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November 2017

Resolution Copper Project and Land Exchange Environmental Impact Statement

DRAFT Alternatives Evaluation Report APPENDICES

Tonto National Forest

APPENDIX A

Summary of Issues Identified Through Scoping Process

(Resolution Copper Project and Land Exchange Environmental Impact Statement FINAL Summary of Issues Identified Through Scoping Process, without Appendices)

United States Department of Agriculture

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Resolution Copper Project and Land Exchange Environmental Impact Statement

FINAL Summary of Issues Identified Through Scoping Process

Tonto National Forest

FINAL
Summary of Issues Identified Through Scoping Process

Resolution Copper Project and Land Exchange EIS

Prepared for

U.S. Forest Service – Tonto National Forest

Prepared by

SWCA Environmental Consultants

November 2017

FINAL
SUMMARY OF ISSUES IDENTIFIED THROUGH SCOPING PROCESS

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1.0 INTRODUCTION

1.1 Background

The Tonto National Forest (TNF), an administrative unit of the U.S. Forest Service (Forest Service), is completing an environmental impact statement (EIS) to evaluate the Resolution Copper Project and Land Exchange proposal. The project is located in the Globe and Mesa Ranger Districts, Tonto National Forest, Arizona. The TNF is evaluating the proposed action at this time to comply with its statutory and regulatory obligations to respond to a proposed plan of operations submitted by Resolution Copper Mining, LLC (Resolution Copper), and to comply with Section 3003 of the Carl Levin and Howard P. 'Buck' McKeon National Defense Authorization Act for Fiscal Year 2015 (NDAA).

The need for this project is to comply with the regulations of the Forest Service that govern the use of surface resources in conjunction with mining operations on National Forest System (NFS) lands as set forth under 36 Code of Federal Regulations (CFR) 228; and to comply with Section 3003 of the NDAA.

The purpose of this project is to analyze the proposed action as required by the regulations at 36 CFR 228.5(a) and Section 3003 of the NDAA, including:

- To facilitate the orderly exploration, development, and production of mineral resources on NFS lands open to these activities.
- To respond to the proposed "General Plan of Operations" (GPO) submitted by Resolution Copper, which would govern surface disturbance on NFS lands from mining operations that are reasonably incident to extraction, transportation, and processing of copper and molybdenum.
- To exchange lands between Resolution Copper and the United States as directed by Section 3003 of the NDAA.
- To ensure that the selected alternative would comply with other applicable Federal and state laws and regulations;
- To ensure that the selected alternative, where feasible, would minimize adverse environmental impacts on NFS surface resources; and
- To ensure that measures would be included that provide for reclamation of the surface disturbance.

The TNF is evaluating the proposed action at this time in order to comply with its statutory obligations to respond to Resolution Copper's preliminary GPO in a timely manner. An amendment to the "Tonto National Forest Land and Resource Management Plan" (forest plan) (1985, as amended) may be required.

The proposed action is to approve the proposed GPO as submitted by Resolution Copper[1] and to complete the land exchange as directed by Congress under Section 3003 of the NDAA. As proposed in the GPO, the Resolution Copper mine would affect Federal, state, and private lands. The proposed action by the Forest Service would only approve mining operations on NFS lands, because the Forest Service does not have jurisdiction to regulate mining operations that occur on private or state land. However, the EIS will consider and disclose environmental effects that would occur on Federal, private, or state lands associated with the proposed mine and the land exchange. Connected actions related to the GPO and amendment of the forest plan will also be analyzed. Impacts of reasonably foreseeable actions in the project area will be

[1] The GPO to be analyzed through the National Environmental Policy Act (NEPA) analysis, with corrections and amendments, is dated May 2016.

considered in combination with the impacts of the project to estimate the potential cumulative impacts of project implementation.

Substantial mining activities described in the GPO would affect a 2,422-acre parcel of land known as the Oak Flat Parcel. Section 3003 of the NDAA directs the conveyance of the Oak Flat Parcel to Resolution Copper. In exchange for the Oak Flat Parcel, Resolution Copper would transfer eight parcels located throughout Arizona, totaling 5,344 acres, to the United States. The Forest Service will not have jurisdiction to regulate mining activities on the Oak Flat Parcel, which is to be conveyed to Resolution Copper, because by law (i.e., the NDAA) it will be private land. The Forest Service will need to approve a plan of operations only for related operations that are proposed on NFS land outside the Oak Flat Parcel.

1.2 Scoping and Issue Identification

This document summarizes relevant issues for analysis that were identified during the scoping process for the project. The purpose of the scoping process is to provide agencies, members of the public, and members of the internal interdisciplinary (ID) team with an opportunity to provide input on the scope of the proposed project and analysis of relevant issues in the EIS. The 120-day public scoping period for the Resolution Copper Project and Land Exchange EIS began on March 18, 2016, with publication in the *Federal Register* of a Notice of Intent to prepare an EIS, and the scoping period ended on July 18, 2016. The Forest Service announced the EIS project and advertised and held five public scoping meetings during the scoping period. The comments received during the public scoping period, input received from the Forest Service ID team and SWCA Environmental Consultants (SWCA) supporting specialists, and input received from cooperating agencies form the raw material from which the concise issue statements in Section 4.0 of this report were distilled.

1.3 Document Organization

This document contains a summary of the EIS issue development process, including:

- Summary of the purpose and goal for identification of relevant issues for detailed analysis;
- Process for developing the list of relevant issues from scoping comments; and
- Concise issue statements, organized by resource.

2.0 ISSUE IDENTIFICATION

The Council on Environmental Quality (CEQ) regulations have specific direction for issues in EISs. Agencies shall determine the scope and the significant issues to be analyzed in depth in the EIS (40 CFR 1501.8(a)(2)), and identify and eliminate from detailed study the issues that are not significant or that have been covered by prior environmental review (40 CFR 1506.3), narrowing the discussion of these issues in the statement to a brief presentation of why they will not have a significant effect on the human environment or providing a reference to their coverage elsewhere (40 CFR 1501.7(a)(3)).

Issues serve to highlight effects or unintended consequences that may occur from the proposed action and alternatives, giving opportunities during the analysis to reduce adverse effects and compare trade-offs for the decision-maker and public to understand. Issues help set the scope of the actions, alternatives, and effects to consider in our analysis (Forest Service Handbook 1909.15.12.4).

Comments from the tribes, public, and other agencies submitted during the scoping period were used to formulate issues concerning the proposed action. An issue is a point of dispute or disagreement with the proposed action based on some anticipated environmental effect. The ID team separated the issues into two groups: significant and nonsignificant. Significant issues were defined as those that would be directly or indirectly caused by implementing the proposed action. Nonsignificant issues were identified as those:

- Outside the scope of the proposed action;
- Already decided by law, regulation, policy, the forest plan, or other higher level decision;
- Irrelevant to the decision to be made; or
- Conjectural and not supported by scientific or factual evidence.

Section 4.0 of this document summarizes what issues were heard and how they will be addressed in the environmental analysis process.

3.0 ISSUE DEVELOPMENT PROCESS

Scoping for the Resolution Copper Project and Land Exchange EIS consisted of gathering comments at public meetings; through a public comment period; through internal Forest Service ID team and supporting SWCA specialist scoping; and through cooperating agency scoping. This information is all described in the "Resolution Copper Project and Land Exchange Environmental Impact Statement Scoping Report," dated March 2017. Comments from each of these sources were considered in the issue development process, which consisted of the following steps:

1. The scoping report summarizes the comments from the sources noted. It is important to note that every comment received during each scoping process step was individually reviewed during preparation of these scoping memoranda. As part of the issue development process, each source listed above was reviewed, and summary statements were brought forward for consideration as a potential relevant issue. Periodic checks against the original comments[2] that are summarized in the scoping report were conducted as needed to ensure the validity of the summaries.
2. Comments were processed using a flow chart as a guide to help determine whether a specific comment summary: (a) raised a potentially significant issue; (b) offered suggestions for analysis; (c) recommended potential alternatives or components of alternatives; (d) requested specific types of mitigation and/or monitoring; (e) cited reasonably foreseeable actions; (f) requested clarifications to the GPO; or (g) met none of these criteria and was dismissed from further consideration. See Appendix A for the flow chart that was developed to guide this process.
3. Comments meeting (a) through (g) above were combined into subject lists. The list of potential significant issues (item a) was again reviewed, combined into like topics, and further refined into issue statements. These synthesized issue statements are presented in Section 4.0 of this document. The comments placed in categories (b) through (f) may not constitute significant issues, but they will be considered in the EIS process in a variety of ways to help guide the analysis of relevant issues. For instance, those comments in category (b) may be used to help develop analysis techniques, while those in category (d) may be used to help develop mitigation strategies. See Appendices A through F of this document for further detail. Appendix G identifies those issues that were dismissed from detailed analysis in the EIS because they addressed topics that were determined to be (1) outside the scope of the proposed action; (2) already decided by law, regulation, forest plan, or other higher level decision; (3) irrelevant to the decision to be made; or (4) conjectural and not supported by scientific or factual evidence.

[2] The full database of public scoping comments was made available to the EIS team on the project SharePoint site, for consideration during the internal scoping and issues development processes.

The goals of the issue development process are to ensure that every comment is considered, identify the concerns raised by respondents, represent the breadth and depth of the public's viewpoints and concerns as fairly as possible, and present those concerns in a way that facilitates the Forest Service's consideration of comments in the EIS process. It is important to note that the content analysis process is not and should not be considered a vote. All comments were treated evenly and were not weighted by number, organizational affiliation, "status" of the commenter, or other factors. Emphasis was on the content of a comment, rather than on who wrote it or the number of submitters who agreed with it.

3.1 Public Concern Statement Report

It is important to note that it is not the purpose of this issues report to include every comment, verbatim, that was made available to the TNF during scoping. Although Appendices B through G contain some verbatim comments that concisely summarize a concern, many of the comments in these appendices are restated or consolidated. Further, Appendices B through G do not contain the most critical comments; the most critical comments are those from category (a) described above, which were used to develop the issue statements.

A separate process has been conducted that allows each individual comment to be linked to the issue statements in this issues report, or alternatively to document a rationale for why a comment does not link to an issue statement.[3] Public concern statements are succinct statements that summarize the public's viewpoints and rationales for concerns. A total of 6,948 unique comments was identified from the 133,653 submittals received during scoping. These unique comments were then assigned to one of 474 public concern statements. Each of these public concern statements was then linked to one of the 12 issue statements presented in this issues report, or the rationale was documented for why that comment did not link to an issue statement. The public concern statement document can be used by a commenter to tell how the commenter's submittal (using unique letter numbers and comment numbers assigned during the scoping comment analysis) was addressed by the TNF in developing this issues report.

4.0 LIST OF RELEVANT ISSUES TO BE CONSIDERED FOR DETAILED ANALYSIS IN THE EIS

The issues considered relevant for detailed analysis in the EIS are listed below. Each relevant issue includes a cause-and-effect statement that relates the actions under consideration to the expected effects or unintended consequences that may occur from the proposed action and alternatives, thereby providing opportunities during the analysis to identify means to reduce adverse effects. Each identified issue also presents a summary of specific factors, such as readily quantifiable metrics or other indicators of change, which may be used to compare anticipated effects under different alternatives and management scenarios.

The detailed analysis contained in the EIS for each resource will focus on these specific factors or indicators and will allow for a concise comparison of impacts. These indicators or factors may be quantitative or qualitative, but each provides a specific point of comparison either between different alternatives, or with established regulatory thresholds. For example, air quality could include the factor "Compliance with National Ambient Air Quality Standards (NAAQS) at the perimeter fence line," which would allow both a quantitative comparison of the predicted air impacts for a given alternative with a regulatory standard and a quantitative comparison of the air quality impacts between various alternatives. These factors will be developed further by the resource specialists and included in the final version of this report.

[3] See "Public Concern Statements," May 2017.

4.1 Issue 1: Impacts to Tribal Values and Concerns

4.1.1 Issue 1A: Disturbance to Tribal Values and Practices from Combined Resource Disturbance

Throughout scoping and the tribal consultation process, tribes voiced concern about the impacts to tribal values that would result from the project's adverse effects on a wide range of resources in the natural and human environments. Resources valued by tribal communities include physical resources like groundwater and surface water, air, plants and animal life, landscapes, and geological features, as well as intangible resources such as sense of place and solitude. As addressed in various other issue statements, specific project impacts concerning tribes include the following:

- Groundwater and surface water availability and quality
- Drought and climate change
- Air pollution
- Habitat loss and changes in vegetation communities
- Landscape and geological alterations
- Destruction of culturally significant sites and resources
- Loss of access to culturally significant areas
- Loss of recreation areas
- Risk of spills, leaks, and environmental contamination
- Noise and light pollution
- Mine-related traffic and congestion
- Health and "quality of life" impacts

These resource impacts, individually and cumulatively, would affect the integrity of tribally valued resources and thereby adversely impact the tribal communities that rely on these resources for cultural, traditional, and spiritual practices. Alterations to the natural setting of resources in the project area would diminish their value to tribal communities and may be perceived as causing spiritual harm to the earth and people.

ISSUE 1A FACTOR FOR ALTERNATIVE COMPARISON

1. Qualitative assessment of how cumulative resource disturbance impacts tribal values and spiritual practices.

4.1.2 Issue 1B: Impacts to Tribal Valued Resources at Oak Flat and Apache Leap

Some members of the San Carlos Apache Tribe and other tribes in the region consider the Oak Flat and Apache Leap areas to be sacred lands, and the Forest Service has agreed with this position. To those who hold these beliefs, these areas are esteemed as places where tribal members could come together to mark important life events; as places for the traditional gathering of acorns and medicinal plants; as locations for communion with nature, the Creator spirit, and the souls of departed forebears; and as settings of historical importance as locations of past confrontations between the Apache and European-American settlers and soldiers. Construction and operation of the proposed mine would profoundly and permanently alter these sacred areas. Effects on cultural resources would include short-term impacts during construction and operation, as well as long-term impacts during the reclamation and post-closure phases.

ISSUE 1B FACTORS FOR ALTERNATIVE COMPARISON

1. Quantitative assessment of number of sacred springs or other discrete sacred sites impacted.
2. Qualitative assessment of the impacts on Native Americans of the desecration of land, springs, burials, and sacred sites.
3. Quantitative assessment of acres of traditional resource collection areas impacted.

4.2 Issue 2: Impacts to Socioeconomics

Construction and ongoing operation of the mine could have substantial economic and "quality of life" effects on the town of Superior, on surrounding communities (including tribal communities), and on this region of Arizona in general. Effects on socioeconomics would include short-term impacts during construction and operation, as well as long-term impacts during the reclamation and post-closure phases.

4.2.1 Issue 2A: Impacts to Municipal Infrastructure

A large influx to the Superior area of mine employees, construction personnel, and persons and businesses providing products and services to the mine itself as well as to mine workers and their families could lead to increased tax revenues, but also to increased use and "capacity" issues for local schools, hospitals and other medical or emergency service providers, water and sewer systems, electrical and telephone/communications systems, roads, available housing, and other basic local and regional infrastructure.

ISSUE 2A FACTORS FOR ALTERNATIVE COMPARISON

1. Quantitative assessment of change in employment, labor earnings and economic output over time, including direct and indirect effects.
2. Quantitative assessment of change in tax revenues per year over time, including changes to payments in lieu of taxes (PILT).
3. Quantitative assessment of change in demand and cost for local road maintenance over time.
4. Qualitative assessment of change in demand and cost for emergency services over time.
5. Quantitative assessment of change in tourism and recreation revenue over time.

4.2.2 Issue 2B: Impacts to Property Values

Development and operation of the mine and associated facilities has the potential to adversely affect property values in communities across the region—including Queen Valley near the large tailings storage area—and the quality of life of property owners themselves. This could also have the effect of reducing property-based tax revenues to local municipal governments.

ISSUE 2B FACTOR FOR ALTERNATIVE COMPARISON

1. Quantitative assessment of change in property values over time.

4.2.3 Issue 2C: Impacts to Groundwater Availability/Usability

Residents in the general area of the proposed mine rely on water produced by privately owned wells. Dewatering of the underground mine and pumping of groundwater within the Magma Arizona Railroad Company (MARRCO) corridor for the mine water supply could lower groundwater levels in the area and thus reduce water supplies available to various residential, commercial, and agricultural users, as well as public and private water systems. In addition, there exists the potential for groundwater quality impacts to affect local groundwater supplies and thereby adversely affect these same populations.

ISSUE 2C FACTORS FOR ALTERNATIVE COMPARISON

1. Qualitative assessment of effect of reduced groundwater availability on property values.
2. Qualitative assessment of effect of reduced groundwater quality on property values.

4.2.4 Issue 2D: Impacts to Local and Regional Living Standards

The inflow of investment capital, wage income, and increased discretionary spending by mine workers, managers, equipment/service suppliers, and contracted technicians and other specialists in the Superior area and surrounding communities would result in a gradual but substantial increase in overall living standards in the area. It is possible that over time, new housing would be constructed and new restaurants, retail outlets, and service providers would move into the area. Negative economic impacts, such as increased traffic, could offset economic benefits.

ISSUE 2D FACTORS FOR ALTERNATIVE COMPARISON

1. Qualitative assessment of the ability to meet rural landscape expectations as expressed by Federal, state, and local plans.
2. Quantitative assessment of economic effects on amenity-based relocation.
3. Quantitative assessment of economic effects from change in visitor uses of TNF and other public lands.

4.3 Issue 3: Environmental Justice

Economic benefits may not be experienced by all sectors of society equally; historically, minority and low-income communities (including tribal communities) in a given area tend to benefit from large-scale land development and mining projects to a lesser degree than the area as a whole due to differences in education, employment, and economic status. Additionally, adverse environmental or resource impacts may disproportionately affect minority and low-income communities.

4.3.1 Issue 3 Factors for Alternative Comparison

1. Quantitative assessment of economic effects on environmental justice communities and qualitative assessment of whether these effects are disproportionate.
2. Qualitative assessment of disproportionate effects of adverse resource impacts to environmental justice communities.

4.4 Issue 4: Impacts to Cultural Resources

Construction and operation of the Resolution Copper Project would profoundly and permanently alter conditions within the National Register of Historic Places (NRHP)-listed Chí'chil Biłdagoteel (Oak Flat)

Historic District Traditional Cultural Property (TCP) through anticipated large-scale geological subsidence as well as other forms of less-permanent surface disturbance, including new pipelines, power lines, roads, and other facilities to be constructed in support of mine operations. In addition, development of the proposed tailings storage facility near Queen Valley would permanently bury an approximately 3,600-acre area that contains many known (and potentially unknown) prehistoric and historic cultural artifacts.

While cultural resource surveys and archaeological data recovery efforts will be conducted on lands to be directly affected by mine-related activities, it remains likely that some proportion of existing yet currently unidentified prehistoric and historic artifacts and resources would be disturbed or destroyed by mine-related construction and operation, especially within the Oak Flat subsidence zones and the footprint of the tailings storage area. These losses could potentially include human burials within these areas. In addition, disturbance of known or unknown cultural resources is an impact that is important to many tribes, regardless of whether data recovery is undertaken.

4.4.1 Issue 4 Factors for Alternative Comparison

1. Qualitative assessment of the impacts to places of traditional and cultural significance to Native Americans including natural resources.
2. Qualitative assessment of the impacts on other non-tribal communities in the region in terms of impacts on resources, such as historical townsites, cemeteries, mines, ranches, and homesteads.
3. Quantitative assessment of number of NRHP-eligible historic properties, including traditional cultural properties, sacred sites, and other landscape-scale properties, to be buried, destroyed, or damaged.
4. Quantitative assessment of number of NRHP-eligible historic properties expected to be visually impacted.
5. Qualitative assessment of potential for vibrations to damage cultural resources within and adjacent to the project areas.
6. Qualitative assessment of impacts to historic properties including visual impacts.
7. Quantitative assessment of number of impacted prehistoric sites known/likely to have human remains.
8. Quantitative assessment of number of historic sites likely to have human remains.

4.5 Issue 5: Impacts to Public Health and Safety

This issue focuses on various impacts that development, operation and reclamation of the mine could have on public health and safety. Note that this issue is closely related to a variety of other issues, such as water quality (Issue 6), air quality (Issue 8), and transportation (Issue 12). Effects on public health and safety would include short-term impacts during construction and operation, as well as long-term impacts during reclamation and post-closure phases.

4.5.1 Issue 5A: Health Impacts

Concerns have been raised about whether potential dust, emissions, and/or contamination from the mine could affect public health in the local area, including increased cancer rates and impacts to people with preexisting health conditions, the elderly, and children. Specific concerns include airborne heavy metals and asbestiform materials; contamination of water from tailings seepage; operational or inadvertent release of hazardous materials, including fuels, explosives, and processing chemicals, into the environment; the potential for radioactive materials in tailings and/or processing facilities; and the potential for disturbance and mobilization by air or water of soil currently contaminated by historic mining activities.

ISSUE 5A FACTORS FOR ALTERNATIVE COMPARISON

1. Qualitative assessment of public health risk from mine operations and facilities, including potential for exposure to historically contaminated soil.
2. Qualitative assessment of public health risk from geological hazards.
3. Qualitative assessment of public health risk from noise and vibrations.
4. Quantitative assessment of ability to meet air quality standards for human health.

4.5.2 Issue 5B: Safety Concerns Related to Tailings Impoundment

The GPO proposes a tailings dam and impoundment. Should a partial or complete dam failure occur in the future, public safety could be affected in the vicinity and downstream of the tailings facility.

ISSUE 5B FACTORS FOR ALTERNATIVE COMPARISON

1. Qualitative assessment of risk of failure of tailings dam and potential impacts downstream in the event of a failure.
2. Quantitative assessment of seismic stability of tailings impoundment.

4.5.3 Issue 5C: Transportation-Related and General Safety Risks

Vehicle traffic associated with the mine has the potential to increase overall traffic levels and change traffic flows in the local area, which has the potential to lead to an increased risk of vehicle accidents resulting in injury. Mine operations could impact the general safety of both public and employees.

ISSUE 5C FACTORS FOR ALTERNATIVE COMPARISON

1. Quantitative assessment of the potential change in traffic accidents.
2. Quantitative assessment of trip count per day for all hazardous materials and qualitative assessment of potential effects.
3. Qualitative assessment of risks to public health from potential accidents or spills during the transportation of hazardous materials.
4. Qualitative assessment of impacts to local emergency response to accidents or spills on public roadways.

4.5.4 Issue 5D: Risks Related to Subsidence

Concerns were expressed regarding how public safety may be affected by subsidence. This includes physical safety of persons in areas of subsidence and adjacent communities, as well as indirect impacts such as increased risk of wildfire should vegetation in subsidence areas die and result in increased fuel accumulations or through relocation of recreation activities from the area.

ISSUE 5D FACTORS FOR ALTERNATIVE COMPARISON

1. Qualitative assessment of public health risk from geological hazards.
2. Qualitative assessment of increased fire risk due to mine operations and subsidence.

4.6 Issue 6: Impacts to Water Resources

This group of issues relates to the effects to the quality and quantity of water resources during the construction, operation, reclamation, and post-closure phases of the mine project. This includes potential impacts to current and future water available for human use, stock watering, wildlife use and habitat, and riparian areas or groundwater-dependent ecosystems.

4.6.1 Issue 6A: Groundwater Availability

The proposed mine would pump groundwater in the East Salt River basin of the Phoenix Active Management Area (AMA) in order to provide a portion of the mine water supply and would also pump groundwater east of Superior in order to dewater the deep mine workings. Pumping of groundwater changes the groundwater level and flow directions in the aquifer and could affect private and public wells, general groundwater availability in each basin, and human water use (domestic, industrial/commercial, agricultural, drinking, and recreational). Changes in geology caused by mining, and specifically by subsidence, could affect the hydraulic characteristics of aquifers and further affect groundwater availability for human uses, stock watering, or wildlife use and habitat (see Issue 7). Creation of a pit lake in the subsidence area after closure of the mine could alter groundwater level and flow directions in the aquifer and affect groundwater availability.

Groundwater and surface water have a complex interaction. Portions of the watershed will no longer contribute flow downstream due to the tailings facility and the subsidence area; impervious areas; detention, retention, and rerouting of stormwater; and seepage and seepage recovery, which may result in changes to groundwater recharge and near-surface groundwater, which in turn may affect surface waters.

Effects on groundwater availability would include short-term impacts during construction and operation, as well as long-term impacts during the reclamation and post-closure phases.

ISSUE 6A FACTORS FOR ALTERNATIVE COMPARISON

1. Quantitative assessment of direction and magnitude of change in aquifer water level, compared with background conditions.
2. Geographic extent in which water resources may be impacted.
3. Duration of the effect (in years).
4. Comparison of mine water needs and water balance with overall basin water balance, both total volume (acre-feet) and annual rate (acre-feet/year).
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).
6. Qualitative assessment of potential for subsidence to occur as a result of groundwater withdrawal.

4.6.2 Issue 6B: Groundwater Quality

Mining of the ore body and the mixing of fractured rock, water, and air underground has the potential to drive geochemical reactions (acid rock drainage) that could impact groundwater quality in the area of underground mining and the quality of dewatering water exported for use elsewhere. Other groundwater quality changes could also occur underground, including impacts from explosives residue.

Seepage would occur from the tailings facility and could impact groundwater quality and the quality of downstream surface waters fed by groundwater. Water quality concerns in tailings seepage include the potential for process chemicals, asbestiform materials, radioactive materials, and explosives residue to be entrained with the tailings, as well as the potential for sulfate and geochemical reactions (acid rock drainage) to occur in the tailings storage facility and affect seepage water quality. In addition, a tailings spill from the tailings pipeline or complete or partial failure of the tailings dam could result in impacts to downstream groundwater quality.

Creation of a pit lake in the subsidence area after closure of the mine could result in changes to groundwater quality due to geochemical reactions from the exposure of previously undisturbed rock, or due to long-term concentration of contaminants from evaporation.

The storage and use of hazardous materials throughout the project area, the storage and handling of hazardous waste, the storage and handling of process water, the transportation of concentrate by truck and as a slurry, and the transportation of tailings slurry carry a risk for inadvertent spills or release, which could impact groundwater quality. The presence of ore stockpiles on the surface could impact groundwater quality.

Effects on groundwater quality would include short-term impacts during construction and operation, as well as long-term impacts during the reclamation and post-closure phases.

ISSUE 6B FACTORS FOR ALTERNATIVE COMPARISON

1. Quantitative assessment of ability to meet Arizona Aquifer Water Quality Standards at points of compliance designated in the aquifer protection permit.
2. Qualitative assessment of ability to demonstrate best available demonstrated control technology.
3. Quantitative assessment of estimated changes in groundwater quality in situ in area of block caving, including estimated fate and transport.
4. Quantitative assessment of estimated changes in groundwater quality due to seepage from tailings area, including estimated fate and transport.
5. Qualitative assessment of potential for spills or inadvertent release of contaminants to groundwater.

4.6.3 Issue 6C: Surface Water Availability

The proposed mining method would create an area of surface subsidence, which would alter surface water flow patterns and could change the amount of surface water moving downstream in the Queen Creek and Mineral Creek drainages, and through such areas as Boyce Thompson Arboretum. Similarly, stormwater management at the proposed tailings storage facility and other facilities could change the amount of surface water moving downstream in the Queen Creek drainage. Lost surface water would not be available for downstream groundwater recharge, beneficial uses, downstream users, riparian vegetation, or wildlife use or habitat.

Effects on surface water availability would include short-term impacts during construction and operation, as well as long-term impacts during the reclamation and post-closure phases.

ISSUE 6C FACTORS FOR ALTERNATIVE COMPARISON

1. Quantitative assessment of number of stream miles changed from intermittent/perennial flow status to ephemeral flow status as a result of the project.
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.

3. Quantitative assessment of number of stock watering tanks that would be lost to direct disturbance or reductions in surface flow.
4. Quantitative assessment of change in volume, frequency, and magnitude of runoff from the project area.

4.6.4 Issue 6D: Surface Water Quality

Stormwater runoff could interact with hazardous materials, tailings, and ore stockpiles, which could result in contaminants moving downstream. This includes metals or other contaminants resulting from exposure to tailings, stockpiled ore, process chemicals, asbestiform materials, radioactive materials, or explosive residues entrained with the tailings, as well as the potential for sulfate, geochemical reactions (acid rock drainage), or surface salt accumulation to occur in the tailings facility and affect surface water runoff.

Disturbance of the land surface could result in increased sediment in downstream waters and cause aggradation or erosion in downstream channels leading to degradation of riparian habitat or impacts to surface water uses. In addition, a tailings spill or complete or partial failure of the tailings dam could result in impacts to downstream surface water quality, and deposition of windblown dust from the tailings storage facility could impact surface water quality.

Creation of a pit lake in the subsidence area after closure of the mine could result in new surface waters with potential surface water quality concerns due to geochemical reactions from the exposure of previously undisturbed rock, or the potential long-term concentration of contaminants from evaporation.

The storage and use of hazardous materials throughout the project area, the storage and handling of hazardous waste, the treatment and release of wastewater, the storage and handling of process water, the transportation of concentrate by truck and as a slurry, and the transportation of tailings slurry carry a risk for inadvertent spills or release, which could impact surface water quality through changes in chemical or sediment load.

Effects on surface water quality would include short-term impacts during construction and operation, as well as long-term impacts during the reclamation and post-closure phases.

ISSUE 6D FACTORS FOR ALTERNATIVE COMPARISON

1. Quantitative assessment of ability to meet Arizona Surface Water Quality Standards, for the appropriate designated uses.
2. Qualitative assessment of change in geomorphology and characteristics of downstream channels.
3. Quantitative assessment of acres and locations that may be affected by surface water quality impacts and the duration (in years) of those impacts.
4. Quantitative assessment of acres of potentially jurisdictional waters of the U.S. impacted.[4]

4.6.5 Issue 6E: Seeps, Springs, Riparian Areas, and Groundwater-Dependent Ecosystems

The proposed mine would pump groundwater in the Salt River basin in order to provide a portion of the mine water supply, and would also pump groundwater east of Superior in order to dewater the deep mine

[4] Designation of potential waters of the U.S., as defined by the Clean Water Act, is solely at the discretion of the U.S. Army Corps of Engineers (USACE). The delineation of waters of the U.S. approved by the USACE, whether preliminary or approved, will form the basis for this metric.

workings. By changing groundwater levels and flow directions, pumping could impact seeps, springs, perennial or intermittent streams, or riparian areas/groundwater-dependent ecosystems such as Devil's Canyon and upper Queen Creek. Changes in geology caused by mining, and specifically by subsidence, could affect the hydraulic characteristics of aquifers and result in the loss of groundwater that currently supports seeps, springs, perennial or intermittent streams, riparian areas/groundwater-dependent ecosystems, or other sensitive non-riparian vegetation areas such as those occurring on Oak Flat.

Changes in surface runoff and groundwater capture due to the tailings storage facility or the subsidence area could change availability of water to downstream riparian habitat and could change the quality of downstream surface waters.

