Projected Consumption of Electricity and Water by the Proposed Resolution Copper Mine, Arizona

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

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LIGHTNING SUMMARY

Rio Tinto has provided no estimate of the electricity consumption of the proposed Resolution Copper Mine, Arizona, but it can be shown to be 3% and 22% of the peak power capacity of the Salt River Project under the best-case and worst-case scenarios, respectively. Rio Tinto has estimated water consumption of only 15,700 acre-feet per year (about one-third of industry standards) while using conventional technologies for water efficiency.

ABSTRACT

The underground Resolution Copper Mine that is being proposed by Rio Tinto in Arizona would process 150,000 metric tons of ore per day from an ore body at a depth of 5000-7000 feet with a grade of 1.47%. The objective of this study was to evaluate the projected consumption of electricity and water by the proposed mine. Rio Tinto has provided no information about electricity consumption, except that power would be supplied by the local grid of the Salt River Project. Based on the depth, grade, and production rate, the projected electricity consumption would be 236 MW. However, the discovery of geothermal water while drilling the primary access shaft could result in additional electricity consumption of 24 MW solely for mine dewatering and refrigeration under the best-case scenario and 1650 MW under the worst-case scenario, corresponding to total electricity consumption of 260 MW and 1900 MW, which are 3% and 22%, respectively, of the peak power capacity of the Salt River Project. Rio Tinto has estimated water consumption as 15,700 acre-feet per year and a possible maximum of 20,000 acre-feet per year, with the Central Arizona Project as the primary water source. However, based on the grade and production rate, water consumption of 50,000 acre-feet per year would be more typical for the copper mining industry. Although Rio Tinto states that "the mine will be operated to maximize internal water reuse," the General Plan of Operations proposes only conventional technologies for water efficiency. These technologies would result in the export of cleaner tailings with 50% water, scavenger tailings with 35% water, and copper concentrates with 9% water, all of which are conventional industry standards. The export of water with the tailings alone would result in water consumption of 25,600 acre-feet of water per year. It is recommended that potential investors or partners seek clarification on the consumption and sources of electricity and water.

INTRODUCTION

Rio Tinto has submitted a proposal to the U.S. Forest Service for an underground copper mine in Arizona, called the Resolution Copper Mine (see Fig. 1). The porphyry copper deposit occurs 5000-7000 feet beneath the surface and has an inferred resource of 1790 million tons with a copper grade of 1.47% and molybdenum grade of 0.037% (Houston et al., 2010; Cherry, 2011; Hehnke et al., 2012). The ore processing rate is predicted to be 120,000 metric tons per day with a maximum processing rate of 150,000 metric tons per day. Process improvements over the anticipated 40-year life of the project could increase the ore processing rate by up to 25%, for a maximum throughput of 187,500 metric tons per day (Resolution Copper Mining, 2014a-c). The ore would be processed on-site by grinding and froth flotation, resulting in concentrates with average copper and molybdenum grades of 30% and 52%, respectively, which would be shipped off-site for further refining (Resolution Copper Mining, 2014a).

The proposed mine is located within a mix of federal public land (Tonto National Forest), Arizona state trust land, and private land (Resolution Copper, 2018a). The proposal includes an exchange of 5344 acres of land privately held by Rio Tinto for 2422 acres of the Tonto National Forest (Resolution Copper Mining, 2014a). The Arizona Mining Reform Coalition and 15 other organizations have submitted scoping comments to the U.S. Forest Service that describe a wide range of detrimental social and environmental impacts of the proposed copper project (Arizona Mining Reform Coalition et al., 2016). Those social and environmental impacts will not be reviewed or further developed in this study.

The objective of this study is to address the following questions:

1) What is the projected electricity consumption of the Resolution Copper Mine?
2) What is the projected water consumption of the Resolution Copper Mine?

Although this study has been prepared at the request of the Arizona Mining Reform Coalition, the intended audience is individuals or companies who might wish to invest in the copper project or the companies managing the copper project. For context, Resolution Copper Mining is owned 55% by Resolution Copper, a Rio Tinto subsidiary, and 45% by BHP Copper, a BHP-Billiton subsidiary (Rio Tinto, 2018). Since the investment community is the intended audience, the study will focus on the ability of Rio Tinto and BHP-Billiton to successfully complete the project, given the available resources of electricity and water. However, it should be noted that a scarcity of electricity and water for the copper project could have the result of depriving all of the other consumers of electricity and water in Arizona. Therefore, the financial and technical aspects of the project cannot be completely separated from the environmental and social impacts.

