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DRAFT MEMORANDUM

TO:	Chris Garrett	**FROM:**	Mark A. Williamson, PhD
ORGANIZATION:	SWCA	**DATE:**	June 19, 2020
CC:	File	**PROJECT:**	1051.10
SUBJECT:	Response to Dr. A. Maest Comments to DEIS		

I have reviewed the comments by Dr. A. Maest on the Resolution Copper draft environmental impact statement (DEIS) and given them due consideration for producing a response in support of the final EIS (EIS). My foremost objective is to capture the technical basis for our understanding, the appropriate response, and needed modifications to the DEIS. Dr. Maest's comments fall into several categories related to geochemical considerations, and in each raises several points. Below, I have copied the original material (not necessarily in it's entirety) from Dr. Maest's comment report categories. I have then supplied below it responses to the individual elements within the category.

Note too that I have thoroughly gone through responses to Dr. Maest's comments by Resolution Copper. Those responses range around a good deal and often do not speak directly to the comments. I see no advantage in drawing out the ultimate responses beyond what is specifically identified by the comments themselves. Just my opinion.

Geochemical Testing Methods and Implications for Predictions

Geochemical Testing Methods Not Best Practice and Additional Testing Needed

Regarding acid-base accounting,

> *"The DEIS says it used "best practices" for geochemical characterization by using methods from INAP and those required by ADEQ (p. 372). However, two methods used will underestimate acid generation and contaminant leaching potential: the Sobek method (Sobek et al., 1978) and the synthetic precipitation leaching procedure (SPLP; US EPA, 1994). The original Sobek method (Sobek et al., 1978) could overestimate acid generation potential because it uses total sulfur rather than sulfide sulfur. However, for the Resolution Copper Project, only the sulfide sulfur was used (MWH Americas, Inc., 2013, p. 2-4). Use of the original Sobek method in this case is more likely to overestimate neutralization potential because of the pH endpoint (Maest et al., 2005). The Modified Sobek method is recommended over the original Sobek method by INAP (2009) and the Nevada Bureau of Land Management (2013). Because most of the test results for Resolution Copper showed that nearly all the mine rock samples, all the PAG tailings, and over half the "NPAG" tailings were potentially acid-generating (PAG; DEIS, p. 372 and 373), the use of the older Sobek method is not particularly concerning for the DEIS. However, it should not be used in the field to distinguish PAG and NPAG rocks for different placement and different mitigation approaches; instead, the Modified Sobek method should be used. No information is provided in the DEIS about methods used in the field to distinguish PAG and NPAG rock? (read project description etc.). An important question is why the DEIS calls the "NPAG" tailings (scavenger tailings) NPAG when half are PAG or acid generating (DEIS, p. 373)."*

Both the original and modified Sobek methods were used over the period of time that data were generated in support of the development of the Resolution Copper project. The comment fails to acknowledge that post-2014 the modified Sobek was the method employed for characterization. This is documented in Duke Hydrochem's 2016 report[1]. Aside from the preceding administrative reality, the use of the original or modified Sobek method does not functionally affect the outcome of characterization to any meaningful extent.

Sobek analysis determines the acid potential (AP) and the neutralization potential (NP) of mine materials. The original method was prone to overestimating the NP value, and overestimating the AP. However, as the comments by Dr. Maest indicate, "Because most of the test results for Resolution Copper showed that nearly all the mine rock samples, all the PAG tailings, and over half the "NPAG" tailings were potentially acid-generating (PAG; DEIS, p. 372 and 373), the use of the older Sobek method is not particularly concerning for the DEIS." Ultimately, from either an administrative or technical perspective, a distinction regarding the specific method employed is not really meaningful.

Owing to Resolution Copper's standard practice, since 2014, to use the modified procedure, concerns expressed by Dr. Maest regarding characterization of mine rock for segregation in the future are positively addressed. Note, however, the characterization of mine rock for purposes of segregation does not appear to be required by the project as it produces no waste rock stream requiring management. Note that this lack of need may need to be pointed out in the FEIS.

