Resolution Copper Project and Land Exchange Environmental Impact Statement

USDA Forest Service
Tonto National Forest
Arizona

October 6, 2020

Process Memorandum to File

Evaluation and Response to Public Comments on Groundwater Modeling Analysis

This document is deliberative and is prepared by the third-party contractor in compliance with the National Environmental Policy Act and other laws, regulations, and policies to document ongoing process and analysis steps. This document does not take the place of any Line Officer's decision space related to this project.

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Purpose of Process Memorandum

The Draft EIS (DEIS) for the Resolution Copper project was released in August 2019 and included the use of a groundwater model to predict impacts to water supplies and sensitive groundwater-dependent ecosystems as a result of dewatering from the proposed mine.

A number of detailed comments were received on the DEIS, related to the use of the groundwater model. The most technical of these comments were contained in a report by Dr. Bob Prucha, under the auspices of the Arizona Mining Reform Coalition et al comment letter; this report is included with this process memo as Attachment 1.

The purpose of this process memorandum is to detail the process used to evaluate these comments, the decisions made by the Tonto National Forest with respect to addressing the comments, and the rationale for those decisions.

Key Process Steps

In order to assist the Tonto National Forest with reviewing public comments, formulating responses to those comments, and revising analysis where appropriate, a Water Resources Workgroup was reconvened in January 2020. This workgroup represented the combination of several workgroups that existed prior to the publication of the DEIS, which were useful to the Tonto National Forest for evaluating groundwater modeling and water quality impacts. The reconvened workgroup included a wide variety of participants including Forest Service specialists, specialists from the NEPA third-party contractors, Resolution Copper and their contractors, cooperating agency specialists including USEPA, the U.S. Army Corps of Engineers (USACE), Arizona Department of Water Resources (ADWR), Arizona Department of Environmental Quality (ADEQ), Arizona Game and Fish Department (AGFD), and a hydrology specialist attending on behalf of the San Carlos Apache Tribe.

Several submittals from workgroup participants formed the basis for the evaluation of the Prucha comments.

- The Prucha comments were discussed at the first meeting of the Water Resources Workgroup on January 23, 2020 (Project Record #0003714). An action item (WR-13) was developed at this meeting for the Resolution Copper modelers (WSP) to provide written responses to these comments. The WSP report was submitted by Resolution Copper on March 23, 2020 (WSP 2020; Project Record #0003812). For reference this report is included as Attachment 2 of this process memo.
- The groundwater modelers working on behalf of the Tonto National Forest (BGC), also conducted additional work to categorize and evaluate the comments (action item WR-14), also taking into account the March 23 submittal. These results were submitted on May 11, 2020 (BGC 2020, Project Record #0004462) and are included as Attachment 3 of this process memo.
- Much of the discussion contained in this process memo originated as a whitepaper prepared by the NEPA team and circulated to the Water Resources Workgroup on June 21, 2020, for discussion at the June 25, 2020 Workgroup (Project Record #0003875). The whitepaper is included Attachment 4 of this process memo. The purpose of the whitepaper was to identify

each concern, identify the pertinent citations and information related to that concern, provide a discussion of the issue, a proposed approach for resolving, and the rationale for that approach.

- With the expectation that there would be disagreement on at least some modeling comments, any dissenting opinions were requested from the Water Resources Workgroup. One written response was provided by Workgroup participant Dr. Jim Wells, working on behalf of the San Carlos Apache Tribe (L. Everett and Associates 2020, Project Record #0004463).

Approach for Assessing Groundwater Modeling Comments

Groundwater modeling requires making choices.

There are multiple groundwater models available, many tools and techniques available within those various models, and an unlimited number of ways to build a model framework using those tools. In order to reasonably replicate real-world aquifer conditions and responses, a groundwater modeler has to choose among all these variables, and those choices must be demonstrably reasonable and appropriate.

There is a wealth of industry and professional groundwater modeling guidance available to guide modeling efforts; these were explored in detail in Appendix B of the Groundwater Modeling Workgroup memo (BGC 2018). This industry guidance primarily focuses on the modeling process to be followed, rather than dictating specific modeling choices to be made. This is because every situation is unique, and there is no "right" way to build any given groundwater model from all the tools and techniques available.

There are 15 specific modeling criticisms discussed in the whitepaper in Attachment 4. This whitepaper contains substantial detail and discussion. For each issue, the WSP response, BGC response, and pertinent documents are summarized. The discussion that then follows these items is at times a lengthy narrative, attempting to work through the complex issues raised and see the issue from different viewpoints. The section below highlights the final decisions with respect to the groundwater modeling comments; however, the whitepaper should be considered a fundamental part of the decision rationale.

Overview of NEPA Team Resolution of Modeling Comments

Assistance by water workgroups[1]

As was noted in the DEIS, the Tonto National Forest did not conduct the groundwater modeling analysis in a vacuum:

[1] The term "Groundwater Modeling Workgroup" refers to the workgroup convened in September 2017 to inform DEIS analyses, the outcomes of which are described in the BGC 2018 memo. The term "Water Resources Workgroup" or "reconvened Water Resources Workgroup" refers to a similar but wider workgroup convened in January 2020 to inform responses to public comments on the DEIS. The term "Workgroup" is used in places as shorthand.

"In September 2017, the Tonto National Forest convened a multidisciplinary team of professionals, referred to as the Groundwater Modeling Workgroup. The Groundwater Modeling Workgroup included Tonto National Forest and Washington-level Forest Service hydrologists, the groundwater modeling experts on the project NEPA team, representatives from ADWR, AGFD, the EPA, the San Carlos Apache Tribe, and Resolution Copper and its contractors. This group included not only hydrologists working on the groundwater model itself, but also the biologists and hydrologists who have conducted monitoring in the field and are knowledgeable about the springs, streams, and riparian systems in the project vicinity. The Groundwater Modeling Workgroup tackled three major tasks: defining sensitive areas, evaluating the model and assisting the Tonto National Forest in making key decisions on model construction and methodology, and assisting the Tonto National Forest in making key decisions on how to use and present model results." (DEIS, p. 296)

It is useful to revisit the founding philosophies of the Groundwater Modeling Workgroup (shared during the September 2017 workgroup kickoff meeting [Project Record #0002056]):

"1) The groundwater model is one tool that can be used to predict impacts, but not the only tool.

2) The groundwater model should represent the best available science.

3) The groundwater model should not be used to answer questions that are beyond its ability to answer.

4) The Forest Service is ultimately responsible for approving the groundwater model in all its aspects, but all voices at the table should be heard and considered.

5) Every effort will be made to make decisions on modeling approach before seeing the model output. It is not appropriate to rethink the model in order to arrive at a particular desired answer."

These founding principles make clear that the goal of the Groundwater Modeling Workgroup wasn't to arrive at any specific answer, but to ensure that whatever modeling choices the Forest Service made, they would be informed choices.

Criticisms of modeling approach in general

The public comments did not challenge the first and most fundamental decision made by the Tonto National Forest with respect to water resources, informed by the Groundwater Modeling Workgroup: the decision to use a numerical groundwater model to assess impacts. As noted in the DEIS:

"To assess impacts on groundwater resources, the long history of baseline data collection was considered holistically alongside

- *the large geographic area involved;*

- *the complex geology and multiple aquifers, including the incorporation of the blockcaving itself, which would fundamentally alter the geological structure of these aquifers over time;*
- *the long timeframes involved for mining (decades) as well as the time for the hydrology to adjust to these changes (hundreds of years); and*
- *the fact that even relatively small changes in water levels can have large effects on natural systems.*

> *A numerical groundwater flow model is the best available tool to assess groundwater impacts."* (DEIS, p. 295)

Notably, no comments received on the DEIS question this fundamental decision to use a numerical groundwater flow model to assess groundwater impacts. A groundwater model remains the most appropriate tool for the EIS analysis. The remaining criticisms largely focus on the professional choices made when designing and using that tool.

General categories of comments received

While the comments received on the groundwater model are highly detailed and specific, they generally group in four categories:

1. Comments that are factually incorrect[2], usually in that they claim a process step was not conducted, when it can be clearly documented in the project record that the step took place. These comments may require no changes, but may reflect a need for better documentation in the DEIS that these steps occurred.
2. Comments that express a professional opinion about a modeling choice that was made, when that modeling choice was explicitly discussed as part of the Groundwater Modeling Workgroup discussions between September 2017 and December 2018 and documented in the workgroup results. In these cases, we need to look at whether a new or different rationale is proposed in the comment that would suggest that the original informed choice should be revisited.
3. Comments that express a professional opinion about a modeling choice that was made, but reflect an aspect of the modeling that was not explicitly discussed as part of the Groundwater Modeling Workgroup.
4. Comments that conflict with global decisions made by the NEPA management team.

[2] We are aware that using the term "factually incorrect", or similar terms, throughout this process memo (and the attached whitepaper) suggests that a personal judgement is being made. On the contrary, whenever these terms are used the intention is to then immediately point to the documentation that exists that contradicts the comment.

Summary of Specific Issues Raised

The general outcome for the 15 issues raised is summarized in table 1.

Table 1. Summary of issues raised with respect to groundwater modeling

Issue	Categorization of Comments				Action Recommended				Page number in Attach. 4 white-paper
	#1	#2	#3	#4	Add text to FEIS	Add to project record	Revised analysis	Response to comments only	
#1: Modeling process, characterization, conceptualization	X	X				X			7
#2: Model code selection	X	X			X				13
#3: GDEs	X	X						X	15
#4: Baseline conditions	X	X		X	X	X			17
#5: Model output (200 years, 10 feet)	X	X			X				20
#6: Skunk Camp modeling	X	X			X		X		24
#7: SW/GW interaction	X	X						X	28
#8: Choice of wells and targets		X			X				32
#9: Calibration	X	X				X			34
#10: Uncertainty	X	X				X			38
#11: Geothermal effects			X		X	X			42
#12: Subsidence crater lake		X			X		X		44
#13: Subsidence		X				X			47
#14: Desert Wellfield model			X		X		X		49
#15: Inappropriate modeling choices for faults, recharge, ET, boundary conditions	X	X				X			50

The specific actions to be taken—arising out of the discussion the whitepaper—are summarized below.

Summary of additional text to add to FEIS

- Issue #2: Add code selection detail to text of FEIS
- Issue #4: Add detail of pre-1998 hydrologic conditions to text of FEIS
- Issue #4: Add detail of calibration to text of FEIS
- Issue #5: Add detail to FEIS to directly call-out where impacts are assessed less than 10-feet and longer than 200-years, and discuss the steady-state vs. transient issue
- Issue #6: Add Skunk Camp new characterization and modeling results to FEIS
- Issue #8: Describe in FEIS why individual wells are not analyzed, and how the results are still available in the figures for wells not near the proxies
- Issue #11: Discuss geothermal gradients in the FEIS
- Issue #12: Revise language on subsidence lake as discussed in Workgroup, add in uncertainty in hydrographs
- Issue #14: Add detail in FEIS about development/use of the Desert Wellfield model

Summary of additions to project record needed

- Issue #1: Edit Section 3.4.7 in the final Workgroup memo
- Issue #4: Compile information on historic water level conditions in record, from available sources already provided
- Issue #9: Provide breakdown of residual heads at wells and aquifer units, to better inform calibration results
- Issue #10: Provide additional explanation in final Workgroup memo to describe that multiple valid approaches exist based on industry modeling guidance, but that both calibration sensitivity analysis and predictive uncertainty analysis were conducted, though not presented in final WSP report.
- Issue #11: Documentation on the topic of geothermal gradients does not exist and is needed. The groundwater experts on the NEPA team should review and concur with the rationale stated in this whitepaper (and in WSP 3/23/20, attachment 1) and document it in some manner for the project record.
- Issue #13: Add explanations of how the block-cave area is modeled to project record (need from WSP)
- Issue #15: Clarify on spring modeling using drains (need from WSP); BGC to explain boundary effects better in final Workgroup memo.

Summary of revised analysis needed

- Issue #6. Under the purview of the reconvened Water Resources Workgroup, obtain and review all new hydrogeologic information for Skunk Camp, all revised water quality modeling for Skunk Camp, and evaluate appropriateness of modeling and techniques used.
    - Note that this analysis was all provided as part of the Water Resources Workgroup. The complete list of reports is covered in detail in sections 3.2, 3.7.1, and 3.7.2 of the FEIS.
- Issue #12. Provide sensitivity hydrographs DHRES-01, DHRES-02, and DHRES-08.
    - Note that details of this analysis are included in the water resources background process memo (Newell and Garrett 2018).
- Issue #14. BGC will conduct a review of the appropriateness and sufficiency of the Desert Wellfield model, and the results of this review will guide the use of the model in the FEIS. This includes additional documentation received from ADWR clarifying how the model scenario used by Montgomery & Associates was constructed.
    - Note that this analysis is contained in Walser (2020).

References

BGC Engineering USA Inc. 2018. *Resolution Copper Project EIS: Review of Numerical Groundwater Model Construction and Approach (Mining and Subsidence Area) - DRAFT*. Project No.: 1704005.03. Golden, Colorado: BGC Engineering Inc. November.

BGC Engineering USA Inc. 2020a. *Draft - Responses to IHS (Prucha) Comments*. Project memorandum. Project No.: 1704005.03. Golden, Colorado: BGC Engineering Inc. May 11.

Integrated Hydro Systems, LLC. 2019. *Review of Hydrologic Impacts In the Draft Environmental Impact Statement, Resolution Copper Project and Land Exchange, August 2019*. October 9.

L. Everett and Associates. 2020. *Dissenting Comments to the Water Resources Working Group Draft Environmental Impact Statement for the Resolution Copper Project and Land Exchange*. Santa Barbara, California: L. Everett and Associates. August 7.

Newell, E. and C. Garrett. 2018. *Water Resource Analysis: Assumptions, Methodology Used, Relevant Regulations, Laws, and Guidance, and Key Documents*. Process memorandum to file. Phoenix, Arizona: SWCA Environmental Consultants. August 8.

WSP USA. 2020. *Response to Integrated Hydro Systems Review*. Greenwood Village, Colorado: WSP USA. March 23.

Walser, Gabriele. 2020. *Review of ADWR Salt River Valley Groundwater Model Application for Resolution's Desert Wellfield – FINAL*. Project memorandum. Project No.: 1704007-06. Golden, Colorado: BGC Engineering Inc. August 3.

ATTACHMENT 1

REVIEW OF HYDROLOGIC IMPACTS IN THE DRAFT ENVIRONMENTAL IMPACT STATEMENT RESOLUTION COPPER PROJECT AND LAND EXCHANGE, AUGUST 2019 – REPORT BY DR. BOB PRUCHA, INTEGRATED HYDRO SYSTEMS, LLC, OCTOBER 9, 2019

Appendix E

Review of Hydrologic Impacts In the Draft Environmental Impact Statement Resolution Copper Project and Land Exchange August 2019

Bob Prucha, Integrated Hydro Systems, LLC

October 9, 2019

INTEGRATED HYDRO SYSTEMS, LLC

Review of Hydrologic Impacts In the Draft Environmental Impact Statement Resolution Copper Project and Land Exchange August 2019

Bob Prucha, Integrated Hydro Systems, LLC
Wednesday October 9, 2019

My review of this DEIS and associated documents looks at two main things:

a) How well **current** (or Baseline) surface water and groundwater hydrologic conditions are understood/defined in areas potentially affected by the proposed mine/operations, particularly preferred Alternative #6, and

b) Whether **predicted** impacts of the proposed mine/operations on both surface water and groundwater hydrologic conditions, during and following mine closure are valid and complete.

1 Major Deficiencies

1. The formation of a pit lake wasn't evaluated and is a major oversight in the DEIS (see Section 2.7.7).
2. Identification of impacted Groundwater-Dependent Ecosystems (GDEs) is lacking (see Section 2.1).
3. Groundwater model development and calibration are flawed and predicted impacts to GDEs are unreliable and highly uncertain (see Sections 2.5, 2.6 and 2.7).
4. Groundwater and Surface Water models were created in virtual isolation from each other, despite clear evidence the two are coupled in key GDE locations. Evaluation of impacts to stream-aquifer flows was not assessed, partly because hydrologic modeling software selected don't have the capability of simulating this critical dynamic flow process. Inappropriate codes were used to assess impacts (see Section 2.4)

2 Key Findings

2.1 Identification of Impacted GDEs is problematic

GDE evaluations Garrett 2018d are suspect. Upper Devils Canyon streams may be baseflow discharge from TAL. Well within 10' contour. Not likely perched hydrogeo included in GW model – hence distancing by workgroup from relying on any SW-GW flow predictions.

- Develop stream profiles, and plot GW levels. Breaks in slope? Add surficial geology. Evaluate potential for disconnectedness between shallow aquifer and Tal.
- Doesn't appear to consider broader impacted area (impacted areas up to for example, 1-ft drawdown vs. 10-ft) – as predicted in model, despite uncertainty band around this. More

GDEs would have shown up as impacted, needing mitigation. Instead only those delineated by uncertain predicted 10-ft drawdown used (at 200 years) to define potentially impacted GDEs.

- Evaluating drawdowns in shallow aquifer at 200 years, or 148 years post-closure, severely limits the number/magnitude of impacted GDEs because the groundwater model still hasn't fully recovered by this point. With a future fractured and highly permeable pathway that developes between the shallow Apache Leap Aquifer (ALT) and DEEP aquifer zone (in Resolution Graben), relatively rapid drainage of ALT would dewater GDEs over the short-term, as it fills voids in the deep aquifer. But then, ALT water levels will eventually return to pre-mining conditions. Choosing 200 years limits the understanding of time-varying impacts extent/magnitude.

- By including continued dewatering of the deep GW aquifer in No Action alternative groundwater model predictive long-term simulations, and then subtracting drawdowns from LOM and post-closure simulations, RCM consultants have effectively biased the magnitude and extent of mine impacts on GDEs towards the low side, or the opposite of conservatively high impacts (see see page 3, paragraph 4, Garrett and Newell, 2018). At a minimum, predicted drawdowns should have been calculated from pre-mining conditions, as these are the levels to which shallow ALT aquifer groundwater levels will eventually recover to. This is known without even using the highly uncertain groundwater modeling results.

- Water quality of the 'perched' upper Devils Canyon drainage doesn't appear to confirm it is disconnected to shallow ALT aquifer, which has likely dropped simply due to the substantial and long-term historical pumping, compounded by the more current 2009-present shaft 9/10 dewatering. The assessment of which GDEs to include, or discard from further analysis (i.e., discarded if perched, vs. connected to impacted ALT or Deep aquifers) appears to be based on relatively recent hydrologic data (i.e., collected after significant unrecovered historical drawdowns (1910-1996) and superimposed re-drawdown of levels post-2009 (i.e., shaft 9/10 dewatering). No analysis of 1910 to 1996 dewatering/recovery is presented in the DEIS, or supporting documents. Knowing how much drawdown has already occurred in the GDE locations/segments would have likely significantly increased the number of GDEs potentially impacted.

- A key question is what additional GDEs, or even those omitted because the Groundwater Modeling Workgroup decided they didn't exhibit "*persistent presence of water, year-to-year and season-to-season*" (stated page 296, paragraph 3 in the DEIS), would have been valid locations had effects of past/current pumping been removed (recovered)? GDEs should have been defined based on **pre-mining groundwater conditions**, where the long-term pumping influence at Magma Mine, and RCM pumping since 2009 don't bias identification of persistent discharge at springs/along streams towards the low side. Because it is unclear how the estimated pre-mining groundwater levels were determined without calibration data, the DEIS should have conservatively identified all GDEs, within uncertain range of flow conditions.

- DC13.5 SW flow assumed disconnected from ALT aquifer – but unconvincing evidence. West-East Cross Section A-A' (Figure 2.3 in WSP, 2019) shows Inferred Tal Water Table at Devil's Canyon at the bottom of the streambed, in the dismissed GDE segment from DC10.9 to DC 15, contradicting assumptions made that this stream segment (albeit ephemeral many years) is due to perched groundwater conditions (see page 28, paragraph 2 in Montgomery and Associates, 2017). Given the likelihood that flow in this segment, well within the 10' groundwater level drawdown zone impacted by mining, is connected to the Tal aquifer, it should have been included as an important GDE in the DEIS. Moreover, it is clear from

2.2 Issues with Approach to Impact Evaluation

Understanding the current hydrologic flow system and predicted changes due to mining rely heavily on modeling involves successfully completing various sequential steps to produce reliable results agencies can use to make informed decisions. Problems with any of these steps translate into subsequent steps that reduce accuracy and reliability of results.

2.2.1 Issues with Overall Methodology Used to Evaluate Impacts

A general 'industry-standard' approach to modeling hydrologic impacts is lacking. A general approach used to develop predictions via use of numerical models was never presented, though many guidance documents are readily available online as noted by BGC, 2018d[2] in Section 2.2 (Description of Best Practices). The most useful, current and relevant to assessing mining impacts is provided by Wels, 2012[1], which shows a standard modeling process on Figure 1. Clearly defined questions related to potential impacts and modeling objectives should have been presented, particularly how groundwater impacts affect surface flows, and vice-versa. These were not evaluated in this DEIS, or supporting documents.

Implications of the lack of a clear overall approach to hydrologic impact evaluations include:

- A major flaw in modeling conducted in this DEIS is that groundwater modeling was done in apparent isolation from surface water modeling, yet surface water clearly recharges groundwater (losing segments), and groundwater clearly discharges to surface streams as baseflow, or via springs. In other words, surface water recharge to groundwater (losing stretches) was not included in the groundwater modeling as a boundary condition, and vice versa. Including this 2-way flow is essential to realistically and accurately assessing mining impacts on surrounding GDEs (and surface water ecosystems).
- A formal code(s) selection process that demonstrated tools selected for the analyses adequately answer key questions/meet objectives wasn't performed. These issues are addressed in more detail in Section 2.4 below.
- Once models were created, the important feedback loops shown on Figure 1 from model calibration to conceptualization and data collection doesn't appear to have been considered. In other words, obvious datagaps identified during modeling weren't addressed.

[1] Wels, C. and Mackie, D., Scibek, J. 2012. Guidelines for Groundwater Modelling to Assess Impacts of Proposed Natural Resource Development Activities, British Columbia Ministry of Environment, Water Protection & Sustainability Branch, Report No. 194001.

* A formal predictive uncertainty analysis wasn't conducted, and partly confused with a predictive sensitivity analysis.

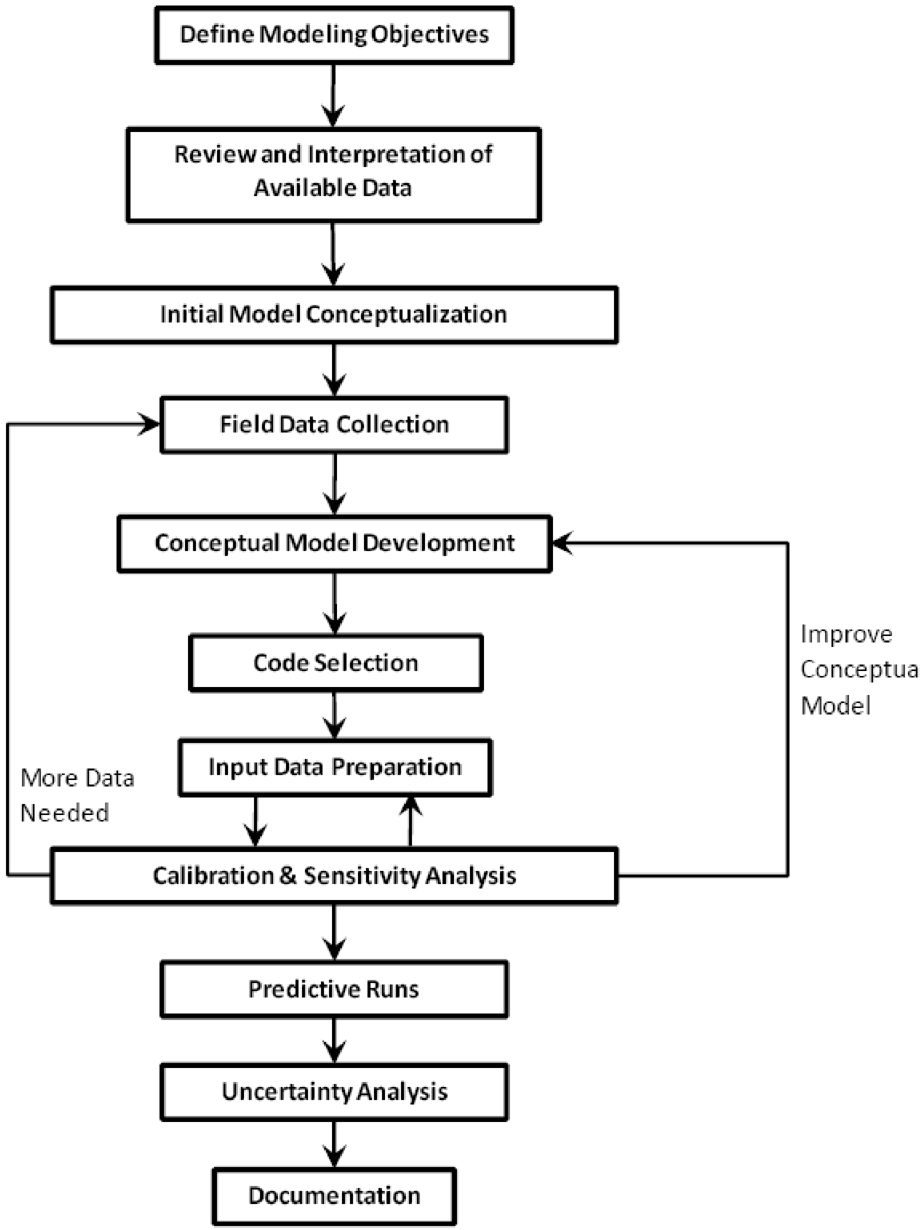

Figure 3-1: Modelling as a multi-phase, iterative process.

Figure 1. Proposed Groundwater Modeling Process (Wels, 2012)

2.3 Conceptualization inadequate/incomplete.

Conceptualization is critical to supporting and developing numerical models of flow as described in numerous modeling guidelines, some of which are cited by BGC, 2018d[2] in their review of the Resolution Copper Mine (RCM) groundwater model. Kolm and Van Der Heijde, 1996[3] describe a detailed approach to conceptualization and characterization of hydrologic systems, as outlined on Figure 2. Though BGC, 2019[2] attempts to review the characterization of the groundwater system (Section 3.4), and even points out "*that building a conceptual model is a crucial step before building a numerical model*", the WSP, 2019 report fails to describe a defensible baseline 3-dimensional conceptual flow model (or future post-closure conceptualization) showing the coupled surface water-groundwater system flows in any detail, using groundwater flow arrows in each aquifer, estimated discharge (at springs, seeps, streams) and recharge areas and rates as described in various reports[5].

Discussion of characterization and conceptualization of both surface water and groundwater flows, and flow interactions between them over the entire mine footprint is confusing, poorly presented and missing important details. For example:

a) The complex hydrogeologic system, especially around the proposed mine area exhibits numerous offsetting faults and multiple tilted hydrogeologic units, and is illustrated in only a single West-East cross-sections (Figure 2.2) groundwater modeling report (WSP, 2019[6]). Yet, critical conceptual details are missing, fundamental to defining an appropriate conceptual flow model (or multiple conceptual models, given subsurface complexity) of the entire potentially-impacted system. For example:

b) Perched zones are hypothesized in various supporting documents, and used to explain how many GDEs are disconnected from mine-impacted groundwater drawdowns. But no data, characterization of the lateral/vertical extents, or conceptualization of such features or associated flows are presented in the DEIS, or supporting documents. This represents a key error in conceptual modeling (see Section 4.6, Wels et al, 2012[1]). The groundwater flow model further appears to have omitted these perched zones (i.e., in upper Devils Canyon, above segment DC10.5), which should have shown lower recharge to deeper aquifer zones (see WSP, 2019, Figure 3.6), but don't appear to have been incorporated into the flow model (see Appendix B HGU Material Property Values, WSP, 2019).

c) Geothermal influence not included in the conceptual flow model, but may be important to evaluating long-term post-closure flow conditions within the subsidence area (i.e., density-driven flows, and water quality impacts).

d) The well-established industry practice (as defined in the flow chart on Figure 2 by Kolm and Van der Heijde, 1996) of going from raw data (i.e., borehole/well data) to characterization, for example of interpolated groundwater surface elevations for perched, shallow and deep aquifer units, over the mine-impacted area (including all TSF alternatives, West Plant, Superior, Queens Creek, MARRCO corridor etc), to conceptualization of flows (both vertical and lateral) within aquifer units, along faults,

[2]BGC, 2018d. Resolution Copper Project EIS: Review of Numerical Groundwater Model Construction and Approach Mining and Subsidence Area) - DRAFT. Project No.: 1704005.03. Golden, Colorado: BGC Engineering Inc. November.

[3]Kolm, K.E., Van Der Heijde, P., 1996. Conceptualization and characterization of envirochemical systems. Calibration and Reliability in Groundwater Modelling (Proceedings of the Model CARE 96 Conference held at Golden, Colorado, September 1996). IAHS Publ. no. 237, 1996.

discharge to surface, flows between surface water-groundwater, recharge from precipitation and runoff etc, is largely absent.

e) Description and illustration of the future conceptual model around the mine, or Alternative #6 TSF area (i.e., baseline conditions) were never provided. Hydrogeologic characterization associated with Alt 6 TSF is largely missing, in Dripping Springs Wash – i.e., they state "It is not known at this time whether these faults act as preferential flowpaths, or low permeability boundaries for groundwater flow[4]"

f) Given the high degree of complexity in the subsurface over the mine footprint, a realistic range of alternative conceptual models should have been considered in the modeling to account for substantial uncertainty in virtually all model input. Conceptual model uncertainty typically accounts for most uncertainty in subsequent numerical model predictions. Neuman and Weiranga, 2003[5] describe in detail how to incorporate alternative conceptual models into formal uncertainty analyses. Typically, conceptual model uncertainty dominates overall predictive uncertainty and as such should have been more fully assessed in the DEIS modeling evaluations.

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[4] Klohn Crippen Berger Ltd. 2018d. Resolution Copper Project: DEIS Design for Alternative 6 - Skunk Camp. Doc. # CCC.03-81600-EX-REP-00006 - Rev.1. Vancouver, Canada: Klohn Crippen Berger Ltd. August 8.

[5] Neuman, S.P., and Weiranga, P.J. 2003. A Comprehensive Strategy of Hydrogeologic Modeling and Uncertainty Analysis for Nuclear Facilities and Sites (NUREG/CR-6805).

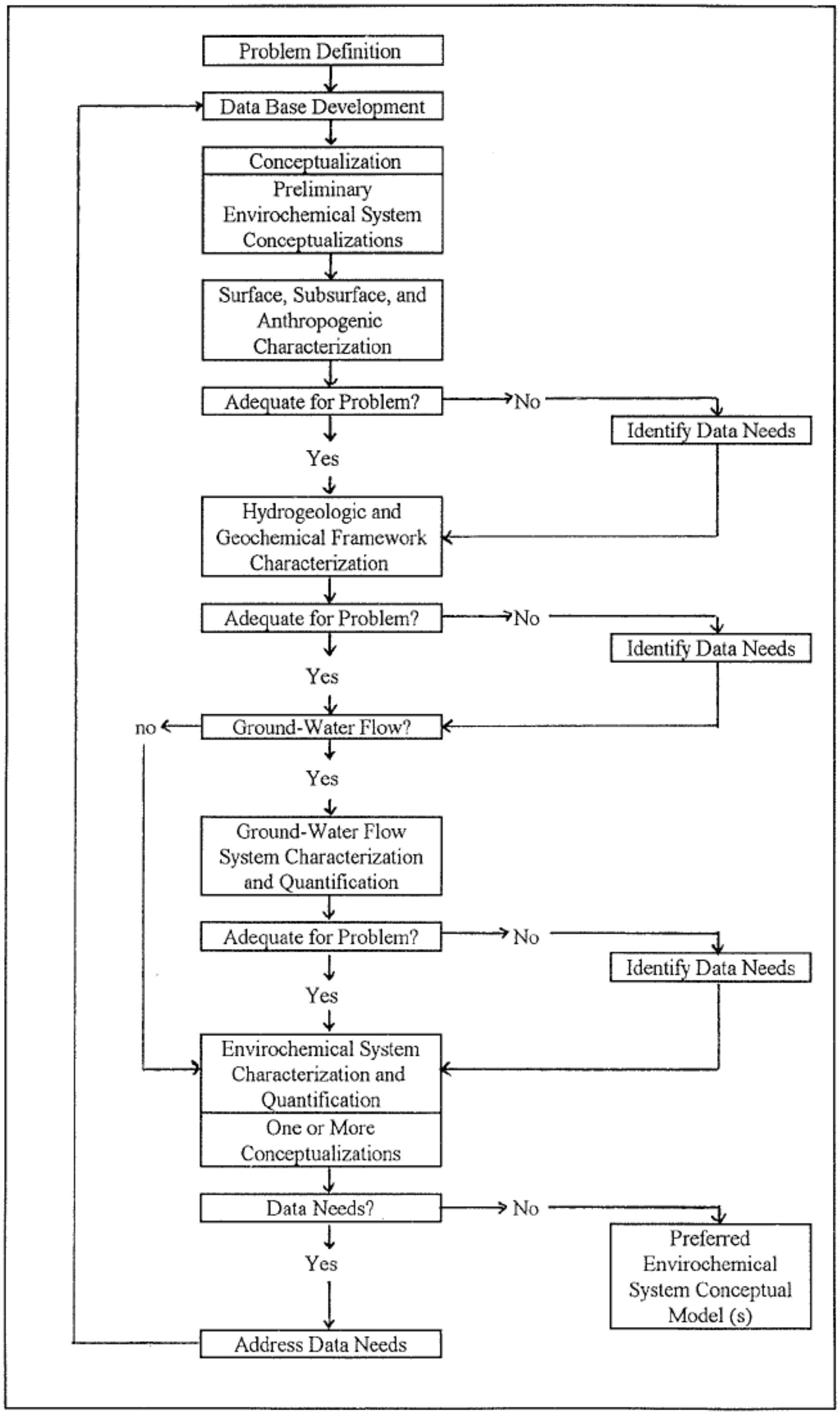

Fig. 1 Procedure for conceptualization and characterization of envirochemical systems.

Figure 2. Hydrologic Characterization and Conceptualization Approach, Kolm and Van der Heijde, 1996.

2.4 Inappropriate Codes Selected to Evaluate Impacts

Several, independent hydrologic modeling efforts were conducted in the DEIS, including the following:

1) 3D Groundwater Modeling – Modflow-surfact[6] mine-area evaluations
2) Hydrologic (Surface water) model – AWBM[7] Monthly Hydrologic Model
3) ADWR's Salt River Valley (SRV) Groundwater Flow Model – Modflow.
4) 2D Conceptual TSF Seepage modeling[8] – SEEP/W

No Formal Code Selection Conducted. A formal code selection process[9] should have been conducted to identify appropriate codes that are able to simulate all required processes needed to fully assess mine impacts on surrounding hydrology, and more importantly, to define required calibration targets for specific EIS impact assessments (i.e,. required predictive accuracy). Section 5 in Wels, 2012[1] provides details on conducting a formal groundwater model selection, even including a flow chart.

The MODFLOW-Surfact groundwater modeling tool used by WSP, 2019 to assess mining impacts at GDEs within the entire mine footprint fails to model important physical processes (i.e., overland surface runoff processes, distributed recharge and evapotranspiration dynamics, stream hydrodynamics, and stream-aquifer dynamics etc.) necessary to simulate physically realistic and defensible mine impacts on surrounding GDEs. Much more robust modeling tools are readily available, but weren't considered because a formal, industry standard code selection process wasn't conducted, where all modeling objectives/needs are carefully defined and evaluated against capabilities of available codes.

Fully integrated hydrologic/hydraulic codes should have been considered for more robust and physically realistic impact evaluation. These codes don't suffer major shortcomings such as: 1) attempting to run one model in isolation (i.e., the groundwater flow model), then attempting to couple non-dynamic results to a separate spreadsheet tool, when the flows between groundwater and surface water is complex, dynamic and spatially variable, and 2) they simulate all relevant physical flow processes and don't require unrealistic and highly uncertain boundary conditions.

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[6] WSP USA. 2019. Resolution Copper Groundwater Flow Model Report. Project No.: 31400968. Greenwood Village, Colorado: WSP USA. February 15.
[7] BGC Engineering USA Inc. 2018c. Resolution Copper Project EIS Hydrologic Model Results for DEIS Alternatives. Project No.: 1704-003. Golden, Colorado: BGC Engineering USA Inc. October 30.
[8] Klohn Crippen Berger Ltd. 2019c. Resolution Copper Project: DEIS Design for Alternative 6 Skunk Camp, Appendix IV Seepage Estimate Amendment. Doc. # CCC.03-81600-EX-REP-0006 Rev.2. Vancouver, Canada: Klohn Crippen Berger Ltd. January 30.
[9] Technical Guide to Ground-Water Model Selection at Sites Contaminated with Radioactive Substances, EPA 402-R-94-012, September 1994. NTIS, PB94-205804/XAB.

Many options are commercially-available[10] and have been applied to mine water balance projects, worldwide for many years.

1) Use of Modflow to explicitly model the effect of faults is inappropriate. Codes like FEFLOW permit actual simulation of flow along faults as planar features. Modflow-Surfact required specifying model cells (with variable dimensions unrelated to actual fault planes/zones in the field). Hydrogeologic characterization of flows along and/or across faults is largely missing – and therefore highly uncertain.

2) The variable saturation, finite element modeling code, FEFLOW, developed by DHI-WASY would have allowed a much higher resolution near critical streams, while decreasing resolution in area of less interest. This would have met stated objectives.

3) Conceptualization should have included heat transfer, due to geothermal waters encountered during construction of shaft 10, which drive density-dependent flows. FEFLOW includes the ability to simulate heat flow, and also has the ability to directly simulate 3-dimensional geochemical modeling based on PHREEQC, similar to its use in the USGS PHAST code.

4) Fully integrated, or coupled, physically-based, fully-distributed hydrologic (and hydraulic) codes have been available for decades and would have allowed RCM consultants to directly simulate the complicated, baseline and mine-impacted coupled surface water-groundwater dynamic flow system response in a robust, realistic way.

   The authors attempted to estimate spatial distributions of recharge, which is a complex spatially distributed, and dynamic process, using an undocumented method. However, fully integrated codes like the USGS GSFLOW code, DHI's code MIKESHE/MIKE11 or even Aquanty's Hydrogeosphere code actually simulate important processes like dynamic, spatially-distributed recharge, surface runoff and channelized hydrodynamics, which are dynamically coupled to subsurface flow (i.e., coupled to a modflow equivalent code). The MIKESHE code was used to simulate hourly impacts of climate change and stream temperature changes associated with Pebble Mine impacts in southeastern Alaska[11].

5) Simulate ET and Recharge processes more realistically:

- ET boundary condition – Instead of using the original MODFLOW EVT package which treats ET loss as a linear function of hydraulic head (not very physically realistic), consider using MODFLOW Riparian ET package (available for MODFLOW-2005) http://pubs.usgs.gov/tm/tm6a39/pdf/tm6a39.pdf, or even the ETS package (http://pubs.er.usgs.gov/publication/ofr00466).

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[10] AquaResource Inc. 2011. "Integrated Surface and Groundwater Model Review and Technical Guide." For The Ontario Ministry of Natural Resources.
[11] Wobus C, Prucha R, Albert D, Woll C, Loinaz M, Jones R (2015) Hydrologic Alterations from Climate Change Inform Assessment of Ecological Risk to Pacific Salmon in Bristol Bay, Alaska. PLoS ONE 10(12): e0143905. https://doi.org/10.1371/journal.pone.0143905

- Recharge boundary condition – See the following publication on the Basin Characterization Method (BCM) currently used by the USGS in a number of southwestern basins. (http://pubs.usgs.gov/pp/pp1703/b/pp1703b.pdf) or (http://pubs.usgs.gov/sir/2007/5099/).