According to Rio Tinto, the Resolution Copper Mine will consume 15,700 acre-feet per year of water at full operation with a possible maximum of 20,000 acre-feet per year (Resolution Copper Mining, 2014a). This range of a maximum of 16-20,000 acre-feet per year of water consumption has been repeated at numerous community forums hosted by Rio Tinto (Resolution Copper, 2018b). Since water is recycled throughout a mining operation, water consumption can be much less than water use. Water consumption refers to water that must be replaced by withdrawals from surface water or groundwater resources. Water consumption is also called the "blue water footprint" and includes water lost by evaporation, water that is incorporated into the product (such as the copper and molybdenum concentrates), and water that is not returned to the same catchment area from which it was withdrawn (Northey and Haque, 2013). Since Rio Tinto has already provided its own projected water consumption, the second objective is equivalent to asking whether the prediction by Rio Tinto is correct.

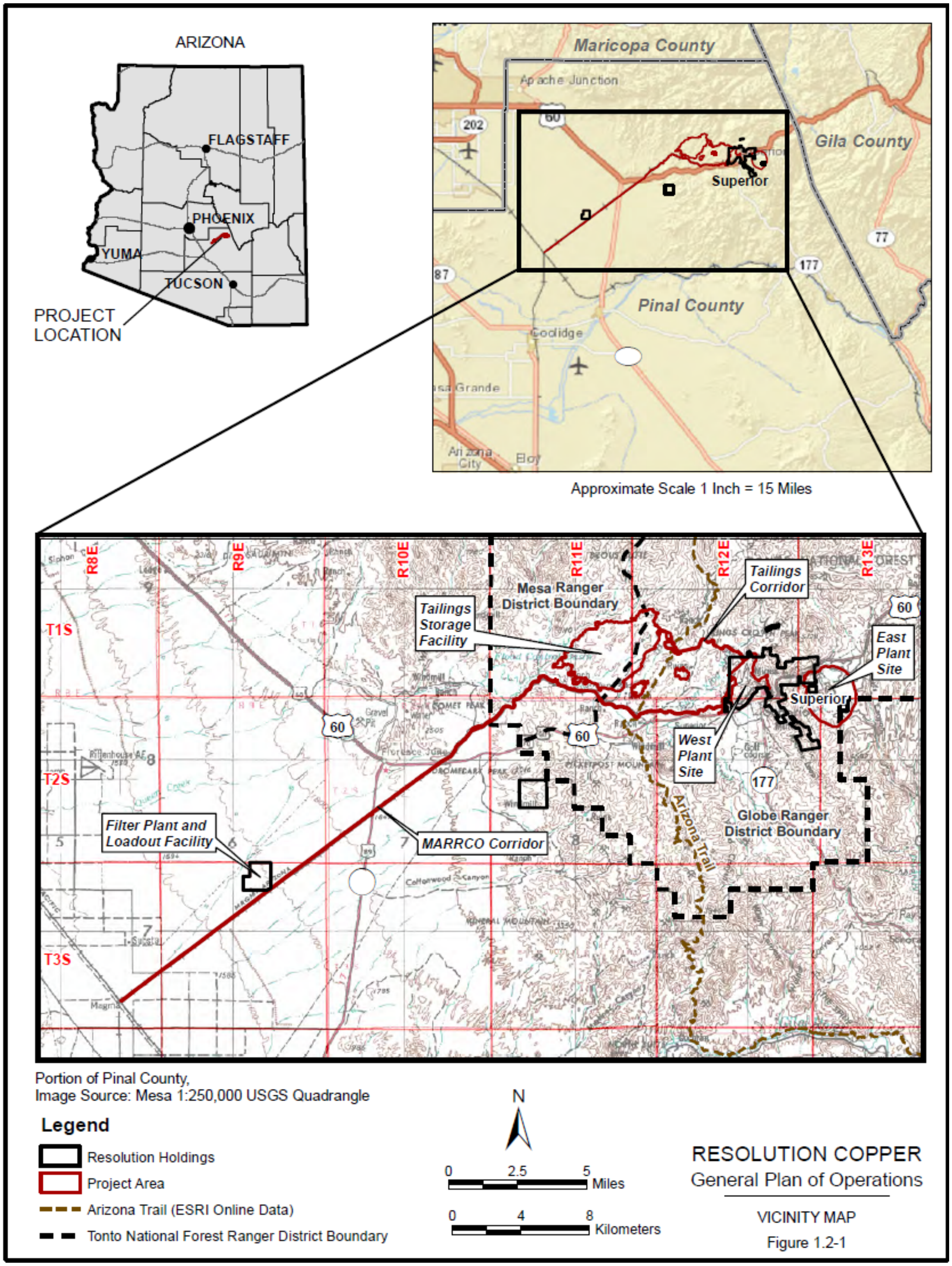

Figure 1. Rio Tinto has submitted a proposal for an underground copper mine, called the Resolution Copper Mine, within a mix of federal public land (Tonto National Forest), Arizona state trust land, and private land, which would process 120,000 metric tons of ore day with a maximum processing rate of 150,000 metric tons per day. Figure from Resolution Copper Mining (2014b).

It has been quite surprising that the 2395 pages of the General Plan of Operations (Resolution Copper Mining, 2014a-c) do not include any estimate of total power requirements or any source of power (besides emergency power) except for the local grid of the Salt River Project. A previous report (Emerman, 2018) provided some insight as to why this lack of projected electricity consumption could be a concern for investors. In 2007 drilling began for the 6943-foot-deep, 28-foot-diameter No. 10 shaft, which was intended for both exploration and as the primary access point for the underground mine (E&MJ, 2014). However, in December 2012, geothermal water at a temperature of 170°F began entering the shaft at a rate of 460 gallons per minute (gpm). According to Tom Goodell, general manager – shaft development for Resolution Copper, "Productivity flattened out at 6500 feet…The consultants told us that we would have little or no water below 4000 feet…They kind of missed that call. We hit it all in one spot and it was quite dramatic" (E&MJ, 2014). The Arizona Daily Star confirmed, "Shaft-sinking equipment had