Approaches for Benchmarking Mine Site Water Management and Contexts

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ABSTRACT

Mining and mineral processing operations have complex, site-specific interactions with water resources that differ significantly according to the nuances of local hydrology, project configuration, site water management policies and decisions and varying regulatory requirements. These interactions can significantly affect local hydrology, whilst also presenting acute risks to water quality, ecosystems and local communities. Historically, this has been the source of much controversy and social license issues in the minerals industry – and so there is a need to understand what constitutes good water behaviour by mineral producers so that the impacts of operations can be more critically evaluated, benchmarked and put into context. Current academic literature on benchmarking water management of mining operations is still fairly limited, and even within the range of industry consultants there are only a handful that are beginning to approach the issue of industry-wide benchmarking with any technical rigour. This may quickly change as key stakeholders to the minerals industry, such as investor groups and downstream consumers, are increasingly demanding that companies justify their environmental performance and demonstrate that they are responsible mineral producers. In this paper and presentation we provide an overview and examples of different styles of benchmarking schemes for mine site water management and their relation to regional water contexts. There is no one approach to benchmarking that will meet the needs of all stakeholder groups, and so we encourage the development of foundational datasets that can be adapted flexibly to support decision making and meet the needs of users.

KEYWORDS

Water use, benchmarking, water risk, datasets

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1. INTRODUCTION

There is rapidly becoming sufficient public data available to support detailed benchmarking schemes for mine site water management. Considerable data on mine site water flows has been released as part of regulatory reporting and through voluntary reporting such as Global Reporting Initiative (GRI) based corporate sustainability reporting. The breadth and consistency of water disclosures by mining companies has dramatically improved over the last decade with the emergence of the Minerals Council of Australia (2022)'s and the International Council on Mining and Metals (2017) water accounting frameworks and reporting guidance. This allows us to produce rich and more consistent datasets of mine site water flows (Mudd et al., 2017; Northey et al., 2019). At the same time, our understanding of how mineral operations and production are distributed across water catchments and hydrological contexts has improved dramatically as well (Northey et al., 2017; 2018). Despite the rich data that is becoming available, there are still open questions regarding how to query this data and build meaningful indicators and comparisons that serve the needs of different stakeholder groups.

In this paper and presentation, we will discuss the potential questions and needs of different stakeholder groups as a basis to begin to understand the advantages and disadvantages of different benchmarking approaches. Following this, we will explore some approaches for benchmarking (1) the internal water balance of a mineral operation, (2) the water context of a mineral operation and (3) the cross-regional water impacts of mineral operations or mined products. Examples are provided highlighting how rich datasets of mine site water flows and regional contexts can be incorporated into benchmarking schemes.

2. HOW MUCH BANG ARE WE GETTING FOR OUR BUCK(ET)? CAN BETTER QUESTIONS INFORM BENCHMARKING APPROACHES?

Benchmarking schemes for mine site water management may be developed on simple metrics such as direct use or consumption of water. However this risks obscuring the significant detail required to fully understand drivers of water management and the risks posed by mining operations within their local hydrological context. As a basic example, water consumption has very different significance in a wet catchment versus a dry catchment. Benchmarking also introduces complexity regarding selection of appropriate reference units used to compare and contrast performance. For instance, should water flows be considered on an absolute volumetric basis (i.e. ML per year)? Or relative to rates of production (i.e. m^3 per kg of product)? Or even in relation to ore throughput (i.e. m^3 per tonne ore)? How should seasonal variability be considered? And extending that further, how do we consider variability throughout a mine's life? Are volumes of water flows even an appropriate measure to use or should we instead seek to measure the consequences or impacts of water flows on water quality or other water users? Should targets be used to assess performance? Should all mines be considered using the same benchmarking scheme?

With this in mind, Table 1 presents a range of competing questions that stakeholder groups may be considering when they attempt to understand water management strategies and performance of mining operations. Answering these questions may require benchmarking schemes to adopt differing boundaries of assessment (Figure 1), differing methodologies and differing units or reference indicators. As an example, a mineral processing engineer focused on optimising the efficiency of a unit process, such as a thickener, probably gains limited insight from understanding how water consumption of the mine will influence downstream water users and the catchment as a whole. In this instance it may be useful to benchmark data against operations employing similar mineral processing technologies on the basis of water inputs to a plant per unit of ore throughput (or perhaps dry tailings). Whereas, a hydrologist seeking to understand

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contributions of mining operations to water scarcity within a catchment may derive greater insight from seasonal or monthly estimates of mine site water withdrawals, discharges or consumption. Stakeholders looking to benchmark the water footprint of mineral products coming from regions with vastly different hydrology may find utility in metrics that attempt to account for differences such as the water scarcity of each catchment. Investors for instance may also wish to benchmark company operations on an aggregated basis, so schemes for translating detailed site data into aggregated metrics may also be need to be considered.

