BRIMM Water Stewardship

White Paper

BRIMM
BRADSHAW RESEARCH INITIATIVE FOR MINERALS & MINING

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EXECUTIVE SUMMARY

Accessing the water necessary for mineral extraction and processing, the transportation of mined ore and waste rock, and storage of tailings is becoming increasingly challenging. Two thirds of the world's largest mines are now located in areas of water scarcity, and the need for water is predicted to increase in coming years lower grades of ore are mined. Climate change and a growing global population will create additional pressure on water supplies. The competition for water that can arise between mining companies and communities is already a frequent cause of tension, and in some cases, conflict. These factors have made sustainable water management increasingly important, as well as a key consideration in the environmental, social and governance (ESG) metrics by which mining companies are judged by shareholders, stakeholders, rightsholders and other interested parties.

There is an urgent need for collective action and effective dialogue between mining companies and those who are affected by the mining sector's use of water to address the challenges the world is currently facing and to prepare for the future. At the Bradshaw Research Institute for Minerals and Mining (BRIMM), a Water Stewardship group has been convened to facilitate research on the critical issues at the intersection of mining and water. Water stewardship has been defined as "the use of water that is socially and culturally equitable, environmentally sustainable and economically beneficial, achieved through a stakeholder-inclusive process that includes both site- and catchment-based actions."[1] A key objective of the Water Stewardship group is to build collaborative, results-oriented partnerships with companies, Indigenous People, communities, governments, investors, civil society and non-governmental organizations, and other water users. Following a period of consultation and engagement with representatives from government, Indigenous nations, industry and society, three research themes were identified to guide BRIMM's Water Stewardship activities for the next three years: valuing water risks; data-driven decision making; and pursuing zero water discharge.

This white paper provides background on the need for water stewardship, defines the challenge ahead, and profiles research underway within the three themes. The paper also serves as a call to action: if you have a water stewardship issue, challenge, or opportunity that would benefit from research, contact us. BRIMM is driving transformation within the mining sector by connecting the unique insights of researchers with external partners, including industry, government, Indigenous nations, investors and communities for the benefit of the economy, society and the environment.

[1] Alliance for Water Stewardship (2017) https://a4ws.org/about/

1. Introduction

Water touches every aspect of life on Earth. All ecosystems depend on it. Humans need fresh water for everyday tasks like drinking and cooking, sanitation and hygiene, agriculture, and industries such as mining.

Mining uses large quantities of water for the extraction of minerals, mineral processing and separation, as well as for the transportation of mined ore and waste rock, and storage of tailings – a waste product from processing ore. At mine sites, water is also needed for dust suppression and equipment washing, and to provide drinking water and sanitation services for site personnel. Yet many mining projects operate in regions where water is scarce. By some estimates, roughly two thirds of the world's largest mines are located in regions with severe water scarcity.[2] Likewise, one of the richest copper-producing regions of the world, the Atacama Desert area of northern Chile and southern Peru, is also one of the driest. Furthermore, a number of the metals necessary for the transition to a low-carbon economy carry water risk; for example, 65% of lithium resources are located in areas of medium to high water risk.[3] Competition over access to water has thus become a major trigger for community-company conflict in many parts of the world.

Excessive quantities of water at mining operations are also problematic. When ore is mined from below the water table, water inflow to the operations can impede ore extraction and put worker safety at risk. Heavy rainfall and flooding events can also damage mining infrastructure and prevent access to orebodies. For example, flooding in 2010 led to billion-dollar production losses and serious concerns about the impacts of saline water discharge on downstream ecosystems in the Queensland coal mining sector.[4] Excess water in tailings storage facilities (dams) can also be a contributing factor to dam failures, as was the case for the 2015 collapse of the Mt Polley tailings dam in British Columbia.[5]

The construction and maintenance of infrastructure to access water is another consideration and can be expensive. For instance, BHP has spent US $3.43 billion to build the largest

[2] Metcalf, A., 2013. Water Scarcity to Raise Capex and Operating Costs, Heighten Operational Risks, in: Moody's Investor Service (Ed.).
[3] Lebre, E., Stringer, M., Svobodova, K., Owen, J., Kemp, D., Côte, C., Arratia-Solar, A., & Valenta, R. (2020). The social and environmental complexities of extracting energy transition metals. Nature Communications 11: 4823
[4] Gao, L., Bryan, B.A., Liu, J., Li, W., Chen, Y., Liu, R., Barrett, D., 2017. Managing too little and too much water: Robust mine-water management strategies under variable climate and mine conditions. J. Clean. Prod.
[5] Byrne, P., Hudson-Edwards, K. A., Bird, G., Macklin, M. G., Brewer, P. A., Williams, R. D., & Jamieson, H. E., 2018. Water quality impacts and river system recovery following the 2014 Mount Polley mine tailings dam spill, British Columbia, Canada. Applied Geochemistry, 91, 64–74.