2.5 Model Setup/Assumptions Flawed.

A number of issues were identified with the setup of the groundwater flow and TSF seepage flow models that severely limit confidence in a realistic range of mine impacts on the surrounding hydrologic system, including water quality impacts.

2.5.1 Seepage Model Setup Issues

Seepage modeling of Alternative 6 Tailings Storage Facility (TSF)[12] is problematic for several reasons, and results should not be relied upon in the DEIS:

- Data required to conduct realistic seepage modeling are inadequate, and introduce significant uncertainty in comparing different TSF alternatives, especially related to estimating valid and defensible impacts of each proposed TSF on the surrounding baseline hydrologic and water quality conditions. In effect, baseline conditions and characterization were not evaluated, but should have been in this DEIS to provide adequate comparison of alternatives.

- Only 2D simulations using the SEEP/W code were performed, when the TSF and underlying hydrogeologic system clearly exhibits 3-dimensional features which would influence groundwater-seepage flows and interaction.

- The model is not based on actual site data and 3-dimensional characterization of subsurface and surface hydrologic system. Instead, modeling is based on a simplified 2-d 'conceptual' configuration which doesn't account for important features such as variable thickness of alluvium (i.e., likely thickest along actual drainages, but thinner at TSF perimeter, away from drainage thalweg). The DEIS should assess likely impacts in this area, using actual data to constrain the 3-d hydrogeology, and local groundwater and surface water conditions. A detailed and complete 3-dimensional conceptual flow model is not presented which shows how the proposed TSF interacts with the natural groundwater and surface water flow system. Centering the TSF over Dripping Springs Wash is where groundwater flow would be expected to be upwards.

- A no flow boundary condition is placed at the surface water divide to the north, but subsurface data is missing in this area to confirm this also coincides with a groundwater divide.

- Effects of faults on groundwater-seepage flows is not assessed in the area, despite the relatively high density of faults clearly evident in exposed rocks to the west, showing notable offsets and likely influential in controlling local groundwater flows below unconsolidated alluvium.

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[12] Klohn Crippen Berger Ltd. 2019d. Resolution Copper Project: DEIS Design forvAlternative 6 - Skunk Camp. Doc. # CCC.03-81600-EXREP-00006 - Rev.1. Vancouver, Canada: Klohn Crippen Berger Ltd. August 8.

- No effort was made to assess impacts of stream routing/diversions around the TSF, and effects of streambed infiltration on shallow groundwater-seepage flows, and associated fate/transport of impaired waters downstream.

2.5.2 Groundwater Flow Model Setup Issues

Several issues were identified with the groundwater flow[6] model setup and are described here.

Model Extent and Boundary Inappropropiate. Just based on reported results using the 10-foot contours, it's clear predictions of mine drawdowns are impacted by the model boundary condition. Had a 1-foot drawdown contour been reported in the modeling, boundary effects would have likely been far more extensive. it would likely show a much greater degree of boundary impact on the model. This boundary should have been extended outward in all directions to:

- avoid influencing internal calculations. This is standard industry practice[13].

- simulate flow conditions for at least preferred Alternative 6 TSF, and downgradient impacts to Gila River, so that:

- fate and transport modeling of seepage from the TSF could have been properly assessed in Dripping Springs Wash,

- 2D seepage modeling[8] could have used realistic/calibrated groundwater boundary conditions as boundary conditions on simulations estimating seepage through the TSF.

- permit estimating impacts down to at least 1' drawdown, which likely extend much further out than estimated maximum extent shown in the DEIS (see Figure 3.7.1-3)

Inappropriate Stream-Aquifer Setup/Assumptions. Use of MODFLOW drain package to simulate stream discharge is in appropriate for several reasons:

- It only permits removal of groundwater from the model, but no streambed recharge in losing river reaches. This is a major flaw in the model setup and non-standard. Many other high profile recent mining DEIS modeling efforts (i.e., Pebble Mine, Rosemont Mine) have utilized the much more robust MODFLOW stream routing packages (STR1, STR2), which actually dynamically route baseflow discharge from upper reaches to lower reaches, which permits downstream recharge in areas where underlying aquifer heads are lower than the dynamically calculated stream stage. Not accounting for streambed recharge results in either under-simulation of heads in critical GDE areas, or incorrect adjustment of other parameters (i.e., reduction in hydraulic conductivity in stream areas) to compensate for lack of focused, higher streambed recharge.

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[13] Reilly, T.E., and Harbaugh A.W., 2004. Guidelines for Evaluating Ground-Water Flow Models, USGS, Scientific Investigations Report 2004-5038.

- Drain 'hydraulic resistance' or drain conductance was set 'sufficiently high' (see page 23, paragraph 5, WSP, 2019) so they would not exhibit resistance to flow. Even if it were acceptable to use one-way flow drain discharge to simulate river discharge, the standard modeling approach is to define drain conductance values as a primary calibration parameter. The modelers here have effectively removed a key parameter value from the calibration process, and specifying high conductance prior to calibration is not valid and should be based on actual field-based measurements and careful calibration (but using a river package, and not a 'drain' package).

- No attempt appears to have been made to couple the MODFLOW drain discharge distribution with surface water modeling (BGC, 2018), so that predicted impacts due to mining on surface water flows could be better simulated, despite simulating at a monthly time period.

Inappropriate Seepage Setup/Assumptions. Springs and seeps do not appear to have been simulated as discharge points in the Modflow model. It would been appropriate, and is typical, to use the Modflow Drain package to simulate discharge at these areas. Not simulating discharge in these areas would cause the model to over-estimate heads otherwise controlled by discharge to seeps/springs.

Areal Recharge Specification Inappropriate

- Many books have been written on the subject – it is complex, but critical to acceptable calibration (Healy and Scanlon, 2010[14]). The USGS[15] has developed a commonly used method called the Basin Characterization Method (BCM) to estimate recharge based on many known factors.
- Factors that Schlumberger indicates control recharge (slope and geologic 'infiltration multipliers) are only some of the factors actually determining recharge at any given cell. No references to this estimation of recharge are provided, yet this is a critical model input, typically strongly correlated with hydraulic conductivity, and influencing calibration.
- Recharge zonation into upper and lower zones, and 'enhanced recharge' zones along Queen Creek and Devils Canyon (see paragraph 1, page 25, WSP, 2019) is arbitrary and unjustified, and has significant effects on calibration. WSP, 2019 states "These zones were conceptualized to concentrate runoff that would lead to higher infiltration rates, which were set at 4% and 8% for the lower and higher elevation areas, respectively. As runoff is concentrated in these areas, water is stored in surface soils longer, providing more time for infiltration and hence a higher recharge rate." This statement is physically incorrect, as streambed recharge occurs only along streams, as indicated in Simmers, 1988[16]. Moreover, the aerial recharge specified in the model (Figure 3.6, WSP, 2019) incorrectly assigns high recharge within a nearly ½ mile wide zone around each of these key mine-impacted

[14] https://pubs.er.usgs.gov/publication/70189200

[15] https://www.researchgate.net/publication/252321691_Fundamental_Concepts_of_Recharge_in_the_Desert_Southwest_A_Regional_Modeling_Perspective

[16] Simmers, I., 1988. Estimation of Natural Groundwater Recharge. Springer Netherlands.

drainages, which causes too much recharge in these areas, and in turn reduces mine impacts. If the model had been calibrated against surface flows (both discharge and recharge), along with a proper number of wells along each of these drainages, recharge in these areas would have been much better constrained. This is a major problem in the DEIS, which focuses on assessing mine-impacts to these very drainages.

Actual Evapotranspiration (AET) from Groundwater is Not Simulated

- Calculation of AET is in fact, a critical water balance component in most hydrologic models, and a complicated function of complex climate inputs (generally accounted for in more robust estimates of PET, like the standard ASCE or FAO Penman-Monteith equation[17]), soil properties (i.e., soil types, layering, moisture contents, unsaturated zone hydraulic properties), precipitation, groundwater depths with time, and vegetation properties (i.e., leaf area index, root depth density with depth, crop coefficients, types, saturation, residual and field and wilting point moistures, canopy properties etc). In single-process codes like MODFLOW, AET is typically simulated either using the standard EVT package, which calculates AET on a cell-by-cell basis, as a function of groundwater depth, maximum evapotranspiration rates, and plant root depths, or by specifying net-recharge, where AET is calculated on a cell by cell basis, and then removed from applied recharge. Importantly, assessing sub-daily impacts at specific locations in the model is strongly influenced by correct calculation of AET. In riparian zones, groundwater loss to AET and baseflow discharge compete against each other, as a function of groundwater depth. Consequently, without directly simulating AET in all cells, groundwater models likely overestimate baseflow loss, and incorrectly parameterize stream-aquifer conductance values. Omitting this critical process (a conceptual error, especially in semi-arid climates) prevents estimation of mine impacts on phreatophyte-dependent riparian vegetation. This is a major oversight in the DEIS evaluation of impacts at GDEs.

Modeling of Groundwater Fate/Transport from Mine not Considered. WSP 2019[6] groundwater model sensitivity analysis provided a range of expected drawdowns, despite not being produced by a robust predictive uncertainty analysis, or by adjusting more realistic changes to key model inputs (i.e., distributed parameter and combinations of parameters). The Block Cave Geochemical modeling (Eary, 2018[18]) apparently did not evaluate or discuss predictive uncertainty, which could be quite high due to the high number of input parameters (beyond groundwater flow model), and high uncertainty in inputs/assumptions.

Subsidence Not Evaluated – Salt River Valley ADWR Model. No effort was made to estimate subsidence in the important Phoenix AMA area, though drawdowns are estimated and subsidence potential acknowledged. Garrett 2018 → states:

> On Page 9, paragraph 2 "*Long-term drawdown from Desert Wellfield pumping of 10 to 30 feet is modeled to occur in the nearby known subsidence areas. Any groundwater*

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[17] http://www.fao.org/3/X0490E/X0490E00.htm

[18] Eary, T. 2018f. Block Cave Geochemical Model - 2018 Update on Calculation Approach and Results. Technical memorandum. Loveland, Colorado: Enchemica, LLC. June 26.

pumping within a groundwater basin with known subsidence has the potential to contribute to that subsidence, including the pumping from the Desert Wellfield.

Further detailed analysis is not feasible beyond noting the potential for any pumping to contribute to drawdown and subsidence. Subsidence effects are a basin-wide phenomenon, and analytical tools do not exist to isolate the impact from one individual pumping source on subsidence."

The Modflow Subsidence package[19] (2003) could easily have been used to assess likely impacts of MARRCO pumping on subsidence.

Evaluation of future drawdown at surrounding wells not conducted. About 285 wells (ADWR database) would be impacted within the 10' drawdown (at 200 years), and more than 400 wells would probably be impacted by drawdowns of at least 1 foot. This is easily done with a properly calibrated model and predictive uncertainty analysis. Newell and Garrett 2018[20] state, page 10, paragraph 3 "*In lieu of analyzing individual wells, typical wells in key communities were analyzed using the groundwater flow model, including wells near Top-of-the-World (using well HRES-06 as a proxy), wells within the town of Superior (using well DHRES-16 as a proxy), and wells near Boyce Thompson Arboretum (using the Gallery well as a proxy)*." Proxies give a misleading sense of impacts to surrounding wells because drawdown is spatially complex. The DEIS should have evaluated a range of maximum drawdowns (given uncertainty in predictions) in all wells, regardless of the amount.

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[19] Höffmann, J., Leake, S.A., Galloway, D.L., and Wilson, A.M., 2003, MODFLOW-2000 Ground-Water Model--User Guide to the Subsidence and Aquifer-System Compaction (SUB) Package: U.S. Geological Survey Open-File Report 03-233, 44 p.

[20] Newell, E., and C. Garrett, 2018. 2018d. Water Resource Analysis: Assumptions, Methodology Used, Relevant Regulations, Laws, and Guidance, and Key Documents. Process memorandum to file. Phoenix, Arizona: SWCA Environmental Consultants. August 8.

2.6 Model Calibrations Unreliable

A number of issues identified with model calibration are summarized here.

2.6.1 Calibration Approach Flawed and Non-unique

Calibrating groundwater flow models to only hydraulic heads, which are spatially biased with higher density near the proposed mine, and sparse further from the mine is well known to produce non-unique solutions.[21] The non-unique solution is typical of groundwater models where recharge and hydraulic conductivity values are highly correlated[22]. Doherty and Hunt, 2010[23] indicate that non-unique solutions can be addressed by adding other types of calibration data (i.e., surface water discharge, water quality data etc).

Representing seasonally dynamic gaining/losing surface water flows as 'drain' cells in the groundwater model, fails to account for stream recharge in losing reaches. This in turn forces incorrect adjustments of hydraulic parameter values to compensate, and further degrades calibration and therefore reliability of the groundwater model for predictions.

2.6.2 Adequate Calibration Data Lacking

The main focus of the DEIS is to estimate potential changes to the surface/subsurface hydrologic system, or GDEs affected by mine drawdown and changes to surface flows. Despite this objective, virtually no observation data for either surface water, or groundwater is available at, or near GDEs to constrain calibration in these critical areas. This is a major flaw in the overall model calibration approach and should have been addressed in the DEIS.

Other major mine modeling efforts (i.e., Rosemont mine[24]) attempt to reproduce spatial distribution and magnitudes of observed baseflow, but the spatial distribution and long-term (i.e., multiple years) of surface water flow (or stage) data appears inadequate to assess even flow along the entire extent of the three main drainages potentially affected by the mine dewatering/TSF (Queen Creek, Mineral Creek and Devils Canyon).

2.6.3 Pre-mining Conditions, and period from 1910 to 1996 Uncalibrated.

[21] Castro, M. C., and P. Goblet, Calibration of regional groundwater flow models: Working toward a better understanding of site-specific systems, Water Resour. Res., 39(6), 1172, doi:10.1029/2002WR001653, 2003

[22] Jyrkama, M. I., and J. F. Sykes (2006), Sensitivity and uncertainty analysis of the recharge boundary condition, Water Resour. Res., 42, W01404, doi:10.1029/2005WR004408.

[23] Doherty, J.E., and Hunt, R.J., 2010, Approaches to highly parameterized inversion—A guide to using PEST for groundwater-model calibration: U.S. Geological Survey Scientific Investigations Report 2010–5169, 59 p.

[24] O'Brien, G. 2010a. Technical Memorandum: Groundwater Flow Model Construction and Calibration. Document No. 198/10-320874-5.3. Prepared for Rosemont Copper Company. Tucson, Arizona: Tetra Tech. July 26.

The approach to determining pre-mining initial 3-dimensional heads (1910) for 39 model layers was never presented in the WSP, 2019 modeling report, but the DEIS really should have required detailed description of these conditions and how they were derived, and associated errors. They are critical to assessing the nature of long-term post-closure groundwater recovery, rather than attempting to assess recovery relative to the start of RCM pumping in 2009, which already induces a substantial drawdown response, superimposed on the partially-recovered heads from 1910 to 1996 pumping. This is essential information in conservatively assessing mine impacts on GDEs.

From 1910 to 1996, the model appears uncalibrated (no reporting on this in DEIS, or WSP, 2019 report) even the historical pumping locations are largely unknown[25], which likely introduces substantial error into the calibration, and further uncertainty in predictions, as the heads by start of RCM pumping in 2009 were no where near recovered to pre-mining conditions.

2.6.4 Calibration Targets Don't Match Modeling Objectives

Page 30, paragraph 7 in WSP, 2019 states "*The strong drawdown responses shown in the Deep Groundwater System in response to dewatering of Shafts 9 and 10, is clearly seen in some of the wells inside Resolution graben, specifically DHRES-01_WL, DHRES-02_WL and DHRES-08_231. These wells were prioritized as key targets to match, as pumping of Shafts 9 and 10 essentially represents a large-scale aquifer test. The fit of these three targets is good and gives an indication of how the model will respond to a large stress on the system, such as the development of the RC mine.*" It is clear from this statement that the focus of the WSP, 2019 model calibration was aimed more at quantifying key inputs useful to the design/operation of the mine (i.e., mine inflow, time to drawdown mine etc) rather than focusing on calibration that would minimize errors at what should have been key priority targets, the GDEs.

Much of the DEIS assessment of mine impacts on the surrounding environment is devoted towards assessing how mine dewatering causes groundwater declines at numerous surrounding GDEs, and therefore also changes in surface water discharge. An arbitrary 10-foot decline is used to identify those GDEs that would be impacted, because the groundwater modeling group deemed the model to be less 'precise' below 10 feet. By not relying on results less than 10 feet drawdown, RCM in effect sets a key calibration target. As such, model calibration should have focused on GDEs. In otherwords, calibration error (or residuals) should have been minimized at all GDEs, and if clearly reported in the DEIS, so that errors in drawdown are well known. This information would then be useful in estimating a range of uncertainty in drawdown predictions at GDEs.

2.6.5 TSF Seepage Modeling Unreliable

[25] Keay, T. 2018. Locations of historical pumping. Personal communication from Todd Keay, Montgomery and Associates, to Chris Garrett, SWCA Environmental Consultants. Clarification requested regarding DEIS. Email dated December 12, 2018.

Review of the seepage modeling[26] associated with TSF alternatives (particularly #6) shows this modeling was never calibrated, because it was based on an idealized, conceptual 2-d profile, rather than using actual field-derived hydrogeologic data. It is understood that the authors of this study (at preferred alternative #6) believe conceptual modeling of this complex, but critical mine component is adequate for assessing different alternatives. But numerous assumptions were made about the subsurface and boundary conditions which would affect leakage estimates, including the implicit assumption that groundwater flows beneath the proposed TSF (for all possible future climate conditions and meteorological conditions) would never interact with internal seepage calculations, which are not conservative. The TSF and surrounding hydrogeologic system is a 3-dimensional flow system, where groundwater flows concentration beneath the central surface drainage. No surface water or groundwater data, or hydrogeologic data support the notion groundwater wouldn't interact with the calculated seepage. If it did, this becomes critically important in subsequent evaluations of water quality impacts both during mining, and post-closure – and comparison of alternatives. Ultimately, estimates of seepage rates during mining and post-closure are not calibrated, and therefore unreliable.

2.6.6 Presentation of Calibration Results Incomplete/Misleading

Model performance and reliability based on model-wide calibration statistics of only head data gives a misleading and unreliable sense the model is adequately calibrated for intended purpose of evaluating impacts at GDEs. For the high degree of hydrogeologic complexity of the subsurface system, including multiple offset faults, perched, shallow and deep aquifer units and historically complex dewatering in the area, the number, locations and depths of calibration targets is inadequate, particularly in key target GDE areas, the main focus of the groundwater modeling evaluation. For example, Table 3.6 in the WSP, 2019 report indicates Residual Mean in the Apache Leap Tuff is -14 ft, indicating on average, the model over-estimates heads in this shallow aquifer. Yet, closer inspection of transient well hydrographs included in Appendix C of WSP, 2019 closer to surface drainages (i.e., DHRES-08, DHRES-10, DHRES-11, DHRES-12, DHRES-17 and DHRES-18) indicates simulated differences more than 100 to more than 600+ feet

Spatial Bias in Calibration. The WSP, 2019 report shows calibration 'Scatter Plots' (see Figures 3.9 and 3.10), but never show spatial bias and residuals at specific wells by aquifer unit. This is essential for assessing calibration error (residuals) at specific GDE locations, generally along streams.

Hydraulic Tests. Calibration to 2 aquifer hydraulic tests appear to reproduce drawdowns in several wells, and even anistropic drawdown trend, but the mine dewatering will continue for several decades, and these hydraulic tests have limited value:

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[26] Klohn Crippen Berger Ltd. 2019c. Resolution Copper Project: DEIS Design for Alternative 6 Skunk Camp, Appendix IV Seepage Estimate Amendment. Doc. # CCC.03-81600-EX-REP-0006 Rev.2. Vancouver, Canada: Klohn Crippen Berger Ltd. January 30.

- Tests are far too small a stress on the aquifer to confirm parameterization, assumed boundary conditions for most of the GDEs.
- These tests already confirm aquifer response in spatially-biased high density of mine wells.
- These tests don't confirm influence of all faults included in the model. It would have been far more instructive to conduct tests, monitoring hydraulic response on both sides of important bounding faults (or faults that act as preferential conduits of groundwater flow.

2.7 Predictions Incomplete and Misleading

A number of issues were identified by predictions in the DEIS, or supporting documents. These are described below.

2.7.1 Predicted change from proper Baseline Conditions Biased.

Historical Magma Mine pumping occurred from 1910 to 1998. RCM pumping started in 2009 (WSP, 2019). WSP states (page 4, paragraph 6) "Water levels had recovered to approximately 2,200 ft amsl by the time dewatering was resumed on March 17, 2009". This clearly indicates the groundwater levels in the vicinity had not fully recovered, and therefore do NOT represent a proper baseline, or pre-mining condition. Pre-mining Furthermore, it is likely streamflows (and springs) in the area that would have been impacted by historical Magma Mine pumping, and which would have recovered had RCM not restarted pumping in 2009, would have increased the number of baseline GDEs in the area (i.e., Devil's Canyon stream from DC10.9to DC15).

Pre-mining (baseline) heads for the Tal shallow aquifer are presented in WSP 2019, but no discussion of associated interaction of groundwaters with surface waters during this period is presented. The DEIS should have evaluated RCM mine dewatering and post-closure crater subsidence related to this condition, as the Magma mine dewatering would presumably have recovered to near these levels.

2.7.2 Predicted flow through fractured crater limited because of model instability.

Page 38, paragraph 1 WSP 2019 indicates that hydraulic conductivities within the fractured crater were limited to only 100 ft/day due to instabilities in the model, if assigned higher values. The fracturing likely produces much higher conductivity values than 100 ft/day, which would enhance vertical drainage from the overlying shallow Tal aquifer due to block caving. The DEIS should require detailed assessment of hydraulic response (or recovery for post-closure) to better assess impacts of this important post-closure condition. It is possible the recovery of water levels post-closure would have been much quicker, leading to better estimates of drawdown and GDE impacts (instead of limiting impacts to 148 years after closure, and 10' drawdown contours).

2.7.3 Evaluation of effect of geothermal water on post-closure flows and water quality not conducted.

No evaluation was presented in the DEIS or associated documents to evaluate geothermally influenced circulation within the post-closure fracture zone, which would act to circulate deep warmer waters with shallow, cooler inflow from ALT aquifer waters, driven by density variations (i.e., warmer waters rise, inducing vertical mixing). Geothermal waters were encountered in Shaft 10[27], which surprised RCM and consultants. Often, geothermal waters are found in permeable fault zones, or where faults intersect each other[28]. Because multiple faults are present in the mine area, the DEIS should have required more characterization, conceptualization and use of an appropriate code capable of simulating heat transport and associated effects of density-driven circulation to better estimate long-term post-closure conditions, and water quality impacts. It's unclear why RCM didn't consider potential to develop the geothermal water source to offset energy requirements.

2.7.4 Clear disclosure of full hydraulic impacts is missing.

Montgomery & Associates, 2017[29], Page ES-6, states "*However, the Magma Mine workings do extend west of the fault, providing the potential for hydraulic impacts to extend beyond the fault.*" A clear description and explanation of the final 3-d mine closure configuration is never presented. It is apparent that WSP failed to account for the change in land surface in their modeling (~800 to 1100 feet). This is a critical oversight in the DEIS, because had a proper future-condition conceptual model been developed showing the 800 to 1000 ft drop in land-surface, it would have required a similar change in the calibrated model. Simulating long-term (steady state to avoid uncertainty associated with the time it takes for system to recover to pre-mining conditions) post-closure conditions would very likely have shown development of a pitlake (see Section 2.7.7). This is a major impact to the system which the DEIS failed to address.

2.7.5 Inappropriate Predictions of Post-Closure Impacts

WSP, 2019[30] Page 4, Paragraph 4 states "*As water level recovery within the block cave is slow, some areas show additional drawdown continuing to propagate outward after 200 years as steady state equilibrium conditions have not yet been re-established.*" Prediction of post-closure hydrologic conditions at an arbitrarily chosen 200 years (or 148 years after closure) is very misleading and incorrectly conveys what will really occur at final steady state conditions. The modeling report suggests even at 148 years post-closure, drawdown is still occurring, due to slow/low recharge, though the flawed calibration/non-unique solution produce model results so

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[27] E&MJ (Engineering and Mining Journal), 2014. Sinking America's deepest shaft: Engineering and Mining Journal—April 2014—Features. Available online at: https://www.e-mj.com/features/sinking-america-s-deepest-shaft/

[28] Prucha, R., S. M. Benson, and P. A. Witherspoon. 1987. Conceptual Model of the Klamath Falls, Oregon Geothermal Area. Proceedings of the 12th Annual Workshop, Geothermal Reservoir Engineering, 20-22 January 1987, Stanford, California.

[29] Montgomery and Associates Inc. 2017b. Analysis of Groundwater Level Trends, Upper Queen Creek/Devils Canyon Study Area: Resolution Copper Mining LLC, Pinal County, Arizona. Prepared for Resolution Copper. Tucson, Arizona: Montgomery and Associates Inc. February 2.

[30] WSP USA. 2019. Resolution Copper Groundwater Flow Model Report. Project No.: 31400968. Greenwood Village, Colorado: WSP USA. February 15.

uncertain SW discharge is not relied on. Clearly the 200 years should not have been arbitrarily used to assess long-term final impact w/uncertain model. This biases estimated drawdown impacts at GDEs towards the low side (not conservatively high as suggested in the WSP study. By comparison, the modeling conducted for the Rosemont DEIS demonstrated Steady State conditions were achieved at streams of interest (at 1000 years out). This continued drawdown by itself should have alerted modeling group to insist on simulating much longer, or steady state post-closure.

2.7.6 Use of 10-foot Drawdown Contour Misleading/Biased

At least a simulated long-term 1-foot drawdown contour should have been used in the identification of GDEs. GDEs, or private wells experiencing even a 1' drawdown could have significant negative impacts. A simulated 1-foot drawdown contour (or lower) was never shown in the DEIS, but probably shows significant effects of model boundary effects, implying the model extent should have been expanded to avoid any influence over internal calculations as is standard modeling practice. Using the 10-foot drawdown contour to define impacts is highly biased, and likely removes many GDEs from further evaluation of impacts/mitigation. The explanation that drawdowns less than 10-feet are imprecise in the DEIS (see page 301) is flawed. Groundwater models are precise, but suffer from accuracy issues. The accuracy at 1-foot drawdown is the same as 10-feet. A predictive uncertainty analysis would effectively provide a means of adding a +/- around drawdown contours.

2.7.7 Assessment of potential Pitlake development/impacts flawed

Pitlake Development. WSP 2019 states on Page 1, Paragraph 2 that 'the potential for a pit lake will be assessed'. Yet the modeling study failed to present any further details on the potential for a pitlake to develop, and to then characterize and evaluate impacts of the pitlake on surrounding flows and water quality. Page 376-377 in the DEIS do describe the 'Potential for Subsidence Lake Development', explored by the Groundwater Modeling Workgroup, but the DEIS states on page 377 "*Ultimately the Forest Service determined that the presence of a subsidence lake was speculative and not reasonably foreseeable, and as such it would therefore be inappropriate to analyze in the EIS*" Table 3.7.2-7 provides an overview of predicted water levels after 1000 years and the DEIS concludes "*groundwater levels are still at least 200 feet below the bottom of the subsidence crater*". However, there are two key reasons why it is likely a pit lake would form post-closure:

- The flow model is highly uncertain, and non-unique due to calibration to only groundwater head data, and not other common calibration datasets (i.e, surface discharge, water quality etc) that would reduce non-uniqueness. As a result, estimated water level recovery at 1000 years is highly uncertain, and levels would likely recover much quicker.
- More importantly, conceptually, it is easy to argue that the groundwater levels will eventually recover to pre-mining levels (steady state), and at least to currently monitored levels, known to be influenced by Shaft 9/10 pumping since 2009. In fact,

these recovered levels, at wells DHRES-01 and DHRES-02 within the crater, exceed 3650 ft, MSL for various screened zones (see observed levels in WSP 2019 report, Appendix C for different well screen zones). According to DEIS Figure 3.7.2-4, these recovered levels would be more than 650 feet above the 1100 ft subsidence crater land surface, and more than 350 feet above the 800 ft landsurface elevations (3000 ft, and 3300 ft, respectively).

- WSP, 2019 failed to include the change in the ground surface due to the crater in the future condition groundwater modeling. Conservatively, they should have dropped the surface 1100 ft, and let the groundwater model simulate eventual development of the subsidence crater, which would, like the Rosemont mine DEIS modeling that also showed long-term development of a pitlake, change the long-term, or eventual groundwater flow regime. More importantly, with continued evaporation, the pitlake waters would likely also significantly change predicted long-term water quality predictions and risks in the area of this pitlake.
- Figure 1 from Meza-Cuadra, 2018b[31] was revised to reflect conceptually what the WSP, 2019 groundwater model should have simulated (change in land surface), and the eventual development of a pitlake as groundwater levels recover. WSP should have included this type of Future Processes Conceptual Model, which is industry standard (see Potential Errors in Conceptual Modeling, Section 4.6 in Wels, 2012[1]). Rosemont DEIS groundwater modeling of the development of a pitlake was developed using Modflow-Surfact coupled to a dynamic systems model using the GoldSim code[32].

[31] Meza-Cuadra, G., C. Pantano, and D. Oliver. 2018a. Resolution Copper Groundwater Flow Model - Predicted Flows to Block Cave. Memorandum. Greenwood Village, Colorado: WSP. September 28.
[32]Roemer, G, Gabora, M., Hudson, A., Williamson, M., 2012. Hydrogeologic and Geochemical Prediction of Rosemont Pit Lake Using Three Different Modeling Programs. 9th Intl. Conf. on Acid Rock Drainage, At Ottawa, CA.

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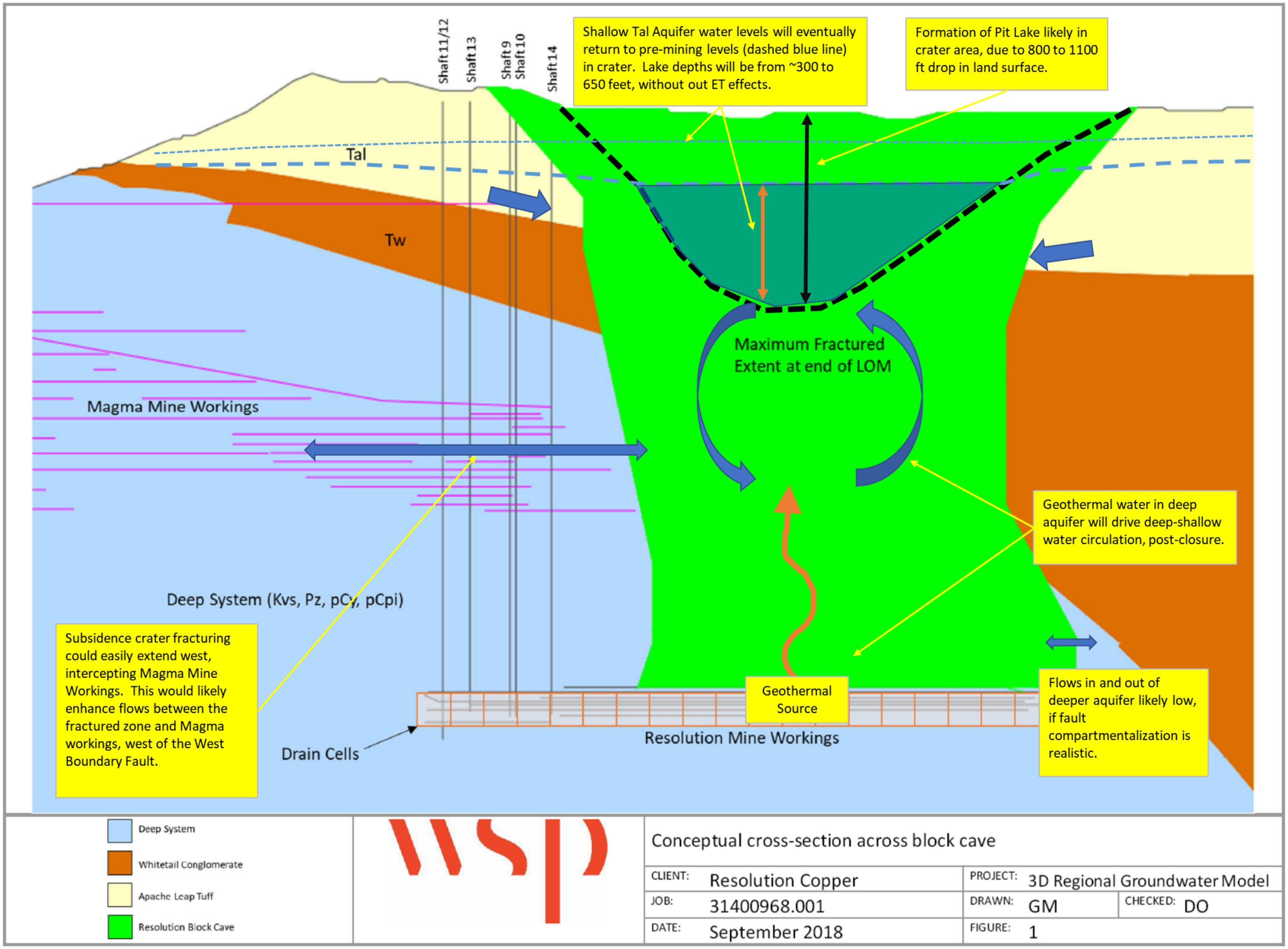

Figure 3. Modified conceptual West-East section through future fractured crater. Note it shows no adjustment to landsurface. Recovered water levels and revised groundsurface added.

Figure 4 below shows a more likely long-term drawdown (at steady state, not arbitrary 148 years after closure) 4 km out from the arbitrarily chosen 10' drawdown, which should really have shown predicted drawdowns of <1', or something which would impact groundwater discharge areas (springs, baseflow in streams, riparian vegetation etc). The figure shows that additional SW areas would likely be affected by long-term drawdown, than evaluated in the DEIS. The DEIS should have also assess impacts within the following watersheds:

- **a.** North of Queen Creek, including Haunted Canyon, Upper Pinto Creek, and West Fork watersheds.
- **b.** Walnut Canyon to the south, which drains into the Gila River via Donnelly Wash.

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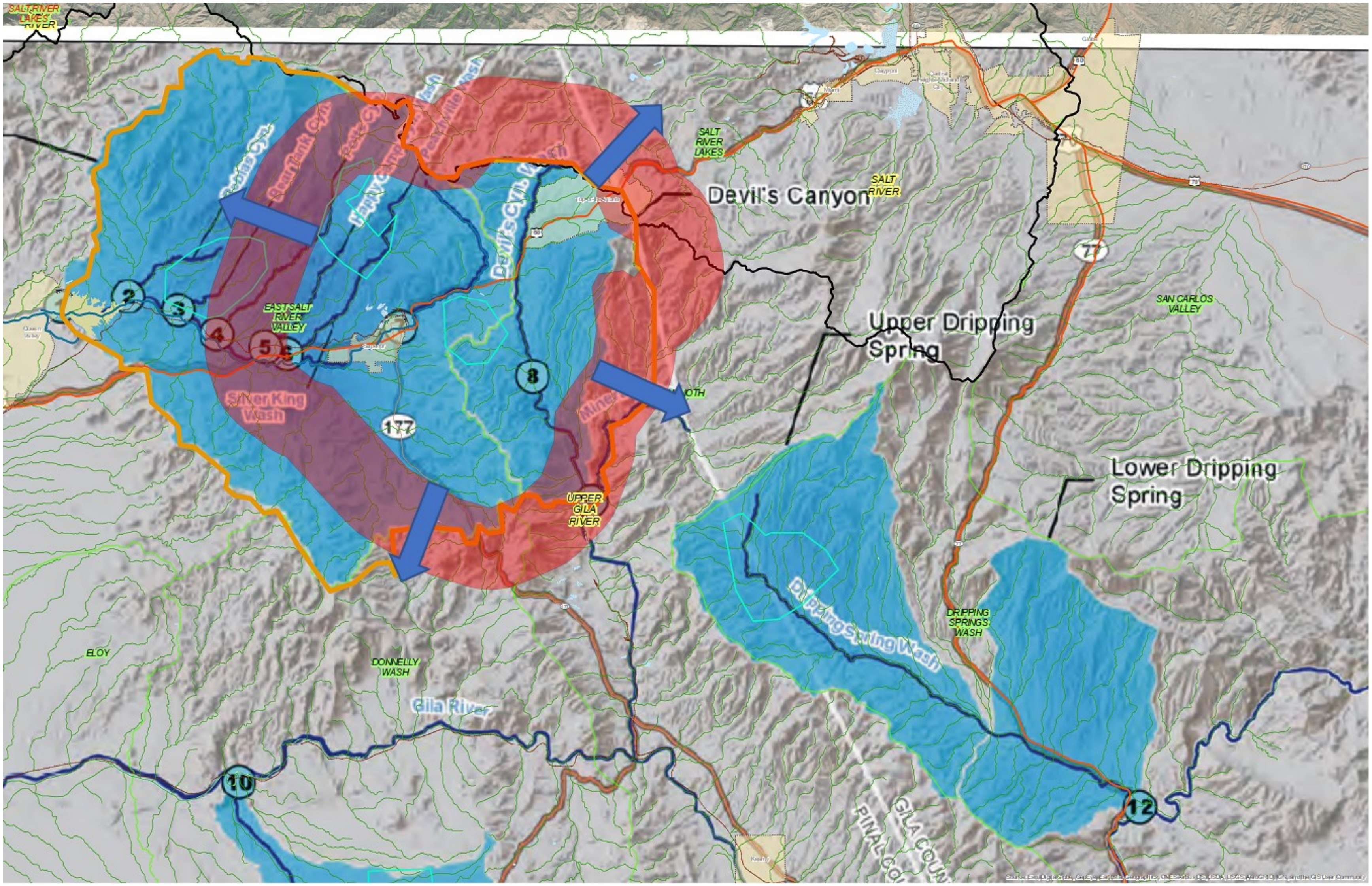

Figure 4. Long-term Drawdown (greater than 1 foot) likely extends several kilometers out in all directions (Red zone shows 4 km buffer around 10 foot maximum drawdown area in DEIS. Blue areas are SW Quantity Analysis Areas (from Figure 3.7.3-1 in DEIS).

2.7.8 Predictive Uncertainty Evaluation Missing

The Groundwater Modeling WorkGroup appeared to acknowledge uncertainty in their modeling predictions of drawdown extent, but then failed to provide a range of predictions for all predictions. Other modeling efforts also appear to have failed to consider any type of predictive uncertainty, despite substantial calibration errors and high input uncertainty. The DEIS should have required a comprehensive approach to dealing with any modeling uncertainty in all model predictions. All of the models developed and referenced in this DEIS (and supporting documents) have numerous assumptions and inputs, each of which translate into prediction uncertainty, but none address the substantial uncertainty in predictions, let alone even identifying and tracking all sources of uncertainty.

Impacts of the proposed Desert Wellfield pumping wells near the proposed MARRCO corridor were evaluated by Bates et al, 2018[33], using ADWR's 2009 Salt River Valley (SRV) model[34]. The ADWR SRV modeling effort never included a predictive uncertainty evaluation, nor did the predictive modeling by Bates et al, 2018. This would have been well warranted in the proposed pumping area, as data used to support model construction are clearly absent in this area. As a result, predictions using this model, in this area are expected to be exhibit high uncertainty, relative to other areas in their model domain, which had much greater data to justify model construction.

