Potential Impact of Geothermal Water on the Financial Success of the Resolution Copper Mine, Arizona

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Lightning Summary

The unanticipated encounter of geothermal water in an exploratory shaft for the underground Resolution Copper Mine proposed by Rio Tinto will increase power requirements for mine dewatering and cooling by at least 24 megawatts, in addition to increased costs of ventilation and corrosion of equipment. The failure of Rio Tinto to estimate total power requirements and to seek any power source besides the local grid leads to serious questions regarding the profitability of the project.

Abstract

Rio Tinto has submitted a proposal to the U.S. Forest Service for an underground 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 produce one billion pounds of copper per year. The objective of this study was to evaluate the ability of Rio Tinto to profitably operate the mine, regardless of the social and environmental impact of the mine. The objective was addressed by considering unanticipated costs, in particular, the encounter of geothermal water (180°F) in a 6943-foot-deep exploratory shaft at a flow rate of 1400 gallons per minute (gpm). The additional costs of mine dewatering and refrigeration were estimated using all best-case scenarios. The Thiem Equation for steady-state groundwater flow was used to estimate an entry rate for geothermal water of 3800 gpm for the completed mine. The Hazen-Williams Equation for pipe flow was then used to estimate a power requirement of 12 megawatts (MW) for dewatering. The theoretical maximum coefficient of performance for exchange of heat between the surface and the geothermal water was used to estimate a power requirement for refrigeration of another 12 MW. The minimum total power requirement for mine dewatering and refrigeration of 24 MW is equivalent to the average power requirement of 20,000 U.S. households. The worst-case scenario is difficult to estimate, but if more highly fractured rock is encountered during construction of the underground mine, the additional power requirements could easily be 100 times greater. Additional costs of ventilation, due to gases exsolving from the geothermal water, and corrosion of mine equipment, due to the persistent saturated atmosphere, were not considered. The most disturbing issue is the failure of the General Plan of Operations to estimate the total power requirements of the copper mine or to seek any source for power besides the local grid of the Salt River Project. Based upon the above concerns, it is not recommended that anyone invest in the copper project without clarification of power requirements and sources.

Introduction

Rio Tinto has submitted a proposal to the U.S. Forest Service 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 (see Fig. 1), which would produce one billion pounds of copper per year (Resolution Copper, 2018a, 2018b). 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 complementary question: Can Rio Tinto profitably operate the proposed Resolution Copper Mine regardless of its impact upon society and the environment? The objective has been addressed by focusing on the following questions:

1) Are there significant unanticipated costs that were not foreseen in the three-volume General Plan of Operations (Resolution Copper Mining, 2014a-c)?
2) Are there significant anticipated costs that were not adequately addressed in the three-volume General Plan of Operations (Resolution Copper Mining, 2014a-c)?

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).

The most significant unanticipated costs thus far have been the costs associated with the unexpected discovery of geothermal water at the location of the proposed underground mine. 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). According to a summary of a presentation by Tom Goodell, general manager – shaft development for Resolution Copper, "Productivity flattened out at 6500 feet. The reason: hot water. 'In late December [2012], we hit a lot of water,' Goodell said. 'We are pumping 460 gpm [gallons per minute]…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; see Fig. 2). The summary continued, "The other wrinkle is that the water coming out of the ground at shaft bottom is as high as 170°F (77°C)" (E&MJ, 2014). The result of the unexpected discovery was a two-year delay in drilling for the installation of upgraded pumping, refrigeration and ventilation equipment (see Fig. 2). 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. According to a report in Bloomberg Businessweek, "A 6-foot-tall submersible pump in 20 feet of water beneath the shaft fills a dumpster-size tank. From the tank, two large pumps each shoot 700 gallons per minute up to the surface" (Phillips, 2016). The existence of two pumps (although not the discharge rate of each pump) was confirmed by the Arizona Daily Star, "Two huge water pumps send water out of the cave" (Bregel, 2016). The report by Bloomberg Businessweek also stated, "Without the elaborate refrigeration system that pumps chilled air down No. 10, the bottom of the mine would be 180°F, far too hot for a human to withstand" (Phillips, 2016). In the analysis of this study, the temperature of the geothermal water will be assumed to be 180°F, although it is not clear that this temperature actually increased since the previous report (E&MJ, 2014).

Based on the unanticipated discovery of geothermal water, the first question regarding significant unanticipated costs can now be subdivided into two questions:

1) What will be the additional cost of mine dewatering once the underground mine has been completed?
2) What will be the additional cost of mine refrigeration once the underground mine has been completed?

Both of the above questions were addressed assuming a best-case scenario at every step of the analysis, so that the absolute minimum additional costs were estimated. It should be pointed out that two more additional costs are difficult to estimate and could be quite large. These additional costs are the costs of ventilation, due to gases exsolving from the geothermal water, and the cost of corrosion of mine equipment, due to 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).