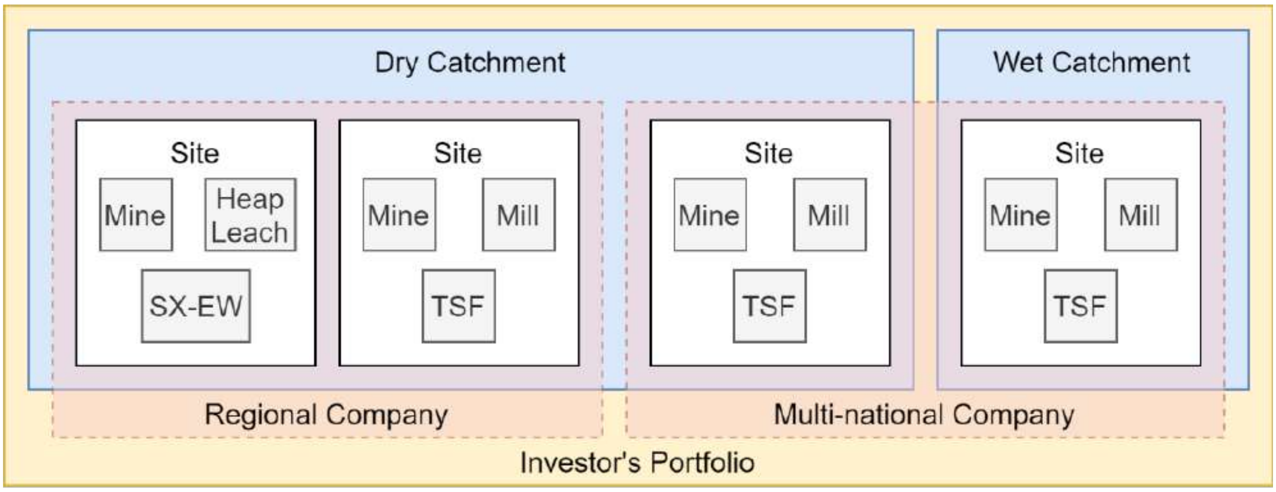

Figure 1 – Example boundaries that could be used by different benchmarking schemes

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Table 1 – Some possible stakeholder questions regarding mine water management and water contexts

	Internal – Site	Internal – Corporate	External - Local	External - Global
Internal Water Balance	- Are our processes water efficient? - Are we effectively managing storage infrastructure?	- Are we using water efficiently across our portfolio? - What sites should we invest in water management?	- Is that mine wasting water? - Is there risk of dam overtopping?	- Where should I promote my water saving or water management technology?
Interactions with Catchment Water Balance and Quality	- Are we exposed to hydrologic variability (e.g. water availability)? - How can we reduce our impact on the surrounding catchment? - Are our data collection and modelling systems sufficient to manage our risk and evaluate our impact?	- Can site level-hydrological risk compound when viewed at the portfolio level? - Are we creating environmental legacies that may increase closure costs or damage reputation?	- Is that mine making the river run dry? - How are mine discharges altering downstream water quality and drought and flood risks? - How will other industries be affected by mine water use? - Are long-term water quality legacies being created?	- What is an objective measure of the impact of that mine? - Does local water risks pose a risk to my investment?
Cross-Basin and Macro Issues	- Can we compare our water management with sites in similar hydrological settings? - How exposed are our operations to changing climate?	- How do we benchmark and aggregate portolio-level efficiency and risks when each site operates in completely different water contexts? - Can there be common water management objectives/targets or do these need to be tailored for each site?	- What are the risks to local communities and eco-systems? - Does mine water use affect our regions broader competitiveness? - Does this mines performance stack-up against international best practices?	- How can we trust what mines and companies are telling us? - How do we fairly compare across regions and against other industries? - What is the societal return from 'investing' water resources in the mining sector?

4. APPROACHES TO BENCHMARK A MINE'S WATER BALANCE

Perhaps the simplest approach to benchmarking water management across mining operations is to consider each individual component of a mine's water balance in isolation and to express this in relation to a variable of interest – such as time, production rates or ore processed. Earlier studies by Mudd (2008) and Gunson (2013) benchmarked reported mine site water use per unit of ore processed or unit of production. These studies identified that there was high degrees of variability in water requirements between individual mineral operations, but that some correlations do exist between ore grades and the water use per unit of metal produced (Figure 2). Both of these studies, also identified differences in average water requirements between commodity groups – which provides some confirmation of the direct component of life cycle assessment (LCA) based embodied water estimates for commodity production that have been produced by Norgate and Lovel (2006) and Northey et al. (2014) among others.