Evaluation of hydrologic model prediction uncertainty is critical, yet modelers confused sensitivity evaluation for standard/formal predictive uncertainty analysis. It is important to note that the non-uniqueness of the groundwater flow model calibration (remembering that it was only calibrated to heads, and not discharge, water quality etc) leads to many equally valid predictive solutions. Assessment of the range of possible impacts of the mine on surrounding hydrology (and WQ) is therefore, inadequate and unreliable. It is misleading/incorrect to assume flawed/unreliable model simulated drawdowns above 10 feet are accurate, and those below are inaccurate. GDEs are very sensitive to groundwater levels – and even a 1-foot change likely significantly changes spring/river discharge or even presence. Gabora et al, 2014[35] appropriately used a Monte Carlo method to predict an entire range of simulated pit model inflows, while maintaining calibration.

The reliability of the model findings is implicitly tied to the accuracy of the model, which by default is uncertain, like all models. Model accuracy can be improved by collecting more data, increasing discretization and better reproducing observations, but in reality this is impossible to achieve, given that models are simplifications of flow systems, and data will always be limited. As such,

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[33] Bates, B., T. Bayley, and H. Barter. 2018. Simulation of Drawdown Impacts from Desert Wellfield. Project #: 605.75. Technical memorandum. Tucson, Arizona: Montgomery and Associates. September 13.
[34] Freihoefer, A., D. Mason, P. Jahnke, L. Dubas, and K. Hutchinson, 2009, Regional Groundwater Flow Model of the Salt River Valley, Phoenix Active Management Area, Model Update and Calibration: Arizona Department of Water Resources, Modeling Report No. 19.
[35] Gabora, M., Martin, N., Clements, N. 2014. Application of the Null Space Monte Carlo Method in a Groundwater Flow Model of Mine Pit Dewatering. An Interdisciplinary Response to Mine Water Challenges - Sui, Sun & Wang (eds).

it is far more important for RCM consultants to acknowledge uncertain model predictions, and instead conduct a detailed and robust predictive uncertainty analysis which focuses not just on predicted groundwater inflow to the pit lake, but also on predicted response at all other mine components, at the same time. A sensitivity analysis (ASTM D5611[36]) doesn't provide a range of possible predicted responses given ranges of uncertain model inputs like an uncertainty analysis, which constrains realizations to maintain calibration within acceptable targets (Doherty, 2010).

Modelers appear to have confused a predictive sensitivity analysis with a predictive uncertainty analysis. The distinction is very important, as a sensitivity analysis does not provide a true assessment of model uncertainty (see Neuman and Weiranga, 2003[5], Doherty et al, 2010[38]) – typically perturbations cause the model to fall out of calibration, which make the results unreliable. Yet the authors report a range of output from simulations using arbitrary adjustment of selective (i.e., cherry picked) parameters, to imply they've considered the full range of possible impacts at GDEs, despite the modelers using the PEST code (described by code author Doherty, 2010) to help refine model calibration (see page 27, WSP, 2019), they failed to use the same code to conduct a predictive uncertainty analysis.

The failure of this DEIS to require formal uncertainty analyses for all of the modeling predicting impacts to the surrounding environment/GDEs is a major oversight. As Doherty et al, 2010 states "*Central to any decision-making process is an assessment of risk. Such an assessment is impossible without some assessment of predictive uncertainty.*", which clearly supports the need for some type of uncertainty analysis to qualify predictions.

Ultimately, model predictions of impacts on GDEs are considered highly uncertain, due to a combination of the high level of input uncertainty, high conceptual model uncertainty, uncertainty in calibration data, and notable model error. While it appears that the the groundwater modeling workgroup has acknowledged results are uncertain, especially with distance from the mine operations, further evaluation of uncertainty was dismissed in favour of selective sensitivity evaluations (Meza-Cuadra et al, 2018c[37]). Conducting a simplified sensitivity evaluation and then claiming it represents model uncertainty is misleading and understates the value of conducting a formal uncertainty analysis (at GDEs). An uncertainty analysis defines a range of equally valid predictions, which maintain calibration constraints, by adjusting individual/combinations of model inputs, to which the solution is most sensitive. Sensitivity analysis identify parameters that predictions are most sensitive to, but do not bracket a realistic range of **equally possible solutions** that meet objective function constraints (i.e., minimizing the difference between historical and simulated heads), and as such shouldn't be used in lieu of a constrained uncertainty analysis. Conducting a formal uncertainty analysis and providing a qualified range of potential impacts, provides a much better way to inform critical decisions related to mine permitting.

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[36] ASTM D5611-94(2016), Standard Guide for Conducting a Sensitivity Analysis for a Groundwater Flow Model Application, ASTM International, West Conshohocken, PA, 2016, www.astm.org

[37] Meza-Cuadra, G., C. Pantano, and D. Oliver, 2018c. Resolution Copper Groundwater Flow Model - Sensitivity Analysis. Greenwood Village, Colorado: WSP. November 19.

The null space Monte Carlo Constrained Maximization/Minimization method (Doherty et al, 2010[38]) can provide the very important result of conveying the range (maximum – minimum) of equally plausible predictions of impacts at GDEs. The current sensitivity analysis is a) too selective and doesn't consider combinations of sensitive parameters and b) isn't constrained to minimize objective function (i.e., reproducing historical conditions within some value).

The well-known parameter estimation code PEST can be used in conjunction with existing calibrated groundwater models to determine a full range of uncertainty in predicted effects on GDEs using the Null-Space Monte Carlo method (see Doherty et al, 2010). The choice of the target or threshold objective function level at which the model is deemed to be "calibrated" is often subjective (Though targets should be determined based on required accuracy in GDE areas of interest following, for example a baseline study of this flow system that defines minimum environmental flows or changes to the hydrologic/ecologic system, to avoid irreversible damage).

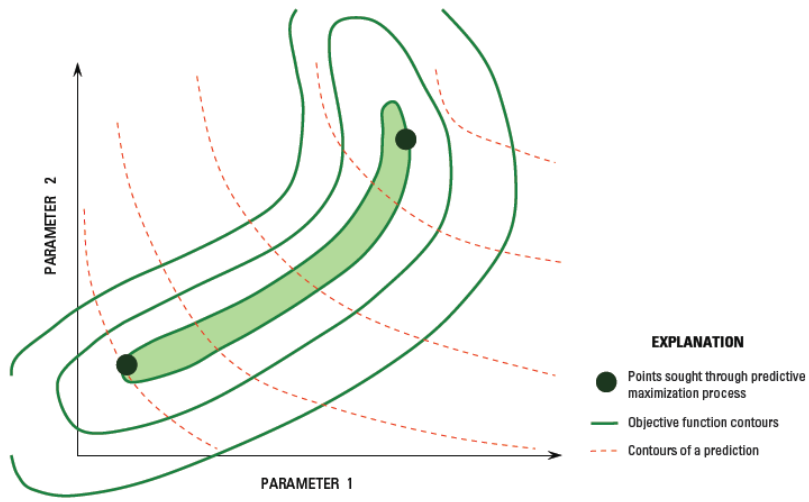

Figure 6. Schematic description of calibration-constrained predictive maximization/minimization.

Doherty et al, 2010 states "The principle that underlies this methodology is illustrated in his figure 6 for a two-parameter system. In this figure, the shaded contour depicts a region of optimized parameters that correspond to the minimum of the objective function. The solid lines depict objective function contours; the value of each contour defines the objective function for which parameters become unlikely at a certain confidence level. Each contour thus defines the constraint to which parameters are subject as a prediction of interest is maximized or minimized in order to define its post-calibration variability at the same level of confidence. The dashed contour lines depict the dependence of a prediction on the two parameters. The constrained maximization/minimization process through which the post-calibration uncertainty of this prediction is explored attempts to find the two points marked by circles on the constraining objective function contour. These points define parameter sets for which the prediction of interest is as high or as low as it can be, while maintaining respect for the constraints imposed by the calibration process."

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[38] Doherty, J.E., Hunt, R.J., and Tonkin, M.J. 2010. Approaches to highly parameterized inversion: A guide to using PEST for model-parameter and predictive-uncertainty analysis: U.S. Geological Survey Scientific Investigations Report 2010–5211, 71 p.

ATTACHMENT 2

RESPONSE TO INTEGRATED HYDRO SYSTEMS REVIEW, WSP, MARCH 23, 2020

MEMO

TO: Greg Ghidotti, Resolution Copper

FROM: Gustavo Meza-Cuadra, Chris Pantano (WSP)

SUBJECT: **Response to Integrated Hydro Systems Review**

DATE: **March 23, 2020**

Integrated Hydro Systems, LLC (IHS) produced the document *Review of Hydrologic Impacts in the Draft Environmental Impact Statement Resolution Copper Project and Land Exchange August 2019 (IHS 2019)*, included as Appendix E of the Arizona Mining Reform Coalition (AMRC) document *Comments on Resolution Copper DEIS (AMRC 2019)*. The Tonto National Forest has requested that Resolution Copper provide data and analysis which can be considered by the Forest Service in reviewing the IHS comments and Resolution has, in turn, requested assistance from WSP. In this document, WSP provides a summarized list of the primary comments with regards to the regional groundwater model, and then details responses to these.

For organizational purposes, WSP has structured the document to correspond with the primary components of the review and organized similar issues together. The sections are summarized as follows:

- Modeling Approach
- Code Selection
- Conceptual Model Development
- Model Setup
- Model Calibration
- Predictive Model Results

Throughout the following document, several references are made with respect to the United States Forest Service (USFS) Groundwater Working Group. The USFS Groundwater Working Group was assembled during the EIS process to collaboratively discuss numerous topics as related to groundwater and the development of the project, including the numerical flow modeling. The USFS Groundwater Working Group was led by the United States Forest Service and consisted of technical representatives of the Forest Service, including its NEPA contractor SWCA, EPA, other state and federal agencies, a representative from the San Carlos Apache Tribe and other associated consultants working on the Resolution Copper EIS.

Several topics raised by IHS were discussed in USFS Groundwater Working Group meetings prior to publication of the Draft EIS (DEIS). Decisions were made by the USFS after consideration of information provided and discussion by the Groundwater Working Group on the regional groundwater modeling efforts and associated disclosures with respect to groundwater impacts.

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Those decisions were described in process memo *Water Resource Analysis: Assumptions, Methodology Used, Relevant Regulations, Laws, Guidance, and Key Documents (Newell 2018d)* and *Draft EIS for Resolution Copper Project and Land Exchange (USFS 2019) [Section 3.7]*. Topics addressed by the USFS Groundwater Working Group will be mentioned in the appropriate sections that follow.

MODELING APPROACH

A general theme of the IHS review is a philosophical difference of approach with respect to model complexity. IHS makes repeated claims that simulating additional physical processes and incorporating more parameters is required for improving accuracy in the model and impact prediction. IHS recommends resolving this issue via use of other model code(s) and/or incorporation of additional model packages.

Although complexity may appear to provide a more accurate result in theory, increased complexity could produce more uncertainty through the requirement of estimating additional parameters where limited or no data is available to justify values. A model can be extremely precise in its output; however, its accuracy will only be determined by how well its parameters are estimated and how well the physical processes are represented. The USFS, informed by discussions within the Groundwater Working Group, determined that a practical modeling approach was ideal and most appropriate in the NEPA context where the agency has to explain and disclose its reasoning to the public.

The performance of the regional groundwater model demonstrates that the modeling approach utilized for the DEIS is appropriate and accomplishes the purpose of assessing impacts to groundwater dependent ecosystems (GDEs). The arguments provided by IHS single out specific topics and offer alternative methodologies without consideration for the way in which the model and representative processes were collectively handled. If considered holistically, it is apparent the groundwater system is well represented by the model as supported by agreement with multiple lines of evidence, including but not limited to, hydraulic conductivity values, estimates of recharge, head levels, streamflow rates, dewatering rates, and responses to transient stresses. The following sections address the specific topics raised by IHS with context and documentation regarding the model decisions and model performance.

CODE SELECTION

A concern brought up by IHS is that no formal code selection process was performed. This is not true as is evidenced by a discussion regarding code selection in report *Resolution Copper Groundwater Flow Model Report (WSP 2019) [Section 3.1.2]* as well as acknowledgment in the model review contained in the process memo performed by BGC Engineering Inc. (BGC) and reported in *Review of Numerical Groundwater Model Construction and Approach (Mining and Subsidence Area) (BGC 2018d) [Section 4.1]*. Additionally, the use of MODFLOW-SURFACT was discussed by the USFS Groundwater Working Group and the USFS made the decision to select this model as an appropriate tool to address the issues raised during scoping after considering discussions and recommendations by the working group.

MODFLOW is an open source code developed by the United States Geological Survey (USGS) and is the most widely used and accepted code in the United States. MODFLOW-SURFACT is a modified version of the USGS's MODFLOW code, which provided several features found desirable for modeling the proposed Resolution Copper project as further described below:

- Consideration that the code is accepted by the USFS and other regulatory agencies and has been used on other mining EIS projects. Large mining EIS reviews in the west and southwest using MODFLOW-SURFACT include recent projects at Rosemont [2017] and Cortez Hills [2019]. Conversely, other codes as recommended by IHS, have not been utilized as widely as the MODFLOW family of codes, especially in the United States.
- Use of the time-varying material properties (TMP) package within MODFLOW-SURFACT for simulation of the block cave progression over time. An accurate simulation of the block cave progression over time, utilizing the geotechnical subsidence model as reported in *Assessment of Surface and Subsidence Associated with Caving, Resolution Copper Mine Plan of Operations (Garza-Cruz 2017)*, was considered very important for simulating the hydraulic stress and estimating predictive impact.

Specific statements regarding code selection with respect to model complexity include:

1. Coupled GW/SW codes
2. Heat transport codes

COUPLED GW/SW CODES

IHS argues that GW/SW interactions were not simulated with a coupled modeling code and therefore calibration and predictions are less reliable. The use of integrated coupled GW/SW modeling codes is a topic that was discussed within the USFS Groundwater Working Group but the USFS determined that these tools are not appropriate in this context for the following reasons:

- Codes fully coupling GW/SW interactions (e.g. GSFLOW, Hydrogeosphere) are seldomly used in regulatory EIS analysis for mining projects. A fully vetted code, frequently utilized for mining EIS projects was an important consideration for code selection.
- Using the cited GW/SW coupled modeling codes would not allow for accurate representation of the block cave mining method (using TMP package to alter hydraulic conductivity and storage), which is critical to predicting the impacts.
- An integrated GW/SW model or use of the Streamflow-Routing (SFR) package would require fine-scale datasets for estimation of model parameters (e.g. stream bed conductance, stream widths) and absent those datasets could amount to further uncertainty. Additional rationale for the use of the drain package in lieu of the SFR package is addressed in more detail in the section on *Groundwater Discharge* later in this document.
- The scale of the regional groundwater model, encompassing three watersheds, makes the grid resolution required to represent point feature (i.e. spring discharges) unfeasible. The smallest model cells are 200-ft x 200-ft and further refinement would generate unwieldly runtimes and would not improve accuracy in the attempted physical representation of these features.

As such, MODFLOW-SURFACT and the packages simulated are an appropriate choice for the purposes of the analysis.

HEAT TRANSPORT CODES

IHS asserts that geothermal gradients were not considered in the groundwater flow modeling. This is false. Groundwater flow considerations associated with the geothermal temperature gradient, within the caved zone, is a topic that was discussed within the USFS Groundwater Working Group but the USFS determined it to have negligible (and likely immeasurable) effects for modeling impacts to GDEs. The Resolution Copper block cave produces a large-scale hydraulic sink within the groundwater system and the associated groundwater flow regime generated by this stress is the predominant driver of flow in the model.

Incorporation of geothermal driven flow would require selection of a different modeling code (e.g. TOUGH, FEFLOW) and for the stated reasons above and previous discussions regarding code selection, this was determined to be unnecessary.

CONCEPTUAL MODEL DEVELOPMENT

A concern brought up by IHS is that conceptual model development is lacking or incomplete. This is false as is evidenced by a discussion regarding the hydrogeologic conceptual model in report *Resolution Copper Groundwater Flow Model Report (WSP 2019) [Section 2.2]* as well as acknowledgment in the model review process memo performed by BGC Engineering Inc. *Review of Numerical Groundwater Model Construction and Approach (Mining and Subsidence Area) (BGC 2018d) [Section 3.0]*.

Specific statements made regarding conceptual model development, or lack thereof, include:

1 Perched groundwater zones
2 Alternative conceptual models
3 Future conceptual model

PERCHED GROUNDWATER ZONES

The purpose of the regional groundwater model was to assess impacts imposed on the regional groundwater system due to development of the proposed mine. It was discussed during the Groundwater Working Group and the decision was made by the USFS that the perched groundwater zones were not tied to the regional groundwater system (Apache Leap Tuff aquifer, Deep groundwater system) as was evident by multiple lines of analytical data as described below, and therefore were not to be considered by the model as these zones are hydraulically disconnected.

Extensive evaluation of GDEs was performed by WestLand Resources and Montgomery & Associates (M&A) in *Spring and Seep Catalog, Resolution Copper Project Area, Upper Queen Creek and Devils Canyon Watersheds (WestLand Resources and Montgomery & Associates 2018)* and by SWCA in *Summary and Analysis of Groundwater-Dependent Ecosystems (Garrett 2018d)* as part of the DEIS. The evaluations assessed all potential GDEs in the study area and specified GDEs that are considered part of the perched groundwater zone (product of shallow groundwater sources and not tied to the regional aquifers), therefore would not be impacted by drawdown associated with the mine or considered in the evaluation with the model.

ALTERNATIVE CONCEPTUAL MODELS

IHS asserts that alternative conceptual models were not evaluated. A conceptual model should be based on the data collected. The conceptual model presented in the DEIS is based upon approximately 15 years of extensive baseline field data including seeps and spring monitoring, stream monitoring, multiple shallow groundwater wells, deep groundwater wells, short term and long term pump testing, geologic information from deep and shallow core holes defining the geologic types and structure and most importantly – extensive and long term continual pump testing from mine dewatering from shafts 9 and 10. The conceptual model was then tested and verified further through the numerical model which calibrated to baseline data within accepted error in well referenced and accepted guidelines; scaled root mean square error (RMSE) of 3.0%, as reported in *Resolution Copper Groundwater Flow Model Report (WSP 2019).*

Additionally, in the predictive modeling, the simulation of 87 model runs with varied model parameters could be considered an assessment of alternative conceptual models. For example, one scenario increased hydraulic conductivity of all graben bounding faults providing an alternative conceptual model with respect to the control of groundwater flow across and along these key faults. *(Meza-Cuadra 2018b)*

BLOCK CAVE CONCEPTUAL MODEL

IHS expressed the need for cross sectional schematics outlining the conceptual hydrogeologic system and groundwater flow dynamics following block cave development. WSP provided a schematic representation of the extent of the fully developed cave along East-West cross section A-A' in *Resolution Copper Groundwater Flow Model – Predicted Flows to Block Cave (Meza-Cuadra 2018a).* WSP did not provide estimated graphical representation of groundwater levels and altered flow directions on this schematic as the predictive model output directly served this purpose. The assumptions associated with the predictive model setup and numerical implementation of the block cave development within the groundwater model utilized the work performed below and was detailed in report *Resolution Copper Groundwater Flow Model Report (WSP 2019) [Section 4]*.

MODEL SETUP

IHS cited numerous issues with respect to model setup and representation of boundary conditions within the regional groundwater model. Highlighted issues include:

1. Model domain
2. Groundwater discharge
3. Recharge
4. Evapotranspiration
5. Historic (1910-1998) dewatering
6. Faults

MODEL DOMAIN

Use of watershed boundaries is standard practice in groundwater modeling as they conceptually serve as groundwater divides and divergence in flow direction (*Anderson and Woessner 1992*). Ideally, boundary conditions will be set at a far enough distance from the main model stress (i.e. mine dewatering), that zero (or minimal) flow volume is provided. A domain was selected with the aim to minimize these effects, and be conscious of the further uncertainty created by including additional watersheds which are currently experiencing large stresses in the region (i.e. Pinto Valley and Ray Mine).

The question of boundary effects was discussed in the USFS Groundwater Working Group and an assessment of flow across the boundaries was reported as action item GW-77 and delivered in *Follow-up: July 17, 2018 Groundwater Modeling Workgroup – Response to Action Items GW-75, GW-76, GW-77, GW-80 and GW-81 (Resolution Copper 2018).* Predictive model flow across the entirety of the model domain boundaries (set as General Head Boundaries) was found to be a small percentage of the flow induced by the dewatering stress from mining; therefore, setup of boundary conditions is considered reasonable.

Additionally, as part of the model sensitivity analysis, a scenario was simulated where boundary conditions were changed from general head to a no-flow boundary condition. Results were reported in *Resolution Copper Groundwater Flow Model – Sensitivity Analysis (Meza-Cuadra 2018b).*

GROUNDWATER DISCHARGE

Use of a fully coupled GW/SW model code was previously addressed. However, additional issues were cited with respect to GW/SW interactions including the use of the drain package for simulating groundwater discharge at stream locations. IHS argues representation of groundwater discharge to streams via drains is inappropriate as it fails to provide a mechanism for water to be re-introduced into the groundwater system in losing stream reaches. Such mechanism could be simulated with the use of the Streamflow-Routing (SFR) package available in MODFLOW-SURFACT.

The methodology implemented is a simplified representation and only requires the assignment of streambed elevation to drain boundaries and estimation of a single parameter representing focused recharge. Alternatively, the SFR package includes several parameters with respect to stream and streambed characteristics, introducing additional uncertainty with such estimations.

Model performance with respect to groundwater discharge was presented in *Responses to Regional Model Queries (Meza-Cuadra 2018f)*, which showed the location and rates of modeled discharge compared well with stream baseflow. Additional assessment of model performance is demonstrated as action item GW-67 in *Comparison of Relative Vegetation Density to Regional Groundwater Model Predicted Discharge in the Floodplains and Stream Channels of Queen Creek, Mineral Creek, and Devils Canyon, Pinal County, Arizona (WestLand Resources 2018)* that shows modeled discharge with stream corridor vegetation density, showing good correlation. Hence, the methodology allows for baseflows to be reproduced and minimizes the number of uncertain parameters.

Two additional criticisms regarding the use of drains are made by IHS and include:

1. Inappropriate to set drain conductance sufficiently high and not estimate streambed conductance.

Drain conductance was set sufficiently high to allow the underlying hydrogeologic unit (HGU) and associated hydraulic parameters to dictate the discharge of groundwater. Given the scale of model cells and HGU assignments along stream reaches (i.e. alluvium vs bedrock), this assignment strategy is appropriate and prevents biasing an unconstrained parameter (drain conductance) values to match desired calibration targets.

2. Springs and seeps were not modeled as drains.

This statement is incorrect. Springs and seeps were simulated as drains and allow the discharge of groundwater within the cell in which they are located.

RECHARGE

IHS provides two issues with respect to assignment of recharge within the regional groundwater model summarized as follows:

1. Areal recharge specification is inappropriate.

IHS suggests use of the USGS Basin Characterization Method (BCM) to estimate recharge. While the BCM is a valid method, site specific, regional data, and research was considered and utilized for estimation of recharge rates applied within the model. Research was referenced in report *Resolution Copper Groundwater Flow Model Report (WSP 2019) [Section 3.1.6]*. Specific research cited includes:

- Recommendations for Representing Recharge in the Numerical Groundwater Flow Model, RCML (*Wickham GeoGroup, 2015b*)
- Perched Water in Fractured, Welded Tuff: Mechanism of Formation and Characteristics of Recharge (*Woodhouse 1997*)
- Implications of Projected Climate Change for Groundwater Recharge in the Western United States (*Meixner et al. 2016*)

Additionally, quantification of total recharge within each watershed was provided in *Resolution Copper Groundwater Flow Model – Watershed Water Balance (Meza-Cuadra 2018d).* Results were compared against an independent water balance developed by M&A, as reported in *System-wide Hydrologic Water Budget (M&A 2018)*, and compared favorably.

2 Representation of focused recharge is incorrect.

IHS argues that the delineation of focused recharge along stream reaches is incorrect and unjustified. The conceptualization and implementation of focused recharge along stream reaches is appropriate and fits with the dual (diffuse and focused) recharge model as outlined in literature cited above *(Meixner et al. 2016).*

IHS expresses concern that the representation of focused recharge along stream reaches is exaggerated and represents an area larger than the physical dimension of streambeds. The use of a larger footprint is justified for purposes of representing stream bank storage which provides a mechanism for longer residence release of storm runoff event water to the groundwater system; particularly in areas with pronounced alluvium like that of Queen Creek. For a narrower stream reach like Devils Canyon, the delineated area is larger than physically present, but consideration should also be given to numerous higher order tributaries that are not accounted for. In total, a holistic view was taken with respect to groundwater recharge and the estimated spatial representation and rates, which reasonably aligned with a separate independently estimated water balance *(M&A 2018).*

Furthermore, as part of the model sensitivity analysis, additional model scenarios were simulated with recharge rates increased and decreased by 50%. Results were reported in *Resolution Copper Groundwater Flow Model – Sensitivity Analysis (WSP 2018b).*

EVAPOTRANSPIRATION

IHS suggests that ET is a necessary component and parameter required for inclusion in the groundwater model. IHS outlines in its document, the complexity of the physical and biological processes associated with ET. ET is a highly complex process, difficult to measure and therefore, difficult to accurately parameterize. While simplifications exist, as utilized in certain MODFLOW packages, the simplest parsimonious approach is to consider ET as a reduction in net recharge. As such, ET was implicitly included in the groundwater model.

FAULTS

IHS asserts faults should be represented as planar features during discussion of model code selection. Representation of faults as planar features does not constitute a valid reason for selection of another modeling code and is unwarranted as calibration of hydraulic responses across faults (discussed below) is more important that strict adherence to geometric representation. On the scale of a regional groundwater model, and in consideration of representing measured hydraulic parameters observed in the extensive baseline data collected, representation of faults in this manner is considered appropriate.

Faults are represented in the regional groundwater model as independent hydraulic property zones and delineated utilizing model grid cells, a representation that is subjected to the constraints of the rectilinear grid. Despite large widths being used, fault zones are conceptualized to include adjacent altered material, and are a numerical means for representing hydraulic resistance within the groundwater model framework and representing the actual hydraulic behavior measured in the field. Calibration of hydraulic properties for these features was focused on properly reproducing transient water levels and propagation of responses to dewatering stresses observed across faults (i.e. non-uniform drawdown inside and outside of graben).

Additional considerations for modeling fault properties utilized findings provided in *Fault Core Review and Guidance for Groundwater Flow Modeling, RCML (Wickham GeoGroup 2015a).*

MODEL CALIBRATION

IHS cited numerous criticisms with respect to model calibration of the regional groundwater model. Criticism regarding model calibration includes:

1. Non-unique solution
2. Location of target datasets
3. Pre-mining & historic conditions
4. Calibration residuals
5. Hydraulic testing

NON-UNIQUE NUMERICAL SOLUTION

IHS expresses the need to calibrate to both head and flow data to provide a unique numerical solution. Flow data was assessed and compared to stream data observed in the field. As previously discussed in section *Groundwater Discharge,* simulated groundwater discharge via drains was compared against observed baseflow estimations and was well matched to baseflow rates measured, particularly along Devil's Canyon. Additionally, the location of simulated groundwater discharge was shown to align well with observed continuously saturated stream reaches. The combination of these two qualitative assessments provided WSP confidence that the streams were relatively well represented and was provided in *Responses to Regional Model Queries (Meza-Cuadra 2018f).*

A supplemental assessment, showing modeled discharge occurring in areas of higher density vegetation, was provided by WestLand Resources as action item GW-67 in *Comparison of Relative Vegetation Density to Regional Groundwater Model Predicted Discharge in the Floodplains and Stream Channels of Queen Creek, Mineral Creek, and Devils Canyon, Pinal County, Arizona (WestLand Resources 2018).*

LOCATION OF TARGET DATASETS

IHS asserts that the location of datasets utilized as targets for calibration is denser in the area of the mine and lacking in areas further from the mine, specifically at GDE locations where impacts are considered important. The datasets near and around the mine are vital for characterization and calibration of the area in which the hydraulic stress will be imposed by the mine. Calibration to observed heads and dewatering responses both inside and outside of the fault graben is key to providing confidence in future predictions. Critically, Devils Canyon has a large network of monitoring points which were carefully considered during calibration efforts.

The monitoring and measuring network proposed in the DEIS was also developed considering certain limitations with regards to the drilling near various sensitive locations and property ownership. The monitoring network proposed in the DEIS covers dozens of GDE's in a far-reaching radius many miles away from the mine and will serve as key in the early detection of potential impacts during mine life as outlined in *Monitoring and Mitigation Plan for Groundwater Dependent Ecosystems and Water Wells* (*M&A 2019*). Additional monitoring locations may be incorporated into the final EIS and record of decision (ROD).

PRE-MINING & HISTORIC CONDITIONS

IHS highlighted the lack of model calibration from 1910-1998. Model calibration is primarily based on targets following Resolution field efforts undertaken after 2002 *(WSP 2019) [Section 3.2.1]* when Rio Tinto became involved in the project. However, available datasets from the 1910-1998 were incorporated, which includes the geometry of the Magma Mine development and associated dewatering rates *(WSP 2019) [Section 1.4 and Figures 1.3 & 1.4]*. The implementation of these hydraulic stresses and simulation of this historical period alongside calibrated parameters derived from more recent datasets, is considered the best approximation of historical conditions, given the available data.

CALIBRATION RESIDUALS

IHS asserts that calibration residuals were not provided for spatially assessing model error near GDEs and streams. This is incorrect. A spatial summary of residuals in the Apache Leap Tuff was provided in memo *Responses to Regional Model Queries (Meza-Cuadra 2018f).*

HYDRAULIC TESTING

IHS is critical of the use of two hydraulic aquifer tests used for model calibration, considering the tests as small scale and spatially biased. This assertion is not correct and contrary to accepted good practice in groundwater modeling as any informative and well-collected dataset should be utilized for verification of conceptual model and improving confidence in calibration. While these specific tests would be considered short term and small scale by comparison to the proposed stress imposed by the mine, aquifer testing is important for characterization and valuable information.

The ability to reproduce the results relatively well, as shown in *Resolution Copper Groundwater Flow Model Report (WSP 2019) [Section 3.2.4 and Figures 3.12 & 3.13]*, provides confidence that these areas of the model are performing and in alignment with the conceptual model. The location of both tests provides critical information and covers a broad area spatially distant from the mine; one test was conducted between the proposed mine and a key impact assessment area, Devils Canyon and the other east of Devils Canyon, and as such the notion that the test locations are spatially biased near the proposed mine is incorrect.

Furthermore, IHS does not recognize that a long-term aquifer test has been ongoing since 2009 as conducted via mine dewatering occurring within the deep groundwater system with continual measurements via the monitoring network. This long-term pumping and associated piezometric responses is a critical component of the model calibration. As previously stated, the calibration to observed water level trends and responses across key hydrogeologic features, including faults and the Whitetail Conglomerate aquitard, must be considered for providing confidence that a future hydraulic stress originating from the mine is accurately captured.

PREDICTIVE MODEL RESULTS

IHS provided several comments with respect to the predictive model and assessment of impacts. Issues include:

1. Definition of baseline conditions
2. Use of 10-ft drawdown contour
3. Impact assessment to 200 years
4. Groundwater flow to cave and subsidence lake
5. Predictive uncertainty analysis

DEFINITION OF BASELINE CONDITIONS

IHS states that pre-mining conditions (represented as 1910) should be utilized as baseline conditions for the impact assessment. Baseline conditions utilized for assessment of impacts associated with the Resolution Copper project was discussed, reviewed and validated the USFS and their third-party consultant as well as the Groundwater Working Group. Discussion and justification regarding this decision is provided in *Draft EIS for Resolution Copper Project and Land Exchange (USFS 2019) [Section 3.7.1.2]* and *Selection of Appropriate Baseline Conditions for NEPA Analysis (Garrett 2018c)*. As detailed in these documents, the current dewatering related to the existing activities is legal, has been ongoing for approximately two decades and will continue legally in order to preserve the mining infrastructure investment made by Resolution Copper. These activities and the resulting conditions represent the baseline.

Current on-going dewatering, held steady through life of mine, was simulated within the No Action scenario (as described above) and compared against the Proposed Action scenario for calculating the impact (difference in drawdown). However, drawdown for both scenarios (No Action and Proposed Action) was also disclosed as part of the affected environment with respect to ongoing dewatering trends.

USE OF 10-FT DRAWDOWN CONTOUR

The use of a 10-ft impact contour was discussed by the USFS Groundwater Working Group and ultimately decided by the USFS as appropriate and reasonable for plan-view impact drawdown contour output. However, and most importantly, the EIS analysis was not limited to the 10-ft contour plan-view map for disclosure of potential impacts to GDE's, but the 10-ft contour was used as a tool for identification of GDE's exhibiting >10-ft of impact. The USFS determined that impacts at all GDE locations would be presented below the 10-ft threshold utilizing hydrographs detailing the range of potential impacts at each GDE location tied to the regional groundwater system, as shown in the DEIS [*Appendix L*].

Factors considered for utilizing the 10-ft contour for plan-view map assessment included model grid scale, seasonal water level variability, and mining EIS precedent. It is valid to say that groundwater models can output results with a high level of precision, however it is also true that accuracy of these results will be nowhere near these levels. The Resolution groundwater model encompasses an area of 190 square miles, with the smallest grid cells being 200-ft x 200-ft, and thus it is appropriate to expect that the accuracy of any output below 10-ft will be limited. This was a key discussion point within the USFS Groundwater Working Group and subsequently, the USFS deemed the 10-ft impact contour appropriate. Additionally, seasonal variations in water levels are observed to fluctuate; to estimate impacts at a threshold below seasonal variations in water levels could inadvertently attribute natural water level declines to mining. The use of the 10-ft impact contour is prevalent and was found to be sufficient for previous mining EIS assessments, including Cortez Hills [2017].

IMPACT ASSESSMENT TO 200 YEARS

The 200-year timeframe assessment was discussed within the USFS Groundwater Working Group and the USFS decided this was appropriate and reasonable for the purposes of the Draft EIS and that impacts beyond 200 years were remote and speculative. Discussion and justification regarding this decision is provided in *Draft EIS for Resolution Copper Project and Land Exchange (USFS 2019) [Section 3.7.1.2]*.

Fundamental limitations of models exist in predictions far into the future but results from the groundwater model could reasonably be assessed out to 200 years and therefore were restricted to this timeframe. Additionally, acknowledgement that groundwater levels and trends that continue past this point in time can be qualitatively explored and additional impacts disclosed even absent of quantitative predictions. It is unreasonable to assume that conditions today such as the climate and non-Resolution Copper activities would be the same at a time frame beyond 200 years. However, the predictive model was run to approximately 1000 years into the future to assess the potential for formation of a subsidence lake as further described below.

GROUNDWATER FLOW TO CAVE AND SUBSIDENCE LAKE

IHS comments on the representation and assumptions associated with cave simulation, future groundwater flow into the cave, and development of a subsidence lake.

1. IHS asserts that the predictive model was incapable of accurately modeling flows within the cave based on a comment regarding the upper limit of hydraulic conductivity applied to caved material.

Upper limits on the hydraulic conductivity were set at 100 ft/day as it was deemed that fractured rock would not on average present values larger than this. Clay content within the Whitetail Conglomerate is likely to fracture and compact, presenting much lower values likely limiting flow. A value of 100/ft per day assumes flow capabilities similar to a gravelly aquifer throughout and assigned to all rock types. The 100 ft/day value did not create any model instability, with cumulative mass balance errors less than 1%.

2. IHS expresses the need to model the change in ground surface elevation associated with the subsidence crater for the purpose of conducting a subsidence lake assessment

As described above, the USFS determined a post-closure assessment period of 200 years was reasonable and appropriate time frame after discussion with the Groundwater Working Group. However, for the purpose of assessing the potential development of a lake within the subsidence crater, a predictive model run was simulated to 1000 years into the future. The recovery associated with this model run was found to be below the lowest elevation of the subsidence crater, as well as other potential discharge points associated with the mine, hence the prediction of a surface water expression in the subsidence crater was determined to be remote and speculative by the Forest Service. The modeling detail, however, is included in the record.

IHS also asserts that groundwater recovery within the cave could be much quicker than predicted due to the use of a maximum hydraulic conductivity within the cave of 100 ft/day. The argument misses that flow into this dewatered block cave is largely dictated by the surrounding HGU hydraulic properties, which are far less than 100 ft/day. Therefore, the predicted recovery and associated timing is principally based on the hydraulic properties as determined from the calibrated model and collected hydraulic properties of data on undisturbed, in situ rock. As previously discussed, the calibration to the long-term dewatering currently ongoing at Resolution Copper was a key consideration and provides confidence that parameter estimation of the surrounding HGUs are favorable.

PREDICTIVE UNCERTAINTY ANALYSIS

IHS comments that the predictive uncertainty analysis provided by the DEIS is insufficient and should be conducted using alternative methodologies. However, the approach taken for the DEIS is commonly used. Uncertainty was discussed during the USFS Groundwater Working Group and the USFS determined that methodologies used in the existing mining EIS literature should be followed as it is accepted and common practice. As described in the response to comments in previous section *Alternative Conceptual Models*, a comprehensive sensitivity analysis was completed with modeled output from 87 sensitivity runs. Parameter values were varied in this predictive model based on their uncertainty, varying log parameters (e.g. hydraulic conductivity) by an order of magnitude and non-log parameters by 50% (e.g. recharge), and 87 forwards runs were carried out. This type of analysis is consistent with other EIS documents previously approved by regulators and provides a conservative approach to capturing uncertainty. A broad conservative impact is disclosed as the outer-most extent of all superimposed sensitivity contours, which was then used to inform the monitoring and mitigation plan for GDEs.

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ATTACHMENT 3

RESPONSES TO IHS (PRUCHA) COMMENTS, BGC, MAY 11, 2020

BGC ENGINEERING USA INC.
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Draft Project Memorandum

To:	**SWCA**	**Doc. No.:**	
Attention:	**Chris Garrett, Donna Morey**	**cc:**	
From:	**Gabriele Walser**	**Date:**	**May 11, 2020**
Subject:	**Responses to IHS (Prucha) Comments**		
Project No.:	**1704005.03**		

BGC has reviewed the following document by Bob Prucha, Integrated Hydro Systems, LLC (IHS) (2019): "Review of Hydrologic Impacts in the Draft Environmental Impact Statement Resolution Copper Project and Land Exchange August 2019, October 9, 2019". The document presents a thorough examination of multiple aspects of the hydrology analysis for the Resolution Copper EIS, with particular emphasis on the Modflow Model created for the analysis of groundwater impacts from the panel mining process (WSP 2019).

Responses to many IHS comments made in the document can be found in prior documents previously prepared by the groundwater modeling work and others in support of the EIS. A complete break-down of the comments can be found in Table 1 and, where applicable, quotes taken from those previously prepared documents are added as responses.

Other comments deserve additional consideration, and possibly additional explanations and/or analysis to support the EIS. These are summarized here, in the order that they appear in the document.

- **Comment 3**: Develop stream profiles, and plot GW levels. Breaks in slope? Add surficial geology. Evaluate potential for disconnectedness between shallow aquifer and Tal.
  Consideration: Completing these tasks would strengthen the argument about which GDE are connected versus disconnected from the regional groundwater system.
- **Comments 20 and 52**: Description and illustration of the future conceptual model around the mine, or Alternative #6 TSF area (i.e., baseline conditions) were never provided.
  Consideration: Additional site characterization was finished, and new conceptual and numerical models are in progress, and expected to be available May 2020, due to the late selection of this alternative.
- **Comment 48 and 51**: The main focus of the DEIS is to estimate potential changes to the surface/subsurface hydrologic system, or GDEs affected by mine drawdown and changes to surface flows. Despite this objective, virtually no observation data for either surface water, or groundwater is available at, or near GDEs to constrain calibration in these critical areas.
  Consideration: Observations of surface and groundwater at GDEs are available, and presented in various reports, however, it would clarify the applicability of the

groundwater model, if the observations would be compared directly to the model calibration.

