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Regulation Branch, Bureau of Mining Regulation and Reclamation
Nevada Division of Environmental Protection
Department of Conservation and Natural Resources
901 S. Stewart Street, Suite 4001
Carson City, NV 89701

RE: Rhyolite Ridge Project, Water Pollution Control Permit NEV2020107 - new

Dear Ms Zittel,

Great Basin Resource Watch, Center for Biological Diversity, and Progressive Leadership Alliance of Nevada collectively (Commenters) submit the following comments regarding the new Water Pollution Control Permit for the Rhyolite Ridge Project. We appreciate the cooperation of the Bureau of Mining Regulation and Reclamation in supplying documentation needed to review this permit application.

There are a number of items that we see as needing to be addressed in order for the permit to be acceptable at this time. We urge the agency to require a better hydrographic model, reassessment of the mining pit lake, data on the draindown characteristics of the tailings impoundment, and an expanded monitoring network.

HYDROLOGIC ASPECTS

**Hydrographic Model has Significant Errors and is not Useful**

Commenters are aware that any groundwater model will have an inherently level of uncertainty; however, we view the model used to support conclusions applied to the permit application has significant errors as to lend serious question on these conclusions.

HGL has prepared two reports in support of the proposed Rhyolite Ridge lithium quarry project. The reports depend on too little field data to support the conclusions. *The lack of evidence is most apparent in the groundwater modeling effort for which there is too little data outside of the immediate pit area. This is obvious in the poor conceptual model established for the groundwater model. There are two*
obvious errors. First, the modeler may assume there is too much segmentation. Second, the amount and location of the recharge is inaccurate in several ways discussed below including the amount not equaling an estimated outflow from the model domain and the application of recharge with little regard for the underlying geology.

The groundwater modeling effort uses spring levels as calibration targets, meaning it attempts to match the water level to the spring elevation. This is appropriate only for springs connected to the intermediate level aquifer being simulated (not the regional aquifer or perched aquifers). Calibration involves minimizing residuals which could be negative or positive meaning there is as much chance for the simulated potentiometric surface being above the ground level as below, which is clearly not appropriate. A spring is better simulated as a DRAIN boundary with a targeted discharge rate than as a groundwater surface target. The boundary would prevent the potentiometric surface rising above the ground surface. Seeps should also not be used for calibration.

The model has a “constant head” boundary at its connection to Fish Lake Valley (HGL 2020a, p 49). However, the report also indicates there is a 3-foot drawdown at the boundary, which is impossible because the boundary head is constant. A constant head boundary will allow whatever flux is necessary to prevent the head from dropping. This is why a general head boundary is preferable – it can limit the inflow from the boundary. The constant head boundary can provide unreasonable changes in the water budget.

HGL changed recharge rates as part of calibration (HGL 2020a, p 52). This indicates the model is nonunique. Calibration usually matches measured outflow or inflows to a model domain. For example, HGL should have measured outflows to Fish Lake Valley (based on pump test determined transmissivity and measured gradient) to which it sets the recharge rate (note this means that using Maxey-Eakin recharge values would be inappropriate, as discussed above). Using an established recharge rate as equal to the outflow rate, the calibration would attempt to match the observed groundwater levels by adjusting conductivity. Adjusting also the inflow leads to a nonunique solution. This means that any combination of recharge and conductivity could result in the observed groundwater levels on which the modeler based the calibration. Because the modeler reduced M-E recharge values, it seems likely that the model simulated too little water flowing through the system. Underpredicting recharge could have resulted in a prediction of too little dewatering and a lower pit lake than will actually occur.

HGL (2020a, p 54) makes assumptions about the conductance of faults that are not supported by data

There are no pump test results showing significant reductions over the fault, so HGL has no evidence for these assumptions. The response of the model is based on the assumptions input to the model, which may have no basis in reality.

The steady state calibration shows a significant areal bias with residual tending to be positive or negative in different areas (HGL 2020a, p 55). For example, springs were underpredicted by up to hundreds of feet especially in the high elevations (Id.). Springs are effectively bounded and make poor targets as discussed above. The estimated conductivity throughout much of the model domain is therefore very inaccurate.
The calibration statistics (HGL 2020a, p 56) are very poor. That the mean residual is -65.7 feet means the potentiometric surface is simulated as way too low under steady state conditions. Mean residual should equal zero. HGL uses the steady state groundwater level as the initial level for project simulation. This would result in the model underpredicting drawdown, flow to the lake, and quarry lake recovery. The supposed improvement in calibration statistics due to considering only project wells and VWP means that removing targets leaves those that are easier to hit with the simulation. The mean residual is still substantially negative meaning the steady state groundwater even at the quarry site is too low. The graph showing observed and simulated water tables (HGL 2000a, Figure 7-6) is very misleading due to the scale; observations that appear close to the 1:1 line could still represent residuals of an order of 200 or more.

HGL acknowledges the poor portrayal of an upward gradient within the pit due to the inability to match different VWP levels (HGL 2000a, p 58). The report acknowledges many errors due to the model's inability to simulate small-scale features (Id.). It is therefore questionable how useful the model predictions are. Most of the observations in these comments suggest the model underpredicts flow into the quarry for both dewatering and quarry lake formation.

**It is Unclear that the Mining Pit Lake will be Terminal**

The pre-mining water table was not flat but sloped across the quarry. A lake would be a flat surface. The question is whether that flat surface exceeds the recovered groundwater level at any point along its perimeter or provides sufficient pressure into a confined aquifer intersected by the lake to cause flow.

As part of the modeling, HGL concluded the pit will be a terminal sink meaning that no water leaves the quarry lake to enter the groundwater. The lake would be mostly full within 40 years and reach a steady state after 60 years (HGL 2020b, p v), although steady state is a misnomer in this area. This would be 66 feet below the pre-quarry groundwater level (Id.), although this does no account for the sloping groundwater level across the quarry.

The modeled potentiometric surface at the end of five years (HGL (2020a) Figure 7-13) shows several areas with very steep gradients, including just west and east of the quarry. This reflects the different lithology in various blocks and the segmented groundwater expected by HGL. A steep gradient is required for flow across blocks of significantly different conductivity.

The long-term pump test held in TW-2 lasted eight days and pumped up to 355 gpm. TW-02 is located in the western portion of the proposed quarry, so it should be representative of the rock that will require dewatering. Groundwater levels reached about 40 ft bgs and leveled out after the pumping rate was reduced to 340 gpm due to drawdown (Figure 1). Recovery occurred almost immediately. HGL (2020a, p 33) suggests the initial response of the test reflects a near-linear trend at the beginning of the test, which indicates an isolated compartment, and the leveling off after several days reflects leakage into the compartment. The test is not long enough to provide information regarding how long the additional leakage would continue but the drawdown is sufficient to draw water from other aquifers or compartments. The model predicted that dewatering rates would vary from 345 to 63 gpm, averaging 144 gpm, over the five-year life of the quarry (HGL 2020a, p 68). Presumably, the dewatering rate decreases over the period.
The numerical model simulated the pump test for transient calibration. The model simulated several nearby monitoring wells reasonably well, but HGL notes that the lack of simulated recovery at TW-03 suggests the model may simulate the system as being too segmented (HGL 2020a, p 64).

There is apparently more connection to surrounding aquifers than simulated in the model. This is based both on the rapid recovery from the TW-02 pump test and the lack of simulated recovery. Dewatering rates may stay high longer than predicted and the lake may recover more quickly than predicted. The model used horizontal flow barriers to simulate the segmentation, but with very little data for transient modeling it is very difficult to calibrate an HFB. The assumption that the area has segmented hydrogeology is based on little supporting data and may be a poor conceptual model of the area.

