCA waterways commences, it would be very difficult to contain or remediate.

The EIS should also discuss where the waste would be dumped because threats to the environment depend on disposal locations and methods. If it is impossible to take adequate precautions due to space limitations, the risks of AMD will be much higher. The mining rate affects the rate that waste is created. Higher mining rates may increase the amount of waste exposed to the environment and increase the risk. The chances for seepage and erosion from exposed waste, especially during the spring runoff, increases with the amount of waste exposed.

The Dunka Mine is an AMD problem in the Kawishiwi watershed that could portend future problems for the area. The EPA used it as an example in its AMD manual because of the amount of pollution it causes (EPA 1994). The mine was developed in Duluth Complex formation and has seeps with pH as low as 5.0 and copper and nickel concentrations at 1.7 and 40 mg/l (ITRC 2010; EPA 1994). The copper maximum level contaminant goal is 1.7 mg/l, which means this water could have toxic effects on people drinking it. The nickel concentration exceeds the former maximum contaminant level by 400 times. This low-quality seepage resulted from a deposit with relatively low sulfide content, averaging around 0.6 ppm in the bulk rock at the site (EPA 1994). This is less than reported at the Spruce Road deposit. The seeps developed over a dozen years, starting in the 1970s (Id.) and new seeps turning acid in 1989 (ITRC 2010). The seepage, estimated at 500,000,000 gallons/year, discharges to a stream which flows into Bob Bay, a part of Birch Lake (EPA 1994, p 40), and increases the concentrations of copper, nickel, cobalt, and zinc in the bay to levels higher than the regional average (Id.). Metals concentrations in sediments are elevated, but less than 40% of the nickel load was removed through natural lake processes (Id.). This indicates that Birch Lake was insufficient to naturally “treat” the AMD seepage from the Dunka Mine.

Waste from proposed mining from Twin Metals' underground deposits could generate seepage just as degraded as from the Dunka Mine, since they are in the same formation. Drainage could affect river reaches that have substantially less dilution potential than is found in Birch Lake. Due to the low buffering capacity of the rivers, contamination could be transported a long distance downstream into the BWCA. A significant transport pathway could be on sediments on which metals have been adsorbed only to be transported into the wilderness by flood flows, which could increase due to climate change. The BLM should complete transport analyses to assess the risk to the BWCA as part of an EIS prior to renewing the leases. The EIS should consider AMD scenarios that would risk downstream water resources.

The AMD risk could continue long-term as well. Once mining ceases and groundwater levels recover, the mines become part of the groundwater system. AMD could generate in the mine tunnel walls and rock fractures that had been dewatered. The discharge points for bedrock groundwater have not been determined, so AMD discharge could occur at a distance from the mine in the future. Because the porosity of the bedrock is low but fracture controlled, groundwater and contaminants would flow through the bedrock many times faster than the estimated groundwater flow rate (because actual water molecules move through the pores whereas the flow rate is determined for the entire cross-section). Areas with bedrock flow rates equal to 10 feet per year could have contaminant transport rates greater than 1000 feet year, which indicates that a discharge point a few miles away could be affected within a couple of decades. If the AMD is generated near the ground surface, it could discharge quickly to nearby streams. These potential flow paths must be analyzed in the EIS.

Tailings Impoundments Leaks and Failures

The tailings have been assumed to be deposited in watersheds draining to the BWCA. The tailings could generate AMD or leak other process chemicals. Nitrate is frequently a problem in tailings. Once it starts, a leaky tailings impoundment is very difficult to remediate. Although they are not designed to leak, liner failures are common (Kuipers et al. 2006). If the leakage is either not detected or not containable, it could reach the surface water system and flow toward the BWCA. Similar arguments apply for spills of process water or other contaminants. Streams draining toward the BWCA have high water quality and would be affected by small amounts of contamination. The EIS should analyze how spills and tailings seepage would affect the streams and discuss how such seepage and spills could be mitigated. Scenarios that cannot be mitigated should be discussed.

The threat that could cause immense water resources damage in the BWCA is that of a tailings failure. They are never planned but are often catastrophic. As written by Carlton and Charlebois (2010): "The thesis of this paper is that tailings impoundments fail as a result of a string of incidents, each of which is trivial and within the bounds of normal events, but which, taken together, constitute an event so unusual that it lies outside of the bound of normal occurrence and experience." Rico et al (2008b) documented over 146 tailings impoundment failures (but did not establish the time period), with the majority occurring in the United States. The vast majority were less than 45 m high. Thirty-six of the failures were due to high rainfall (Rico et al 2008a and b), although as noted by Carlton and Charlebois (2010), there were probably smaller items that failed leading to the ultimate failure. The run-out distance for tailings dam failures has been as high as 100 km, with the maximum distance occurring when the failure is into a river system (Rico et al. 2008a).