- **Comment 54**: Spatial Bias in Calibration. The WSP, 2019 report shows calibration 'Scatter Plots' (see Figures 3.9 and 3.10), but never show spatial bias and residuals at specific wells by aquifer unit.
  Consideration: This information will be requested from WSP.
- **Multiple comments**: A recurring theme is that perched zones and (coupled) SW/GW interactions are not considered by the GW model.
  Consideration: These concerns may have some merit because GDEs are inherently linked to GW processes occurring near the land surface. These include, for example, recharge and discharge to perched zones, discharge from deeper GW (to SW in some cases), GW recharge from losing streams. It is worth noting that SW/GW interactions are included in the model through boundary conditions; however, this does mean that feedback mechanisms are not explicitly considered. Perched zones are more problematic if they are extensive. However, since the GW model did not to explicitly consider these processes, the evaluation of impacts on GDEs did not rely on the groundwater model.

CLOSURE

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Yours sincerely,

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Attachment(s): Tables

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TABLES

Table 1. Responses to comments from prior EIS supporting documents.

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
1	GDE evaluations Garrett 2018d are suspect. Upper Devils Canyon streams may be baseflow discharge from TAL. Well within 10' contour.	Garrett (GDE) 2018	Assume stream reach is disconnected from regional aquifer, based on all water quality lines of evidence.	Garrett conclusions are based on best available site information, and show enough evidence to conclude that Upper Devils Canyon baseflow is unlikely to be connected to TAL.
2	Not likely perched hydrogeo included in GW model – hence distancing by workgroup from relying on any SW-GW flow predictions.	BGC 2018, Section 4.9.2	Changes in stream flow cannot be evaluated based on the groundwater model.	The GW Model modeled the main regional aquifers which would be impacted by the mining operations. No predictions to SW flow were made based on GW model alone.
3	Develop stream profiles, and plot GW levels. Breaks in slope? Add surficial geology. Evaluate potential for disconnectedness between shallow aquifer and Tal.			This would be a useful addition to Garrett 2018

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
4	Doesn't appear to consider broader impacted area (impacted areas up to for example, 1-ft drawdown vs. 10-ft) – as predicted in model, despite uncertainty band around this. More GDEs would have shown up as impacted, needing mitigation. Instead only those delineated by uncertain predicted 10-ft drawdown used (at 200 years) to define potentially impacted GDEs.	BGC 2018, Section 4.17.6.1, and Appendix B	Through the Groundwater Modeling Workgroup meetings, a consensus was reached regarding how the output of the groundwater models would be used and described in the EIS. Because groundwater models have uncertainty associated with their results, narrative descriptors of predicted impacts are used to divide impacts into three categories: • Anticipated impacts • Possible impacts • Impacts not anticipated. Anticipated impacts occur where the predicted drawdown is larger or equal to 10 feet (for the no-action alternative), or where the predicted additional drawdown beyond the no-action alternative drawdown is larger or equal to 10 feet (for the action alternatives). Possible impacts occur where the predicted drawdown from any sensitivity analysis is larger or equal to 10 feet (for the no-action alternative), or where the predicted additional drawdown from any sensitivity analysis beyond the no-action alternative drawdown is larger or equal to 10 feet (for the action alternatives). Impacts are not anticipated where predicted drawdown from any sensitivity analysis is less than predicted 10 feet (for the no-action alternative), or the predicted additional drawdown beyond the no-action alternative drawdown is less than 10 feet (for the action alternatives). the Groundwater Modeling Workgroup recognized that the uncertainties inherent in the model limited its use as a tool to analyze smaller changes in groundwater level (less than 10 feet) that could still have substantial impacts on GDEs. To address this uncertainty, the Groundwater	Stay with decision made by GWMWG

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
			Modeling Workgroup envisions real-world monitoring of GDEs during operations in order to identify any changes, even if not anticipated by the groundwater model.	

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
5	Evaluating drawdowns in shallow aquifer at 200 years, or 148 years post-closure, severely limits the number/magnitude of impacted GDEs because the groundwater model still hasn't fully recovered by this point. With a future fractured and highly permeable pathway that develops between the shallow Apache Leap Aquifer (ALT) and DEEP aquifer zone (in Resolution Graben), relatively rapid drainage of ALT would dewater GDEs over the short term, as it fills voids in the deep aquifer. But then, ALT water levels will eventually return to pre-mining conditions. Choosing 200 years limits the understanding of time-varying impacts extent/magnitude.	BGC 2018, Section 4.5.1	The model was initially run for a predictive time period of 1,000 years, however, the GMWG decided that model results for greater than 200 years are highly speculative and not reasonably foreseeable. Thus, only results up to 200 years from the start of mine construction were included in the quantitative results presentation... Most members of the Groundwater Modeling Workgroup acknowledged the substantial uncertainty involved with using any model at long time frames.... The Tonto National Forest ... in December 2018 modified the Draft EIS to discuss longer-term impacts (past 200 years) in qualitative terms. Five subsections were added to the Draft EIS to discuss longer-term effects under the No Action alternative, and longer-term effects due to the block-caving on springs, Devil's Canyon, Queen Creek, Telegraph Canyon, Arnett Creek, and water supply wells. These new qualitative discussions were based on longer-term modeled hydrographs disclosed during the Groundwater Modeling Workgroup in May 2018.	USDA 2019: Draft EIS, Chapter 3 (pages 333 and 334)

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
6	By including continued dewatering of the deep GW aquifer in No Action alternative groundwater model predictive long-term simulations, and then subtracting drawdowns from LOM and post-closure simulations, RCM consultants have effectively biased the magnitude and extent of mine impacts on GDEs towards the low side, or the opposite of conservatively high impacts (see see page 3, paragraph 4, Garrett and Newell, 2018). At a minimum, predicted drawdowns should have been calculated from pre-mining conditions, as these are the levels to which shallow ALT aquifer groundwater levels will eventually recover to. This is known without even using the highly uncertain groundwater modeling results.	BGC 2018, Section 5.1	Appropriate baseline conditions for the modeling analysis was one of the first topics discussed by the Groundwater Modeling Workgroup, focused specifically on how the current groundwater pumping for dewatering would be accounted for in the model results. ... Ultimately this question was viewed not as a technical modeling question, but rather a fundamental NEPA question. The decision by the Forest Service is clearly described in the Draft EIS (see “Key Decision on Use of Model Results – Baseline Conditions” section in the “Groundwater Quantity and Groundwater-Dependent Ecosystems” section in Chapter 3 of the Draft EIS), and the rationale is also contained in detail in the project record (Garrett 2018). The Forest Service made the decision that continued dewatering of the mine would be included as part of the no action alternative, and that the impacts resulting from the mine would be defined as the difference between the proposed action model and no action model.	

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
7	Water quality of the ‘perched’ upper Devils Canyon drainage doesn’t appear to confirm it is disconnected to shallow ALT aquifer, which has likely dropped simply due to the substantial and long-term historical pumping, compounded by the more current 2009-present shaft 9/10 dewatering. The assessment of which GDEs to include, or discard from further analysis (i.e., discarded if perched, vs. connected to impacted ALT or Deep aquifers) appears to be based on relatively recent hydrologic data (i.e., collected after significant unrecovered historical drawdowns (1910-1996) and superimposed re-drawdown of levels post-2009 (i.e., shaft 9/10 dewatering). No analysis of 1910 to 1996 dewatering/recovery is presented in the DEIS, or supporting documents. Knowing how much drawdown has already occurred in the GDE locations/segments would have likely significantly increased the number of GDEs potentially impacted.	Garrett (GDE) 2018		see comment 1 Little good data available pre 1996

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
8	A key question is what additional GDEs, or even those omitted because the Groundwater Modeling Workgroup decided they didn't exhibit "persistent presence of water, year-to-year and season-to-season" (stated page 296, paragraph 3 in the DEIS), would have been valid locations had effects of past/current pumping been removed (recovered)? GDEs should have been defined based on pre-mining groundwater conditions, where the long-term pumping influence at Magma Mine, and RCM pumping since 2009 don't bias identification of persistent discharge at springs/along streams towards the low side. Because it is unclear how the estimated pre-mining groundwater levels were determined without calibration data, the DEIS should have conservatively identified all GDEs, within uncertain range of flow conditions.		See responses to comments 1, 6, and 7	

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
9	DC13.5 SW flow assumed disconnected from ALT aquifer – but unconvincing evidence. West-East Cross Section A-A' (Figure 2.3 in WSP, 2019) shows Inferred Tal Water Table at Devil's Canyon at the bottom of the streambed, in the dismissed GDE segment from DC10.9 to DC 15, contradicting assumptions made that this stream segment (albeit ephemeral many years) is due to perched groundwater conditions (see page 28, paragraph 2 in Montgomery and Associates, 2017). Given the likelihood that flow in this segment, well within the 10' groundwater level drawdown zone impacted by mining, is connected to the Tal aquifer, it should have been included as an important GDE in the DEIS.	Garrett (GDE) 2018	Assume stream reach is disconnected from regional aquifer, based on all lines of evidence.	Can this argument be strengthened?
10	A general 'industry-standard' approach to modeling hydrologic impacts is lacking. A general approach used to develop predictions via use of numerical models was never presented, though many guidance documents are readily available online as noted by BGC, 2018d[2] in Section 2.2 (Description of Best Practices). The most useful, current and relevant to assessing mining impacts is provided by Wels, 2012[1], which shows a standard modeling process on Figure 1.	BGC 2018, Appendix B		The adherence to the "industry standard" is described in detail in BGC 2018, Appendix B.

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
11	Clearly defined questions related to potential impacts and modeling objectives should have been presented, particularly how groundwater impacts affect surface flows, and vice-versa. These were not evaluated in this DEIS, or supporting documents.	BGC 2018, Section 1.1, from SWCA 2016, and Section 5.7	ISSUES TO BE ADDRESSED BY THE GROUNDWATER MODEL The Groundwater Model Workgroup identified the following issue factors (Issues) to be addressed by the groundwater model (SWCA, 2016). • 6A-1. Quantitative assessment of direction and magnitude of change in aquifer water level, compared with background conditions. • 6A-2. Geographic extent in which water resources may be impacted. • 6A-3. Duration of the effect (in years). • 6A-5. Number of known private and public water supply wells within the geographic extent of the water-level impact, and assessment of impact to these water supplies (feet of water-level decrease). • 6C-2. Quantitative assessment of potential lowering of the water table/reduced groundwater flow to Queen Creek, Devil’s Canyon, Arnett Creek, Mineral Creek, or other perennial waters that results in permanent changes in flow patterns and that may affect current designated uses. ...the groundwater flow model ... does not explicitly model groundwater/surface water interaction.	

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
12	A major flaw in modeling conducted in this DEIS is that groundwater modeling was done in apparent isolation from surface water modeling, yet surface water clearly recharges groundwater (losing segments), and groundwater clearly discharges to surface streams as baseflow, or via springs. In other words, surface water recharge to groundwater (losing stretches) was not included in the groundwater modeling as a boundary condition, and vice versa. Including this 2-way flow is essential to realistically and accurately assessing mining impacts on surrounding GDEs (and surface water ecosystems).	BGC 2018, Section 5.7	the Tonto National Forest asserts that: A three-dimensional numerical finite-difference groundwater model is the only tool that can be reasonably used to predict the results of the block-caving and dewatering, given the complex geology, changes in geology and hydrology introduced by the block-caving, long time frames, and large geographic area. That tool has clear limitations. These limitations are represented in the decisions about how to use the model and what model output should be relied upon. This includes the decision to not explicitly model groundwater/surface water interaction with a streamflow package; this decision is an acknowledgment of a limitation of the model's ability to predict impacts. Also see response to comment 2.	
13	Once models were created, the important feedback loops shown on Figure 1 from model calibration to conceptualization and data collection doesn't appear to have been considered. In other words, obvious datagaps identified during modeling weren't addressed.			Practicality of collecting more data has to be considered.

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
14	A formal predictive uncertainty analysis wasn't conducted, and partly confused with a predictive sensitivity analysis.	BGC 2018, Section 4.18	Sensitivity analysis is the process of changing one parameter in the model at a time and re-computing the error function. The purpose is two-fold. First, it can determine those parameters most sensitive to model output for use in the calibration process. Parameters that have the greatest impact on model output make better calibration parameters than those parameters less sensitive. Secondly, a sensitivity analysis allows some quantification of uncertainty in simulated response if parameters are adjusted over expected ranges. Calibration sensitivity was evaluated for a broad range of parameters. Calibration sensitivity confirmed that the calibrated conductivity parameters resulted in the smallest residuals. Groundwater model results are influenced by uncertainty, due to the inability to define the exact temporal and spatial distribution of all parameter values and boundary conditions	Section 4.18.2 will be rewritten to discuss the uncertainty analysis. The description of the uncertainty analysis will be improved.

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
15	Conceptualization inadequate/incomplete. Conceptualization is critical to supporting and developing numerical models of flow as described in numerous modeling guidelines, some of which are cited by BGC, 2018d2 in their review of the Resolution Copper Mine (RCM) groundwater model. Kolm and Van Der Heijde, 19963 describe a detailed approach to conceptualization and characterization of hydrologic systems, as outlined on Figure 2. Though BGC, 20192 attempts to review the characterization of the groundwater system (Section 3.4), and even points out “that building a conceptual model is a crucial step before building a numerical model”, the WSP, 2019 report fails to describe a defensible baseline 3-dimensional conceptual flow model (or future post-closure conceptualization) showing the coupled surface water-groundwater system flows in any detail, using groundwater flow arrows in each aquifer, estimated discharge (at springs, seeps, streams) and recharge areas and rates as described in various reports5. Discussion of characterization and conceptualization of both surface water and groundwater flows, and flow interactions between them over the entire mine footprint is confusing, poorly presented and missing important details.	BGC 2018, Section 5.7 and Section 3.4.7	...the groundwater flow model ... does not explicitly model groundwater/surface water interaction. Resolution Copper and their contractors collected a large amount of information characterizing the groundwater system, including recharge, discharge, water budget, flow paths, and boundary and initial conditions in the model area. The groundwater system characterization contains all the information pertinent to the model area and recommended to be collected by ASTM standard D5979 (ASTM 2014). The conceptualization of the potentiometric surface for the groundwater model follows the general recommendations of the ASTM standards (ASTM, 2014a and 2017) as well the guidelines presented in USGS, 2004, Anderson et al., 2015, and NDEP, 2018. BGC and the GWMG concur with the groundwater system characterization presented in WSP (2019) and Montgomery & Associates (2017b) and considers the information sufficient for the groundwater model.	Section 3.4.7 will be edited to include information from Montgomery & Associates 2017b and 2018, and refer the reader to both those documents which contain the conceptual model.

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
16	The complex hydrogeologic system, especially around the proposed mine area exhibits numerous offsetting faults and multiple tilted hydrogeologic units, and is illustrated in only a single West-East cross-sections (Figure 2.2) groundwater modeling report (WSP, 20196). Yet, critical conceptual details are missing, fundamental to defining an appropriate conceptual flow model (or multiple conceptual models, given subsurface complexity) of the entire potentially-impacted system.	BGC 2018, Section 3.2	The Superior Basin, which underlies the western part of the model area, is comprised of a large, east-tilting block bounded by two major north-northwest trending, normal faults that dip to the west: Elephant Butte Fault and Concentrator Fault. These faults are interpreted to largely control the pattern of geologic units exposed at land surface and their distribution in the sub-surface. The geologic interpretations used for the conceptual hydrogeologic model is presented in: • 4DGeo – Applied Structural Geology, 2017. Summary of Geologic Information Relevant to Development of the Porphyry Cu-Mo Resolution Deposit, Arizona. Report prepared for Resolution Copper Mining LLC, May 2017, 58 p. This study presents the most up to date analysis of the subsurface geology of the project area.	

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
17	Perched zones are hypothesized in various supporting documents, and used to explain how many GDEs are disconnected from mine-impacted groundwater drawdowns. But no data, characterization of the lateral/vertical extents, or conceptualization of such features or associated flows are presented in the DEIS, or supporting documents. This represents a key error in conceptual modeling (see Section 4.6, Wels et al, 20121). The groundwater flow model further appears to have omitted these perched zones (i.e., in upper Devils Canyon, above segment DC10.5), which should have shown lower recharge to deeper aquifer zones (see WSP, 2019, Figure 3.6), but don't appear to have been incorporated into the flow model (see Appendix B HGU Material Property Values, WSP, 2019).	BGC 2018, Section 5.7	the groundwater flow model ... does not explicitly model groundwater/surface water interaction.	Generally, regional groundwater flow models omit perched zones. WSP 2019 (page 31): … the shallow alluvial (perched) groundwater system is not included in the groundwater model.
18	Geothermal influence not included in the conceptual flow model, but may be important to evaluating long-term post-closure flow conditions within the subsidence area (i.e., density driven flows, and water quality impacts).			WSP has provided response

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
19	The well-established industry practice (as defined in the flow chart on Figure 2 by Kolm and Van der Heijde, 1996) of going from raw data (i.e., borehole/well data) to characterization, for example of interpolated groundwater surface elevations for perched, shallow and deep aquifer units, over the mine-impacted area (including all TSF alternatives, West Plant, Superior, Queens Creek, MARRCO corridor etc), to conceptualization of flows (both vertical and lateral) within aquifer units, along faults, discharge to surface, flows between surface water-groundwater, recharge from precipitation and runoff etc, is largely absent.	BGC 2018, Section 3.3.3	The conceptual model is based on site exploration and multiple reports. BGC and the GWMG concur that the hydrostratigraphic and hydrostructural units have been appropriately conceptualized using available site specific geologic and hydrogeologic test boreholes, hydrologic testing, historic mining data, and current underground exploration mine and shaft data. Note that evaluation of the geologic and hydrogeologic conceptual model extends well beyond just the groundwater model. Substantial review of the available geologic and geotechnical information has been conducted by a Geology and Subsidence Workgroup (Geology Workgroup), which was formed by the Resolution Copper Project EIS team in order to review RCM's procedures, data, and geologic and geotechnical baseline documents and subsidence model.	
20	Description and illustration of the future conceptual model around the mine, or Alternative #6 TSF area (i.e., baseline conditions) were never provided. Hydrogeologic characterization associated with Alt 6 TSF is largely missing, in Dripping Springs Wash – i.e., they state "It is not known at this time whether these faults act as preferential flowpaths, or low permeability boundaries for groundwater flow4"			Additional site characterization was finished, and new conceptual and numerical models are in progress, and expected to be available May 2020, due to the late selection of this alternative.

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
21	Given the high degree of complexity in the subsurface over the mine footprint, a realistic range of alternative conceptual models should have been considered in the modeling to account for substantial uncertainty in virtually all model input. Conceptual model uncertainty typically accounts for most uncertainty in subsequent numerical model predictions. Neuman and Weiranga, 2003[5] describe in detail how to incorporate alternative conceptual models into formal uncertainty analyses. Typically, conceptual model uncertainty dominates overall predictive uncertainty and as such should have been more fully assessed in the DEIS modeling evaluations.			Section 3.4.7 will be edited to include information from Montgomery & Associates 2017b and 2018, and refer the reader to both those documents which contain the conceptual model, and the description on how the conceptual model was created.

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
22	Several, independent hydrologic modeling efforts were conducted in the DEIS, including the following: 1) 3D Groundwater Modeling – Modflow-surfact[6] mine-area evaluations 2) Hydrologic (Surface water) model – AWBM7 Monthly Hydrologic Model 3) ADWR's Salt River Valley (SRV) Groundwater Flow Model – Modflow. 4) 2D Conceptual TSF Seepage modeling[8] – SEEP/W **No Formal Code Selection Conducted.** A formal code selection process[9] should have been conducted to identify appropriate codes that are able to simulate all required processes needed to fully assess mine impacts on surrounding hydrology, and more importantly, to define required calibration targets for specific EIS impact assessments (i.e., required predictive accuracy). Section 5 in Wels, 2012[1] provides details on conducting a formal groundwater model selection, even including a flow chart.	BGC 2018. Section 4.1.2	BGC and the GWMG concur that MODFLOW-SURFACT is an appropriate model code to be used for the groundwater model.	Flowchart assumes unlimited ability to collect data.

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
23	The MODFLOW-Surfact groundwater modeling tool used by WSP, 2019 to assess mining impacts at GDEs within the entire mine footprint fails to model important physical processes (i.e., overland surface runoff processes, distributed recharge and evapotranspiration dynamics, stream hydrodynamics, and stream-aquifer dynamics etc.) necessary to simulate physically realistic and defensible mine impacts on surrounding GDEs. Much more robust modeling tools are readily available, but weren't considered because a formal, industry standard code selection process wasn't conducted, where all modeling objectives/needs are carefully defined and evaluated against capabilities of available codes.	BGC 2018, Section 4.1.2	See responses to comment 22.	
24	Fully integrated hydrologic/hydraulic codes should have been considered for more robust and physically realistic impact evaluation. These codes don't suffer major shortcomings such as: 1) attempting to run one model in isolation (i.e., the groundwater flow model), then attempting to couple non-dynamic results to a separate spreadsheet tool, when the flows between groundwater and surface water is complex, dynamic and spatially variable, and 2) they simulate all relevant physical flow processes and don't require unrealistic	BGC 2018, Section 4.8.2, 4.8.4, and 4.8.6	BGC and the GWMG concur that no-flow boundaries along the western and southern boundaries of the Silver King Wash-Queen Creek watersheds are appropriate. Groundwater flow is parallel to boundaries and does not cross boundaries. BGC and the GWMG concur that general head boundaries along Mineral Creek and Lyons Fork is appropriate. BGC and the GWMG concur that general head or no-flow boundaries are appropriate to use along the northern boundary. Boundary conditions were evaluated during sensitivity testing. This is a surface watershed boundary, and flow across the boundary is unlikely in the shallow aquifers. There	

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
	and highly uncertain boundary conditions.		is no information available regarding flow in the deeper aquifers. A general head boundary can be used in the deeper layers to evaluate flows across this boundary.	
25	Many options are commercially-available[10] and have been applied to mine water balance projects, worldwide for many years.	BGC 2018, Section 4.1.2	See responses to comment 22.	
26	Use of Modflow to explicitly model the effect of faults is inappropriate. Codes like FEFLOW permit actual simulation of flow along faults as planar features. Modflow-Surfact required specifying model cells (with variable dimensions unrelated to actual fault planes/zones in the field).	BGC 2018, Section 4.13.2	BGC and the GWMG concur that using separate hydrologic conductivities is appropriate to model faults. Faults may be conduits to flow as well as barriers. Using separate hydraulic conductivities gives flexibility in handling hydraulic characteristics faults in the model.	The Forest Service preferred a publicly available product developed by the USGS to a commercial product.
27	Hydrogeologic characterization of flows along and/or across faults is largely missing – and therefore highly uncertain.	BGC 2018, Section 3.2.2 and Section 3.3.3	Study area subsurface structure, including fault locations, geometries, and offsets has also been well defined and delineated using borehole and mine workings data (4DGeo, 2017). Also see responses to comment 19.	
28	The variable saturation, finite element modeling code, FEFLOW, developed by DHI-WASY would have allowed a much higher resolution near critical streams, while decreasing resolution in area of less interest. This would have met stated objectives.	BGC 2018, Section 4.1.2	See responses to comment 22.	

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
29	Conceptualization should have included heat transfer, due to geothermal waters encountered during construction of shaft 10, which drive density-dependent flows. FEFLOW includes the ability to simulate heat flow, and also has the ability to directly simulate 3-dimensional geochemical modeling based on PHREEQC, similar to its use in the USGS PHAST code.			WSP has provided response
30	Fully integrated, or coupled, physically-based, fully-distributed hydrologic (and hydraulic) codes have been available for decades and would have allowed RCM consultants to directly simulate the complicated, baseline and mine-impacted coupled surface water-groundwater dynamic flow system response in a robust, realistic way.	BGC 2018, Section 4.1.2	See responses to comment 22.	

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
31	The authors attempted to estimate spatial distributions of recharge, which is a complex spatially distributed, and dynamic process, using an undocumented method. However, fully integrated codes like the USGS GSFLOW code, DHI's code MIKESHE/MIKE11 or even Aquanty's Hydrogeosphere code actually simulate important processes like dynamic, spatially-distributed recharge, surface runoff and channelized hydrodynamics, which are dynamically coupled to subsurface flow (i.e., coupled to a modflow equivalent code). The MIKESHE code was used to simulate hourly impacts of climate change and stream temperature changes associated with Pebble Mine impacts in southeastern Alaska11.	BGC 2018, Section 4.11.2	BGC and the GWMG concur that the best available data was used to estimate recharge. Sensitivity analysis used a range of recharge rates to allow for changes in recharge rates due to changes in long term climatic changes.	
32	Simulate ET and Recharge processes more realistically: • ET boundary condition – Instead of using the original MODFLOW EVT package which treats ET loss as a linear function of hydraulic head (not very physically realistic), consider using MODFLOW Riparian ET package (available for MODFLOW-2005) http://pubs.usgs.gov/tm/tm6a39/pdf/tm6a39.pdf, or even the ETS package (http://pubs.er.usgs.gov/publication/ofr00466).			ET was not modeled explicitly at all (no use of EVT package).

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
33	Recharge boundary condition – See the following publication on the Basin Characterization Method (BCM) currently used by the USGS in a number of southwestern basins. (http://pubs.usgs.gov/pp/pp1703/b/pp1703b.pdf) or (http://pubs.usgs.gov/sir/2007/5099/).			Method that could be used to verify recharge applied in model..
34	Seepage modeling of Alternative 6 Tailings Storage Facility (TSF)[12] is problematic for several reasons, and results should not be relied upon in the DEIS ...			Additional site characterization was finished, and new conceptual and numerical models are in in progress, and expected to be available May 2020, due to the late selection of this alternative.
35	Groundwater Flow Model Setup Issues Several issues were identified with the groundwater flow[6] model setup and are described here. Model Extent and Boundary Inappropriate. Just based on reported results using the 10-foot contours, it's clear predictions of mine drawdowns are impacted by the model boundary condition. Had a 1-foot drawdown contour been reported in the modeling, boundary effects would have likely been far more extensive. it would likely show a much greater degree of boundary impact on the model. This boundary should have been extended outward in all directions to: • avoid influencing internal calculations. This is standard industry practice13.	BGC 2018, Section 4.8.6	ASTM D5609-64 (2015) emphasizes the need to evaluate boundaries as part of sensitivity testing and the verification and validation process for the model. BGC and the GWMG concur that general head or no-flow boundaries are appropriate to use along the northern boundary. Boundary conditions were evaluated during sensitivity testing. This is a surface watershed boundary, and flow across the boundary is unlikely in the shallow aquifers. There is no information available regarding flow in the deeper aquifers. A general head boundary can be used in the deeper layers to evaluate flows across this boundary.	The groundwater modeling group also was concerned with the location of this boundary, but was ultimately convinced through a sensitivity analysis using different boundary conditions that expansion of the model boundary was not necessary. We should describe this better in the text.

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
36	This boundary should have been extended outward in all directions to: permit estimating impacts down to at least 1' drawdown, which likely extend much further out than estimated maximum extent shown in the DEIS (see Figure 3.7.1-3)	BGC 2018, Appendix B.	Much effort was put into determining the appropriate precision of modeling results, considering the uncertainties inherent in the model. Ultimately, the Groundwater Modeling Workgroup selected 10 feet as the limit of precision. See also response to comment 4.	

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
37	Inappropriate Stream-Aquifer Setup/Assumptions. Use of MODFLOW drain package to simulate stream discharge is in appropriate for several reasons: • It only permits removal of groundwater from the model, but no streambed recharge in losing river reaches. This is a major flaw in the model setup and non-standard. Many other high profile recent mining DEIS modeling efforts (i.e., Pebble Mine, Rosemont Mine) have utilized the much more robust MODFLOW stream routing packages (STR1, STR2), which actually dynamically route baseflow discharge from upper reaches to lower reaches, which permits downstream recharge in areas where underlying aquifer heads are lower than the dynamically calculated stream stage. Not accounting for streambed recharge results in either undersimulation of heads in critical GDE areas, or incorrect adjustment of other parameters (i.e., reduction in hydraulic conductivity in stream areas) to compensate for lack of focused, higher streambed recharge.	BGC 2018, Section 4.9.2	The SFR package allows for the most comprehensive modeling of groundwater-surface water interaction. The SRF package is not suited to model streamflow in response to short-term events like storms, but allows for modeling of changes in stream baseflow over time. Since most of the streams in the model area are ephemeral or intermittent streams, which flow only in response to rainfall events, the SFR package would not be applicable for those streams. Perennial reaches in Devils Canyon could be simulated with the SFR package. BGC and the GWMG concur that drains are the adequate model tool to simulate all springs and most streams, as well as underground workings. Drains remove water from the aquifer, similar to actual springs and groundwater fed streams.	

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
38	Drain ‘hydraulic resistance’ or drain conductance was set ‘sufficiently high’ (see page 23, paragraph 5, WSP, 2019) so they would not exhibit resistance to flow. Even if it were acceptable to use one-way flow drain discharge to simulate river discharge, the standard modeling approach is to define drain conductance values as a primary calibration parameter. The modelers here have effectively removed a key parameter value from the calibration process, and specifying high conductance prior to calibration is not valid and should be based on actual field-based measurements and careful calibration (but using a river package, and not a ‘drain’ package).	BGC 2018, Section 5.7	See response to comment 17.	
39	No attempt appears to have been made to couple the MODFLOW drain discharge distribution with surface water modeling (BGC, 2018), so that predicted impacts due to mining on surface water flows could be better simulated, despite simulating at a monthly time period.	BGC 2018, Section 5.7	See response to comment 17.	

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
40	Inappropriate Seepage Setup/Assumptions. Springs and seeps do not appear to have been simulated as discharge points in the Modflow model. It would been appropriate, and is typical, to use the Modflow Drain package to simulate discharge at these areas. Not simulating discharge in these areas would cause the model to over-estimate heads otherwise controlled by discharge to seeps/springs.	BGC 2018, Section 4.9.1	The groundwater model uses drains to simulate springs and streams in the model area.	It would be good to clarify whether springs are modeled individually, or only as part of a stream tributary

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
41	Areal Recharge Specification Inappropriate Recharge zonation into upper and lower zones, and 'enhanced recharge' zones along Queen Creek and Devils Canyon (see paragraph 1, page 25, WSP, 2019) is arbitrary and unjustified, and has significant effects on calibration. WSP, 2019 states "These zones were conceptualized to concentrate runoff that would lead to higher infiltration rates, which were set at 4% and 8% for the lower and higher elevation areas, respectively. As runoff is concentrated in these areas, water is stored in surface soils longer, providing more time for infiltration and hence a higher recharge rate." This statement is physically incorrect, as streambed recharge occurs only along streams, as indicated in Simmers, 198816. Moreover, the aerial recharge specified in the model (Figure 3.6, WSP, 2019) incorrectly assigns high recharge within a nearly ½ mile wide zone around each of these key mine-impacted drainages, which causes too much recharge in these areas, and in turn reduces mine impacts. If the model had been calibrated against surface flows (both discharge and recharge), along with a proper number of wells along each of these drainages, recharge in these areas would have been much better constrained. This is a major problem in	BGC 2018, Section 4.11.2	According to Anderson et al. (2015), there are no universally applicable methods to estimate groundwater recharge. The recharge rate may be adjusted during calibrations. BGC and the GWMG concur that the best available data was used to estimate recharge. Sensitivity analysis used a range of recharge rates to allow for changes in recharge rates due to changes in long term climatic changes.	

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
	the DEIS, which focuses on assessing mine-impacts to these very drainages.			

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
42	Actual Evapotranspiration (AET) from Groundwater is Not Simulated • Calculation of AET is in fact, a critical water balance component in most hydrologic models, and a complicated function of complex climate inputs (generally accounted for in more robust estimates of PET, like the standard ASCE or FAO Penman-Monteith equation17), soil properties (i.e., soil types, layering, moisture contents, unsaturated zone hydraulic properties), precipitation, groundwater depths with time, and vegetation properties (i.e., leaf area index, root depth density with depth, crop coefficients, types, saturation, residual and field and wilting point moistures, canopy properties etc). In single-process codes like MODFLOW, AET is typically simulated either using the standard EVT package, which calculates AET on a cell by-cell basis, as a function of groundwater depth, maximum evapotranspiration rates, and plant root depths, or by specifying net-recharge, where AET is calculated on a cell by cell basis, and then removed from applied recharge. Importantly, assessing sub-daily impacts at specific locations in the model is strongly influenced by correct calculation of AET. In riparian zones, groundwater loss to AET and baseflow discharge compete against each other, as a function of groundwater depth.	BGC 2018, Section 4.11.1	Percent recharge from precipitation was estimated to account for water lost from canopy interception and evaporation, as well as evapotranspiration.	Prucha himself writes: “In single-process codes like MODFLOW, AET is typically simulated …. or by specifying net-recharge, where AET is calculated on a cell by cell basis, and then removed from applied recharge.”

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
	Consequently, without directly simulating AET in all cells, groundwater models likely overestimate baseflow loss, and incorrectly parameterize stream aquifer conductance values. Omitting this critical process (a conceptual error, especially in semi-arid climates) prevents estimation of mine impacts on phreatophyte-dependent riparian vegetation. This is a major oversight in the DEIS evaluation of impacts at GDEs.			

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
43	Modeling of Groundwater Fate/Transport from Mine not Considered. WSP 2019[6] groundwater model sensitivity analysis provided a range of expected drawdowns, despite not being produced by a robust predictive uncertainty analysis, or by adjusting more realistic changes to key model inputs (i.e., distributed parameter and combinations of parameters). The Block Cave Geochemical modeling (Eary, 201818) apparently did not evaluate or discuss predictive uncertainty, which could be quite high due to the high number of input parameters (beyond groundwater flow model), and high uncertainty in inputs/assumptions.			Refer to new memo created by WSP 2020 describing hydraulic gradients in vicinity of mine.

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
44	Subsidence Not Evaluated – Salt River Valley ADWR Model. No effort was made to estimate subsidence in the important Phoenix AMA area, though drawdowns are estimated and subsidence potential acknowledged. Garrett 2018 → states: On Page 9, paragraph 2 "Long-term drawdown from Desert Wellfield pumping of 10 to 30 feet is modeled to occur in the nearby known subsidence areas. Any groundwater pumping within a groundwater basin with known subsidence has the potential to contribute to that subsidence, including the pumping from the Desert Wellfield. Further detailed analysis is not feasible beyond noting the potential for any pumping to contribute to drawdown and subsidence. Subsidence effects are a basin-wide phenomenon, and analytical tools do not exist to isolate the impact from one individual pumping source on subsidence."	Garret 2018	"Long-term drawdown from Desert Wellfield pumping of 10 to 30 feet is modeled to occur in the nearby known subsidence areas. Any groundwater pumping within a groundwater basin with known subsidence has the potential to contribute to that subsidence, including the pumping from the Desert Wellfield. Further detailed analysis is not feasible beyond noting the potential for any pumping to contribute to drawdown and subsidence. Subsidence effects are a basin-wide phenomenon, and analytical tools do not exist to isolate the impact from one individual pumping source on subsidence."	Refer to new BGC 2020 evaluation of Salt River Valley Groundwater Model (in process).
45	The Modflow Subsidence package19 (2003) could easily have been used to assess likely impacts of MARRCO pumping on subsidence.			Refer to new BGC 2020 evaluation of Salt River Valley Groundwater Model (in process).

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
46	Evaluation of future drawdown at surrounding wells not conducted. About 285 wells (ADWR database) would be impacted within the 10' drawdown (at 200 years), and more than 400 wells would probably be impacted by drawdowns of at least 1 foot. This is easily done with a properly calibrated model and predictive uncertainty analysis. Newell and Garrett 2018[20] state, page 10, paragraph 3 "In lieu of analyzing individual wells, typical wells in key communities were analyzed using the groundwater flow model, including wells near Top-of-the-World (using well HRES-06 as a proxy), wells within the town of Superior (using well DHRES-16 as a proxy), and wells near Boyce Thompson Arboretum (using the Gallery well as a proxy)." Proxies give a misleading sense of impacts to surrounding wells because drawdown is spatially complex. The DEIS should have evaluated a range of maximum drawdowns (given uncertainty in predictions) in all wells, regardless of the amount.			Maybe expand explanation of using one proxy for each (similar) spatial location

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
47	Calibration Approach Flawed and Non-unique Calibrating groundwater flow models to only hydraulic heads, which are spatially biased with higher density near the proposed mine, and sparse further from the mine is well known to produce non-unique solutions.[21] The non-unique solution is typical of groundwater models where recharge and hydraulic conductivity values are highly correlated[22]. Doherty and Hunt, 2010[23] indicate that non-unique solutions can be addressed by adding other types of calibration data (i.e., surface water discharge, water quality data etc). Representing seasonally dynamic gaining/losing surface water flows as 'drain' cells in the groundwater model, fails to account for stream recharge in losing reaches. This in turn forces incorrect adjustments of hydraulic parameter values to compensate, and further degrades calibration and therefore reliability of the groundwater model for predictions.	BGC 2018, Section 4.15.1 and 4.15.2	Transient fluxes were evaluated qualitatively. Fluxes into drains represent water discharged from groundwater into streams. They were not evaluated statistically but were qualitatively compared to measured flows. Flows out of model drains were analyzed for the calibrated model. Simulated flows match estimates of baseflow recharge of perennial streams. This confirms that the calibration for the model is appropriate. The groundwater model was calibrated with realistic hydraulic properties, therefore BGC and the GWMG concur that the calibration supports the model.	Drains were located along dry/ephemeral and perennial reaches of Devils Creek. Drains did start to pick up water where perennial baseflow started, indicating a good match of the modeled groundwater heads to actual conditions.

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
48	The main focus of the DEIS is to estimate potential changes to the surface/subsurface hydrologic system, or GDEs affected by mine drawdown and changes to surface flows. Despite this objective, virtually no observation data for either surface water, or groundwater is available at, or near GDEs to constrain calibration in these critical areas. This is a major flaw in the overall model calibration approach and should have been addressed in the DEIS. Other major mine modeling efforts (i.e., Rosemont mine[24]) attempt to reproduce spatial distribution and magnitudes of observed baseflow, but the spatial distribution and long-term (i.e., multiple years) of surface water flow (or stage) data appears inadequate to assess even flow along the entire extent of the three main drainages potentially affected by the mine dewatering/TSF (Queen Creek, Mineral Creek and Devils Canyon).			Point to M&A reports.

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
49	Pre-mining Conditions, and period from 1910 to 1996 Uncalibrated The approach to determining pre-mining initial 3-dimensional heads (1910) for 39 model layers was never presented in the WSP, 2019 modeling report, but the DEIS really should have required detailed description of these conditions and how they were derived, and associated errors. They are critical to assessing the nature of long-term post-closure groundwater recovery, rather than attempting to assess recovery relative to the start of RCM pumping in 2009, which already induces a substantial drawdown response, superimposed on the partially-recovered heads from 1910 to 1996 pumping. This is essential information in conservatively assessing mine impacts on GDEs. From 1910 to 1996, the model appears uncalibrated (no reporting on this in DEIS, or WSP, 2019 report) even the historical pumping locations are largely unknown[25], which likely introduces substantial error into the calibration, and further uncertainty in predictions, as the heads by start of RCM pumping in 2009 were no where near recovered to pre-mining conditions.	BGC 2018, Section 4.15.1	Calibration was focused on the post-March 1998 period, to allow for shorter model runtimes and utilize the most reliable head measurements. Forty-seven targets with a total of 2805 observations were available for the shallow groundwater system, and 48 targets with a total of 2899 observations for the deep groundwater system. Little data are available for pre-mining steady state conditions, and BGC and the GWMG concur that a quantitative calibration for steady state conditions is not feasible.	