Methods

The expected flow rate of geothermal water into the completed underground mine was calculated by starting with the Thiem Equation for steady-state groundwater flow for confined aquifers (Fetter, 2001)

$$T = \frac{Q}{2\pi(h_2 - h_1)} ln\left(\frac{r_2}{r_1}\right) \tag{1}$$

where T is aquifer transmissivity (product of aquifer thickness and hydraulic conductivity), Q is groundwater discharge (positive in the inward radial direction), and h_1 and h_2 are the hydraulic heads at distances r_1 and r_2 from the center of the pumping well, respectively (see Fig. 3). The assumption of steady-state flow is a best-case scenario since the reports by E&MJ (2014) and Phillips (2016) indicate that the entry rate of geothermal water in the No. 10 shaft has increased from 460 to 1400 gpm. The flow rate might be increasing since the high hydraulic gradient created between the open shaft and the aquifer might be causing an increase in the aperture of fractures within the aquifer. On the other hand, the increase in flow rate might result simply from the increase in penetration of the aquifer from the depth of the first encounter with geothermal water until the completion of the shaft. Based on Fig. 2, geothermal water was encountered at a depth of 6458 feet and the flow rate of 460 gpm occurred when the shaft had penetrated 162 feet into the aquifer (6620 feet below the surface). Since the shaft is now 6943 feet deep, the flow rate of 1400 gpm is taking place at an aquifer penetration of 485 feet. The increase in flow rate is remarkably consistent with the increase in penetration based on the ratios 485 ft/162 ft = 2.99 and 1400 gpm/460 gpm = 3.04. Since there is no way to reliably estimate any future increase in flow rate, it will be assumed that the flow rate into the No. 10 shaft will continue to be 1400 gpm indefinitely.