desalination plant in Latin America to supply water to its Escondida Mine, which is 3,200 meters above sea level. [6]

While water quantity is one issue, water quality is another. Variability in water quality can adversely affect ore processing and mineral concentration, creating a need for water treatment. The water contamination that can result from discharge from mine sites can lead to regulatory penalties as well. In 2021, Teck's Elk Valley operations was fined $60 million for selenium pollution, the largest-ever penalty issued under Canada's federal Fisheries Act.[7]

Water quality is not just an issue while mines are active. Around the world, numerous historic mines require perpetual water treatment due to poor mine waste management practices during operations. The Faro Mine in the Yukon Territory of Canada is one: in 2009, the costs of rehabilitation and clean-up due to acid rock drainage were estimated at over $500 million, with recent estimates predicting the actual cost will be much higher.[8]

All of these factors have made the need for sustainable water management increasingly important for mining companies. Investors are calling for companies to make a greater effort to understand the impact of their operations on water resources. Communities and governments are encouraging industry to support efforts to deliver progress on the United Nations Sustainable Development Goal #6: access to clean water and sanitation. Regulators and non-governmental organizations are endorsing reporting protocols such as the Global Reporting Initiative (GRI), CDP (formerly known as the Carbon Disclosure Project), the Extractive Industries Transparency Initiative (EITI) and Towards Sustainable Mining (TSM). The result has been pressure for the industry to transition away from risk management and liability approaches to water management, and to view water as a strategic asset, rather than as commodity to be bought and sold. This new way of thinking has led to interest in water stewardship: "the use of water that is socially and culturally equitable, environmentally sustainable and economically beneficial, achieved through a stakeholder-inclusive process that includes both site- and catchment-based actions."[9]

There is a great deal of money already at stake in water management systems for mining. However, the pressure on water systems will only grow with climate change and the associated changing weather patterns and rising temperatures worldwide. And this pressure will be exacerbated as the global population increases and urbanizes. At the same time, the mining sector is being called upon to provide the metals, minerals and materials critically needed for

[6] Jamasie, C., 2020. BHP to supply water for Escondida mine from desalination plant only. Mining.com
[7] Cruickshank, A., 2021. Teck fined $60 million for water pollution in B.C.'s Elk Valley. The Narwhal.
[8] Croft, D., 2017. Massive Faro mine clean-up will begin in 2022, two decades after closure. CBC News.
[9] Alliance for Water Stewardship (2017) https://a4ws.org/about/

the transition to a low-carbon economy. Yet ore grades for many metals, minerals and materials are declining; miners will therefore need to process increasing volumes of ore to meet production goals, meaning even more water will be needed than in the past.[10]

At this critical juncture, with all of these pressures converging, new ideas are needed to address the water challenges the world is facing and to prepare for the challenges likely to arise. This will require collective action and effective dialogue between mining companies themselves and with those who are affected by the sector's use and interactions with water, including Indigenous nations, communities, regulators, investors and others. The BRIMM Water Stewardship initiative has thus been established to facilitate research to address some of the critical issues at the intersection of mining and water by building collaborative, results-oriented partnerships.

2. BRIMM – Challenge-Based Cross-Disciplinary Research

The Bradshaw Research Initiative for Minerals and Mining (BRIMM) was founded in 2017 to connect scientists and engineers across the University of British Columbia (UBC) to promote cross-disciplinary research spanning the entire lifecycle of mining, from early exploration to mine closure and rehabilitation.

Created by a generous philanthropic gift from Dr. Peter Bradshaw, a long-time supporter of mining and minerals research at UBC, BRIMM operates primarily within the Faculties of Science and Applied Science at the University of British Columbia (UBC). BRIMM connects several centres of excellence, including the Norman B. Keevil Institute for Mining Engineering (NBK), the Mineral Deposit Research Unit (MDRU), the Clean Energy Research Center, the UBC Data Sciences Institute, and the Hydromet Group. Within the wider UBC community, BRIMM collaborates with Blockchain@UBC, the Sauder Business School and the Faculty of Forestry. Additionally, the Water Stewardship group has established connections with the Future Waters Research Excellence Cluster, an interdisciplinary group of scholars spanning five faculties (Applied Science, Science, Forestry, Medicine, and Arts) who examine water system design, management, policy, and governance.