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
50	Calibration Targets Don't Match Modeling Objectives Page 30, paragraph 7 in WSP, 2019 states "The strong drawdown responses shown in the Deep Groundwater System in response to dewatering of Shafts 9 and 10, is clearly seen in some of the wells inside Resolution graben, specifically DHRES-01_WL, DHRES-02_WL and DHRES-08_231. These wells were prioritized as key targets to match, as pumping of Shafts 9 and 10 essentially represents a large-scale aquifer test. The fit of these three targets is good and gives an indication of how the model will respond to a large stress on the system, such as the development of the RC mine." It is clear from this statement that the focus of the WSP, 2019 model calibration was aimed more at quantifying key inputs useful to the design/operation of the mine (i.e., mine inflow, time to drawdown mine etc) rather than focusing on calibration that would minimize errors at what should have been key priority targets, the GDEs.			Transient Calibration used the best available datasets for calibration.

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
51	Much of the DEIS assessment of mine impacts on the surrounding environment is devoted towards assessing how mine dewatering causes groundwater declines at numerous surrounding GDEs, and therefore also changes in surface water discharge. An arbitrary 10-foot decline is used to identify those GDEs that would be impacted, because the groundwater modeling group deemed the model to be less ‘precise’ below 10 feet. By not relying on results less than 10 feet drawdown, RCM in effect sets a key calibration target. As such, model calibration should have focused on GDEs. In other words, calibration error (or residuals) should have been minimized at all GDEs, and if clearly reported in the DEIS, so that errors in drawdown are well known. This information would then be useful in estimating a range of uncertainty in drawdown predictions at GDEs.			

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
52	TSF Seepage Modeling Unreliable Review of the seepage modeling[26] associated with TSF alternatives (particularly #6) shows this modeling was never calibrated, because it was based on an idealized, conceptual 2-d profile, rather than using actual field-derived hydrogeologic data. It is understood that the authors of this study (at preferred alternative #6) believe conceptual modeling of this complex, but critical mine component is adequate for assessing different alternatives. But numerous assumptions were made about the subsurface and boundary conditions which would affect leakage estimates, including the implicit assumption that groundwater flows beneath the proposed TSF (for all possible future climate conditions and meteorological conditions) would never interact with internal seepage calculations, which are not conservative. The TSF and surrounding hydrogeologic system is a 3-dimensional flow system, where groundwater flows concentration beneath the central surface drainage. No surface water or groundwater data, or hydrogeologic data support the notion groundwater wouldn't interact with the calculated seepage. If it did, this becomes critically important in subsequent evaluations of water quality impacts both during mining, and post-closure – and comparison of			Additional site characterization was finished, and new conceptual and numerical models are in progress, and expected to be available May 2020, due to the late selection of this alternative.

No.	Comment	Respon se Source	Response from prior EIS document	Water Work Group Additional Thoughts
	alternatives. Ultimately, estimates of seepage rates during mining and post-closure are not calibrated, and therefore unreliable.			

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
53	Presentation of Calibration Results Incomplete/Misleading Model performance and reliability based on model-wide calibration statistics of only head data gives a misleading and unreliable sense the model is adequately calibrated for intended purpose of evaluating impacts at GDEs. For the high degree of hydrogeologic complexity of the subsurface system, including multiple offset faults, perched, shallow and deep aquifer units and historically complex dewatering in the area, the number, locations and depths of calibration targets is inadequate, particularly in key target GDE areas, the main focus of the groundwater modeling evaluation. For example, Table 3.6 in the WSP, 2019 report indicates Residual Mean in the Apache Leap Tuff is -14 ft, indicating on average, the model over-estimates heads in this shallow aquifer. Yet, closer inspection of transient well hydrographs included in Appendix C of WSP, 2019 closer to surface drainages (i.e., DHRES-08, DHRES-10, DHRES-11, DHRES-12, DHRES-17 and DHRES-18) indicates simulated differences more than 100 to more than 600+ feet	BGC 2018, Section 4.15.1 and 4.15.2	Hydrographs comparing the simulated heads to observed heads were plotted for all targets (WSP 2017). The trends of the model hydrographs match the trends of the observed hydrographs reasonably well for the time period where calibration data are available. Actual simulated heads vary from observed heads from a few feet to several hundred feet. Modeled heads for wells closer to the proposed mine site show a better match to observed wells than heads for more distant wells. No data was made available comparing measured pre-1998 heads to modeled heads. The groundwater model was calibrated with realistic hydraulic properties, therefore BGC and the GWMG concur that the calibration supports the model.	

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
54	Spatial Bias in Calibration. The WSP, 2019 report shows calibration 'Scatter Plots' (see Figures 3.9 and 3.10), but never show spatial bias and residuals at specific wells by aquifer unit. This is essential for assessing calibration error (residuals) at specific GDE locations, generally along streams.			This info should be provided.
55	Hydraulic Tests. Calibration to 2 aquifer hydraulic tests appear to reproduce drawdowns in several wells, and even anistropic drawdown trend, but the mine dewatering will continue for several decades, and these hydraulic tests have limited value: Tests are far too small a stress on the aquifer to confirm parameterization, assumed boundary conditions for most of the GDEs. • These tests already confirm aquifer response in spatially-biased high density of mine wells. • These tests don't confirm influence of all faults included in the model. It would have been far more instructive to conduct tests, monitoring hydraulic response on both sides of important bounding faults (or faults that act as preferential conduits of groundwater flow.	BGC 2018, Section 4.15.1	Forty-seven targets with a total of 2805 observations were available for the shallow groundwater system, and 48 targets with a total of 2899 observations for the deep groundwater system. The groundwater heads in the shallow groundwater system ranged from 2211 feet amsl to 4434 feet amsl, while they ranged from 450 feet below msl to 3845 feet amsl in the deep groundwater system, giving a total range of observations of 4884 feet.	Improve the explanation that calibration is based on multi-year mine dewatering, not pumping tests.

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
56	Predicted change from proper Baseline Conditions Biased. Historical Magma Mine pumping occurred from 1910 to 1998. RCM pumping started in 2009 (WSP, 2019). WSP states (page 4, paragraph 6) "Water levels had recovered to approximately 2,200 ft amsl by the time dewatering was resumed on March 17, 2009". This clearly indicates the groundwater levels in the vicinity had not fully recovered, and therefore do NOT represent a proper baseline, or pre-mining condition. Pre-mining Furthermore, it is likely streamflows (and springs) in the area that would have been impacted by historical Magma Mine pumping, and which would have recovered had RCM not restarted pumping in 2009, would have increased the number of baseline GDEs in the area (i.e., Devil's Canyon stream from DC10.9to DC15). Pre-mining (baseline) heads for the Tal shallow aquifer are presented in WSP 2019, but no discussion of associated interaction of groundwaters with surface waters during this period is presented. The DEIS should have evaluated RCM mine dewatering and post-closure crater subsidence related to this condition, as the Magma mine dewatering would presumably have recovered to near these levels.	BGC 2018, Section 5.1	See response to comment 6.	

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
57	Predicted flow through fractured crater limited because of model instability. Page 38, paragraph 1 WSP 2019 indicates that hydraulic conductivities within the fractured crater were limited to only 100 ft/day due to instabilities in the model, if assigned higher values. The fracturing likely produces much higher conductivity values than 100 ft/day, which would enhance vertical drainage from the overlying shallow Tal aquifer due to block caving. The DEIS should require detailed assessment of hydraulic response (or recovery for post-closure) to better assess impacts of this important post-closure condition. It is possible the recovery of water levels postclosure would have been much quicker, leading to better estimates of drawdown and GDE impacts (instead of limiting impacts to 148 years after closure, and 10' drawdown contours).			Add explanation that even higher conductivities to model empty space would not make much difference.

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
58	Evaluation of effect of geothermal water on post-closure flows and water quality not conducted. No evaluation was presented in the DEIS or associated documents to evaluate geothermally influenced circulation within the post-closure fracture zone, which would act to circulate deep warmer waters with shallow, cooler inflow from ALT aquifer waters, driven by density variations (i.e., warmer waters rise, inducing vertical mixing). Geothermal waters were encountered in Shaft 1027, which surprised RCM and consultants. Often, geothermal waters are found in permeable fault zones, or where faults intersect each other28. Because multiple faults are present in the mine area, the DEIS should have required more characterization, conceptualization and use of an appropriate code capable of simulating heat transport and associated effects of density-driven circulation to better estimate long-term post-closure conditions, and water quality impacts.			WSP has provided response.
59	It's unclear why RCM didn't consider potential to develop the geothermal water source to offset energy requirements.			

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
60	Clear disclosure of full hydraulic impacts is missing. Montgomery & Associates, 201729, Page ES-6, states “However, the Magma Mine workings do extend west of the fault, providing the potential for hydraulic impacts to extend beyond the fault.” A clear description and explanation of the final 3-d mine closure configuration is never presented. It is apparent that WSP failed to account for the change in land surface in their modeling (~800 to 1100 feet). This is a critical oversight in the DEIS, because had a proper future-condition conceptual model been developed showing the 800 to 1000 ft drop in land-surface, it would have required a similar change in the calibrated model. Simulating long-term (steady state to avoid uncertainty associated with the time it takes for system to recover to pre-mining conditions) postclosure conditions would very likely have shown development of a pitlake (see Section 2.7.7). This is a major impact to the system which the DEIS failed to address.	BGC 2018, Section 4.17.3	Under the proposed action alternative, time varying properties were also necessary to model the panel cave and subsidence zone.	Explain better that subsidence zone was modeled same as panel cave (and that it doesn't make a difference, because there is no groundwater anyhow).

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
61	Inappropriate Predictions of Post-Closure Impacts WSP, 2019[30] Page 4, Paragraph 4 states "As water level recovery within the block cave is slow, some areas show additional drawdown continuing to propagate outward after 200 years as steady state equilibrium conditions have not yet been re-established." Prediction of post-closure hydrologic conditions at an arbitrarily chosen 200 years (or 148 years after closure) is very misleading and incorrectly conveys what will really occur at final steady state conditions. The modeling report suggests even at 148 years post-closure, drawdown is still occurring, due to slow/low recharge, though the flawed calibration/non-unique solution produce model results so uncertain SW discharge is not relied on. Clearly the 200 years should not have been arbitrarily used to assess long-term final impact w/uncertain model. This biases estimated drawdown impacts at GDEs towards the low side (not conservatively high as suggested in the WSP study. By comparison, the modeling conducted for the Rosemont DEIS demonstrated Steady State conditions were achieved at streams of interest (at 1000 years out). This continued drawdown by itself should have alerted modeling group to insist on simulating much longer, or steady state post-closure.	BGC 2018, Section 4.5.1	See response to comment 5.	USDA 2019: Draft EIS, Chapter 3 (pages 333 and 334)

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
62	Use of 10-foot Drawdown Contour Misleading/Biased At least a simulated long-term 1-foot drawdown contour should have been used in the identification of GDEs. GDEs, or private wells experiencing even a 1' drawdown could have significant negative impacts. A simulated 1-foot drawdown contour (or lower) was never shown in the DEIS, but probably shows significant effects of model boundary effects, implying the model extent should have been expanded to avoid any influence over internal calculations as is standard modeling practice. Using the 10-foot drawdown contour to define impacts is highly biased, and likely removes many GDEs from further evaluation of impacts/mitigation. The explanation that drawdowns less than 10-feet are imprecise in the DEIS (see page 301) is flawed. Groundwater models are precise, but suffer from accuracy issues. The accuracy at 1-foot drawdown is the same as 10-feet. A predictive uncertainty analysis would effectively provide a means of adding a +/- around drawdown contours.	BGC 2018, Appendix B.	See response to comment 4 and 36.	

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
63	Assessment of potential Pitlake development/impacts flawed Pitlake Development. WSP 2019 states on Page 1, Paragraph 2 that ‘the potential for a pit lake will be assessed’. Yet the modeling study failed to present any further details on the potential for a pitlake to develop, and to then characterize and evaluate impacts of the pitlake on surrounding flows and water quality. Page 376-377 in the DEIS do describe the ‘Potential for Subsidence Lake Development’, explored by the Groundwater Modeling Workgroup, but the DEIS states on page 377 “Ultimately the Forest Service determined that the presence of a subsidence lake was speculative and not reasonably foreseeable, and as such it would therefore be inappropriate to analyze in the EIS” Table 3.7.2-7 provides an overview of predicted water levels after 1000 years and the DEIS concludes “groundwater levels are still at least 200 feet below the bottom of the subsidence crater”. However, there are two key reasons why it is likely a pit lake would form postclosure:	DEIS, page 376	Ultimately the Forest Service determined that the presence of a subsidence lake was speculative and not reasonably foreseeable, and as such it would therefore be inappropriate to analyze in the EIS” Table 3.7.2-7 provides an overview of predicted water levels after 1000 years and the DEIS concludes “groundwater levels are still at least 200 feet below the bottom of the subsidence crater”	

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
64	The flow model is highly uncertain, and non-unique due to calibration to only groundwater head data, and not other common calibration datasets (i.e, surface discharge, water quality etc) that would reduce non-uniqueness. As a result, estimated water level recovery at 1000 years is highly uncertain, and levels would likely recover much quicker.	BGC 2018, Section 4.15.2	The groundwater model was calibrated with realistic hydraulic properties, therefore BGC and the GWMG concur that the calibration supports the model.	Also, recharge estimates are within a reasonable range and locations and rates of groundwater discharge are reasonable at Whitlow Ranch dam are reasonable (recharge can be a constraining flux). Also, flow model calibrations are always non-unique. And recovery rates could also be much slower.
65	More importantly, conceptually, it is easy to argue that the groundwater levels will eventually recover to pre-mining levels (steady state), and at least to currently monitored levels, known to be influenced by Shaft 9/10 pumping since 2009. In fact, these recovered levels, at wells DHRES-01 and DHRES-02 within the crater, exceed 3650 ft, MSL for various screened zones (see observed levels in WSP 2019 report, Appendix C for different well screen zones). According to DEIS Figure 3.7.2-4, these recovered levels would be more than 650 feet above the 1100 ft subsidence crater land surface, and more than 350 feet above the 800 ft landsurface elevations (3000 ft, and 3300 ft, respectively).			Dewatering for decades, the occurrence of subsidence and the complete removal of the Tal aquifer are large changes, which will influence recharge and discharge, and a return to pre-mining (steady state) conditions cannot be assumed.

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
66	WSP, 2019 failed to include the change in the ground surface due to the crater in the future condition groundwater modeling. Conservatively, they should have dropped the surface 1100 ft, and let the groundwater model simulate eventual development of the subsidence crater, which would, like the Rosemont mine DEIS modeling that also showed long-term development of a pitlake, change the long-term, or eventual groundwater flow regime. More importantly, with continued evaporation, the pitlake waters would likely also significantly change predicted long-term water quality predictions and risks in the area of this pitlake.	BGC 2018, Section 4.17.3	See response to comment 60.	
67	Figure 1 from Meza-Cuadra, 2018b31 was revised to reflect conceptually what the WSP, 2019 groundwater model should have simulated (change in land surface), and the eventual development of a pitlake as groundwater levels recover. WSP should have included this type of Future Processes Conceptual Model, which is industry standard (see Potential Errors in Conceptual Modeling, Section 4.6 in Wels, 2012[1]). Rosemont DEIS groundwater modeling of the development of a pitlake was developed using Modflow-Surfact coupled to a dynamic systems model using the GoldSim code32.	BGC 2018, Section 4.17.3	See response to comment 60.	

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
68	Figure 4 below shows a more likely long-term drawdown (at steady state, not arbitrary 148 years after closure) 4 km out from the arbitrarily chosen 10' drawdown, which should really have shown predicted drawdowns of <1', or something which would impact groundwater discharge areas (springs, baseflow in streams, riparian vegetation etc). The figure shows that additional SW areas would likely be affected by long-term drawdown, than evaluated in the DEIS. The DEIS should have also assess impacts within the following watersheds: a. North of Queen Creek, including Haunted Canyon, Upper Pinto Creek, and West Fork watersheds. b. Walnut Canyon to the south, which drains into the Gila River via Donnelly Wash.	BGC 2018, Section 5.7	Tonto National Forest asserts that: ...Operational monitoring of all potentially impacted groundwater-dependent ecosystems, regardless of groundwater model predictions of impact, provides a backstop to the acknowledged uncertainty of the groundwater model.	Steady state will be a long time out, and the atmospheric inputs and outputs to the system may have changed appreciably over this time
69	Predictive Uncertainty Evaluation Missing The Groundwater Modeling Work Group appeared to acknowledge uncertainty in their modeling predictions of drawdown extent, but then failed to provide a range of predictions for all predictions.	BGC 2018, Appendix B	However, recognizing the uncertainties inherent in the modeling, the base case 10-foot contours was supplemented with the 10-foot contour encompassing all sensitivity runs. Any sensitive receptors within this area were also considered to have potential anticipated impacts.	The Groundwater Modeling Work Group report will be edited to state "predictive uncertainty runs" instead of "sensitivity runs", where appropriate.

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
70	Other modeling efforts also appear to have failed to consider any type of predictive uncertainty, despite substantial calibration errors and high input uncertainty. The DEIS should have required a comprehensive approach to dealing with any modeling uncertainty in all model predictions. All of the models developed and referenced in this DEIS (and supporting documents) have numerous assumptions and inputs, each of which translate into prediction uncertainty, but none address the substantial uncertainty in predictions, let alone even identifying and tracking all sources of uncertainty.			The Desert Wellfield model is currently undergoing review, with a report available June 2020.
71	Impacts of the proposed Desert Wellfield pumping wells near the proposed MARRCO corridor were evaluated by Bates et al, 201833, using ADWR's 2009 Salt River Valley (SRV) model34. The ADWR SRV modeling effort never included a predictive uncertainty evaluation, nor did the predictive modeling by Bates et al, 2018. This would have been well warranted in the proposed pumping area, as data used to support model construction are clearly absent in this area. As a result, predictions using this model, in this area are expected to be exhibit high uncertainty, relative to other areas in their model domain,			

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
	which had much greater data to justify model construction.			
72	Evaluation of hydrologic model prediction uncertainty is critical, yet modelers confused sensitivity evaluation for standard/formal predictive uncertainty analysis.			Agree that sometimes the groundwater modeling work group report description is misleading, but a sensitivity analysis was conducted separately from an uncertainty analysis.

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
73	It is important to note that the nonuniqueness of the groundwater flow model calibration (remembering that it was only calibrated to heads, and not discharge, water quality etc) leads to many equally valid predictive solutions. Assessment of the range of possible impacts of the mine on surrounding hydrology (and WQ) is therefore, inadequate and unreliable. It is misleading/incorrect to assume flawed/unreliable model simulated drawdowns above 10 feet are accurate, and those below are inaccurate. GDEs are very sensitive to groundwater levels – and even a 1-foot change likely significantly changes spring/river discharge or even presence. Gabora et al, 2014[35] appropriately used a Monte Carlo method to predict an entire range of simulated pit model inflows, while maintaining calibration.	BGC 2018, Section 4.15.1 and 4.15.2	See response to comment 47.	Fluxes were used for model calibration, however, even if many equally valid solutions exist, this does not necessarily lead to "inadequate and unreliable". Many of these other solutions may be quite similar to the chosen conceptual model and the calibrated model.

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
74	The reliability of the model findings is implicitly tied to the accuracy of the model, which by default is uncertain, like all models. Model accuracy can be improved by collecting more data, increasing discretization and better reproducing observations, but in reality this is impossible to achieve, given that models are simplifications of flow systems, and data will always be limited. As such, it is far more important for RCM consultants to acknowledge uncertain model predictions, and instead conduct a detailed and robust predictive uncertainty analysis which focuses not just on predicted groundwater inflow to the pit lake, but also on predicted response at all other mine components, at the same time. A sensitivity analysis (ASTM D561136) doesn’t provide a range of possible predicted responses given ranges of uncertain model inputs like an uncertainty analysis, which constrains realizations to maintain calibration within acceptable targets (Doherty, 2010).	BGC 2018, Appendix B	See response to comment 69.	

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
75	Modelers appear to have confused a predictive sensitivity analysis with a predictive uncertainty analysis. The distinction is very important, as a sensitivity analysis does not provide a true assessment of model uncertainty (see Neuman and Weiranga, 20035, Doherty et al, 201038) – typically perturbations cause the model to fall out of calibration, which make the results unreliable. Yet the authors report a range of output from simulations using arbitrary adjustment of selective (i.e., cherry picked) parameters, to imply they've considered the full range of possible impacts at GDEs, despite the modelers using the PEST code (described by code author Doherty, 2010) to help refine model calibration (see page 27, WSP, 2019), they failed to use the same code to conduct a predictive uncertainty analysis.	BGC 2018, Appendix B	See response to comment 69.	
76	The failure of this DEIS to require formal uncertainty analyses for all of the modeling predicting impacts to the surrounding environment/GDEs is a major oversight. As Doherty et al, 2010 states "Central to any decision-making process is an assessment of risk. Such an assessment is impossible without some assessment of predictive uncertainty.", which clearly supports the need for some type of uncertainty analysis to qualify predictions.	BGC 2018	See response to comment 70	The Desert Wellfield model is currently undergoing review, with a report available June 2020.

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
77	Ultimately, model predictions of impacts on GDEs are considered highly uncertain, due to a combination of the high level of input uncertainty, high conceptual model uncertainty, uncertainty in calibration data, and notable model error. While it appears that the groundwater modeling workgroup has acknowledged results are uncertain, especially with distance from the mine operations, further evaluation of uncertainty was dismissed in favour of selective sensitivity evaluations (Meza-Cuadra et al, 2018c[37]). Conducting a simplified sensitivity evaluation and then claiming it represents model uncertainty is misleading and understates the value of conducting a formal uncertainty analysis (at GDEs). An uncertainty analysis defines a range of equally valid predictions, which maintain calibration constraints, by adjusting individual/combinations of model inputs, to which the solution is most sensitive. Sensitivity analysis identify parameters that predictions are most sensitive to, but do not bracket a realistic range of equally possible solutions that meet objective function constraints (i.e., minimizing the difference between historical and simulated heads), and as such shouldn't be used in lieu of a constrained uncertainty analysis. Conducting a formal uncertainty	BGC 2018, Section 4.18	See response to comment 14.	Section 4.18.2 will be rewritten to discuss the uncertainty analysis. The description of the uncertainty analysis will be improved.

No.	Comment	Response Source	Response from prior EIS document	Water Work Group Additional Thoughts
	analysis and providing a qualified range of potential impacts, provides a much better way to inform critical decisions related to mine permitting.			

ATTACHMENT 4

WHITE PAPER ON MODELING COMMENTS CIRCULATED JUNE 21, 2020 TO WATER RESOURCES WORKGROUP

WHITE PAPER

PROPOSED PATH FORWARD FOR GROUNDWATER MODELING CRITICISMS

I.A Purpose of White Paper

Groundwater modeling requires making choices.

There are multiple groundwater models available, many tools and techniques available within those various models, and an unlimited number of ways to build a model framework using those tools. In order to reasonably replicate real-world aquifer conditions and responses, a groundwater modeler has to choose among all these variables, and those choices must be demonstrably reasonable and appropriate.

We have plenty of industry and professional groundwater modeling guidance available to us—we went to great pains to explore this in Appendix B of the Groundwater Modeling Workgroup[1] memo (BGC 2018d)[2]. This guidance primarily focuses on the modeling process to be followed, rather than dictating specific choices to be made. This is because every situation is unique, and there is no "right" way to build any given groundwater model from all the tools and techniques available.

We received numerous comments—criticisms to be more specific—on the groundwater modeling analysis and results used in the Draft EIS. These comments have been reviewed by both Resolution Copper's groundwater modelers (WSP) and by the groundwater modelers on the Forest Service NEPA team (SWCA and BGC). The purpose of this white paper is to propose a path forward for responding to these groundwater modeling comments, considering the input from these professionals as well as the overall NEPA process.

There are 15 specific modeling criticisms discussed in this whitepaper. The intent is to first provide all pertinent background on these criticisms: WSP response, BGC response, and pertinent documents. The discussion that follows these items is at times a lengthy narrative, attempting to work through the complex issues raised and see the issue from different viewpoints.

This whitepaper is being prepared behind the scenes of the reconvened Water Resources Workgroup. However lengthy the discussion of the comments, the intent of this whitepaper is to make very clear the conclusion the NEPA team arrived at internally and the direction they intend to follow, for sharing with the Workgroup. These clear intentions can be found:

- In the Executive Summary (Section I.B.)
- In the "Proposed Path Forward" bullets (that appear at the end of each of the Issue discussions).

[1] In this whitepaper, the term "Groundwater Modeling Workgroup" refers to the workgroup convened in September 2017 to inform DEIS analyses, the outcomes of which are described in the BGC 2018d memo. The term "Water Resources Workgroup" or "reconvened Water Resources Workgroup" refers to a similar but wider workgroup convened in January 2020 to inform responses to public comments on the DEIS. The term "Workgroup" is used in places as shorthand.

[2] In this whitepaper, whenever possible the citations match the literature cited in the DEIS, all of which can be found here: https://www.resolutionmineeis.us/documents/draft-eis/documents-cited. For references not cited in the DEIS, either project record numbers are given or the full citation, or both.

I.B. Executive Summary

The results discussed below are summarized here, for 15 specific issues raised in public comments:

	Categorization of Comments*				Action Recommended				Page number in this white paper
Issue	**#1**	**#2**	**#3**	**#4**	**Add text to FEIS**	**Add to project record**	**Revised analysis**	**RTC only**	
#1: Modeling process, characterization, conceptualization	X	X				X			7
#2: Model code selection	X	X			X				13
#3: GDEs	X	X						X	15
#4: Baseline conditions	X	X		X	X	X			17
#5: Model output (200 years, 10 feet)	X	X			X				20
#6: Skunk Camp modeling	X	X			X		X		24
#7: SW/GW interaction	X	X						X	28
#8: Choice of wells and targets		X			X				32
#9: Calibration	X	X				X			34
#10: Uncertainty	X	X				X			38
#11: Geothermal effects			X		X	X			42
#12: Subsidence crater lake		X			X		X		44
#13: Subsidence		X				X			47
#14: Desert Wellfield model			X		X		X		49
#15: Inappropriate modeling choices for faults, recharge, ET, boundary conditions	X	X				X			50

* See section II.B for full descriptions of categories: #1 factually incorrect; #2 discussed in workgroup; #3 not discussed in workgroup; #4 overall NEPA decision

Summary of additional text to add to FEIS

- Issue #2: Add code selection detail to text of FEIS
- Issue #4: Add detail of pre-1998 hydrologic conditions to text of FEIS
- Issue #4: Add detail of calibration to text of FEIS
- Issue #5: Add detail to FEIS to directly call-out where impacts are assessed less than 10-feet and longer than 200-years, and discuss the steady-state vs. transient issue
- Issue #6: Add Skunk Camp new characterization and modeling results to FEIS
- Issue #8: Describe in FEIS why individual wells are not analyzed, and how the results are still available in the figures for wells not near the proxies
- Issue #11: Discuss geothermal gradients in the FEIS
- Issue #12: Revise language on subsidence lake as discussed in Workgroup, add in uncertainty in hydrographs
- Issue #14: Add detail in FEIS about development/use of the Desert Wellfield model

Summary of additions to project record needed

- Issue #1: Edit Section 3.4.7 in the final Workgroup memo
- Issue #4: Compile information on historic water level conditions in record, from available sources already provided
- Issue #9: Provide breakdown of residual heads at wells and aquifer units, to better inform calibration results
- Issue #10: Provide additional explanation in final Workgroup memo to describe that multiple valid approaches exist based on industry modeling guidance, but that both calibration sensitivity analysis and predictive uncertainty analysis were conducted, though not presented in final WSP report.
- Issue #11: Documentation on the topic of geothermal gradients does not exist and is needed. The groundwater experts on the NEPA team should review and concur with the rationale stated in this whitepaper (and in WSP 3/23/20, attachment 1) and document it in some manner for the project record.
- Issue #13: Add explanations of how the block-cave area is modeled to project record (need from WSP)
- Issue #15: Clarify on spring modeling using drains (need from WSP); BGC to explain boundary effects better in final Workgroup memo.

Summary of revised analysis needed

- Issue #6. Under the purview of the reconvened Water Resources Workgroup, obtain and review all new hydrogeologic information for Skunk Camp, all revised water quality modeling for Skunk Camp, and evaluate appropriateness of modeling and techniques used.
- Issue #12. Provide sensitivity hydrographs DHRES-01, DHRES-02, and DHRES-08.
- Issue #14. BGC will conduct a review of the appropriateness and sufficiency of the Desert Wellfield model, and the results of this review will guide the use of the model in the FEIS. This includes additional documentation received from ADWR clarifying how the model scenario used by Montgomery & Associates was constructed.

II. Approach for Assessing Comments

As was noted in the DEIS, the Tonto National Forest did not conduct the groundwater modeling analysis in a vacuum:

> *"In September 2017, the Tonto National Forest convened a multidisciplinary team of professionals, referred to as the Groundwater Modeling Workgroup. The Groundwater Modeling Workgroup included Tonto National Forest and Washington-level Forest Service hydrologists, the groundwater modeling experts on the project NEPA team, representatives from ADWR, AGFD, the EPA, the San Carlos Apache Tribe, and Resolution Copper and its contractors. This group included not only hydrologists working on the groundwater model itself, but also the biologists and hydrologists who have conducted monitoring in the field and are knowledgeable about the springs, streams, and riparian systems in the project vicinity. The Groundwater Modeling Workgroup tackled three major tasks: defining sensitive areas, evaluating the model and assisting the Tonto National Forest in making key decisions on model construction and methodology, and assisting the Tonto National Forest in making key decisions on how to use and present model results."* (DEIS, p. 296)

It is useful to revisit the founding philosophies of the Groundwater Modeling Workgroup (shared during the September 2017 workgroup kickoff meeting [Project Record #0002056]):

> *"1) The groundwater model is one tool that can be used to predict impacts, but not the only tool.*
>
> *2) The groundwater model should represent the best available science.*
>
> *3) The groundwater model should not be used to answer questions that are beyond its ability to answer.*
>
> *4) The Forest Service is ultimately responsible for approving the groundwater model in all its aspects, but all voices at the table should be heard and considered.*
>
> *5) Every effort will be made to make decisions on modeling approach before seeing the model output. It is not appropriate to rethink the model in order to arrive at a particular desired answer."*

These founding principles make clear that the goal of the Groundwater Modeling Workgroup wasn't to arrive at any specific answer, but to ensure that whatever modeling choices the Forest Service made, they would be <u>informed</u> choices.

II.A. Overall Decision to Use Groundwater Modeling

We shouldn't overlook the first and most fundamental decision made by the Tonto National Forest, informed by the Groundwater Modeling Workgoup: the decision to use a numerical groundwater model to assess impacts. As noted in the DEIS:

> *"To assess impacts on groundwater resources, the long history of baseline data collection was considered holistically alongside*
>
> - *the large geographic area involved;*

- *the complex geology and multiple aquifers, including the incorporation of the blockcaving itself, which would fundamentally alter the geological structure of these aquifers over time;*
- *the long timeframes involved for mining (decades) as well as the time for the hydrology to adjust to these changes (hundreds of years); and*
- *the fact that even relatively small changes in water levels can have large effects on natural systems.*

A numerical groundwater flow model is the best available tool to assess groundwater impacts." (DEIS, p. 295)

Notably, no comments received on the DEIS question this fundamental decision to use a numerical groundwater flow model to assess groundwater impacts. A groundwater model remains the most appropriate tool. The remaining criticisms largely focus on the professional choices made when designing and using that tool.

II.B. General Categories of Comments Received

While the comments received on the groundwater model are highly detailed and specific, they generally group in four categories:

1. Comments that are factually incorrect[3], usually in that they claim a process step was not conducted, when it can be clearly documented in the project record that the step took place. These comments may require no changes, but may reflect a need for better documentation in the DEIS that these steps occurred.

2. Comments that express a professional opinion[4] about a modeling choice that was made, when that modeling choice was explicitly discussed as part of the Groundwater Modeling Workgroup discussions between September 2017 and December 2018 and documented in the workgroup results. In these cases, we need to look at whether a new or different rationale is proposed in the comment that would suggest that the original informed choice should be revisited.

3. Comments that express a professional opinion about a modeling choice that was made, but reflect an aspect of the modeling that was not explicitly discussed as part of the Groundwater Modeling Workgroup.

4. Comments that conflict with global decisions made by the NEPA management team.

[3] We are aware that using the term "factually incorrect", or similar terms, throughout this whitepaper suggests that a personal judgement is being made. On the contrary, whenever these terms are used in this whitepaper, the intention is to then immediately point to the documentation that exists that contradicts the comment.
[4] It is worth noting that most of the public comments received on the groundwater model are from professionals with modeling experience. Many of the comments were made by Dr. Bob Prucha, under the auspices of the Arizona Mining Reform Coalition et al comment letter (see Attachment 1).

II.C. Organization of Comments

BGC organized the Prucha comment letter into 77 separate comments for the purposes of detailed analysis (see Attachment 2). These group into 15 specific questions that are discussed below, and the specific comment numbers associated with those categories are noted.

<u>III. Issue #1: The modeling process was not followed, including appropriate characterization and conceptualization of the hydrologic framework.</u>

III.A. Specific comments included (see Attachment 2): 10, 11, 13, 15, 19, 21, 55

III.B. General category of these comments:

- #1 – Some comments are factually incorrect
- #2 – Professional opinion expressed about an issue explicitly discussed by Groundwater Modeling Workgroup

III.C. RCM/WSP response (paraphrased from WSP 3/23/20, Attachment 1):

- WSP notes that the comments that conceptual model development is lacking or incomplete are incorrect (p. 4)
- WSP notes that conceptual model is based on 15 years of extensive baseline field data, and was then tested and verified through the model development and calibration (p. 4-5)
- WSP notes that alternative conceptual models were assessed through other modeling scenarios (p. 5)
- WSP notes that small-scale aquifer tests perform well with the conceptual model, and notes that the large-scale dewatering tests were not considered by the commenter (p. 9)

III.D. NEPA/BGC response (paraphrased from BGC 5/11/20, Attachment 2):

- BGC notes that industry-standard approaches were documented and adhered to
- BGC notes that issues to be addressed were documented and adhered to
- BGC notes that documentation on conceptual model can be added to workgroup memo
- BGC notes that documentation on aquifer tests used can be added to workgroup memo

III.E. Pertinent documentation in project record:

- Issues Report: "FINAL Summary of Issues Identified Through Scoping Process", November 2017 (see p. 10-13)
- DEIS Section 1.7, p. 24 see esp. Issue 6 – Water Resources
- DEIS Appendix E, Alternatives Issue Summary, see esp. E-24 through E-36 for the 25 specific sub-issues related to water resources
- Meeting notes (9/2017 [PR #0002056], 11/2017 [PR #0002170], 12/2017 [PR #0002209])
- BGC 2018a, see specifically section 4.0 "Review of RCM's Geologic Interpretations"
- BGC 2018d, see specifically section 1.1 (issues), 2.2 (conceptual model), Appendix B (adherence to industry standards)
- Montgomery & Associates characterization documents:
    - Montgomery & Associates, 2002. Results of short-term hydraulic testing at Exploration Borehole RES-3D
    - Montgomery & Associates, 2008. Hydrogeologic Characterization Well HRES-4: Results of long-term aquifer test

- Montgomery & Associates, 2010. Preliminary results and analysis of data obtained at deep hydrogeologic test wells DHRES-01 and DHRES-02
- Montgomery & Associates, 2010. Results and analysis of long-term pumping test at well HRES-07
- Montgomery & Associates, 2011. Results of drilling, construction, equipping, and testing at hydrologic test well DHRES-06
- Montgomery & Associates, 2011. Results of drilling, construction, equipping, and testing at hydrologic test wells HRES-10 and HRES-11
- Montgomery & Associates, 2011. Results of drilling, construction, and testing at hydrologic test wells DHRES-03, DHRES-04, DHRES-05, and DHRES-05B
- Montgomery & Associates, 2011. Results of drilling, construction, and testing at hydrologic test well DHRES-09
- Montgomery & Associates, 2011. Results of drilling, construction, and testing at hydrologic test wells DHRES-11 and HRES-12
- Montgomery & Associates, 2011. Results of drilling, construction, and testing at hydrologic test wells DHRES-12 and DHRES-13
- Montgomery & Associates, 2012. Results of drilling, construction, and testing at hydrologic test wells HRES-09 and DHRES-07
- Montgomery & Associates, 2012. Results and Analysis of 23-Day Aquifer Test at Well HRES-09
- Montgomery & Associates, 2012. Results of hydrochemical characterization of groundwater, upper Queen Creek/Devils Canyon study area
- Montgomery & Associates, 2013. Surface Water Baseline Survey: Devils Canyon, Mineral Creek, and Queen Creek Watersheds
- Montgomery & Associates, 2014. Well HRES-20 – Results of 90-day aquifer test,
- Montgomery & Associates, 2015. Well DHRES-15 – Results of 70-day aquifer test
- Montgomery & Associates, 2017a. Analysis of Groundwater Level Trends Queen Creek / Devils Canyon Study Area
- Montgomery & Associates, 2017b. Surface Water Baseline Addendum: Upper Queen Creek, Devils Canyon, and Mineral Creek
- Montgomery and Associates Inc. 2017. Construction, Development, and Testing of Hydrologic Test Wells at the Near West Tailings Site
- Montgomery and Associates Inc. 2018. System-wide Hydrologic Water Flow Budget: Resolution Copper, Pinal County, Arizona
- Montgomery and Associates Inc., and Resolution Copper. 2016. Hydrograph Set for Current Hydrogeologic Monitoring Network

III.F. Proposed path forward to resolve comment:

Comment #10 indicates “a general ‘industry-standard’ approach to modeling hydrologic impacts is lacking.” This is an incorrect statement. The need to follow an industry-standard approach was raised very early in the workgroup meetings by Forest Service personnel, and specific guidance documents were identified by the workgroup and adhered to. The documentation of this can be found in Appendix B of BGC 2018d, titled “Adherence of Groundwater Modeling Process to Professional Standards”. This appendix identifies the exact location where documentation can be found for four highly common modeling reference documents: Anderson, Woessner & Hunt; ASTM Standards; USGS Scientific Investigations Report 2004-5038; and Nevada BLM guidance.

- Proposed path forward: No changes to EIS or analysis. Industry-standard approach were used and explicitly documented in the project record. Prepare response-to-comment.

Comment #11 indicates "Clearly defined questions related to potential impacts and modeling objectives should have been presented, particularly how groundwater impacts affect surface flows, and vice-versa. These were not evaluated in this DEIS, or supporting documents." This is an incorrect statement. Identifying these questions was the focus of the initial scoping steps in the NEPA process. The analysis for groundwater impacts was designed to answer these issues. The issues are discussed in Chapter 1 of the DEIS (p. 24, see Issue 6 – Water Resources), and the specific sub-issues and metrics that were derived during scoping are shown in more detail in DEIS, Appendix E – Alternatives Impact Summary. These same issues were introduced in the first meeting of the groundwater workgroup (meeting notes 9/2017), and the issues report circulated to the workgroup. In addition to this, a handout at the initial groundwater workgroup meeting is titled "INITIAL LIST OF KEY MODELING QUESTIONS". These issues were explicitly discussed throughout the workgroup (see meeting notes 11/2017, 12/2017). The BGC 2018d workgroup memo includes this same information in section 1.1 "ISSUES TO BE ADDRESSED BY THE GROUNDWATER MODEL".