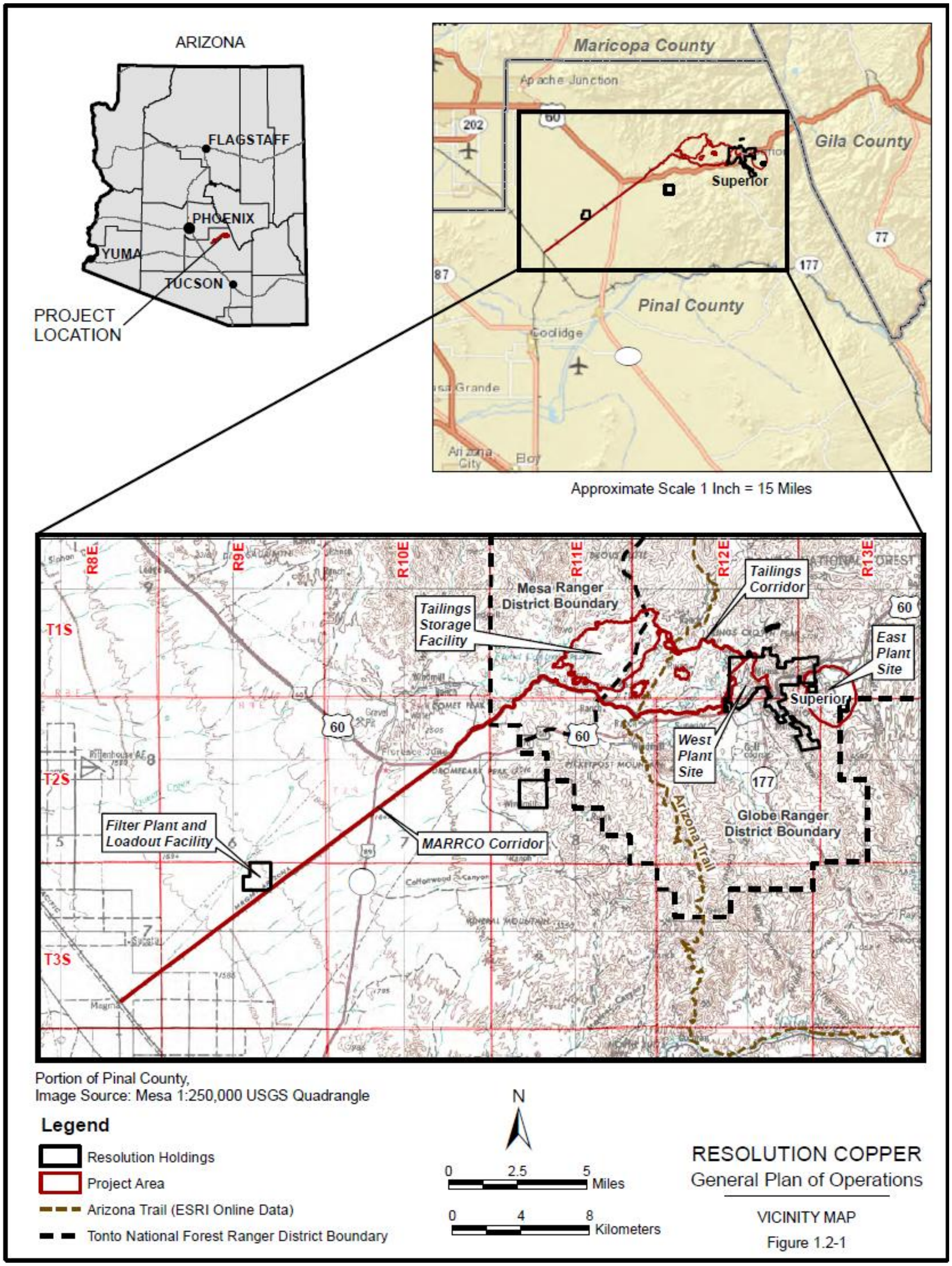

Figure 1. Rio Tinto has submitted a proposal for an underground copper mine, called the Resolution Copper Mine, within a mix of federal public land (Tonto National Forest), Arizona state trust land, and private land, which would produce one billion pounds of copper per year. The underground portion of the mining operation would be beneath the East Plant Site. Figure from Resolution Copper Mining (2014b).