Global warming and the consequent increase in extreme events will affect mines in many ways, but with increasing flood runoff, the proximity of any potential tailings impoundment to the river system, the connectivity with the BWCA, and the fact that a tailings impoundment must not fail forever, the development of tailings impoundments in the BWCA watershed presents a large risk to the BWCA.

Sedimentation and Wetland Disturbance

All disturbed soil in the watershed would increase sediment runoff reaching the rivers. Large storms and failures of sediment would allow additional sediment to reach rivers regardless of any implemented best management practices. Sedimentation would also occur due to direct disturbance of wetlands, which mining would cause. Increased sediment movement could increase the movement of mercury through the aquatic systems. As discussed, baseflow in this watershed depends on the interconnections of many wetlands and small lakes. Losing wetlands either to sedimentation or direct disturbance decrease baseflow.

Mining and Minnesota Environmental Law

The intent of Minnesota law appears to prohibit activities that have a significant chance of causing discharge to these river systems. The waters in the BWCA are classified as "outstanding resource values waters" (MAR 7050.0180), as noted above. The State treats these waters according to antidegradation standards, meaning there may be no new or expanded discharges to waters in the BWCA. Any discharge, intentional or otherwise, that reaches the Kawishiwi River system will eventually reach the BWCA because there is little attenuation in those rivers. The transport of AMD from the Dunka Mine is a small example of the potential for degradation to harm the BWCA.

Minnesota statute provides some setbacks to protect the BWCA and the Kawishiwi River (MAR 6130.1200). Mines shall not occur within 300 feet of the river or within one-quarter mile of the BWCA, with some exceptions. Based on the connectivity of the wetlands and small tributaries and the lack of buffering capacity in the rivers, and the documented runout distances of tailings impoundment failures (Rico et al. 2008a), these setbacks would not protect the river or wilderness.

Any spill or seepage of contaminants into the Kawishiwi River will also violate the Class 1B standards for drinking water. Disinfection would not remove metals or even salts that could reach the river. Therefore, mining would have to employ only the most stringent standards to prevent discharges into the river.

Summary of Risks

Developing the ore deposits held by Twin Metals is extremely risky for the BWCA because of the current high quality and low buffering capacity of the streams. Small amounts of contamination, including AMD or tailings failures, would have a significant effect. The potential for mining to affect low wintertime flows is also substantial. Because the downstream water resource in the BWCA is highly valuable, the highest level of prevention must be applied to prevent harm. Adaptive management should not be relied upon because it essentially means that management will be applied to fix problems and damage after they occur. Due to the rapid surface water flow time and inability to rapidly remediate many contaminant issues, mining should not be permitted unless no failure of the facilities can be guaranteed. That is a standard that no mine can meet.

Summary

The Kawishiwi watershed may host numerous nickel/copper mines in the future. About a third of the average 28 in/y of precipitation that falls in the watershed becomes river flow, with the remainder becoming ET. River flow is a combination of runoff and discharge from groundwater, including interflow. After a peak in surface runoff, the flow decreases slowly due to the storage in wetlands, small lakes, and surficial aquifer. There are two aquifers, a till-formed surficial aquifer and a bedrock aquifer. The upper few hundred feet of the aquifer may be fractured and transmit small amounts groundwater. The surficial aquifer is conductive but the transmissivity is low due to it being very thin.

Potential mine development of leases held by Twin Metals within the Kawishiwi watershed pose substantial risks to downstream water resources in the BWCA. The primary risks are due to the potential for contaminants from acid mine drainage or tailings seepage or spills to the river. The risk is even greater when all potential mines in the watershed are considered. The watershed is poorly buffered and historic mining has degraded waters in Birch Lake. Extensive mine development could degrade the entire watershed. Because contaminant seepage problems develop slowly or are not immediately detected, by the time mine development reaches a given threshold, the degradation may be underway and impossible to stop or remediate. At a minimum, this should be considered in an EIS prior to renewing any leases within the watershed that drains to the BWCA.

The potential for tailings impoundments to fail is a major risk to this watershed, especially since global warming is increasing the potential for large storm events. Tailings impoundments must contain contamination in perpetuity. The risk for failure may be low during any given year at any given site, but cumulatively the probability is high that one or more impoundments draining to the BWCA will eventually fail. The damages potentially caused by a failure make the risks of developing these impoundments very high.

Development of the potential mines would not likely cause significant dewatering effects due to the deposits lying deep in the bedrock, unless they intersect a significant fracture zone. Obtaining production water from groundwater could be difficult because of the low storage in aquifers. Surface diversions for production water could decrease baseflow during the winter and significantly impact the area hydrogeology.

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