reached a depth of about 6,500 feet when water from an underground aquifer began rushing in. The miners were prepared to handle 80 gallons per minute, which is what core samples from 30 feet away predicted" (Bregel, 2016). The result of the unexpected discovery was a two-year delay in drilling for the installation of upgraded pumping, refrigeration and ventilation equipment. The shaft was completed in 2014 and is now the deepest single-lift shaft in the U.S. (EM&J, 2014; Resolution Copper, 2018c). Later reports indicated that the entry rate of geothermal water into the No. 10 shaft had increased by over a factor of three to 1400 gpm and that the temperature of the geothermal water was 180°F (Bregel, 2016; Phillips, 2016).

Neither the existence of the geothermal water, nor the additional costs associated with geothermal water, are mentioned anywhere in the General Plan of Operations (Resolution Copper Mining, 2014a-c). The geothermal water is not even mentioned in any of the discussions of regional hydrology or the potential impacts of mining upon groundwater. This is again surprising, since the document states a publication date of May 9, 2016 (title page) with an initial submittal date of November 2013 and a revision date of September 23, 2014 (page ii). The additional costs include the electricity required to dewater, refrigerate, and ventilate the mine. (Additional ventilation would be required due to the gases exsolving from the geothermal water.) An additional cost unrelated to consumption of electricity would be the cost of replacing mine equipment that is subject to corrosion by the persistent saturated atmosphere. The report by Bloomberg Businessweek (Phillips, 2016) emphasized that the latter is a real concern. According to the report, "Steaming hot water pours off the rocks…It's like standing in a tropical rainstorm. A digital hydrometer on the wall registers 100 percent humidity" (Phillips, 2016).

Emerman (2018) calculated an additional power requirement of 24 MW solely for the additional mine dewatering and refrigeration that would result from the geothermal water under a best-case scenario. The best-case scenario was based upon the following assumptions:

1) The flow of geothermal water into the No. 10 shaft has achieved a steady-state.
2) The aquifer has uniform transmissivity (product of aquifer thickness and hydraulic conductivity).
3) The recharge rate of the aquifer does not exceed 0.1 inches per year.
4) All mine dewatering can be carried out through a single vertical pipe.
5) The mine can be refrigerated with maximum theoretical efficiency.