It worth addressing, in light of Dr. Maest's comment "*all the PAG tailings, and over half the "NPAG" tailings were potentially acid-generating*" that the while a very pyrite enriched tailings stream, PAG tailings, would be produced, this does not automatically indicate that remaining tailings in *not* PAG (NPAG). The separation of the tailings stream is an operational distinction, not a mineralogic or acid-base accounting goal. The EIS text should be edited to replace "NPAG" tailings with scavenger tailings. This is clearly a longer and perhaps more awkward term, but it is more accurate and is consistent with the mine GPO.

Regarding the use of SPLP (Synthetic Precipitation Leaching Procedure),

> *The SPLP test will underestimate the leaching potential of mined materials, especially in arid areas like southern Arizona, because it calls for a 20:1 solution:solid ratio (Maest et al., 2005). The meteoric water mobility procedure (MWMP) is recommended by the Bureau of Land Management for the State of Nevada, another arid state in the western US. The MWMP has a solution:solid ratio of 1:1 and should have been used by the proponents to evaluate the short-term contaminant leaching potential of mined materials. As noted in the DEIS (p. 381), a drawback of relying only on the SPLP test is that it is usually conducted on unweathered fresh core or lab-created tailings when in the field over time, these mined materials will weather. As especially sulfidic mine materials weather, secondary sulfate salts are formed that can release metal(oid)s, sulfate, and acidity rapidly during a storm event or as waters rise into mined areas; the effects of this rapid dissolution are rarely taken into account when predicting mine waste behavior (Maest and Nordstrom, 2017 and references contained therein).*

Resolution Copper was required to make use of the SPLP test as a requirement of the Arizona BADCT guide, which specifies this method. But, as noted in the DEIS, other methods such as barrel tests and humidity cell tests were also used to gauge storm water runoff quality. These methods use water-to-rock ratios that are consistent with the MWMP that Dr. Maest mentions. Further, these tests do indeed account for weathering of reactive sulfide minerals to provide the broadest description of water quality. SPLP is only one component of a weigh-of-evidence approach used to characterize and disclose the likely leaching potential of mined materials.

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[1] Duke Hydrochem (2016) Chemical Characterization of Resolution Tailings Update: 2014-2016. Report to Resolution Copper from Duke Hydrochem dated June, 2016.

SPLP results are applied, according the comments, to stormwater runoff quality, and I address that perspective in the section below *Predicted Stormwater Quality.*

Regarding characterization work applicable to subaqueous tailings disposal,

> *A more important issue is the lack of geochemical testing for the lone proposed mitigation measure for PAG tailings. The PAG tailings (that is, the pyritic or cleaner tailings) would be subaqueously deposited because "this limits oxygen from interacting with the concentration of sulfides in the PAG tailings, minimizing and preventing water quality problems (acid rock drainage)" and the NPAG tailings would "eventually encapsulate the PAG tailings." (DEIS, p. 41). However, no testing was done to determine if depositing the PAG tailings under water would minimize or prevent the formation of acidic drainage. Because submerging PAG tailings is the only mitigation measure proposed for minimizing acid drainage at the source, saturated column tests on tailings should be conducted. The testing will require months to a year or more to complete and evaluate.*

Subaqueous disposal of mine tailings has been demonstrated to be an effective method of suppressing sulfide mineral oxidation for nearly 30 years, as documented[2] by MEND (1989), Fraser and Robertson (1994), and MEND (1996). In practice, MEND (1998) describes design criteria by the year 1998 and Larkins (2020) describes current practices in constructed impoundments. The fundamental chemistry involved, that of severely limiting the access to oxygen to drive the reaction, is not site specific and is applicable anywhere sulfide minerals are underwater. However, there are also site specific testing data for Resolution tailings that demonstrate this fundamental reality. These tests are reported in Duke Hydrochem (2016)[1]. Column tests were conducted that measured the rate of oxygen consumption by tailings. Tests were run with variable percentages of the pyritic tailings submerged in water and the results clearly demonstrate the expected; as greater amounts of pyritic tailings are submerged the rate of oxygen consumption, and therefore sulfide mineral oxidation, decreases. The diminished reactivity of sulfide minerals upon submersion in water by restricting the rate of oxygen supply is conceptually clear, demonstrated and practiced for some 30 years in both lake settings and engineered impoundment and no further testing is required.