Those earlier studies tended to provide data suitable for benchmarking water use and to some extent water withdrawals of mining operations. However, mining's interactions with local hydrology are complex and so there are many other aspects of a mines water balance that could be informative to benchmark and understand. For instance, benchmarking schemes can also be informed by understanding the types of water

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sources that withdrawals are occurring from (e.g. groundwater, surface water), rates of water discharges, internal water flows and recirculation or recycling of water, evaporation rates. Adoption of the MCA (2022) and ICMM (2017)'s water accounting and reporting frameworks has resulted in these components of mine site water balances now being much more routinely reported by companies. These improvements in water reporting enabled us to develop a dataset of 8,314 datapoints for components of mine site water balances, compiled from 359 mining company reports (Northey et al., 2019). This was only scratching the surface of disclosed data at the time, as the compilation effort was constrained by our time rather than the availability of reports to process and data to extract and classify.

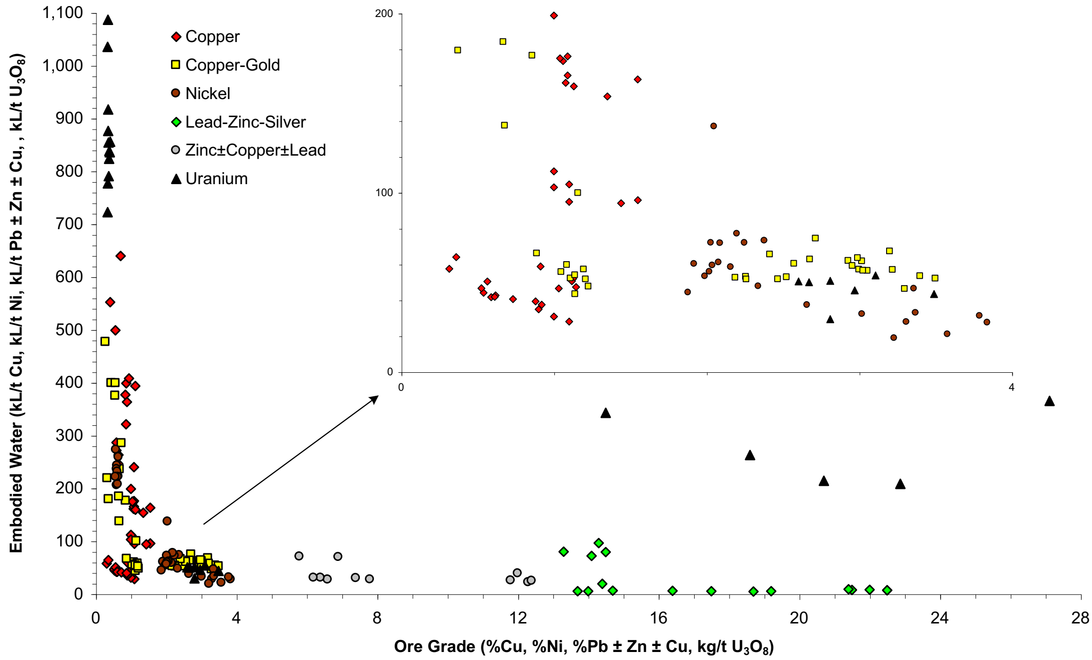

Figure 2 – Water use per unit of metal production versus ore grade. Reproduced from Mudd (2008).

Analysis of these disclosures provides us with rich datasets to begin to benchmark industry performance (Mudd et al., 2017; Northey et al., 2019). Figure 3 shows how mine site water flows, when expressed per unit of ore processed, can vary by orders of magnitude across individual sites and through time. Understanding the range of this data is useful for sites looking to understand their own water use efficiency. For instance, whilst raw water use and worked water use (recycled or reused) generally varies between 0.1 to 10 m^3/t ore across sites, total water use (sum of raw and worked) typically falls in a much tighter range between 1 to 10m^3/t ore. This demonstrates that sites are employing very different strategies to meet their total water use requirements. Water use requirements and achievable rates of efficiency are to large part dictated by the ore processing techniques employed by each site, as this influences required rates of water addition and also the ability to recirculate water between site processes (for instance from tailings thickeners or TSF decants back into milling operations). Figure 4 shows this same data averaged across time and classified by the ore processing methods used at each site. This data confirms prior industry analysis that indicates flotation and/or vat leaching operations have higher water requirements than heap leaching operations. When seeking to optimise water use efficiency in mineral processing circuit design we suggest consideration of a basic principle: it's easy to add water to ore mass, but hard to remove it. So as much unnecessary ore mass should be removed before additions of water to reduce the requirements for subsequent water

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recovery. This suggests that mineral/metal/gangue separation occurring in dry processes or semi-saturation processes (e.g. heap leaching) should be prioritised ahead of suspension processes (e.g. flotation or vat leaching).