Changes in groundwater quality or surface water quality could affect the use of seeps, springs, perennial or intermittent streams, and riparian areas/groundwater-dependent ecosystems and could result in harm to riparian vegetation. A tailings spill or complete or partial failure of the tailings dam could result in impacts to seeps, springs, and riparian areas.

Disturbance of the land surface could result in increased sediment in downstream waters, which could impact downstream riparian areas/groundwater-dependent ecosystems and riparian vegetation.

Effects on seeps, springs, and riparian areas/groundwater-dependent ecosystems would include short-term impacts during construction and operation, as well as long-term impacts during the reclamation and post-closure phases.

ISSUE 6E FACTORS FOR ALTERNATIVE COMPARISON

1. Quantitative assessment of acres of riparian areas disturbed, by vegetation classification.
2. Quantitative assessment of number of seeps and springs degraded or lost.
3. Qualitative assessment of change in the function of riparian areas.
4. Qualitative assessment of ability to meet legal and regulatory requirements for riparian areas.[5]

4.6.6 Issue 6F: Floodplains

Placement of the tailings storage facility, pipelines, or other alteration of the landforms within floodplains could change the flood risk, recharge, geomorphology, and runoff characteristics of the watershed. This could impact riparian habitat and the overall functionality of the floodplain. Effects on floodplains would include short-term impacts during construction and operation, as well as long-term impacts during the reclamation and post-closure phases.

ISSUE 6F FACTORS FOR ALTERNATIVE COMPARISON

1. Quantitative assessment of acreage of 100-year floodplains impacted[6] (acreage).
2. Qualitative assessment of impact of floodplain changes to upstream or downstream users or residents.

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[5] This analysis will reflect criteria developed and analyzed by the Forest Service, which may differ from those used by the State of Arizona to make its determination of the ability of the proposed project to meet regulatory requirements under Section 401 of the Clean Water Act. The Forest Service has a responsibility under NEPA to take a hard look at impacts to riparian areas and surface waters and disclose these findings, regardless of any parallel analysis conducted by the State of Arizona.

[6] Because large portions of the analysis area lie within the TNF, 100-year floodplains have not been delineated for most major waterways by the Federal Emergency Management Area (FEMA). This analysis would be based on a reasonable estimate of the extent of 100-year floodplains, in lieu of FEMA-delineated floodplains.

4.7 Issue 7: Impacts to Biological Resources

Large-scale mine development, including anticipated future subsidence at the East Plant (Oak Flat) site, construction and operation of ore processing facilities at the West Plant site, development of the approximately 3,600-acre tailings storage facility near Queen Valley, and various pipeline, power line, conveyor, road, and other physical linkages between these facilities, has the potential to adversely affect local flora and fauna, including through direct injury, harassment, mortality, habitat alteration and loss, reduction in water available to the ecosystem, habitat fragmentation, reproduction, pollination, seed dispersal, and other biological processes.

4.7.1 Issue 7A: Adverse Effects of Dewatering at the East Plant Site or Pumping at the West Plant Site

Dewatering at the underground mine site or other pumping at the West Plant site could adversely affect or eliminate nearby seeps, springs, perennial or intermittent streams, or riparian areas and the vegetation and wildlife these areas support and thereby impact riparian vegetation, aquatic species, birds, and other wildlife in these areas. These areas could include Devil's Canyon, Queen Creek, Mineral Creek, Arnett Creek, and potentially as far south as the Gila River.

Effects on biological resources from dewatering would include short-term impacts during construction and operation, as well as long-term impacts during the reclamation and post-closure phases.

ISSUE 7A FACTOR FOR ALTERNATIVE COMPARISON

1. Qualitative assessment of effects on riparian habitat and species due to changes in flow to Queen Creek, Devil's Canyon, Arnett Creek, Mineral Creek, or other perennial or intermittent waters. [This assessment will be based on the results of the Issue 6 Analysis Factors.]

4.7.2 Issue 7B: Loss or Harassment of Individual Plants and Animals[7]

Development of the project would result in loss of individual plants and animals, particularly through long-term subsidence in the Oak Flat Parcel and burial of existing Sonoran Desert habitat under the proposed tailings storage facility. Further losses would be expected to occur through ground disturbance necessary for the construction of pipelines, power lines, roads, and other ancillary facilities, as well as through increased mine-related vehicle–wildlife interactions. Subsidence at Oak Flat presents a particular risk to the federally endangered Arizona hedgehog cactus (*Echinocereus coccineus* var. *arizonicus*), which occur primarily on the TNF in certain microclimates within a relatively narrow elevational range (3,300 to 5,800 feet), such as in the higher rocky outcroppings east of the town of Superior. Short of loss, harassment of individuals could occur through artificial night lighting, noise and vibrations, changes in surface water or groundwater quality or availability, exposure to process ponds or canals, exposure to a potential pit lake, erosion, loss of vegetation or open water habitat, and the spread of pathogens or noxious or invasive weeds. This includes potential impacts to migratory birds and Important Bird Areas.

Effects on biological resources would include short-term impacts during construction and operation, as well as long-term impacts during the reclamation and post-closure phases from habitat loss.

ISSUE 7B FACTORS FOR ALTERNATIVE COMPARISON

1. Quantitative assessment of acres of suitable habitat disturbed for each special-status species, including impacts to designated and proposed critical habitat.

[7] Prior to conducting this analysis, the Forest Service will determine the appropriate species lists to evaluate in the DEIS.

2. Qualitative assessment of the potential to affect the population viability of any species.
    - Qualitative assessment of mortality of various animal species resulting from the increased volume of traffic related to mine operations.
3. Qualitative assessment of the potential for disturbance to create conditions conducive for invasive species.
4. Qualitative assessment of effects on wildlife behavior from noise, vibrations, and light.

4.7.3 Issue 7C: Habitat Fragmentation and Loss

Development of the mine, ore processing facilities, and tailings storage facility, as well as construction and operation of related linear support facilities such as roads, pipelines, fencing, and power lines, could further contribute to fragmentation of existing vegetative communities and wildlife forage, mating, protective cover, nesting/denning, and travel corridors in the Superior area. Dewatering effects could lead to habitat fragmentation and loss, as well.

Effects on biological resources from habitat fragmentation would include short-term impacts during construction and operation, as well as long-term impacts during the reclamation and post-closure phases.

ISSUE 7C FACTORS FOR ALTERNATIVE COMPARISON

1. Qualitative assessment of the change in movement corridors and connectivity between wildlife habitats.
2. Quantitative assessment of acres by type of terrestrial and aquatic habitat lost, altered, or indirectly impacted.
3. Qualitative assessment of impacts to aquatic habitats and surface water that support wildlife and plants such as stock tanks, seeps, and springs.
4. Qualitative assessment of how changes in the function of riparian areas could impact wildlife habitat.

4.8 Issue 8: Impacts to Air Quality

Changes in air quality could potentially occur from the mine. Construction, mining, and reclamation activities at the mine and along transportation and utility corridors would increase dust, airborne chemicals, and transportation-related (mobile) emissions in the area. The Clean Air Act (CAA) and other laws, regulations, policies, and plans set thresholds for air quality, including Class I airsheds, and the GPO has the potential to exceed one or more of these thresholds. Long-term trends in precipitation and temperature have the potential to affect many resources.

4.8.1 Issue 8 Factors for Alternative Comparison

1. Quantitative estimate of particulate emissions (particulate matter less than or equal to 2.5 microns in diameter ($PM_{2.5}$) and particulate matter less than or equal to 10 microns in diameter (PM_{10})), compared with background (pounds per hour [for 24-hour impacts] and tons per year [tons/year]) and expected seasonal dust patterns and impact area.
2. Volatile organic compound (VOC) and hazardous air pollutant (HAP) emissions and emission rates (tons/year).
3. Quantitative assessment of total mine emissions (lb/hour and tons/year), compared with the current total regional emissions (tons/year), including criteria and other pollutants (carbon

monoxide, lead, sulfur dioxide, nitrogen dioxide, particulate matter, and carbon dioxide). Include tabulation of greenhouse gas emissions of CO_2, CH_4, and N_2O. Depict location of sources for considered alternatives.

4. Quantitative assessment of the ability to meet air quality standards, include impacts based on representative background air quality levels and analyze cumulative emissions and impacts.
5. Quantitative assessment of the off-site impacts of hazardous or toxic air pollutants compared to health-based levels.
6. Quantitative assessment of the ability to meet NAAQS for criteria pollutants (carbon monoxide, lead, sulfur dioxide, nitrogen dioxide, ozone, and particulate matter), as modeled at the perimeter fence line of the mine facility, taking into account all mobile and stationary emission sources. Include spatial depictions of impacts for the area around the mine and alternative sites.[8]
7. Quantitative assessment of the impacts at Class I airsheds, specifically, changes to air quality–related values (AQRVs) of visibility, ozone, and deposition of sulfur dioxide and nitrogen oxides, as modeled at perimeter of Class I airsheds, and compared with current deposition rates and critical loads.[9]
8. Assessment using best available science of long-term trends in precipitation and temperature that may affect resources.

4.9 Issue 9: Impacts to Long-term Land Stability

This group of issues relates to the long-term stability of land, including soils, geology, and the ability for lands to be reclaimed after cessation of mining operations.

4.9.1 Issue 9A: Subsidence

The block cave mining proposed in the GPO has the potential to cause surface subsidence. Additionally, concerns have been expressed that groundwater pumping to supply mine operations could lower groundwater and result in subsidence of the land surface near the wells. Surface resources and uses could be impacted by subsidence where it occurs.

Development and operations of the mine have the potential to increase seismic activity in the area, which in turn can impact nearby structures and uses of the area.

Concerns have been expressed about whether the mine would directly or indirectly impact caves and karst resources.

ISSUE 9A FACTORS FOR ALTERNATIVE COMPARISON

1. Quantitative assessment of the extent, amount, and timing of land subsidence, with estimates of uncertainty.
2. Qualitative assessment of the potential of subsidence to impact caves, karst resources, and/or mine shafts and adits in the project area that are used as bat roosts.

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[8] This analysis will reflect criteria developed and analyzed by the Forest Service, which may differ from those used by Pinal County to make its determination of the ability of the proposed project to meet regulatory requirements under the CAA. The Forest Service has a responsibility under NEPA to take a hard look at impacts to air quality and disclose these findings, regardless of any parallel analysis conducted by Pinal County.

[9] See Federal Land Managers' Air Quality Related Values Work Group (FLAG) Phase I Report—Revised (2010) Natural Resource Report NPS/NRPC/NRR—2010/232.

3. Qualitative assessment of the impact of the project to seismic activity.

4.9.2 Issue 9B: Impact to Existing Landscape Productivity, Stability, and Function

Ground disturbance from clearing vegetation, grading, and stockpiling soils, and waste storage (e.g., landfills, tire disposal) has the potential to compact soils, accelerate erosion, and reduce soil productivity. The tailings and waste rock facilities could be unstable over time, and reclamation may not adequately result in a stable, revegetated landscape. This could affect soil productivity and future uses of the area. The geochemical composition of tailings and waste rock facilities may not support native vegetation. Soils are nonrenewable resources. Damage, disturbance, contamination, or removal of the soil resource may result in a loss of soil productivity, physical structure, and ecological function across the proposed mine site and across downgradient lands. The mining area could potentially act as a barrier to sourcing and supporting natural downslope transportation of geological material, water, and nutrients through alluvial, aeolian, and fluvial processes.

ISSUE 9B FACTORS FOR ALTERNATIVE COMPARISON

1. Qualitative assessment of long-term stability of tailings and other mine facilities, including expected results of reclamation.
2. Quantitative level of disturbance leading to lost soil productivity (acres).
3. Qualitative and quantitative assessment of the potential for revegetation of tailings and other mine facilities, using data (where available and if equivalent) from other mine site revegetation efforts conducted in central and southern Arizona.
4. Qualitative evaluation of alteration of soil productivity and soil development.
5. Quantitative assessment of changes in sediment delivery to Queen Creek, Arnett Creek, or other key streams and washes (tons/year), compared with background sediment loading.

4.10 Issue 10: Impacts to Recreation Resources

Once the proposed mine is approved and the land exchange specified in the NDAA is completed, nearly all of the Oak Flat site will be removed from NFS lands and become the private property of Resolution Copper. Most of the area will subsequently be fenced off and no longer accessible to hikers, rock climbing enthusiasts, cyclists, equestrians, campers, hunters, and other recreational users of these former public lands, and the Oak Flat Campground will be lost. In addition, although it would occur in established phases over many years, the entire proposed tailings storage area will ultimately be closed to all recreational uses, resulting in displacement of recreation to other locations. Changes in water availability could affect recreational experiences. The fencing of areas with existing Forest Service roads and trails may also reduce access to adjacent sites, such as the Apache Leap Special Management Area. Finally, mine-related linear facilities such as pipelines, power lines, and development within the MARRCO corridor could sever connectivity of existing roads and trails on TNF lands and further limit recreational access. Mine operations could affect the trail user experience and introduce safety concerns.

Effects on recreation would include short-term impacts during construction and operation, as well as long-term impacts during the reclamation and post-closure phases.

4.10.1 Issue 10 Factors for Alternative Comparison

1. Quantitative assessment of acres that would no longer meet current forest plan Recreation Opportunity Spectrum designations.

2. Quantitative assessment of acres of the TNF that would be unavailable for recreational use, for various phases of mine life and reclamation.
3. Quantitative assessment of change in visitor uses.
4. Quantitative assessment of miles of NFS roads lost, for various phases of mine life and reclamation.
5. Qualitative assessment of potential for noise to reach recreation areas (i.e., audio "footprint").
6. Qualitative assessment of impacts on solitude in designated wilderness and other backcountry areas.
7. Quantitative assessment of hunter-days lost (quantity based on number of permits available and number of days in season).
8. Quantitative assessment of miles of Arizona National Scenic Trail, NFS trails, or other known trails requiring relocation, and qualitative assessment of user trail experience.
9. Qualitative assessment of increased pressure on other areas, including roads and trails/trailheads, from displacement and relocation of recreational use as a result of mine facilities.

4.11 Issue 11: Impacts to Scenic Resources

Construction and operation of the Resolution Copper Project would, as a result of anticipated geological subsidence at the East Plant site, permanently alter the topography and scenic character of the Oak Flat area. Development of the proposed tailings storage facility near Queen Valley would ultimately result in a new and permanent landform approximately 3,600 acres in area and several hundred feet higher than the current landscape. It would thus would forever alter the existing viewshed for residents of that community, for users of the Arizona National Scenic Trail and, to a lesser extent, for persons traveling along U.S. Route (U.S.) 60 in the area of Gonzalez Pass to the west of the town of Superior. New utility lines and construction of other mine facilities and infrastructure at the West Plant Site, East Plant Site, and filter/loadout facility could also alter existing viewsheds.

Effects on scenic resources would include short-term impacts during construction and operation, as well as long-term impacts during the reclamation and post-closure phases.

4.11.1 Issue 11 Factors for Alternative Comparison

1. Quantitative assessment of acres that would no longer meet current forest plan Scenic Integrity Objective designations.
2. Qualitative assessment/degree of change in landscape character from key analysis viewpoints, for various phases of mine life and reclamation.
3. Quantitative assessment of miles of U.S. 60, State Route (SR) 79 or SR 177 with direct line-of-sight views of the project area.
4. Quantitative assessment of miles of project area visibility along concern level 1 and 2 roads and trails.
5. Qualitative assessment of increase in sky brightness resulting from mine facility and vehicle lighting.

4.12 Issue 12: Impacts to Transportation/Access

Transportation of personnel, equipment, supplies, and materials related to mine development, operation, and reclamation has the potential to increase traffic. Increased mine-related traffic on local roads and highways has the potential to impact local and regional traffic patterns, level of service, and planned transportation projects and users of NFS roads.

Increased rail traffic along the MARRCO corridor associated with the mine has the potential to impact traffic patterns in the local area.

Mine development also has the potential to permanently alter, add, or decommission NFS roads or temporarily restrict access to NFS roads and lands, which could impact forest users and permittees. Effects on transportation/access would include short-term impacts during construction and operation, as well as long-term impacts during the reclamation and post-closure phases.

4.12.1 Issue 12 Factors for Alternative Comparison

1. Quantitative assessment of change in type and pattern of traffic by road and vehicle type.
2. Quantitative assessment of the change in level of service on potential highway routes and local roads.
3. Quantitative assessment of roads decommissioned by the mine and roads lost to motorized access.

4.13 Issue 13: Impacts Caused by Mine-Related Noise and Vibrations

Development, operation, and reclamation of the mine would result in an increase in noise and vibrations in the immediate vicinity of mine facilities. Activities that could increase noise and vibrations include blasting, underground conveyance of ore, processing operations, operations at the filter/loadout facility, and episodic land subsidence events. Increases in traffic associated with worker commuting, material delivery, and mine product shipment could also contribute to an overall increase in noise on area roads and highways.

4.13.1 Issue 13 Factors for Alternative Comparison

1. Qualitative assessment of the potential for noise to reach recreation areas.
2. Qualitative assessment of the ability of alternatives to meet rural landscape expectations.
3. Quantitative assessment of noise levels (A-weighted decibels (dBA)) and geographic area impacted from mine operations, blasting, and traffic and qualitative assessment of effects of noise at nearby residences and sensitive receptors.
4. Quantitative assessment of acres of habitat impacted from noise, vibrations, and light, at frequencies pertinent to species of concern.
5. Qualitative assessment of effects of vibrations from blasting and mine operations at nearby residences and sensitive receptors.

4.14 Issue 14: Impacts to Land Ownership and Boundary Management

Changes in land ownership could have impacts as a result of the loss of public lands from the land exchange and mine proposal, including impacts to ranching in the area from changes in easements, rights-of-way, conservation efforts, fencing, and/or livestock access.

Boundary management includes impacts to survey markers, boundary markers, fences, or similar features from development of the mine. Protection of survey monuments and land ownership boundaries is an important concern for the Forest Service. The activities described in the GPO would damage, destroy, or obliterate corner monuments and land ownership boundaries, particularly in the area of tailings storage facilities. The proposed tailings facility location on NFS lands open to entry under the mining laws may unreasonably restrict or prevent mining claimants (other than the proponent) from accessing their claims. Land status and claim block tenure for the entire area may be affected.

4.14.1 Issue 14 Factors for Alternative Comparison

1. Quantitative assessment of acres of public lands no longer accessible, for various phases of the mine life and reclamation.
2. Quantitative assessment of lands that will be conveyed to public ownership through the land exchange (i.e., approximately 5,344 acres in all parcel groups).
3. Quantitative assessment of changes to acreage of grazing allotments, loss of animal unit months (AUMs), and qualitative assessment of impact from loss of grazing-related facilities (waters, stock tanks, roads, fences).
4. Qualitative assessment of changes in fencing, boundary markers, and survey markers.
5. Qualitative assessment of impacts to regional land conservation effort.
6. Qualitative assessment of impact to mining claims.

APPENDIX B

Council on Environmental Quality and Forest Service NEPA Guidance on Alternatives Development

The following selected excerpts from regulations, guidance, or policy have been used to guide the alternatives development process, with a specific focus on determining the standard of “reasonableness”. All emphasis added.

CEQ Regulations for Implementing the Procedural Provisions of NEPA (40 CFR 1500-1508)

- §1501.2 (C). Each agency shall: (c) Study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources as provided by section 102(2)(e) of the act.
- §1502.14. Alternatives including the proposed action. This section is the heart of the environmental impact statement. …it should present the environmental impacts of the proposal and the alternatives in comparative form, thus sharply defining the issues and providing a clear basis for choice among options by the decisionmaker and the public.
- § 1502.14. Alternatives including the proposed action. In this section agencies shall:
    - (a) Rigorously explore and objectively evaluate all reasonable alternatives, and for alternatives which were eliminated from detailed study, briefly discuss the reasons for their having been eliminated.
    - (c) Include reasonable alternatives not within the jurisdiction of the lead agency.
    - (d) Include the alternative of no action.

Forest Service Procedures for NEPA Compliance (36 CFR 220)

- § 220.5 - Environmental Impact Statement and Record of Decision.
    - (e) Alternative(s). The EIS shall document the examination of reasonable alternatives to the proposed action. An alternative should meet the purpose and need and address one or more significant issues related to the proposed action. Since an alternative may be developed to address more than one significant issue, no specific number of alternatives is required or prescribed.

Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations

- Question 1a. Range of Alternatives. What is meant by "range of alternatives" as referred to in Sec. 1505.1(e)?
    - Answer 1a: The phrase "range of alternatives" refers to the alternatives discussed in environmental documents. It includes all reasonable alternatives, which must be rigorously explored and objectively evaluated, as well as those other alternatives, which are eliminated from detailed study with a brief discussion of the reasons for eliminating them. Section 1502.14.
    - Decisionmaker must not consider alternatives beyond the range of alternatives discussed in the relevant environmental documents. Moreover, a decisionmaker must, in fact, consider all the alternatives discussed in an EIS. Section 1505.1(e).

- Question 2a. Alternatives outside the capability of applicant or jurisdiction of agency. If an EIS is prepared in connection with an application for a permit or other federal approval, must the EIS rigorously analyze and discuss alternatives that are outside the capability of the applicant or can it be limited to reasonable alternatives that can be carried out by the applicant?

  - Answer 2a. Section 1502.14 requires the EIS to examine all reasonable alternatives to the proposal. In determining the scope of alternatives to be considered, the emphasis is on what is "reasonable" rather than on whether the proponent or applicant likes or is itself capable of carrying out a particular alternative. Reasonable alternatives include those that are practical or feasible from the technical and economic standpoint and using common sense, rather than simply desirable from the standpoint of the applicant.

- Question 2b. Must the EIS analyze alternatives outside the jurisdiction or capability of the agency or beyond what congress has authorized?
  - Answer 2b: An alternative that is outside the legal jurisdiction of the lead agency must still be analyzed in the EIS if it is reasonable. A potential conflict with local or federal law does not necessarily render an alternative unreasonable, although such conflicts must be considered. Section 1506.2(d). Alternatives that are outside the scope of what Congress has approved or funded must still be evaluated in the EIS if they are reasonable, because the EIS may serve as the basis for modifying the congressional approval or funding in light of NEPA's goals and policies. Section 1500.1(a).

Forest Service NEPA Handbook 1909.15, Chapter 10 – Environmental Analysis

14 - DEVELOP ALTERNATIVES

Under the CEQ regulations, the Agency is required to:

> Study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources as provided by section 102(2)(E) of the Act. (40 CFR 1501.2(c))

No specific number of alternatives is required or prescribed. Develop other reasonable alternatives fully and impartially. Ensure that the range of alternatives does not prematurely foreclose options that might protect, restore, and enhance the environment.

Reasonable alternatives to the proposed action should fulfill the purpose and need and address unresolved conflicts related to the proposed action. Be alert for alternatives suggested by participants in scoping and public involvement activities. Consider alternatives, even if outside the jurisdiction of the Agency.

Descriptions of the alternatives should include relevant mitigation measures that could reduce the impacts of the project, even if those measures are outside the jurisdiction of the Agency. Examples include; project design features to avoid or minimize impacts, forest plan requirements, Best Management Practices, and statutory and regulatory requirements related to Federal, State, and local laws and regulations.

As established in case law interpreting the NEPA, the phrase "all reasonable alternatives" has not been interpreted to require that an infinite or unreasonable number of alternatives be analyzed, but does require a range of reasonable alternatives be analyzed whether or not they are within Agency jurisdiction to implement

(40 CFR 1502.14(c)). For further guidance, see questions 1, 2, and 3 of the "NEPA's 40 Most Asked Questions" and in section 65.12.

For EISs:

The EIS shall document the examination of reasonable alternatives to the proposed action. An alternative should meet the purpose and need and address one or more significant issues related to the proposed action. Since an alternative may be developed to address more than one significant issue, no specific number of alternatives is required or prescribed. (36 CFR 220.5(e))

Develop and consider alternatives that would reduce significant impacts.

(1) The responsible official may modify the proposed action and alternative(s) under consideration prior to issuing a draft EIS. In such cases, the responsible official may consider the incremental changes as alternatives considered. The documentation of these incremental changes to a proposed action or alternatives shall be included or incorporated by reference in accord with 40 CFR 1502.21. (36 CFR 220.5(e))

The intent of the regulation is to encourage collaboration throughout the analysis and decisionmaking process. Ongoing collaboration may often result in modification of a proposed action or alternative(s), resulting in a better proposal and ultimately a better decision. Such changes may not necessarily require the development of a new alternative if they can be accommodated through modification of an existing alternative. Incremental modifications that occur as a result of collaboration should be clearly described and documented in the analysis record, so that interested parties have a clear understanding of the nature of and reasons for the incremental changes.

14.4 - Alternatives Not Considered in Detail

The range of alternatives considered by the responsible official includes all reasonable alternatives to the proposed action that are analyzed in the document, as well as other alternatives eliminated from detailed study. Alternatives not considered in detail may include, but are not limited to, those that fail to meet the purpose and need, are technologically infeasible or illegal, or would result in unreasonable environmental harm.

Note that a potential conflict with local or federal law does not automatically render an alternative unreasonable, although such conflicts must be considered. See the "NEPA's 40 Most Asked Questions", #2b.

Because alternatives eliminated from detailed study are considered part of the range of alternatives, the project or case file should contain descriptions of the alternatives and the reasons for their elimination from detailed study. If an EIS is required, this information must be disclosed in the chapter on alternatives (sec. 22.3, para. 5(a)).

APPENDIX C

Technical Memorandum for Alternative Mining Methods

TECHNICAL MEMORANDUM

TO: Resolution Copper Project Record
Attn: Chris Garrett, SWCA Project Manager

FROM: Charles A. Kliche, P.E., PhD

DATE: November 1, 2017

RE: **Technical Memorandum for Alternative Mining Methods, Resolution Copper Mining, LLC, Superior, AZ**

INTRODUCTION

Resolution Copper Mining (RCM) is a limited liability company owned 55 per cent by Resolution Copper Company, a Rio Tinto PLC subsidiary, and 45 per cent by BHP Copper, Inc., a BHP-Billiton PLC subsidiary. The Resolution Project will be managed by Resolution Copper Mining, LLC, through its majority member, Resolution Copper Company, a wholly owned subsidiary of Rio Tinto.

The project targets a deep-seated porphyry copper deposit located adjacent to and beneath the now inactive Magma Mine. Rio Tinto has reported an indicated plus inferred resource of 1.969 billion short tons containing 1.54 percent copper and 0.035 percent molybdenum at depths exceeding between -500 and -2,500 ft below MSL[1] (5,000 to 7,000 ft below the surface).

Resolution Copper proposes to use an underground mining method known as *panel caving*, which is a variation of *block caving*. Panel caving allows for the mining of very large relatively low-grade underground ore bodies by dividing the deposit into smaller strips, or panels, so that the ore can be removed by a safe and efficient manner[2].

Because of the depth of the orebody, RCM maintains that an open pit mine is not economically or logically feasible. Furthermore, because of this great depth of the orebody, relatively low grade of the resource, and disseminated nature of the copper within the orebody, the only real feasible mining method which could maximize extraction of the copper-bearing ore deposit, is *Block Caving*, or a variation thereof.

The scope of the review for this memorandum included:

- a comprehensive review and classification of underground stoping methods which may be applicable as an alternative to block caving;
- a review of literature to estimate an Operating Cost per ton (or per tonne) for the more feasible alternatives to block caving;
- a review of other pertinent block caving operations world-wide;
- a meeting with RCM personnel (Mses. Vicky Peacy and Kim Heuther, and Mr. Bill Hart) on 3/23/17 to discuss information needs to complete this assessment;
- develop an estimate, based on limited information provided by RCM, of the total tons of potentially mineable material above a cut-off grade of 2% which lies at or above the -2,500 ft level;

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[1] Parker, Harry M. 2017. *Geologic and Mineral Resource Model - Suitability for Declaration of Mineral Resources and Support for Mine Plans to Develop a Block or Panel Cave Mine*, Letter prepared exclusively for Resolution Copper Mining (RCM), by Amec Foster Wheeler E&C Services Inc. March 14, 2017.

[2] RCM. 2016. *General Plan of Operations - Resolution Copper Mining,* Section 1.5 "Proposed Operations."

- project the tons vs cut-off grade (COG) line to other COGs to estimate the tons available if the COG were to rise due to utilizing a more expensive alternative mining method; and
- discuss possible realistic alternative mining methods which may be utilized instead of block caving.

REVIEW AND CLASSIFICATION OF STOPING METHODS

In mining, it is most desirable to select the appropriate mining method which will yield the largest net return. The method employed must be safe and must also permit optimum extraction under the particular geologic conditions encountered[3].

An initial classification of stoping methods was developed and adopted by the U.S. Bureau of Mines, and was devised largely on the basis of rock stability[4].

Lewis and Clark[3] took Jackson and Gardner's work and developed it further, primarily from a structural engineering point of view; and Hustrulid[5] added to and modernized the Lewis and Clark's classification. Basically, Lewis and Clark determined that the following characteristics were the most important for selecting the most applicable underground mining method: (1) the size and shape of the orebody; (2) the depth and type of overburden; (3) the location, strike and dip of the deposit; (4) the strength and physical character of the ore; (5) the strength and physical character of the surrounding rock; (6) water and drainage, that is, the presence or absence of aquifers; (7) grade and type of ore and other economic factors. Furthermore, as an aid for the classification of stoping methods, Lewis and Clark developed four (4) overall general classifications based upon the principles of rock stability: (1) stopes naturally supported; (2) stopes artificially supported; (3) caved stopes; and (4) combination of supported and caved stopes. Hustrulid expanded classification #4 further to include such methods as Longwall Mining, Shortwall Mining and VCR stoping.

Presented below in Table 1 is Lewis and Clark's classification[3] as modified by Hustrulid[5];

[3] Lewis, Robert S. and G.B. Clark. 1964. *Elements of Mining.* Chapter XII - Underground Mining Methods Selection. John Wiley & Sons, New York.
[4] Jackson, C.F. and E.D. Gardner, 1936. *Stoping Methods and Costs,* USBM Bull. 390.
[5] Hustrulid, W.A., ed. 1982. *Underground Mining Methods Handbook.* Society of Mining Engineers of The American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York.