The conductivity is highly variable among hydrogeologic units. There are also conductive faults in the area. There is a long fracture zone along the Cave Spring drainage north of the quarry. Any connection has been only poorly examined by HGL (2020a).

![Figure 1: Groundwater level response in well TW-02 during the TW-02 pump test.](image)

![Figure 6-4 TW-02 pumping test response](image)

The predictive modeling uses an annual time step for 200 years (HGL 2020b, p 25). Therefore, the modeling does not account for seasonal variability or long-term dry conditions. Groundwater levels that respond to recharge by rising tens of feet could cause significant fluctuations in the pit lake. Due to differing geologic formations intersecting the quarry, the groundwater level may recover at different rates around the quarry. It is possible that quarry water could enter formations either seasonally or after the rapid recovery from a long-term drought. Due to the steep groundwater gradient to the northwest, groundwater could reach the pathway down the drainage and discharge Fish Lake Valley. The modeling does not preclude such an outcome.
The evidence therefore is that the quarry lake will likely be terminal some of the time but that it is also possible that quarry lake water will discharge into surrounding groundwater during some periods.

Errors Simulating Recharge
The report describes conceptual recharge accurately with respect to runoff reaching drainages where it sinks into alluvium and then into underlying fractured bedrock with some recharge occurring at elevations due to melting snow and rainfall (HGL 2020a, p 27). However, the report in many places overestimates the amount that would recharge at high elevations because it does not adequately account for geology.

The report uses the Maxey-Eakin method for estimating recharge but commits two errors in its use. Conceptually, the method relates recharge simply to the amount of rainfall that occurs in varying bands of precipitation estimated to occur throughout a basin. The bands of precipitation are 8 to 12, 12 to 15, 15 to 20 and greater than 20 inches with coefficients equal to 3, 7, 15, and 25%, respectively. This means that, for example, 15% of the total volume of water falling within the area having between 15 and 20 inches of precipitation becomes recharge. The method was developed by assuming that recharge to a basin would equal discharge from that basin, accounting for interbasin inflow. Discharge is spring flow and groundwater evapotranspiration from the regional aquifer within the basin. It does not include perched aquifers and springs although perched springs that discharge to a flow that eventually recharges the regional aquifer would be recharge. The recharge coefficients were derived through a trial-and-error process using an annual precipitation map of Nevada dated 1936, applied to natural discharge by phreatophytes in 13 unidentified valleys in Nevada. Details of the derivation have not been published and have not been reproduced by anyone. The coefficients, and overall method, required use of the 1936 precipitation map or it will provide estimates not consistent with the original method. The method has been updated to different precipitation maps, including the recent PRISM mapping, and it is therefore essential that any use be limited to coefficients derived using the same precipitation estimation mapping.

The second error with its use by HGL (2020a) is the tendency to assume that precipitation enters the ground where it falls. Although the report mentions the geologic control, it does not adequately apply it; there will be no recharge into granitic outcrops and no runoff from highly porous carbonate outcrops. The report must provide adequate reasoning for applying recharge as it does. Based on HGL (2020a) Figures 6-10 and 7-4, it appears that the groundwater model applies the precipitation where it falls and does not account for the fact it actually occurs along the washes, probably including into the fracture zone along the Cave Spring wash downstream from the spring. This affects the modeling because it forces groundwater to flow through portions of the model domain where geology would limit the flow. To not have simulated water levels that are too high, it is likely the calibrated conductivity values are too high, primarily in high elevation areas.

How Cave Spring Will be Affected is Unclear
A negative effect on Cave Spring would include a reduction in flow due to the mining operations, primarily the quarry dewatering. HGL (2020a) states the spring is outside the project boundaries, but this is simply due to them drawing the project boundary with a small semicircle excluding the spring. HGL (2020a) provides just one flow measurement – 0.31 cfs (HGL (2020a) Table 6-1) – taken on June 26, 2019. The pictures and data in HGL (2020a) Attachment A show a substantial riparian vegetation cover, so there is probably more groundwater reaching the surface than reflected by the
measurement. In late June, the flow is likely higher than it would be in the fall after a hot summer, but the vegetation indicates that moisture reaching the surface is perennial.

Cave Spring is at elevation 6208 amsl. The groundwater model predicts less than ten feet of drawdown at the spring, but it only requires that the water level drop a foot to cause substantial changes in the flow. The spring will only be affected if there is a connection between the aquifers being dewatered and the aquifer feeding the spring. HGL (2000a) essentially assumes the dewatering will not affect the spring. Evidence can be gleaned from water chemistry, geology maps, and pump tests; the model should not be considered evidence because its conceptualization depends on the modeler’s interpretation of the evidence.

Cave Springs chemistry shows low concentrations of most ions, with TDS at 270 mg/l; SO$_4^{2-}$ and Na are much of the TDS (Table B-3). Arsenic is at 0.067 mg/l and the only constituent that exceeds state standards at the spring. This chemistry suggests a short flow path. Based on TDS and individual ions, wells MW-1, MW-2a and MW-2B also have similar chemistry, but TW-1 and TW-2 have twice the TDS concentration and exceedences of aluminum and antimony. The monitoring wells and the spring are near the fracture zone down the middle of Cave Spring drainage northwest of the spring. Chemistry suggests there is a different source of water for the monitoring wells and spring than for the pumping wells in the proposed quarry. Chemistry does not indicate there is a connection between the quarry and Cave Spring. However, quarry dewatering could significantly change groundwater flow gradients so that flow directions could be affected.

HGL reports on an eight-day pump test at well TW-02 (reviewed more below) that did not significantly affect vibrating wire piezometer (VWP) VWP-11, which is located just east of Cave Spring, although it can only be an analogue for the spring. Pumpage averaged near 350 gallons per minute (gpm). VWP-11 levels dropped about 1.5 feet from September through December, including through the period of the pump test. This water level decline probably reflects decreased recharge through the end of summer. Apparent cyclic variations at the well could be barometric because they are of low magnitude. Water level behavior through the TW-02 pump test differs from the long period in that the larger cyclic variations have been virtually eliminated and the water level was relatively flat. Nothing in the VWP-11 response suggests a connection to the level being pumped.

Newfields installed both VWP-11 and TW-02 in tuff breccia (Tbx) with TW-02 to 600 feet and VWP-11 to 300 feet with two VWPs at 190 and 300 ft below ground surface (bgs) in tuff breccia (Tbx). The Tbx in TW-02 is below 350 ft bgs. Geology map Figure 3-2 indicates Rhyolite Ridge Tuff outcrops near both locations. VWP-06 is adjacent to TW-02 and is constructed in Tbx, confirming that the tuff is widespread at depth on the west side of the proposed quarry. Airlift tests produced over 50 gpm at depths greater than 160 ft bgs. Compared to most other VWP installations, VWP-11 produces substantial flow during the tests (VWP-08 produces flow similar to VWP-11 and is installed in tuff) indicating its completion in a relatively conductive zone. Because VWP-11 does not show much response to an eight-day pump test, it is likely there is a disconnect between the pumping well and VWP-11. The disconnect could be the deep basin between the ridge where the proposed quarry would be located and the Rhyolite Ridge massif. The quarry would excavate Cave
Spring for Information. Wells constructed between TW-02 and Cave Spring support the hypothesis of there being a disconnect. VWP-05, although constructed at an angle, does not reach Tbx until it reaches 900 ft bgs. VWP-2, TW-03 and TW-01 do not reach Tbx at greater than 800, 700 and 655 ft bgs, respectively. It is possible that dewatering could transmit at depth through the tuff beneath the basin or through lower conductivity material between the quarry and spring, but the pump test does not reflect it, although it could be because the test was not long enough.