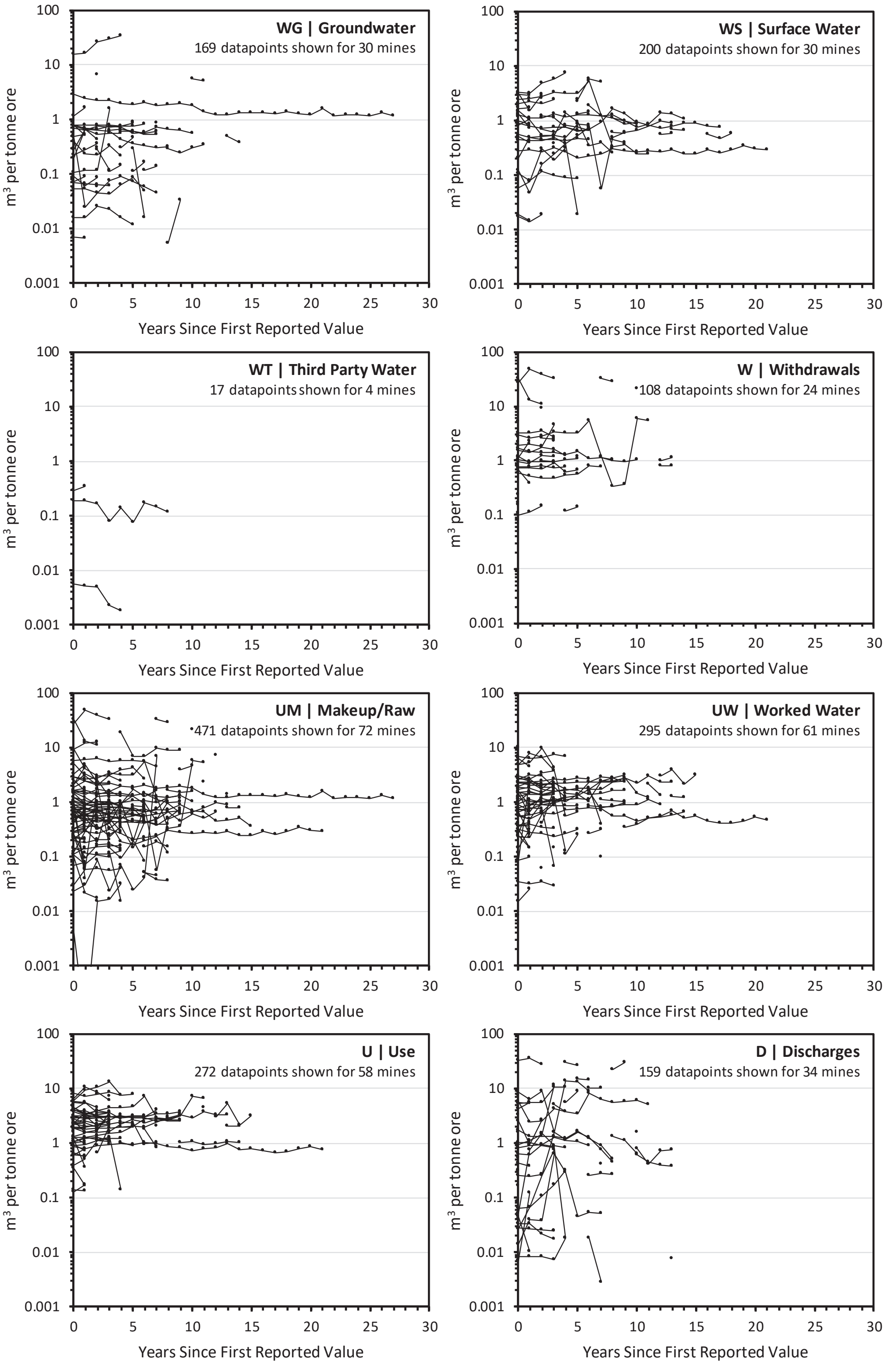

Figure 3 – Annual mine site water withdrawals, use and discharges overtime, per unit of ore processed. Reproduced from Northey et al. (2019).