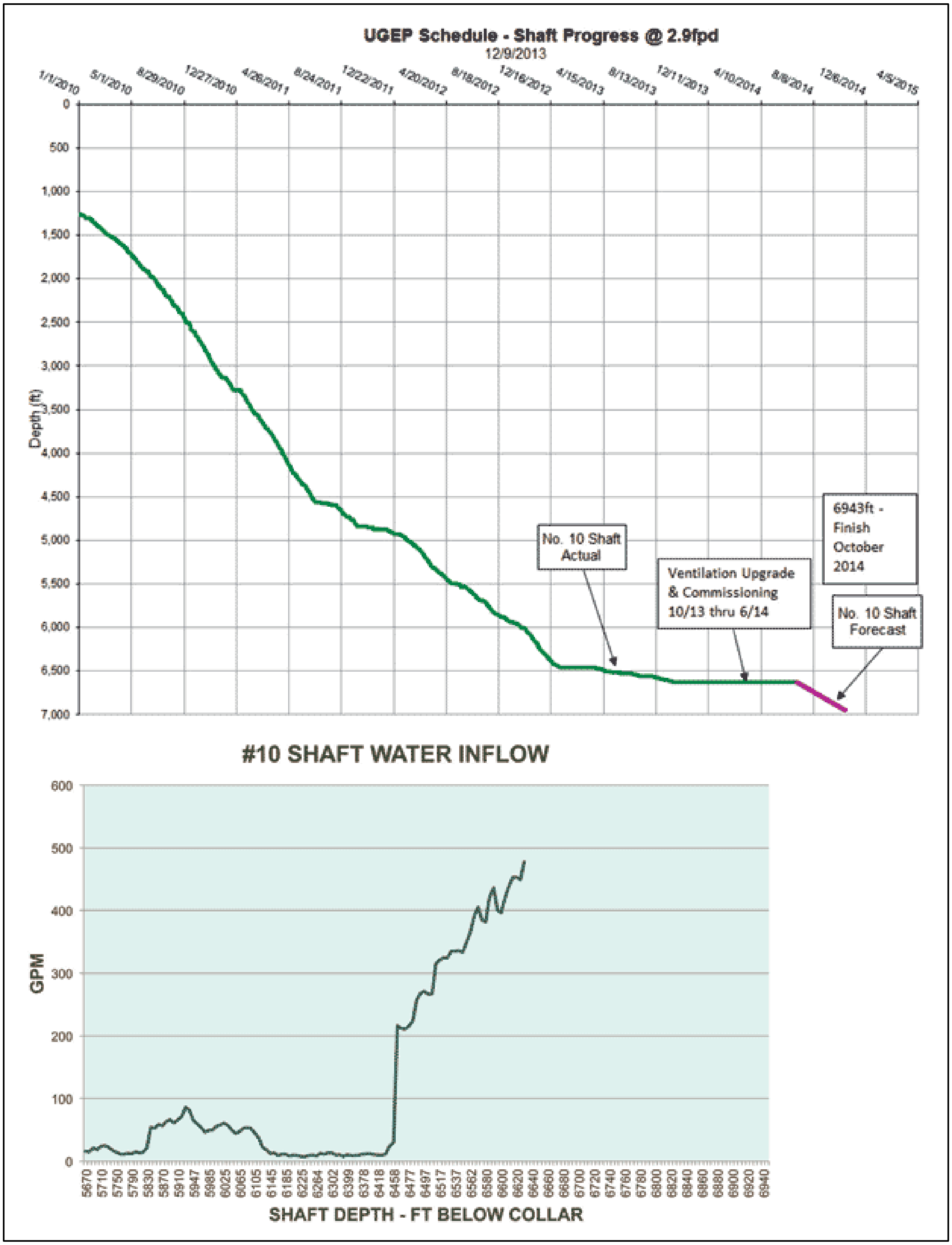

Figure 2. While drilling the No. 10 Shaft, the deepest single-lift shaft in the U.S., geothermal water (77°F) with a flow rate of 460 gallons per minute was encountered at a depth of 6458 feet, causing a two-year delay in drilling. By the time the shaft was completed at a depth of 6943 feet, the flow rate had increased to 1400 gallons per minute. Figure from E&MJ (2014).

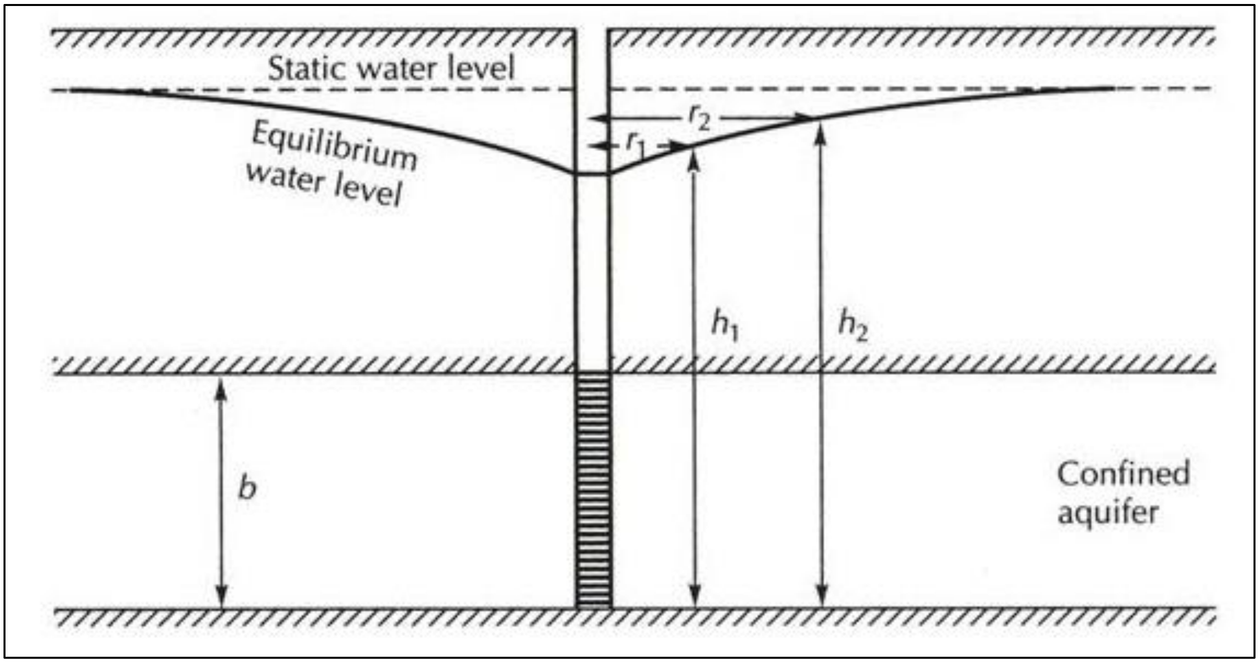

Figure 3. The Thiem Equation is used to calculate the steady-state discharge of groundwater into a well, based on the transmissivity of the aquifer and the heads at two distances from the pumping well. If r_1 is equal to the well radius, then h_1 is the water level in the well. At a sufficient distance from the well (called the radius of influence of the well), the head retains its equilibrium level and is undisturbed by the presence of the well. Figure from Fetter (2001).

Eq. (1) can be rewritten as

$$T = \frac{Q}{2\pi(H - h_1)} \ln\left(\frac{R}{r_1}\right) \tag{2}$$

where H is the equilibrium head of the aquifer (the head before the shaft was drilled), and R is the distance from the center of the shaft where the aquifer head is undisturbed by the presence of the shaft (called the radius of influence of the pumping well, or shaft in this case). In the absence of any structural or hydrogeologic control, the cone of depression of the pumping well (see Fig. 3) will spread until it intersects sufficient recharge to establish a steady state. The limit of spreading of the cone of depression then defines the radius of influence so that