Evidence is not conclusive regarding Cave Spring being affected by dewatering. Cave Spring may be perched, based on the short flow path as documented by TDS. Also, the elevation of the spring is 300 to 400 feet above the groundwater levels in the quarry area. The spring elevation is close to that of VWP-11 which HGL suggests is due to the step in the potentiometric surface across the Cave Springs fault. That the predicted drawdown in the groundwater model (HGL (2000a) Figure 7-13) does not extend very far to the east, including to the spring, reflects the natural gradient, step in the potentiometric surface, and fault. The natural gradient and the barriers between the quarry and spring indicate that effects on the spring are unlikely. Dewatering deep groundwater may not affect it (and other springs) it is indeed perched.

Due to the importance of Cave Spring, Ioneer should complete two additional tasks to provide a better estimate regarding the affect on the spring. One, to assess the seasonal flow rates, Ioneer should measure the flow monthly to determine whether there are seasonal effects. If the spring goes dry, it would suggest that the flowpath is short and would suggest it is perched. Second, Ioneer should establish a VWP installation within a couple hundred feet of the spring in the direction of the quarry. Simply developing the VWP would provide information on nearby geology and water levels. It should monitor four VWP levels and be monitored for a year prior to quarry development and be used for monitor.

Monitoring Plan Is Insufficient

Appendix P to the WPCP application contains the proposed monitoring plan. Primary concerns for monitoring are whether contaminants from quarrying or from the tailings deposits could reach the Cave Spring drainage. Also, the groundwater level in the area of the tailings appears to be close to the ground surface based on the level of springs 6 and 7, which appear to be connected to the intermediate aquifer based on their high TDS values; there is concern whether contaminants from the tailings could reach groundwater.

In addition the requested additional monitoring well for the quarry lake discussed below, there is a need for another baseline monitoring well upgradient of the tailings pile. MW-1 is insufficient because it is near the main drainage whereas the bedrock underlying the tailings is outside of the drainage. MW SOSF, downgradient of the tails, is probably sufficient for monitoring leaks from the tails if it is placed properly in the most permeable bedrock below the tails and if there is leak detection under the tails.

The monitoring plan does not discuss the screened or open interval for the wells. Because monitoring wells should not screen more than about 20 feet, the monitoring wells should be
sampled with low flow pumps to draw from specific levels if the open interval exceeds 20 feet. To establish a vertical profile of chemistry within the aquifer, the monitoring wells should be sampled using low flow sampling at various levels prior to the commencement of quarrying.

The monitoring plan relies on the assumption that the quarry lake will be terminal. This review has disputed the certainty of that assumption as discussed above. The monitoring does not, but should include monitoring to verify whether the lake is terminal. Prior to closure, an additional monitoring well should be added between the quarry and the Cave Springs drainage north of the quarry. It should be established to both monitor the recovering groundwater table and the changing groundwater chemistry. Because it would be in an area of varying groundwater levels, it should be screened either in multiple development or sampled using low flow pumps to draw from various levels to ascertain a vertical profile in the aquifer.

Additionally, to verify whether the evolving groundwater table near the quarry will flow toward the forming pit lake, the VWP near the quarry should be retained; this is especially critical for VWP-3 which appears to be just north of the quarry. If it will not survive quarry construction, a replacement VWP should be installed to its north as close to the quarry as possible. This should be completed prior to quarry construction so that natural water levels as well as evolving water levels due to construction can be determined. Additionally, another VWP should be installed between VWP-3 (or its replacement) and VWP-8, which is within the Cave Spring drainage. VWP-3 (or its replacement), -8, and a new VWP between the two would allow a water surface profile to be monitored between the quarry, the forming quarry lake, and the drainage to verify whether the quarry is terminal. These VWP should each have four monitoring levels as were used in VWP-3. Three additional VWP monitoring levels should be added to VWP-8 and the new VWP between -3 and -8 should also have four levels. Four levels are essential to monitor the vertical gradient of flow to and from the quarry and quarry lake and to provide monitoring data that would allow groundwater surface profile modeling to predict the future status of the forming quarry lake (a vertical two-dimension groundwater flow model could be used for this).

The monitoring plan recommends quarterly sampling for the monitoring wells. That would be sufficient only after a year of monthly sampling to establish seasonal trends. As noted above, the groundwater level probably varies substantially due to seasonal changing recharge and it could lead to seasonal wetting and drying which could also lead to seasonal flushes of contaminants. Understanding natural seasonal variability is essential for understanding whether observed changes are natural or due to the quarry.

The monitoring plan fails to include any spring monitoring which it should. As described above, a VWP should be installed near Cave Spring to provide warning of impacts to Cave Spring. It is understandable that Cave Spring will not be sampled for chemistry because that would not show anything regarding the spring going dry, but it its flow rate should be monitored at least quarterly, after monthly monitoring for a year prior to quarrying to establish a baseline.
Chemistry at the springs just west of the tailings, SP-06 and -07, should also be monitored quarterly to verify whether the tails affect those springs.

WATER QUALITY ASPECTS

Pit Lake Model Time Step is Incorrect

The modeling appears to use an annual time step for 200 years (HGL 2000b, p 25). Therefore, the predicted chemistry misses the fluctuations that would occur seasonally. The report notes that pit lake runoff flushes chemical constituents from the pit walls that have accumulated there due to precipitation wetting the walls but not causing runoff into the pit. Runoff through each slice of the pit wall flushes these contaminants but once the lake rises to a given level, oxidation and contribution of contaminants will be assumed to cease (HGL 2000b, p 6). The reality in a semiarid pit lake is that the water level will rise and fall seasonally and probably annually during drought periods, as noted above regarding the flow-through quarry lake question. Oxidation will not be shut off permanently once the lake reaches a given elevation because it will not remain inundated. As the pit lake level falls, a wetted perimeter will remain within which much additional oxidation will occur. Fluctuating lake water levels will cause a much higher contaminant load to reach the pit lake. **The model should be rerun to include monthly time steps and variable precipitation and evaporation. Droughts should be considered by using actual annual precipitation rates.**

Pit Lake Model Evaporation Rate

The lake model may also simulate a much too high evaporation rate from the quarry lake. Based on standard pan evaporation, the model assumes evaporation will equal 63.5 in/y. Standard pan coefficients do not apply in a quarry or pit lake situation because the water surface is usually protected from the wind by the quarry walls. Therefore, the simulation could be withdrawing too much water from the quarry lake and preventing the simulation from allowing it to rise as far as it otherwise would.

Pit Lake Model Underestimates Pollution Loading into Pit Lake

Much of the Rhyolite Ridge quarry wall rock will have appreciable concentrations of sulfide-bearing minerals, so the walls will be an ongoing source of pollutants as they oxidize and leach reaction products—sulfuric acid and metals—to the quarry lake.

Specifically, average sulfide sulfur concentrations in the lithologic units exposed in pit walls include:

- 7 units with average sulfide S content above 0.5% (S3 PAG, G4 Gritstone, S5 Upper Barren Siltstone, G6 Gritstone, G7 Gritstone, Tbx Rhyolite Ridge Tuff Breccia, and Z Silver Peak Formation), and
- 5 units with sulfide S content between 0.2 and 0.5% (M4 Carbonate/Marl, M5 Upper High-Li Clay, Lower Zone Marls, Lsi Lower Silicified.
  (HydroGeoLogica 2020b, Table 5.1 Summary of Acid Base Accounting Results).