Table 1. ***Classification of stoping methods adopted by the U.S. Bureau of Mines (adapted from Lewis & Clark, 1964; and Hustrulid, 1982)***

	Important Characteristics from a Structural Geological Engineering Point of View:						
Classification of Stoping Methods	***Size & Shape of the Orebody***	***Depth and Type of Overburden***	***Location, Strike and Dip of the Deposit***	***Strength and Physical Character of the Ore***	***Strength and Physical Character of the Surrounding Rock***	***Water and Drainage (presence or absence of aquifers)***	***Grade and Type of Ore, and other Econ Factors***
A. Stopes naturally supported							
1. Open stoping	Stoping in which no regular artificial method of support is employed, although occasional props or cribs may be used to hold local patches of insecure ground. The walls and roof are self-supporting and open stopes can be used only where the ore and wall rocks are firm (*Dictionary of Mining, Mineral, and Related Terms,* 1997)						
- Open stopes in small orebodies	Small	Strong. Not an issue	Flat-lying to steeply-dipping	Strong ore	Strong surrounding rock	Not an issue	High grade pockets of ore
- Sublevel stoping	Large orebodies desirable; well-defined; regular in shape; steeply dipping (> 20 ft thick)	Strong. Not an issue	Steeply inclined deposits (dip > 55°)	Strong ore; not subjected to fracturing is best (> 14,000 psi)	Strong wall rock (> 14,000 psi)	Water might be an issue in sulfide ore, causing oxidation	Reqs extensive ore body development with rel high cap expenditures. Prod costs are comparatively low
2. Open stopes with pillar supports	Pillars of ore are left to support the back of stopes in deposits of uniformly low-grade ore, generally extending over a large area and either horizontal or flat-dipping, in which it is cheaper to leave pillars of ore than to use artificial support (Lewis & Clark, 1964)						
- Casual pillars (random pillars)	Uniformly low-grade ore, generally extending over a large area	Competent	Horizontal or flat-dipping (Dip < 35°)	Strong; walls and roof self-supporting	Strong; walls and roof self-supporting	Not an issue, but dry is best	Low to moderately low; pillars of waste within the ore left to support the back
- Room (or stope) and pillar (reg. arrangement)	Uniformly moderate grade extending over a large area (< 30 ft thick for R&P; < 150 ft thick for S&P)	Competent	Horizontal or flat-dipping (dip < 35°)	Strong; walls and roof self-supporting (> 14,000 psi)	Strong; walls and roof self-supporting (> 14,000 psi)	Not an issue, but dry is best	Pillars regularly spaced within the orebody left to support the back. Often robbed.

Classification of Stoping Methods	Important Characteristics from a Structural Geological Engineering Point of View:						
	Size & Shape of the Orebody	***Depth and Type of Overburden***	***Location, Strike and Dip of the Deposit***	***Strength and Physical Character of the Ore***	***Strength and Physical Character of the Surrounding Rock***	***Water and Drainage (presence or absence of aquifers)***	***Grade and Type of Ore, and other Econ Factors***
B. Stopes artificially supported							
3. Shrinkage stoping	A vertical, overhand mining method whereby most of the broken ore remains in the stope to form a working floor for the miners. Another reason to leave the broken ore in the stope is to provide additional wall support until the stope is completed and ready for drawdown. Stopes are mined upward in horizontal slices. Normally, about 35% of the ore derived from the stope cuts (the swell) can be drawn off ("shrunk") as mining progresses. [classified by some as an open stope method and by others as a supported stope method]						
- With pillars	Narrow to wide (4 to 100 ft thick)	Not an issue	Must be greater than angle of repose to facilitate drawing of ore (Dip > 55°)	Should be strong (> 14,000 psi)	Weaker than those mined by sub-level stoping and shrinkage w/o pillars (> 14,000 psi)	Water might be an issue in sulfide ore, causing oxidation	Much ore tied up in inventory in the stope until final drawing of the ore
- Without pillars	Narrow to wide (4 to 100 ft thick)	Not an issue	Must be greater than angle of repose to facilitate drawing of ore (Dip > 55°)	Should be strong (> 14,000 psi)	Weaker than those mined by sub-level stoping (> 14,000 psi)	Water might be an issue in sulfide ore, causing oxidation	Much ore tied up in inventory in the stope until final drawing of the ore
- With subsequent waste filling	Narrow to wide (4 to 100 ft thick)	Not an issue	Must be greater than angle of repose to facilitate drawing of ore	Should be strong (> 14,000 psi)	Weaker than those mined by sub-level stoping (> 14,000 psi)	Water might be an issue in sulfide ore, causing oxidation	Better long-term stability. Oxidation may be an issue for sulfides
4. Cut-and-fill stoping	A method of underground mining used in vertical stopes and in mining high-grade irregular ore bodies. The rock mass surrounding the ore deposit is also usually weak—unable to support loads over an extended stoping height. As the name of the method implies, successive cutting of the ore into horizontal slices is carried out starting from the bottom of the stope and progressing upwards towards the surface (or, starting from the top and progressing downwards, as in Underhand C-and-F). This horizontal slicing leaves a void that is backfilled with material to provide support until all the ore is extracted from the mine.						
- Overhand cut-and-fill	Narrow to wide; steeply dipping to low dips (> 6 ft thick)	Not an issue	Steep to flat. Draw chutes must be greater than angle of repose (Dip* > 45°)	Should be strong (> 8,000 psi)	Weak. Supported immediately by fill (6,000 – 14,000 psi)	Fill usually placed wet. Can be an issue for sulfide waste when it dries	Higher grade since filling is expensive; cost of mining greater than for shrinkage
- Underhand cut-and-fill	Narrow to wide; steeply dipping to low dips (> 6 ft thick)	Not an issue	Steep to flat. Draw chutes must be greater than angle of repose (Dip* > 45°)	Should be strong (> 8,000 psi)	Weak. Supported immediately by fill (6,000 – 14,000 psi)	Fill usually placed wet. Can be an issue for sulfide waste when it dries	Higher grade since filling is expensive; cost of mining greater than for shrinkage

* Any, if thick

	Important Characteristics from a Structural Geological Engineering Point of View:						
Classification of Stoping Methods	***Size & Shape of the Orebody***	***Depth and Type of Overburden***	***Location, Strike and Dip of the Deposit***	***Strength and Physical Character of the Ore***	***Strength and Physical Character of the Surrounding Rock***	***Water and Drainage (presence or absence of aquifers)***	***Grade and Type of Ore, and other Econ Factors***
5. Stulled stopes in narrow veins	The walls of narrow veins frequently are supported by stull timbers placed between the foot and hanging walls, which constitute the only artificial support provided during the excavation of the stopes. Stulls may be placed at irregular intervals to support local patches of insecure ground, in which case the stopes are virtually open stopes. Sometimes the stulls are placed at regular intervals both along the stope and vertically, in which case stull stoping should be considered a distinctive method.						
"	Narrow vein; steep to low dips (10° to 45°)	Not an issue	Narrow vein, usually less than 12 ft. Steep or flat.	strong to weak	Competent hanging and footwall rock	Not an issue	High grade as stull timbers or steel supports are expensive
6. Square-set stoping	This method is most applicable in mining deposits in which the ore is structurally weak. Also, the surrounding rock may be fractured, faulted and altered to such an extent that it is also very weak. The geometry of the deposit is such, and the value of the ore is of sufficient magnitude, that caving methods may not be employed. The method is flexible in that sets can be extended in any direction or can be terminated as irregularities in the shape of the orebody are encountered. The sets can be filled with waste or tailings for additional support and to stop oxidation of exposed sulfide materials.						
"	Narrow vein to massive; wider than for stulls. Useful for irregular-shaped orebodies	Not an issue	Too deep may have serious ground pressure issues; shallow to deep	Weak; running ground;	Weak	Water can be introduced if backfilled with tailings	Very expensive; high grade ore a necessity. Need a ready source of timber. Labor intensive.
7 Modified Mitchell Stoping	Vein, chimneys to massive deposits	Weak or strong OB		Weak	Weak to moderately strong		May not need quite so much timber as Sq Set
C. Caved stopes							
1. Caving (ore broken by induced caving)	There are two distinct types of caved stopes: In the first, the ore is broken by caving induced by undercutting a block of ore. In the second, the ore itself is removed by excavating a series of horizontal or inclines slices, while the overlying capping is allowed to cave and fill the space occupied previously by the ore.						
- Block caving	Block caving is most applicable to large orebodies which have a capping which may be caved. Development consists of driving a series of evenly spaced crosscuts below the bottom of the ore, from which main, branch, and finger raises are driven up to the ore. The ore is then undercut, and the weight of the ore plus the capping is employed to force the ore to crush, run down through the raises and thus mine itself. ***The most ideal conditions for block caving are found in the porphyry copper deposits where both the ore and capping are weak.***						
"	(> 100 ft thick). Massive. Outlines of orebody fairly regular and the sides should dip steeply.	Very weak OB which caves. Breaks into lg pieces & resists attrition as the block is drawn. Some dilution inevitable.	(Dip^{v}* > 55°). Lg orebodies with a capping which may be caved.	(> 6,000 psi**) Proper fracture pattern (several sets with various orientations and will break into sizes & shapes that can pass thru the drawpoints).	(6,000 – 18,000 psi**). Strong wall rock preferable to limit dilution.	Should limit water into the caved muck & capping to minimize acid or metals production.	Large, massive orebodies. Disseminated ore grades. High to low grades, but usually applied to low grade deposits. Porphyry Cu.

* Any, if thick   ** Caveable

^{v}* Any, if very thick

Classification of Stoping Methods	Important Characteristics from a Structural Geological Engineering Point of View:						
	Size & Shape of the Orebody	***Depth and Type of Overburden***	***Location, Strike and Dip of the Deposit***	***Strength and Physical Character of the Ore***	***Strength and Physical Character of the Surrounding Rock***	***Water and Drainage (presence or absence of aquifers)***	***Grade and Type of Ore, and other Econ Factors***
- Sublevel caving	Sublevel caving is very similar to top slicing. The general plan of operation is to mine every other slice, permitting the weight of the capping to assist in mining of the ore. The capping should be somewhat stronger than that in which top slicing is applicable. ***For both top-slicing and sublevel methods of mining, it is absolutely essential that the capping be weak enough to cave when it is undermined.***						
"	(> 20 ft thick). Can yield lower recoveries in some longitudinal layouts	No longer requires weak, caveable OB as the ore between sublevels is drilled & blasted. Can blast down the OB.	(Dip* > 50°) Can mine shallower dips but may get low recoveries	(> 14,000 psi) Moderately strong ore; drilled & blasted.	(6,000 – 18,000 psi**) Caveable waste rock.	Good drainage is essential to provide good roadbeds	Can be applied to hard & moderately weak ground; also to irreg orebodies & wide or narrow orebodies
2. Top slicing	A method of stoping in which the ore is extracted by excavating a series of horizontal (sometimes inclined) timbered slices alongside each other, beginning at the top of the orebody and working progressively downward; the slices are caved by blasting out the timbers, bringing the capping or overburden down upon the bottom of the slices that have been previously covered with a floor or mat of timber to separate the caved material from the solid ore beneath. Succeedingly lower slices are mined in a similar manner up to the overlying mat or gob, which consists of an accumulation of broken timbers and lagging from the upper slices and of caved capping.						
"	Fairly wide to massive orebodies	Weak capping material. Should not bridge or arch during caving	Moderately deep to deep; flat to steep to massive.	Weak ore	weak to strong	Water in the caved material can be an issue—may produce acid & bad air	Plentiful & relatively cheap timber required
D. Combination of supported and caved stopes							
E. Others							
- Longwall mining	(< 30 ft thick) Deposits up to 200 ft thick have been mined successfully	200 to 2000 ft Caveable.	(Dip < 15°)	Coal & trona, mainly. Trona ≈ 6600 psi;	Moderately strong to strong floor. Caveable roof.	Water-filled Cavities or mined out areas can cause major probs.	All types of coal; trona; Others: potash, iron, copper, uranium, gold
- Shortwall mining	3.5 to +12 ft thick seams	200 to 2000 ft; Reasonable strong roof, supportable by roofbolting,	Dip no steeper than what mobile equip or continuous miner can handle	Coal, mainly.	Firm floor, preferable;	Wet floor can be a prob for mobile equip.	All types of coal, trona, other soft rocks.
- VCR stoping	(> 40 ft thick)	Any depth.	(Dip > 45°)	(> 14,000 psi); widths > 12 to 15 m. May or may not be backfilled.	(> 14,000 psi); strong enough to blast against w/o adding much dilution	Oxidizing ore mined relatively quickly.	Strong ore. Good grades. Gold (HMCo) has been mined this way.
F. Resolution Copper deposit[6]	Very large; massive & thick	Deep. Weak to moderate. Highly jointed.	Deep; flat-lying to steeply-dipping	Weak to moderate	Weak to moderate; very thick; uniform	Much very hot water present	Large tonnage of low-grade ore. Porphyry copper deposit

[6] Taken from "Resolution Copper Mining, LLC - Mine Plan of Operations and Land Exchange - Follow-up Alternatives Information;" August 14, 2017; Ms. Vicky Peacey to Ms. Mary Rasmussen. Project Record #0001734.

ESTIMATE OF COSTS FOR VARIOUS UNDERGROUND MINING METHODS

Edumine, which provides a source for education and training through a set of on-line and short courses, developed a table[7] of underground mining costs based upon 2010 dollars. The authors of the table used a publication developed by CostMine (a division of InfoMine) titled Mining Cost Service[8] to estimate the costs (Table 2).

Mining Cost Service is the industry standard for mine cost estimating. It is a 2-volume loose-leaf system which includes information on the following topics:

- Mine and Mill Cost Models
- Smelting
- Mining Taxes
- Mine and Mill Equipment Costs
- Electric Power Costs
- Metal Prices
- Transportation Costs
- Cost Indexes
- Labor Costs
- Mine and Mill Supply Costs
- Development Costs
- Natural Gas Costs

Table 2. ***For a shaft entry underground mine, the approximate total operating costs (in dollars per tonne ore) and the total capital costs (millions of dollars).***

U/G Mining Method	Production Rate (t/day)	Op Cost ($/t)	Cap Cost ($M)
Cut & Fill	1,000	68.03	32.7
Mechanized Cut & Fill	1,000	52.48	68.4
Shrinkage	1,000	51.49	31.5
End Slice	2,000	25.58	45.0
Vertical Crater Retreat	2,000	40.36	66.8
Sublevel Longhole	4,000	19.02	63.7
Room & Pillar	8,000	20.83	118.2
Sublevel Caving	8,000	21.99	142.6
Block Caving	30,000	9.10	163.7

A similar table of relative operating cost per tonne of ore vs underground mining method is presented below within Figure 1[9]. This figure shows that a mining method such as Cut-and-Fill mining can be 20, or more, times as expensive per ton (tonne) as a bulk method such as Block Caving.

[7] Hem, Priyadarshi, G. Fenrick and J. Caldwell. rev 2011. *Underground Mining Methods.* http://technology.infomine.com/reviews/UgMiningMethods/welcome.asp?view=full Accessed 7/7/2017.
[8] http://costs.infomine.com/miningcostservice/ Accessed 7/7/2017.
[9] Moss, Allan. 2011. *An Introduction to Block and Panel Caving.* BMO Capital Markets 2011 Global Metals and Mining Conference. https://www.scribd.com/document/217853788/Introduction-to-Panel-Caving

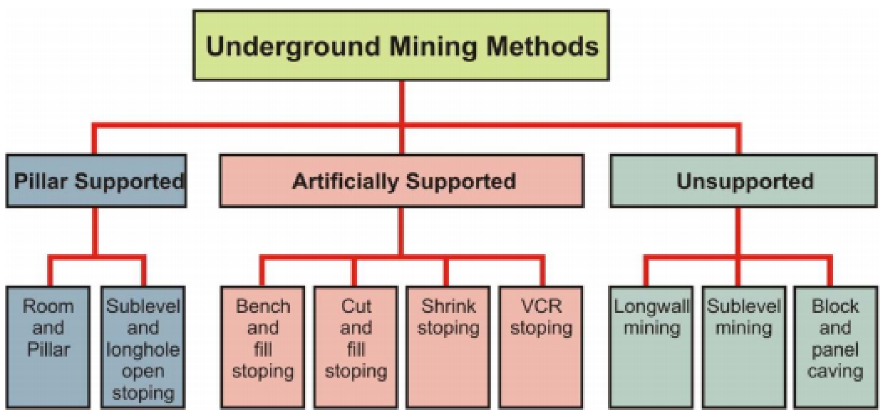
It is important at this point to discuss the concept of **<u>Cutoff Grade</u>** as it pertains to mining. The cutoff grade is defined as the lowest grade of mineralized material that qualifies as ore in a given deposit[10]. That is, the cutoff grade is the lowest grade of ore-type material that, at the current price and mill recovery, just equals the cost of stripping, drilling & blasting (ore & waste), mining (ore & waste), hauling (ore & waste), crushing, processing, G&A, applicable taxes, and other associated costs to produce 1 ton (tonne) of ore.

For a copper porphyry deposit, it can be written in simple form as:

Cutoff Grade (decimal form) =

$$\frac{(\text{mining cost/ton of ore}) + (\text{haulage cost/ton of ore}) + (\text{milling cost/ton of ore}) + (\text{applicable taxes/ton of ore}) + (\text{G \& A/ton of ore})}{\text{anticipated price (\$/lb of Cu)} \; X \left(\frac{2000\text{ lb}}{\text{ton}}\right) X \left(\frac{\%\text{ mill recovery}}{100}\right)}$$

So, it can be seen that with a more expensive mining technique that, as the cost of mining goes up, and with the copper price and metal recovery from the mill remaining the same, then the cutoff grade also goes up.



Method	T / Manshift	Avg. T / Day	Relative Operating Cost per tonne
Resuing	0.2 - 0.5	50 - 100+	70+
Cut and Fill	12 - 48	500 – 1,500	20 to 70
Shrinkage	20 - 28	200 - 800	20 to 50
Room and Pillar	15 - 150	1,500 – 10,000	7 to 20
Open Stoping	20 - 115	1,500 – 25,000	7 to 25
Sub-level Caving	65 - 180	1,500 – 50,000	7 to 17
Block Caving	300 - 2000	10,000 – 100,000	1 to 2.5

Figure 1. ***Relative operating cost for various stoping and caving underground mining methods.***

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[10] American Geological Institute. 1997. *Dictionary of Mining, Mineral, and Related Terms,* American Geological Institute in cooperation with the Society for Mining, Metallurgy, and Exploration, Inc., Alexandria, VA.

REVIEW OF BLOCK CAVING OPERATIONS WORLDWIDE

General Characteristics of Block Caving

As summarized in Table 1, block caving is most applicable to large ore bodies which have a capping which may be caved.

Tobie and Julin (1982)[11] state some of the requirements for a successful block caving application as: *Included as a necessary characteristic in an ore body suited to a successful block caving operation is a proper fracture pattern. Ore hardness should be another governing factor, and the toughness or softness of the ore should be considered. There must be sufficient horizontal area available for expansion of the undercut, if necessary to start the caving process. Large, massive orebodies usually meet these conditions.*

Furthermore, they state: *In block caving, a fairly uniform distribution of values in the ore is necessary. Grade values may range from low grade to high grade, but most often the system is applied to low-grade ores. The ore must be such that it can be supported while blocks are being developed and undercut, but breaks up readily when caved. Some applications include porphyry copper….*

Outline of the orebody should be fairly regular, and the sides of the orebody should dip steeply. It may not be economical to mine small portions of the ore extending into the walls of the deposit, and low-grade inclusions in the ore cannot be left unmined.

The intensity of the (rock) fracture pattern is a critical parameter to be analyzed (to determine a deposit's suitability for caving). Several sets of fractures are essential to promote good caving. Ideally, two vertical sets at nearly right angles to each other and a third set nearly horizontal are required to insure a good caving ore body.

Additional considerations include[3]:

- *Some dilution of the ore with waste and some loss of ore always occur when this system of mining is used. It is important to know the grade of the ore before selecting the method by which the ore is to be mined. If the loss of from 12 to 15% of the ore is of more importance than the additional cost of mining by the other method, caving would not be used.*
- *In general, an ore body must be of large size to justify the expense of the haulage drifts, rises and other development work (high capital cost).*
- *The thickness of the capping is the most important factor in deciding whether the mine should be worked by the open-cut method or by caving*. Some sort of method must be used to determine the break-even stripping ratio between surface mining and underground (block caving) mining. If the stripping ratio via proposed open pit mining exceeds this break-even ratio, then underground mining (block caving) is an alternative.

Table 3 below lists some of the more important advantages and disadvantages of block caving[12].

Summarizing for block caving: Where applicable, it is a mining alternative with a high initial capital investment cost, but low operating cost per ton of ore (see Table 2).

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[11] Tobie, Ray L and Douglas E Julian. 1982. *Block Caving,* In Underground Mining Methods Handbook. Hustrulid, W.A., ed. Society of Mining Engineers of The American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York.
[12] Source: http://minewiki.engineering.queensu.ca/mediawiki/index.php/Block_caving

Table 3. ***Advantages/disadvantages of block/panel caving.***

Parameter	Advantage	Disadvantage
Cost	• Low unit cost ($/ton ore) ➢ Little to no drill and blast • Can be profitable even with relatively low grade ore bodies	• High capital cost ➢ Development infrastructure needs to be in place before first ore ton produced
Safety	• Inherent safety • No large open stopes standing • High degree of mechanization possible	• Poor ground conditions during development • Explosive handling could be an issue for draw point blasting
Production & Development	• High productivity ➢ Centralized, one level production ➢ Few workers required to muck all ore • Fewer active areas allows for easier ventilation	• Long time for development, construction, commissioning ➢ Required to reach bottom production level to develop haulage infrastructure and drawpoints • High dilution ➢ From hanging wall ➢ When overburden fragmentation is higher than expected • Low recovery • Risk of subsidence (must be able to predict) ➢ Potential to damage surface infrastructure • Uncertainty ➢ Limited draw control ➢ Lower selectivity at ore face

Hem (2012)[10] compiled a list of developing, producing and closed (one on the list) block caving mines worldwide (Table 4). A mine added to Table 4 by Dr. C. Kliche is the San Manuel mine outside of Tucson, AZ, which closed in 2003.

Figure 2 shows a map of many of the planned and operating block caving mines around the world.

Table 4. ***Block caving mines worldwide***[13]

Mine	Location	Commodity	Status
Northparks	Australia	Cu, Au	Production
Jeffrey	Canada	Asbestos	Closed (2012)
New Afton	Canada	Au	Development
Andina (Rio Blanco)	Chile	Cu	Production
Chuquicamata (Subterranea)	Chile	Cu	Development
El Teniente	Chile	Cu	Production
El Salvador	Chile	Cu	Production
Tongkuangya	China	Cu	Production
Freeport DOZ	Indonesia	Cu	Development
Grasberg Block Cave	Indonesia	Cu	Development
Oyu Tolgoi (Hugo North Deposit)	Mongolia	Cu, Au	Development
Cullinan	South Africa	Diamond	Production
Finsch	South Africa	Diamond	Production
Kimberley	South Africa	Diamond	Production
Koffiefontein	South Africa	Diamond	Production
Palabora	South Africa	Cu	Production
Bingham Canyon	USA	Cu	Development
Climax	USA	Mo	Production
Henderson	USA	Mo	Production
Resolution	USA	Cu, Mo	Development
San Manuel	USA	Cu	Closed (2003)
Questa	USA	Mo	Production
Shabani	Zimbabwe	Asbestos	Production

Figure 2. ***Map of block cave mines around the world***[14]

[13] Hem, Priyadarshi. 2012. *Block Caving.* InfoMine. Located at: https://queensminedesign.miningexcellence.ca/index.php/Block_caving
[14] TechnoMine. *Block Caving*. http://technology.infomine.com/reviews/Blockcaving/welcome.asp?view=full Accessed 7/7/2017.

Discussion of Selected Block Caving Operations

1. Codelco's El Teniente

Location[15]**:** El Teniente ("The Lieutenant") is an underground copper mine in the Chilean commune of Machalí in Cachapoal Province, Libertador General Bernardo O'Higgins Region, near the town of Sewell, 2,300 m (7,500 ft) above mean sea level in the Andes.

Coordinates: 34°05′16″S 70°23′15″W

Facts:

- El Teniente is the world's largest underground copper operation and the sixth biggest copper mine by reserve size.
- El Teniente is owned and operated by Codelco, the state-owned copper miner and the world's largest copper producer (Codelco also owns Chuquicamata, the world's largest open pit mine).
- The El Teniente mine extracts the porphyry copper deposit, located 2,500m above sea level in the core of a volcanic mountain in the Libertador General Bernardo O'Higgins region in the Andes. Mining is carried out at different levels around a non-mineralised formation called the Braden Pipe that houses mining infrastructure of each level.
- The underground mine was estimated to contain 15.2 million tonnes of fine copper (1,538 million tonnes of ore grading 0.99% copper) in proven and probable reserves at the beginning of 2013.
- Located 80km south of Santiago, in the Andes mountain range, El Teniente is undergoing an extensive $5.4bn expansion project called New Mine Level project, which will extend the mine's production life by 50 years.
- The New Mine Level project will access approximately 2.02 billion tonnes of ore reserves (grading 0.86% copper) lying at about 350 metres below the existing undercut level of the mine.
- The massive deposit was discovered in the early 19th century and has been operational since 1905, when U.S.-based Braden Copper Company began operations.
- Block caving is used for extracting ore. More than 2,400km of underground drifts and in excess of 1,500km of underground road have been developed in the mine since it began operations.
- The mine is accessed by a 3.5km tunnel and the ore is hauled to the surface through a railroad system. The hauled ore is sent to the crushing plants on surface from where it is conveyed to a concentrator and the produced copper concentrate is sent to nearby smelter.
- El Teniente employs 4,000 staff workers and about 11,000 contractors.
- The El Teniente mine produced 450,000t of copper in 2013 compared with 417,000t in 2012, becoming Codelco's biggest copper producing mine during the year.
- It will process approximately 137,000t of ore per day and maintain El Teniente's the existing production level for a period of 50 years. The project also keeps the option open to expand the mine's ore output capacity to 180,000t per day.

[15] https://en.wikipedia.org/
(NOTE: Wiki was used **only** for location data for the block caving mines discussed)

Figure 3. ***El Teniente from Codelco Annual Report, 2015***

Figure 4. ***Google Earth image of same area as shown above (Red pin is located at 34°05'16"S 70°23'15"W).***

2. Magma Copper's (later BHP Billiton's) San Manuel

Location[14]**:** The San Manuel Copper Mine was a surface and underground porphyry copper mine located in San Manuel, Pinal County, Arizona.

Coordinates: 32°41′46″N 110°41′22″W

Facts[16]**:**

- The San Manuel group of mining claims was located in the 1920s and '30s.
- The San Manual Copper Corp. formed as a subsidiary of the Magma Copper Co. to carry on the exploration, revealing reserve estimates for copper ore that totaled 30 million tons, averaging 0.80 percent copper.

[16] Most San Manuel facts from: Ascarza, Wm. 2014. "Mine Tales: San Manuel was once world's largest underground copper mine," *Arizona Daily Star*. http://tucson.com/news/local/mine-tales-san-manuel-was-once-world-s-largest-underground/article_cbe2c60f-9516-520d-bcd3-b58679c1435d.html

- Development of the San Manuel ore deposit — 7,700 feet long, 3,500 wide and up to 2,700 feet deep — began in 1952 with the approval of a $94 million loan by the Reconstruction Finance Corp. to the Magma Copper Corp.
- By the 1980s, the San Manuel mine was the largest underground copper mine in the world in terms of production capacity, size of the ore body and infrastructure. It also included the similarly sized "Kalamazoo" ore body a mile to the west, which was a faulted segment of the San Manuel ore body.
- Mining operations during the 44-year life of the mine included underground block-caving methods that extracted more than 700 million tons of sulfide ore that was processed at the mill, smelter and refinery. Open-pit mining and a heap leach facility were initiated in 1985 to extract and process 93 million tons of oxide ore over 10 years
- Between 1955 and 1999, copper concentrates, finished and unfinished copper, ore and sulfuric acid were shipped 30 miles via the San Manuel Arizona Railroad Company from the San Manuel Mine and smelter to an interchange at Hayden with the Southern Pacific and later the Copper Basin Railway, a Southern Pacific spinoff railroad.
- BHP Billiton acquired the property through a merger with Magma in 1996. Mining operations ended in 1999 due to the decline in mineable ore reserves, along with sinking copper prices from a high of $1.39 per pound in 1995 to 65 cents in 1999. The mine, closed in 2003, holds the distinction of being the largest open-pit reclamation project undertaken in Arizona history, completed in 2006.
- The underground mine at San Manuel was first established in the 1940s and in 1952 Magma Copper Company constructed the mine, plant and railroads and started developing the community of San Manuel. By 1972, the mine mill was processing more than 60,000 tons of ore per day. The development of the open pit mining operations began in 1985. By the 1990s, the operation included an open pit, solvent extraction-electrowinning operation, an in-situ leaching process and underground sulfide mine. Prior to being placed on care and maintenance in 1999, the San Manuel Mine produced a world record 703 million tons of ore hoisted.

Figure 5. ***Aerial view of the San Manuel mill and smelter*[15]*.***

Figure 6[17] ***Open pit at San Manuel, looking south toward Santa Catalina Mountains on skyline. Broken ground in the far wall resulted from the collapse of surface exposures above the underground block caving operation.***

[17] Briggs, David F. 2014. *History of the San Manuel-Kalamazoo Mine, Pinal County, Arizona.* Contributed Report CR-14-A, Arizona Geological Survey.

Figure 7. ***Google Earth of the San Manuel Mine. Where's the subsidence?***

Figure 8. ***Zoomed in on the Magma Copper Open Pit/Mammoth Gold Mine. Subsidence visible in the foreground and on the left side of the open pit.***

3. Freeport's Henderson

Location[14]**:**

The Henderson molybdenum mine is a large underground molybdenum mine west of the town of Empire in Clear Creek County, Colorado, USA. The Henderson mine, which has produced molybdenum since 1976, is owned by Freeport-McMoRan.

Coordinates: 39°46′13″N 105°50′00″W

Facts[14] **:**

- The Henderson molybdenum mine is just east of the snow-capped continental divide
- The Henderson mine is North America's largest producer of primary molybdenum. 2007 production was 40 million pounds of molybdenum, with a value of $1.1 billion.
- The Henderson mine is near the Urad mine, which produced molybdenum from 1914 to the 1960s, before exhausting its orebody. The owner, Climax Molybdenum Co., recognized the potential for deeper orebodies in the area, and discovered the Henderson deposit in 1964. The mine was named after mining engineer Robert Henderson.
- Production began in 1976, and, on Jan. 4, 2010, the workers mined the billionth pound of molybdenum. In 2006, remaining ore reserves were estimated to be 500 million pounds of recoverable molybdenum.
- The deposit is a porphyry-type deposit consisting of a stockwork of small veins of molybdenite in rhyolite porphyries of Tertiary age that intrude into Precambrian Silver Plume granite. The ore averages 0.2% molybdenum. The molybdenite is associated with pyrite and quartz. The deposit is similar to other porphyry molybdenum deposits such as the Climax mine in Colorado and the Questa mine in New Mexico.
- Mining is done by block caving. In 1980 the cavity produced by the panel caving broke through to the surface, producing a large glory hole (subsidence) on the side of Bartlett Mountain.
- The ore is carried by a 15-mile conveyor belt system through a tunnel beneath the Continental Divide to the ore processing mill near Parshall, Colorado. The ore is treated by froth flotation to obtain molybdenite concentrate, which is shipped to a plant in Fort Madison, Iowa for further processing.

Figure 9. ***Henderson Mine glory hole (subsidence crater).***

Figure 10. ***Henderson Mine subsidence crater as viewed with Google Earth.***

4. Petra Diamond's Cullinan

__Location__:

The Premier Mine is an underground diamond mine owned by Petra Diamonds. It is situated in the town of Cullinan, 40 kilometers (25 mi) east of Pretoria, Gauteng Province, South Africa.