The worst-case scenario is a more difficult question, since worst cases tend to be unbounded. Of the five assumptions that led to the best-case estimate, the violation of the second assumption (uniform aquifer transmissivity) would have the greatest consequences. Aquifer thickness can vary somewhat, but hydraulic conductivities of fractured crystalline rock can vary by four orders of magnitude (Charbeneau, 2000). The real worst-case scenario is that, as the underground mine expands, it encounters increasingly fractured rock.

Emerman (2018) estimated the power requirement for the additional mine dewatering and refrigeration under the worst-case scenario simply by multiplying the best-case scenario by a factor of two orders of magnitude to obtain 2400 MW. Another approach is to note that, if the hydraulic conductivity increases by two orders of magnitude, then the entry rate for geothermal water could increase from the 3800 gpm that would occur from expanding the mine with uniform hydraulic conductivity up to 380,000 gpm. At such high flow rates, the head loss becomes very sensitive to the diameter of pipes through which the geothermal water is pumped to the surface. The problem can be avoided by assuming pipes with infinite diameter (zero head loss), which would result in a power requirement under the "minimum" worst-case scenario of 1650 MW (500 MW for dewatering and 1150 MW for refrigeration).

A still earlier study that was funded by Rio Tinto (Bluhm et al., 2013) proposed a design for 140 MW of refrigeration capacity for the Resolution Copper Mine. This refrigeration capacity was intended to be sufficient to accommodate the heat load of 32 MW that would be generated by mobile and static equipment, as well as the heat flow of 30 MW from the broken rock in the underground mine. It is important to note that the heat flow of 30 MW assumed a dry mine and did not take into account the additional heat that would be exhausted from geothermal water entering the mine, which would be proportional to the flow rate of the water. Moreover, the ventilation capacity proposed by Bluhm et al. (2013) was designed to handle only dust and not gases exsolving from geothermal water. The ventilation capacity was expressed as a flow rate (3000 m^3/s) without a corresponding power requirement. However, the ventilation power requirement can be estimated using the formula for ideal power consumption for a fan without losses

$$P = q \, \Delta p \tag{1}$$

where P is the power requirement, q is the airflow and Δp is the pressure increase in the fan. Although Bluhm et al. (2013) did not state a design fan pressure, typical underground mines require airflows at pressures of 2-3 kPa, along with more typical airflows of 200-300 m^3/s (AusIMM, 2012). Using Eq. (1) with a pressure of 2.5 kPa and airflow of 3000 m^3/s results in a ventilation power requirement of 7.5 MW.

METHODOLOGY

The objectives of this study were addressed by comparing a literature review of estimates of electricity and water consumption by the copper mining industry with the information provided in the General Plan of Operations (Resolution Copper Mining, 2014a-c). Consumption estimates in the literature varied due to the use of different datasets and different schemes for categorizing copper mines. In general, the most reliable estimates were taken from the most recent studies and the studies that took into account the particular aspects of the Resolution Copper Mine (such as the depth and grade of the copper deposit). The ability of Rio Tinto to achieve their predicted water efficiencies was assessed by considered the technologies that would be used in the Resolution Copper Mine and the typical water efficiencies for those technologies. All calculations assumed the maximum ore processing rate (before process improvements that could increase the rate by 25%) of 150,000 metric tons per day.

RESULTS

Prediction of Electricity Consumption

Much of the earlier data on electricity consumption by copper mines came only from Chilean mines, which had stricter reporting requirements. For example, based on data from Chilean mines from 2004-2008, Bleiwas (2011) estimated electricity consumption of 460 kilowatt hours per metric ton of copper (kWh/t Cu) for underground mining, 2100 kWh/t Cu for beneficiation, and 144 kWh/t Cu for services (administrative offices, general maintenance, security, and other general support operations), for a total of 2704 kWh/t Cu. Beneficiation referred to the production of concentrate by grinding and flotation, but without further refining by smelting, electro-refining, or LX-SX-EW (heap leaching, solvent extraction and electrowinning). The dataset used by Bleiwas (2011) did not distinguish between mining of copper oxide and copper sulfide ores. The above per unit consumption would result in 248 MW for an ore processing rate of 150,000 metric tons per day at a grade of 1.47%. Based on production of ore from a polymetallic body to produce two concentrates (such as the mining of a Cu-Mo ore body to produce concentrates of Cu and Mo), Bleiwas (2011) estimated 51 kWh/t ore for underground mining, and 40 kWh/t ore for beneficiation and tailings disposal for a total of 91 kWt / ore, corresponding to 569 MW for the proposed Resolution Copper Mine. A more recent dataset from Chile used by Fagerström (2015) estimated 655 kWh/t Cu for underground mining, 3075 kWh/t Cu for concentrate production and 188 kWh/t Cu for services, for a total of 3918 kWh/t Cu, which would yield 360 MW for the Resolution Copper Mine. For unit consumption based on ore production without regard to grade, Fagerström (2015) estimated 6.0 kWh/t ore for underground mining and 22.5 kWh/t ore for concentrate production for a total of 28.5 kWh/t ore, corresponding to 178 MW for the proposed Resolution Copper Mine. Finally, based on a global dataset, Northey et al. (2013) found the unit electricity consumption for copper mines that produced only concentrate to be