- Proposed path forward: No changes to EIS or analysis. The step of defining the questions to ask when reviewing and preparing the model took place and is explicitly documented in the project record. Prepare response-to-comment.

Comments #15 and #19 focuses on a perceived lack of conceptualization of the aquifer system, and points specifically to WSP 2019 (the WSP modeling report) as lacking this documentation. Comment #13 focuses on feedback loops between conceptualization and modeling, and the need for additional data collection. These criticisms represent professional opinion, not a demonstrable lack, as the project record supports that conceptualization of the system took place, was thorough, and was documented. Specifically, the WSP 2019 report contains a section titled "Hydrogeologic Conceptual Model" (section 2.2, p. 7), and Appendix B of BGC 2018d not only points to this section but also lists 7 separate sub-categories of model conceptualization (table 1.2) and where the documentation can be found.

The criticism may stem from the possibility that only the WSP modeling report was reviewed; for a project as complex as the Resolution site, a single report is insufficient to document all the data collection and characterization that informed the model. Note that all of the supporting data reports are in the project record and were available on the project website, and reviewed by the Forest Service. For example, see the list above of over 20 Montgomery & Associates documents in the project record that inform and define the conceptual model.

It could be argued that the above are merely basic data reports and do not reflect the thoughtful and thorough conceptualization of the system envisioned by the commenter. In fact, understanding the conversion of raw data (boreholes, aquifer tests, water levels, surface mapping, geophysics) into a conceptual model of the hydrogeologic framework was one of the explicit tasks of the other major workgroup: the Geology and Subsidence Workgroup. The results of this workgroup are documented in BGC 2018a; this memo walks through the conceptualization starting with the appropriate standards, assessing Resolution's quality control procedures, and then assessing Resolution's geologic interpretations. The effort put into reviewing and assessing the geologic framework was necessary, as that conceptualization is key to both the subsidence model and the groundwater model.

Employing the "feedback loops" mentioned by the commenter was the very purpose of the Groundwater Modeling Workgroup. This is noted in BGC 2018d, Appendix B, Table 1.2—in response to the industry-standard step of "Analysis of data deficiencies and potential sources of error with the model", it is noted that "Discussion of data deficiencies and potential sources of error was a primary topic of discussion by the Groundwater Modeling Workgroup."

Indeed, this critical review and feedback role of the Workgroup was codified during the first workgroup meeting (meeting notes 9/2017) (emphasis added):

> *Purpose of Workgroup*
>
> *1) <u>Review initial modeling efforts</u> by RCM;*
>
> *2) Discuss appropriate modeling approach (i.e., parameters and assumptions) for this situation, and review RCM model against that approach;*
>
> *3) <u>Identify appropriate model runs or sensitivity analyses to conduct</u> and desired output;*
>
> *4) <u>Review results of revised modeling efforts and request modifications or additional runs</u> [to maintain integrity of the process, any modifications to previously agreed-upon and established modeling parameters/assumptions must document a specific rationale];*
>
> *5) Provide conclusions on the appropriateness of the groundwater modeling results for use in the EIS, and the uncertainty and limitations associated with those results.*

The record amply demonstrates that this feedback loop worked as intended. By the end of the 11 workgroup meetings and review of workgroup documentation, over about 15 months, roughly 98 individual action items were identified. Two-thirds of these (67 action items) were assigned to Resolution and their contractors, typically to produce additional analysis, modeling runs, clarifications, or data to address questions raised by the Groundwater Modeling Workgroup. These were submitted to the Workgroup for review and in some cases led to changes in modeling approach.

- ➢ Proposed path forward: Proper conceptualization and feedback loops, as envisioned by the commenter and by industry-standard guidance, all took place and were documented in the project record. BGC notes that Section 3.4.7 in the final Workgroup memo can be edited to include information from Montgomery & Associates 2017b and 2018, and refer the reader to both those documents which contain the conceptual model.

Comment #21 indicates that alternative conceptual models should have been modeled as part of the uncertainty analysis and were not. This is an incorrect statement; the project record documents that many of the additional modeling runs were used to assess uncertainty by looking at different conceptual models. Besides the typical sensitivity runs varying hydraulic conductivity and storativity, runs included assessment of these different conceptual models:

- Different fault response
  - The Conley-Woods (Model Runs 39-40), Devil's Canyon (41-42), JI Ranch (43-44), North Boundary (45-46), Rancho Rio (47-48), South Boundary (49-50), and West Boundary (51-52) faults were all assessed separately for different conceptual responses (barrier to flow vs. conductive to flow)
  - All graben-bounding faults were also assessed together in the same manner (Model Runs 53-54)
- Different boundary conditions, changing general-head boundaries to no-flow boundaries (Model Run 81)
- Different recharge conditions, including different high and low elevation responses (Model Runs 84-87)
- Different response of the block-cave zone once fracturing begins (Model Runs 82-83)

➢ Proposed path forward: No changes to the EIS or analysis. A number of different conceptual models were assessed and documented in the course of the Workgroup evaluation of the model. Prepare response-to-comment.

Comment #55 suggests that the hydraulic tests used to inform the model "have limited value", and specifically that "tests are far too small a stress on the aquifer to confirm parameterization" and that "it would have been far more instructive to conduct tests, monitoring hydraulic response on both sides of important bounding faults (or faults that act as preferential conduits of groundwater flow." This comment reflects a lack of understanding of the fundamental inputs that informed the model. It is true that the stress placed on the aquifer during mining will dwarf the stress than can be applied from pumping a well during performance of an aquifer test. Conceptually this criticism can never be answered; the purpose of groundwater modeling is to predict the impacts of an action that can't be directly replicated. However, in this case, a remarkable data set was able to be brought to bear that comes closer to the future stresses than any single aquifer test.

The data sources are clearly described in WSP 2019 (page 6), and include: short-term aquifer tests, slug tests, and packer tests; long-term aquifer tests (pumped for 23 to 90 days) at 5 wells; monitoring of pumping rates and water levels during shaft dewatering and recovery. The data set from the first two categories is summarized in Section 2.2.3 and Appendix A of WSP 2019; in all, something like 93 estimates of hydraulic conductivity were obtained from aquifer tests. This magnitude of aquifer testing is rarely seen for any type of project, and is sufficient to the scope and complexity of the Resolution project.

And yet, this isn't the most pertinent data that informed the model. Wholesale dewatering of the deep groundwater system in order to construct mine infrastructure began in 2009 and has been monitored in detail ever since. Essentially, this represents a massive decade-long aquifer test that very nearly replicates the types of stresses that will be put on the system during mining (though nothing can replicate the changes wrought by the block-caving). The usefulness of these data was described in the DEIS, table 3.7.1-1 (p. 309), specifically showing the influence of the graben-bounding faults on the hydrology—exactly the type of "monitoring hydraulic response on both sides of important bounding faults" mentioned by the commenter.

- Proposed path forward: No changes to EIS or analysis. The comprehensive data set provided by the body of aquifer tests, combined with the large-scale pumping since 2009, provides a robust and appropriate basis for parametrizing the model and confirming the conceptual model. Prepare response-to-comment.

<u>IV. Issue #2: Inappropriate model code was selected; other codes could have been used that were more appropriate.</u>

IVI.A. Specific comments included (see Attachment 2): 22, 23, 25, 28, 30, 31

IV.B. General category of these comments:

- #1 – Some comments are factually incorrect
- #2 – Professional opinion expressed about an issue explicitly discussed by Groundwater Modeling Workgroup

IV.C. RCM/WSP response (paraphrased from WSP 3/23/20, see Attachment 1):

- WSP notes that the claim no formal code selection occurred is not true (page 2)
- WSP notes that use of the time-varying material properties package within MODFLOW-SURFACT was a key decision point for using this code (page 3)
- WSP indicates that the codes suggested in comments cannot replicate block-caving (page 3)
- WSP indicates that the codes suggested in comments lack fine-scale datasets required to implement and therefore would increase uncertainty (page 3)
- WSP indicates that model cell refinement required for suggested codes would increase run-times and not improve accuracy (page 3)

IV.D. NEPA/BGC response (paraphrased from BGC 5/11/20, see Attachment 2):

- BGC Cites section 4.1.2 in BGC 2018d and the overall conclusion of workgroup.

IV.E. Pertinent documentation in project record:

- BGC 2018d, Section 4.1 "Model Code"
- BGC 2018d, Appendix B "Adherence of Groundwater Modeling Process to Professional Standards"; see process step C – Selection of Mathematical Model and Code
- WSP 2019, Section 3.1.2 "Code Selection"
- Groundwater Workgroup Meeting notes:
    - 9/19/2017 [PR #0002056] (discussion of MODFLOW-SURFACT use by WSP)
    - 11/14/2017 [PR #0002170] (same)
    - 12/12/2017 [PR #0002209] (discussion of and approval by Forest Service for WSP to run predictive simulations using MODFLOW-SURFACT)
    - 5/15/2018 [PR #0002755] (additional discussion about why MODFLOW-SURFACT is appropriate, with specific comparisons to MODFLOW-6 and MODFLOW-USG.

IV.F. Proposed path forward to resolve comment:

Comments #22 and 23 claim that "a formal, industry standard code selection process wasn't conducted". This is an incorrect statement. The rationale for selection of the code is included in the original modeling report from WSP, was discussed by the Workgroup as a whole (9/2017, 11/2017, 12/2017 and 5/2018 meetings), and those deliberations are summarized in the Workgroup memo (BGC 2018d).

- Proposed path forward: Minor text revisions—documentation already appears in project record; but we could consider adding additional detail to body of FEIS.

Comments #25, 28, 30, and 31 point to a series of other commercially-available model codes that could have been used. However, the explanations provided in the comments for why these codes should have been used (to simulate faults, to integrate groundwater and surface flow) do not override the specific reasons why MODFLOW-SURFACT was selected and approved in the first place, after Workgroup discussion and a documented code selection process.

- Proposed path forward: No changes to EIS or analysis. Prepare response-to-comment.

V. Issue #3: Conclusions as to the water sources of Groundwater-Dependent Ecosystems (GDEs) are not supported.

V.A. Specific comments included (see Attachment 2): 1, 3, 9

V.B. General category of these comments:

- #1 – Some comments are factually incorrect
- #2 – Professional opinion expressed about an issue explicitly discussed by Groundwater Modeling Workgroup

V.C. RCM/WSP response (paraphrased from WSP 3/23/20, see Attachment 1): Not addressed

V.D. NEPA/BGC response (paraphrased from BGC 5/11/20, see Attachment 2):

- BGC notes that the GDE conclusions are based on best available site information, and show enough evidence to conclude that Upper Devils Canyon baseflow is unlikely to be connected to TAL.
- BGC suggests looking to see if conclusions could be strengthened with analysis proposed in comment

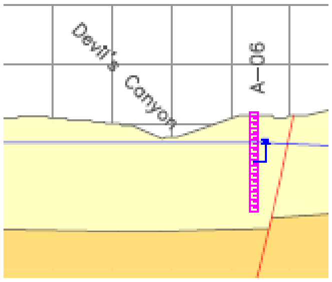
V.E. Pertinent documentation in project record:

- Garrett 2018d, see specifically table 2, p. 23-24 for specific lines of evidence leading to conclusions that Upper Devil's Canyon locations (including DC 13.5) are disconnected from Apache Leap Tuff aquifer. As an example (DC 13.5):
    - Carbon-14 data points to shallow groundwater source
    - Tritium data points to shallow groundwater source
    - Piper diagram points to shallow groundwater source
    - Other water quality constituents show "moderately strong" consistency with a shallow groundwater source (5 of 9 constituents), and "weak" consistency with Apache Leap Tuff (3 of 9 constituents) and deep groundwater system (4 of 9 constituents)
    - Stream elevation at DC 13.5 is 3,901 feet amsl, while nearest Apache Leap Tuff groundwater levels measured are 3,670 to 3,790 feet amsl, over 100 feet lower, suggesting a hydraulic disconnect
    - Garrett 2018d concludes that this is consistent evidence that DC 13.5 is "disconnected from regional aquifer"

V.F. Proposed path forward to resolve comment:

Comments #1, 3, and 9 call the GDE evaluations in Garrett 2018d "suspect", and specifically calls the evidence for DC 13.5 "unconvincing". The GDE evaluations in Garrett 2018d were based on multiple lines of evidence, with a clear methodology and framework identified for how each line of evidence would be evaluated. Not only do the comments lack specificity for why these lines of evidence are unconvincing, but the specifics provided in the comments are incorrect. Comment #3 calls for evaluating slope and water levels: this very approach was done and is shown in Table 2 in Garrett 2018d as one of the lines of evidence (see column titled "Physical Constraints"). Comment #9 focuses specifically on DC 13.5, and points to WSP 2019 figure 2.3 as showing

"…Inferred Tal Water Table at Devil's Canyon at the bottom of the streambed…" This is an incorrect statement, as shown below; the inferred Apache Leap Tuff water table does not intersect the bottom of the streambed in WSP 2019, Figure 2.3.



- ➢ Proposed path forward: No changes to EIS or analysis. Prepare response-to-comment.

VI. Issue #4: Improper baseline conditions were used.

VI.A. Specific comments included (see Attachment 2): 6, 7, 8, 49, 56

VI.B. General category of these comments:

- #1 - Some comments are factually incorrect
- #2 – Professional opinion expressed about an issue explicitly discussed by Groundwater Modeling Workgroup
- #4 – Conflicts with global decisions made by the NEPA management team

VI.C. RCM/WSP response (paraphrased from WSP 3/23/20, see attachment 1):

- WSP notes that available datasets from 1910-1998 were incorporated into the model (page 9)
- WSP notes that baseline conditions utilized for assessment of impacts were discussed, reviewed, and validated in the Groundwater Modeling Workgroup (page 10)

VI.D. NEPA/BGC response (paraphrased from BGC 5/11/20, see attachment 2):

- BGC indicates that appropriate baseline conditions for the modeling analysis was one of the first topics discussed by the Groundwater Modeling Workgroup, focused specifically on how the current groundwater pumping for dewatering would be accounted for in the model results. ... Ultimately this question was viewed not as a technical modeling question, but rather a fundamental NEPA question.
- BGC notes that little data are available for pre-mining steady state conditions, and notes that BGC and the GWMG concurred that a quantitative calibration for steady state conditions is not feasible.
- BGC notes that dewatering for decades, the occurrence of subsidence and the complete removal of the Tal aquifer are large changes, which will influence recharge and discharge, and a return to pre-mining (steady state) conditions cannot be assumed.

VI.E. Pertinent documentation in project record:

- DEIS, p. 299-300 "Key Decision on use of Model Results – Baseline Conditions"
- DEIS, p. 312 "Current and Ongoing Pumping and Water Level Trends"
- BGC 2018d, section 4.15 "Groundwater Model Calibration" (discussed pre-1998 calibration)
- BGC 2018d, Section 5.1 "Baseline conditions for modeling analysis" (acknowledging dissenting opinion on this topic and providing rationale for selected baseline conditions)
- Garrett 2018c, "Selection of Appropriate Baseline Conditions for NEPA Analysis"
- WSP 2019, section 4.1.2 "Dewatering from 1910 to 1998"
- Montgomery & Associates 2017b "Analysis of Groundwater Level Trends Upper Queen Creek/Devils Canyon Study Area"
- Garrett 2019d "Review of Hydrologic Trends in Devil's Canyon and on Oak Flat"
- Meeting notes:
  - 9/2017 [PR #0002056] (first discussion of no-action modeling including ongoing pumping; discussion of steady-state conditions and evidence)

- 11/16/2017 field trip [Not in PR—being remedied] (specific discussion in the field about historic hydrologic conditions along Queen Creek and in Superior)
- 12/2017 [PR #0002209] (specific disagreement with approach, that ultimately was captured in BGC 2018d, section 5.1; request for more detail on pre-development water levels)
- 1/9/2018 data submittal [PR #0002212] (data response from RCM on steady-state water levels

VI.F. Proposed path forward to resolve comment:

Comment #6 indicates that pre-mining conditions should have been used for predicted drawdowns. This was a specific point of discussion in the groundwater meetings (see meeting notes 9/2017 and 12/2017) and consensus was not reached. Ultimately, the Forest Service made a decision on how to approach the No Action alternative for the entire NEPA analysis, and the groundwater modeling conforms to that decision. Not only has the rationale for this decision has been clearly articulated in the project record (see Garrett 2018c), but the dissenting opinion has been fully articulated and considered as well (see BGC 2018d section 5.1).

- Proposed path forward: No changes to EIS or analysis. Prepare response-to-comment.

Comment #6 also indicates the belief that pre-mining conditions are important "as these are the levels to which shallow ALT aquifer groundwater levels will eventually recover to. This is known without even using the highly uncertain groundwater modeling results." This is an unsupportable assumption. As noted in the DEIS (p. 295): "the complex geology and multiple aquifers, including the incorporation of the blockcaving itself…would fundamentally alter the geological structure of these aquifers over time". There is no guarantee that water levels would recover to pre-mining levels. This complexity is one reason a numerical groundwater flow model—with time-varying properties as part of the model code--is required in the first place.

- Proposed path forward: No changes to EIS or analysis. Prepare response-to-comment.

Comment #7 notes that no analysis of 1910 to 1996 dewatering/recovery is presented in the DEIS or supporting documents. This is an incorrect statement. The available data—though limited—are discussed in WSP 2019, Section 4.1.2. The available evidence for historic hydrologic conditions was also discussed by the Groundwater Modeling Workgroup (9/2017; 12/2017; 11/2017 field trip). Available information from all known sources was compiled for the groundwater model; the commenter expresses a desire for better information, but no specific identification of sources where better information can be found.

- Proposed path forward: Minor text revisions—documentation already appears in project record; but could consider adding additional detail of pre-1998 hydrologic conditions to body of FEIS.

Comment #49 states that "From 1910 to 1996, the model appears uncalibrated (no reporting on this in DEIS, or WSP, 2019 report) even the historical pumping locations are largely unknown, which likely introduces substantial error into the calibration, and further uncertainty in predictions, as the heads by start of RCM pumping in 2009 were nowhere near recovered to pre-mining conditions." This is an incorrect statement. The discussion of the pre-1998 calibration is included as part of BGC 2018d Section 4.15, and WSP 2019 Section 3.1.5 and 3.1.7, discussing the pre-1998 calibration approach and why the calibration for this period is qualitative.

- Proposed path forward: Minor text revisions—documentation already appears in project record; but could consider adding additional detail of calibration and modeling efforts to body of FEIS.

Comment #56 claims "it is likely streamflows (and springs) in the area that would have been impacted by historical Magma Mine pumping, and which would have recovered had RCM not restarted pumping in 2009, would have increased the number of baseline GDEs in the area (i.e., Devil's Canyon stream from DC10.9to DC15)." The comment suggests that baseline GDEs should be based on pre-mining conditions, but the comment does not suggest any method to actually determine these pre-mining GDEs. There is no detailed dataset of GDEs that exists before Resolution Copper began collecting field data; what available information about historic groundwater conditions is in the historic record was brought forward by RCM during the model development.

This comment is in part based on the pervasive belief (in the public comments) that the ongoing dewatering pumping (since 2009) has dried up GDEs. Based on measured groundwater levels, the Apache Leap Tuff has not experienced the same drawdown as the deep groundwater system (Montgomery 2017b), which is attributed to the presence of the relatively impermeable Whitetail Conglomerate below the Apache Leap Tuff. This led the NEPA team to assess whether any hydrologic data sets associated with GDEs have shown a downward trend since pumping reinitiated; this analysis included 13 separate hydrologic data sets, and a qualitative camera study for features on Oak Flat. These are summarized in the DEIS (p. 312) and in Garrett 2019d, concluding: "Based on the analyses in this memo, there are no objective indications from any of the data reviewed that surface water features have been impacted by ongoing dewatering pumping conducted by Resolution Copper."

The Garrett 2019d analysis does not directly address the comment concern, which is that GDEs may already have dried long ago due to mine dewatering, prior to Resolution. However, the analysis does provide further tangible evidence that the Apache Leap Tuff is hydraulically disconnected from the deep groundwater system that has been the focus of historic dewatering. In other words, not only are there no data sets that suggest GDEs were widely extensive across the landscape before Resolution resumed pumping in 2009 (although evidence does exist that GDEs were present earlier in the 20th century), neither does analysis of the intensive data collected since 2009 suggest the type of hydrologic connection that would have led to the elimination of wide swaths of GDEs after pumping began 2009.

- Proposed path forward: Project record additions. The above concepts should be explored in the project record, using existing information in hand, and then used to develop a response to comment.

VII. Issue #5: The choices made for model output were in inappropriate, including limiting quantification to a time frame of 200 years, and a drawdown of 10 feet.

VII.A. Specific comments included (see Attachment 2): 4, 5, 36, 61, 62, 68

VII.B. General category of these comments:

- #1 - Some comments are factually incorrect
- #2 – Professional opinion expressed about an issue explicitly discussed by Groundwater Modeling Workgroup

VII.C. RCM/WSP response (paraphrased from WSP 3/23/20, see attachment 1):

- WSP notes that EIS analysis is not limited to the 10-foot contour plan view map
- WSP notes that all GDE locations were presented below the 10-foot threshold utilizing hydrographs
- WSP notes the use of the 10-foot impact contour is prevalent in other mining EISs
- WSP notes that the time frames beyond 200 years were found to be remote and speculative by the Workgroup

VII.D. NEPA/BGC response (paraphrased from BGC 5/11/20, see attachment 2):

- BGC notes that the comment ignores the expansion of disclosed results to include sensitivity analyses
- BGC notes that the comment ignores the decision to monitor all GDEs, regardless of predicted impact
- BGC notes that the analysis in EIS is not limited to just 200 years; qualitative assessment of longer trends included in EIS

VII.E. Pertinent documentation in project record:

- DEIS, p. 300 "Key Decision on Use of Model Results – Time Frame"
- DEIS, p. 301 "Key Decision on Use of Model Results – Level of Precision"
- DEIS, p. 301-303 "Key Decision on Use of Model Results – Strategies to Address Uncertainty"
- DEIS, p. 343-344 "Seeps and springs monitoring and mitigation plan (RC-211)"
- BGC 2018d, sections 4.5 "Time Frame for Model Runs", 5.2 "Strict use of 200-year Time Frame", Appendix B "Process Step G – Uncertainty Analysis"
- Montgomery & Associates 2019 "Monitoring and Mitigation Plan for Groundwater Dependent Ecosystems and Water Wells"
- Meeting notes:
    - 9/2017 [PR #0002056] (initial discussion of ramifications of a 10-foot contour limit; initial question on using steady-state vs. transient modeling)
    - 5/2018 [PR #0002755] (initial discussion and decision to limit quantitative analysis to 200 year time frame; discussion of appropriate contour to use)
    - 6/2018 [PR #0002667] (continued discussion of 200 year time frame; continue discussion of appropriate contour to use)
    - 7/2018 [PR #0002786] (continued discussion of ramifications of a 10-foot contour limit)

- 9/2018 [PR #0110613] (specific disagreement on use of 200 year time frame, ultimately captured in BGC 2018d, section 5.2; continued discussion of ramifications of a 10-foot contour limit; specific disagreement on use of transient instead of steady-state modeling)

VII.F. Proposed path forward to resolve comment:

Comment #4, 36, 62, and 68 all argue that a 1-foot groundwater contour should have been used to assess impacts, and that by doing so potentially more GDEs would have been impacted. This potential was explicitly discussed by the Groundwater Modeling Workgroup multiple times. The Groundwater Modeling Workgroup recognized the fundamental tradeoff of uncertainty versus impacts, and reached a balance of: 1) using the 10-foot drawdown contour, but 2) expanding the use of that contour to encompass all model runs, not just the single baseline, best-calibrated model, and 3) real-world monitoring of all GDEs, regardless of predictions made in the EIS, in order to identify impacts.

Comment #62 notes that selection of the 10-foot contour "is highly biased, and likely removes many GDEs from further evaluation of impacts/mitigation". This is an incorrect statement in three ways: 1) the claim of bias, 2) that this choice removed GDEs from evaluation of impacts, 3) that this choice removed GDEs from mitigation.

With respect to bias:

> A modeling choice had to be made. "Bias" suggests that this choice was arbitrary and uninformed. This is not the case. The choice was made based on the judgment of a diverse group of groundwater modeling professionals and hydrologists, after full consideration of the technical capabilities of the model. There were indeed dissenting opinions on this topic, and these were heard and documented as well, before the Forest Service made an informed choice as to the appropriate approach.

With respect to removing GDES from evaluation:

> Appendix L of the DEIS depicts the modeled drawdown for ALL GDEs that were determined to have any connection to regional groundwater, regardless of whether they meet the 10-foot threshold or not. All GDEs with a connection to regional groundwater were evaluated by the modeling effort; none were discarded from the analysis for any reason. That the quantification of anticipated impacts was selected as 10-feet does not change the fact that the evaluation was indeed done.

With respect to removing GDEs from mitigation:

> As noted above, monitoring and mitigation are to be applied to ALL GDEs, regardless of predictions of impact. This was one of the fundamental choices made by the modeling workgroup to address the uncertainty in predictions. This is stated very clearly in the DEIS: "*If monitoring identifies real-world impacts that were not predicted by the modeling, mitigation would be implemented. Mitigation is not restricted to unanticipated impacts; mitigation may also be undertaken for those GDEs where impacts are expected to occur.*" (DEIS, p. 303)

Comment #4 notes that “only those delineated by uncertain predicted 10-ft drawdown used (at 200 years) to define potentially impacted GDEs.” This is a partially incorrect statement. Part of the workgroup response to uncertainty was to use the 10-ft drawdown contour *from all 87 model sensitivity runs*, not just the baseline, best-calibrated model. See item BGC 2018d, Appendix B, item G.4: “*Based on this decision, the 10-foot contour was used to identify areas of “anticipated” impact from the groundwater model, with output provided as spatial contours, and as hydrographs at each specific sensitive receptor location. However, recognizing the uncertainties inherent in the modeling, the base case 10-foot contours was supplemented with the 10-foot contour encompassing all sensitivity runs. Any sensitive receptors within this area were also considered to have potential anticipated impacts*.”

Comment #5 and 61 both indicate that the 200-year threshold is inappropriate: “Prediction of post-closure hydrologic conditions at an arbitrarily chosen 200 years (or 148 years after closure) is very misleading and incorrectly conveys what will really occur at final steady state conditions.” This is an incorrect statement. As with the use of the word “bias”, use of the word “arbitrary” suggests that this choice was uninformed. This is not the case. The choice was made based on the judgment of a diverse group of groundwater modeling professionals and hydrologists, after full consideration of the technical capabilities of the model. There were indeed dissenting opinions on this topic, and these were heard and documented as well, before the Forest Service made an informed choice as to the appropriate approach. It also is not correct to say that impacts beyond 200 years were not analyzed. Impacts beyond 200 years were <u>not quantified</u>, due to the limitations of the model, but in fact changes were made to the DEIS to address post-200 year impacts qualitatively. During the workgroup meetings, consensus was not reached on this issue, and the dissenting opinion along with the rationale for selection the 200 year threshold is included in BGC 2018d, Section 5.2 “Strict use of the 200-year timeframe” (which discusses how impacts beyond 200 years were added to the DEIS to address these concerns),

Comment #5 argues that steady-state conditions should have been selected, instead of a 200-year transient model: “But then, ALT water levels will eventually return to pre-mining conditions.” This is not a supportable assumption. The hydrologic system is being altered in ways that may never allow a return to pre-mining conditions. This is noted as one of the reasons that groundwater modeling is needed in the first place: “the complex geology and multiple aquifers, including the incorporation of the blockcaving itself, which would fundamentally alter the geological structure of these aquifers over time;”(DEIS, p. 295). BGC notes this as well in response to Comment #65 in Attachment 2: “Dewatering for decades, the occurrence of subsidence and the complete removal of the Tal aquifer are large changes, which will influence recharge and discharge, and a return to pre-mining (steady state) conditions cannot be assumed.” Steady-state modeling was discussed during the modeling workgroups; in fact, it was one of the very first questions asked of the Workgroup (9/2017 meeting), and the discussion (and disagreement) continued throughout (9/2018 meeting).

On a whole, these comments mischaracterize that the two specific choices made to quantify impacts (10-ft threshold, 200-years), as precluding analysis or mitigation of impacts less (or later) than this. Both of these are demonstrably incorrect characterizations: the DEIS contains disclosure of impacts less than 10-feet, contains disclosure of impacts greater than 200-years, and the mitigation plan for GDES explicitly ignores any anticipated modeled impacts and assumes all GDES should be monitored—and if needed—mitigated if impacted. The comments are correct that the "anticipated" GDEs impacted in the DEIS would change if different modeling choices had been made, but are incorrect that the modeling choices made were biased or arbitrary. Nor do the comments provide an alternative rationale not already considered by the workgroup.

- Proposed path forward: Minor text revisions—the fundamental rationale and decisions are already included in the project record, but could add additional detail to FEIS to directly call-out where impacts are assessed less than 10-feet and longer than 200-years, and discuss the steady-state vs. transient issue.

VIII. Issue #6: Skunk Camp modeling was not adequately assessed.

VIII.A. Specific comments included (see Attachment 2): 20, 34, 52

VIII.B. General category of these comments:

- #1 – Some comments are factually incorrect
- #2 – Professional opinion expressed about an issue explicitly discussed by Groundwater Modeling Workgroup

VIII.C. RCM/WSP response (paraphrased from WSP 3/23/20, see attachment 1): Not addressed

VIII.D. NEPA/BGC response (paraphrased from BGC 5/11/20, see Attachment 2):

- BGC notes that additional site characterization was finished, and new conceptual and numerical models are in progress, and expected to be available May 2020.

VIII.E. Pertinent documentation in project record:

- DEIS, p. 354-357 "Assumptions, Uncertain and Unknown Information" for Tailings Seepage Models
- DEIS, p. 358-361 "Assumptions, Uncertain and Unknown Information" for Bypass/Seepage Mixing/Loading Models
- DEIS, p. 361-363 "Overall Effect of Uncertainties on the Model Outcomes"
- DEIS, p. 363 "Conclusion as to reasonableness of models"
- KCB 2018d "Resolution Copper Project: DEIS Design for Alternative 6 - Skunk Camp. Rev. 1"
- KCB 2019c "Resolution Copper Project: DEIS Design for Alternative 6 Skunk Camp, Appendix IV Seepage Estimate Amendment"
- KCB 2019d "Resolution Copper Project: Summary of DEIS Tailings Alternatives Seepage Control Levels"
- Montgomery & Associates, September 14, 2018 "TSF Alternative 6 – Skunk Camp: Life of Mine and Post-Closure Seepage Transport Modeling"
- Montgomery & Associates, February 6, 2019 "Results of Updated Seepage Transport Models Incorporating Additional Seepage Controls for TSF Alternative Sites"
- Garrett 2019c "Receipt of Water Quality Modeling Results in Native Format"
- Newell and Garrett 2018c "Water Resource Analysis: Assumptions, Methodology Used, Relevant Regulations, Laws, and Guidance, and Key Documents"
- Geochem modeling workgroup meetings:
    - 9/2018 [PR #0110648]
    - 10/2018 [PR #0110718]
    - 11/2018 [PR #0110767]
    - 12/2018 [No PR, being remedied]
    - 1/2019 [PR #0003071]

VIII.F. Proposed path forward to resolve comment:

There are three issues raised in these comments:

1) That a conceptual model wasn't provided for the Alternative 6 water analysis
2) That hydrogeologic characterization associated with Alternative 6 is missing
3) A concern that the analysis assumes "groundwater wouldn't interact with the calculated seepage"

Comment #20 states that a conceptual model for Alternative 6 was never provided. This is an incorrect statement. Note that the work and modeling at Alternative 6 is not associated with the large mine site groundwater model, and therefore indeed was not part of the Groundwater Modeling Workgroup discussions and therefore is not addressed in any WSP reports or BGC 2018d.

However, the project record contains descriptions of the conceptual model for Alternative 6, and these documents were reviewed by a separate workgroup reviewing the water quality analyses (meetings 9/2018 through 1/2019). Specifically, see Montgomery & Associates, September 14, 2018 "Technical Memo - TSF Alternative 6 – Skunk Camp: Life of Mine and Post-Closure Seepage Transport Modeling", section titled "Conceptual Model" (p. 2).

Comments #20 and #52 both indicate that hydrogeologic characterization associated with Alternative 6 is largely missing, and therefore numerous assumptions were made. This statement represents a professional judgment on the adequacy of the data used for the modeling. To be clear, hydrogeologic data were available that informed the modeling for Alternative 6; in fact, the concern about available data was very clearly raised in the workgroup meetings, resulting in the type and amount of available data being very clearly described in the DEIS. See "Assumptions, Uncertain and Unknown Information" section in "3.7.2 Groundwater and Surface Water Quality", and see specifically the bullet point starting at the bottom of page 356 that starts "Alternative 6 has limited site-specific information on the foundation conditions…" [Note that this bullet point should be indented at one higher level—this is a typo that needs correcting]. Not only does this item describe exactly what data are available and were used, but the DEIS draws a clear conclusion about what this potential limited information means:

> *"Likely magnitude of effect for Alternative 6: Moderate to low. Although not as large as Alternative 5, the volume of groundwater flow in the alluvial aquifer downstream creates dilution and can accept larger amounts of seepage without resulting in concentrations above water quality standards. The flow characteristics of the downstream alluvial aquifer are relatively straightforward, and the spatial extent is well-defined from surface geological mapping. The thickness of the aquifer is uncertain, however, which could affect the overall amount of water available for dilution in the modeling. Seasonal fluctuations in water levels could affect the aquifer capacity. Countering these uncertainties, the relatively narrow aquifer width likely makes existing planned controls (like the grout curtain) simpler to implement, and with the nearest perennial water over a dozen miles downstream, there is substantial room to add or modify seepage controls."* (DEIS, p. 357)

With respect to limited surface water quality information at Skunk Camp, this question was also directly evaluated in the backup memo to the groundwater sections, Newell and Garrett 2018c, see section titled "Assessment of Need to Collect Additional Information" (p.32-33). This concludes:

"*CEQ regulations address the need for additional data collection under 40 CFR 1502.22. The ability to collect additional information needs to be addressed when "…the incomplete information relevant to reasonably foreseeable significant adverse impacts <u>is essential to a reasoned choice</u> among alternatives…" (emphasis added).*

In this case, while beneficial to reduce uncertainty, additional water quality is by no means essential to understanding the differences between the alternatives. The current modeling provides reasonably clear answers to the risks posed to water quality by each alternative, and the conclusions would not be likely to change by variations in Gila River water quality. This is demonstrated below."

These water quality limitations and their effects on the groundwater models are explored in the DEIS as well, p. 358-361. This wraps up with an overall assessment of the uncertainties associated with the water quality modeling and this conclusion:

"While future work or additional information could reduce some of these uncertainties, the water quality modeling results disclosed in the EIS (section 3.7.2.4) are sufficiently different between alternatives that such refinements are not "essential to a reasoned choice among alternatives."

The broad conclusions in section 3.7.2.4 are not likely to change, specifically:

• It is difficult to meet water quality objectives at Alternatives 2, 3, and 4 without extensive engineered seepage controls.

• Alternatives 5 and 6 not only meet water quality objectives as modeled but have substantial additional capacity to do so, and flexibility" (DEIS, p. 363)

The assessment of the sufficiency of hydrogeologic data used for the DEIS analysis was reasoned, and the rationale documented. However, regardless of this, additional hydrogeologic information has been collected since publication of the DEIS, as well as a revised water quality assessment. All of this information will need to be incorporated into the FEIS.

Comment #52 includes another concept which is not entirely clear:

"*But numerous assumptions were made about the subsurface and boundary conditions which would affect leakage estimates, including <u>the implicit assumption that groundwater flows beneath the proposed TSF (for all possible future climate conditions and meteorological conditions) would never interact with internal seepage calculations</u>, which are not conservative. The TSF and surrounding hydrogeologic system is a 3-dimensional flow system, where groundwater flows concentration beneath the central surface drainage. No surface water or groundwater data, or hydrogeologic data s<u>upport the notion groundwater wouldn't interact with the calculated seepage</u>. If it did, this becomes critically important in subsequent evaluations of water quality impacts both during mining, and post-closure – and comparison of alternatives*." (Prucha, section 2.6.5, emphasis added)

This appears to be an incorrect statement. The entire point of the water quality modeling effort is to predict what happens when seepage from the tailings storage facility interacts with groundwater, then moves downgradient, and then interacts with surface water. This comment either reflects a misunderstanding of what water quality modeling was conducted for Alternative 6, or the meaning is not clear.

- Proposed path forward: Under the purview of the reconvened Water Resources Workgroup, obtain and review all new hydrogeologic information for Skunk Camp, all revised water quality modeling for Skunk Camp, and evaluate appropriateness of modeling and techniques used. Revise FEIS accordingly.

IX. Issue #7: Handling of surface water/groundwater interaction in the model was inappropriate.

IX.A. Specific comments included (see Attachment 2): 2, 12, 37, 39, 48

IX.B. General category of these comments:

- #1 – Some comments are factually incorrect
- #2 – Professional opinion expressed about an issue explicitly discussed by Groundwater Modeling Workgroup

IX.C. RCM/WSP response (paraphrased from WSP 3/23/20, see attachment 1):

- WSP notes that alternative methods of modeling surface water/groundwater interaction besides the RCH/DRN approach would require estimation of additional parameters, adding more uncertainty.
- WSP includes detailed responses to discharge (drains), recharge, and evapotranspiration criticisms (handled under Issue #15).

IX.D. NEPA/BGC response (paraphrased from BGC 5/11/20, see attachment 2):

- BGC notes that the decision not to use the SFR package was an informed decision that was based on an understanding of the limitations of modeling
- BGC notes that SFR package isn't appropriate for ephemeral, intermittent streams which account for much of the flow in the project area

IX.E. Pertinent documentation in project record:

- BGC 2018d, see specifically section 4.9 (groundwater-surface water interaction), and 5.7 (professional disagreement on "Direct modeling of groundwater/surface water interaction")
- Meeting notes:
  - 11/2017 [PR #0002170] (issue initially raised)
  - 12/2017 [PR #0002209] (specific discussion about possible approaches)
  - 2/2018 [PR #0002320] (return to discussion of possible approaches, including a written summary of approaches discussed in December)

IX.F. Proposed path forward to resolve comment:

These comments concern three aspects of the modeling. First, that the code selection was inappropriate and that a fully-coupled surface water/groundwater model would have been more appropriate. Second, that even within the selected model, the wrong techniques or packages were used to model surface water/groundwater interaction. Third, that perched groundwater zones were not modeled.

Code selection is also discussed in Issue #2, above, and as noted there a formal code selection process was undertaken and has been documented. Comment #12 is more specific in that it provides a reason why a different model could be more appropriate—something not provided in the comments discussed under Issue #2. Comment #12 indicates that "A major flaw in modeling conducted in this DEIS is that groundwater modeling was done in apparent isolation from surface water modeling, yet surface water clearly recharges groundwater (losing segments), and groundwater clearly discharges to surface streams as baseflow, or via springs."

Comment #12 is correct that two models were created—one for surface water, one for groundwater. However, it is an important distinction that the surface water model (the Australian Water Balance Model) was intended solely to estimate the impact on precipitation-driven flood events due to the loss of part of the watershed. The technique selected (AWBM) was highly appropriate for estimating that specific impact, because the primary streams impacted in this way—Queen Creek, Dripping Springs Wash, Donnelly Wash—are ephemeral in nature (with some exceptions for small portions of Queen Creek). In practice, Devil's Canyon is almost the sole location where both groundwater impacts from drawdown might combine with the loss of ephemeral flow caused by the subsidence crater capturing precipitation.