More significantly, approximately 17% of the pit wall rock will be net acid generating:
- Mixed Lacustrine (PAG) [S3], 5.1% of the pit wall (area = 479,654 ft²), and
- Rhyolite Ridge Tuff Breccia [Tbx], 11.7% of the pit wall (area = 1,104,880.

(HydroGeoLogica 2020a, Table 4.1 Summary of Predicted Quarry-Wall Lithological Composition at Closure)

The model used to estimate quarry-lake water quality does recognize at these wall-rock oxidation products are a source of pollution:

“If sulfide minerals are present in a lithologic unit, there is a potential for oxidation that will contribute acidity, and that could result in lowering the pH and additional metals loading” (HydroGeoLogica 2020a, Pg 6).

But in its implementation, the Rhyolite Ridge quarry lake model then veers away from the standard approach used to estimate pollution release from sulfide-bearing mine waste, and instead chooses to ignore the fundamental fact that pollution release from such materials is time-dependent. That is, the quarry-lake model assumes that the runoff quality under field conditions can be approximated as a constant, in this case the average solute concentration measured in the last 8 weeks of laboratory humidity-cell testing:

“For the Base Case scenario, the steady-state, terminal concentrations from the humidity cell tests were used to represent quarry wall runoff chemistry in the modeling; the average of results from the final eight weeks of testing were used to calculate steady-state concentrations.” (HydroGeoLogica 2020a, Pg 20)

In contrast to this “constant concentration” approach used for Rhyolite Ridge, widely accepted water-quality models of sulfide-bearing mine waste incorporate the fact that under oxygenated conditions (such as those that will exist in quarry walls), the reactions that convert sulfide-bearing minerals into soluble pollutants reflect chemical reaction kinetics and/or oxygen transport. In these established models, the composition of runoff from sulfide-bearing mine waste, particularly when it is acid-generating, varies dramatically depending on the duration over which the waste has been exposed to atmospheric weathering before it is flushed with water. Thus, HydroGeoLogica’s decision to use directly the average effluent concentrations in laboratory humidity cells tests (values in HydroGeoLogica 2002a, Appendix A) to approximate the concentration of pollutants in runoff under field conditions does not make logical sense.

Most importantly, the direct use of humidity cells effluent concentrations to estimate pollutant concentrations in leachate from sulfide-bearing wall rock will produce a large and systematic underestimate for pollutant loads to the quarry lake. In part, this is because the water to rock ratio in weekly humidity cell tests (1:1 mass ratio) can be hundreds of times higher than the water:rock ratio under field conditions in pit benches. As a result, the concentrations of soluble pollutants released by sulfide oxidation in the lab tests will very dilute relative to concentrations under field conditions. In addition, the humidity cell test measures solutes released after only one week of oxidation; but wall rock can sit oxidizing under field conditions for months or years before the accumulated pollutants are eventually leached out. Some of this leaching of oxidation products
occurs by surface runoff or infiltration, which can be separated by many months. But much of the 
solutes will be flushed by groundwater only after several years, when sections of wall rock are 
inundated by the lake itself. The Lone Tree mine lake is an example of this delayed pollution load, 
where the lake filled initially with neutral water, but then became acidic as solutes in the 
acid-generating wall rock higher in the lake were flushed by inflowing groundwater.

In response, the model of water quality in the quarry lake needs to be revised so that it includes estimates 
for: 1) The rate at which sulfide minerals in the wall rock oxidize over time, 2) the mass fraction of these 
total oxidation products (pollutants including sulfuric acid and metals) that are flushed out by meteoric 
water over time, and 3) the mass of remaining pollutants that are stored in the wall rock and flushed to the 
quarry by inflowing groundwater when the rock is inundated below the lake surface.

**Permit Should Require a Bond for Early Treatment to Mitigate the Potential Human and 
Ecological Risk**

The systematic underestimate of acid and solute loading in the quarry lake water-quality model 
(HydroGeoLogic 2020a) means that the quarry lake could be acidic pH (e.g., <pH 4.5) for at least part of the 
time it is filling. Under these conditions, the lake would violate the NDEP Profile III levels for pH (pH 6.5 – 
8.5), and could have higher concentrations of arsenic and other solutes than estimated, particularly in the early 
period of quarry filling. (i.e., because the quarry water-quality model assumes that arsenic is removed by 
adsorption to ferricydrate, and ferricydrate is much more soluble in acidic water, the lower pH could mean 
that the concentration of dissolved arsenic is much higher than predicted.) In response, the permit should 
include a fund adequate to begin mitigating acidity and metals in the quarry lake as soon as the lake 
begins to fill.

**Pit Lake Model Report is Fails to Describe Calculations Adequately**

The quarry-lake water-quality model implies that it includes a term for solutes that are accumulated by 
oxidation in the wall rock before it’s flushed to the lake:

“During each timestep as the quarry lake rises, additional quarry wall will be inundated. As the water 
inundates the quarry wall rock, the accumulated reaction products on the quarry wall, on rubble on 
benches, and from the damaged rock zone will rinse into the quarry lake. This will result in a flush of 
chemical mass from the inundated interval into the quarry lake” (HydroGeoLogic 2020a, Pg 6).

But the model report then provides no description of how the amount of stored oxidation products are 
calculated or tracked within the model.

If the quarry lake model is in fact tracking accumulated pollutants released by oxidation in pit walls, this needs 
to be described quantitatively in words, and also with a mathematical expression that includes dimensional 
units for mass, length, and time.

*The public needs to have a clear description of the path to arriving at the various conclusions. The 
application needs to be updated for the necessary public transparency in government decision making.*
**NDEP Needs to Update their Guidance for Geochemical Modeling**

The Ryholite Ridge quarry lake water quality model report indicates that the “modeling approach is consistent with regulatory guidance from the Nevada Division of Environmental Protection (NDEP),” and lists specifically the NDEP’s “Guidance for Geochemical Modeling at Mine Sites (NDEP 2018)” (HydroGeoLogica 2020a, Pg 3). Yet the quarry lake water-quality model was still able to omit incorporating a description of how the rate of sulfide mineral oxidation and total duration of atmospheric exposure were used to calculate the cumulative mass of pollutant release from sulfide-bearing mine waste. This suggests that the NDEP’s guidance for geochemical models at mine sites needs to be revised.

At the invitation of NDEP in 2019, GBRW provided comments on how to improve the 2018 NDEP guidance for “Geochemical Modeling at Mine Sites.” In response, GBRW provided NDEP with the following brief but focused suggested addition to their guidance for geochemical modeling of sulfide-bearing mine waste (tailings, waste rock, pit wall rock, and process waste):

“...the model reports need to describe in particularly clear detail...the methods and assumptions used to estimate sulfide oxidation and associated solute release, with descriptions in both the conceptual model and the numerical model sections...[including] The method used to simulate the time-dependent rate of solute release from the sulfide-bearing sources, where the relevant time interval is between when the source rock is first exposed to air and when it is either isolated from further oxidation, fully oxidized, or the model simulation period ends.” (March 2020).

The Ryholite Ridge Quarry Lake Evaluation Report is another geochemical modeling study that underestimates pollution load to the mine lake by ignoring the fact that pollutants will be released from wall rock in proportion to actual duration—from several months to many years—over which the rock is exposed to meteoric water and atmospheric oxygen.