Block Cave Groundwater After Mining Ceases

The block cave zone has been identified as a long-term hydrologic sink and the impacts related to water quality within it are not currently assessed. That said, The potential chemical quality of water in the flooded block cave zone has been considered, and data have been collected. However, no explicit modeling has been conducted to refine this.

Borden (Appendix R of the GPO) indicates

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[2] MEND (1989) Subaqueous disposal of reactive mine wastes: An Overview. Mine Environment Neutral Drainage (MEND) program report Project 2.11.1a. Dated June 1989.

Fraser, W.W. and J.D. Robertson (1994) Subaqueous disposal of reactive mine wastes: An Overview and Update of Case Studies. International Land Reclamation and Mine Drainage Conference and the Third International Conference on the Abatement of Acidic Drainage, Pittsburgh, PA, April 24-29, 1994.

MEND (1996) Review of MEND Studies on Subaqueous disposal of Tailings (1993-95) Mine Environment Neutral Drainage (MEND) program report Project 2.11.1e. Dated October, 1996.

MEND (1998) Design Guide for the Subaqueous Disosal of Reactive Tailings in Constructed Impoundments. Mine Environment Neutral Drainage (MEND) program report Project 2.11.9. Dated March, 1998.

Larkins, C. (2020) Subaqueous Disposal in a Waste Management Facility. Geological Survey of Finland. https://mineclosure.gtk.fi/subaqueous-disposal-in-a-waste-management-facility/.

"The oxidation front is only anticipated to extend tens to hundreds of feet into the caved rock overlying the production level. At any given time, less than five percent of the rock within the caved zone is anticipated to be both net acid generating and to be in contact with oxygen. Approximately 1000 gpm of water is predicted to report to the production level workings, most of which must travel through the overlying caved ore. On average, this water is anticipated to be weakly to moderately acidic with elevated sulfate and some elevated metals concentrations."

"At closure both the underground ventilation and pumping systems will be turned off. Oxidation and potential ARD generation from the mineralized caved rock above the draw points will end almost immediately. The dewatered rock mass within and surrounding the block cave will also begin to slowly resaturate. Reflooding to near pre-mining groundwater levels is anticipated to take approximately 1000 years and radial flow towards the underground workings and the caved rock zone will persist for centuries, maintaining a hydraulic sink."

"Within several years of closure, the underground workings and the mineralized rock immediately above the inactive draw points will be reflooded. Any residual oxidation that may persist after the ventilation system is turned off will effectively end as the flooding front advances upward. The mineralized rock near the draw points which is most likely to have been oxidized and potentially acidified during operation will be the first material in the caved rock zone to be reflooded. Early reflood water quality will largely be controlled by the interaction of good quality, alkaline water from above with the partially oxidized mineralized rock. The first flush of water which accumulates in the underground workings will release any residual sulfide oxidation products into solution. The first water which accumulates at the production level is thus likely to have the poorest quality within the caved zone. Subsequent reflood waters which accumulate above this in the mineralized rock zone will have progressively better water quality as saturation progresses upward."

Accordingly, lab tests were conducted to collect data for saturated column testing (GPO Appendix G). These columns are HCTs that were run to completion in the normal subaerial fashion, and then run as saturated columns (subaqueous). These columns were run (as described in Appendix G) to characterize water quality that refloods the block cave zone and focused on mineralized non-ore (below cutoff grade) and country rock. Some samples of ore were also run to consider unrecovered ore that remains (efficiency issue of mining). The data in the table speak for themselves and are shown in the table below (Table 6 of Appendix G).

Table 6. Summary of leachate chemistry (pH, alkalinity, acidity, and sulfate) for the final week of humidity cell testing, first week of saturated column testing, and final week of saturated column testing.