Coordinates: 25°40′S 28°30′E

__Facts__:

- Cullinan Diamond Mine is a carrot shaped volcanic pipe and has a surface area of 32 hectares (79 acres).
- On 22 November 2007, De Beers, the world's largest diamond producer, sold its historic Cullinan mine to Petra Diamonds Cullinan Consortium (PDCC), a consortium led by Petra Diamonds.
- The mine rose to prominence in 1905, when the Cullinan Diamond — the largest rough diamond of gem quality ever found — was discovered there. The mine has produced over 750 stones that are greater than 100 carats and more than a quarter of all the world's diamonds that are greater than 400 carats. It is also the only significant source of blue diamonds in the world.
- Ownership: Petra Diamonds Limited: 74%
  Kago Diamonds (Pty) Ltd: 14%
  Itumeleng Petra Diamonds Employee Trust: 12%
- Current depth of Resources : 1,073m
- Depth of current mining: 747m
- Mining Method: Block cave
- Potential Mine Life: +50 years

- Reserves & Resources[18]:

Category	Gross		
	Tonnes (millions)	**Grade (cpht)**	**Contained Diamonds (Mcts)**
Reserves			
Proved	-	-	-
Probable	47.8	45.1	21.59
Sub-total	47.8	45.1	21.59
Resources			
Measured	-	-	-
Indicated	251.5	70.3	176.88
Inferred	171.2	10.1	17.29
Sub-total	422.7	45.9	194.17

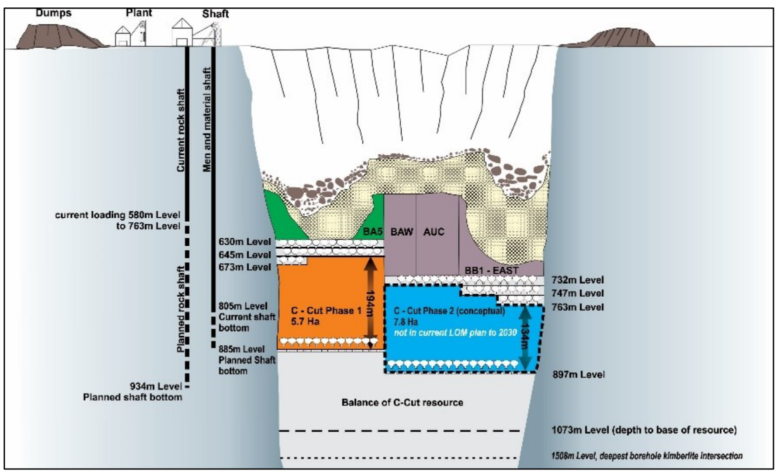

Figure 11. ***The orange block demonstrates both the* C-Cut *Phase 1 block cave that will be brought into production from* FY *2016 onwards. The blue block represents* C-Cut *Phase 2 which is available for mining post the end of the current mine plan (2030).***

[18] Petra Diamonds Limited, 2016 Resource Statement, pg 2. https://www.petradiamonds.com/wp-content/uploads/Petra-Diamonds-2016-Resource-Statement-FINAL-1.pdf

Figure 12. ***The pit at the Premier Mine, Cullinan, Gauteng, South Africa. The cross-sectional area of the 190 meter deep pit at its surface is about 32 hectares. The mine was the source of the 3106 carat Cullinan Diamond, the largest diamond ever found.***

5. Northparkes

Location[19]**:**

CMOC-Northparkes Mines (Northparkes) is a copper and gold mine located 27 kilometres north west of Parkes in the Central West of New South Wales, Australia. Northparkes is a joint venture between China Molybdenum Co., Ltd (CMOC) (80%) and the Sumitomo Groups (20%).

Coordinates: 33°08′16″S 148°10′29″E

Facts:

- The mine was originally started in 1994 using open pit mining, with underground mining using the block caving method starting in 1997.
- The mine has an operational capacity to process six million tonnes of ore per year, containing roughly 60,000 tonnes of copper and 50,000 ounces of gold. Economic viability of the mine is projected to extend at least to the year 2032.
- In 2006 Northparkes began construction of a new block cave mine on the E48 copper/gold deposit with production officially commencing in September 2010. In 2012, the joint venture partners approved a $35.6 million extension of the E48 block cave mine, extending the life of mine by approximately two years. Recently Northparkes' Environmental Assessment was approved by government taking Northparkes' mine life to 2032.
- The Northparkes deposits occur within the Ordovician Goonumbla Volcanics, part of a volcanic belt in the Central Lachlan Orogen of NSW. The ore deposits are typical copper-gold porphyry systems; the highest grades associated with the most intense stockwork veining. Sulphide species in the systems are zoned from bornite-dominant cores, through a chalcopyrite-dominant zone to minor distal pyrite.

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[19] http://www.mining-technology.com/projects/goonumbla/

- The porphyry copper deposits at Northparkes are typically narrow but extend to great depths. The E26 and E48 deposits range from 200 to 400m in diameter (>0.5% copper) and extend vertically for more than 1,000m.
- Northparkes currently holds ~1,000 km^2 of Exploration leases around the Northparkes Mines.

Figure 13. ***Google Earth image of Northparkes Mine. Subsidence crater in the foreground, mine pit at top left.***

Figure 14. ***Subsidence crater at Northparkes Mines.***

6. Palabora Copper (Pty) Ltd, a subsidiary of Palabora Mining Company.

Location:

Palabora Copper (Pty) Limited, a subsidiary of Palabora Mining Company Ltd, is a copper mine that also operates a smelter and refinery complex based in the town of Phalaborwa, in South Africa's Limpopo Province. The mine owes its origins to a unique rock formation in the region known as the Palabora Igneous Complex.

Coordinates: 23°56′S 31°7′E

Facts[20]**:**

- Palabora has been operational since its incorporation in 1956 and is the country's major producer of refined copper, producing approximately 45,000 tonnes of copper per annum. Palabora Copper is South Africa's sole producer of refined copper, which it supplies mainly to the local market and export the balance. Whilst copper forms the base-load of its business, Palabora also mines and exports other by-products such as Magnetite, Vermiculite Sulphuric acid, anode slimes and nickel sulphate.
- The company owes its origin to the unique formation known as the Palabora Igneous Complex. Nowhere else is copper known to occur in carbonitites as is the case at Palabora, and a host of other minerals such as phosphates, vermiculite, phlogopite, magnetite, nickel, gold, silver, platinum and palladium also occur.
- Palabora operates a large block cave copper mine and smelter complex employing approximately 2,200 people. The refinery produces continuous cast rod for the domestic market and cathodes for export. Useful byproduct metals and minerals include zirconium chemicals, magnetite and nickel sulphate as well as small quantities of gold, silver and platinum. Palabora has developed a US$410 million underground mine with a production capacity of 30,000 tonnes of ore per day.
- Palabora Mining Company operates a successful underground block-cave mine, producing 80,000 tonnes of copper ore per annum.
- The construction of the underground mine was completed in October 2004 when the 20th cross-cut was brought into full production. By May, 2005 the mine was consistently achieving 30,000 tonnes per day - one of the fastest ramp-ups to full production in the world.
- During 2006, Palabora treated 10.7Mt of ore grading 0.71% copper, giving an output of 61,500t of copper in concentrates. While production in the early stages of the underground operation had been hampered by problems with fragmentation in the block cave and secondary breaking systems, these seem to have been overcome in the past two-to-three years. The Palabora smelter produced 81,200t of copper metal, compared with 80,300t in 2005.
- The underground mine has been developed on a proven reserve of 225Mt at 0.7% copper, plus an additional probable reserve of 16Mt grading 0.49% copper. By the end of 2005, proven and probable reserves totaled 112Mt grading 0.56% copper, representing a significant reduction from the tonnage and grade cited the year before. Rio Tinto recorded a US$161m asset write-down in its 2005 accounts to reflect this

[20] PMC Palabora Mining Company http://www.palabora.com/

Figure 15. ***Palabora mine pit. Caved area from UG block caving operations on the left.***

Figure 16. ***Palabora pit showing subsidence from UG block caving operation.***

Figure 17. ***Google Earth image of Palabora, SA.***

7. Freeport's DOZ

Location: The Deep Ore Zone (DOZ) Mine is in the Ertsberg Mining District in Papua, Indonesia. The operation is run by P.T. Freeport Indonesia (PTFI) under contract to the Republic of Indonesia. The PTFI project site is located approximately 4°-6'S latitude, 137°-7'E longitude, in the Sudirman Mountain range of Papua, the eastern most province of Indonesia which occupies the western half of the island of New Guinea.

The ore deposits, discovered in 1936 and then acquired and developed by PTFI beginning in 1967, are located approximately 96 kilometers north from the southwest coast, between elevations of 2900m and 4000m above sea level. Access to the project is through the PTFI portsite of Amamapare on the Tipoeka River, and from the international airport of Timika, some 43 kilometers north of Amamapare. The mine site is 118 kilometers from Amamapare. An access road to the mine project site connects the portsite to the mill, passing by the Timika airport en route.

Facts[21]**:**

- Ownership: 90.64% FCX (including 9.36% owned through their wholly owned subsidiary, PT Indocopper Investama); 9.36% the Government of Indonesia (Freeport recently has agreed to sell 41.64 percent of PT-FI to the Indonesian government, adding to the 9.36 percent share the government already holds, to reach the divestment target of 51% ownership by the government).
- DOZ is a copper-gold skarn deposit located on the northeast flank of the Ertsberg diorite intrusive body. It comprises the lower elevations of the East Ertsberg Skarn System (EESS). The EESS outcropped on surface at about 4000 meters, and the DOZ lift of the EESS is located on the 3100 meter level.
- Current operations in the district include the Grasberg open pit (200,000 tpd ore) and the DOZ block cave mine (40,000 tpd).
- The DOZ mine is a mechanized block caving operation. The DOZ is the third lift of the block cave mine that has exploited the East Ertsberg Skarn complex since 1980, and design and operation has benefited from the previous experience gained while mining the upper lift (GBT)

[21] FCX Freeport-McMoRan http://www.fcx.com/operations/grascomplx.htm

and the intermediate lift (IOZ). There are four main levels at the DOZ mine, from top to bottom they are; undercut level, extraction level, exhaust level, and the truck haulage level. An advanced undercutting system is employed at DOZ.

- Freeport Indonesia's first block caving operations began in 1980 with the Gunung Bijih Timur – East Ertsberg (GBT) mine. This achieved a maximum production rate of 28,000 t/d and was depleted in 1994. The IOZ mine began production in 1994 and ramped up to a maximum production rate of 32,000 t/d.
- It was in 1997 that the pre-production development of the DOZ block cave mine began, and caving was initiated in November 2001. That same year the combined Grasberg/Ertsberg District operations achieved new record copper production of over 1,640M lb of copper. In 2002 the record was raised to over 1,800M lb of copper and DOZ achieved a sustainable production rate of 25,000 t/d. In 2003 the DOZ expansion to 35,000 t/d was approved and completed. The following year DOZ operated at 43,600 t/d, over 8,000 t/d above design-capacity and expansion to 50,000 t/d was approved. Today the mine has reached a sustained production rate of 80,000 t/d – the 80K project.
- DOZ is the third level of block caving to exploit the copper-gold Ertsberg East Skarn System.

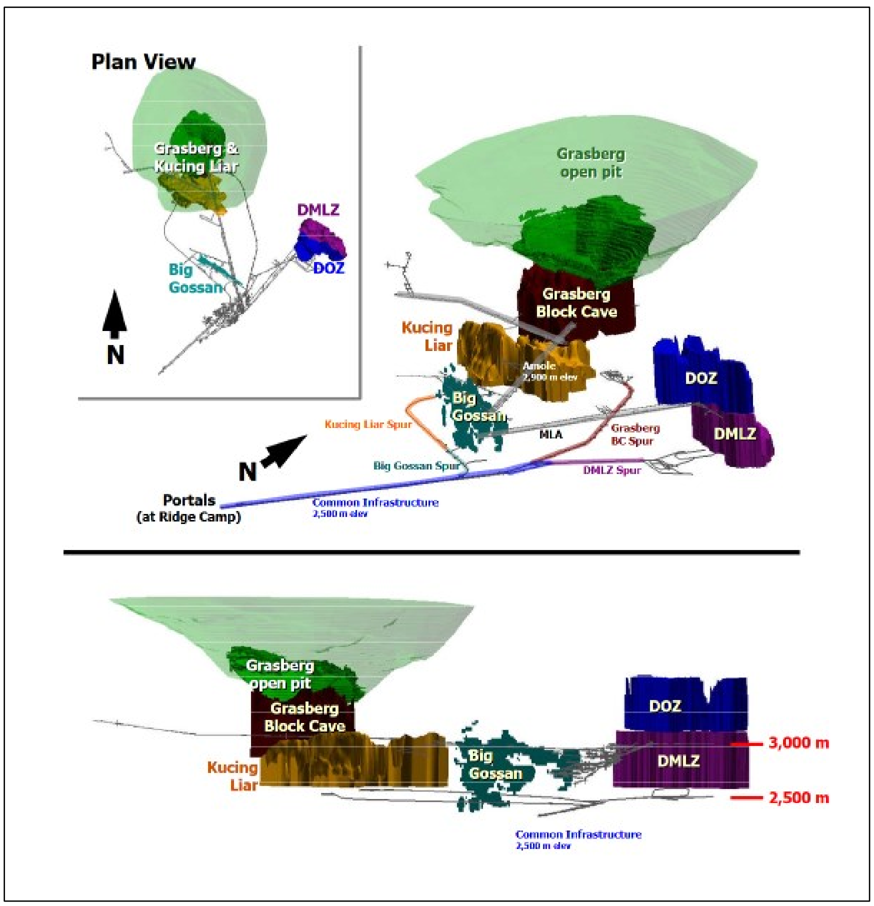


Figure 18. ***Grasberg District ore bodies*[22].**

[22] Brannon, C.A., M.W. Patton, R. Toba and G.A. Williams. 2012. Grasberg Block Cave: Logistical Support System Design. *Proceedings of the MassMin Conference,* Sudbury, Ont, Canada. 10 - 14 June 2012.

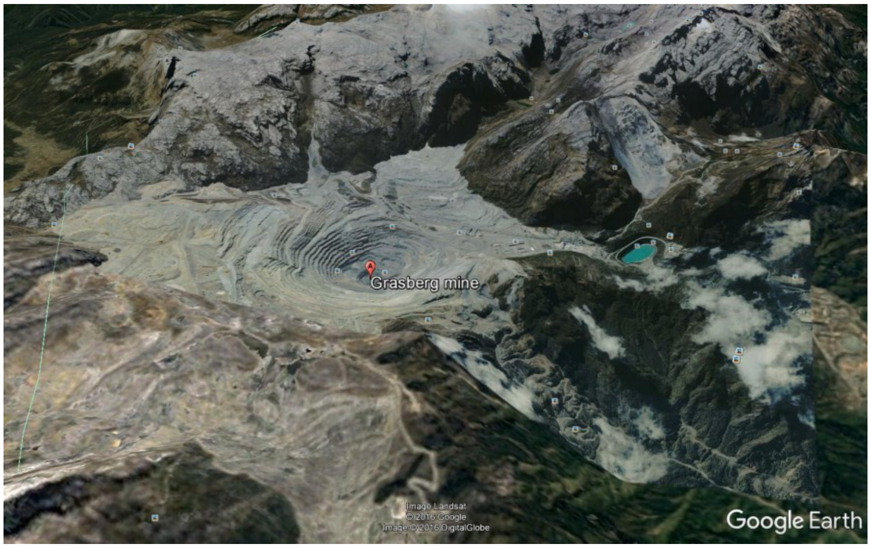


Figure 19. ***Google Earth image of the Grasberg Mine. So, where is the subsidence area?***

8. Resolution Copper

Location: Resolution Copper (RCM) is a joint venture owned by Rio Tinto and BHP Billiton formed to develop and operate an underground copper mine near Superior, Arizona, U.S. The project targets a deep-seated porphyry copper deposit located under the now inactive Magma Mine.

Coordinates: 33° 17' 57.2676" N 111° 5' 56.7708" W

Facts:

- Resolution Copper has a reported[1] mineral resource within a 1% Cu shell (implied COG of 1%) of 1,969M st at 1.54% Cu and 0.035% Mo.
- The project targets a deep-seated porphyry copper deposit located under the now inactive Magma Mine.
- The Resolution Copper deposit is located in an area that has a long history of use by Native Americans including the Salt River Pima Maricopa Indian Community, the Gila River Indian Community, the Pueblo of Zuni, the Yavapai Prescott Indian Tribe, the Yavapai-Apache Nation, the Hopi Tribe, the San Carlos Apache Tribe, the Tonto Apache Tribe, and the White Mountain Apache Tribe.
- In December 2014, Congress passed, and the president signed, the Carl Levin and Howard P. 'Buck' McKeon National Defense Authorization Act (NDAA) for Fiscal Year 2015. Section 3003 of this federal law authorizes and directs the exchange of land between Resolution Copper and the United States.

  The NDAA authorizes and directs the exchange of 2,422 acres of national forest lands located east of Superior, Arizona. In exchange, 5,344 acres of high priority conservation lands would be transferred to the Forest Service and Bureau of Land Management in Arizona, and other lands would be transferred to the Town of Superior.

Opponents (of the land swap) — including Native American tribes, officials and former miners in Superior, and conservationists — say the bill could not have passed Congress on its own merits.

- Through 2012 Resolution Copper had invested almost a billion dollars in the Superior project, and planned a $6 billion investment to develop the mine, if the Federal land exchange is approved. Pending approval, the project budget was cut from about $200 million in 2012 to $50 million in 2013.

  Resolution Copper also owns the mineral rights acquired from ASARCO to the Superior East deposit which is another deep seated porphyry deposit within a mile to the east.

- The mine is expected to take 10 years to construct, have a 40 year operational life, followed by 5-10 years of reclamation.
- Mining would use an underground mining technique known as panel caving. Using this process, a network of shafts and tunnels is constructed below the ore body. Access to the infrastructure associated with the panel caving would be from vertical shafts in an area known as the East Plant Site, near Oak Flat. Using the panel caving technique, ore is fractured using explosives, moves downward by gravity, and then is removed from below. As the ore moves downward and is removed, the land surface above the ore body subsides, or moves downwards. At the surface, a subsidence zone is expected to develop near Oak Flat, with potential downward movement of up to 1,000 feet.
- Crushed ore would be transported underground to an area known as the West Plant Site for processing. The West Plant Site is the location of the old Magma Mine in Superior. Processing would utilize a flotation process.
- Once processed, copper concentrate would be pumped as a slurry about 22 miles to a filter/loadout facility near Magma, Arizona. The slurry pipelines would follow an existing right-of-way known as the Magma Arizona Railroad Company (MARRCO) corridor. The MARRCO corridor would also include: an upgraded rail line, new water pipelines, new utility lines, several intermediate pump stations, and an estimated 30 new groundwater wells. From the filter/loadout facility, copper concentrate would be sent to market using rail or trucks.
- Tailings—the waste material left over after processing—would be pumped as a slurry 4.7 miles from the West Plant Site to a tailings disposal facility located on national forest land. The tailings facility would grow in phases, and eventually occupy about 4,400 acres (including associated structures) of national forest land.

Figure 20. ***Aerial view of Resolution Copper area showing the town of Superior, AZ, Queen Creek Canyon, Oak Flats and Apache Leap[23].***

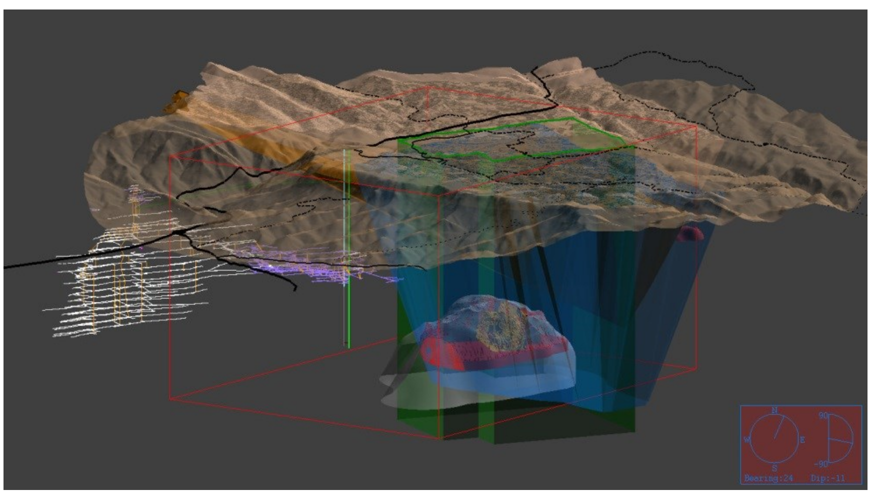


Figure 21. ***3-D view of Resolution Copper area in approximately the same direction as Figure 20 showing the Resolution deposit, the topography above the deposit and the Magma Mine workings.[24]***

[23] Author: zeesstof from The Woodlands, TX, USA; https://www.flickr.com/people/35041397@N00
[24] Courtesy: Resolution Copper, (3/25/2017).

Table 5. ***Summary of important attributes of the block caving mines featured above.***

Mine	Location	Commodity	Mining Method	Production (year)	Ore Mat'l	OB/Waste Mat'l	Ore Depth (Shallow (S): Depth ≤ 300m; Medium (M): 300m < Depth ≤ 1000m Deep (D): 100 m < Depth < ∞)
Northparks	Australia	Cu, Au	Block caving	60,000 tonnes Cu/50,000 oz Au	Copper-gold porphyry	porphyry	M: 850m below surface
El Teniente	Chile	Cu	Block caving	450,000 t Cu	Copper porphyry	porphyry	New Mine Level (M: appx 400m below original workings)
Freeport DOZ	Indonesia	Cu	Mechanized block caving	80,000 tpd	Copper-gold skarn	diorite	Production level of DOZ (D: 1200m below surface)[25]
Cullinan	South Africa	Diamonds	Block caving	920,000 ct to 2.2M ct	Kimberlite	?	M: depth of current mining is 747m. Current depth of resources is 1,073m
Palabora	South Africa	Cu	Block caving	45,000 tonnes Cu per year	Carbonitites	Palabora Igneous Complex	D: 500m below the pit bottom; 1,280m -deep shaft.
Henderson	USA	Mo	Block caving	40 million lb molybdenum	Molybdenite porphyry	rhyolite porphyry	M to D
Resolution	USA	Cu, Mo	Panel caving		Porphyry copper	Porphyry granite	D: orebody is 5,000 ft to 7,000 ft below surface
San Manuel Closed (2003)	USA	Cu	Block caving	60,000 tons ore per day	Porphyry copper	Porphyry granite	M to D (depths from 0 to 2,700 ft for Magma deposit; 2,500 ft to 4,600 ft for Kalamazoo)

ALTERNATIVES TO BLOCK CAVE MINING AT RESOLUTION

The potential alternatives to block cave mining for RCM can be boiled down to:

1. Do not mine
2. Open pit mining
3. Non-caved stopes underground mining (see Table 1: Naturally supported and Artificially supported stopes)

<u>Do Not Mine Alternative</u>. The "Do Not Mine" alternative is beyond the scope of this Technical Memorandum, but will likely be discussed in detail in the Draft EIS.

[25] Operation Focus - Indonesia, *DOZ mine*, International Mining, January 2010, pp 12 - 24.

<u>Open Pit Mine Alternative</u>. When determining whether or not a deposit might be amenable to open pit mining, a well-established process should be followed. Basically what is done is to divide the deposit and surrounding rock mass into cells (blocks), each having a net value (positive, null or negative) based upon the present worth of the commodity contained within the block less all costs associated with removing and processing that block. A sample level map from the Resolution deposit showing color-coded average copper values within each block is shown in Figure 22. The objective is to devise a mining sequence that maximizes the total net undiscounted profit, yet following certain specific rules.

Simply stated, the open pit mining rules and basic assumptions are (Lerchs & Grossmann, 1965[26]; and modified by Caccetta & Giannini, 1986[27]):

Assumptions:

1. The cost of mining each block does not depend on the sequence of mining.
2. The desired wall slopes and pit outlines can be approximated by removed blocks.
3. The objective of the optimization is to maximize total undiscounted profit.

Rule:

1. In order for a block to be considered ***ore***, it must have a value sufficient to pay for its own mining and processing costs <u>plus</u> the cost of mining the waste blocks above it, at the chosen pit slope angle.

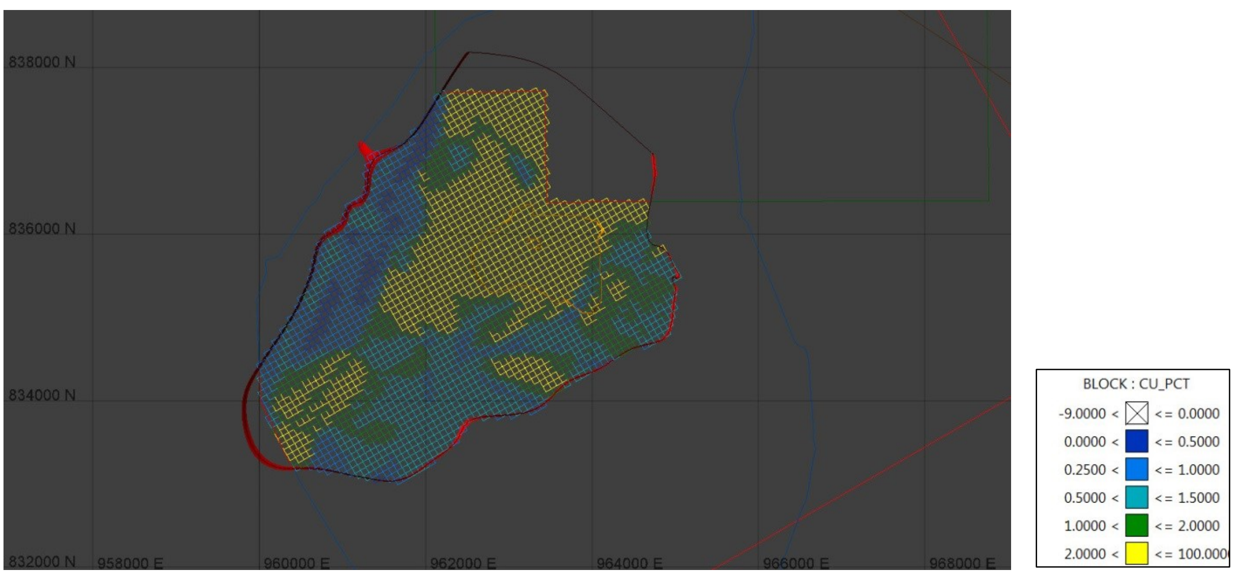


Figure 22. ***Slice through the -1600 level of the Resolution deposit showing block distribution by grade classes.***

[26] Lerchs, H., & Grossmann, I. (1965). Optimum Design of Open-Pit Mines. Transactions, C.I.M. Volume LXVII, 17-24.
[27] Caccetta, L., & Giannini, L. (1986). Optimisation Techniques for the Open Pit Limit Problem. Bull. Proc. Australas. Inst. Min. Metall, Volume 291, No 8.

With these assumptions and the above-stated rule in mind the Lerchs-Grossmann algorithm assigns a cell value (block value) based on the unit of the mineral assessed. A cell is defined as ore if[28]:

Grade x tonnage x Dollar value per unit x recovery - mining cost ≥ profit cut-off

This generates a cut-off grade for the bench. Processing costs are then applied to ore cells after the cut-off is defined. If the resultant cell value is less than the cut-off value, after mining costs are removed, then the waste removal cost is assigned to the cell to indicate that it is waste. If more than one ore type (mineral type) is extracted, the cumulative value is used.

Assay cut-offs/block dollar values are determined by the equations below:

Equation 1: Calculation of grade cut-off
Grade Cut-off (unit/t) = Processing cost ($/t) / Recovery (%) x Ore Price ($/unit)

Equation 2: Calculation of raw cell value
Raw Cell Value ($) = [Assay (unit/t) x Tonnes (t) x Recovery (%) x Ore Price ($/unit) x Ore Proportion (%)] – Modifiers ($/T)

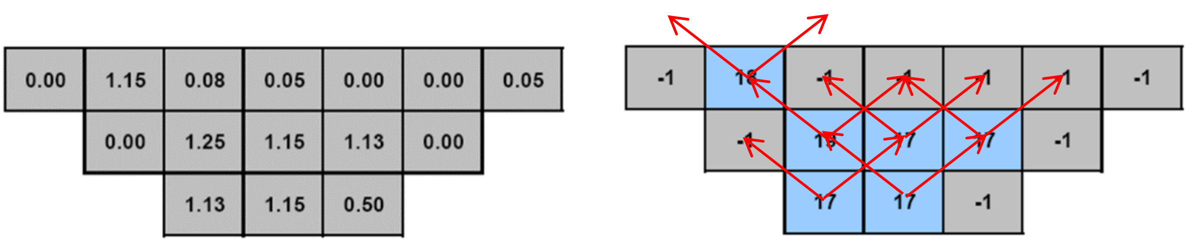
Equation 3: Calculation of cell processing
Cell Processing ($) = [Tonnes (t) x Processing cost ($/t)]

Equation 4: Calculation of cell value
Cell Value ($) = Raw Cell Value ($) - Cell Processing Value ($)

Equation 5: Calculation of final cell value
Final Cell ($) = Cell Value ($) – [Tonnes (t) x Ore Mining Cost ($/t)]

If *Final Cell ≤ Tonnes x Waste Mining Cost,* then the cell is assigned the value of *Tonnes x Waste Mining Cost* (i.e. a model cell cannot cost more to mine than the basic cost of mining).

Figure 23 illustrates how the Lerchs-Grossmann technique (or other optimization technique for open pit mining) works. Red arrows indicate ore blocks which can be mined, removing the associated waste blocks above (Rule 1).



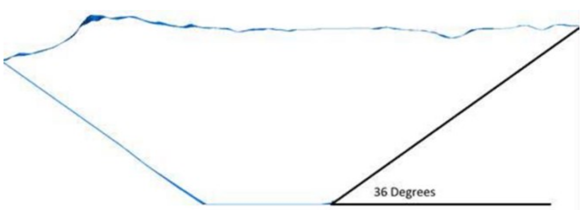
Geologic Model, Copper Grades (lb/ton)   Economic Model, Value per block ($/ton)

Figure 23. ***Deposit representation orebody model.***

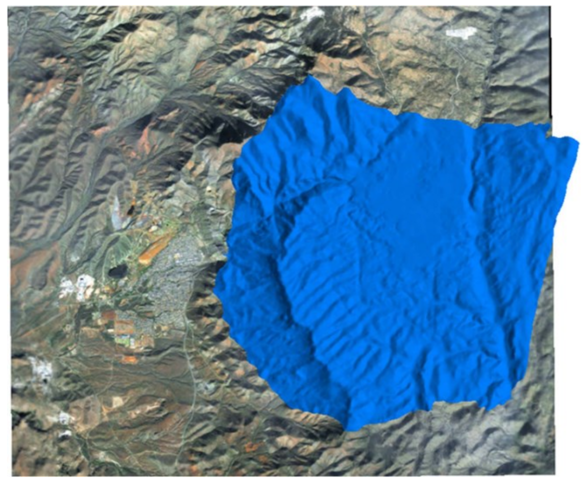
The open pit alternative to developing the Resolution Copper deposit would result in an extremely large volume of waste rock being removed, plus a very large surface footprint of the pit perimeter, plus required storage of the large volume of waste rock in waste repositories. Summarizing[29]:

[28] Mart, W.S. and G. Markey. 2013. *Intelligent Mining Software "Solutions" IMS - Lerch-Grossmann Pit Optimization.* For MineMap Pty Ltd.
[29] Email from Ms. Vicky Peacey, April 7, 2017. Project Record #0001316.