Comment #12 states that "surface water recharge to groundwater (losing stretches) was not included in the groundwater modeling as a boundary condition". This is an incorrect statement. Recharge was indeed included in the model along stream channels. It was simply done with the RCH package, not the SFR package as suggested by the comment. This doesn't represent a flaw, it represents a choice of modeling technique.

Comment #12 would be correct in its criticism if surface water impacts and groundwater impacts were analyzed separately and never looked at for their cumulative impact. This is not the case, as the combined impact is described in the DEIS in "Anticipated Impacts on Devil's Canyon":

> *"Potential runoff reductions in Devil's Canyon are summarized in table 3.7.1-5. Percent reductions in average annual flow due to the subsidence area range from 5.6 percent in middle Devil's Canyon to 3.5 percent at the confluence with Mineral Creek; percent reductions during the critical low-flow months of May and June are approximately the same. Combined with loss from spring DC-6.6W due to groundwater drawdown, total estimated flow reductions along the main stem of lower Devil's Canyon caused by the proposed project could range from 5 to 10 percent.*" (DEIS, p. 329)

Similarly, comment #37 provides similar criticism of the opposite issue—modeling the discharge along stream channels using the DRN package instead of the SFR package. Use of the RCH/DRN combination is a valid modeling choice. Use of the SFR package would have been a different choice, and use of the RIV package would have been yet another different choice. The pertinent question is: does the RCH/DRN combination model the movement of water between the surface water and aquifer, either outflow (gaining streams), or inflow (losing streams)? The answer is yes, the RCH/DRN combination models this physical concept. That it could have been done differently doesn't mean it wasn't done properly.

Comments #12, 37, and 48 all suggest the Resolution modeling is improper because other EISs have used the SFR package, citing Rosemont and Pebble in particular. Every project is different. This is why modeling guidance focuses on process, not on prescriptive approaches. The differences aren't hard to see—for instance, Rosemont is an open-pit mine modeling impacts to a single aquifer, whereas Resolution is a deep underground mine, with multiple aquifers, and block-caving that will fundamentally alter the hydrologic framework. Frankly, it would have been professionally deficient to blindly use the same techniques as used at some other mine, solely because they'd been used before.

Comment #48 provides a different viewpoint, harking back to the ultimate purpose of the model: *"The main focus of the DEIS is to estimate potential changes to the surface/subsurface hydrologic system, or GDEs affected by mine drawdown and changes to surface flows.*" This is a reasonable restatement of the goals of the modeling. Those goals were accomplished with the models selected. Specifically, GDEs affected by mine drawdown (including potential reductions in surface flow) were assessed using a groundwater model, and changes in ephemeral surface flow were assessed using the AWBM model. The combined impacts were assessed together in the DEIS. No impacts were ignored by the techniques chosen, even if there were other methods available to analyze them.

It's important to note that these very issues were not ignored by the Groundwater Modeling Workgroup. The appropriate approach (SFR package versus DRN package) was the subject of much debate (see meeting notes 11/2017, 12/2017, and especially the summary writeup discussed on 2/2018), and in fact this discussion ultimately led to a difference of professional opinion. This disagreement and the rationale for proceeding is fully discussed in BGC 2018d, in section 5.7 "Direct modeling of groundwater/surface water interaction".

Comment #2 notes that perched groundwater zones were not analyzed by the model. This is a true statement. The DEIS explains the reasoning:

> *"There are generally two regional aquifers in the area: the Apache Leap Tuff, and the deep groundwater system. Any GDEs tied to these two aquifers have the potential to be impacted by mining. The deep groundwater system is being and would continue to be actively dewatered, and once block-caving begins the Apache Leap Tuff would begin to dewater as well.*
>
> *In addition to the regional groundwater systems, another type of groundwater results from precipitation that is temporarily stored in near surface fractures or alluvial sediments. While temporary, this water still may persist over many months or even years as it slowly percolates back to springs or streams or is lost to evapotranspiration. These near-surface features are perched well above and are hydraulically disconnected from both the Apache Leap Tuff aquifer and the deep groundwater system; therefore, this groundwater source does not have the potential to be impacted by mine dewatering. However, changes in the surface watershed could still affect these shallow, perched groundwater sources. Predictions of reductions in runoff caused by changes in the watershed are discussed in section 3.7.3; these changes are also incorporated into this section (3.7.1) in order to clearly identify all the combined effects that could reduce water available for a GDE.*" (DEIS, p. 296-299)

In other words, there is no physical mechanism by which dewatering in the lower aquifers will affect localized perched areas, and no purpose in attempting to model these shallower areas.

To be entirely fair, the criticisms all have one overriding point that has not been addressed above: if a different technique had been used, the predictions of impacts would have been more accurate. WSP speaks to this (see Attachment 1):

> *"Although complexity may appear to provide a more accurate result in theory, increased complexity could produce more uncertainty through the requirement of estimating additional parameters where limited or no data is available to justify values…*
>
> *…If considered holistically, it is apparent the groundwater system is well represented by the model as supported by agreement with multiple lines of evidence, including but not limited to, hydraulic conductivity values, estimates of recharge, head levels, streamflow rates, dewatering rates, and responses to transient stresses."* (p. 2)

In other words, the conclusion that other techniques are better is not an obvious one as suggested by the comments, and cannot be simply assumed. The ultimate answer to the criticisms is this: are the predictions accurate using the selected techniques? Yes, the model meets industry-standard thresholds for accuracy as quantitatively demonstrated through the calibration.

- ➢ Proposed path forward: No changes to EIS or analysis. These comments represent disagreements about modeling approach that were fully discussed in the Groundwater Modeling Workgroup. Prepare response-to-comment.

X. Issue #8: The choice of wells and targets to assess was inappropriate.

X.A. Specific comments included (see Attachment 2): 46

X.B. General category of these comments:

- #2 – Professional opinion expressed about an issue explicitly discussed by Groundwater Modeling Workgroup

X.C. RCM/WSP response (paraphrased from WSP 3/23/20, see attachment 1): Not addressed

X.D. NEPA/BGC response (paraphrased from BGC 5/11/20, see attachment 2):

- BGC also suggests expanding discussion of the use of a proxy for impacts to individual wells.

X.E. Pertinent documentation in project record:

- Newell & Garrett 2018c, see p. 9 "Inability to Analyze Individual Wells"

X.F. Proposed path forward to resolve comment:

Comment #46 expresses the opinion that all registered wells should have been individually analyzed for drawdown, rather than proxy wells to represent key water supplies. A single concrete reason is given: "Proxies give a misleading sense of impacts to surrounding wells because drawdown is spatially complex."

The choice to analyze proxies instead of every individual well was not accidental. It was a specific choice made by the NEPA team, and the rationale for doing so is clearly articulated in Newell & Garrett 2018c:

> *"To evaluate the effects of groundwater drawdown on an individual well, a number of details need to be known about the well construction and operation. These include depth to water, depth of well, location of perforated intervals, and the type and depth of pump equipment within the well. In general, individual water supply wells vary so much that it is not feasible to analyze them one-by-one. For instance, a hypothetical 10-foot drop in the water table could leave a shallow well completely dry and require it to be redrilled to a greater depth. The same drawdown could require a different well owner to set their pump 10 feet lower but otherwise not be affected, or could have no noticeable effect at all on a well drilled slightly deeper with a deeper pump. The impact depends heavily on the exact construction of the well and equipment installed…Most wells in the modeling area are considered to be exempt wells; these wells are small enough that they do not require a specific groundwater right in order to pump for domestic and stock purposes. Reporting requirements for exempt wells are virtually non-existent, except when the well is originally drilled. Even then, often key details like pump type and depth are not reported. This makes any compilation of individual well information from existing data sources incomplete. Nor is it feasible to collect such information in the field. If not known by the well owner, observing pump depth or pump settings would require disrupting water service for wells by physically pulling the pump from the well." (p. 9-10)*

Logistically, it would indeed be entirely feasible to report modeled drawdown at individual wells. While this might better reflect spatial complexity of the drawdown, this level of reporting would only compound the "misleading sense of impacts", because the information required to assess how drawdown would affect each of these wells still simply does not exist. Nothing in the comment changes the reason given in the rationale.

The larger question is whether the DEIS lacks disclosure of important drawdown impacts that aren't shown by the proxies. In fact, the DEIS contains the information necessary for anybody to understand the drawdown at their individual well. If the proxy wells (one for Superior, one for Top-of-the-World, one for Boyce Thompson) are deemed insufficient for this purpose, perhaps because a reader owns a well farther afield, the full spatial distribution across the landscape is still shown in the DEIS—figure 3.7.1-2 for drawdown near the Desert Wellfield (DEIS, p. 298), figure 3.7.1-3 for drawdown at the mine site under the proposed action (DEIS, p. 302), and figure 3.7.1-8 for drawdown at the mine site under the no action alternative (DEIS, p. 323). Also note that figure 3.7.1-3 does show the full range of drawdown from all the uncertainty analysis as suggested by the comment, not just the single best-calibrated run.

- Proposed path forward: No changes to EIS or analysis. These comments represent disagreements about modeling approach that has a clearly articulated rationale, but provides no way to overcome the issues raised in the rationale. Meanwhile, the disclosure already accomplishes what is requested in the comment. That said, the explanation could be added to the FEIS in more detail, rather than left in the supporting documentation. Other than that, prepare response-to-comment.

<u>**XI. Issue #9: The calibration of the groundwater model was flawed.**</u>

XI.A. Specific comments included (see Attachment 2): 47, 50, 51, 53, 54, 73

XI.B. General category of these comments:

- #1 – Some comments are factually incorrect
- #2 – Professional opinion expressed about an issue explicitly discussed by Groundwater Modeling Workgroup

XI.C. RCM/WSP response (paraphrased from WSP 3/23/20, see attachment 1):

- WSP notes that flow data were assessed and compared to stream data observed in the field, and the spatial distribution of groundwater discharge via drains was compared to perennial reaches of streams, and groundwater discharge via drains was compared to observed baseflow estimations and was well matched (particularly in Devil's Canyon).
- WSP notes that the calibration data set was appropriate, regardless of greater density near the mine site, as it includes calibration targets both inside and outside the graben, and that the critical perennial areas of Devil's Canyon has a large network of monitoring points.
- WSP notes that spatial summary of calibration residuals in the Apache Leap Tuff was provided to the workgroup.

XI.D. NEPA/BGC response (paraphrased from BGC 5/11/20, see attachment 2):

- BGC notes that drains were located along dry/ephemeral and perennial reaches of Devils Creek, and did start to pick up water where perennial baseflow started, indicating a good match of the modeled groundwater heads to actual conditions.
- BGC notes that fluxes were used for model calibration, including recharge and discharge.
- BGC also notes that even if many equally valid solutions exist, this does not necessarily lead to "inadequate and unreliable". Many of these other solutions may be quite similar to the chosen conceptual model and the calibrated model.
- BGC notes that the transient Calibration used the best available datasets for calibration.
- With respect to residuals, this is addressed in BGC 2018d, noting that hydrographs comparing the simulated heads to observed heads were plotted for all targets, and that the groundwater model was calibrated with realistic hydraulic properties, therefore BGC and the GWMG concur that the calibration supports the model.
- With respect to spatial bias and residual heads at wells and aquifer units, BGC suggests this info should be provided.

XI.E. Pertinent documentation in project record:

- WestLand Resources, November 6, 2018, "Comparison of Relative Vegetation Density to Regional Groundwater Model Predicted Discharge in the Floodplains and Stream Channels of Queen Creek, Mineral Creek, and Devils Canyon, Pinal County, Arizona" [PR #0003063]

- WSP, February 13, 2018, “Response to Regional Model Queries” [PR #0002323]
- BGC 2018d, see section 4.15 “Groundwater Calibration”
- WSP 2019, see section 3.2 “Model Calibration”
- Meeting notes:
    - 9/2017 [PR #0002056]
    - 11/2017 [PR #0002170]
    - 12/2017 [PR #0002209]
    - 2/2018 [PR #0002320]
    - 5/2018 [PR #0002755]
    - 6/2018 [PR #0002667]
    - 7/2018 [PR #0002786]
    - 9/2018 [PR #0110613]

XI.F. Proposed path forward to resolve comment:

These comments raise critical issues regarding the groundwater model, appropriately noting that the choice of calibration targets directly affects the accuracy of the model and its ability to reasonably predict mine impacts. Three specific criticisms are raised: the sole use of hydraulic heads for calibration targets, the distribution of those targets, and the disclosure of residual head data.

The claim that solely hydraulic heads were used to calibrate the model is not a correct statement. The Groundwater Modeling Workgroup explicitly discussed the ability of the model to calibrate to perennial flow areas. Specifically:

- WestLand Resources conducted an NDVI assessment (WestLand Resources 2018) with this goal stated in the introduction: “This comparison is intended to inform the regional groundwater model data validation process by visually demonstrating the degree of spatial correlation between areas of dense vegetation and regional groundwater model predicted discharge locations.” Figures 1-3 in this report show the comparison requested.
- WSP was requested to directly compare the drain flux to observed flow in the field and submitted this information to the workgroup (WSP 2018), specifically “Item #5: Present a figure with the gaining reaches (i.e., flows to DRN cells), in Devils Canyon, versus the measured flows from surveys conducted by M&A.” The comparison for monitoring locations DC5.5 and DC8.8 is shown on page 2 of the memo.

The comments also suggest that improperly selecting the targets will lead to improper estimation of hydraulic conductivity. However, the hydraulic conductivity as calibrated matches a wide variety of field data—not just aquifer tests, but the massive *ad hoc* aquifer test represented by the dewatering in Shafts 9 and 10. The evidence at hand—that calibrated K values match real-world K values—demonstrates that the selection of calibration targets simply did not result in the type of error suggested in the comment.

The criticism that the hydraulic head targets have an inadequate geographical distribution, with a spatial bias closer to the proposed mine, has three aspects to look at: is it a correct statement? was it inappropriate? and is there an alternative dataset that was ignored?

Is it a correct statement? While acknowledging that this is a matter of professional opinion, the implication that the calibration targets did not cover critical areas is not correct. Figure 3.7 of the WSP modeling report (WSP 2019) shows the geographic distribution of the calibration targets. There are calibration targets located as far away as Top-of-the-World, Mineral Creek, Boyce Thompson Arboretum, and lower Queen Creek—this essentially is the range within which the GDEs identified as being potentially impacted can be found.

Is it inappropriate? The geographic distribution is expansive, but in fairness it does have a heavier concentration near the mine site, as indicated by the commenter. This is viewed in the comment as inappropriate. An alternative viewpoint is that a higher concentration near the mine site highly appropriate for two reasons. First, as WSP notes, this is the area where the future stresses are going to occur and it is appropriate to concentrate characterization in this area. Second, this is also the area where the most sensitive and nearest GDEs and perennial waters are, notably Devil's Canyon. The concentration of calibration targets near and along Devil's Canyon is not only appropriate, but highly desirable.

Is there an alternative dataset? Groundwater modelers make use of the hydrologic data that are available, particularly for transient calibrations. One simply can't go back in time and re-create a 10- or 20-year long hydrograph at any desired point on the landscape; the calibration is necessarily limited to the existing wells and data sets. Suggesting that transient calibration targets be used at every GDE is an impossible request. In this case, WSP made use of all data they could find, particularly trying to replicate historic hydrologic conditions for which there is very limited data. There is no exhaustive data set that would have better represented GDEs that was left on the table.

- ➢ Proposed path forward: No changes to EIS or analysis. With respect to criticisms of calibration, portions of the comments are incorrect or partially incorrect. The calibration was not limited solely to hydraulic heads, and the hydraulic head calibration targets represent not only the compilation of the best transient hydrologic data in the modeling area, but they reflect the areas in which GDEs are found, and especially the nearest GDEs and perennial water. Prepare response-to-comments.

With respect to disclosure of residual heads, the comment is partially incorrect. Distribution of residuals in space and by unit is disclosed in these locations:

- Figure 3.9 from WSP 2019, shows the modeled v. observed water levels for all calibration targets.
- As does Appendix B from WSP 2019, which contains an individual modeled v. observed hydrograph for every calibration target. While aquifer units aren't labeled as part of this figure, the record contains plenty of documentation on which aquifer units each target belongs to.
- Figure 3.10 from WSP 2019 explicitly shows just the Apache Leap Tuff modeled v. observed water levels for calibration targets.
- Figure B from WSP 2018 shows the distribution of residuals in a geographic sense.

However, BGC does acknowledge that with respect to spatial bias and residual heads at wells and aquifer units, additional information could be provided.

- Proposed path forward: Request additional output, as suggested by BGC, but do not change the modeling approach. While the residual head data was provided, additional ways of plotting it—by aquifer unit and geographically—could be useful for disclosure.

XII. Issue #10: Modeling uncertainty was inappropriately conflated with model sensitivity.

XII.A. Specific comments included (see Attachment 2): 14, 64, 69, 72, 74, 75, 76, 77

XII.B. General category of these comments:

- #1 – Some comments are factually incorrect
- #2 – Professional opinion expressed about an issue explicitly discussed by Groundwater Modeling Workgroup

XII.C. RCM/WSP response (paraphrased from WSP 3/23/20, see attachment 1):

- WSP notes that the uncertainty methodologies selected and approved by the Groundwater Water Workgroup are accepted and common practice, and provides a conservative approach to capturing uncertainty.
- They note in particular that the use of the outer-most extent of sensitivity contours provides a conservative impact that informs the monitoring and mitigation plan.

XII.D. NEPA/BGC response (paraphrased from BGC 5/11/20, see attachment 2):

- BGC has numerous notes on the calibration question (Issue #9)
- Section 4.18.2 will be rewritten to discuss the uncertainty analysis. The description of the uncertainty analysis will be improved.
- Section 4.18 notes that the sensitivity analysis has two purposes: understanding the effect of parameter variation, and also understanding uncertainty.
- The Groundwater Modeling Work Group report will be edited to state "predictive uncertainty runs" instead of "sensitivity runs", where appropriate.
- Agree that sometimes the groundwater modeling work group report description is misleading, but a sensitivity analysis was conducted separately from an uncertainty analysis.

XII.E. Pertinent documentation in project record:

- WSP 2017, Resolution Copper Groundwater Flow Model Report, Section 3.2.6 Parameter Sensitivity (discusses calibration sensitivity)
- WSP 2018, Resolution Copper Groundwater Flow Model – Sensitivity Analysis (to use the verbiage of the commentator, this could more accurately be called "Predictive Uncertainty Analysis" or ''prediction sensitivity analysis" as per Anderson et al.)
- BGC 2018, Section 4.18, "Sensitivity Analysis and Model Uncertainty"
- BGC 2018, Appendix B, see Item #G
- ASTM Standard D5611-94 [PR #0002590]
- Newell and Garrett 2018c, Table 1
- Meeting notes:
    - 9/2017 [PR #0002056]
    - 11/2017 [PR #0002170]
    - 6/2018 [PR #0002667]
    - 7/2018 [PR #0002786]

XII.F. Proposed path forward to resolve comment:

This is a complicated and difficult issue to consider. At first read, it isn't clear whether these comments represent a difference of professional opinion about what constitutes an uncertainty analysis, a difference of semantics, or reflects a modeling step that should have been undertaken and was not.

BGC and WSP both indicate that the analysis conducted (87 model runs, varying a variety of parameters) reflects common practice that not only analyzes the sensitivity of the model to parameter changes, but also reflects the uncertainty:

> *"Sensitivity analysis is the process of changing one parameter in the model at a time and re-computing the error function. The purpose is two-fold. First, it can determine those parameters most sensitive to model output for use in the calibration process. Parameters that have the greatest impact on model output make better calibration parameters than those parameters less sensitive. Secondly, a sensitivity analysis allows some quantification of uncertainty in simulated response if parameters are adjusted over expected ranges."* (BGC 2018d, 4.18)

However, the commenter suggests a "predictive uncertainty analysis" is a different animal entirely, and that not conducting this step is a fundamental flaw.

Fortunately, this point of order is relatively easy to check, since the Groundwater Modeling Workgroup intentionally adhered to a variety of industry and scientific guidance. Appendix B of BGC 2018d contains a summary of all of the modeling guidance identified by the Groundwater Modeling Workgroup to guide the preparation and use of the model. This guidance does include two separate steps: sensitivity analysis (Step E) and predictive uncertainty analysis (Step G). Interestingly, as can be seen in table 1.1 of Appendix B, of the four sources of modeling guidance used by the Workgroup (Anderson et al, ASTM standards, USGS report 2004-5038, and Nevada BLM guidance), only one of the guidance documents (Anderson et. al.) calls out predictive uncertainty analysis as a separate step, as indicated by the commenter.

This is such a key difference in modeling approach that ASTM Standard D5611-94 "Standard Guide for Conducting a Sensitivity Analysis for a Groundwater Flow Model Application" goes so far as to explicitly explain why the Anderson et. al. approach is not sufficient:

> *3.1.8.1 Discussion—Anderson and Woessner use "calibration sensitivity analysis" for assessing the effect of uncertainty on the calibrated model and ''prediction sensitivity analysis" for assessing the effect of uncertainty on the prediction. The definition of sensitivity analysis for the purposes of this guide combines these concepts, because only by simultaneously evaluating the effects on the model's calibration and predictions can any particular level of sensitivity be considered significant or insignificant." (p. 1)*

BGC and WSP are correct in stating that using the sensitivity analysis for two purposes (as described in BGC 2018d, section 4.18) this is a common industry practice. On this point, the industry-standard modeling guidance identifies this as a clear professional disagreement on approach, but not a flaw in the modeling process.

That said, the commenter also suggests that while predictive uncertainty was acknowledged by the Groundwater Modeling Workgroup, it was not properly disclosed. This is not a correct statement. The range of impacts is shown in the DEIS and record in multiple places:

- DEIS, figure 3.7.1-3 (p. 302), showing not only the best-calibrated contours, but the same drawdown contour for any and all of the 87 modeling runs.
- DEIS, appendix L, "Detailed Hydrographs Describing Impacts on Groundwater-Dependent Ecosystems". These detailed hydrographs don't just show the single best-calibrated model run, they show the hydrograph under every other of the 87 modeling runs.
- DEIS, table 3.7.1-3 (p. 318-322) showing not only the best-calibrated drawdown results, but also describing the results of the other 87 modeling runs (see column "Number of Sensitivity Runs with Drawdown greater than 10 Feet (based on Proposed Action, 200 years after start of mine)").
- Newell and Garrett 2018c, see table 1 (shows same column as table 3.7.1-3 in the DEIS).

There are two other statements in these comments worth noting. Comment #64 suggests that "estimated water level recovery at 1000 years is highly uncertain, and levels would likely recover much quicker." There is simply no basis for claiming that water levels would likely recover much quicker. Certainly under a different modeling scenario other than best-calibrated run, the recovery time might be different—but this is not something that can be blankly stated as being obvious and likely. Note response to Issue #12, which will look at uncertainty that is directly related to the question of how fast water levels recover in the subsidence zone.

Finally, Comment #76 quotes this: "Central to any decision-making process is an assessment of risk. Such an assessment is impossible without some assessment of predictive uncertainty." The Groundwater Modeling Workgroup was fully aware of the risk of the groundwater model being incorrect, and used the uncertainty analysis explicitly to help address this risk, as described in BGC 2018d, Appendix B, Item G:

> *"(Item 4) However, recognizing the uncertainties inherent in the modeling, the base case 10-foot contours was supplemented with the 10-foot contour encompassing all sensitivity runs. Any sensitive receptors within this area were also considered to have potential anticipated impacts."*
>
> *"Item (6) Finally, the Groundwater Modeling Workgroup recognized that the uncertainties inherent in the model limited its use as a tool to analyze smaller changes in groundwater level (less than 10 feet) that could still have substantial impacts on GDEs. To address this uncertainty, the Groundwater Modeling Workgroup envisions real-world monitoring of GDEs during operations in order to identify any changes, even if not anticipated by the groundwater model."*

In summary, the commenter believes that the appropriate modeling technique would have been to strictly separate the sensitivity analysis from the predictive uncertainty analysis, as espoused by Anderson et al. The 2017 WSP report (Resolution Copper Groundwater Flow Model Report, Section 3.2.6 Parameter Sensitivity) discusses calibration sensitivity analysis. The WSP 2018 report (Resolution Copper Groundwater Flow Model – Sensitivity Analysis 2018) discusses the predictive sensitivity analysis (or uncertainty analysis), however, also labels it as "Sensitivity Analysis". This led to understandable confusion, which was not cleared up previously.

The implications that uncertainty and risk were ignored by the Groundwater Modeling Workgroup are not supported. Not only are the results of the 87 model runs disclosed to the public in a variety of ways, but they formed a fundamental basis for predicting impacts. More importantly, the uncertainty informed the need for mitigation and monitoring to encompass all GDEs, regardless of model predictions.

- Proposed path forward: BGC notes that additional explanation can be added to the Groundwater Modeling Workgroup memo to describe the two different types of sensitivity analyses performed, calibration sensitivity and prediction sensitivity, as envisioned in guidance like the ASTM standards and Anderson et al. No change in modeling approach is warranted.

XIII. Issue #11: Geothermal effects were not considered in the modeling.

XIII.A. Specific comments included (see Attachment 2): 18, 29, 58, 59

XIII.B. General category of these comments:

- #3 – Professional opinion expressed about an issue that was not explicitly discussed by Groundwater Modeling Workgroup

XIII.C. RCM/WSP response (paraphrased from WSP 3/23/20, see attachment 1):

- WSP notes Topic of heat transfer discussed within the working group, but determined it to have negligible and likely immeasurable effects for modeling impacts to GDEs. Simply put: those effects are overwhelmed by the massive hydraulic sink and the stresses it causes.

XIII.D. NEPA/BGC response (paraphrased from BGC 5/11/20, see attachment 2):

- Refers back to WSP response

XIII.E. Pertinent documentation in project record:

- Meeting notes:
  - 2/2018 [PR #0002320]
  - 4/2018 [PR #0002720]
  - 7/2018 [PR #0002786]

XIII.F. Proposed path forward to resolve comment:

Comments #18, 29, and 58 all point to the importance of geothermal effects with modeling groundwater impacts at the mine site. WSP's response is twofold: 1) that the topic was discussed in the workgroup, and 2) that the rationale for not pursuing geothermal effects is that they are negligible compared to the huge stress caused by the subsidence and dewatering.

If these effects were discussed for the groundwater model during the workgroup meetings, the discussion failed to make it into the notes or project record. Geothermal gradients appear to have been discussed three times (2/13/18, 4/7/18, 7/17/18). In each case, the discussion appears to have been specific to the potential for geothermal mixing effects related to a subsidence crater lake, not for the groundwater model as a whole. Nor do the meeting notes capture any clear decision or rationale on this topic.

This is a legitimate comment, in that no documentation exists that contains a rationale for not including geothermal effects. That said, the rationale provided by WSP is a reasonable one.

1) Geothermal effects have no ramifications on impacts to GDEs
2) During active dewatering the geothermal effects would be negligible compared to the massive stress of dewatering—the entire system is operating under extreme gradients and there simply is no recirculation that could occur.
3) After dewatering pumping stops, we do anticipate the possibility of poor quality water in the block-cave zone, but no outlet, exposure, or transport of that poor water quality is

anticipated. This point has been explored further during the reconvened Water Resources Workgroup (action item WR-22). Geothermal gradients post-closure may indeed exist but without exposure points they have no ramifications on impacts to the environment.

- Proposed path forward: Documentation on this topic is needed, both in the project record and in the FEIS. The groundwater experts on the NEPA team should review and concur with the above rationale and document it in some manner.

Comment #59 refers to geothermal effects, but is much different, pondering why Resolution Copper didn't consider geothermal energy development. This is outside the scope of analysis for the Water Resources Workgroup, and will be responded to in the context of alternatives development.

- Proposed path forward: No changes to EIS or analysis. Response-to-comment to be prepared along with other alternatives comments.

XIV. Issue #12: Subsidence crater lake was not analyzed appropriately, and fate and transport of contaminants was not considered.

XIV.A. Specific comments included (see Attachment 2): 43, 63, 65, 67

XIV.B. General category of these comments:

- #2 – Professional opinion expressed about an issue explicitly discussed by Groundwater Modeling Workgroup

XIV.C. RCM/WSP response (paraphrased from WSP 3/23/20, see attachment 1):

- Refers to Forest Service conclusion, after review of data, that is "remote and speculative"

XIV.D. NEPA/BGC response (paraphrased from BGC 5/11/20, see attachment 2):

- Notes that dewatering for decades, the occurrence of subsidence and the complete removal of the Tal aquifer are large changes, which will influence recharge and discharge, and a return to pre-mining (steady state) conditions cannot be assumed.

XIV.E. Pertinent documentation in project record:

- DEIS, p. 375-379 "Potential for Subsidence Lake Development"
- WSP November 19, 2018 "Resolution Copper Groundwater Flow Model - Sensitivity Analysis", including Excel hydrograph data
- May 2019 email with Graben hydrographs [PR #0003210]
- Meeting notes:
    - 11/2017 [PR #0002170]
    - 2/2018 [PR #0002320]
    - 4/2018 [PR #0002720]
    - 5/2018 [PR #0002755]
    - 6/2018 [PR #0002667]
    - 7/2018 [PR #0002786]

XIV.F. Proposed path forward to resolve comment:

Comment #43 concerns the specific topic of the block-cave geochemistry modeling. This topic is being handled elsewhere and is not part of this white paper.

Comments #63, 65, and 67 argue that "conceptually, it is easy to argue that the groundwater levels will eventually recover to pre-mining levels (steady state), and at least to currently monitored levels, known to be influenced by Shaft 9/10 pumping since 2009", and if this occurs water levels would be 650 above the bottom of the crater. The comments then suggest that if the groundwater model had incorporated the physical lowering of the ground surface—and run to steady-state conditions—a subsidence lake would have developed.

There are three aspects to this scenario that bear discussion: 1) whether the steady-state recovery argument is appropriate, 2) whether simulating subsidence in the groundwater model was required, and 3) whether analysis of the subsidence lake was inappropriately ignored.

The first issue has already been covered (see Issue #5, discussion regarding Comment #5). The assumption made by the commenter that "it is easy to argue that the groundwater levels will eventually recover to pre-mining levels" is not appropriate, and the issue of steady-state versus transient modeling was discussed during the Groundwater Modeling Workgroup as part of the decision to limit quantification to 200 years (but not limit all analysis to 200 years, see Issue #5). A return to steady-state conditions is no more certain and realistic than the transient modeling that was conducted and approved by the Forest Service.

The second issue is of modeling subsidence is covered in detail in Issue #13 below. With respect to the subsidence lake development, the commenter appears to be suggesting that the subsidence model should have been linked to the groundwater model. Not only is this an unrealistic technical feat, potentially unprecedented, but it is not in any way required to analyze and disclose the impact to the public.

The comment appropriately points to p. 375-379 of the DEIS for the analysis of whether a subsidence crater lake could develop, or the consequences if it did. This, in effect, is exactly what is asked for by the comment: the coupling of the subsidence model and the groundwater model. The two outputs need not be predicted with the same computer program to be coupled in an analysis of subsidence lake development. Both models used for this analysis are based on a lengthy, robust, informed review by a diverse group of professionals through the Geology and Subsidence Workgroup and the Groundwater Modeling Workgroup.

As to the third item—was the subsidence lake improperly ignored? Frankly, the viewpoint of the commenter is a fair one, and the same viewpoint was a subject of much discussion during the Groundwater Modeling Workgroup (meetings 11/2017, 2/2018, 4/2018, 5/2018, 6/2018, 7/2018). The same logic was considered and debated, with the ultimate decision that the best evidence simply did not suggest that a subsidence crater lake would form. Ultimately what shows up in the DEIS represents the approach most fitting.

It is also fair to note, as is noted in the DEIS, that just assuming a subsidence crater lake would form is not enough to allow any analysis of the water quality of that lake. "For instance, the depth of the lake cannot be known with any accuracy. That single parameter would affect both the amount of inflow of native groundwater and the amount of evaporation that would occur from the lake surface, and it is the interplay of these two parameters that largely determines how constituents would concentrate in the lake and whether the ultimate water quality would be hazardous to wildlife." (DEIS, p. 378) The DEIS settles for conveying the range of possible water quality (table 3.7.2-8) that could form part of a theoretical lake.

- Proposed path forward: No valid argument is raised in the comment that supports the analysis of a subsidence lake, and the desire to analyze one remains a professional opinion. Two points have been noted by the reconvened Water Resources Workgroup where the discussion of this topic should be changed:

1) The language used in the DEIS is confusing, in that it acknowledges the long-term trends that could create a subsidence crater lake, but then calls it "speculative". The language in the DEIS is going to be revised, though the analysis remains the same.

2) There is one modification to the analysis that could be made in light of the comments. While the uncertainty range for the depth of the subsidence crater is shown in table 3.7.8-7, no similar range is given for the modeled groundwater levels. This can be added to the analysis, and this output for DHRES-01, DHRES-02, and DHRES-08 needs to be requested from WSP.

XV. Issue #13: Subsidence was not incorporated into the mine-site model appropriately.

XV.A. Specific comments included (see Attachment 2): 57, 60, 66

XV.B. General category of these comments:

- #2 – Professional opinion expressed about an issue explicitly discussed by Groundwater Modeling Workgroup

XV.C. RCM/WSP response (paraphrased from WSP 3/23/20, see attachment 1):

- WSP notes that flow into this dewatered block cave is largely dictated by the surrounding HGU hydraulic properties, which are far less than 100 ft/day.

XV.D. NEPA/BGC response (paraphrased from BGC 5/11/20, see attachment 2):

- BGC notes that increasing the conductivity to model empty space makes no difference in the model outcomes.

XV.E. Pertinent documentation in project record:

- DEIS, p. 375-379 "Potential for Subsidence Lake Development"
- WSP 2019

XV.F. Proposed path forward to resolve comment:

These comments are related to the criticism discussed under Issue #12, the development of a subsidence lake. Issue #13 focuses solely on the incorporation of subsidence itself into the MODFLOW model.

Comment #60 states "It is apparent that WSP failed to account for the change in land surface in their modeling (~800 to 1100 feet). This is a critical oversight in the DEIS, because had a proper future-condition conceptual model been developed showing the 800 to 1000 ft drop in land-surface, it would have required a similar change in the calibrated model."

This is an incorrect assumption. Once block-caving begins, the upper fractured zone where the subsidence crater will develop is unsaturated with respect to the regional aquifer. This is clearly shown in the DEIS, in Figure 3.7.2-4 (p. 377). There is no groundwater flow in this area and the modeling indicates there will not be groundwater flow in this area even 1,000 years in the future. There is indeed water percolating downwards from precipitation, but this downward movement is essentially decoupled recharge to the aquifer. The modeling of a change in elevation of land surface above the regional aquifer has no bearing on the outcome of the model.

Comment #57 focuses on the assigned conductivity of the block-cave zone. WSP correctly points out that the conductivity of the block-cave zone is immaterial (attachment 2): "*IHS also asserts that groundwater recovery within the cave could be much quicker than predicted due to the use of a maximum hydraulic conductivity within the cave of 100 ft/day. The argument misses that flow into this dewatered block cave is largely dictated by the surrounding HGU hydraulic* *properties, which are far less than 100 ft/day*." BGC notes that increasing the conductivity to model empty space makes no difference in the model outcomes.

Both comments #60 and 66 suggest that this modeling is important in the very long term, when a lake might form in the subsidence crater. This is directly responded to under Issue #12.

- Proposed path forward: None of these aspects have any bearing on the model outcomes. However, these explanations of how the block-cave area is modeled are not necessarily described in the modeling documentation and could be added to the documentation in the project record.

XVI. Issue #14: The Desert Wellfield model was not appropriately reviewed.

XVI.A. Specific comments included (see Attachment 2): 70, 71

XVI.B. General category of these comments:

- #3 – Professional opinion expressed about an issue that was not explicitly discussed by Groundwater Modeling Workgroup

XVI.C. RCM/WSP response (paraphrased from WSP 3/23/20, Attachment 1): Not addressed

XVI.D. NEPA/BGC response (paraphrased from BGC 5/11/20, Attachment 2):

- Notes that the Desert Wellfield model is undergoing review

XVI.E. Pertinent documentation in project record:

- Newell & Garrett 2018c, see p. 8 "Rationale for Use of East Salt River Valley Model for Desert Wellfield"
- Bates, B., T. Bayley, and H. Barter. 2018. *Simulation of Drawdown Impacts from Desert Wellfield*.

XVI.F. Proposed path forward to resolve comment:

The commenter is correct that the Desert Wellfield model did not receive the same level of scrutiny (i.e., the Groundwater Modeling Workgroup) as the mine site model. The rationale for this is clearly stated in Newell and Garrett (p. 8), but it ultimately comes down to this conclusion: "Because this tool has already been widely validated, the Forest Service did not consider it necessary for the Groundwater Modeling Workgroup to review this modeling work."

Review of comments during the reconvened Water Resources Workgroup has identified that this is a shortcoming that should be remedied. Though a regulatory model, the Desert Wellfield model still is being reviewed for appropriateness and sufficiency, and this review will be documented for the FEIS.

- ➢ Proposed path forward:
  1) BGC will conduct a review of the appropriateness and sufficiency of the Desert Wellfield model, and the results of this review will guide the use of the model in the FEIS. This includes additional documentation received from ADWR clarifying how the model scenario used by Montgomery & Associates was constructed.
  2) Additional detail needs to be put in the FEIS about this review and the development/use of the Desert Wellfield model

XVII. Issue #15: Inappropriate modeling choices for faults, recharge, ET, boundary conditions.

XVII.A. Specific comments included (see Attachment 2): 16, 17, 24, 26, 27, 32, 33, 35, 38, 40, 41, 42

XVII.B. General category of these comments:

- #1 – Some comments are factually incorrect
- #2 – Professional opinion expressed about an issue explicitly discussed by Groundwater Modeling Workgroup

XVII.C. RCM/WSP response (paraphrased from WSP 3/23/20, see attachment 1):

- WSP notes that springs and seeps were modeled as drains to allow discharge of groundwater
- WSP notes that the purpose of the regional GW model is to assess impacts on the regional system, and that perched areas are not tied to regional groundwater, and evidenced through numerous lines of data.
- WSP notes that use of watershed boundaries is standard practice, and that the question of boundary effects was explicitly looked at by the Groundwater Modeling Workgroup
- WSP notes that with respect to modeling discharge with the SFR package instead of the DRN/RCH package, substantial uncertainty is introduced because of the use of multiple parameters instead of simply streambed elevation. Further, the performance of the DRN/RCH package for replicating real-world conditions was looked at and found to be acceptable
- WSP notes that the drain conductance was set sufficiently high specifically to allow the underlying hydrogeologic units to dictate discharge to streams, and prevents an unconstrained parameter (drain conductance) from biasing the calibration targets in the aquifer units.
- WSP notes that the Basin Characterization Method is valid, more site-specific data were used for the modeling effort. This included specific memos, and a comparison of the modeled water balance to the conceptual water budget prepared by M&A.
- WSP notes that focused recharge is more appropriate for the hydrologic conditions in Devil's Canyon, and the effects of recharge were evaluated in the sensitivity analysis.
- WSP notes that with respect to ET, all of the methods mentioned in the comment are highly complex and introduce uncertainty, whereas a much simpler (and standard practice) method of subtracting ET from recharge was selected instead to reduce uncertainty.
- WSP notes that the calibration of hydraulic properties across faults is more important than the strict adherence to modeling them as planes, rather than zones. The calibration was focused on properly reproducing transient water levels and propagation of responses to dewatering stresses across faults.

XVII.D. NEPA/BGC response (paraphrased from BGC 5/11/20, see attachment 2):

- BGC notes that it may be worth clarifying whether these springs are modeled only as part of stream discharge, or individually.