$$y = 15.697\ x^{-0.573} \tag{2}$$

where y is energy intensity (GJ/t Cu) and x is ore grade (% Cu). Using an ore processing rate of 150,000 metric tons per day at a grade of 1.47% would result in an electricity consumption of 321 MW.

The most reliable estimate is probably that of Koppelaar and Koppelaar (2016), who used the most recent and complete dataset, and who explicitly took depth and grade into account in estimating per unit electricity consumption. Koppelaar and Koppelaar (2016) considered six functional forms, of which the best-fit for mining that including only milling and flotation was

$$E = \alpha + \gamma D + \beta / G \tag{3}$$

where E is energy consumption to produce a copper concentrate with greater than 30% purity (MJ/kg copper concentrate), D is depth (m), and G is grade (% Cu). Koppelaar and Koppelaar (2016) found a strong correlation ($r = 0.66$) with the best-fit parameters $\alpha = 1.569$, $\gamma = 0.00066$, and $\beta = 0.0067$ for a dataset that combined surface and underground mining, included beneficiation only by milling and flotation, and considered energy consumption only as the consumption of electricity. When surface and underground mining were separated, there were not enough data points to obtain a statistically significant fit that separated electricity from diesel fuel, so that only total energy (diesel + electricity) could be estimated. Applying Eq. (3) to the Resolution Copper Mine with $D = 2100$ meters, $G = 1.47\%$, and an ore production rate of 150,000 metric tons per day yields 253 MW. Using the same values with the minimum depth of the ore body ($D = 1500$ m) yields 218 MW. On the above basis, the best estimate for electricity consumption by the Resolution Copper Mine is the average of the estimates for the minimum and maximum depths, or 236 MW.

The additional electricity consumption required to dewater and refrigerate the mine due to the entry of geothermal water should be added to the electrical consumption that was estimated from typical copper mining industry practice. The need to remove and mitigate the impact of geothermal water would not normally be a factor in the power requirements of a typical copper mine. Therefore, the appropriate best estimate for the electricity consumption of the Resolution Copper Mine under the best-case scenario (minimum input of geothermal water) should be 260 MW. The appropriate best estimate for the electricity consumption of the Resolution Copper Mine under the worst-case scenario (maximum input of geothermal water) should be 1900 MW (roundest to the nearest 10 MW).

Prediction of Water Consumption

There is considerable variation in estimates of water consumption by copper mines, whether the unit water consumption rate is based upon the ore production rate or the copper production rate. Mudd (2008) estimated water consumption rates of 1.27 cubic meters per metric ton of ore (m^3/t ore) and 172 m^3/t Cu, corresponding to predictions for the Resolution Copper Mine of 56,000 and 112,000 acre-feet of water, respectively. Gunson (2013) built on the work of Mudd (2008) and estimated water consumption rates of 0.59 m^3/t ore and 89 m^3/t Cu, corresponding to estimates for the Resolution Copper Mine of 26,000 and 58,000 acre-feet of water, respectively. Northey et al. (2013) emphasized the large variation in water consumption among copper mines world-wide and gave 74 m^3/t Cu as a global average, corresponding to an estimate for the Resolution Copper Mine of 48,000 acre-feet of water.