Test ID	HCT Final Week	SCT Week 1	SCT Week 12	HCT Final Week	SCT Week 1	SCT Week 12	HCT Final Week	SCT Week 1	SCT Week 12	HCT Final Week	SCT Week 1	SCT Week 12
	pH			Total Alkalinity			Total Acidity			Sulfate		
	(s.u.)			(mg/L as $CaCO_3$)			(mg/L as $CaCO_3$)			(mg/L)		
SC2	7.05	7.18	6.77	16	29	11.6	<5	<5	<5	615	1470	1020
SC11	3.74	3.09	3.64	<5	<5	<5	137	5183	66	158	6750	77
SC12	4.92	4.58	5.06	<5	<5	<5	329	2190	71	376	3310	85
SC14	5.77	5.03	5.56	<5	<5	<5	65	411	15	807	1750	1580
SC21	3.63	3.08	4.46	<5	<5	<5	108	1544	9	105	1530	<10
SC28	3.76	2.94	4.61	<5	<5	<5	237	7280	27	225	11000	20
SC34	7.10	7.44	7.55	8	51	26	<5	<5	<5	33	299	<10
SC38	8.58	7.95	8.02	23	86	23	<5	<5	<5	<10	10	<10
SC39	8.78	8.34	8.86	57	148	48	<5	<5	<5	<10	151	<10
SC44	2.7	2.43	3.80	<5	<5	<5	482	2180	60	567	2790	63
SC49	4.57	3.17	4.09	<5	<5	<5	49	14980	40	50	17400	34
SC50	4.21	3.81	4.72	<5	<5	<5	345	1750	33	496	2660	49
SC52	7.32	7.57	7.79	14	130	42	<5	<5	<5	77	1340	10
SC54	6.30	6.37	7.53	<5	12	35	10	28	<5	603	1600	1350

Note: A week 1 water sample was not collected in Test SC14 due to insufficient volume; week 2 data are presented.

Subsidence Lake

A subsidence lake has been evaluated as not forming in response to mining. Hence, consideration of water quality for such a feature would seem moot.

Predicted Stormwater Quality

Regarding stormwater quality,

> *Results from the SPLP tests for NPAG and PAG tailings are presented in Table 3.7.2-9 of the DEIS. The concentrations predicted for PAG tailings runoff should be higher than those for NPAG tailings, but they are not, as shown in table 3.7.2-9. This is an indication that either the SPLP tests include too much dilution or that the SPLP results in the table are not taken from PAG and NPAG samples. For example, predicted concentrations of antimony, beryllium, cadmium, chromium, copper, iron, mercury, silver, thallium, and zinc in the table are identical, and oddly, sulfate and total dissolved solids concentrations are higher in the NPAG than in the PAG sample. The report from Verburg and Harvey (2008) is cited as the source for the SPLP results in the table. Upon reviewing the report, no sample identified as 7/7A 7C is included in the report, and the report is not about SPLP results – it is about humidity cell test (HCTs – much longer-term leach tests) results for six tailings samples. This discrepancy needs to be corrected.*
>
> *The inclusion of SPLP results in the DEIS (see Table 3.7.2-9) is confusing because it implies that the results were used to calculate stormwater runoff concentrations. However, it appears that SPLP results were not used for tailings runoff water quality predictions (Eary, 2018a) and barrel and early HCT results were instead used.*

The SPLP results in Table 3.7.2-9 for so-called NPAG and PAG tailings is misleading. These tests were conducted on relatively freshly processed tailings from metallurgical method development. They were unoxidized, and stored to maintain that condition, and as such have relatively limited masses of rapidly soluble chemical constituents. Thus, the reported values for multiple constituents are at the detection limit. Hence, the two samples, with very different reactive sulfide mineral content, appear similar. Table 3.7.2-9 should be edited to indicate which constituents are reported at their method detection limits.

As this comment surmises, stormwater runoff quality was not estimated using SPLP and instead made most use of HCT and barrel test results (see above comment regarding suitability of the SPLP method). Ultimately specific concentrations of chemical constituents in stormwater runoff were not presented, but the DEIS identifies that several constituents are anticipated to leach at concentrations of concern.