BRIMM drives transformation of the mining sector by connecting the unique insights of researchers and industry to generate solutions for the benefit of the economy, society and the environment.

[10] Scott, M., 2018. Reducing Water, Energy and Emissions through Grade Engineering®, in: 3rd International Seminar on Operational Excellence in Mining. pp. 1–8.

BRIMM provides seed funding to UBC research projects that drive data integration across the traditional silos of exploration, mining, and environmental impact. BRIMM's goals are to:

- Expand capacity and visibility of mining-related research on campus at UBC and across the globe
- Foster collaboration and engage new UBC research expertise
- Engage with the minerals industry to identify new and relevant areas of multi-disciplinary research
- Motivate and provide seed funding to new integrated and multi-disciplinary research across the entire mine cycle in projects that attract direct industry financial support
- Provide advanced training across mineral systems and the mining life cycle

2.1 Water Stewardship Research Themes

In late 2020, several exploratory workshops, one-on-one interviews, and faculty discussions were held to identify priority research themes for BRIMM's Water Stewardship initiative. More than 40 representatives participated in these activities, including researchers from eight departments in UBC, key figures from industry, Indigenous nations, regulators from the Canadian federal and provincial (British Columbia) government, and an NGO. From these activities, the Water Stewardship team was able to discern three themes to guide research activities for the next three years.

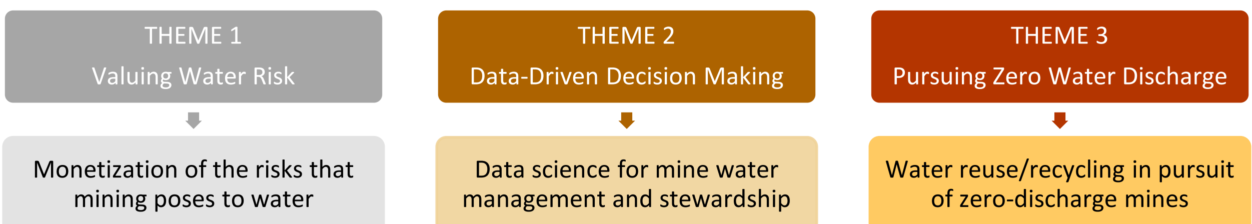

Figure 1: BRIMM's Water stewardship research themes

2.1.1. Theme 1: Valuing water risks

Accurately valuing the risks that mining poses to water supplies and aquatic ecosystems is a difficult task, and one that can create tension amongst water users. Three principal difficulties were flagged by those consulted as areas in need of future research.

Figure 2: Difficulties associated with valuing water risk

The value of water – There is a need to recognize that water has an inherent, invaluable social and cultural worth. However, accurately valuing the risks that mining poses to water supplies and aquatic ecosystems is a difficult task, largely due to the disagreement over the very meaning of the word "value." The experts consulted noted that monetizing water (reducing water into dollars and cents in an accounting spreadsheet) is not sufficient to address water's full value. Nevertheless, there was agreement amongst those consulted that:

- There is a need to understand the magnitude of the risk for both companies and communities.
- Some objective means of quantifying water risk is therefore required.
- Value needs to be understood in objective, universal, and unambiguous terms.

Inadequate water valuation – Disagreements about how to value water and inaccuracies in the valuation of water in mining contexts create risks. For example, there are real, potentially catastrophic, inequities between the amount for which water-impacting infrastructure – such as tailings dams – are bonded or insured for and the actual cost that a community will bear in the event of infrastructure failure. Once again, there was agreement that:

- Reducing water – such a vital component of human health and wellbeing – to a simple dollar value was insufficient.
- With no alternative proposed, this is a critical area for further discussion and research.

Upfront cost versus legacy cost – Within the mining industry, infrastructure projects, equipment and maintenance choices are generally considered in terms of their upfront costs rather than the legacy cost. However:

- If viewed over the timescales that tailings dams and other infrastructure will exist, the "legacy" valuation would look starkly different.
- These issues require innovative thinking and more extensive conversations between the different groups involved to arrive at a workable agreement.

2.1.2. Theme 2: Data-driven decision making using data science

The opportunities to use data science to guide decision making in the mining industry are significant. "Data science encompasses a set of principles, problem definitions, algorithms, and processes for extracting non-obvious and useful patterns from large datasets."[11] Good data—which experts stressed is not synonymous with big data—could lead to improvements in performance that would lessen environmental footprint, increase productivity, and reduce equipment downtime.