The best estimate for the Resolution Copper Mine might come from Singh (2010), who examined only copper mines in Arizona. The advantage of restricting the dataset to Arizona is that it takes into account the high evaporation rates that might not be present at copper mines in the rest of the world. Using the data in Singh (2010) from seven Arizona copper mines (Bagdad, Miami, Mission, Morenci, Ray, Sierrita, Silver Bell) from 2004-2008 resulted in an average water consumption of 28.3 gallons per pound of copper. This average for Arizona would correspond to 154,000 acre-feet per year for the Resolution Copper Mine, which is considerably higher than the estimates based on global datasets. The water consumption rate may be lower for newer mines. According to the Environmental Impact Studies, the projected water consumptions by the Safford Mine (which began full production in 2008) and the Rosemont Mine (which has just been approved by the U.S. Army Corps of Engineers) are 7.5 and 7.4 gallons per pound of copper, corresponding to water consumption rates for the Resolution Copper Mine of 41,000 and 40,000 acre-feet of water per year, respectively. Unfortunately, the owners of the Safford Mine, Freeport-McMoran Copper and Gold, have not released any actual water consumption data for comparison with the projections (Northey et al., 2019). Taking into account the fact that the water consumption rates for the newer mines are only projections and not actual measurements, the best prediction for water consumption by the Resolution Copper Mine is 50,000 acre-feet per year, which is also quite close to the global average (Northey et al., 2013).

Since the seven Arizona copper mines studied by Singh (2010) are all open-pit mines, it is worth considering whether there should be a difference between water consumption of surface and underground copper mines. None of the previously mentioned water-consumption studies (Mudd, 2008; Gunson, 2013; Northey et al., 2013) separated copper mines into surface and underground. According to Bleiwas (2012), the water required to operate the flotation plant accounts for most of the water use at a copper mine and may outweigh all other uses of water. The most significant sources of water consumption are the water that is entrained with the tailings that are shipped to the tailings storage facility and the evaporation of water from the surface of the tailings storage facility (Bleiwas, 2012). None of the above relate to the transport of ore from the mine to the beneficiation plant. The only possible exception is that underground mines could use additional water for dust suppression. However, there is virtually no data on this subject (Northey and Haque, 2013). Based on the above, the underground nature of the Resolution Copper Mine was not taken into account in predicting its water consumption.

DISCUSSION

Comparison of Prediction of Electricity Consumption with Available Electricity

The predictions of electricity consumption of 260 MW under the best-case scenario and 1900 MW under the worst-case scenario for the Resolution Copper Mine can now be compared with the available sources of electricity. As mentioned earlier, the General Plan of Operations (Rsolution Copper Mining, 2014a-c) lists no sources of power besides the local grid of the Salt River Project. For Fiscal Year 2018, the Salt River Project (2019) reported peak power of 7610 MW and peak power capacity of 8801 MW. The above predictions of electricity consumption correspond to 3% and 22% of the peak power capacity of the Salt River Project under the best-case and worst-case scenarios, respectively. For another comparison, the average electricity generation rate in the state of Arizona for November 2018 was 11,196 MW (EIA, 2019a), of which the predicted electricity consumptions under the best-case and worst-case scenarios would be 2.3% and 17%, respectively. Finally, the predicted electricity consumption for the Resolution Copper Mine would be equivalent to the electricity consumed by 219,000 U.S. households under the best-case scenario and 1.6 million U.S. households under the worst-case scenario (EIA, 2019b). There is certainly no mention on the website of the Salt River Project or anywhere else for plans to increase power capacity to accommodate the Resolution Copper Mine.

Comparison of Predictions of Water Consumption by Rio Tinto and this Study

Rio Tinto has predicted average water consumption by the Resolution Copper Mine of 15,700 acre-feet per year with a maximum of 20,000 acre-feet per year (Resolution Copper Mining, 2014a), whereas this study has predicted water consumption of 50,000 acre-feet per year. For other comparisons, the water-consumption prediction from Rio Tinto is 10.2% of the average for copper mines in Arizona (Singh, 2010), 32.5% of the global average (Northey et al., 2013), and 38.9% of the predicted water consumption for the just-approved Rosemont Mine in Arizona (Singh, 2010). The only explanation from Rio Tinto for the above discrepancy has been their promise that, “Maximizing water reuse is critical to the Resolution Project from a physical resource and cost perspective. Reuse and reclaim water supplies will be used for mine operations to the greatest extent possible, including water from mine dewatering, tailings dewatering, seepage collection, overflow water from the copper/molybdenum thickeners and tailings thickeners, and concentrate filtrate" (Resolution Copper Mining, 2014a).