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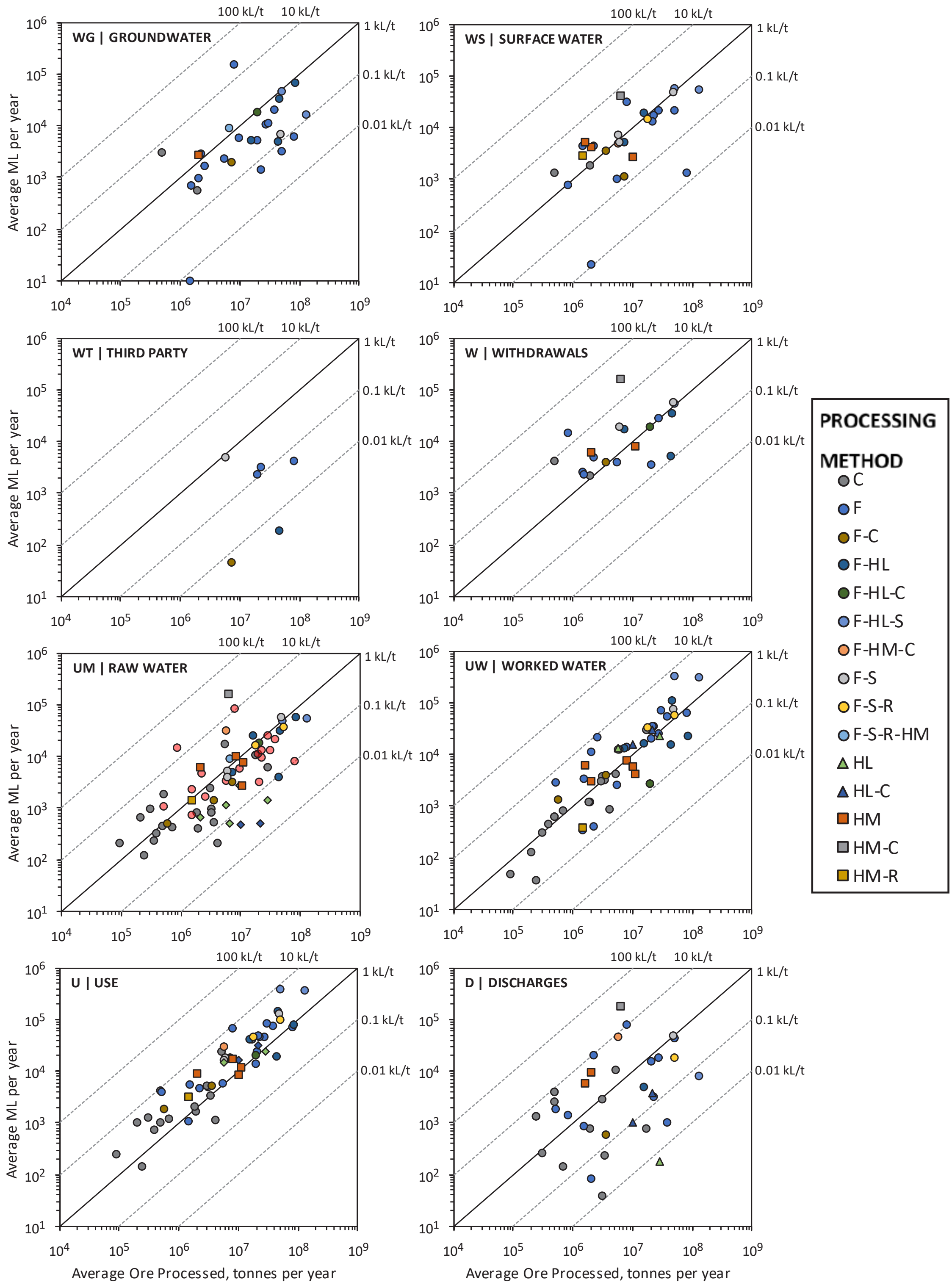

Figure 4 – Average of annual mine site water flows and ore processing rates for key water categories, classified by ore processing method. Diagonal lines represent constant water flows per unit of ore processed. Process abbreviations: C = Cyanidation, F = Flotation, HL = Heap Leach, S = Smelter, HM = Hydrometallurgical Plant, R = Refinery. Derived from data compiled by Northey et al. (2019).