$$Q = \pi R^2 i \tag{3}$$

where i is the average recharge rate. Combining Eq. (2) and (3) then yields

$$T = \frac{Q}{4\pi(H - h_1)} \ln\left(\frac{Q}{\pi r_1^2 i}\right) \tag{4}$$

The relationship between the current flow rate into the No. 10 shaft and the radius of the shaft is revealed by rewriting Eq. (4) as

$$T = \frac{Q_1}{4\pi(H-h)} \ln\left(\frac{Q_1}{\pi r_1^2 i}\right) \tag{5}$$

where Q_1 is the flow rate into the open shaft (equal to the rate at which water is pumped out of the shaft), r_1 is the radius of the shaft, and h is the hydraulic head in the shaft, Since the shaft is being pumped all the way to the bottom, the head in the shaft h is simply the elevation of the bottom of the shaft. In the same manner, the relationship between the future flow rate into the completed underground mine and the radius of the completed mine is given by

$$T = \frac{Q}{4\pi(H-h)} \ln\left(\frac{Q}{\pi r^2 i}\right) \tag{6}$$

where Q is the projected flow rate into the completed mine and r is the radius of the completed underground mine (approximated as a circle; see Fig. 4). Note that the hydraulic head in the entire mine will be the same as the hydraulic head in the current shaft, since both structures are or will be pumped all to the bottom. The relationship between the current flow rate into the open shaft and the future flow rate into the completed underground mine is then obtained by combining Eqs. (5) and (6) yielding

$$Q \ln\left(\frac{Q}{\pi r^2 i}\right) = Q_1 \ln\left(\frac{Q_1}{\pi r_1^2 i}\right) \tag{7}$$

Note that, according to Eq. (7), although both T and H are completely unknown, it is not necessary to know these quantities in order to predict the future flow rate as long as H is constant in time, and T is constant in both space and time, which are assumptions in the derivation of the Thiem Equation (Fetter, 2001).

Eq. (7) predicts that Q, the future flow rate into the completed underground mine, must be greater than Q_1, the current flow rate into the No. 10 shaft. This can be seen mathematically by taking the derivative of Eq. (7) with respect to r^2 yielding

$$\frac{dQ}{d(r^2)}\left[1 + \ln\left(\frac{Q}{\pi r^2 i}\right)\right] = \frac{Q}{r^2} \tag{8}$$

The quantity in parentheses in Eq. (8) must be greater than one because of Eq. (3) and the observation that R, the radius of influence of the well, must exceed r, the radius of the well. Since both the quantity in brackets in Eq. (8) and the right-hand side of Eq. (8) are positive, Q must be an increasing function of r. In other words, as the underground mine expands, the entry rate of geothermal water must increase. The same result can be obtained intuitively by noting that, as the mine expands (r increases), the edge of the mine moves closer to the radius of influence. This increases the hydraulic gradient since the hydraulic head in the mine is independent of its size (the water in the mine will always be pumped down to the bottom of the mine). A counterbalancing factor is that, according to Eq, (2), the radius of influence moves farther from the center of the well (or mine) as the pumping rate (equal to the entry rate in steady-state) increases. However, there will be a net increase in hydraulic gradient, and thus Q, since the radius of influence increases only as the square root of Q.