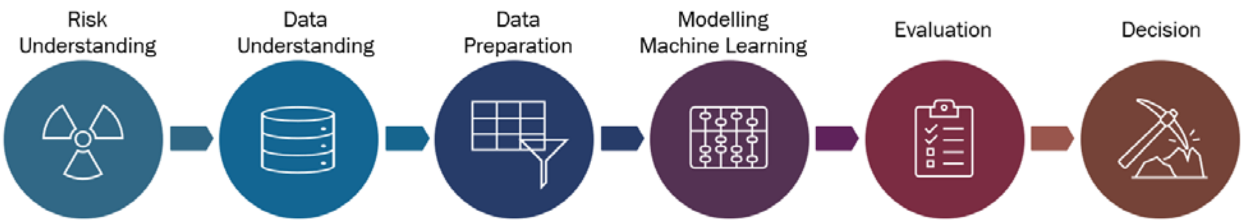

Figure 3: Components of data science and data-driven decision-making (adapted from shutterstock.com)

In the area of mine water stewardship, the potential opportunities from rapid advances in data science and remote sensing technologies have to date been underexplored.[12] Historically, data scarcity has impeded the development of reliable mine water optimization models at many sites (particularly those in remote areas), from the local to regional scale. Increased availability of satellite data, low-cost sensing technologies and advanced computational tools provide enormous opportunities to fill data gaps and rapidly analyze large datasets in ways that could transform water management and governance. Increased availability of real-time, open data – i.e. "structured data that is machine-readable, freely shared, used and built on without restrictions"[13] – also creates opportunities for greater scrutiny of mining companies by actors external to the industry.

[11] Kelleher, J. D., and Brendan T., 2018. Data Science. The MIT Press, 1-38.
[12] Kunz, 2020. Towards a broadened view of water security in mining regions. Water Secur. 11.

[13] https://open.canada.ca/en/open-data-principles

Despite these potential benefits, we heard concerns during our strategic planning activities about the competing needs for open data to study and analyze, versus private data for proprietary technology and competitive advantage. Questions around data ownership and sovereignty were also identified as paramount when data are being collected on Indigenous lands. Reconciling these tensions creates important research questions to explore.

Furthermore, it was discovered that discussions about data are often happening in a language and context that is not inclusive, transparent, or that accommodates traditional Indigenous knowledge. Those consulted stressed the need to communicate data science in a manner that enables members of affected communities, including those without extensive scientific training, to understand mining's effects on their region. If residents of communities located adjacent to mining, and the traditional users of the land, do not have access to data that is clear, consistent and comparable, the data may not be regarded as trustworthy. Good communication is therefore critical for data to be used as a means to secure social "license" – the tacit approval of mining by its communities of interest.

2.1.3. Theme 3: Pursuing zero discharge

Increasingly, mining companies are aspiring towards waterless or 'zero discharge' mines, whereby water consumption and/or discharge of water are minimized.[14] These efforts are often in response to community, investor or regulatory pressures. While zero-discharge mining is promoted for its social and environmental benefits, these will ultimately be context-dependent. For example, actions taken to move toward zero discharge at a given site may inadvertently increase energy consumption, lead to water quality changes that can impede mineral recovery processes, increase the risks of tailings dam failure (if excess water is being stored in tailings dams), and/or contribute to more detrimental environmental impacts in scenarios of unplanned wastewater discharge. Some workshop participants also noted that even if a mine site has zero water use, mining transforms the land and has the potential to impact local water resources. An important research need is therefore to better understand how to minimize the overall impacts of mining on water from a systems perspective. This should include understanding how to quantify and manage the trade-offs associated with water quantity and quality, as well as energy use and other site and regional objectives. In evaluating these questions, participants emphasized the importance of engaging with Indigenous peoples and local communities who are ultimately impacted by decisions relating to water and mine waste management.

[14] https://magazine.cim.org/en/technology/water-pressure-en/

At sites where personnel are working towards zero discharge, there are various new and emerging technologies that can facilitate the transition towards zero-waste or zero-liquid-discharge mining. Such processes involve the treatment of mine wastewater and chemicals for reuse, pre-concentrating the brine to recover water and evaporation/crystallization of impurities into solid. These technologies can however be cost prohibitive and industry representatives therefore emphasized the importance of developing fit-for-purpose water treatment solutions.

While some countries, for example Peru and Chile, have regulatory incentives to encourage zero-liquid discharge, workshop participants expressed the opinion that current regulations and enforcement relating to mine water use and discharge within the Canadian province of British Columbia are inadequate. In some cases, it is more expensive for companies operating in British Columbia to treat and discharge water than it is to extract water; as a result, excess extracted water gets stored onsite. External pressure is therefore important to incentivize companies to invest in new water treatment technologies rather than defaulting to the cheapest option. This challenge therefore complements the first theme on valuation of water risks.