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3. BENCHMARKING A MINE'S WATER CONTEXT

The relationship between a mine and surrounding water contexts is dynamic and complex. Attempts to benchmarking these relationships may consider two competing perspectives: assessment of (1) inside-out risks or (2) outside-in risks. The inside-out risk perspective considers the mining operation as something that imposes itself on and impacts the outside water context. In these cases, benchmarking of mine water contexts could consider proximity and sensitivity of connected hydrology, vulnerable ecosystems, or downstream communities and industry. Whereas from an outside-in risk perspective, the surrounding water context acts as an outside force or risk multiplier that imposes itself on the mining operation. The mining operation must either weather, bear, mitigate or manage this external risk which may eventually be realised in a variety of ways, such as: drought, flood, supply short-falls, excess mine infiltration, water source intermittency or storm water. Some quantitative benchmarking approaches have been developed for assessing these forms of risk. For instance, Bonnafous et al. (2016; 2017) developed approaches for considering financial exposure associated with drought and other climatic risks to mine sites at the portfolio level. Skarn Associates (2022) have also recently developed water risk benchmarking services and products for the minerals sector.

Consideration of qualitative regional risk factors could also be incorporated into benchmarking schemes. Socio-political risks, such as the regulatory system for water management in a region, can also impose themselves as external pressures or risks affecting the function or viability of a mining operation. With this in mind, water can also be conceptualized as having classes of risk not dissimilar to those facing mineral resources, and so authors such as Sonderegger et al. (2015) have adapted mineral criticality assessment methodology to understand the criticality of water. A regions 'water criticality' (CRIT) defined using this approach is the sum of several composite indicators: (1) Water Supply Risk (SR) - composed of the hydrological, governance and geopolitical indicators, (2) Vulnerability to Water Supply Restrictions (VSR) – composed of indicators for economic importance, capacity to compensate and the susceptibility of the region to supply restrictions. (3) Environmental Implications (EI) – composed of weighted life cycle impacts of water use.

Water scarcity risks are also often conceptualized as major external risk factors for mining operations (although in reality flooding may be a more financially significant risk). Indicators for water scarcity are often "stress" based metrics that consider the intensity of water use in a region relative to water availability. Regional indicators can also be devised that specifically consider how water use may contribute to depriving water from other human or environmental. Figure 5 provides an example of how differing indicators can be used to assess the relative risks of regions containing mineral resources. These indicators suggest that the copper sector is more exposed to these contextual water scarcity risks than either the lead-zinc sector or the nickel sector.

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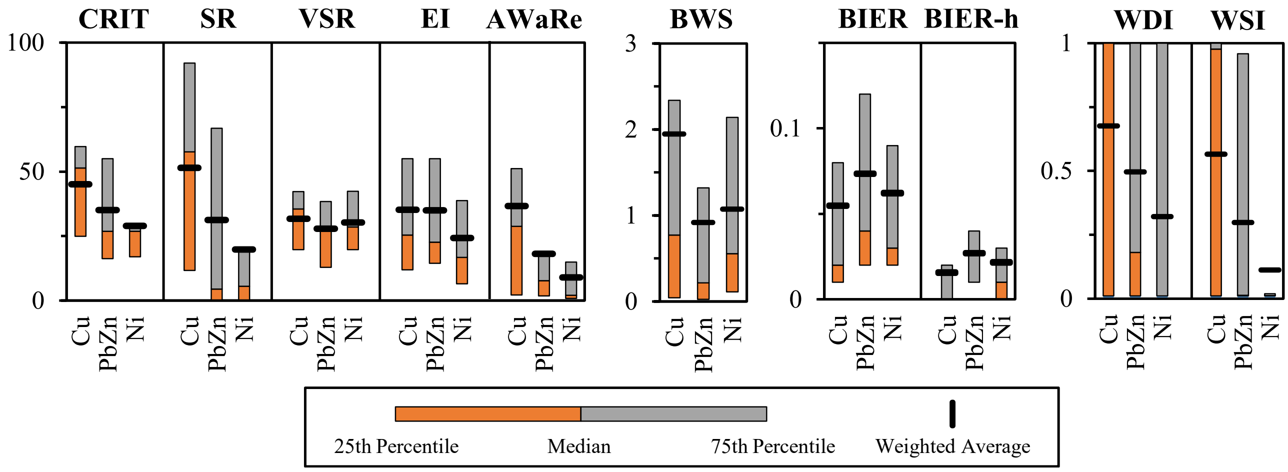

Figure 5 – Distribution of base metal resources in relation to regional water risk indicators (Northey et al., 2017). Criticality, Supply Risk, Vulnerability to Supply Restrictions, Environmental Implications, Available Water Remaining, Blue Water Scarcity, Basin Internal Evaporation Recycling, hydrologically effective Basin Internal Evaporation Recycling, Water Depletion Index and Water Stress Index.