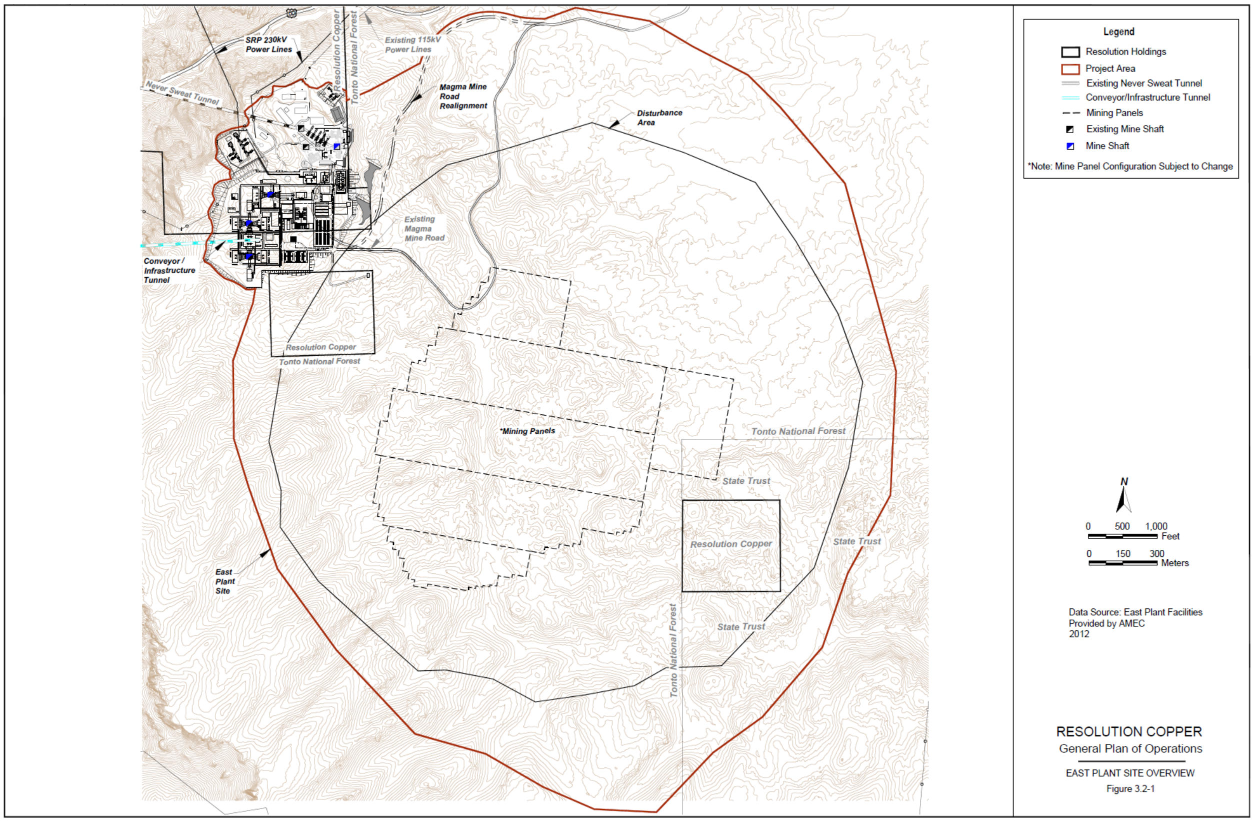

Figure 4. The underground portion of the Resolution Copper Mine would be beneath the East Plant Site. For estimation of the flow rate of geothermal water, the underground operation was approximated as a circle with a radius of 1400 meters. Figure from Resolution Copper Mining (2014b).

The flow rate of geothermal water into the underground mine can then be estimated from a knowledge of Q_1 (1400 gpm = 0.08833 m^3/s), r_1 (14 feet = 4.267 m), r and R. The value of r was estimated as 1400 meters from the plan view of the underground mine, which will be beneath the East Plant Site (see Figs. 1 and 4). The most difficult parameter to measure is i, the average recharge rate of the deep confined aquifer that is the source of the geothermal water. In humid climates, the typical recharge rate can be estimated as the average precipitation rate minus the average evapotranspiration rate minus surface runoff. However, this procedure fails in arid climates where average evapotranspiration exceeds average precipitation. Based on the nearest weather station at Miami, Arizona, the mean annual precipitation is 18.8 inches at the East Plant site, while the mean annual evapotranspiration is 55 inches (Resolution Copper Mining, 2014a). Recharge in arid climates occurs only through sudden events, such as thunderstorms and flash floods, which can temporarily overwhelm the counterbalance of evapotranspiration. Even with a knowledge of precipitation patterns, the most important controlling factor is the soil texture, due to its influence on the surface infiltration rate (Charbeneau, 2000). For example, Albuquerque, New Mexico, with an annual precipitation of 8.2 inches, has been estimated to have groundwater recharge rates of 0.24-0.35 inches per year, depending upon the soil texture (Charbeneau, 2000). However, according to the General Plan of Operations, "Very few soils data are available for EPS [East Plant Site]" (Resolution Copper Mining, 2014a). Much of the mapped surface consists of either mined land or rock outcrops (Resolution Copper Mining, 2014a), so that surface infiltration rates are controlled by the characteristics of surface fracturing, which are again unknown. Even if the surface infiltration rates were known, it would not be known how much of that infiltration contributes to recharge of the deep aquifer under consideration, as opposed to shallower aquifers.

Following the objective of this study to consider the best-case scenario for power requirements, it was decided to assume a recharge rate of i = 0.1 inches per year (8.049×10^{-11} m/s) as the minimum reasonable recharge rate. Fortunately, the correct choice of recharge rate is not critical since the flow rate of geothermal water depends only upon the logarithm of the recharge rate (see Eq. (7)). The assumption of a minimum recharge rate minimizes the predicted flow rate into the future underground mine. As above, this can be seen mathematically by taking the derivative of Eq. (7) with respect to i, yielding

$$\frac{dQ}{di}\left[1+\ln\left(\frac{Q}{\pi r^2 i}\right)\right]=\frac{Q-Q_1}{i} \tag{9}$$

It has already been shown that the quantity in parentheses must be greater than one and that $Q > Q_1$, so that Q must be an increasing function of i. Otherwise, it should be intuitively clear that increasing the rate of recharge of the deep aquifer will cause the expansion of the underground mine to intercept a greater flow rate of geothermal water.