BRIMM's Internationally Recognized Research Experts in Water Stewardship

This "living list" of experts is continuing to grow with our expanding portfolio within the BRIMM Water Stewardship team.

UBC Researcher	Title and Areas of Expertise
 **Nadja Kunz** nadja.kunz@ubc.ca	**Theme Lead for BRIMM Water Stewardship** **Assistant Professor and Canada Research Chair in Mine Water Management and Stewardship, School of Public Policy and Global Affairs and the Norman B Keevil Institute of Mining Engineering** Faculty Steering Committee of the Future Waters Research Excellence Cluster • Mine water management and stewardship • Water risk assessment and modelling • Water, tailings and climate risk quantification and mitigation
 **Jocelyn Fraser** jocelyn.fraser@ubc.ca	**Theme Co-Lead for BRIMM Water Stewardship** **Research Associate, Norman B Keevil Institute of Mining Engineering** University of British Columbia Public Scholar • Social risk and social responsibility in the mining sector • Collaboration between mining companies and communities • Business strategy for meeting ESG goals

Postdoctoral Research Fellow, School of Public Policy and Global Affairs and the Norman B Keevil Institute of Mining Engineering

- Water and climate risk assessment and mitigation
- Strategic and multi-objective water management
- Terrestrial hydrologic processes and their climate interactions
- Hydroinformatics (hydrologic and hydraulic modelling)
- Prediction of floods and droughts, flood inundation modelling
- Data analytics and data-driven modelling

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- Hydrometallurgy
- Sea water in heap leaching
- Release of selenium and associated toxic elements from mine waste materials
- Heap leach modelling

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- Modeling and Experiment Design
- Model Predictive Controllers
- Iterative Identification and Control
- Data Analytics
- Fault Detection and Diagnosis

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Professor in the Department of Earth, Ocean and Atmospheric Sciences (Hydrogeology Group)

- The physical, geochemical and biological processes and conditions in the hyporheic zone of the lower Fraser River, Vancouver
- Arsenic in the Bengal Basin
- Neutral - pH drainage from mine waste rock at Antamina, Peru
- Scale up for models of reactive transport in porous media
- Characterization strategies in integrated surface-water groundwater

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- Geohazards
  - Landslides
  - Rock avalanches
  - Debris flows and floods
  - Tailings dam breaches
  - Shoreline erosion
  - Landslide-generated waves

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- Groundwater Ecohydrology
- Hydro-geological Engineering and Applied Hydro-geochemistry
- Watershed Management
- Groundwater – Surface water & Land Interaction
- Green Infrastructure

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- MIN3P
- Dissolved and vapor phase gases as tracers or indicators of microbiological activity in groundwater systems

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Faculty Steering Committee of the Future Waters Research Excellence Cluster
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- Community and population ecology
- Benthic invertebrates, amphibians, fish
- Detrital-based food webs and donor-controlled systems
- Conservation Biology

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- Pricing the environmental commons

In addition, UBC has several unique research groups, facilities and laboratories to support water-related research, including:

- Future Waters Research Excellence Cluster
- Data Science Institute

3. CALL TO ACTION

BRIMM is driving transformation in the mining sector by connecting the unique insights of researchers with external partners, including industry, government, Indigenous nations, investors, and communities for the benefit of the economy, society and the environment. The steps to begin a research project are straightforward. Timelines for funding approval are typically between one to six months with projects lasting between one to five years. If you have a water stewardship issue, challenge, or opportunity that would benefit from research, contact us.

STEP 1	Interested parties contact BRIMM • Email: info@brimm.ubc.ca • BRIMM website: https://brimm.ubc.ca/ • LinkedIn: https://www.linkedin.com/company/brimm-university-of-british-columbia/ • Twitter: @BRIMMinnovation
STEP 2	Parties discuss the problem statement and identify collaboration opportunities that match BRIMM's expertise
STEP 3	Develop a research funding approach • BRIMM can leverage financial contributions from external partners by up to three times with Canadian government grants. For some partners (e.g. NGOs and Indigenous organizations) funding opportunities may also be available without the need for financial contributions from the partner.
STEP 4	Execute the project in partnership with our funders and collaborators, ensuring that there is feedback to support and guide the project.

3.1. For more information

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If you are interested in learning more about current research within the BRIMM Water Stewardship theme, please refer to the projects listed on our website. We sincerely thank each individual who participated in our planning activities and whose insights informed the development of this document. We look forward to continued partnerships with you in future.