**The remedy is to update the NDEP guidance for geochemical modeling at mine sites to incorporate the above text from GBRW (or similar language) so that mine operators and their technical consultants are required to consider how they account for total pollution released over time before they have designed their water quality model. This again is another key aspect of transparency in governmental decision making.**

**The Pit Lake Will be a Perpetual Pollution Source**

The predicted long-term water quality trend for the Ryholite Ridge quarry lake is for perpetually increasing concentrations of several solutes with regulatory standards, notably arsenic, boron, and antimony (HydroGeoLogica 2020a, Figure 5.12 Selected Metals/Metalloids – Base Case). If the quarry lake is terminal as concluded by HydroGeoLogica Inc, and these solutes will be loaded to the lake from groundwater inflow and wall rock runoff for the foreseeable future, the concentrations are expected to continue increasing beyond the 200-year model simulation period. However, as noted above the case that is made for the quarry lake to be terminal at all times is technically poorly supported, so the quarry lake is a potential source of groundwater contamination as well. Given the
increasing uncertainty into the future conditions, the 200-year forecast interval seems reasonable. However, it is not acceptable to close the Rhyolite Ridge mine quarry with a lake that is expected to continue to pose an increasing risk to ecological and human health perpetually into the future.

**In response, the permit should include a closure bond sufficient to:** 1) **Initially treat the quarry lake to maintain pollutant concentrations below risk-based water-quality thresholds; and 2)** backfill the quarry lake over time to stop the long-term evaporative water loss and solute concentration, and thereby remove the potential for future exposure of humans or wildlife to the quarry water; 3) **plan for addressing the potential for quarry lake to a perpetual source of groundwater contamination so as to avoid degrading groundwater and violating state law.**

**The Pit Lake Water Quality Model is Insufficient with Regards to Uranium**

The geochemical characterization report includes uranium as one of the “parameters considered in the Geochemical Characterization Program,” citing the NDEP Profile III value (i.e., reference value for pit lakes) for uranium of 6.995 mg/L (HydroGeoLogica2020b, Table 4.2). The federal maximum contaminant level for uranium--0.03 mg/L-- is over a thousand times lower that the Nevada reference value for pit lakes. The uranium concentrations in acidic humidity-cell leachate from some of the representative wall-rock samples far exceeded this drinking water threshold. One of the S3 samples produced leachate with pH between 2.8 and 3.5, and had a uranium concentration of 0.327 mg/L in the initial flush (HydroGeoLogica2020b, Appendix H, table of Humidity Cell Test Results for sample S3-SBHC-18_251-255). In this specific humidity cell test, the uranium concentration decreased by a factor of over 100 by the end of the test (i.e., uranium = 0.0015 mg/L in the effluent at week 48). But effluent sulfate in this sample decreased by a similar factor between week 1 and 48 (from 5,630 to 30 mg/L), suggesting that the uranium release may be related to the amount of sulfate released by the oxidation of sulfidesulfur. If this is the case, the long-term oxidation of sulfide S minerals in the quarry wall rock has at least the potential to release enough uranium to the quarry lake to pose an unacceptable risk to humans and/or wildlife. **Thus, uranium should be included as a constituent included in the forecast of quarry-lake water quality, and also included in the proposed risk assessments for the quarry lake.**

**The Application Lacks Sufficient Data to Analyze Risks from the Tailings Dump**

Tailing drainage is likely to be highly toxic based on the Rhyolite Ridge Baseline Geochemical Characterization Report, Appendix F. The Meteoric Water Mobility Profile table shows some results for the three ore processing waste streams destined for the tailing dump. **It is not clear from the application if the test results in Appendix F is theexpected chemical profile of the drainage, nor how the chemical profile changes over time.**

The Mobility test shows extremely high levels of TDS, sulfate, boron, aluminum, magnesium, sodium, fluorine, and low pH for the Sulfate Salt Residue and Spent Ore (tailings). There are also high levels of a number of other metals such as arsenic,thallium, uranium, and chromium to name a few, especially in the Sulfate Salt Residue. Indeed if this is representative of drainage there therewill need to be a plan for drainage management.
There is also no estimated volumetric draindown profile provided in the application. Appendix J of the application only states, “It is anticipated that the operational draindown from the SOSF [Spent Ore Storage Facility] will be minimal.” (Newfields 2020) This is an inadequate description. The application needs to include a summary from the original source, and there needs to be a description of how the draindown is to be managed. Given the information in the application the toxicity of the tailings drainage could remain very toxic for a long time. Is Ioneer planning to treat this fluid after mining and processing is discontinued?

CONCLUSION

The reports by HydroGeoLogica Inc of the groundwater modeling and the mining pit lake contain significant errors:

- groundwater modeler may assume there is too much segmentation.
- the amount and location of the recharge is inaccurate in several ways discussed above including the amount not equaling an estimated outflow from the model domain and the application of recharge with little regard for the underlying geology.
- significant underestimation of the load of pollution from sulfide-bearing wall rock to the quarry lake.
- lack of uranium analysis for the mining quarry lake.

The hydrologic reports depend on too little field data to support the conclusions. The lack of evidence is most apparent in the groundwater modeling effort for which there is too little data outside of the immediate pit area. This is obvious in the poor conceptual model established for the groundwater model. The errors lead to a vast uncertainty regarding the future of Cave Spring. Although there are indications it will not be affected by drawdown, unsupported assumptions in the modeling may have underestimated the dewatering and its effect to surrounding hydrogeology. The same problem exists for the question of whether the quarry lake will be terminal. Faster, seasonal, or interannual variations of inflow could lead to the lake rising and falling and discharging water to surrounding groundwater. The lack of understanding of quarry lake refilling also manifests in poor or no prediction of the groundwater chemistry entering the lake after flowing through the surrounding quarry lithology.

Given, the uncertainty in whether the pit lake will be terminal or not, Ioneer should revise the permit application to include for either contingency,

Given errors combined with and inadequate monitoring plan and the lack of needed data to fully evaluate the consequences on water pollution at the Rhyolite Ridge site leads Commenters to not support this permit as is.
Please feel free to contact Great Basin Resource Watch, Center for Biological Diversity, and Progressive Leadership Alliance of Nevada if there are any clarifications needed.

Sincerely,

John Hadder, Director Great Basin Resource Watch,

Patrick Donnelly, Nevada State Director, Center for Biological Diversity

Ian Bigley, Mining Justice Organizer, Progressive Leadership Alliance of Nevada
REFERENCES


Technical Memorandum

April 23, 2021

Re: Review of Rhyolite Ridge Hydrogeology and Quarry Lake

Prepared for: Center for Biological Diversity and Great Basin Resource Watch

This technical memorandum provides review of two technical documents with respect to the proposed Rhyolite Ridge Project, the baseline hydrogeology including groundwater modeling and the quarry lake development and chemistry report titled as follows:


This memorandum provides specific comments regarding the question whether Cave Spring will be affected by quarry dewatering and whether the quarry lake will have flow through conditions at any point during its development. It also discusses production water, recharge, the groundwater model, and makes general comments.

Additionally, this memorandum considers the water pollution control permit (WPCP) application submitted to the Nevada Division of Environmental Protection (NDEP). The specific focus is on the monitoring plan presented in appendix P. NDEP should require at least two more monitoring wells, one between the quarry and Cave Spring drainage and one upgradient of the tailings, and additional vibrating wire piezometers to track the development of the quarry as described below. NDEP should also require monitoring of three springs also described below.

Will dewatering affect Cave Spring?

A negative effect on Cave Spring would include a reduction in flow due to the mining operations, primarily the quarry dewatering. HGL (2020a) states the spring is outside the project boundaries, but this is simply due to them drawing the project boundary with a small semicircle excluding the spring. HGL (2020a) provides just one flow measurement – 0.31 cfs (HGL (2020a) Table 6-1) – taken on June 26, 2019. The pictures and data in HGL (2020a) Attachment A show a substantial riparian vegetation cover, so there is probably more groundwater reaching the surface than reflected by the measurement. In late June, the flow is
likely higher than it would be in the fall after a hot summer, but the vegetation indicates that moisture reaching the surface is perennial.