In opposition to the above quote, the General Plan of Operations (Resolution Copper Mining, 2014a-c) describes only the most conventional technologies for water efficiency. The only areas for which specific water losses have been calculated are the water entrained with the copper concentrate (which is shipped off-site for further refining) and the water entrained with the tailings (which are exported to the tailings storage facility). The copper concentrate would have a water content of 9% by mass (Resolution Copper Mining, 2014a), which is exactly the average in the copper mining industry (Singh, 2010). The tailings would consist of 85% scavenger tailings and 15% cleaner tailings. During operation, the scavenger tailings line would contain 5300 tons of solids and 2.1 acre-feet of water, or 65% solids by mass in the mixture of tailings and water. The cleaner tailings line would contain 971 tons of solids and 0.71 acre-feet of water for 50% solids in the mixture of tailings and water (Resolution Copper Mining, 2014a). The weighted average for the two types of tailings would be 63% solids in the mixture of solid tailings and water. Such solids contents are on the high end for an unthickened or thickened slurry (typically, 20-40%, and up to 60% solids (Klohn Crippen Berger, 2017)) and on the low end for a high-density thickened slurry or paste (typically 60-75% solids). By contrast, the more advanced technology of filtered tailings results in the export of mixtures of tailings and water that are more than 80% solids (Klohn Crippen Berger, 2017).

The water loss from the export of tailings alone can be calculated from the data available in the General Plan of Operations (Resolution Copper Mining, 2014a-c). Given an ore processing rate of 150,000 metric tons of ore per day, an ore grade of 1.47% Cu, and a concentrate grade of 30% Cu, each day of processing will result in 7350 metric tons of concentrate, 121,252.5 metric tons of scavenger tailings and 21,397.5 metric tons of cleaner tailings, where the preceding amounts are solids only. Based upon the above values, the water exported to the tailings storage facility would be 25,600 acre-feet per year (rounded to the nearest 100 acre-feet per year), which is already 10,100 acre-feet per year greater than the average water consumption of 15,700 acre-feet per year that was predicted by Rio Tinto (Resolution Copper Mining, 2014a). Of course, it is possible that some of the supernatant water from the tailings storage facility could be pumped back to the ore processing plant after the tailings are allowed to settle. However, the feasibility of this scheme depends upon the location of the tailings storage facility, which has not yet been determined. For example, one of the alternatives for the tailings storage facility (Peg Leg site) is 18 miles from the mining area (USDA, 2018a), while the alternative site that was considered by Rio Tinto for their estimation of water use (Near West site) is only seven miles from the mining area (Resolution Copper Mining, 2014a; USDA, 2018b).

Comparison of Water Consumption with Available Water

The primary water source for the Resolution Copper Mine would be the water resources of the Central Arizona Project. According to the General Plan of Operations (Resolution Copper Mining, 2014a), "The Non-Indian Agricultural water allocation and the renewable long-term storage credits from the CAP [Central Arizona Project] and the Gila River Water Storage LLC constitute the current water supply portfolio. These renewable water supplies will provide for over 65 percent of Resolution Copper's water supply needs over the life of the mine." The

General Plan of Operations (2014a) continues, “Acquisition of the balance of the renewable water supply needed for the full projected 40 years of operations… is expected to be an ongoing process that will continue during permitting, construction, and likely into production.” In other words, even using the prediction by Rio Tinto of water consumption of 15,700 acre-feet per year, only 65% of the necessary water access has been secured. Potentially complicating that ongoing process is the likelihood that Lake Mead will soon drop below 1,075 feet, triggering a water shortage declaration, and a reduction of available Colorado River water to CAP by some 320,000 acre-feet per year. Pinal County agricultural water users are predicted to be among the most severely impacted CAP water users when a shortage declaration is announced, requiring them to access ground water to make up for CAP supply cutbacks—and Pinal County happens to be where Rio Tinto plans to also seek groundwater via a number of new wells (Resolution Copper Mining, 2014a; Allhands, 2018).