Contextual water risks are also not static and may change through life of a mine. Some regions may become more water abundant and others more water scarce through time due to changes in water availability and use patterns in the region. Changes to hydrology in many regions is also possible as a consequence of climate change. Climate risks for individual sites should ideally be considered through incorporation into water balance modelling and regional hydrological modelling. However, this starts to become less meaningful when attempting to benchmark the minerals industry as a whole – as the drivers of water and climate risks can be very site specific. So more generic approaches may be required. For instance, Figure 6 shows how regions containing copper and nickel resources are exposed to potential changes in Köppen-Geiger climate classification. An example of a major classification changes would be transitioning from a warm temperate zone to an arid zone. Whereas, sub-classification changes are alterations to temperature and precipitation sub-classifications within the major classifications – such as a transition from a fully humid-equatorial classification to a monsoonal-equatorial classification.

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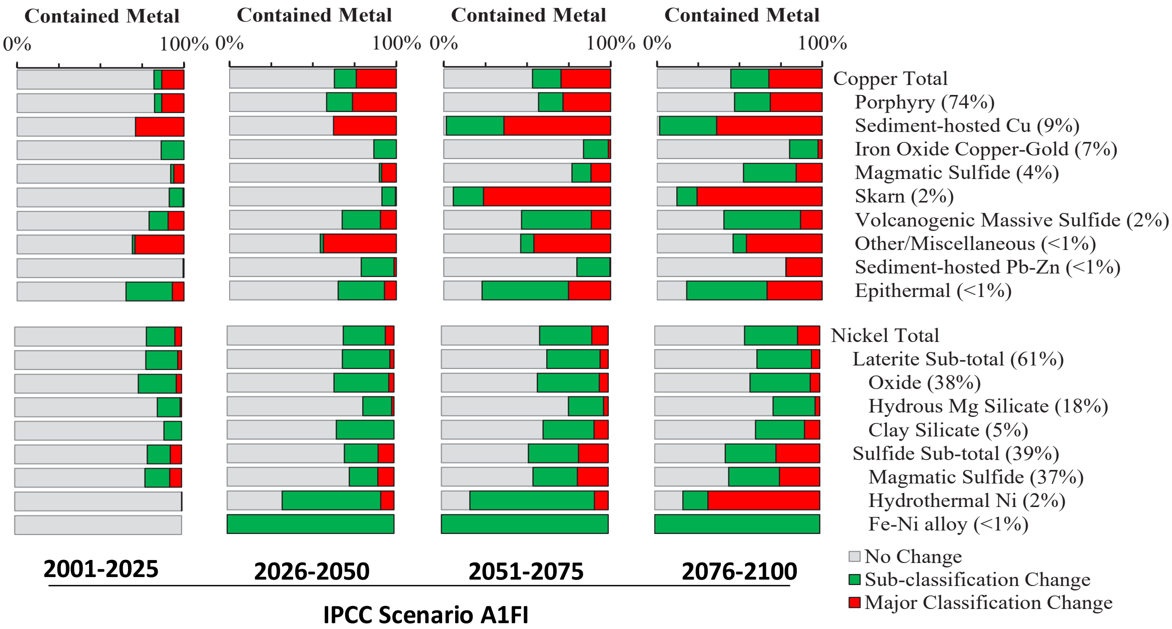

Figure 6 – Contained copper and nickel resources in regions that may change Köppen-Geiger climate classification under the IPCC A1FI scenario, a worst-case scenario (adapted from Northey et al., 2017).

5. COMPARATIVE BENCHMARKING OF MINE WATER 'IMPACT'

Benchmarking approaches grounded in the concept of a water footprint are well suited for comparing water consumption along supply chains, across regions and catchments, against other industries or sectors, or within aggregated metrics for regions or company divisions. Derivation of a water footprint estimate typically requires consideration of standardised definitions for water consumption and the use of spatial impact characterization procedures and datasets that consider how water availability and scarcity differs between regions, and how this influences the potential impact of water consumption on other water users or ecosystems. Two competing standards for water footprinting exist: ISO14046 and those of the Water Footprint Network (WFN). ISO14046 based water footprint assessments provide a standardized approach to developing a quantified estimates of the water use impacts of a product, production system or service. This is aligned with the principles and approach of life cycle assessment (LCA), and so a water footprint using the ISO14046 standard can be conducted as part of a product or site based LCA or carbon footprint. A four-step process is defined by this standard. These are (1) goal and scope setting, (2) water inventory development, (3) water impact assessment, and (4) interpretation. The competing WFN standard defines a water footprint as a volumetric indicator rather than as the results of impact assessment, as is the case with ISO14046. The WFN standard also classifies water into blue water (surface and groundwater), green water (rainfall and runoff) and grey water to distinguish between different categories of consumed water. Northey et al. (2016) provides an overview of some of the opportunities and challenges for implementing benchmarking schemes based upon these 'water footprint' based methods. In short, there is conceptual difficulty in resolving water flows at the mine level with the consumption definitions used in water footprint assessments. Water footprint assessments will also struggle to capture the variety of water use outcomes and impacts associated with mining operations. However, they are suited for generating data that is comparable across regions and along supply chains. In general, there has been limited uptake of these methods within the minerals industry to date – likely due to insufficient awareness and expertise in the industry. We have produced some data to support future uptake, for instance Figure 7 shows water use impact characterization factors that have been

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averaged according to the spatial distribution of commodity production. These can also be used as a general ranking of commodity exposure to water stress and scarcity risks.