The power that is required to pump water from the bottom of the mine or shaft to the surface depends upon both the static head and the head loss due to friction between the moving water and the pipe. The sum of the static head Δz and the head loss Δh is called the total dynamic head *TDH* (Nathanson and Schneider, 2014). The static head is simply the vertical distance from the bottom of the mine or shaft to the surface (Δz = 6943 feet = 2116.226 m). The head loss is given by the empirical Hazen-Williams Equation (Nathanson and Schneider, 2014)

$$\Delta h = L\left(\frac{Q}{0.28CD^{2.63}}\right)^{1/0.54} \tag{10}$$

where Q is the flow rate in gpm, C is the roughness coefficient, D is the pipe diameter in inches, and L is the length of pipe (same units as Δh). The roughness coefficient is typically chosen as C = 100, which is appropriate for cast iron (Nathanson and Schneider, 2014). Based on the photo in the Arizona Daily Star article (see Fig. 5), the pipe used for shaft dewatering has a diameter of D = 6 inches. Continuing the practice of basing power requirements on a best-case scenario, the length of pipe is assumed to be simply the vertical distance to the surface (so that $L = \Delta z$ = 6943 feet = 2116.226 m), which would be an absolute minimum length. Since some portion of the pipe is horizontal (see Fig. 5), the assumption minimizes the head loss from friction and, thus, the power required to overcome the head loss.

It cannot necessarily be assumed that mine dewatering will occur through a single pipe or that the current No. 10 shaft is being dewatered through a single pipe (see Fig. 5). However, the assumption of a single pipe again constitutes a best-case scenario. For example, based on the Continuity Equation (Nathanson and Schneider, 2014)

$$Q = \frac{\pi v D^2}{4} \tag{11}$$

where v is flow velocity (assumed to be constant), if a total flow rate Q is divided through two pipes, then each pipe must have diameter $D/\sqrt{2}$. In that case, using Eq. (7), the head loss through each pipe will be 2.245 times the head loss through a single pipe of diameter D, for a total head loss of 4.9 times the head loss through a single pipe. Once the flow rate Q has been calculated from Eq. (4), and the head loss Δh has been calculated from Eq. (7), the power required for mine dewatering $P_{dewater}$ is given by

$$P_{dewater} = (\Delta z + \Delta h) Q \rho g \tag{12}$$

where ρ is the density of water (1000 kg/m^3) and g is acceleration due to gravity (9.8 m/s^2).

Figure 5. Based on the photo, the pipe diameter for mine dewatering was assumed to be six inches. Moreover, since the pipe in the photo is horizontal, the assumption that mine dewatering is accomplished through a single vertical pipe is a best-case scenario. The photo caption clarifies that the photo shows "pipes that move water…to pumps that send it to a water treatment facility on the surface" (Bregel, 2016). Photo from Bregel (2016).

The additional power required for refrigeration due to the entry of geothermal water into the mine is based upon the additional thermal power of the water. This thermal power of flowing groundwater will be far greater than the thermal power introduced by the slow conduction of heat from the surrounding rocks. The additional thermal power $P_{thermal}$ is given by

$$P_{thermal} = Q\rho C_P \Delta T \tag{13}$$

where C_P is the specific heat capacity of water (4186 J/kg·ºC) and ΔT is the difference between the water temperature (180ºF = 82ºC) and the refrigerated air temperature at the bottom of the mine (75ºF = 24ºC). The power required for refrigeration is equal to the thermal power given in Eq. (13) divided by the coefficient of performance *COP*. The theoretical maximum value of *COP* (representing maximum efficiency of refrigeration) is given by

$$COP = \frac{T_C}{T_H - T_C} \tag{14}$$

where T_C is the temperature of the reservoir of cold air (surface temperature) and T_H is the temperature of the reservoir of hot water. The surface temperature T_C was taken as the mean annual temperature at East Plant Site of 64ºF = 18ºC (Resolution Copper Mining, 2014a). Note that the use of Eq. (14) requires the absolute temperature (K) for T_C.