Cave Spring is at elevation 6208 amsl. The groundwater model predicts less than ten feet of drawdown at the spring, but it only requires that the water level drop a foot to cause substantial changes in the flow. The spring will only be affected if there is a connection between the aquifers being dewatered and the aquifer feeding the spring. HGL (2000a) essentially assumes the dewatering will not affect the spring. Evidence can be gleaned from water chemistry, geology maps, and pump tests; the model should not be considered evidence because its conceptualization depends on the modeler’s interpretation of the evidence.

Cave Springs chemistry shows low concentrations of most ions, with TDS at 270 mg/l; SO4 and Na are much of the TDS (Table B-3). Arsenic is at 0.067 mg/l and the only constituent that exceeds state standards at the spring. This chemistry suggests a short flow path. Based on TDS and individual ions, wells MW-1, MW-2a and MW-2B also have similar chemistry, but TW-1 and TW-2 have twice the TDS concentration and exceedences of aluminum and antimony. The monitoring wells and the spring are near the fracture zone down the middle of Cave Spring drainage northwest of the spring. Chemistry suggests there is a different source of water for the monitoring wells and spring than for the pumping wells in the proposed quarry. Chemistry does not indicate there is a connection between the quarry and Cave Spring. However, quarry dewatering could significantly change groundwater flow gradients so that flow directions could be affected.

HGL reports on an eight-day pump test at well TW-02 (reviewed more below) that did not significantly affect vibrating wire piezometer (VWP) VWP-11, which is located just east of Cave Spring, although it can only be an analogue for the spring. Pumpage averaged near 350 gallons per minute (gpm). VWP-11 levels dropped about 1.5 feet from September through December, including through the period of the pump test. This water level decline probably reflects decreased recharge through the end of summer. Apparent cyclic variations at the well could be barometric because they are a low magnitude. Water level behavior through the TW-02 pump test differs from the long period in that the larger cyclic variations have been virtually eliminated and the water level was relatively flat. Nothing in the VWP-11 response suggests a connection to the level being pumped.

Newfields installed both VWP-11 and TW-02 in tuff breccia (Tbx) with TW-02 to 600 feet and VWP-11 to 300 feet with two VWPs at 190 and 300 ft below ground surface (bgs) in tuff breccia (Tbx). The Tbx in TW-02 is below 350 ft bgs. Geology map Figure 3-2 indicates Rhyolite Ridge Tuff outcrops near both locations. VWP-06 is adjacent to TW-02 and is constructed in Tbx, confirming that the tuff is widespread at depth on the west side of the proposed quarry. Airlift tests produced over 50 gpm at depths greater than 160 ft bgs. Compared to most other VWP installations, VWP-11 produces substantial flow during the tests (VWP-08 produces flow similar to VWP-11 and is installed in tuff) indicating its completion in a relatively conductive zone.
Because VWP-11 does not show much response to an eight-day pump test, it is likely there is a disconnect between the pumping well and VWP-11. The disconnect could be the deep basin between the ridge where the proposed quarry would be located and the Rhyolite Ridge massif. The quarry would excavate Cave Spring formation. Wells constructed between TW-02 and Cave Spring support the hypothesis of there being a disconnect. VWP-05, although constructed at an angle, does not reach Tbx until it reaches 900 ft bgs. VWP-2, TW-03 and TW-01 do not reach Tbx at greater than 800, 700 and 655 ft bgs, respectively. It is possible that dewatering could transmit at depth through the tuff beneath the basin or through lower conductivity material between the quarry and spring, but the pump test does not reflect it, although it could be because the test was not long enough.

Evidence is not conclusive regarding Cave Spring being affected by dewatering. Cave Spring may be perched, based on the short flow path as documented by TDS. Also, the elevation of the spring is 300 to 400 feet above the groundwater levels in the quarry area. The spring elevation is close to that of VWP-11 which HGL suggests is due to the step in the potentiometric surface across the Cave Springs fault. That the predicted drawdown in the groundwater model (HGL (2000a) Figure 7-13) does not extend very far to the east, including to the spring, reflects the natural gradient, step in the potentiometric surface, and fault. The natural gradient and the barriers between the quarry and spring indicate that effects on the spring are unlikely. Dewatering deep groundwater may not affect it (and other springs) it is indeed perched.

Due to the importance of Cave Spring, Ioneer should complete two additional tasks to provide a better estimate regarding the affect on the spring. One, to assess the seasonal flow rates, Ioneer should measure the flow monthly to determine whether there are seasonal effects. If the spring goes dry, it would suggest that the flowpath is short and would suggest it is perched. Second, Ioneer should establish a VWP installation within a couple hundred feet of the spring in the direction of the quarry. Simply developing the VWP would provide information on nearby geology and water levels. It should monitor four VWP levels and be monitored for a year prior to quarry development and be used for monitoring and mitigating impacts to the spring. Both should be done prior to developing the quarry.

**Will the lake that forms in the quarry after dewatering ceases be terminal? In other words, could water accumulating in the quarry flow from the quarry into surrounding groundwater potentially causing degradation?**

The pre-mining water table was not flat but sloped across the quarry. A lake would be a flat surface. The question is whether that flat surface exceeds the recovered groundwater level at any point along its perimeter or provides sufficient pressure into a confined aquifer intersected by the lake to cause flow.

As part of the modeling, HGL concluded the pit will be a terminal sink meaning that no water leaves the quarry lake to enter the groundwater. The lake would be mostly full within 40 years.
and reach a steady state after 60 years (HGL 2020b, p v), although steady state is a misnomer in this area. This would be 66 feet below the pre-quarry groundwater level (Id.), although this does no account for the sloping groundwater level across the quarry.

The modeled potentiometric surface at the end of five years (HGL (2020a) Figure 7-13) shows several areas with very steep gradients, including just west and east of the quarry. This reflects the different lithology in various blocks and the segmented groundwater expected by HGL. A steep gradient is required for flow across blocks of significantly different conductivity.

The long-term pump test held in TW-2 lasted eight days and pumped up to 355 gpm. TW-02 is located in the western portion of the proposed quarry, so it should be representative of the rock that will require dewatering. Groundwater levels reached about 40 ft bgs and leveled out after the pumping rate was reduced to 340 gpm due to drawdown (Figure 1). Recovery occurred almost immediately. HGL (2020a, p 33) suggests the initial response of the test reflects a near-linear trend at the beginning of the test, which indicates an isolated compartment, and the leveling off after several days reflects leakage into the compartment. The test is not long enough to provide information regarding how long the additional leakage would continue but the drawdown is sufficient to draw water from other aquifers or compartments. The model predicted that dewatering rates would vary from 345 to 63 gpm, averaging 144 gpm, over the five-year life of the quarry (HGL 2020a, p 68). Presumably, the dewatering rate decreases over the period.

The numerical model simulated the pump test for transient calibration. The model simulated several nearby monitoring wells reasonably well, but HGL notes that the lack of simulated recovery at TW-03 suggests the model may simulate the system as being too segmented (HGL 2020a, p 64).

There is apparently more connection to surrounding aquifers than simulated in the model. This is based both on the rapid recovery from the TW-02 pump test and the lack of simulated recovery. Dewatering rates may stay high longer than predicted and the lake may recover more quickly than predicted. The model used horizontal flow barriers to simulate the segmentation, but with very little data for transient modeling it is very difficult to calibrate an HFB. The assumption that the area has segmented hydrogeology is based on little supporting data and may be a poor conceptual model of the area.