- Overall pit slope of 36° (Figure 24A)
- Overall strip ratio of 35:1
- Footprint of the open pit would be approximately 10,000 acres and would result in the removal of all of Oak Flat, all of Apache Leap, approximately 4 miles of Hwy 60, approximately 3 miles of Queen Creek, and approximately 3 miles of Devils Canyon (Figure 24B)
- Disturbance from an open pit would be approximately 8 times larger than the projected maximum disturbance from subsidence (approximately 1200 acres)
- Estimated volume of waste rock from an open pit would be over 100 times more volume than the projected volume for tailings.
- Results in approximately 205 billion tons of waste rock.



A. Cross-section showing overall open pit slope angle.



B. Approximate open pit disturbance.

Figure 24. ***Cross-section (A) and plan view (B) of the open pit option for the Resolution copper deposit.***

Non-Caved Stopes Underground Mining Alternatives.

The grade - tonnage relationship is widely used in the mining industry. Once modeled for a deposit, it is probably one of the most important tools for representing the variation in tonnage available within a deposit above various cutoff grades. It is especially important for low-grade porphyry copper deposits.

A problem with the grade - tonnage relationship curve, though, is the questionable continuity of grade zones. Depending on the geological characteristics of the deposit and the grade distribution, significant changes in the geometry of a deposit can occur due to variations in the cutoff grade. The grade tonnage curve calculation which is based on a block model counts every single block irrespective of its location and relationship to neighboring blocks, ie, without any consideration of continuity. A block or group of blocks separated from the mineable areas will still be counted and added to the tonnage totals in spite of their isolation and the fact that these blocks will have less probability of being mined if utilizing some sort of selective mining technique.

The grade - tonnage curve, therefore, shows the “best case” scenario, ie, at any cutoff grade the curve assumes implicitly total continuity of the mineralization and every block is considered as equally available to be mined. An example of the above is shown on Figure 22, which is a block representation of the -1600 level of the Resolution deposit. High grade zones are in yellow. If, based upon some constraints, the operator was required to mine only the material above a cutoff of 2% (the yellow zones), then that operator would have great difficulty devising a mining technique to recover all of the +2% material.

Some of the earliest work on the subject of tonnage - grade relationships for the prediction of ore reserves was conducted by Lasky[30] (1950). Lasky found that within porphyries the cumulative tonnage increases at a constant geometric rate as the grade decreases at an arithmetic rate.

Other early researchers in the field of tonnage - grade relationships among copper deposits, including porphyry copper were Singer, Cox and Drew[31] from the US Geological Survey who found a lack of correlation of tonnage and grade amongst deposits for both strata-bound and porphyry deposits. Their conclusions were: (1) Geologic factors influencing tonnage of a particular deposit type are probably distinct from those influencing grade; (2) frequency distributions of tonnages and grades approximate lognormality, making it possible to predict probability of various tonnage-grade classes and to test correlation between variables; (3) no significant correlation was found between tonnage and grade for porphyry or strata-bound deposits; (4) significant negative correlation between tonnage and grade was found for the massive sulfide subset, probably reflecting a mixture of high-grade low-tonnage massive ores, low-grade high-tonnage stockwork, and disseminated ores characteristic of some massive sulfide deposits; (5) significant negative correlation was found between tonnage and grade for the mixture of deposit types in the whole sample.

Given the above discussion, it is worthwhile to attempt to estimate the amount of mineable material which could be available to RCM if they were to opt for a more expensive underground mining technique. This is where the development and utilization of a grade - tonnage relationship for the Resolution copper deposit has value.

Basically, what these researchers, and others (Harris[32], 1984, for example) found for porphyry-type copper deposits was an inverse tonnage - grade relationship within a deposit, but no real relationship amongst deposits. That is, for a given deposit, as the cut-off grade rises, the tonnage available above that cut-off grade decreases by some definable exponential function.

Two charts below (Figures 25 and 26)[33] help determine which underground mining methods may be best suited as alternatives for the Resolution copper deposit. The first one (Figure 25) plots Ore stability vs Ore value; the second one plots Walls stability vs Ore stability.

From Figure 25, it can be seen that for deposits of low value and low ore stability, block caving is the most suitable method. It must also be noted that block caving requires an overlying material (overburden) that will cave.

Figure 26 is appropriate because if one of the non-caving underground stoping methods were to be utilized due to factors such as requiring the tailings material to be repositioned underground in mined-out stopes, then, instead of a massive, disseminated, low-grade deposit, the Resolution deposit would be broken up into smaller higher-grade deposits. This is due to the raising of the cutoff grade, thus lowering the tonnage available above said cutoff grade, by imposing some higher cost mining method (Tables 2 and 3 above). These several higher-grade deposits may or, more likely, may not be contiguous and may not constitute a mineable unit together by the alternative method. Therefore, additional non-contiguous potentially mineable material may be lost by imposing some higher-cost alternative stoping method.

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[30] Lasky, S.G. 1950. How tonnage and grade relations help predict ore reserves: Eng, and Mining JHour., v. 151, no. 4, p 81 - 85.

[31] Singer, D.A., D.P. Cox and L.J. Drew. 1975. *Grade and Tonnage Relationships Among Copper Deposits.* Geological Survey Professional Paper 907-A. US Government Printing Office, Washington, DC.

[32] Harris, D.P. 1984. *Mineral Resources Appraisal: Mineral Endowment, Resources, and Potential Supply: Concepts, Methods and Cases*. Oxford Press.

[33] Author unknown. https://www.slideshare.net/smhhs/mining-methods

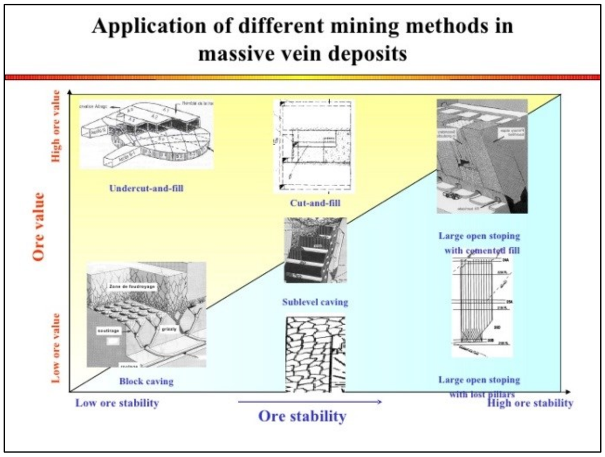

Figure 25.

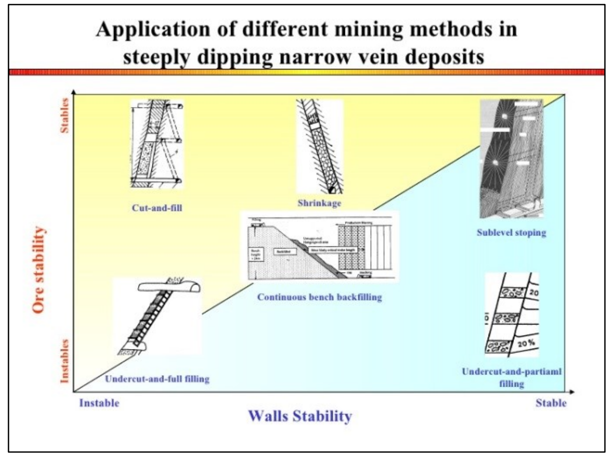

Figure 26.

The most probable mining method which could be imposed and which would allow for the repositioning of mill tailings material back underground is the "cut-and-fill" method. From Figure 26, it can be seen that cut-and-fill stoping is most applicable for material with low wall stability but with somewhat high ore stability; and from Figure 25, it can be seen that cut-and-fill stoping is appropriate for ore of high value (material above a higher cutoff grade).

Upon reviewing Table 1, it can be seen that other non-caving stoping underground mining methods may be applicable to the Resolution deposit. These would include: open stoping, open stoping with pillar support, shrinkage stoping, and VCR stoping.

Open stoping requires strong ore and strong surrounding rock; open stoping with pillars (either regular or random) requires strong ore and somewhat weaker surrounding rock. Generally, open stoping with pillar support is utilized in flat-lying deposits, but it has been used successfully in steeply dipping vein-type or bed-type deposits. Leaving pillars as support results in a loss of ore which is left in place, unless "robbed." Robbing the pillars at the end of mining the stope results in eventual collapse (caving) of the stope, unless backfilled.

Shrinkage stoping requires: (a) steeply dipping ore zones; (b) somewhat strong ore, but weaker wall rock; (c) steeply dipping (60° to 90°) tabular or lenticular ore deposit; (d) uniform ore; and (e) fairly high grade ore. A major drawback to the method, and one from which the method gets its name, is that a large proportion of ore is left in place within the stope to provide wall support as mining progresses upward, and only enough ore is "shrunk" (or withdrawn) out of the stope to allow for a safe working platform for the working personnel in the stope. If the ore material is sulfide in composition and oxidizes, then heat, fire, low oxygen and high noxious fumes (H_2S, amongst others) can be a problem in the stope. Another problem with shrinkage is that a large proportion of the ore is tied up in inventory within the stope until mining is complete within the stope and the ore is shrunk off (withdrawn). After shrinking of the stope, it can be backfilled with tailings or some sort of tailings paste mixture. If not backfilled, collapse (caving) can occur.

VCR (Vertical Crater Retreat) stoping requires both moderate-to-strong ore (> 14,000 psi) and moderate-to-strong waste (> 14,000 psi). VCR mining also requires a fairly thick (> 40 ft), steeply dipping (Dip > 45°; or greater than the angle of repose of the broken material) ore bed of sufficient height and uniformity to justify the method. It is a bulk mining method.

In a nutshell, VCR stopes are developed at some relatively large height, top to bottom. As an example, say 150 ft. A chamber is excavated at the top of the stope of large enough height to accommodate a drill with mast extended. Drill holes are often around 6 inches in diameter. Drill mast heights for underground drills capable of drilling 6 inch diameter holes are around 10 to 15 ft. Another chamber is excavated, along with draw points, at the bottom of the ore zone. This chamber must be of sufficient volume to accommodate the broken ore from a blast round, swelled. A pattern is laid out on the top of the ore zone at some pre-determined burden and spacing. Holes are drilled from the top of the ore zone through the ore zone until they punch out at the bottom of the zone. Deviation of the drilled holes should be minimized. Explosives are loaded at some pre-determined location at the bottom of the ore zone and sequentially blasted in order to drop a slice of the material into the excavated chamber at the bottom of the ore zone. This broken material is withdrawn out of the chamber using appropriate excavators. Another slice is loaded in the same way as the first and blasted into the void. This continues (the retreat up the ore zone) slice by slice until a final top sill of material of sufficient thickness to support blast loading operations remains at the top of the ore zone (usually 2 or 3 times the thickness of each mined slice). This final top sill is taken down in one large blast.

After the stope is blasted and the material is removed, a large void remains. This void can be backfilled with mill tailings or a paste made from the mill tailings to support the walls of the stope.

The name of the method comes from:

> V (Vertical): the stope should be near-vertical (or Dip > 45°)
> C (Crater): the blasting theory applied to break the material in the ore zone slice by slice (Livinston's Cratering Theory[34])
> R (Retreat): Blasting slice by slice retreats up the stope bottom to top.

In order to determine the tonnages available within the Resolution copper deposit above various cutoff grades, it became necessary to estimate the tonnages available at, at least, two known points. The first point was given by RCM in the Parker report of reference 1. The second point was estimated utilizing the level maps provided by RCM (levels -500 to -2500, in steps of 100 ft) similar to Figure 22. All yellow blocks on said level maps were counted and the tonnage per level above the 2% COG was determined. A tonnage factor of 12.5 ft^3/st was used for the porphyry[35].

Tallying the tonnage per level resulted in the tonnage above a COG of 2% as shown in Table 6.

A plot of the two COG vs tonnage points on a semi-logarithmic scale is shown in Figure 27. And Figure 28 shows the same COG vs tonnage plot, but with the addition of the projected tonnage above COGs of 3%, 4% and 5%. It is apparent from Figure 28 that raising the COG lowers substantially the ore grade material available above that cutoff grade. It should be noted that plotted in Figures 27 and 28 is ALL material within the 1% shell above the cutoff grades, and NOT the mineable material. The difference is that some (or in some cases, MUCH) of the ore-grade material may not be mineable via the technique chosen.

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[34] Livingston, C.W., 1956. Fundamentals of Rock Failure, *Quarterly of the Colorado School of Mines*, 51 (3).
[35] Private conversation with Ms. Nichole King, Sr. Geotechnical Engineer, Haile Gold Mine. Formerly at the Freeport-McMoRan Tyrone Mine)

Table 6. ***Total tons (above the -2500 level) within the Resolution copper deposit above a COG of 2%.***

Level	Tons	Level	Tons
-500	0	-1600	40,590,000
-600	0	-1700	41,355,000
-700	675,000	-1800	44,325,000
-800	1,890,000	-1900	30,757,500
-900	2,880,000	-2000	29,700,000
-1000	12,577,500	-2100	23,265,000
-1100	14,040,000	-2200	16,740,000
-1200	13,185,000	-2300	12,870,000
-1300	17,955,000	-2400	7,875,000
-1400	32,175,000	-2500	7,245,000
-1500	36,337,500		
Total = 386,437,500			

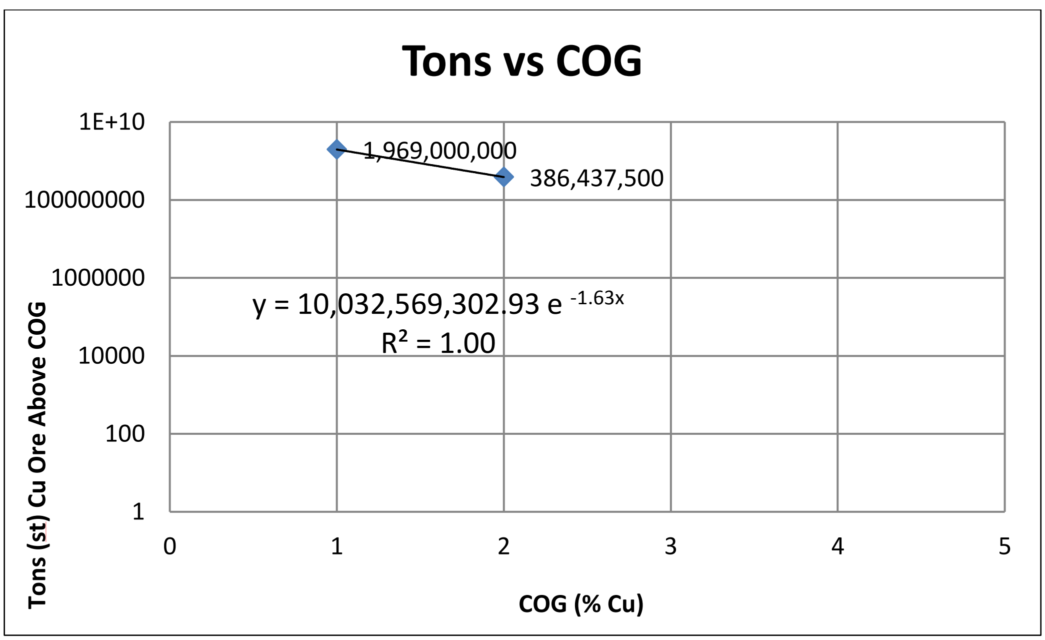

Figure 27. ***Plot of COG vs tonnage for points (1%; 1,969,000,000) and (2%; 386,437,500) for the Resolution copper deposit***[36]

[36] The second point was estimated utilizing the level maps provided by RCM (levels -500 to -2500, in steps of 100 ft) similar to Figure 20. Project Records #0001320 and #0001321.

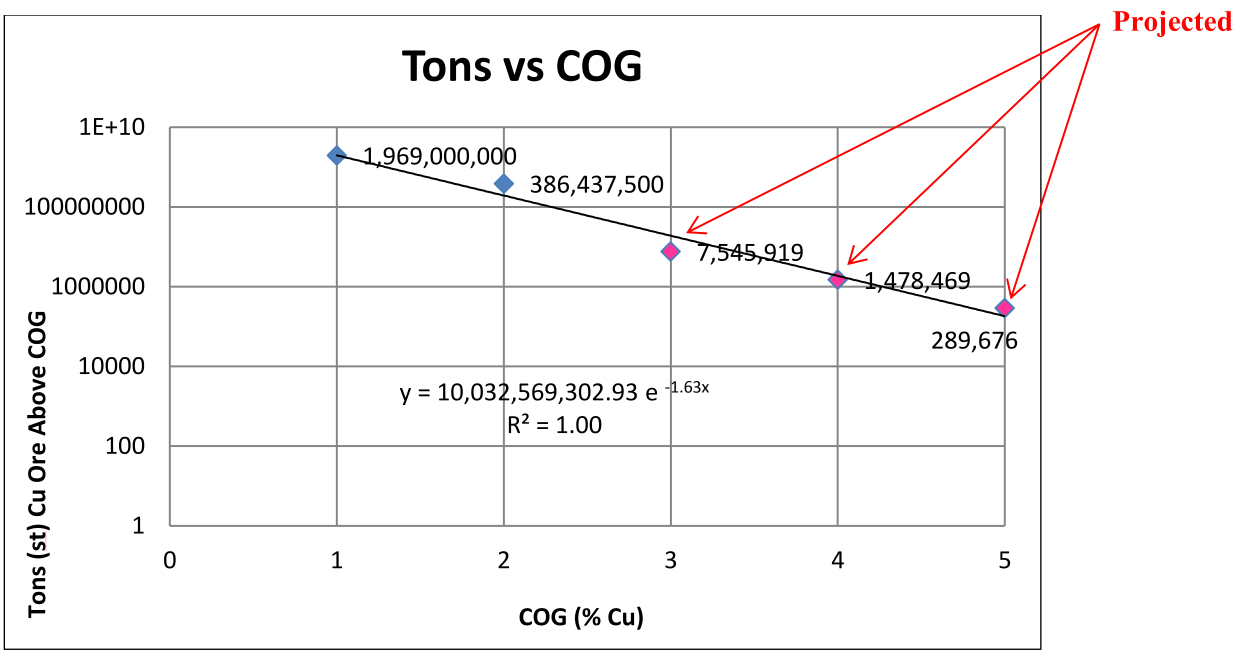

Figure 28. ***Plot of COG vs tonnage for points (1%; 1,969,000,000) and (2%; 386,437,500) for the Resolution copper deposit, plus the extension of the least squares best fit line through 3%, 4% and 5% COG.***

CONCLUSIONS

Block cave mining is by no means new. In the United States, it was used at the Miami Mine (Miami Copper Company, Gila County, AZ), the Climax Mine (Climax Molybdenum, Lake and Summit Counties, CO), Inspiration Mine (Inspiration Consol. Copper Co., Gila County, AZ), Questa Mine (Chevron Mining, Taos County, NM) and others[3]. It is a mass mining method that allows for the bulk mining of large, relatively lower grade, orebodies. This method is increasingly being proposed for a number of deposits worldwide. In general terms block cave mining is characterized by caving and extraction of a massive volume of rock which potentially translates into the formation of a surface depression whose morphology depends on the characteristics of the mining, the rock mass, and the topography of the ground surface.

Block cave mining can be used on any orebody that is sufficiently massive and fractured; a major challenge at the mine design stage is to predict how specific orebodies will cave depending on the various geometry of the undercut.

Other underground stoping mining methods may be substituted for block caving, then backfilled with tailings or a tailings paste mixture, thusly possibly eliminating all or a portion of the subsidence associated with caving. However, this would normally come at a substantial price: higher mining cost and the high cost associated with a tailings batch and pumping plant, resulting in a higher cut-off grade, which in turn results in the loss of block cave mineable resources. As the tons-grade relationship has been shown to be logarithmic[30, 31, 32], substantial low grade material may be lost, and these resources may be lost for good. A stope mining method, however, could allow for more selectivity of mining as only the higher grade material would be selected.

Without data for the copper grade of each block utilized to crate Figures 27 and 28, it is impossible to estimate the amount of actual recoverable copper at a 2% or 3% or other percent cut-off grade. Simply, one cannot estimate the average grade of the potentially mineable material above a given cut-off grade without knowing at least the average grade of the material left after deleting the material below the cut-off grade. This data was not provided by RCM.

In the final analysis, it can be seen from Table 6 and Figure 28 that a substantial amount of potentially mineable resources may be lost by choosing a higher cost mining method over the lower cost bulk method of block caving. The higher operating cost of one of the underground stoping methods results in a raised cutoff grade and, correspondingly, a lowered amount of available mineable material. If maximization of the recovery of the available resource is a priority, this then can be a large problem and can also be unacceptable to whoever owns the resource.

APPENDIX D

Alternative Tailings Public Workshop Summary Report

Alternative Tailings Public Workshop Summary Report

Resolution Copper Project and Land Exchange EIS

Prepared for

U.S. Forest Service – Tonto National Forest

Prepared by

The Rozelle Group
SWCA Environmental Consultants

October 2017

ALTERNATIVE TAILINGS PUBLIC WORKSHOP SUMMARY REPORT

Prepared for

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October 2017

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INTRODUCTION

The Tonto National Forest, an administrative unit of the U.S. Forest Service (Forest Service), is preparing an environmental impact statement (EIS) to consider and disclose the environmental effects from: (1) approval of a proposed plan of operations for mining activities on National Forest System (NFS) land; (2) the exchange of land between Resolution Copper Mining, LLC (Resolution Copper), and the United States; and (3) any necessary amendments to the Tonto National Forest Land and Resource Management Plan. As part of the EIS process, the Forest Service is required to investigate alternatives to various aspects of the proposed action described above. One component of the Resolution Copper Mine General Plan of Operations (GPO) that the Forest Service is investigating is potential alternatives to the proposed location for the tailings storage facility. The Forest Service will evaluate tailings facility locations based upon a variety of technical, environmental, and social criteria.

At the outset of investigating alternative tailings facility locations, the Forest Service hosted two workshops in order to better understand the public's preferences and concerns and solicit input on the relative importance of a variety of environmental and social criteria that it will use to evaluate alternative tailings facility locations. Interactive polling technology was used to solicit preferences from the workshop participants. The results of the preference polls were immediately discussed by the workshop participants in order to gain more insight into the polling results.

The Forest Service also prepared an online workshop with similar polling questions in order for people who could not attend the "live" workshops to participate in the process and submit their opinions regarding the importance of the environmental and social criteria to be used to identify alternative tailings facility locations. The online workshop was available from March 23 to April 5, 2017.

This report documents the public outreach process and presents the results from the two "live" workshops and the online workshop. More detailed information regarding the EIS process can be viewed online at www.resolutionmineeis.us/.

INTERACTIVE PUBLIC WORKSHOPS

The Forest Service hosted two interactive workshops, one in Superior, Arizona, on March 21, 2017, and a second in Gilbert, Arizona, on March 22, 2017. The purpose of the workshops was to:

1. update the public on the status of the EIS process;
2. describe the alternatives development process; and
3. solicit input on the criteria being used to evaluate alternative tailings storage facility locations.

The agenda for the Superior workshop included the following activities:

Open House	5:00 – 5:30 pm
Presentation from Forest Service	5:30 – 6:00 pm
Questions & Answers	6:00 – 6:30 pm
Interactive Workshop	6:30 – 8:00 pm

Based feedback from the Superior meeting, the agenda of the Gilbert meeting was revised to include questions and answers at the end of the workshop:

Open House	5:00 – 5:30 pm
Presentation from Forest Service	5:30 – 6:00 pm
Interactive Workshop	6:00 – 7:30 pm
Questions & Answers	7:30 – 8:00 pm

The open house portion of the workshops provided the opportunity for the public to review information on the EIS process, including the activities and timing of the EIS process. Forest Service representatives and technical staff were available to discuss issues and concerns and answer questions from individual workshop participants. The open house displays and handout materials are presented in Appendix A.

Tom Torres, Deputy Forest Supervisor for the Tonto National Forest, opened the formal portion of the workshop and welcomed the public participants. He briefly reviewed the past activities on the EIS process and introduced Mary Rasmussen, the Tonto National Forest EIS Project Manager. Mary provided a presentation on the EIS decision framework, timing for completion of EIS activities, the results of the public scoping meetings and comments period conducted from March through July 2016, and the requirement to develop “alternatives” as part of the EIS process (Appendix B).

Mary noted that alternatives must (1) meet the purpose and need of the proposed project, (2) be technically feasible from an engineering perspective, (3) be economically viable and (4) address environmental and social concerns. She explained that the purpose of the workshop portion of the meeting was to better understand the public’s priorities regarding the environmental and social concerns as they proceed with the development of alternative locations for the mine tailings. She noted that the EIS public scoping process identified six primary categories of environmental and social concerns, and she reviewed each category (Table 1).

Table 1. Alternative Tailings Locations Environmental and Social Criteria

Resource Criterial	Description
Cultural Resources *Avoids known historic properties and traditional use areas*	Archaeological sites Historic properties (ranches, homesteads, mines) Regional “sense of place” Sites important to Native Americans Traditional resource collection areas (plants, rock, fuel wood, etc.)
Proximity to Existing Communities *Avoids impacting existing communities and residences*	Dust Loss of natural character of the landscape Noise Property values Public health and safety Water quality
Recreation *Protects area recreational opportunities*	Backcountry camping/wilderness Boyce Thompson Arboretum Hiking / climbing / equestrian Hunting Non-motorized trails (Arizona Trail, LOST Trail, etc.) Off-highway vehicle [OHV] routes Scenic driving / touring
Scenery *Protects the area’s scenic qualities*	Clear skies (minimal dust or haze) Dark skies for nighttime viewing Minimize contrast to blend with existing landscape character Potential for concurrent reclamation to reduce impacts to scenery Views from existing residential areas Views from recreational sites Views from area highways
Streams & Springs	Degradation of water quality

Resource Criterial	Description
Protects perennial and intermittent streams and area springs	Loss of riparian vegetation Loss of species that depend on water Loss of unique areas on the national forest Loss of water for irrigation or livestock
Wildlife Habitat *Protects wildlife habitat*	Aquatic species and fish Availability and quality of wildlife habitat Game species Migratory birds Washes and riparian areas Wildlife corridors and movement

Mary also noted that the Forest Service has developed an online workshop that was active between March 23 and April 5 that asked the same questions as the "live" workshops for people who could not attend either the Superior or Gilbert meetings.

Demographic Polling Results

The number of persons that signed in to the workshops was 61 in Superior and 45 in Gilbert. Additional persons that did not sign in may have attended the workshops. During the workshop, interactive polling technology was used to collect participants' opinions regarding the importance of the alternative location criteria. Each participant was given a wireless interactive keypad to respond to questions presented on the projection screen. The individual preferences were electronically collected and compiled so the participants could immediately view and discuss the results. It was noted that the polling results were not intended to be statistically representative of the community as a whole and were designed to focus discussion on the most critical issues and generate discussion regarding the opinions of the workshop participants. While individual responses were anonymous, demographic information was collected to understand preferences of various subgroups.

The polling workshop started out with participant answering a variety demographic questions that asked about participants experience and interests in the Resolution Copper EIS. Following are the polling results of the demographic questions:

Where do you live?

Choices	Combined Results	Superior	Gilbert
Greater Phoenix area	29	7	22
Queen Valley	15	14	1
San Carlos Apache Community	0	0	0
San Tan	0	0	0
Superior / Globe Area	19	13	6
Tucson	2	1	1
Other	10	3	7

What is the primary reason you visit or use this area?

Choices	Combined Results	Superior	Gilbert
Camping	5	1	4
Cultural / traditional uses	5	4	1
Hiking / biking	16	8	8
Horseback riding	2	1	1
Hunting	4	3	1
Off-road vehicle	9	6	3
Rock climbing	6	1	5
Scenery / wildlife viewing	13	7	6
Other	13	6	7

How often do you use this area?

Choices	Combined Results	Superior	Gilbert
Daily	26	19	7
Weekly	23	12	11
Monthly	10	3	7
2 or 3 times a year	11	1	10
Rarely or never	3	1	2

What is your primary concern about the proposed mine?

Choices	Combined Results	Superior	Gilbert
Tailings facility location	21	16	5
Environmental impacts	25	11	14
Regional socioeconomic impacts	6	0	6
Increased employment opportunities	5	3	2
Scenery impacts	2	0	2
Impacts to cultural resources	2	0	2
Mining technique / subsidence	8	5	3
Impacts on recreation opportunities	5	2	3
Other	1	0	1

What is your secondary concern about the proposed mine?

Choices	Combined Results	Superior	Gilbert
Tailings facility location	9	4	5
Environmental impacts	20	11	9
Regional socioeconomic impacts	3	2	1
Increased employment opportunities	3	0	3
Scenery impacts	9	5	4
Impacts to cultural resources	7	1	6
Mining technique / subsidence	14	9	5
Impacts on recreation opportunities	8	3	5
Other	0	0	0

Assuming the mine will be built and assuming that the option is technologically feasible to do, would you prefer:*

Choices	Combined Results	Superior	Gilbert*
The mine tailings be placed in the proposed location	-	-	5
The mine tailings be placed in a different location	-	-	7
A different type of tailings be used, such as dry-stack tailings	-	-	2
A different mining technique be used that might reduce the amount of tailings	-	-	20
Other	-	-	3

*Question added after the Superior meeting because many of the participants expressed frustration that they were only being asked their opinion about alternative locations for the mine tailings and not about mining techniques or the type of tailings being placed.

Importance of Alternative Location Assessment Criteria Polling Results

The participants were asked to rate the importance of each of the following six assessment criteria on a scale of 1 to 9:

A-Cultural Resources - Avoids known historic properties and traditional use areas.
B-Proximity to Existing Communities - Avoids impacting existing communities and residences.
C-Recreation - Protects area recreation opportunities
D-Scenery - Protects the area's scenic qualities.
E-Streams and Springs - Protects perennial and intermittent streams and area springs.
F-Wildlife Habitat - Protects wildlife habitat.

How important is this Assessment Criteria for the Forest Service to consider when selecting a tailings facility location?