Results and Discussion

Solving Eq. (7) with input parameters r_1 (radius of No. 10 shaft) = 4.267 meters, Q_1 (current flow rate into No. 10 shaft) = 0.08833 m^3/s, r (approximate radius of underground mine) = 1400 meters, and i (minimum reasonable recharge rate) = 8.049 × 10^{-11} m/s, results in projected flow rate of geothermal water into the underground mine Q = 0.2396 m^3/s (3798 gpm). Increasing the recharge rate by an order of magnitude to 1 inch per year (8.049 × 10^{-10} m/s) would increase the flow rate of geothermal water to Q = 0.3092 m^3/s (4900 gpm), that is, by only 29%. Using Eq. (10) with Q = 3798 gpm, roughness coefficient C = 100, pipe diameter D = 6 inches, and pipe length L = 6943 feet (2116.226 m) leads to a head loss Δh = 10,014 feet (3052 meters). The use of Eq. (12) with the above values and Δz = 6943 feet results in minimum power required for mine dewatering $P_{dewater}$ = 12 MW. Applying Eq. (13) with ΔT = 58°C leads to thermal power of the incoming geothermal water $P_{thermal}$ = 58.18 MW. Using Eq. (14) and T_C = 18°C for the reservoir of cold air yields a maximum coefficient of performance *COP* = 5.02. Finally, dividing the thermal power by *COP* = 5.02 results in a minimum refrigeration power of 12 MW (coincidentally equal to the minimum power required for mine dewatering). In summary, under the best-case scenario, the power required for both dewatering and refrigeration of the completed underground mine will be 24 MW. For comparison, the average U.S. household power usage is 1228 W (EIA, 2018), so that the minimum power required for mine dewatering and refrigeration is approximately equal to the total power usage by 20,000 U.S. households.

The best-case scenario resulting in an additional power requirement of 24 MW due to the unexpected encounter with geothermal water can now be reconsidered. That best-case scenario was based on 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.
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.

According to common sense, no one would budget for a best-case scenario. It is probably more appropriate to double the cost of the best-case scenario and assume that an extra 48 MW (approximate power usage by 40,000 U.S. households) will be required for mine dewatering and refrigeration. It should be recalled that no attempt has been made to estimate the additional costs of increased ventilation to remove exsolving gases from the geothermal water or the corrosion of mine equipment due to the persistent saturated atmosphere.

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. The assumption of uniform transmissivity (product of aquifer thickness and hydraulic conductivity) is an assumption behind the Thiem Equation (Fetter, 2001). 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. If the hydraulic conductivity increases by only two orders of magnitude, then both the dewatering power and the refrigeration power could be multiplied by approximately 100, for a total power requirement closer to 2400 MW.

The original objectives of this study can also now be reconsidered. With regard to the first objective, it could be asked whether the encounter with geothermal water still constitutes an "unanticipated cost." According to the E&MJ (2014) article, it was certainly unanticipated at the end of 2012. The Arizona Daily Star article 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…It took a year for workers to figure out how to pump out that much water and install the air-conditioning system that lets humans work in such hot conditions" (Bregel, 2016). It is confusing that the three-volume, 2395-page General Plan of Operations (Resolution Copper Mining, 2014a-c) gives 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). However, all of those dates are well after the end of 2012 and nowhere in the 2395 pages is there any mention of the geothermal water and how that will affect the power requirements of the project. Therefore, it could be said that the additional costs associated with geothermal water have not yet moved into the category of "anticipated costs." It should also be emphasized that the significant difference in the flow rate of geothermal water over a distance of only 30 feet (Bregel, 2016) is consistent with a strong spatial variability in aquifer fracturing, as mentioned above.

The second objective was to consider whether the three-volume General Plan of Operations (Resolution Copper Mining, 2014a-c) adequately addressed all of the anticipated costs. On this basis, it would be tempting to ask how the additional power requirements associated with the encounter with geothermal water compare with the total power requirements of the copper project. It is shocking 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. It is difficult to remain objective about this when even a business plan for a one-man machine shop would estimate power requirements and would assure the bank that an adequate source of power was available. The obvious follow-up questions are:

1) What are the total power requirements of the Resolution Copper Mine?
2) How will the consumption of that power affect the other consumers of power from the Salt River Project?

I would be happy to address these questions if they were of interest to the Arizona Mining Reform Coalition or other parties.

Conclusions

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

1) Under the best-case scenario, the completed underground mine will encounter geothermal water at a flow rate of 3800 gpm.
2) Under the best-case scenario, the additional power requirements for mine dewatering and refrigeration will be 24 MW.
3) The worst-case scenario is difficult to estimate, but if more highly fractured rock is encountered during construction of the underground mine, the additional power requirements could easily be 100 times greater.
4) The above estimates do not include the additional costs of ventilation, due to gases exsolving from the geothermal water, and corrosion of mine equipment, due to the persistent saturated atmosphere.
5) The most disturbing issue is the failure of the General Plan of Operations to estimate the total power requirements of the copper mine or to seek any source for power besides the local grid of the Salt River Project

Recommendations

It is recommended that anyone who is interested in investing in the Resolution Copper Mine or in the companies that are managing the copper mine seek answers to the following questions:

1) What are the total additional costs associated with the discovery of geothermal water?
2) What are the total power requirements of the copper project?
3) How will the consumption of power by the Resolution Copper Mine affect the other consumers of power from the Salt River Project?

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 assessing the environmental impacts of mining on behalf of mining companies, as well as governmental and nongovernmental organizations.

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