The conductivity is highly variable among hydrogeologic units. There are also conductive faults in the area. There is a long fracture zone along the Cave Spring drainage north of the quarry. Any connection has been only poorly examined by HGL (2020a).

The predictive modeling uses an annual time step for 200 years (HGL 2020b, p 25). Therefore, the modeling does not account for seasonal variability or long-term dry conditions. Groundwater levels that respond to recharge by rising tens of feet could cause significant fluctuations in the pit lake. Due to differing geologic formations intersecting the quarry, the
groundwater level may recover at different rates around the quarry. It is possible that quarry water could enter formations either seasonally or after the rapid recovery from a long-term drought. Due to the steep groundwater gradient to the northwest, groundwater could reach the pathway down the drainage and discharge Fish Lake Valley. The modeling does not preclude such an outcome.

The evidence therefore is that the quarry lake will likely be terminal some of the time but that it is also possible that quarry lake water will discharge into surrounding groundwater during some periods.

Figure 1: Groundwater level response in well TW-02 during the TW-02 pump test.

Errors Simulating Recharge

The report describes conceptual recharge accurately with respect to runoff reaching drainages where it sinks into alluvium and then into underlying fractured bedrock with some recharge occurring at elevations due to melting snow and rainfall (HGL2000a, p 27). However, the report in many places overestimates the amount that would recharge at high elevations because it does not adequately account for geology.
The report uses the Maxey-Eakin method for estimating recharge but commits two errors in its use. Conceptually, the method relates recharge simply to the amount of rainfall that occurs in varying bands of precipitation estimated to occur throughout a basin. The bands of precipitation are 8 to 12, 12 to 15, 15 to 20 and greater than 20 inches with coefficients equal to 3, 7, 15, and 25%, respectively. This means that, for example, 15% of the total volume of water falling within the area having between 15 and 20 inches of precipitation becomes recharge. The method was developed by assuming that recharge to a basin would equal discharge from that basin, accounting for interbasin inflow. Discharge is spring flow and groundwater evapotranspiration from the regional aquifer within the basin. It does not include perched aquifers and springs although perched springs that discharge to a flow that eventually recharges the regional aquifer would be recharge. The recharge coefficients were derived through a trial-and-error process using an annual precipitation map of Nevada dated 1936, applied to natural discharge by phreatophytes in 13 unidentified valleys in Nevada. Details of the derivation have not been published and have not been reproduced by anyone. The coefficients, and overall method, required use of the 1936 precipitation map or it will provide estimates not consistent with the original method. The method has been updated to different precipitation maps, including the recent PRISM mapping, and it is therefore essential that any use be limited to coefficients derived using the same precipitation estimation mapping.

The second error with its use by HGL (2000a) is the tendency to assume that precipitation enters the ground where it falls. Although the report mentions the geologic control, it does not adequately apply it; there will be no recharge into granitic outcrops and no runoff from highly porous carbonate outcrops. The report must provide adequate reasoning for applying recharge as it does. Based on HGL (2000a) Figures 6-10 and 7-4, it appears that the groundwater model applies the precipitation where it falls and does not account for the fact it actually occurs along the washes, probably including into the fracture zone along the Cave Springs wash downstream from the spring. This affects the modeling because it forces groundwater to flow through portions of the model domain where geology would limit the flow. To not have simulated water levels that are too high, it is likely the calibrated conductivity values are too high, primarily in high elevation areas.

**Pit Lake Modeling Errors**

The pit lake model simulates the chemistry of water accumulating in the pit. This review considers just the hydrogeologic aspects of the modeling effort. There are two primary errors in the hydrology input that can affect the predicted pit lake chemistry.

First, the modeling appears to use an annual time step for 200 years (HGL 2020b, p 25). Therefore, the predicted chemistry misses the fluctuations that would occur seasonally. The report notes that pit lake runoff flushes chemical constituents from the pit walls that have accumulated there due to precipitation wetting the walls but not causing runoff into the pit. Runoff through each slice of the pit wall flushes these contaminants but once the lake rises to a
given level, oxidation and contribution of contaminants will be assumed to cease (HGL 2000b, p 6). The reality in a semiarid pit lake is that the water level will rise and fall seasonally and probably annually during drought periods, as noted above regarding the flow-through quarry lake question. Oxidation will not be shut off permanently once the lake reaches a given elevation because it will not remain inundated. As the pit lake level falls, a wetted perimeter will remain within which much additional oxidation will occur. Fluctuating lake water levels will cause a much higher contaminant load to reach the pit lake. The model should be rerun to include monthly time steps and variable precipitation and evaporation. Droughts should be considered by using actual annual precipitation rates.

Second, groundwater inflow enters by flowing through various pit wall lithologies. The model ignores this variable chemistry by setting inflow chemistry based on observed groundwater chemistry data without considering the leaching that would occur from the groundwater leaching through the damage zone in the skin of the pit lake. The groundwater level may be higher than the pit lake level so that groundwater inflow would reach the damaged layers above the lake level and therefore flow through multiple feet of damaged pit wall before entering the lake. The model apparently neglects a substantial input of contaminants that could leach from the pit wall.

The lake model may also simulate a much too high evaporation rate from the quarry lake. Based on standard pan evaporation, the model assumes evaporation will equal 63.5 in/y. Standard pan coefficients do not apply in a quarry or pit lake situation because the water surface is usually protected from the wind by the quarry walls. Therefore, the simulation could be withdrawing too much water from the quarry lake and preventing the simulation from allowing it to rise as far as it otherwise would.

**Production Water**

The project would use about 2150 gpm for processing. HGL (2020a) models this water as withdrawn from the fracture zone along the drainage. The simulated drawdown does not extend far because of the high conductivity of the fracture zone. However, HGL does not analyze the potential impacts to the water balance of Fish Lake Valley. Assuming this flow enters the basin fill of that valley, it could have a substantial impact on the water rights in that valley. This would be especially true if the project extends longer than expected.

**Groundwater Modeling Comments**

The groundwater modeling effort uses spring levels as calibration targets, meaning it attempts to match the water level to the spring elevation. This is appropriate only for springs connected to the intermediate level aquifer being simulated (not the regional aquifer or perched aquifers). Calibration involves minimizing residuals which could be negative or positive meaning there is as much chance for the simulated potentiometric surface being above the ground level as below, which is clearly not appropriate. A spring is better simulated as a DRAIN boundary with
a targeted discharge rate than as a groundwater surface target. The boundary would prevent
the potentiometric surface rising above the ground surface. Seeps should also not be used for
calibration.

The model has a “constant head” boundary at its connection to Fish Lake Valley (HGL 2000a, p 49). However, the report also indicates there is a 3-foot drawdown at the boundary, which is
impossible because the boundary head is constant. A constant head boundary will allow
whatever flux is necessary to prevent the head from dropping. This is why a general head
boundary is preferable – it can limit the inflow from the boundary. The constant head
boundary can provide unreasonable changes in the water budget.

HGL changed recharge rates as part of calibration (HGL 2000a, p 52). This indicates the model is
nonunique. Calibration usually matches measured outflow or inflows to a model domain. for
example, HGL should have measured outflows to Fish Lake Valley (based on pump test
determined transmissivity and measured gradient) to which it sets the recharge rate (note this
means that using Maxey-Eakin recharge values would be inappropriate, as discussed above).
Using an established recharge rate as equal to the outflow rate, the calibration would attempt
to match the observed groundwater levels by adjusting conductivity. Adjusting also the inflow
leads to a nonunique solution. This means that any combination of recharge and conductivity
could result in the observed groundwater levels on which the modeler based the calibration.
Because the modeler reduced M-E recharge values, it seems likely that the model simulated too
little water flowing through the system. Underpredicting recharge could have resulted in a
prediction of too little dewatering and a lower pit lake level than will actually occur.