1	2	3	4	5	6	7	8	9
Not at all important		Not very important		Moderately Important		Important		Very Important

The average of all responses for the Superior Workshop, Gilbert Workshop, and the combined results can be seen in the following chart (see Figure 1). The frequency distribution combined from the Superior and Gilbert workshops are presented in Figure 2 below. The results for each demographic subgroup are presented in Appendix C.

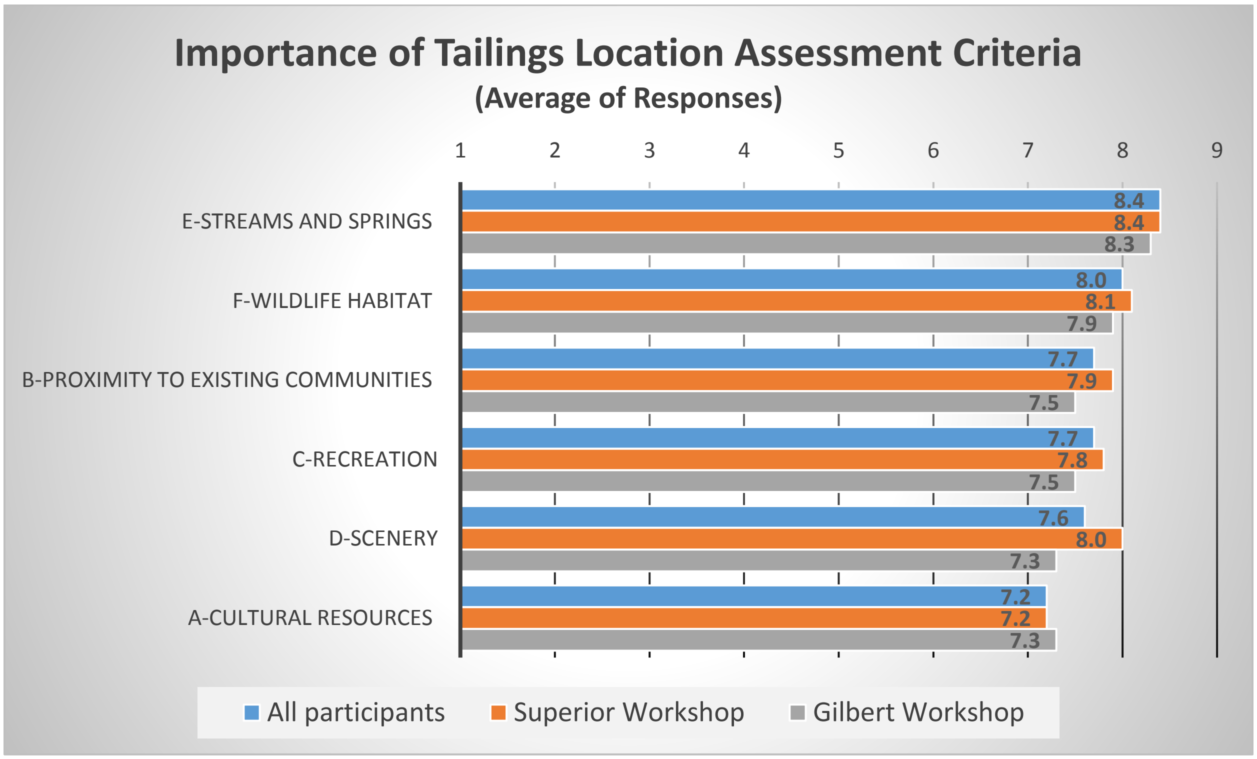

Figure 1. Importance of tailings location assessment criteria.

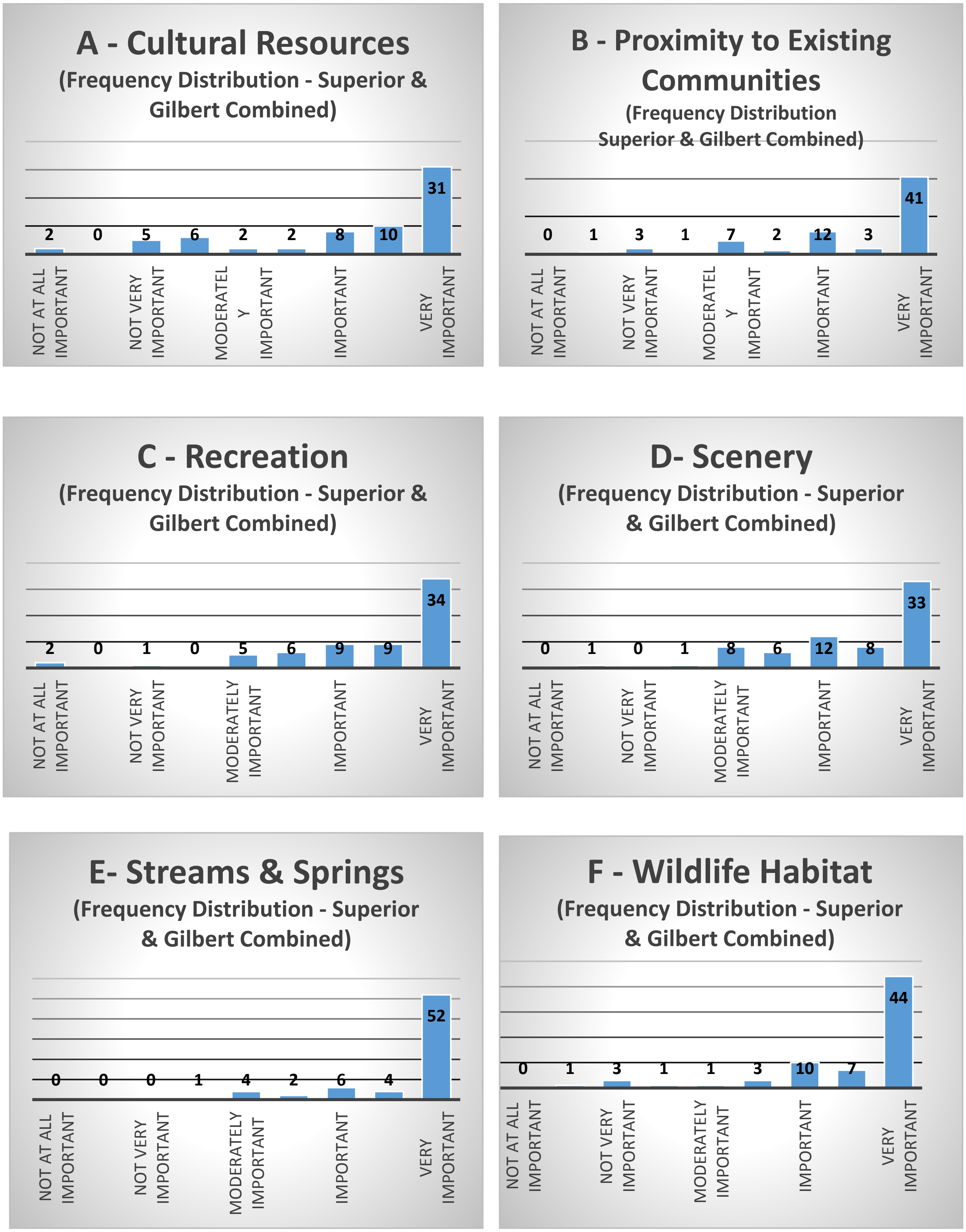

Figure 2. Frequency distributions for each criterion for the online workshop.

Relative Importance of Alternative Location Assessment Criteria Polling Results

The results of the importance poll indicated that all the criteria were considered important (7) to very important (9). A paired-comparison process was used to gain further insight into the participant's preferences and values. The participants were presented with two criteria and were asked to select the one that was more important for the Forest Service to use to select a tailings facility location. For example:

It is more important for the Forest Service to select a tailings facility location that best…

Protects area recreational opportunities (Recreation)
Protects perennial and intermittent streams and area springs (Streams & Springs)

Each workshop participate would select one from the two choices until every possible combination of criteria were assessed. It was emphasized to the participants that they were not selecting one criteria at the exclusion of the other. All things being equal, which was more important to consider when selecting a tailings location.

The results of the paired-comparison exercise are presented in the following table. The table shows the number of polling responses for each workshop and the average percent of time a particular criterion was selected each time it was presented in a pair. Results by demographic subgroup are presented in Appendix D.

Assessment Criteria	**Combined**	**Superior**	**Gilbert**
Number of Responses	50	21	29
E-Streams and Springs - Protects perennial and intermittent streams and area springs.	70%	61%	76%
B-Proximity to Existing Communities - Avoids impacting existing communities and residences.	51%	49%	52%
F-Wildlife Habitat - Protects wildlife habitat.	51%	49%	52%
C-Recreation - Protects area recreation opportunities.	35%	35%	35%
A-Cultural Resources - Avoids known historic properties and traditional use areas.	34%	27%	39%
D-Scenery - Protects the area's scenic qualities.	29%	32%	27%

SUPERIOR WORKSHOP PUBLIC COMMENT AND QUESTIONS

Workshop participants offered general comments and they were also asked to comment on the polling results and provide insight into why specific criteria were ranked higher or lower. Questions and comments below represent what was brought forth at the meeting and have been edited for clarity.

Questions and Comments on Polling Results

- This is pitting the Native Americans against the communities and vice versa.
- Streams and springs are important because it's the desert and you need clean water.
- I would say protecting streams and springs protects all issues down line- if you do that, the tailings wont effect important resources.
- Your polling started with 38 participants and at the end it was 16. Is there a statistical method to correct for the change in numbers?
- It is significant that 28-58% of people did not answer these questions.
- I think there is a bias just in the way questions were asked, and can't be changed, the top two (streams and springs/existing communities). I would say our cultural resources are existing communities. Don't just assume that towns and golf courses are the only communities, our Native American lands are important.
- This is set up to get people to swallow a pill.
- Demographics question "where do you live?" "Other" – we live here by the tailings pile.
- There are a lot people that live down there from here that moved down there years ago (Superior to Gilbert).
- With these pads you are asking us to pick one that is important, when they are all important to us.
- You asked for community input, and that is actually what you are getting with these electronic pacifiers. It's just not in the form you like with your narrow mind.
- At the last discussion, I was under the impression that this was the only alternative proposed. Are you going to other communities to gather this information and comparing the data?
- Can you say again how this information is going to be used in the future? I am worried that by answering the questions that I like the idea of a tailings pile at all. You first question should be "What type of mining would you prefer"? and one option should be "a type of mining that doesn't produce tailings at all".

General Questions and Comments

- I understand why focusing on tailings, it's a huge deal, but it puts the cart before the horse because if you look at the mining method first, you can eliminate 90% of the problems resulting from the tailings.
- I thank you for looking at cut and fill, if you take away block mining we don't create a lot of problems like all the tailings.
- In looking at the alternatives and I noticed you had dry stack- can you explain if that would be a good alternative? You need to look into the feasibility of that. In my opinion it would be a good alternative versus contaminating Queen Creek. I heard they are dumping water into Queen Creek without permits and during rains it runs into Queen Creek. I have a piece of property that has Queen Creek running through it, do I own that land? If tailings contaminate Queen Creek, how will that be dealt with?
- Why don't they store the tailings at Oak Flat? Put it back in the hole.
- On the tailings, why can't you fill the cavity with it?

- How are people in San Tan Valley going to know about this? People out there hardly know about it.
- Why was Gilbert chosen as a place to have a meeting?
- Over a period of time, the pile will fail. It will affect all of us, and the pinheads want us to pick a spot- they don't care about us down here. We will have health issues and dust and property values will go down. Can't sue the government, can't sue the company because it's federal lands. We are concerned about our health.
- Do you have some alternatives you can mention on other lands? BLM, private, other forest lands?
- Why does it have to be on federal lands? They're not paying the citizens of the US for that land, why do they get to put it there? They have permits to mine all over picket post, why can't the tailings go on their properties? Why isn't US being paid to use the land for tailings?
- The US people pay the FS for the land, why doesn't Resolution?
- We live in a capitalistic society, and the company wants profits and that is probably why they don't want to cut and fill. I don't understand why cost is a factor for tailings?
- Mining companies are notorious for filing bankruptcies when they have bonds, what will happen if they declare bankruptcy? How does that bond get forced?
- I am concerned you are using the community working group alternatives because it seems highly biased toward the mine and there were bullying personalities and they didn't like other opinions.
- I have an idea of the five alternatives that Rio Tinto working group came up with, they are biased and not viable. I think if you are going to throw them out you have to tell us what they are. The point of tonight is for us to tell you where our alternative tailings locations are, and we haven't done that. Your exercises don't get to that point, we need a discussion on it, not this attempt to get us to fit your mold. That's not the real rationale for having a public meeting.
- There is institutional bias in the slideshow, Forest Service cannot approve permits for project unless all regulations and laws are met (in response to cost feasibility slide). People should not be required to couch alternatives based on cost.
- In NEPA document will the Purpose and Need be determined by applicant? The proponent attempted to run it through Congress on its own and failed. Will this be addressed? Will the undercutting of NEPA by using the NDAA be addressed in the NEPA document? The precedent that is set by these foreign companies will hurt other companies that go through the process.
- The No Action is a reasonable alternative.
- Under the No Action Alternative, no matter what happens, they still get their mine so the No Action is not a real alternative. If Congress gave the land to the mine, then there isn't a no action.
- Is there a No Action Alternative for the tailings pile? I think there should be. We are being asked to put it on our public lands. Resolution should be required to put it on their private lands. Can the Forest Service tell Resolution Copper to put it private lands? Since Resolution proposed to put it on federal lands, does it have to be considered? Who makes the final EIS decision?
- With the tailings pile on federal lands, there is permanent impact and costs fall on the American taxpayer. Who decides how much money goes into the bond?
- We assume there is a bond in place already. At this point, have you seen any of the money? We've been talking about the profit of the company and the taxpayer's money but the company hasn't paid the money yet. I was hoping for specific dollars.
- What is the Baseline EA bond amount?
- Does the Arizona Realtors Association get a heads up about these projects? People are buying land near the proposed tailings site now and they should know ahead of time if there are environmental problems. Isn't it an ethics problem that people don't know about this mine?
- I live in San Tan and the water that is available there is not good- the water in the rest of Superior is bad. Will good clean water be made available to residents of Superior and Queen Creek during the project? The water from the taps is poor and people drink bottled water. You can't know now

what the water quality is likely to be in the future, but should the water quality be poor as said by the people, what sort of mitigation will be done? If in 20 years it all falls apart and people can't drink the water, what will happen then?

- Mary's comment about "people won't be around", but my grandsons are the fourth generation to enjoy Queen Valley and it sounds like there won't be anyone to protect Queen Valley. Does the community need to come up with an alternative? Why don't you just put the stuff up in Globe? It's already trashed.
- How involved is Arizona Game and Fish Department, University of Arizona, and Arizona State Parks in this decision? I work at the Boyce Thompson Arboretum and they don't seem to know what is going on. The tailings will impact their lands.
- You talk about economic impacts of the company- you don't mention they are exempt from environmental and cultural laws on their private site. Are you taking this into consideration of the bond? Are you notifying the public that there are exemptions to laws for the mining company? Because of the private property (land exchange).

GILBERT WORKSHOP PUBLIC COMMENTS AND QUESTIONS

Workshop participants offered general comments and they were also asked to comment on the polling results and provide insight into why specific criteria were ranked higher or lower. Questions and comments below represent what was brought forth at the meeting and have been edited for clarity.

Questions and Comments on Polling Results

Cultural Resources

- I actually have no idea what the cultural resources of the area are, I would like to know that as well.
- Earth and I are one, the earth is considered the altars.
- Cultural resources are the only resources that are actually and truly non-renewable.

Proximity to Existing Communities

- My family all still lives in Superior and it's important to have clean air. Particles are carcinogens and it's important to keep dust down
- Go to the state of Utah to see what mining looks like.
- I live in Queen Valley, from parts of Queen Valley you can see the tailing pile. It will use 40 times more water than the whole town and the pile will cover the watershed that feeds the Queen Creek aquifer. When it rains in Superior our wells rise up because it's feeding our aquifer.

Recreation

- If we are not able to get out in the wild nature, we don't know to love it.
- If you've ever been in that 4,400 acres, its right in the heart of an awful lot of recreation that's going to be cut off from me and my friends.
- It's easily accessible and egalitarian and it's free at Oak Flat. I bring my kids and they love it.
- Oak Flat is the area where I learned to rock climb. I know thousands of people that go there. There are tons of routes and AZ Mountaineering Club does training there twice a year at sites like

lower lunar, pond, Atlantis. It is an incredible destination close to Phoenix that cannot be replicated.

- Every time we have visitors from the northwest we go to Boyce Thompson Arboretum. My friend goes out there to walk her dog because it is so wonderful.
- Soldiers coming back need places like that to calm their inner selves, as Arizona gets more populated we need these places.
- Oak Flat should be known and protected like Chiricahua National Monument, etc.

Scenery

- Once the scenery, Superior's lifeblood, is gone (people go there for the scenery) it'll be just like any other town.
- Resolution said the ore body has 6% copper rate is great and the ore is far down. This means 94% of Picket Post is going to be above ground.
- During reclamation is there any chance that the subsidence can be backfilled with tailings?
- I'd like to see an alternative mining under the top left structures.
- As far as subsidence is concerned, as I understand it, the place will never be able to be used again ever for recreation, for anything.
- What authority does the Forest Service have left to impose any restrictions on the mine? It is smoke and mirrors that were just talking about tailings.

Streams and Springs

- We live in a community downstream from the process and are concerned about water and air quality.
- We can't live without clean water.
- If the focus has been on mine, I would have ordered things differently, but because its tailings I chose streams and springs.
- I backpack and camp in AZ and there's no way to survive in the desert without water.
- Water is life.
- Superior is the headwaters of Queen Creek. Before 1952 it ran year round. Now after pumping 24/7 private wells are being dug deeper and the creek is only underground. This is the desert, why are we letting any company come in and take our precious resource. Every community needs 100 year water supply, but it's getting harder and harder to guarantee that.
- Why does the Forest Service not say no to a foreign company that give tons of money for a secret mine?
- Any federal agency only has to permit the project through the NEPA process if it's a federal action. Given that the land exchange mandates that, does the Forest Service have a choice with the mine as a connected action? After the land exchange who owns the land? If it's Resolution, it's not a federal action.

Wildlife Habitat

- This question ties into spring and streams due to the leaching of the chemicals from the tailings pile. This is detrimental to wildlife.
- Streams and wildlife are the environment.
- Humans are not the only important people.
- Once wildlife is gone from this earth it will never come back.
- Wildlife itself has a right to exist. As a person, I want it to be part of my life and we have to go farther and farther away until you won't be able to go that far anymore.

Superior and Gilbert Workshop Criteria Results Comparison

- I am just curious if your meeting in Superior had different results?
- It came out in Superior that these questions are choices and when you're in a situation where the tailings are is totally unacceptable, it's like would you rather have an arm or a leg? You need to look at the validity of that section.
- Since we are talking about data and statistics, will the Forest Service be working with Arizona Department of Health Services and using the data on cancer clustering and health of small communities when putting together the EIS? You can use that data to identify vulnerable populations in the future.
- My statement is about the graphs. Water is the top concern for both nights. That says we are so concerned about water and the tailings going in the proposed area. You are ruining the area with no liner under the tailings. The springs and the water concern being so big it goes to show that where the tailings are proposed to be is not a good place.

General Comments and Questions

- Any idea what the size of the tailings will be? How high will it be?
- I really question the validity of the approach. It's like a Sophie's choice- none of the alternatives are mutually exclusive. You're creating false dichotomies. I encourage you to come up with a different approach in the future.
- I am concerned about the exchange value of properties in the land exchange. I want to make sure the economy is relevant. During the NDAA an article was written about the copper value being given away. I am curious to know if the appraisal decision process is considering this. It supposedly is the most valuable ore deposit in the world.
- Why is the land used for tailings not included in the exchange? It sounds like the mining company is getting more land if you include the tailings?
- Where is the increase in budget to pay for the USFS reports? Who pays for the consultants?
- When all these decisions are made and all of the analysis is done, who holds Resolution Copper responsible? Are they fined if they are not doing what they said they'd be doing? Who polices them?
- I was in Green Valley this weekend. We can do better than that tailing pile and also tailings piles in Globe.
- I come from San Carlos and I worked in mine. In the underground mine why not undo that block caving? It's going to be an eyesore. Open pit mining is an eyesore. Underground mining as done at Inspiration is the most feasible as you can shore it up from the inside.
- I am concerned about tailings and Highway 60. How is it supposed to cross the 60 in a safe manner? Tourists enjoy the highway and the pullouts.
- Is all of the land off limits in the proposal or are there areas for rock climbing for people to enjoy? There is a close corridor next to the highway that people enjoy.
- Will Highway 60 be closed? How can it not be if there's going to be a crater? Mines fall into the crater all the time.
- I want to point out that in the MARRCO corridor the Plan calls for 30 water wells for main water uptake, after the CAP water runs out, that will take 120,000 gallons every minute between Florence and Magma.
- The Forest Service is between a rock and hard place. In addition to mining law, there are problems with McCain, Flake, and friends of the mining industry in congress. When the Forest Service says their hands are tied it's not exactly the case. You could make it more difficult for Rio Tinto. Rio Tinto is flailing and cannot accomplish it, if we work really hard we can take this decision out of the USFS hands and Rio Tinto will leave on their own.

- Where is the Superstition Vistas alternative location on the map?
- When you presented the questions, it said should the Forest Service will select a site for the tailings. It's not really your decision is it? If the tailings are going on Forest Service land they're going to go where they are proposing and where there is opposition. Only if the Forest Service denies the permit does it go on other land for consideration.
- I just wanted to say I do volunteer work for Forest Service. Last April and May in the Coronado National Forest Patagonia was having a problem that we are having here. There were stories about a mining company that was coming in there and the destruction that was happening to the roads. If you go out on the highway – they are two lane highways- the trucks take up the whole highway.
- On the map does the blocked off part with the yellow line the tailings go -- it shows it would wipe out Happy Camp Road. Is that correct? That's the main road going to Montana Mountain and is a popular ATV route. A lot of people move to Arizona to ride ATVs. They're going to have to go up on a ride and turn around and come back down. Loop opportunities would be lost. I know a lot of people don't know they would lose the roads.
- At the beginning of the presentation one of the criteria for evaluating the alternatives is the financial cost. Is this the cost of the EIS, of the EPA for clean ups, or the cost to Resolution Copper? Resolution Copper is essentially a shell company. They have nearly unlimited resources and I do not want to hear that there are any options too expensive for them to shoulder.
- As we know at the federal level, there are potentially a lot of changes happening. How will that effect the NEPA process? Will it cause you to redo things, delay it, or speed things up?
- Last night you mentioned the No Action Alternative was not an option. Isn't it true that it's a violation of NEPA if you go forward with that not as an option?
- Would Resolution consider mining with some other method, other than block caving?

ONLINE WORKSHOP

An online workshop was available from March 23 through April 5, 2017. The polling questions were the same as the polling questions asked at the live public workshops. Following are the polling results of the online workshop.

Demographic Information

Where do you live?

Choices	Online Results
Greater Phoenix area	118
Other	68
Queen Valley	9
San Carlos Apache Community	2
San Tan	2
Superior / Globe area	7
Tucson	24
Grand Total	230

Additional text response for those choosing "Other"

Arizona City	1	Mesa	3
Bisbee	1	Mesa, AZ	1
California	2	Newbury Park	1
Chandler	1	Patagonia	1
Chandler/Gila River Indian Com	1	Phoenix	1
Corydon, In.	1	Prescott	3
Cottonwood	1	Prescott Valley, AZ	1
Dundee Scotland	1	Redondo Beach, CA (born in Ray)	1
Flagstaff	1	San Antonio	1
Florence, AZ	1	San Diego, CA	1
Graham County	1	Santa Fe	1
Kansas	1	Saratoga Springs, NY	1
Lake Point, UT	1	South East	1
Lave	1	Tennessee	1
Los Angeles	2	Texas	1
Los Angeles County	1	Venice, Florida	1
Los Angeles, CA.	1	Virginia	1
Maricopa	6	White Mountain	1
Marin County, CA	1		

What is the primary reason you visit or use this area?

Choices	Online Results
Camping	27
Cultural / traditional uses	24
Hiking / biking	56
Horseback riding	3
Hunting	4
Off road vehicle	5
Rock climbing	14
Scenery / wildlife viewing	87
Other	10

Additional text response for those choosing "Other"

Bird watching, want to protect

Conservation

I don't use this area

Never

Off roading

Public land needs preservation

school discussion Biotech

How often do you use this area?

Choices	Online Results
Daily	8
Weekly	14
Monthly	43
2 or 3 times a year	112
Rarely or never	52

What is your primary concern about the proposed mine?

Choices	Online Results
Tailings facility location	24
Environmental impacts	151
Regional socioeconomic impacts	4
Increased employment opportunities	5
Scenery impacts	5
Impacts to cultural resources	25
Mining technique / subsidence	6
Impacts on recreation opportunities	6
Other	5

Additional text response for those choosing "Other"

All of the above.

All of the above concern me.

All of the above.

Destruction of public lands.

It belongs to the Indians.

What is your secondary concern about the proposed mine?

Choices	Online Results
Tailings facility location	38
Environmental impacts	53
Regional socioeconomic impacts	6
Increased employment opportunities	4
Scenery impacts	29
Impacts to cultural resources	56
Mining technique / subsidence	12
Impacts on recreation opportunities	26
Other	7

Additional text response for those choosing "Other"

All of the above.

All of the above.

Each one affects the other.

Environmental impacts & tailings.

Jobs will be minimal.

Poisoned health.

Privatization of public lands.

Assuming the mine will be built and assuming that the option is technologically feasible to do, would you prefer:

Choices	Online Results
The mine tailings be placed in the proposed location	9
The mine tailings be placed in a different location	52
A different type of tailings be used, such as dry-stack tailings	6
A different mining technique be used that might reduce the amount of tailings	117
Other	42

Additional text response for those choosing "Other"

All of the above.	No mine is built.
Destruction is unacceptable.	No mine.
Do no harm.	NO MINING.
Do not allow the mining, period.	NO MINING.
Don't assume.	NO MINING TO BE DONE!!
Don't build the mine!!	No mining to start.
Don't destroy this area.	No tailings.
Dry stack tailings backfill.	None. I do not approve.
I can't imagine toxic.	Not mine at all.
I do not want the mine built.	NOT put anywhere near this are.
I prefer the mine not be built.	Tailings back into mine.
I will not assume destruction.	taken to Resolution Copper.
Least impact, highest cost.	That the mine NOT be built!
Leave the copper alone!	The mine not be permitted.
No Action on tailings.	The mine shouldn't be built.
NO MINE.	The mine would not be built.
No mine.	This is a bad assumption.
No mine.	We have enough copper why more.

Importance of Alternative Location Assessment Criteria Polling Results

The participants were asked to rate the importance of each of the following six assessment criteria on a scale of 1 to 9:

A-Cultural Resources - Avoids known historic properties and traditional use areas.
B-Proximity to Existing Communities - Avoids impacting existing communities and residences.
C-Recreation - Protects area recreation opportunities
D-Scenery - Protects the area's scenic qualities.
E-Streams and Springs - Protects perennial and intermittent streams and area springs.
F-Wildlife Habitat - Protects wildlife habitat.

How important is this Assessment Criteria for the Forest Service to consider when selecting a tailings facility location?

1	2	3	4	5	6	7	8	9
Not at all important		Not very important		Moderately Important		Important		Very Important

The average of all responses for the online workshop can be seen in Figure 3 below. The frequency distributions for each criterion for the online workshop are presented below (Figure 4). The results for each demographic subgroup are presented in Appendix C.

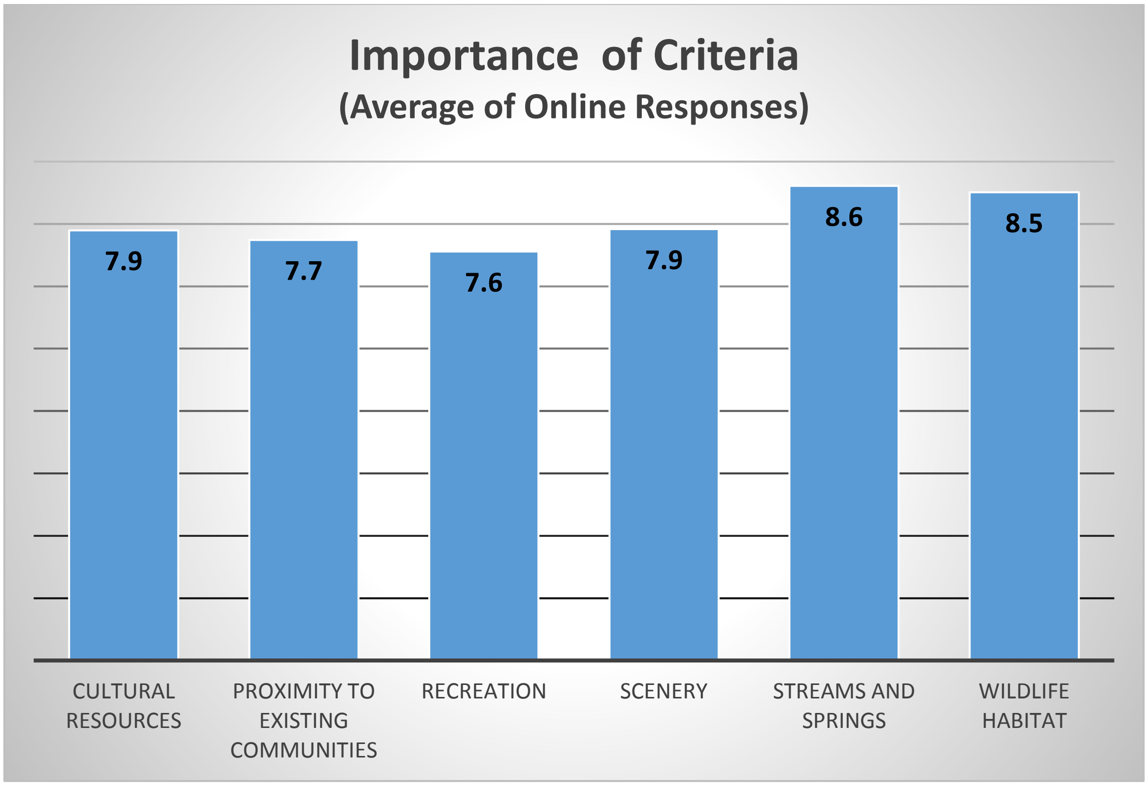

Figure 3. Importance of criteria for the online workshop.