- BGC notes that generally, regional groundwater flow models omit perched zones.
- BGC calls back to the specific assessment of the boundaries and their appropriateness, and that the northern boundary was specifically tested during sensitivity analysis as a concern of the Groundwater Modeling Workgroup.
- BGC notes that the conceptual model is extensive and contained in numerous reports.
- BGC indicates that the best available data was used to estimate recharge, and that sensitivity analysis used a range of recharge rates to allow for changes in recharge rates due to changes in long term climatic changes. According to Anderson et al. (2015), there are no universally applicable methods to estimate groundwater recharge. The recharge rate may be adjusted during calibrations.
- BGC notes that we should describe the boundary effects and analyses better in the text.
- BGC notes that Prucha himself writes: "In single-process codes like MODFLOW, AET is typically simulated …. or by specifying net-recharge, where AET is calculated on a cell by cell basis, and then removed from applied recharge."

XVII.E. Pertinent documentation in project record:

- WSP 2019, section 3.1.6, Areal Recharge
- Wickham, 12/15/17 "Recommendations for representing recharge in the numerical groundwater flow model" [PR #0002900]
- Woodhouse 1997, "Perched Water in Fractured, Welded Tuff: Mechanisms of Formation and Characteristics of Recharge" [PR #0002312]
- WSP October 10, 2018 "Resolution Copper Groundwater Flow Model - Watershed Water Balance" [PR #0110676]
- Montgomery and Associates Inc. 2018. System-wide Hydrologic Water Flow Budget: Resolution Copper
- Wickham 2015, 12/8/15 "Fault core review and guidance for groundwater flow modeling" [PR #0002641]
- BGC 2018a, Geologic Data and Subsidence Modeling workgroup memo
- Garrett 2018d, "Summary and Analysis of Groundwater-Dependent Ecosystems"
- Meeting notes: Note that almost all of the meeting notes include discussions in one way or another about boundaries, recharge, drains, perched zones, or evapotranspiration approaches
- 4DGeo – Applied Structural Geology, 2017. Summary of Geologic Information Relevant to Development of the Porphyry Cu-Mo Resolution Deposit, Arizona. [PR #0001347]

XVII.F. Proposed path forward to resolve comment:

These comments have in common that they contend the modeling choices made for representing recharge, evapotranspiration, faults, perched zones, and groundwater discharge were improperly made, and that better choices exist.

As noted in the introduction to this whitepaper, there are many modeling tools and techniques available, and modelers have to make choices about which tools and techniques to use. There are always other tools that could have been used. That the comments raise other possible approaches is a moot point. The appropriate threshold for concern is whether the comments make a valid argument that the existing method is actually in error, or that the rationale for using the existing method is incorrect.

Comment #16 focuses on how the complex hydrogeologic system is graphically conveyed in the WSP modeling report. This comment focuses solely on the WSP report and ignores the large amount of other reports and information in the project record. At the very least, key hydrogeologic conceptualization reports include the 4DGeo summary of geologic information, the Montgomery & Associate numerous aquifer tests reports, the Montgomery & Associates numerous water quality and water level monitoring reports, the various Wickham memos, and the system-wide water budget reports (WSP and M&A). That the WSP report needs to show every nuance of the hydrogeologic system is not realistic; a look at the WSP list of references indicates that they were privy to the full record of available information. What is more important is that the Forest Service and the Groundwater Modeling Workgroup considered the full breadth of information; all of these reports are documented in the project record, as well as in an entirely separate review and validation of the geologic framework (BGC 2018a).

- Proposed path forward: With respect to documentation, what doesn't appear in the WSP report still appears in the record and was available to the Forest Service and the modelers. No lack of numerous figures in the WSP report is not a modeling flaw. Prepare response-to-comment.

Comment #17 suggests perched zones were erroneously left out of the model. Both BGC and WSP note that this is a regional groundwater model, focused on impacts to water sources that derive from the regional groundwater system. Perched zones do not interact with the regional groundwater. Nor was this an arbitrary assumption. Multiple lines of evidence were used to determine which water sources were tied to regional groundwater and which were not (Garrett 2018d). See Issue #3 for more detail. This does not represent a "key error in conceptual modeling", but an appropriate translation of the conceptual model based on real-world data into a numerical groundwater flow model.

Comments #24 and 35 focus in part on the model boundaries. Selecting model boundaries is a fundamental modeling choice. Standard approaches were used to define obvious boundaries: watershed boundaries and no-flow boundaries. The use of general-head boundaries is a choice that requires more evaluation to ensure appropriate use. In these cases, it is incumbent on the modeler to ensure that the GHBs are not only realistic, but don't unduly influence the model results. The commenter specifically notes the potential for drawdown to reach the GHB boundary. The Groundwater Modeling Workgroup looked at this issue explicitly, requesting information on the fluxes across the GHB boundaries, and as a backstop a sensitivity run that changes the GHB boundary to a no-flow boundary. Impacts to the predictive results were negligible, which is the appropriate outcome. While the concern raised in the comments is generally a valid modeling issue, the modeling process undertaken by the Forest Service has already properly evaluated it.

Comments #26 and #27 focus on the modeling of faults, indicating that different modeling code should have been used (FEFLOW) to model faults as planar features. The WSP model instead assigns different conductivity zones to reflect faults. This again is a modeling choice. WSP notes that the approach taken was demonstrably appropriate, because it accurately reproduced the real-world hydrologic responses that occur across faults. The importance of these faults needs to be noted. Flow across these graben-bounding faults is a primary control in the groundwater model, and presumably if flow were greater, impacts might extend further in space.

Fortunately, we have ample information to assess this. Not only was fault conductivity increased during the sensitivity analysis—and those results incorporated into the DEIS impacts (figure 3.7.1-3, p. 302)—but the real-world effect of the faults is quite clear from the response to dewatering both inside and outside the graben, as disclosed in DEIS, table 3.7.1-1, p. 309. Comment #27 specifically points out that hydrogeologic characterization of flows along the faults is largely missing—this is not a correct statement. Evaluation of the hydrologic response along the faults is contained in the record, specifically summarized in Wickham 2015a.

In this case, while any number of different techniques could have been used to model the faults, the selected approach is supported by substantial aquifer test and dewatering data, and the potential for the faults to act differently was incorporated into the uncertainty analysis. The approach used does not represent a flaw, but a valid modeling choice, and the comments do not suggest an overriding reason why planar modeling would be more accurate or better reproduce the real-world conditions than the current model.

Issue #7 deals directly with the modeling choice to use the RCH/DRN cell combination instead of a different package. Comments #32, #33, and #41 focus rather on how recharge was assigned, including suggesting an alternative method (the Basin Characterization Method used by the USGS). Part of this criticism is aimed at the amount of recharge, and part of this criticism is aimed at how the recharge is applied—applied in focused areas along the stream channels, in contrast to being applied areally. Both BGC and WSP acknowledge that the USGS method is a valid method and even could be used to backstop the recharge estimates, but WSP notes that the method chosen instead was based on site-specific data rather than generalizations. Two documents in particular are noted that informed the site-specific assessment (Wickham 2015b and Woodhouse 1997). WSP argues that using a focused recharge approach is more appropriate for areas without substantial stream bank storage, like Devil's Canyon.

This appears to be a difference of professional opinion, with the chosen method not being demonstrably wrong, just different than what the commenter would have chosen. BGC notes that Anderson et al specifically indicate there is no one standard way to estimate recharge for groundwater models. In this case, there are three specific items reviewed by the Groundwater Modeling Workgroup that confirm that the approach used is valid, regardless of other opinions:

- The distribution of recharge was compared to real-world conditions (see Issue #9 for more detail on how the calibration compared drain flux to real-world conditions).
- The recharge used in the groundwater model is consistent with a conceptual basin-wide water budget (see the WSP water balance versus the M&A water budget).
- And recharge was varied as part of the sensitivity/uncertainty analysis to understand how it would change model results, and the potential for recharge to be incorrect is already included in the disclosure in the DEIS (see Issue #10 on uncertainty).

Comment #38 and 40 focus on the use of the drain cells. Comment #38 suggests that setting the drain conductance high effectively removes it as a calibration parameter. WSP notes that the important part of the drain packages is that uncertain assumptions at the stream channel (the streambed conductivity) not inhibit the more certain hydrologic properties of the aquifer. Indeed, given the fractured nature of the Apache Leap Tuff, it is the fractures in the rock unit—not the overlying streambed material—that is the important driver of perennial flow.

Again, this appears to be a difference of professional opinion, with a clear rationale for why the current approach was taken. More importantly, the drain flux was compared to the real-world stream observations as a qualitative calibration tool. In other words, whether a different choice could have been made or not on the drain conductance, the chosen approach reasonably matches real-world conditions and is demonstrably acceptable.

Comment #40 further notes that springs and seeps were not simulated as discharge points. WSP indicates they were. This is actually a point that needs clarification. We believe the proper description would be: "Seeps and springs were simulated as discharge points in the Modflow model, where they lie along stream channels like Devil's Canyon; individual springs away from these channels were not explicitly modeled as discharge points." This clarification will be requested.

Comment #42 focuses on evaporation estimation. In this case the commenter suggests a bevy of complex approaches that could have been undertaken to estimate—and explicitly model—evapotranspiration. In lieu of these, WSP chose to use a simplified approach in which evaporation is subtracted from recharge. Both WSP and BGC note that this is a common approach, and indeed even the commenter notes that (emphasis added): "…AET is typically simulated either using the standard EVT package, which calculates AET on a cell by-cell basis, as a function of groundwater depth, maximum evapotranspiration rates, and plant root depths, <u>or by specifying net-recharge, where AET is calculated on a cell by cell basis, and then removed from applied recharge</u>."

It appears the concern here is not the subtraction of AET from recharge, but rather the scale at which it was done, both temporally and spatially (emphasis added):

> *"Importantly, assessing <u>sub-daily impacts</u> at specific locations in the model is strongly influenced by correct calculation of AET. In riparian zones, groundwater loss to AET and baseflow discharge compete against each other, as a function of groundwater depth. Consequently, without directly simulating AET <u>in all cells</u>, groundwater models likely overestimate baseflow loss, and incorrectly parameterize stream aquifer conductance values. Omitting this critical process (a conceptual error, especially in semi-arid climates) prevents estimation of mine impacts on phreatophyte-dependent riparian vegetation. This is a major oversight in the DEIS evaluation of impacts at GDEs."*

With respect to temporal effects, this is a regional model that appropriately makes no attempt to model time scales as short as a day—this is a model meant to reflect the large-scale changes and effects to GDEs over the 50-year life of the mine, and then hundreds of years after that. Assessing AET on daily time steps using real-world meteorological data is a valid technique, but one that is inappropriate for the goals of this modeling effort.

With respect to "all cells", the commenter also notes that the key areas are the riparian zones. Indeed, for the purposes of this model, the impacts to riparian vegetation that occurs along with perennial flow in Devil's Canyon is one of the fundamental concerns. The chosen approach—subtracting AET from recharge along the channel—accomplishes the same thing along the channel that modeling AET separately from recharge would accomplish. For the watershed as a whole, being a desert environment, AET acts primarily in the shallow subsurface (evaporation from soil, and transpiration by terrestrial vegetation that removes water from the soil) or along areas where riparian vegetation can directly draw on groundwater. AET effects on the landscape far away from riparian areas do not affect regional groundwater in any way, and are already incorporated into the amount of runoff that reaches the channels. Adding AET to each and every cell is appropriate in some conditions—and isn't necessarily incorrect even for this model—but the selected approach is just as valid. This is demonstrated by the adherence of the modeled water budget to the regional water budget.

- Proposed path forward: No changes to EIS or analysis. With respect to model boundaries, faults, recharge, drain cells, evaporation, and faults, multiple modeling choices are available. That alternative modeling choices are suggested by the comments is a moot point. In every case, though, the existing approaches not only are valid options, but they are demonstrated in various ways to accurately predict real-world conditions. Or, where uncertainty exists, it was properly incorporated into the uncertainty analysis and disclosed in the DEIS (specifically fault flow, recharge, and boundary changes). Prepare response to comment.
- Proposed path forward: There is a small clarification to be made on spring modeling using drains, and this will be requested; BGC also notes that the boundary effects should be better explained in the text.

ATTACHMENT 1

MARCH 23, 2020 WSP RESPONSE TO INTEGRATED HYDRO SYSTEMS PUBLIC COMMENTS

ATTACHMENT 2

MAY 11, 2020 BGC BREAKDOWN OF INTEGRATED HYDRO SYSTEMS PUBLIC COMMENTS WITH NOTES

ATTACHMENT 5

LETTER FROM L. EVERETTT AND ASSOCIATES, DATED AUGUST 7, 2020

August 7, 2020

Ms. Mary Rasmussen
Project Manager
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Re: Dissenting Comments to the Water Resources Working Group Draft Environmental Impact Statement for the Resolution Copper Project and Land Exchange

Dear Ms Rasmussen:

On behalf of the San Carlos Apache Tribe ("Tribe"), I provide additional comments and dissenting opinions related to the findings of the Water Resources Working Group and subsequent water resource-related decisions made by Tonto National Forest's ("TNF"). As you know, since 2017, I have participated in both the Groundwater Modeling and the Water Resources Working Groups convened to advise TNF on water-related issues relevant to the Environmental Impact Statement ("EIS") for the mining project and land exchange for Resolution Copper Mine, L.L.C., a partnership of the foreign mining giants, BHP Billiton (Britain) and Rio Tinto (Australia). Specifically, the purpose of the Groundwater Modeling Working Group was to advise TNF on groundwater modeling issues, including:

- Review initial modeling efforts by Resolution Copper;
- Discuss appropriate modeling approach (i.e., parameters and assumptions) for this situation, and review RCM model against that approach;
- Identify appropriate model runs or sensitivity analyses to conduct and desired output;
- Review results of revised modeling efforts and request modifications or additional runs; and
- Provide conclusions on the appropriateness of the groundwater modeling results for use in the EIS, and the uncertainty and limitations associated with those results (SWCA, Resolution Biweekly Management Meeting 8/17/2017).

The Groundwater Modeling Working Group wrapped up its work in late 2018. Subsequently, an expanded group, renamed the "Water Resources Working Group", reconvened in early 2020, and held meetings up until the end of July 2020. The purpose of this group was to advise TNF on its responses to water-related public comments on the Draft

EIS and potential revisions to the Draft as TNF worked toward a Final EIS. While the membership and participation varied over time, these two working groups consisted at one time or another of experts from the U.S. Forest Service ("USFS"), SWCA (TNF's EIS contractor), Resolution Copper and its contractors, as well as state and federal stakeholders such as US Environmental Protection Agency, US Army Corps of Engineers, Arizona Game and Fish, Arizona Department of Environmental Quality, Arizona State Lands Department and Arizona Department of Water Resources.

As detailed below, the Tribe has significant concerns about the process of analyzing and disclosing environmental impacts from the proposed Resolution Copper Mine.

I. Voluminous and Consequential New Data Incorporated into the Final EIS Without Opportunity for Public Comment

Based on comments received on the Draft EIS, the public has expressed deep concerns about the water quality and water resource implications of the proposed mining project. SWCA reports that water resources was "the largest grouping of substantive comments received with about 500 of the 2,500 substantive comments" received from the public on the Draft EIS. (SWCA, February 2020, Meeting Minutes, Resolution All Things Water Working Group Meeting 1/23/2020). Thus, this is an issue of utmost importance to the public.

There are very significant new analyses that have been conducted and data that has been collected subsequent to issuance of the Draft EIS that are important components of the overall record and would assist the public in understanding TNF's assessment of alternatives and disclosure of impacts. 40 CFR §1502.9 requires that agencies "shall" prepare supplements if "There are significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts."

We strongly believe that a Supplemental Draft EIS is called for in this situation because there is significant, technically substantial new information consisting of dozens of new studies and reports totaling thousands of pages that are relevant to environmental concerns. The Supplement is needed to allow the public to review and comment on the vast body of new information now available about this project. In my 25 years of experience, I find it highly unusual for a project with so much new and previously undisclosed information to proceed directly to a Final EIS, without the issuance of a Supplemental Draft which would allow for additional public comment. Specifically, as detailed below, there are voluminous new studies of the Skunk Camp tailings storage facility ("TSF"), new groundwater modeling work on the East Salt River Valley groundwater basin (site of the proposed Desert Wellfield where much of the water required by the mine would be pumped), and a brand new assessment of possible surface water discharges from the mine operations under Resolution's AZDEPES permit.

A. Skunk Camp

New data for Skunk Camp ("Alternative 6" for the TSF and the preferred alternative in the DEIS) includes:

1) KCB Consultants, November 2019, Skunk Camp Site Investigation, documenting geophysical surveys, test pits, a geotechnical drilling program, a hydrogeological drilling program and hydraulic testing. Together with its appendices, this report contains more than 2,700 pages of technical documentation relevant to the adequacy of Skunk Camp as the preferred alternative for the TSF. Absent this data, it is hard to see how the public can be adequately informed of the potential impacts of the TSF on Dripping Springs Wash, the Gila River and the underlying groundwater.

2) KCB Consultants, January 2020, Letter Report: Skunk Camp TSF Stability Implications Post Site Investigation.

3) Montgomery and Associates, November 7, 2019, Aquifer Testing Results for Skunk Camp Hydrogeologic Investigation.

4) Lettis Consultants International, January 6, 2020, Site-Specific Seismic Hazard Analyses and Development of Time Histories for Tailings Storage Facility, Southern Arizona.

5) Montgomery & Associates, April 24, 2020, Skunk Camp Area Data Submittal, Summary and Data for Water Quality and Water Level Database for Skunk Camp and Gila River.

6) KCB Consultants, June 2020, Skunk Camp TSF Seepage Assessment.

7) Montgomery & Associates, July 17, 2020, Numerical Groundwater Flow Model for the Skunk Camp Tailings Storage Facility.

8) Montgomery & Associates, July 3, 2020, Summary of Results for 2020 Site Investigations at the Skunk Camp Storage Facility Site.

9) Montgomery & Associates, June 29, 2020, Conceptual Hydrogeologic Model: Skunk Camp Tailings Storage Facility Alternative.

Briefly stated, these voluminous documents are full of new data not previously disclosed to the public, and these provide the fundamental basis for TNF's selection of Skunk

Camp as the preferred alternative for the TSF. However, the public has not been granted the opportunity to review or comment on any of it.

B. East Salt River Valley

RCM has conducted significant new groundwater modeling of the East Salt River Valley to evaluate cumulative impacts on the groundwater basin from RCM's pumping (Montgomery & Associates, January 23, 2020, Technical Memo: Desert Wellfield Pumping 100-Year Drawdown Analysis for ADWR Evaluation in Support of the Resolution Copper EIS). The new modeling found maximum drawdown in the East Salt River Valley of 212 feet and disclosed that an area encompassing approximately 150 square miles would experience drawdown of at least 25 feet due to RCM's pumping in the Desert Wellfield. This was a major issue of concern for many people who commented on the Draft EIS, with no fewer than 100 comments expressing concern about water scarcity or the need for improved analysis of cumulative impacts. As you know, the Draft EIS was inadequate on this issue – that is a given.

The public should now have a chance to review the necessary and new data now compiled on cumulative impacts and be granted the opportunity to weigh in on the adequacy and significance of this work. This work is documented in an unpublished PowerPoint presentation shown to the Water Resources Working Group and in a May 26, 2020 memo from Montgomery & Associates entitled, "Summary of Additional Data Presented in the April 23, 2020 Resolution-All Things Water Working Group from Desert Wellfield Pumping 100-Year Drawdown Analysis for ADWR Evaluation in Support of the Resolution Copper EIS" and possibly other forthcoming studies that even the Working Group has not seen.

C. ***Stormwater Releases to Queen Creek***

TNF has acknowledged that "there will be a substantial new section added to the FEIS on this new analysis done to answer public comments." (SWCA, August 2020, Meeting Minutes, Resolution Water Work Group Meeting #7 7/30/2020; see also, July 5, 2020 letter from RCM to USFS, Subject: Resolution Copper Mining, LLC – Mine Plan of Operations and Land Exchange – Response to Water Work Group Action Item WR-20).

We now know that there are certain conditions during which stormwater could be released into Queen Creek by RCM. This potential impact to Queen Creek was simply not disclosed in the Draft EIS, so the public was not informed of this potential impact and will be denied its right to comment on this issue unless a Supplemental Draft EIS is issued.

II. Alternative Mining Methods

How much lower would the impacts be to Oak Flat, Queen Creek and Ga'an Canyon (also known as Devil's Canyon) if the ore was extracted using a method that does not induce massive subsidence and an eventual collapse crater nearly two miles wide? Without a supplemental EIS, the public will never know because this alternative was not evaluated in a detailed way.

Underground mining alternatives to block cave mining were eliminated from further consideration and are not substantively evaluated in the DEIS. These alternative mining methods were eliminated from detailed consideration by TNF. TNF simply deferred to RCM's opinion that any alternative would be costlier and because of the alleged infeasibility of large-scale tailings backfill. TNF did not seek any independent review of alternatives. There is no reason that the EIS did not evaluate an alternative involving alternative mining methods and one or more of the evaluated surface TSFs. This singular omission is a mistake, especially considering the fact that other mining methods have the potential to vastly reduce environmental and cultural impacts that cannot be avoided if the block cave mining technique is employed.

Since RCM has withheld detailed information about ore grade, TNF is not really in a position to independently analyze mining costs. As such, TNF's conclusions on cost are based largely on RCM's assurances, which are, in turn, based on supposedly proprietary information that neither TNF nor the public have a means to validate. It goes without saying that the RCM has an exceptionally strong incentive to downplay alternative mining methods that would be more expensive (although possibly still profitable), even if they <u>are</u> technically feasible.

With regard to water resources, TNF failed to disclose the myriad ways in which other means of underground mining (*i.e.*, methods that do not entail block caving) would have resulted in vastly less environmental, recreational and cultural impacts. The public should have been given the opportunity to see the level of exchange of environmental protections for RCM's profits, especially if the public will pay for resulting cleanup efforts and other costs not born by RCM, given the nature of its limited liability.

Under Section 3003(c)(3)(B) of the Southeast Arizona Land Exchange and Conservation Act, the Secretary of Agriculture is required to engage in government-to-government consultations with affected Indian tribes. But more than that, Section 3003 also requires the Secretary to:

> "seek to find mutually acceptable measures to—
> (i) address the concerns of the affected Indian tribes; and

> (ii) minimize the adverse effects on the affected Indian tribes resulting from mining and related activities on the Federal land conveyed to Resolution Copper under this section." (§3003(c)(3)(B); emphasis added).

By eliminating alternative mining methods from detailed review, TNF disregarded alternatives that would have vastly minimized the adverse effects of this project on affected Indian tribes (by preserving Oak Flat and reducing losses to springs and creeks, among other things). On this matter, TNF has not satisfied its obligations under Section (§3003(c)(3)(B)(ii) of the Southeast Arizona Land Exchange and Conservation Act.

III. Surface Water Groundwater Interaction

The Forest Service's conceptual model upon which the groundwater model is based and upon which hydrogeological interpretations are made does not account for the possibility of direct recharge of springs and stream flow in Ga'an Canyon via fracture flow from deep groundwater (not solely from precipitation and the Apache Leap Tuff). This is not a theoretical concern – deep groundwater is connected to surface water flows just a few miles east of the Resolution mine site, on Pinto Creek.

Three test wells (depths between 755 and 1,220 feet) were installed near Pinto Creek by the Carlota Copper Mine. A 25-day pump test on one of the wells induced a drop in streamflow in Pinto Creek from 45 gallons per minute (gpm) to 5 gpm. Flow in Pinto Creek subsequently increased once the pump test was completed. (US Forest Service, May 2007, Technical Guide to Managing Ground Water Resources, pp. 20-21). Water levels in a shallow alluvial well also declined during the deep aquifer pump test, attesting to an intimate connection in the Pinto Creek area between a deep aquifer, a shallow alluvial aquifer and surface water flows.

At the Resolution study area, it is notable that the water level elevation, or more precisely, the head in deep monitoring well, DHRES-14 (DHRES-14_WL) was measured at about 3,500 feet above mean sea level (Montgomery & Associates, July 2016, Hydrograph Set for Current Hydrogeologic Monitoring Network). The elevation of the nearest spring in Ga'an Canyon (DC-8.2W) is approximately 3,540 feet msl (Montgomery & Associates, March 2012, Results of Hydrochemical Characterization of Groundwater Upper Queen Creek/Devils Canyon Study Area, Table 2), suggesting the possibility of spring recharge from deep groundwater.

The USFS "Technical Guide to Managing Ground Water Resources" from 2007 was withdrawn for non-scientific policy reasons but it represents sound science and USFS's best thinking on groundwater resources. The Technical Guide articulates an important example of the Precautionary Principal that is relevant for this EIS that managers should assume that surface water-groundwater connections exist:

> "Always assume that hydrological connections exist between ground water and surface water in each watershed, unless it can be reasonably shown none exist in a local situation." (USFS, May 2007, Technical Guide to Managing Ground Water Resources, p. 6).

In conclusion, the presentation of the hydrogeology of the region in the EIS fails to fully examine the interaction between surface waters and deep groundwater and how this interaction may change if the mine project proceeds. In addition, the DEIS's conclusions about deep groundwater in and around Ga'an Canyon are based on a single deep monitoring well, which is very poorly calibrated in the model. As a result, the conclusions drawn by the computer model and the DEIS are unreliable and probably inaccurate.

IV. Misstatements About Independence of TNF's Analysis

All groundwater modeling for this environmental analysis was performed by RCM and its contractors. There is much misinformation about TNF's involvement in this work. For example, RCM's modeling consultant, WSP states [in response to comments about the adequacy of model selection], "Additionally, the use of MODFLOW-SURFACT was discussed by the USFS Groundwater Working Group and the USFS made the decision to select this model as an appropriate tool to address the issues raised during scoping after considering discussions and recommendations by the working group." (WSP, March 23, 2020, Memo: Response to Integrated Hydro Systems Review, p. 2). It is simply untrue that the Forest Service selected this model.

As a matter of fact, RCM had been developing this groundwater model for years prior to the formation of the Groundwater Working Group. It was undoubtedly needed for evaluations of the effects of its ongoing dewatering from shafts 9 and 10 and for mine planning purposes. RCM certainly has the right to develop its own groundwater model, but it is disingenuous to imply that TNF had anything to do with the selection of this model. However, the groundwater model was a *fait accompli* before the Groundwater Working Group ever met.

Instead of obscuring these facts, the public, which the TNF serves, has been kept in the dark as to just how dependent TNF is on RCM for performing complex analyses that are fundamental to the EIS. We are not claiming that this symbiosis is improper, but the public should be informed of TNF's reliance on RCM so it can judge for itself the significance of this obvious conflict of interest, especially given the scale of impacts by the mine on scarce water resources.

V. Uncertainties in Groundwater Modeling and Groundwater-Dependent Ecosystems

> *"Remember that all models are wrong; the practical question is how wrong do they have to be to not be useful."* -- George Edward Pelham Box

This quote by the esteemed British statistician, George Edward Pelham Box, reminds us that even the most sophisticated models are not useful if the errors and uncertainties render the model a poor simulation of the real world. 40 CFR §1502.24 requires that agencies ensure scientific integrity of analyses in environmental impact statements. This means that scientific analyses must be reliable. As noted in the DEIS,

> The Groundwater Modeling Workgroup recognized that a fundamental limitation of the model—of any model—is the unreliability of predictions far in the future, and the workgroup was tasked with determining a time frame that would be reasonable to assess. … the Groundwater Modeling Workgroup determined that to properly reflect the level of uncertainty inherent in the modeling effort, results less than 10 feet should not be disclosed or relied upon, as these results are beyond the ability of the model to predict. (DEIS, pp. 300, 301).

These statements acknowledge that due to the sheer enormity of the proposed mining project and its profound and permanent impacts on the natural hydrogeologic system, even the sophisticated groundwater model (selected, developed and run by RCM, not TNF) has inadequacies in predicting impacts on both spatial and temporal scales.

TNF was asking too much of a single groundwater model. It was asking the model to predict future impacts from mine dewatering and from the subsidence crater. As RCM admits, that crater will develop into a 2-mile diameter hole into the Apache Leap Tuff Aquifer for time immemorial) across a vast area of more than 190 square miles. On a smaller scale, TNF then asked the model to predict small changes in water levels at specific groundwater-dependent ecosystems (such as springs and creeks).

The smallest cell size in the model is 200 x 200 feet, meaning that in this model, all hydrogeological characteristics and all modeling results are reported as a constant or average across each 200 x 200 ft cell. WSP notes a consequence of the large lateral and vertical extent of the model is that it “makes the grid resolution required to represent point feature (i.e. spring discharges) unfeasible.” (WSP, March 23, 2020, Memo: Response to Integrated Hydro Systems Review, p. 3). As discussed below, the model calibration data illustrate how small-scale predictions (such as groundwater declines of 10 feet or less under specific GDEs) are rendered highly unreliable due to the scale and complexity of the groundwater model. There was nothing preventing TNF from constructing a more detailed but smaller scale model focused solely on the area immediately around the mine site, including Ga’an Canyon.

The attached figure is reproduced from WSP’s July 17, 2020 Memo, “Additional Mine-Site Groundwater Model Output.” This figure summarizes the calibration performance of the groundwater computer model. The figure shows that in different areas, the model’s predictions deviate from actual measured groundwater heads by as much as 200 feet. In some parts of the modeling domain the model underpredicts actual groundwater levels and in other parts, it overpredicts.

Entries 47-50 on the attached figure show calibration results for DHRES-14, the only deep monitoring well east of Ga’an Canyon. Depending on depth, the model overpredicts water levels by between 100 and 200 feet. For monitoring wells in the Apache Leap Tuff (the Apache Leap Tuff Aquifer is important because—among other reasons—its groundwater has been shown to support GDEs in and around Ga’an Canyon) the maximum residual was 54 feet and the mean deviation between predicted water level and actual water level was -14 ft, indicating that the model consistently overestimates heads across the Apache Leap Tuff (WSP, February 2019, Resolution Copper Groundwater Flow Model Report, pp. 29-30). TNF’s response to calibration criticisms is essentially that this is the best one can do for a complex modeling project. We do not dispute that it is a great technical challenge to construct a groundwater model of this size and complexity, but “best we can do” is not an adequate answer if the calibration issues render the model unreliable for its intended purpose.

Considering that the EIS specifies that a change of 10 feet in the groundwater elevation qualifies as an impact to GDEs, it is problematic for the groundwater model to contain errors of 200 feet or more in the vicinity of GDEs. There is a concept in science of signal to noise ratios: if a measurement technique has too much error or uncertainty (i.e., “noise”) then it compromises the accuracy of the intended measurement (i.e., “the signal”). If a radio transmission has just a small amount of static, we can still understand the broadcast but if there is too much static (i.e., noise) then we cannot understand the broadcast and the ability to transmit information is compromised. The groundwater modeling in this EIS is a situation in which the noise (calibration residuals) appears to be overwhelming the signal (accurate predictions of groundwater changes due to mine dewatering and assessment of impacts to GDEs).

TNF and RCM also reply that relative changes in predicted water levels are still accurate even if absolute predictions are poor. This is only true if the model is truly capturing the interplay between the physical processes and material properties that combine to control groundwater dynamics. The fact that the model consistently overpredicts water levels in the Apache Leap Tuff is just one example suggesting that the model may be unable to simulate conditions (such as mine dewatering) that are contributing to groundwater declines, thus is unreliable as a predictive tool.

In this instance, the Forest Service is not meeting its obligation under 40 CFR §1502.24, because it is relying on a scientific method (groundwater modeling) that is not capable of accurately predicting hydrogeological impacts for this complex project. TNF is giving the public a false sense that it understands the groundwater impacts from this project at the scale of individual GDEs when, in reality, the uncertainties in the groundwater modeling are often too large for the modeling results to be considered reliable at that scale.

Conclusion

Thank you for the opportunity to participate in the Working Groups which advised TNF on water-related components of the Environmental Impact Statement for the Resolution Copper Project and Land Exchange and for accepting these dissenting comments on the findings and conclusions of the Water Resources Working Group. The Tribe wishes to reiterate its opinion that the EIS should not be finalized without an opportunity for further public comment, thus we respectfully request that TNF issue a Supplemental Draft EIS at this time, rather than the Final EIS.

Sincerely yours,
L. EVERETT & ASSOCIATES, LLC

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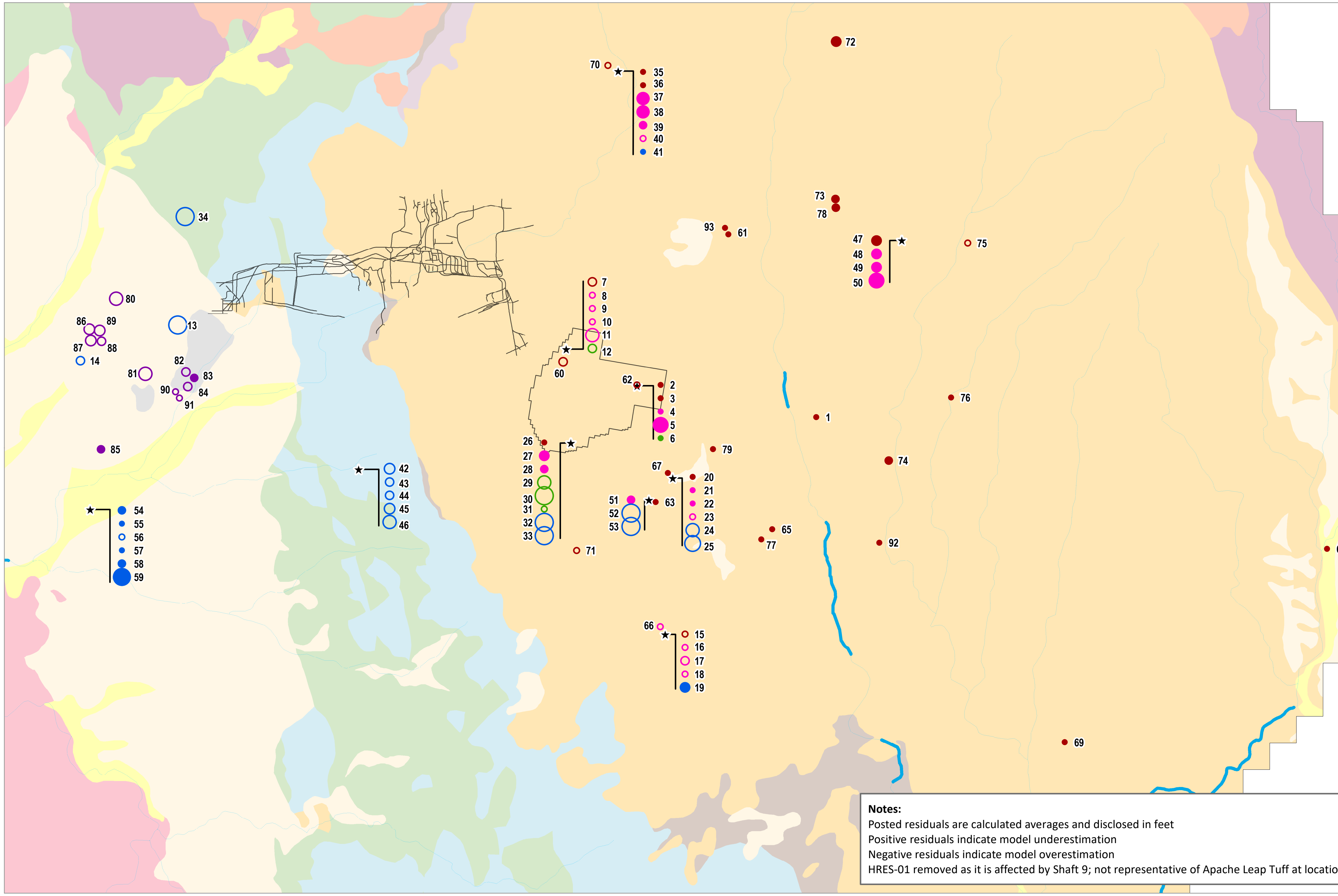
A. B. Ritchie, Attorney General, San Carlos Apache Tribe



ID	Target	Avg Res [ft]	ID	Target	Avg Res [ft]
1	A-06	-42	47	DHRES-14_1071	-103
2	DHRES-01_973	0	48	DHRES-14_888	-122
3	DHRES-01_772	-19	49	DHRES-14_822	-125
4	DHRES-01_683	-30	50	DHRES-14_WL	-228
5	DHRES-01_374	-214	51	DHRES-15_710	-87
6	DHRES-01_WL	-28	52	DHRES-15_398	418
7	DHRES-02_915	52	53	DHRES-15_355	303
8	DHRES-02_666	16	54	DHRES-16_743	-75
9	DHRES-02_608	48	55	DHRES-16_577	-3
10	DHRES-02_458	39	56	DHRES-16_535	4
11	DHRES-02_319	160	57	DHRES-16_287	-1
12	DHRES-02_WL	77	58	DHRES-16_-157	-78
13	DHRES-04_WL	300	59	DHRES-16_-387	-320
14	DHRES-05B_WL	66	60	HRES-02	51
15	DHRES-06_1152	22	61	HRES-03	-17
16	DHRES-06_1022	17	62	HRES-04	11
17	DHRES-06_994	74	63	HRES-05	-18
18	DHRES-06_928	31	64	HRES-06	-6
19	DHRES-06_WL	-118	65	HRES-07	-34
20	DHRES-07_920	-35	66	HRES-08	44
21	DHRES-07_800	-14	67	HRES-09	-15
22	DHRES-07_374	-20	68	HRES-10	-15
23	DHRES-07_169	20	69	HRES-11	-10
24	DHRES-07_95	171	70	HRES-12	29
25	DHRES-07_-108	234	71	HRES-13	25
26	DHRES-08_980	-15	72	HRES-14	-131
27	DHRES-08_792	-127	73	HRES-15	-97
28	DHRES-08_512	-52	74	HRES-16	-58
29	DHRES-08_406	193	75	HRES-17	45
30	DHRES-08_196	416	76	HRES-18	-6
31	DHRES-08_-231	8	77	HRES-19	-40
32	DHRES-08_-580	282	78	HRES-20	-96
33	DHRES-08_-657	300	79	HRES-21	-26
34	DHRES-09_WL	457	80	MCC-1	192
35	DHRES-11_967	-49	81	MCC-2	163
36	DHRES-11_705	-1	82	MCC-3A	69
37	DHRES-11_565	-159	83	MCC-3B	-68
38	DHRES-11_457	-196	84	MCC-3C	77
39	DHRES-11_320	-70	85	MCC-4	-74
40	DHRES-11_214	9	86	MCC-6A	113
41	DHRES-11_WL	-49	87	MCC-6B	146
42	DHRES-13_846	131	88	MCC-6C	91
43	DHRES-13_788	73	89	MCC-6D	106
44	DHRES-13_730	93	90	MCC-9	24
45	DHRES-13_649	111	91	MCC-9A	23
46	DHRES-13_WL	181	92	MJ-11	-26
			93	OakFlatWell	-25

N

0 0.25 0.5 1 1.5 2 Miles

1:50,000

Coordinate System: NAD83 / Arizona Central (ft)

Target Unit
- Apache Leap Tuff
- Whitetail Conglomerate
- West Plant Site
- Graben (KVS)
- Deep GW System

Average Residual

Over-estimated	Under-estimated
0 - 50 ft	0 - 50 ft
50 - 100 ft	50 - 100 ft
100 - 150 ft	100 - 150 ft
150 - 200 ft	150 - 200 ft
200 - 250 ft	200 - 250 ft
> 250 ft	> 250 ft

★ Multi-level Target

\## Target ID

Model Calibration - Average Head Residuals

PROJECT:	NEPA Groundwater Model Support	FIGURE #:	1
CLIENT:	Resolution Copper	PROJECT #:	31400968.002
DRAWN: CP	CHECKED: GM	DATE:	July 2020

Document Path: D:\Resolution\Residual Map\Resolution_CalibrationHeadResiduals.mxd