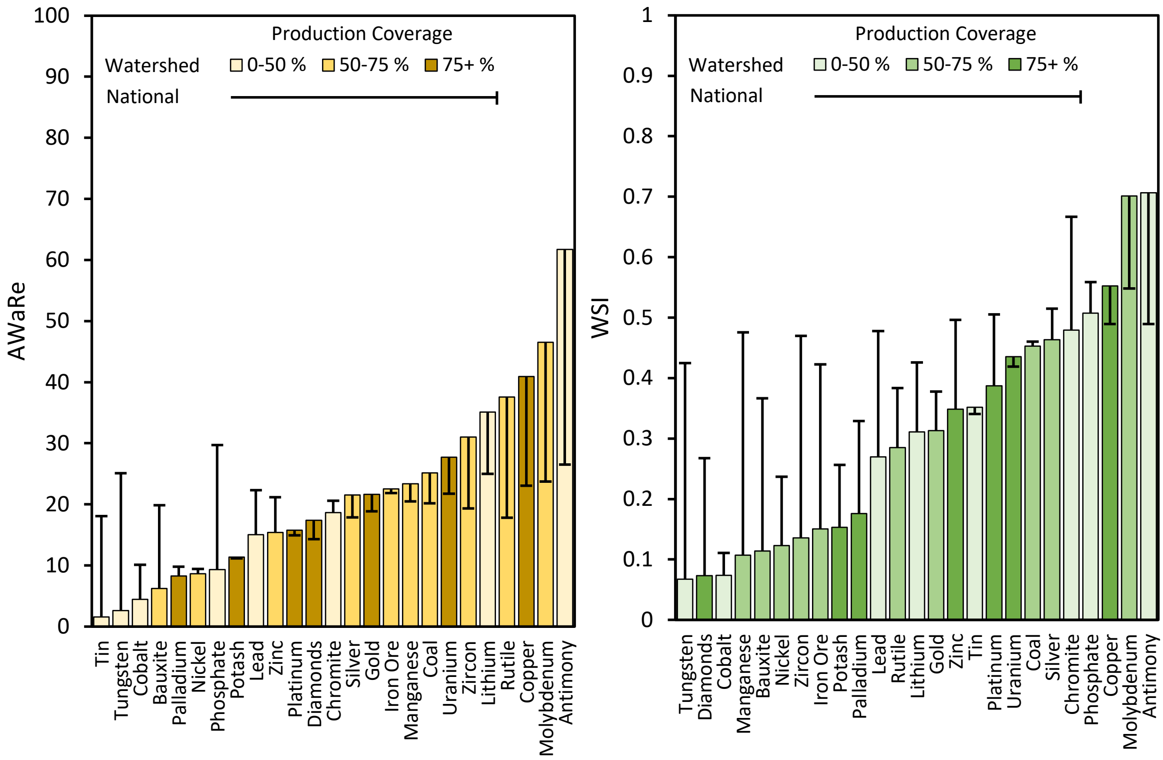

Figure 7 – Weighted average Available Water Remaining (AWaRe) and Water Stress Index (WSI) factors for primary commodity production in 2014 determined using national average and watershed-specific datasets. Note that while watershed level data avoids certain biases embedded in national average factors, there is incomplete production mapping for some commodities. Reproduced from Northey et al. (2018).

5. CONCLUSIONS

Minerals industry reporting of water use and flows has advanced considerably over the past two decades, with key definitions and reporting practices being increasingly standardised and adopted across the sector. What is now required going forward is sustained efforts to compile this data and develop analytic and benchmarking tools around this to drive industry performance and understanding. With that in mind we are very encouraged by the gradual emergence of mining industry focused water benchmarking tools and products, such as those being developed by Skarn Associates (2022). We encourage others to also consider developing complementary approaches to benchmarking water flows, risks and impacts in the minerals industry so that the needs of broader stakeholder groups can be met. Finally, advancement of this type of industry understanding and knowledge requires companies to have a sustained commitment to transparency. So please be an advocate for water data transparency within your organisation, as there are potential long-term benefits that may drive improvements in the sector as a whole.

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