It is possible to consider making up for the shortfall in water availability by taking full advantage of the unanticipated geothermal water. Of course, this geothermal water cannot be relied upon as a solution to the water shortage since there are no guarantees that there will be too little, too much, or just the right amount of geothermal water. Moreover, there is a trade-off between the availability of geothermal water and the need for electricity to pump the water out of the underground mine and to refrigerate the mine. The short-term shortfall could be 34,300 acre-feet of water per year, which is the difference between what was predicted by this study (50,000 acre-feet per year) and what was predicted by Rio Tinto (15,700 acre-feet per year). Assuming no head loss, this rate of entering geothermal water would require 93 MW solely for dewatering and refrigeration. (The power requirement would increase to 126 MW if the mine was dewatered through a 12-inch pipe.) The long-term shortfall could be the need to provide for the entire water consumption of 50,000 acre-feet per year. Assuming no head loss, this rate of entering geothermal water would require 135 MW solely for dewatering and refrigeration, and 233 MW if mine dewatering occurred through a 12-inch pipe.

The Observational Method in Mine Management

Almost all mines are designed and managed using some version of what is called the Observational Method. This methodology was both reviewed and critiqued by Independent Expert Engineering Investigation and Review Panel (2015), who investigated the causes of the 2014 tailings dam failure at the Mount Polley Mine in British Columbia. According to Expert Engineering Investigation and Review Panel (2015), the Observational Method “uses observed performance from instrumentation data for implementing preplanned design features or actions in response.” However, the Observational Method is not simply a license to figure things out later. Expert Engineering Investigation and Review Panel (2015) continued “the Observational Method is useless without a way to respond to the observations.” As just one example from the sequence of events that led to the Mount Polley disaster, when there was insufficient mine waste for constructing the tailings dam, the embankment was simply constructed at a steeper slope, there being no alternative source for construction material for the dam.

The plan for the Resolution Copper Mine could be regarded as the Observational Method run amok, in that no alternatives have been planned if any of the best-case scenarios do not come to fruition. Note the emphasis in the Observational Method on “preplanned design features.” In particular, there are no alternative sources of electricity if the entry of geothermal water into the completed mine is significantly greater than what could be extrapolated from the current entry rate into the primary access shaft. There are no alternative sources of water if the promises to hold water consumption to one-third of copper mining industry standards cannot be kept. Even if the promises of extraordinary water efficiency can be kept, there do not appear to be alternative sources of water beyond the 65% already secured besides the additional promise that "acquisition...is expected to be an ongoing process."

CONCLUSIONS

The conclusions of this study can be summarized as follows:

1) The predicted electricity consumption of the Resolution Copper Mine is 260 MW and 1900 MW under the best-case and worst-case scenarios, which are 3% and 22%, respectively, of the peak power capacity of the Salt River Project.
2) The predicted water consumption of the Resolution Copper Mine is 50,000 acre-feet per year.
3) Although Rio Tinto has promised water consumption of only 15,700 acre-feet per year, they are using only conventional technologies for achieving water efficiency.
4) The export of water in the tailings alone would result in a water consumption of 25,600 acre-feet per year. Although some water could be recycled from the tailings storage facility, the feasibility depends upon its location, which has not yet been determined.

RECOMMENDATIONS

It is recommended that potential investors in the Resolution Copper Mine seek clarification from Rio Tinto on the following questions:

1) Does Rio Tinto have a guarantee from the Salt River Project that they will supply power to the Resolution Copper Mine that is equal to 3% and 22% of their peak power capacity under the respective best-case and worst-case scenarios?
2) Why does Rio Tinto believe that the water consumption for the Resolution Copper Mine will be 10.2% of the average for copper mines in Arizona, 32.5% of the global average, and 38.9% of the predicted water consumption for the just-approved Rosemont Mine?
3) Why does Rio Tinto believe that water consumption for the Resolution Copper Mine will be only 15,700 acre-feet per year when the water exported with the tailings alone will be 25,600 acre-feet of water per year, according to their General Plan of Operations?
4) What alternatives does Rio Tinto have for water supply if they cannot meet their promise to consume only 15,700 acre-feet of water per year?
5) Even if Rio Tinto can fulfill their promise to consume only 15,700 acre-feet of water per year, how will they secure the shortfall of 35% of necessary water supply, as stated in their General Plan of Operations?

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 and has 66 peer-reviewed publications in these areas. Dr. Emerman is the owner of Malach Consulting, which specializes in evaluating the environmental impacts of mining for mining companies, as well as governmental agencies and non-governmental organizations.

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