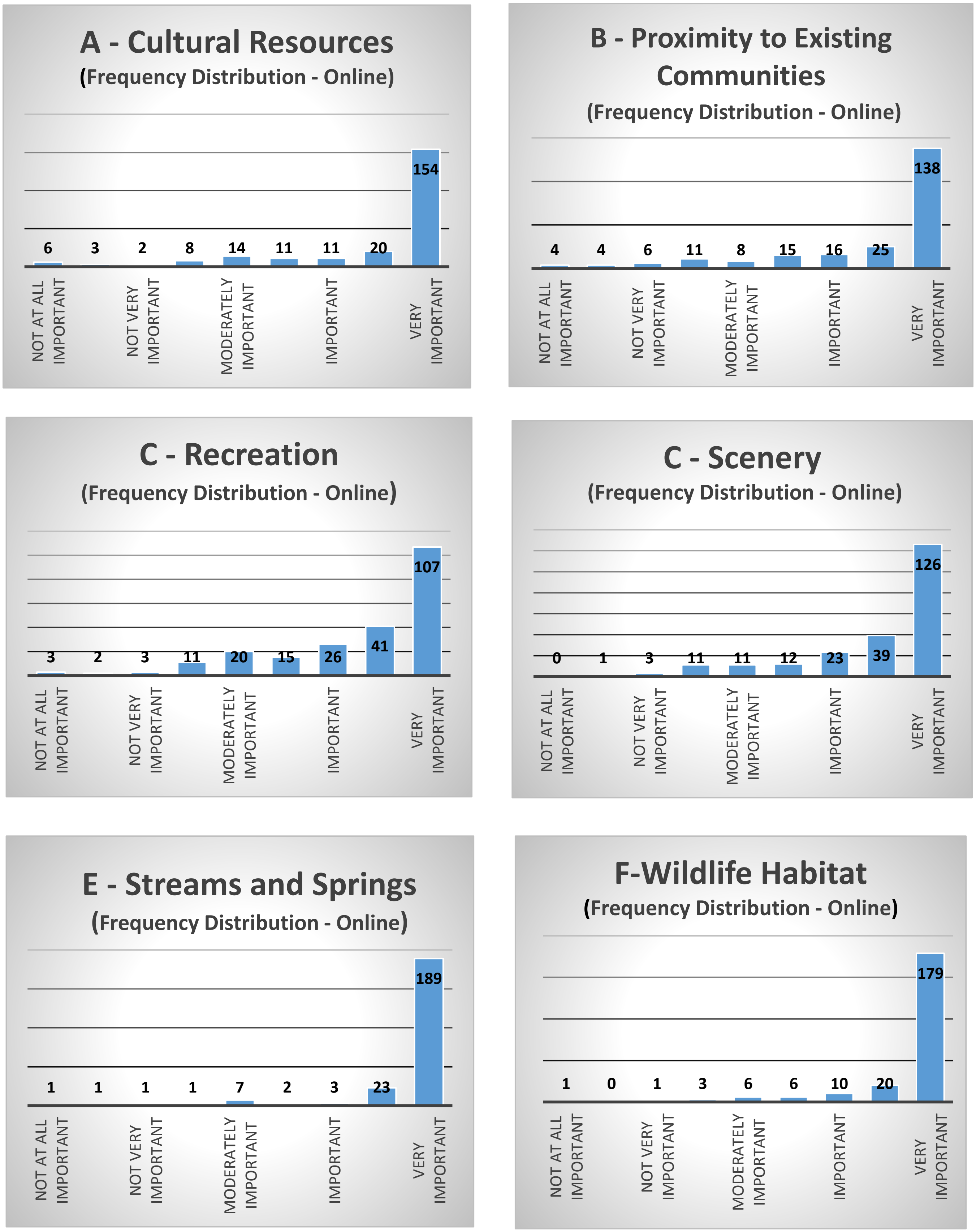

Figure 4. Frequency distributions for each criterion for the online workshop.

Relative Importance of Alternative Location Assessment Criteria Polling Results

The results of the importance poll indicated that all the criteria were considered important (7) to very important (9). A paired-comparison process was used to gain further insight into the participant's preferences and values. The participants were presented with two criteria and were asked to select the one that was more important for the Forest Service to use to select a tailings facility location. For example:

It is more important for the Forest Service to select a tailings facility location that best…

Protects area recreational opportunities (Recreation)
Protects perennial and intermittent streams and area springs (Streams & Springs)

Each workshop participate would select one from the two choices until every possible combination of criteria were assessed. It was emphasized to the participants that they were not selecting one criteria at the exclusion of the other. All things being equal, which was more important to consider when selecting a tailings location.

The results of the paired-comparison exercise are presented in the following figure. Figure 5 shows the average percent of time a particular criterion was selected each time it was presented in a pair.

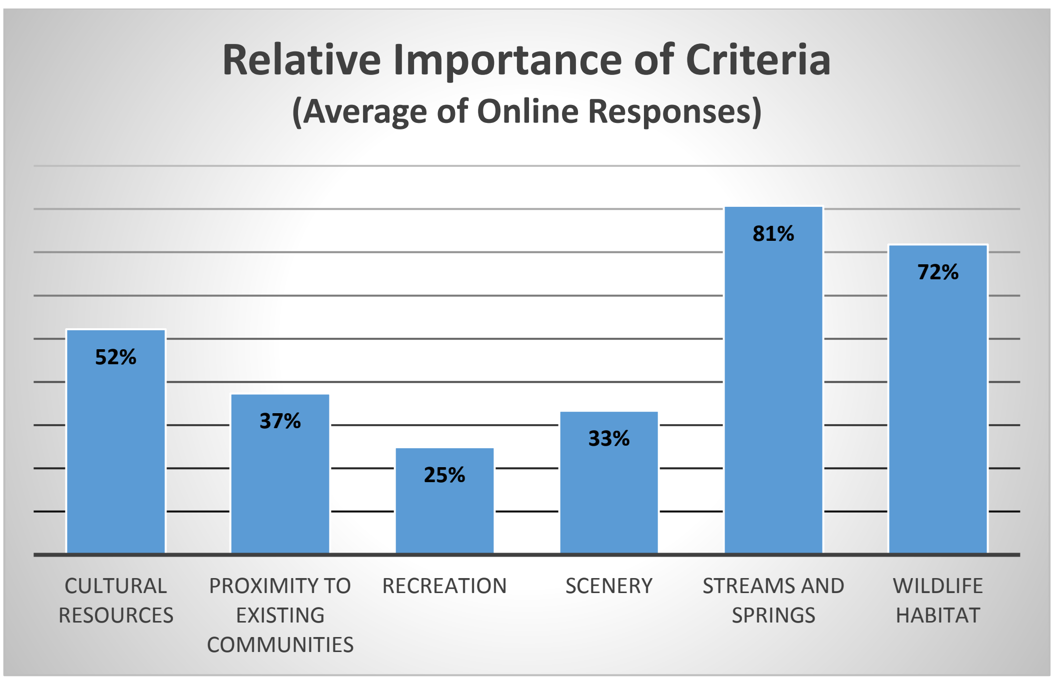

Figure 5. Relative importance of criteria for the online workshop.

APPENDIX A

Open House Meeting Displays and Handout Materials

APPENDIX B

Forest Service Presentation Slides

APPENDIX C

Workshop Polling Results: Importance Ratings by Demographic Subgroup

APPENDIX D

Workshop Polling Results: Relative Importance Ratings by Demographic Subgroup

APPENDIX E

Tailings Disposal Alternatives Technical Memorandum

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Project Memorandum

To:	**SWCA Environmental Consultants**		
Attention:	**Chris Garrett**		
From:	**Derek Hrubes, Tony Monasterio, Jorge Castillo**	**Date:**	**October 24, 2017**
Subject:	**Resolution Copper Project EIS– Tailings Disposal Alternatives Development - DRAFT**		
Project No.:	**1704002**		

The purpose of this memorandum is to document technical and engineering input provided for the development of potential tailings storage facility (TSF) alternatives, as part of the broader development of a reasonable range of alternatives to be analyzed in the Resolution Copper Project Draft Environmental Impact Statement (EIS). BGC Engineering (BGC) is providing mine tailings expertise to SWCA Environmental Consultants (SWCA) and the United States Department of Agriculture Tonto National Forest (TNF). The TNF is the lead Federal agency for the EIS, and SWCA is the TNF's third-party EIS contractor. The TNF, SWCA and their consultants, including BGC, comprise the EIS project team.

The proposed action, described by Resolution Copper Mining (RCM) in the General Plan of Operations (GPO 2016), includes a thickened[1] slurry TSF, with an upstream-constructed dam embankment. Located west of Superior, Arizona, between Roblas Canyon and Potts Canyon, this location is referred to as the "Lower West" site, as shown in Figure 1-1. As part of the alternatives development process, the TNF-led EIS project team considered a broad range of potential alternative TSF locations and configurations to address issues raised during scoping.

Of 30 potential locations initially considered for tailings disposal, 11 total design scenarios at 6 distinct locations met the screening criteria established by the EIS project team. These have been evaluated as possible tailings disposal alternatives, as described in the sections below. The alternatives carried forward for further analysis in the EIS are described in the *Briefing Paper – Proposed Range of Alternatives for Detailed Analysis* (SWCA, September 2017).

Note that the design scenario evaluations conducted by BGC were prepared as one input into the next phase of the overall alternatives development process. Details contained in this memo should not be construed to represent the entirety of the alternatives analysis or the only considerations in front of the project team.

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[1] Thickened tailings involve the mechanical process of dewatering low solids concentrated slurry to produce a solids density generally ranging from 35 to 65 percent. The GPO indicates that scavenger (NPAG) tailings would be thickened to 65% solids density, and cleaner (PAG) tailings to 55% solids density.

1.0 ALTERNATIVE TSF LOCATIONS

1.1. Initial Alternative Locations

An initial list of 30 alternative tailings disposal site locations was identified by the EIS project team, and summarized below. This initial identification of alternative locations did not include consideration of different dam configurations or disposal methods, only general geographic location. Figure 1-1 depicts the location of all the following identified sites:

1. Lower-West (GPO base case)
2. Far-West
3. Hewitt Canyon
4. Lower-East Happy Camp
5. Pinto Valley Mine
6. Silver King Canyon
7. Telegraph Canyon
8. Whitford Canyon
9. SWCA 1
10. SWCA 2
11. SWCA 3
12. SWCA 4
13. BGC- A
14. BGC- B
15. BGC- C (Later renamed the Peg Leg site by the TNF)
16. BGC- D
17. Proposed Resolution Copper Mine Subsidence Area
18. Pinenut Mine
19. United Verde
20. Copperstone
21. Casa Grande
22. San Manuel (Mammoth)
23. Tohono
24. Johnson's Camp
25. Twin Buttes
26. Copper Queen
27. Upper Arnett
28. Carlota
29. Globe/Miami
30. Ajo

1.2. Initial Screening and Consolidation of Alternative Locations

The 30 potential alternative locations were evaluated and consolidated during several alternatives development meetings with the EIS project team. These locations have also been termed the "initial alternative tailings locations". Members of the EIS project team, representing a range of technical expertise, held a two-day workshop in April 2017 to begin evaluation of all the possible alternative tailings facility locations. A qualitative discussion and screening was conducted using criteria established by the EIS project team, and categorized by potential impacts to water resources, biological resources, scenic resources, recreation, and public health and safety. If an alternative location had, in the opinion of EIS project team, significant disadvantages over the proposed action, then the site was eliminated.

A summary of discussion considerations for each location is included below in Table 1-1.

Table 1-1. Considerations for potential alternative tailings locations.

Location	Advantages	Disadvantages
Lower-West (GPO proposed location)	Proposed action	Potential downstream impacts and proximity to residences/towns
Far-West	Proximity to water source (usage), limited visual impacts, no public recreation, limited identified vegetation and animal habitat, further visually from frequented areas (roads, trails, etc.), potential downstream impacts and proximity to residences/towns	State Land is set aside for residential use, proximity to water source (leakage/seepage) with geological containment, limited vegetation
Hewitt Canyon	Further from frequented areas (roads, trails, etc.) as compared to the proposed GPO location, lower potential downstream impacts and proximity to residences/towns	Significant good vegetative coverage, near a Wilderness Area
Lower-East Happy Camp	N/A	Proximity to Superior and highway, adjacent to Boyce Thompson, potential downstream impacts and proximity to residences/towns
Pinto Valley Mine	Some tailings could potentially go into pit (minimizes tailings disposal), groundwater is already impacted and so less change to current condition, pre-disturbed area	Currently in operation with projected 22-year mine life.
Silver King Canyon	Not visible from highway, good topography for water recovery	Significant number of intermittent streams, visible from Arizona Trail, existing workings under TSF, significant good vegetative coverage, potential downstream impacts and proximity to residences/towns
Telegraph Canyon	N/A	Adjacent to major cultural area, perennial waters, possibility to native fish repopulation, beautiful geology and floral/fauna, footprint partially covers a protected bird area, close in proximity to frequented areas (roads, trails, etc.), right on top of Arizona Trail
Whitford Canyon	Lower potential downstream impacts and proximity to residences/towns	Significant good vegetative coverage
SWCA 1	No springs, limited identified vegetation and animal habitat	Proximity to Gila River, but might already have poor quality, more difficult stormwater management, proximity to Arizona Trail

Table 1-2. Considerations for potential alternative tailings locations. (Continued)

Location	Advantages	Disadvantages
SWCA 2	No springs, limited identified vegetation and animal habitat	Proximity to Gila River, might partly cover Ray Land Exchange, proximity to Arizona Trail, more difficult stormwater management
SWCA 3	Limited identified vegetation and animal habitat	Steep terrain and difficult water management, impacts multiple water sheds (flows north and south within basin, right on top of Arizona Trail
SWCA 4	Further in proximity from frequented areas (roads, trails, etc.)	Drainage to Roosevelt Lake, perennial stream, undisturbed land, visual impacts, high recreation, cuts off access, tough terrain, capacity requirement takes it into wilderness area
BGC A	Limited identified vegetation and animal habitat	Close proximity to town of San Tan Valley and new developments
BGC B	Limited identified vegetation and animal habitat	Proximity to town of Florence and rural homes
BGC C	No springs, further from Gila River, limited identified vegetation and animal habitat, lower potential downstream impacts and proximity to residences/towns	Proximity to Arizona Trail
BGC D	No springs, limited identified vegetation and animal habitat, potential downstream impacts and proximity to residences/towns	Proximity to Gila River, proximity to Arizona Trail
Proposed Resolution Copper Mine (backfill underground disposal)	N/A	Not technologically feasible with proposed panel caving
Pinenut Mine	N/A	Too far, not enough capacity, other side of Grand Canyon
United Verde	N/A	Insufficient capacity
Copperstone	N/A	Insufficient capacity
Casa Grande	N/A	Insufficient capacity
San Manuel (Mammoth)	Sufficient capacity for pyrite tailings.	Eventual receptor is San Pedro River. Not sufficient capacity for all tailings.
Tohono	N/A	Insufficient capacity
Johnson's Camp	N/A	Insufficient capacity
Twin Buttes	Sufficient capacity for pyrite tailings.	Ownership by Freeport McMoRan with stated intent to develop property, and significant declared mineral resource. Significant distance from project area.
Copper Queen	N/A	Public objection due to previous activities
Upper Arnett	Proximal to RCM mine site and away from town. Geologically suitable.	Next to Route 177. Headwaters of Queen Creek, Superior area and above Boyce Thompson.
Carlota	N/A	Does not have sufficient capacity
Globe/Miami	N/A	Part of an Arizona Superfund/ Water Quality Assurance Revolving Fund (WQARF) site
Ajo	N/A	Significant distance (> 100 miles) from project area.

The initial screening resulted in a consolidation to 11 locations for developing alternative design scenarios:

1. Lower-West (GPO base case)
2. BGC B
3. BGC C
4. Pinto Valley Mine
5. San Manuel (Mammoth)
6. Casa Grande
7. Carlota
8. Upper Arnett
9. Whitford
10. Hewitt
11. Silver King

2.0 TSF ALTERNATIVE DESIGN SCENARIOS

Following the screening of initial TSF locations, and consolidation to the 11 alternative TSF locations, BGC was tasked by the TNF to develop conceptual design scenarios for each location. These locations have been termed the "preliminary alternative tailings locations". The purpose of developing these design scenarios was to provide enough information so that the options could be comparatively screened further to identify which alternatives to carry forward for detailed analysis. These design scenarios include different dam construction methods (i.e., upstream, downstream, and centerline), disposal facilities (i.e., new TSF vs. existing facility), tailings deposition (i.e., whole tailings, segregated tailings, and filtered tailings), and liner containment (i.e., unlined, completely lined, and lined for potentially acid generating (PAG) tailings only). As summarized in Table 2-1, a total of 24 potential design scenarios are considered across the 11 locations.

BGC developed a conceptual layout for each of the design scenarios. For the existing open pit scenarios, BGC provided an estimate of the maximum storage capacities. Figures 2-1 to 2-3 depict the conceptual design scenarios.

Table 2-1. Summary of design scenarios considered for each preliminary alternative tailings location.

		New TSF	*Existing Open Pit*	*Existing HLF*	*Wet (Whole) 100% NPAG/PAG*	*Wet (Segregated) 85% NPAG, 15% PAG-lined*	*Filtered (Whole)*	*Earthfill Downstream*	*Tailings Downstream*	*Tailings Upstream*	*Unlined*	*Lined Under PAG Tails Only*	*Completely Lined*
Site Name	**Scenario #**	**Disposal Facility**			**Tailings Deposition**			**Embankment**			**Containment**		
	1	X			X			X					X
	2	X			X			X			X		
Lower West	3	X				X		X				X	
	4	X				X			X			X	
(GPO Base Case)	5	X				X				X	X		
	6	X					X				X		
	1	X			X			X					X
	2	X			X			X			X		
BGC B	3	X				X		X				X	
	4	X				X			X			X	
	5	X				X				X	X		
	1	X			X			X					X
	2	X			X			X			X		
BGC C	3	X				X		X				X	
	4	X				X			X			X	
	5	X				X				X	X		
Pinto Valley	1		X			X					X		
San Manuel (Mammoth)	1		X			X					X		

Table 2-2. Summary of design scenarios considered for each preliminary alternative tailings location.

		New TSF	Existing Open Pit	Existing HLF	Wet (Whole) 100% NPAG/PAG	Wet (Segregated) 85% NPAG, 15% PAG-lined	Filtered (Whole)	Earthfill Downstream	Tailings Downstream	Tailings Upstream	Unlined	Lined Under PAG Tails Only	Completely Lined
Site Name	**Scenario #**	**Disposal Facility**			**Tailings Deposition**			**Embankment**			**Containment**		
Casa Grande	1		X			X					X		
Carlota	1			X	X			X					X
Upper Arnett	1	X					X				X		
Whitford	1	X					X				X		
Hewitt	1	X					X				X		
Silver King	1	X					X				X		

2.1. Conceptual Design Basis

The conceptual design basis used to develop the design scenarios at a conceptual level are summarized below in Table 2-2. This information was either provided directly from the GPO, or where information was not available in the GPO, based on previous experience by BGC experts.

Table 2-3. Conceptual design basis.

Description	Value	Unit
Life of mine and ore processing	45	Years
Tailings production		
Approximate total production	1.50	billion tons
Tailings dry density		
Thickened tailings	84.46	pcf
Filtered tailings (assumed)	93.45	pcf
Tailings solid content (by weight)		
Thickened tailings		
- Scavenger tailings	65	%
- Cleaner or pyrite tailings	55	%
Filtered tailings	80	%
Starter Dam Capacity	2	years
Tailings geochemistry		
Approximate NPAG Production (Scavenger tailings)	90	% of total
Approximate PAG Production (Cleaner or pyrite tailings)	10	% of total
Thickened whole tailings volume		
First two years (Year 1 to Year 2)	13.04	million yd^3
Total (Year 1 to Year 45)	1315.45	million yd^3
Filtered whole tailings volume		
First two years (Year 1 to Year 2)	11.79	million yd^3
Total (Year 1 to Year 45)	1188.98	million yd^3

Table 2-4. Conceptual design basis. (Continued)

Description	Value	Unit
Thickened tailings volume by type		
NPAG Scavenger tailings (Year 1 to Year 2)	12.15 (93%)	million yd^3
PAG Cleaner tailings (Year 1 and Year 2)	0.89 (7%)	million yd^3
NPAG Scavenger tailings (Year 1 and Year 45)	1178.29 (90%)	million yd^3
PAG Cleaner tailings (Year 1 and Year 45)	137.16 (10%)	million yd^3
Starter Embankment (all construction methods)		
Downstream Slope	2	H:1V
Upstream Slope	2.5	H:1V
Crest width	26.2	ft
Ultimate Embankment (downstream construction)		
Downstream Slope when borrow mat. is used	2.5	H:1V
Downstream Slope when tailings mat. is used	4	H:1V
Upstream Slope (only for earthfill construction)	2	H:1V
Crest width	26.2	ft
Ultimate Embankment (upstream construction)		
Downstream Slope	5	H:1V
Dam freeboard	6.6	ft

2.2. Evaluation Parameters

Each of the 24 design scenarios were developed to a conceptual level, and then compared considering the following parameters:

- Tailings Corridor - The overall length, elevation gain, and elevation loss for tailings delivery systems (i.e., pipelines for thickened tailings and access roads for filtered tailings), as measured from the West Plant to TSF.
- Stormwater Management – The approximate tributary watershed area, as a criterion for stormwater management.
- Cost (Capital, Operating, and Closure) – A relative comparison, on a 0-10 scale, of the costs for constructing a TSF operation (capital), operating the TSF during tailings production (operating), and closing of the facility once the TSF is no longer being used by the mine (closure).

- Dam Breach – A relative comparison, on a 0-10 scale, of the runout area, and a rough order of magnitude estimate of the potential number of people and structures potentially affected by a dam breach event. These estimates are very preliminary and not based on an actual dam breach analysis.
- Geotechnical Stability – A relative comparison, on a 0-10 scale, considering the historic performance of similar dam designs construction methods (downstream, centerline, upstream methods). The maximum height of the embankment is also provided for comparative purposes, but is not meant to imply that there is a direct correlation between embankment height and stability.
- Dam Fill Volumes - An estimate of the starter embankment volumes, footprint areas, raise volumes, and liner areas that would be required for each alternative.
- Reclamation Volumes – A relative comparison of the area footprint requiring recontouring, and estimated time in years required for reclamation of the facility.

2.3. Design Scenario Evaluation

The comparative evaluation for all 24 TSF design scenarios is summarized below in Table 2-6. It is important to note that some of the parameters were quantified, such as the tailings pipeline corridor length, elevation gain and loss, tributary area, embankment volumes, TSF footprint areas, and lined areas. However, for some parameters, it was impractical to directly quantify at this conceptual level (e.g., cost, dam breach, embankment stability, and reclamation) and a relative, qualitative value on a scale of 0-10 was used.

Note that the design scenario evaluations conducted by BGC were prepared as one input into the next phase of the overall alternatives development process. As with the initial screening, details contained in this memo should not be construed to represent the entirety of the alternatives analysis or the only considerations in front of the project team.

Table 2-5. TSF design scenarios evaluation.

		Overall Length (mi)	Total Elevation Gain (ft)	Total Elevation Loss (ft)	Tributary Area (ac)	Capital (0-10 scale)	Operating (0-10 scale)	Closure (0-10 scale)	Runout Area (0-10 scale)	Number of People & Structures Affected (order of mag)	Historic Performance of Similar Designs (0-10 scale)	Maximum Height of Embankment (ft)	Starter Embankment Volume (cu yd)	Footprint Area (sq ft)	Raises Volume (cu yd)	Lined Area (sq ft)	Area Outside Footprint Requiring Recontouring (0-10 scale)	Time Required for Reclamation (yrs)
Site Name	**Alternative #**	**Tailings Corridor**			**Stormwater Mngmnt**	**Cost**			**Dam Breach**		**Geotech Stability**		**Dam Fill**				**Reclamation**	
	1	4.5	1,489	1,807	3,903	4.5	10	6	2	100	6	410	2,913,013	158,131,398	622,001,705	114,492,713	4	3
	2	4.5	1,489	1,807	3,903	2.2	10	6	2	100	5	410	2,913,013	158,131,398	622,001,705	0	4	3
Lower West	3	4.5	1,489	1,807	3,903	2.8	10	6	2	100	5	410	3,107,926	158,131,398	622,001,705	28,519,837	4	3
	4	4.5	1,489	1,807	3,752	2.7	1.4	8	2	100	3	410	2,545,798	154,886,953	434,384,199	28,095,461	4	3
(GPO Base Case)	5	4.5	1,489	1,807	4,874	2.1	0.4	8	2	100	0	410	1,888,528	156,340,837	117,743,386	0	4	3
	6	4.5	1,489	1,807	4,555	3.5	0.2	2	5	100	8	410	0	139,376,171	0	0	4	1
	1	35.7	4,225	5,378	13,915	10	3.6	6	1	1000	6	308	2,613,064	273,168,160	213,622,188	245,606,730	6	3
	2	35.7	4,225	5,378	13,915	4.9	3.6	6	1	1000	5	308	2,613,064	273,168,160	213,622,188	0	6	3
BGC B	3	35.7	4,225	5,378	13,915	7.9	3.6	6	1	1000	5	308	2,823,805	273,168,160	213,622,188	143,899,626	6	3
	4	35.7	4,225	5,378	13,708	7.8	1.2	8	1	1000	3	312	2,707,208	268,541,368	312,841,387	141,381,701	6	3
	5	35.7	4,225	5,378	12,987	4.6	0.5	8	1	1000	0	285	2,604,339	251,458,307	97,425,061	0	6	3
	1	28.9	5,352	5,849	36,594	7.2	6.2	6	3	10	6	505	3,439,324	197,969,974	373,231,534	166,257,479	6	3
	2	28.9	5,352	5,849	36,594	3.7	6.2	6	3	10	5	505	3,439,324	197,969,974	373,231,534	0	6	3
BGC C	3	28.9	5,352	5,849	36,594	4.6	6.2	6	3	10	5	505	3,727,561	197,969,974	373,231,534	39,391,720	6	3
(Donnally Wash)	4	28.9	5,352	5,849	38,820	4.8	1.9	8	3	10	3	545	3,727,561	216,183,011	519,713,388	36,814,342	6	3
	5	28.9	5,352	5,849	36,419	3.6	0.6	8	3	10	0	482	4,419,573	181,838,944	119,391,645	0	6	3
Pinto Valley	1	13.7	4,880	3,973	0	0	0.1	1	10	1	10	0	0	0	0	0	10	1
San Manuel (Mammoth)	1	55.9	5,439	5,391	0	1.4	0.2	1	10	1	10	0	0	0	0	0	10	1
Casa Grande	1	59.0	1,113	2,820	0	1.4	0	1	10	1	10	0	0	0	0	0	10	1
Carlota	1	10.8	3,939	3,029	22,780	6.7	2.6	6	8	10	6	699	1,327,322	206,496,498	155,187,517	178,034,098	1	3
Upper Arnett	1	8.1	2,266	1,575	3,364	3.4	0.3	2	5	1000	8	830	0	102,851,150	0	0	5	1
Whitford	1	3.3	1,582	862	7,855	3.2	0.2	2	6	100	8	860	0	120,805,401	0	0	5	1
Hewitt	1	8.8	3,960	3,513	5,277	3.6	0.3	2	3	100	8	870	0	117,509,880	0	0	5	1
Silver King	1	1.1	1,120	105	3,743	2.7	0.2	3	1	1000	8	970	0	102,613,088	0	0	5	1

2.4. Design Scenarios Discussion

2.4.1. Existing Open Pit Alternatives

The Casa Grande existing pit is insufficient to provide storage for the life of the mine and it is the farthest pit from the West Plant Site.

The Pinto Valley mine is currently in operations, with published proven and probable reserves, and a stated intent to extend operations.

The San Manuel pit has potential capacity to store all the PAG tailings, but not the total volume of tailings.

2.4.2. Dry Stack TSF Alternatives

The dry stack alternatives provide favorable stability and concurrent reclamation opportunities, and have relatively low capital costs; however, they are relatively expensive to operate. Operating costs are reduced when the site is close to the plant facilities, such as Silver King. The Whitford and Upper Arnett sites are also reasonably close.

2.4.3. Thickened TSF Alternatives

The Carlota site has the advantage of being located on an existing brownfield site. Current topography was not publicly available for the site and the topography used for the drawings was measured before mining operations began.

The case considered in the GPO, referred in this analysis as Lower West Scenario 5, offers relatively low capital costs. However, upstream constructed tailings dams have relatively less stability than centerline and downstream facilities.

The TSF alternatives at Lower West, BGC-B, and BGC-C, which include earthfill and tailings embankments with downstream construction, have the advantage of being relatively stable as compared with upstream construction (assuming similar and competent foundation conditions). The capital cost of implementing the earthfill downstream construction method is relatively high because the overall dam volume is larger when compared with centerline and upstream constructed dams.

The design scenarios that include downstream construction using tailings as the dam construction material offer a lower capital cost than those using borrowed earthfill. These offer a middle ground between the upstream constructed dam using tailings as the dam fill, and the downstream constructed earthfill alternatives.

The cost of lining the tailings impoundment is relatively low compared to the other tailings capital expenditures, however if an over-liner drain is included the capital cost would increase. This should be considered in analyzing lined alternatives. Lining of the area beneath the PAG tailings only may offer a capital savings, but the efficiency should be further evaluated.

2.5. Screened Design Scenarios

The 24 potential design alternatives were presented and discussed with the EIS project team during alternatives workshops in July 2017. Following discussions with the EIS project team, these 24 conceptual design scenarios were then further screened down to 11 design scenarios, summarized below and in Table 2-4. Design scenario cross-sections are provided in Figures 2-1 through 2-3.

The Lower West site includes:

- The GPO base case, including thickened tailings, upstream dam construction with cyclone tailings, segregated PAG and non-potentially acid generating (NPAG) tailings disposal, and a fully unlined facility (Lower West Scenario 5 shown in Table 2-4).
- Modified GPO, including additional thickening of the PAG tailings, downstream dam construction, segregated PAG and NPAG tailings disposal (split stream), partially lined where the PAG tailings are placed (Lower West Scenario 3 in Table 2-4).
- Modified GPO including tailings center line dam construction method, segregated PAG and NPAG tailings disposal, partially lined where the PAG tailings is placed (Lower West Scenario 7 in Table 2-4).

The BGC-C site includes:

- Earthfill downstream dam construction, whole tailings disposal (mixed PAG and NPAG tailings), and a fully lined facility (BGC-C Scenario 1 in Table 2-4).
- Earthfill downstream dam construction, split-stream PAG and NPAG tailings disposal, partially lined where the PAG tailings are placed (BGC-C Scenario 3 in Table 2-4).
- Earthfill centerline dam construction, whole tailings disposal (mixed PAG and NPAG tailings), and a fully lined facility (BGC-C Scenario 6 in Table 2-4).
- Tailings centerline dam construction, split-stream PAG and NPAG tailings disposal, and a fully unlined facility (BGC-C Scenario 7 shown in Table 2-4).

The Carlota site includes:

- Using the existing Heap Leach Pad (HLP), for thickened tailings disposal, including earthfill downstream dam construction, whole tailings disposal (mixed PAG and NPAG tailings), and a fully lined facility (Carlota Scenario 1 in Table 2-4).

The Upper Arnett site includes:

- Filtered tailings, including whole tailings disposal (mixed PAG and NPAG tailings), and an unlined facility (Upper Arnett Scenario 1 in Table 2-4).

The Silver King site includes:

- Filtered tailings, including whole tailings disposal (mixed PAG and NPAG tailings), and an unlined facility (Silver King Scenario 1 in Table 2-4).