HGL (2000a, p 54) makes assumptions about the conductance of faults that are not supported
by data. There are no pump test results showing significant reductions over the fault, so HGL
has no evidence for these assumptions. The response of the model is based on the
assumptions input to the model, which may have no basis in reality.

The steady state calibration shows a significant areal bias with residual tending to be positive or
negative in different areas (HGL 2000a, p 55). For example, springs were underpredicted by up
to hundreds of feet especially in the high elevations (Id.). Springs are effectively bounded and
make poor targets as discussed above. The estimated conductivity throughout much of the
model domain is therefore very inaccurate.

The calibration statistics (HGL 2000a, p 56) are very poor. That the mean residual is -65.7 feet
means the potentiometric surface is simulated as way too low under steady state conditions.
Mean residual should equal zero. HGL uses the steady state groundwater level as the initial
level for project simulation. This would result in the model underpredicting drawdown, flow
to the lake, and quarry lake recovery. The supposed improvement in calibration statistics due
to considering only project wells and VWPs means that removing targets leaves those that are
easier to hit with the simulation. The mean residual is still substantially negative meaning the
steady state groundwater even at the quarry site is too low. The graph showing observed and simulated water tables (HGL 2000a, Figure 7-6) is very misleading due to the scale; observations that appear close to the 1:1 line could still represent residuals of an order of 200 or more.

HGL acknowledges the poor portrayal of an upward gradient within the pit due to the inability to match different VWP levels (HGL 2000a, p 58). The report acknowledges many errors due to the model’s inability to simulate small-scale features (Id.). It is therefore questionable how useful the model predictions are. Most of the observations in these comments suggest the model underpredicts flow into the quarry for both dewatering and quarry lake formation.

**General Comments**

The spring survey does not indicate other springs near the quarry, but the perched aquifers could flow toward the fracture zone defining the Cave Spring drainage. Quarry construction could intercept groundwater that supports resources along the drainage. In summary, quarry construction could intercept shallow groundwater and have two significant effects:

- Dewatering requirements, especially at the beginning of construction, could be substantially higher than predicted.
- Dewatering of shallow groundwater could intercept flow down the Cave Springs drainage. There does not appear to have been investigations of shallow groundwater at the pit.

HGL (2020a, p 30) notes that the groundwater monitoring data shows an upward gradient within the quarry area. The numerical model does not simulate this upward gradient or the probably flow upward into the quarry. This could result in an underestimate of the quarry dewatering rate and the potential for water leaving the quarry lake.

A pump test completed in TW-01 failed due to the water being geothermal with temperature between 80 and 90°F. HGL does not explore the meaning or consequences of there being geothermal water in the area. It could reflect the tendency for upward flow into the quarry.

**Monitoring Plan**

Appendix P to the WPCP application contains the proposed monitoring plan. Primary concerns for monitoring are whether contaminants from quarrying or from the tailings deposits could reach the Cave Spring drainage. Also, the groundwater level in the area of the tailings appears to be close to the ground surface based on the level of springs 6 and 7, which appear to be connected to the intermediate aquifer based on their high TDS values; there is concern whether contaminants from the tailings could reach groundwater.

In addition, the requested additional monitoring well for the quarry lake discussed below, there is a need for another baseline monitoring well upgradient of the tailings pile; MW-1 is insufficient because it is near the main drainage whereas the bedrock underlying the tailings is
outside of the drainage. MW SOSF, downgradient of the tails, is probably sufficient for monitoring leaks from the tails if it is placed properly in the most permeable bedrock below the tails and if there is leak detection under the tails.

The monitoring plan does not discuss the screened or open interval for the wells. Because monitoring wells should not screen more than about 20 feet, the monitoring wells should be sampled with low flow pumps to draw from specific levels if the open interval exceeds 20 feet. To establish a vertical profile of chemistry within the aquifer, the monitoring wells should be sampled using low flow sampling at various levels prior to the commencement of quarrying.

The monitoring plan relies on the assumption that the quarry lake will be terminal. This review has disputed the certainty of that assumption as discussed above. The monitoring does not but should include monitoring to verify whether the lake is terminal. Prior to closure, an additional monitoring well should be added between the quarry and the Cave Springs drainage north of the quarry. It should be established to both monitor the recovering groundwater table and the changing groundwater chemistry. Because it would be in an area of varying groundwater levels, it should be screened either in multiple development or sampled using low flow pumps to draw from various levels to ascertain a vertical profile in the aquifer.

Additionally, to verify whether the evolving groundwater table near the quarry will flow toward the forming pit lake, the VWPs near the quarry should be retained; this is especially critical for VWP-3 which appears to be just north of the quarry. If it will not survive quarry construction, a replacement VWP should be installed to its north as close to the quarry as possible. This should be completed prior to quarry construction so that natural water levels as well as evolving water levels due to construction can be determined. Additionally, another VWP should be installed between VWP-3 (or its replacement) and VWP-8, which is within the Cave Spring drainage. VWP-3 (or its replacement), -8, and a new VWP between the two would allow a water surface profile to be monitored between the quarry, the forming quarry lake, and the drainage to verify whether the quarry is terminal. These VWPs should each have four monitoring levels as were used in VWP-3. Three additional VWP monitoring levels should be added to VWP-8 and the new VWP between -3 and -8 should also have four levels. Four levels are essential to monitor the vertical gradient of flow to and from the quarry and quarry lake and to provide monitoring data that would allow groundwater surface profile modeling to predict the future status of the forming quarry lake (a vertical two-dimension groundwater flow model could be used for this).

The monitoring plan recommends quarterly sampling for the monitoring wells. That would be sufficient only after a year of monthly sampling to establish seasonal trends. As noted above, the groundwater level probably varies substantially due to seasonal changing recharge and it could lead to seasonal wetting and drying which could also lead to seasonal flushes of contaminants. Understanding natural seasonal variability is essential for understanding whether observed changes are natural or due to the quarry.
The monitoring plan fails to include any spring monitoring which it should. As described above, a VWP should be installed near Cave Spring to provide warning of impacts to Cave Spring. It is understandable that Cave Spring will not be sampled for chemistry because that would not show anything regarding the spring going dry, but its flow rate should be monitored at least quarterly, after monthly monitoring for a year prior to quarrying to establish a baseline.

Chemistry at the springs just west of the tailings, SP-06 and -07, should also be monitored quarterly to verify whether the tails affect those springs.

Conclusion

HGL has prepared two reports in support of the proposed Rhyolite Ridge lithium quarry project. The reports depend on too little field data to support the conclusions. The lack of evidence is most apparent in the groundwater modeling effort for which there is too little data outside of the immediate pit area. This is obvious in the poor conceptual model established for the groundwater model. There are two obvious errors. First, the modeler may assume there is too much segmentation. Second, the amount and location of the recharge is inaccurate in several ways discussed above including the amount not equaling an estimated outflow from the model domain and the application of recharge with little regard for the underlying geology.

The errors lead to a vast uncertainty regarding the future of Cave Spring. Although there are indications it will not be affected by drawdown, unsupported assumptions in the modeling may have underestimated the dewatering and its effect to surrounding hydrogeology. The same problem exists for the question of whether the quarry lake will be terminal. Faster, seasonal, or interannual variations of inflow could lead to the lake rising and falling and discharging water to surrounding groundwater. The lack of understanding of quarry lake refilling also manifests in poor or no prediction of the groundwater chemistry entering the lake after flowing through the surrounding quarry lithology.