San Manuel site includes:

- Use of the existing depleted open pit, with disposal of 100% of the PAG tailings, but not the NPAG tailings (San Manuel Scenario 1 in Table 2-4).

Table 2-6. TSF design scenarios.

Site Name	Scenario	Disposal Facility			Tailings Deposition			Embankment					Containment		
		New TSF	*Existing Open Pit*	*Existing HLF*	*Wet (Whole) 100% NPAG/PAG*	*Wet (Split Stream) 85% NPAG, 15% PAG-lined*	*Filtered (Whole)*	*Earthfill Downstream*	*Tailings Downstream*	*Tailings Upstream*	*Earthfill Centerline*	*Tailings Centerline*	*100% Unlined*	*Lined Under PAG Tails Only*	*100% Lined*
Lower West	5 (GPO base case)	X				X				X			X		
Lower West	3	X				X		X						X	
Lower West	7	X				X						X		X	
Lower West	1	X			X			X							X
BGC-C	3	X				X		X						X	
BGC-C	6	X			X						X				X
BGC-C	7	X				X						X	X		
Carlota HLP	1			X	X			X							X
Upper Arnett	1	X					X						X		
Silver King	1	X					X						X		
San Manuel (only for PAG tailings)	1		X			X							X		

3.0 COMPARISON OF TSF ALTERNATIVE DESIGN SCENARIOS

As described in the previous section, 11 potential TSF alternative design scenarios were identified during the alternatives development meetings on July 5 and 6. The six locations associated with these alternatives, along with the land surface management, are shown on Figure 3-1 and Figure 3-2; the regional geology and footprints of the alternatives are shown on Figure 3-3; and an aerial photo with footprints of the alternatives are shown on Figure 3-4.

A qualitative and quantitative comparative study was performed for all the TSF alternatives identified, as described below.

3.1. Qualitative Comparison

A qualitative comparison was used for the six (6) TSF site locations (Lower West, BGC-C, Carlota, Upper Arnett, Silver King and San Manuel). The criteria factors for comparison are presented in Table 3-1 and described as follows:

1. Mineral Resource - Established mineral resources or reserves would be a constraint to disposal of tailings at that location.
2. Geological Constraints - Stable, relatively watertight formations (i.e., geologic containment) are preferable for tailings facilities. Fault systems may require detailed investigations, and poor geological conditions may require additional consideration during design and construction.
3. Distance from West Plant Site - The shorter the distance from the mill, the lower the relative cost of access roads, pipelines and pumping. In addition, the project footprint is reduced with a shorter pipeline or conveyor length.
4. Topographic Relief - Containment is affected by topographic relief and can minimize dam construction material requirements, improve aesthetics, reduce environmental impacts and provide an inherently safe facility.
5. Basin Capacity - Basin capacity accounts for the opportunity to optimize tailings storage using site topography, and for the potential expansion of the facility. Flat topographic slopes require more containment structures, while steep valley slopes provide natural barriers allowing for optimized designs.
6. Hydrogeological Barrier - The use of a geomembrane as a hydrogeological barrier can detain or reduce the seepage from the foundation to the PAG tailings and minimize tailings oxidation.

Table 3-1. Qualitative comparison of the Tailings Storage Facilities sites.

Factor	Site 1 Lower West	Site 2 BGC C	Site 3 Carlota HLP	Site 4 Upper Arnett	Site 5 Silver King	Site 6 San Manuel
Mineral Resource	None	None	Possible	None	Possible	Depleted
Geological Constraints	None Identified	Moderate	High	Moderate	None Identified	High
Distance from Plant Site	Close	Close-Far	Close	Close	Close	Far
Topographic Relief	Fair	Good	Excellent	Fair	Good	Nonexistent
Basin Capacity	Fair	Good	Good	Fair	Fair	Good
Hydrogeological Barrier	Yes	Yes	Yes	No	No	No

Lower West

The land management of the area falls under the US Forest Service. There are no known ore bodies in the area. Regional geology data shows the site to be on moderately to strongly consolidated conglomerate and sandstone, with no visible major faults, and there are no identified geological and hydrogeological constraints for this scope level.

The site is approximately 5 miles from the West Plant site (straight line distance – mill to center basin). The topographic relief is fair due to low to flat slopes on the containment surface. The basin capacity is fair because this site has the capacity to store tailings production for present reserves and can be raised to meet future storage demands. Due to the natural topography, significant effort in design and construction may be needed for future raises.

BGC- C

The property's surface management falls under the Bureau of Reclamation, Bureau of Land Management, and Arizona State Land Department. There are no known ore bodies in the area. Regional geology data shows the site to be on unconsolidated to weakly consolidated alluvial fan, terrace and basin floor deposits, but no major faults were identified. As a result, there are moderate geological and hydrogeological constraints associated with potential foundation preparation involved in this area.

The site is approximately 18 miles from the West Plant site (straight line distance – mill to center basin). The topographic relief is good due to almost uniform flat slopes on the containment surface. The basin capacity is good because this site has the capacity to store tailings production for present reserves and can potentially be raised to meet future storage demands.

Carlotta Heap Leach Pad (HLP)

The surface management of the area falls under the US Forest Service. There are possible ore bodies in the area, southwest of the site limits.

Regional geology data shows the site to be located on a complex geological area, comprised of fine grained intrusive rocks and diverse pyroclastic rocks to moderately and strongly consolidated conglomerate with sandstone deposits. No visible major faults were noted but a network of small local faults trending downstream to lower elevations was observed on regional geologic maps. The geology at this location of this site results in high geological and hydrogeological constraints.

The site is approximately 8.7 miles from the West Plant site (straight line distance – mill to center basin). The topographic relief is excellent due to very steep valley slopes that can optimize containment surface. The basin capacity is good because this site has the capacity to store tailings production for present reserves and can be easily raised to meet future storage demands.

Upper Arnett

The surface management of the area falls under the US Forest Service. There are no known ore bodies in the area.

Regional geology data shows the site to be on granitic and sedimentary bedrock with no visible major faults but few clusters of local fault systems. The geological and hydrogeological constraints are considered moderate.

The site is approximately 6.2 miles from the West Plant site (straight line distance – mill to center basin). The topographic relief is fair due to overall flat and wavy slopes on the containment surface. The basin capacity is good because this site has the capacity to store tailings production for present reserves and can be raised to meet future storage demands.

Silver King

The surface management of the area falls under the US Forest Service. The area shows some mining activity in the past but there are no known remaining ore bodies in the area. Regional geology data shows the site to be located on porphyritic to equigranular granite to diorite, with no visible major faults. As a result, there are no identified geological and hydrogeological constraints.

The site is approximately 1.9 miles from the West Plant site (straight line distance – mill to center basin). The topographic relief is good due to steep slopes on the containment surface. The basin capacity is good because this site has the capacity to store tailings production for present reserves and can be raised to meet future storage demands.

San Manuel

This site is privately owned and not owned by RCM. The ore bodies at this site are known to be depleted. Regional geology data shows the site to be on porphyritic biotite granite and sedimentary bedrock. There is a high angle fault in the area and because San Manuel is an open pit, further data is needed to evaluate hydrogeological constraints. Due to the high angle fault and necessary review of hydrogeological conditions, the geological and hydrogeological constraints for this scope level are considered high.

The site is approximately 49.1 miles from the West Plant site (straight line distance – mill to center basin). The topographic relief is non-existent in this site because it is a depleted open pit.

The basin capacity is good because this site has the capacity to store tailings production for present reserves and PAG tailings will be placed.

3.2. Quantitative Comparison

A quantitative comparison of the 11 design scenarios at the six alternative site locations, is shown in Table 3-2 below.

Table 3-2. Quantitative comparison of TSF design scenarios.

Site Name	Design Scenario	Description	Straight line distance - mill to centre basin (miles)	Tailings storage capacity at Year 45 (million yd^3)				Embank. earthfill volume (million yd^3) at Year 45	Storage / dam ratio	Maximun height of embankment (feet)	Facility footprint area (acres)	Impoundment lined area (acres)	Watershed area (acres)		Tailings transport system length (miles)	Elevation difference mill to ultimate embankment elevation (feet)	Ultimate embankment elevation (feet)
				NPAG Cycloned coarse sand	NPAG	PAG	Total tailings						Impounded NPAG/PAG watershed area (acres)	Diverted watershed area (acres)			
Lower West	5 (GPO base case)	Tailings u/s, split stream, 100% unlined	5.0	287.6			1321.8	6.2	213.5	557.7	3591.0			1096.2	8.7	444.9	2805.1
	3	Earthfill d/s, split stream, lined only PAG			1179.1	142.4	1321.5	462.7	2.9	557.7	4062.5	669.9	3219.1	1096.2		444.9	2805.1
	7	Tailings c/l, split stream, lined only PAG		318.8	891.2	142.4	1352.4	50.6	26.7	557.7	3544.8	669.9	2443.9	1096.2		444.9	2805.1
BGC C	1	Earthfill d/s, whole tailings, 100% lined	18.0		0.0	0.0	1331.7	376.6	3.5	505.2	4533.7	4760.4	4533.7	30411.8	33.1	625.3	2624.6
	3	Earthfill d/s, split stream, lined only PAG			1221.7	147.0	1368.7	423.1	3.2	538.1	4876.8	998.1	4008.1	30411.8		651.6	2598.4
	6	Earthfill c/l, whole tailings, 100% lined			0.0	0.0	1322.5	214.0	6.2	495.4	4129.8	4979.5	3327.6	30411.8		612.2	2637.8
	7	Tailings c/l, split stream, 100% unlined		244.7	950.6	147.8	1343.0	52.7	25.5	475.7	4429.1		3406.9	30411.8		651.6	2598.4
Carlotta HLP	1	Eartfill d/s, whole tailings, 100% lined	8.7		0.0	0.0	1339.8	237.7	5.6	754.6	3543.1	379.4	3044.4	17878.4	16.7	-719.8	3969.8
Upper Arnett	1	Whole tailings, 100% unlined	6.2		0.0	0.0	1192.0			935.0	2526.6			891.6	7.8	-719.8	3969.8
Silver King	1	Whole tailings, 100% unlined	1.9		0.0	0.0	1181.1			1197.5	21.2			8221.3	1.6	-703.4	3953.4
San Manuel (PAG tailings only)	1	PAG volume required: 104.87 Mm3	49.1	Only PAG (Y1 to Y45)			137.5							3373.1	55.7	382.5	2867.4

Based on quantitative comparison information shown on Table 3-2, the main advantages and disadvantages are discussed below for each site and alternatives:

Lower West Site

The Lower West site is the closest proposed thickened tailings storage facility (compared with BGC-C (Peg Leg) and Carlota), located approximately 5 miles northwest from the West Plant (straight line distance). This short distance from the plant decreases costs related to access roads, pipelines, and pumping. In addition, potential environmental impacts are reduced due to a shorter pipeline length, and reduced interference with wildlife and the local habitat.

This site has the smallest watershed area (1096.2 acres). A small watershed minimizes potential run-on and runoff, diversion and spillway costs and reduces the quantity of runoff that in contact with tailings. This site is also located at a lower elevation compared to the plant location (elevation difference between 360 feet and 460 feet), which reduces pumping costs.

Specific characteristics for the Lower West alternative design scenarios are described below:

- Lower West Scenario 5 (GPO base case) is attractive because it has the highest storage/dam ratio of 213.5 (relatively low embankment earthfill volume, approximately 6.2 million cubic yards), and it would be an unlined facility; both aspects significantly reduce the capital cost. The disadvantages of this alternative are: the permitting process might require more effort due to the historical poor performance of upstream dam construction method, and the potential for acid water and metals to mobilize into the environment via seepage because the facility is unlined.
- Lower West Scenario 3 is attractive because the dam downstream construction method is considered the most accepted construction method, from a dam stability perspective, and the PAG tailings are encapsulated with a liner at the northeast corner of the facility, simplifying the environmental permitting process. The main disadvantage is the high cost related with the highest earthfill dam volume (462.7 M yd^3), which results in a low storage volume/dam volume ratio of 2.9. However, using dam construction material sources within the TSF limit increases the tailings storage capacity and minimizes haulage costs and access roads construction.
- Lower West Scenario 7 has a storage/dam ratio increase from 2.9 to 26.7, reducing the capital cost as compared with Lower West Scenario 3. As a disadvantage, the dam stability for Alternative 7 relies on the operational control of tailings cycloning and coarse tailings compaction during dam raises.

BGC-C Site (“Peg Leg”)

The BGC-C site is the farthest proposed thickened tailings storage facility (when compared with Lower West and Carlota thickened TSFs), located approximately 18 miles southwest from the West Plant (straight line distance). This distance increases the cost related to access roads, pipelines, and pumping.

The site is located at lower elevation relative to the plant location (elevation difference between 590 feet and 624 feet), which will reduce the overall pumping costs. This site has a larger watershed area (30,411.8 acres), which would increase water management requirements.

Specific characteristics for the BGC-C (Peg Leg) alternatives are described below:

- BGC-C Scenario 1 and Scenario 3 both involve earthfill dams, and downstream construction, where Scenario 1 is fully lined to store the combined PAG and NPAG tailings, and Scenario 3 is partially lined at the south corner to store the PAG tailings. Scenario 3 has the advantage of isolating the PAG tailings in a specific area of the facility, while Scenario 1 will have the PAG tailings spread along the entire facility. Cost differences between Scenario 1 and Scenario 3 can be seen as a balance between the reduction of earthfill material and increase in liner area for Scenario 1, and an increase of earthfill material and a decrease in liner area for Scenario 3.
- BGC-C Scenario 6 is an optimization of Scenario 1, where the construction method was changed from earthfill downstream construction to the earthfill centerline construction method. The result is a storage/dam ratio increase from 3.5 to 6.2, reducing the capital cost when compared with Scenario 1.
- BGC-C Scenario 7 is an optimization of Scenario 3, where the construction method was changed from earthfill downstream construction to the tailings centerline construction method, and fully unlined. The portion of the PAG tailings disposal and the dam construction method remains the same for both as downstream construction method. The result is a storage/dam ratio increase significantly from 3.2 to 25.5, reducing the capital cost when compared with Scenario 3.

Carlota Site

The Carlota thickened tailings storage facility includes earthfill dams to be constructed using the downstream method, and the facility will be fully lined. It is located approximately 8.7 miles northeast from the West Plant. The advantage of this site is good topographical containment with a storage/dam ratio of 5.6 when compared with the others downstream construction alternatives, where the ratios range from 2.9 to 3.5.

A disadvantage of this site is that it would hold a relatively large watershed (17,878.4 acres), which increases the water diversion costs. This site is located at higher elevation in relation to the West Plant location (approximately 722 feet above the West Plant elevation), which increases pumping costs.

San Manuel Site

The San Manuel PAG tailings storage facility is composed of a depleted open pit. It is located approximately 49.1 miles south from the West Plant (straight line distance). Advantages of this site are: the open pit allows for a ready-to-go storage space; no dam construction would be necessary for only PAG tailings; good aesthetics and reduced environmental impact (pending further review of hydrogeological data of pit).

A disadvantage of this site is that it is very far away from the plant site, which adds costs associated with the transportation and management of tailings.

Filtered Tailings Dry Stack Sites

Two filtered tailings stacks were considered for further analysis at the Silver King and Upper Arnett sites.

Due to the need to convey or truck filtered tailings, it is beneficial to have the facility relatively close to the plant site. The Silver King filtered tailings stack is located approximately 1.9 miles northwest from the West Plant site. The Upper Arnett filtered tailings stack is located approximately 6.2 miles south from the West Plant site.

Both facilities would be unlined with the assumption that the dry stack would not release seepage, or have very limited seepage.

The advantages of dry stack facilities, when compared with conventional and thickened TSFs, include:

- Stack can be built anywhere on level ground or against a hillside
- Higher water recovery for use in the plant is particularly important in arid climates
- Less risk of catastrophic failure and tailings runout
- Limited earthfill borrow material is required
- Progressive reclamation and closure of the facility
- Less embankment footprint area, since the filtered tailings are denser
- Potential seepage to groundwater is reduced.

Some of the disadvantages of dry stack include:

- Higher capital and operating costs
- Oxidation of PAG tailings can create high concentrations (but low volumes) of seepage water
- Exposed areas of the stack can generate fugitive dust.

4.0 CLOSURE

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Yours sincerely,

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per:

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REFERENCES

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Project Memorandum

To:	**SWCA Environmental Consultants**		
Attention:	**Chris Garrett**		
From:	**Derek Hrubes, Tony Monasterio, Jorge Castillo**	**Date:**	**October 24, 2017**
Subject:	**Resolution Copper Project EIS– Tailings Disposal Alternatives Development - DRAFT**		
Project No.:	**1704002**		

The purpose of this memorandum is to document technical and engineering input provided for the development of potential tailings storage facility (TSF) alternatives, as part of the broader development of a reasonable range of alternatives to be analyzed in the Resolution Copper Project Draft Environmental Impact Statement (EIS). BGC Engineering (BGC) is providing mine tailings expertise to SWCA Environmental Consultants (SWCA) and the United States Department of Agriculture Tonto National Forest (TNF). The TNF is the lead Federal agency for the EIS, and SWCA is the TNF's third-party EIS contractor. The TNF, SWCA and their consultants, including BGC, comprise the EIS project team.

The proposed action, described by Resolution Copper Mining (RCM) in the General Plan of Operations (GPO 2016), includes a thickened[1] slurry TSF, with an upstream-constructed dam embankment. Located west of Superior, Arizona, between Roblas Canyon and Potts Canyon, this location is referred to as the "Lower West" site, as shown in Figure 1-1. As part of the alternatives development process, the TNF-led EIS project team considered a broad range of potential alternative TSF locations and configurations to address issues raised during scoping.

Of 30 potential locations initially considered for tailings disposal, 11 total design scenarios at 6 distinct locations met the screening criteria established by the EIS project team. These have been evaluated as possible tailings disposal alternatives, as described in the sections below. The alternatives carried forward for further analysis in the EIS are described in the *Briefing Paper – Proposed Range of Alternatives for Detailed Analysis* (SWCA, September 2017).

Note that the design scenario evaluations conducted by BGC were prepared as one input into the next phase of the overall alternatives development process. Details contained in this memo should not be construed to represent the entirety of the alternatives analysis or the only considerations in front of the project team.

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[1] Thickened tailings involve the mechanical process of dewatering low solids concentrated slurry to produce a solids density generally ranging from 35 to 65 percent. The GPO indicates that scavenger (NPAG) tailings would be thickened to 65% solids density, and cleaner (PAG) tailings to 55% solids density.

1.0 ALTERNATIVE TSF LOCATIONS

1.1. Initial Alternative Locations

An initial list of 30 alternative tailings disposal site locations was identified by the EIS project team, and summarized below. This initial identification of alternative locations did not include consideration of different dam configurations or disposal methods, only general geographic location. Figure 1-1 depicts the location of all the following identified sites:

1. Lower-West (GPO base case)
2. Far-West
3. Hewitt Canyon
4. Lower-East Happy Camp
5. Pinto Valley Mine
6. Silver King Canyon
7. Telegraph Canyon
8. Whitford Canyon
9. SWCA 1
10. SWCA 2
11. SWCA 3
12. SWCA 4
13. BGC- A
14. BGC- B
15. BGC- C (Later renamed the Peg Leg site by the TNF)
16. BGC- D
17. Proposed Resolution Copper Mine Subsidence Area
18. Pinenut Mine
19. United Verde
20. Copperstone
21. Casa Grande
22. San Manuel (Mammoth)
23. Tohono
24. Johnson's Camp
25. Twin Buttes
26. Copper Queen
27. Upper Arnett
28. Carlota
29. Globe/Miami
30. Ajo

1.2. Initial Screening and Consolidation of Alternative Locations

The 30 potential alternative locations were evaluated and consolidated during several alternatives development meetings with the EIS project team. These locations have also been termed the “initial alternative tailings locations”. Members of the EIS project team, representing a range of technical expertise, held a two-day workshop in April 2017 to begin evaluation of all the possible alternative tailings facility locations. A qualitative discussion and screening was conducted using criteria established by the EIS project team, and categorized by potential impacts to water resources, biological resources, scenic resources, recreation, and public health and safety. If an alternative location had, in the opinion of EIS project team, significant disadvantages over the proposed action, then the site was eliminated.

A summary of discussion considerations for each location is included below in Table 1-1.

Table 1-1. Considerations for potential alternative tailings locations.

Location	Advantages	Disadvantages
Lower-West (GPO proposed location)	Proposed action	Potential downstream impacts and proximity to residences/towns
Far-West	Proximity to water source (usage), limited visual impacts, no public recreation, limited identified vegetation and animal habitat, further visually from frequented areas (roads, trails, etc.), potential downstream impacts and proximity to residences/towns	State Land is set aside for residential use, proximity to water source (leakage/seepage) with geological containment, limited vegetation
Hewitt Canyon	Further from frequented areas (roads, trails, etc.) as compared to the proposed GPO location, lower potential downstream impacts and proximity to residences/towns	Significant good vegetative coverage, near a Wilderness Area
Lower-East Happy Camp	N/A	Proximity to Superior and highway, adjacent to Boyce Thompson, potential downstream impacts and proximity to residences/towns
Pinto Valley Mine	Some tailings could potentially go into pit (minimizes tailings disposal), groundwater is already impacted and so less change to current condition, pre-disturbed area	Currently in operation with projected 22-year mine life.
Silver King Canyon	Not visible from highway, good topography for water recovery	Significant number of intermittent streams, visible from Arizona Trail, existing workings under TSF, significant good vegetative coverage, potential downstream impacts and proximity to residences/towns

Location	Advantages	Disadvantages
Telegraph Canyon	N/A	Adjacent to major cultural area, perennial waters, possibility to native fish repopulation, beautiful geology and floral/fauna, footprint partially covers a protected bird area, close in proximity to frequented areas (roads, trails, etc.), right on top of Arizona Trail
Whitford Canyon	Lower potential downstream impacts and proximity to residences/towns	Significant good vegetative coverage
SWCA 1	No springs, limited identified vegetation and animal habitat	Proximity to Gila River, but might already have poor quality, more difficult stormwater management, proximity to Arizona Trail
SWCA 2	No springs, limited identified vegetation and animal habitat	Proximity to Gila River, might partly cover Ray Land Exchange, proximity to Arizona Trail, more difficult stormwater management
SWCA 3	Limited identified vegetation and animal habitat	Steep terrain and difficult water management, impacts multiple water sheds (flows north and south within basin, right on top of Arizona Trail
SWCA 4	Further in proximity from frequented areas (roads, trails, etc.)	Drainage to Roosevelt Lake, perennial stream, undisturbed land, visual impacts, high recreation, cuts off access, tough terrain, capacity requirement takes it into wilderness area
BGC A	Limited identified vegetation and animal habitat	Close proximity to town of San Tan Valley and new developments
BGC B	Limited identified vegetation and animal habitat	Proximity to town of Florence and rural homes
BGC C	No springs, further from Gila River, limited identified vegetation and animal habitat, lower potential downstream impacts and proximity to residences/towns	Proximity to Arizona Trail
BGC D	No springs, limited identified vegetation and animal habitat, potential downstream impacts and proximity to residences/towns	Proximity to Gila River, proximity to Arizona Trail
Proposed Resolution Copper Mine (backfill underground disposal)	N/A	Not technologically feasible with proposed panel caving

Location	Advantages	Disadvantages
Pinenut Mine	N/A	Too far, not enough capacity, other side of Grand Canyon
United Verde	N/A	Insufficient capacity
Copperstone	N/A	Insufficient capacity
Casa Grande	N/A	Insufficient capacity
San Manuel (Mammoth)	Sufficient capacity for pyrite tailings.	Eventual receptor is San Pedro River. Not sufficient capacity for all tailings.
Tohono	N/A	Insufficient capacity
Johnson’s Camp	N/A	Insufficient capacity
Twin Buttes	Sufficient capacity for pyrite tailings.	Ownership by Freeport McMoRan with stated intent to develop property, and significant declared mineral resource. Significant distance from project area.
Copper Queen	N/A	Public objection due to previous activities
Upper Arnett	Proximal to RCM mine site and away from town. Geologically suitable.	Next to Route 177. Headwaters of Queen Creek, Superior area and above Boyce Thompson.
Carlota	N/A	Does not have sufficient capacity
Globe/Miami	N/A	Part of an Arizona Superfund/ Water Quality Assurance Revolving Fund (WQARF) site
Ajo	N/A	Significant distance (> 100 miles) from project area.

The initial screening resulted in a consolidation to 11 locations for developing alternative design scenarios:

1. Lower-West (GPO base case)
2. BGC B
3. BGC C
4. Pinto Valley Mine
5. San Manuel (Mammoth)
6. Casa Grande
7. Carlota
8. Upper Arnett
9. Whitford
10. Hewitt
11. Silver King

2.0 TSF ALTERNATIVE DESIGN SCENARIOS

Following the screening of initial TSF locations, and consolidation to the 11 alternative TSF locations, BGC was tasked by the TNF to develop conceptual design scenarios for each location. These locations have been termed the "preliminary alternative tailings locations". The purpose of developing these design scenarios was to provide enough information so that the options could be comparatively screened further to identify which alternatives to carry forward for detailed analysis. These design scenarios include different dam construction methods (i.e., upstream, downstream, and centerline), disposal facilities (i.e., new TSF vs. existing facility), tailings deposition (i.e., whole tailings, segregated tailings, and filtered tailings), and liner containment (i.e., unlined, completely lined, and lined for potentially acid generating (PAG) tailings only). As summarized in Table 2-1, a total of 24 potential design scenarios are considered across the 11 locations.

BGC developed a conceptual layout for each of the design scenarios. For the existing open pit scenarios, BGC provided an estimate of the maximum storage capacities. Figures 2-1 to 2-3 depict the conceptual design scenarios.

Table 2-1. Summary of design scenarios considered for each preliminary alternative tailings location.

Site Name	Scenario #	Disposal Facility			Tailings Deposition			Embankment			Containment		
		New TSF	Existing Open Pit	Existing HLF	Wet (Whole) 100% NPAG/PAG	Wet (Segregated) 85% NPAG, 15% PAG-lined	Filtered (Whole)	Earthfill Downstream	Tailings Downstream	Tailings Upstream	Unlined	Lined Under PAG Tails Only	Completely Lined
	1	X			X			X					X
	2	X			X			X			X		
Lower West	3	X				X		X				X	
	4	X				X			X			X	
(GPO Base Case)	5	X				X				X	X		
	6	X					X				X		
	1	X			X			X					X
	2	X			X			X			X		
BGC B	3	X				X		X				X	
	4	X				X			X			X	
	5	X				X				X	X		
	1	X			X			X					X
	2	X			X			X			X		
BGC C	3	X				X		X				X	
	4	X				X			X			X	
	5	X				X				X	X		
Pinto Valley	1		X			X					X		
San Manuel (Mammoth)	1		X			X					X		
Casa Grande	1		X			X					X		
Carlota	1			X	X			X					X
Upper Arnett	1	X					X				X		
Whitford	1	X					X				X		
Hewitt	1	X					X				X		
Silver King	1	X					X				X		

2.1. Conceptual Design Basis

The conceptual design basis used to develop the design scenarios at a conceptual level are summarized below in Table 2-2. This information was either provided directly from the GPO, or where information was not available in the GPO, based on previous experience by BGC experts.

Table 2-2. Conceptual design basis.

Description	Value	Unit
Life of mine and ore processing	45	Years
Tailings production		
Approximate total production	1.50	billion tons
Tailings dry density		
Thickened tailings	84.46	pcf
Filtered tailings (assumed)	93.45	pcf
Tailings solid content (by weight)		
Thickened tailings		
- Scavenger tailings	65	%
- Cleaner or pyrite tailings	55	%
Filtered tailings	80	%
Starter Dam Capacity	2	years
Tailings geochemistry		
Approximate NPAG Production (Scavenger tailings)	90	% of total
Approximate PAG Production (Cleaner or pyrite tailings)	10	% of total
Thickened whole tailings volume		
First two years (Year 1 to Year 2)	13.04	million yd^3
Total (Year 1 to Year 45)	1315.45	million yd^3
Filtered whole tailings volume		
First two years (Year 1 to Year 2)	11.79	million yd^3
Total (Year 1 to Year 45)	1188.98	million yd^3
Thickened tailings volume by type		
NPAG Scavenger tailings (Year 1 to Year 2)	12.15 (93%)	million yd^3
PAG Cleaner tailings (Year 1 and Year 2)	0.89 (7%)	million yd^3
NPAG Scavenger tailings (Year 1 and Year 45)	1178.29 (90%)	million yd^3
PAG Cleaner tailings (Year 1 and Year 45)	137.16 (10%)	million yd^3
Starter Embankment (all construction methods)		
Downstream Slope	2	H:1V

Description	Value	Unit
Upstream Slope	2.5	H:1V
Crest width	26.2	ft
Ultimate Embankment (downstream construction)		
Downstream Slope when borrow mat. is used	2.5	H:1V
Downstream Slope when tailings mat. is used	4	H:1V
Upstream Slope (only for earthfill construction)	2	H:1V
Crest width	26.2	ft
Ultimate Embankment (upstream construction)		
Downstream Slope	5	H:1V
Dam freeboard	6.6	ft

2.2. Evaluation Parameters

Each of the 24 design scenarios were developed to a conceptual level, and then compared considering the following parameters:

- Tailings Corridor - The overall length, elevation gain, and elevation loss for tailings delivery systems (i.e., pipelines for thickened tailings and access roads for filtered tailings), as measured from the West Plant to TSF.
- Stormwater Management – The approximate tributary watershed area, as a criterion for stormwater management.
- Cost (Capital, Operating, and Closure) – A relative comparison, on a 0-10 scale, of the costs for constructing a TSF operation (capital), operating the TSF during tailings production (operating), and closing of the facility once the TSF is no longer being used by the mine (closure).
- Dam Breach – A relative comparison, on a 0-10 scale, of the runout area, and a rough order of magnitude estimate of the potential number of people and structures potentially affected by a dam breach event. These estimates are very preliminary and not based on an actual dam breach analysis.
- Geotechnical Stability – A relative comparison, on a 0-10 scale, considering the historic performance of similar dam designs construction methods (downstream, centerline, upstream methods). The maximum height of the embankment is also provided for comparative purposes, but is not meant to imply that there is a direct correlation between embankment height and stability.
- Dam Fill Volumes - An estimate of the starter embankment volumes, footprint areas, raise volumes, and liner areas that would be required for each alternative.
- Reclamation Volumes – A relative comparison of the area footprint requiring recontouring, and estimated time in years required for reclamation of the facility.

2.3. Design Scenario Evaluation

The comparative evaluation for all 24 TSF design scenarios is summarized below in Table 2-6. It is important to note that some of the parameters were quantified, such as the tailings pipeline corridor length, elevation gain and loss, tributary area, embankment volumes, TSF footprint areas, and lined areas. However, for some parameters, it was impractical to directly quantify at this conceptual level (e.g., cost, dam breach, embankment stability, and reclamation) and a relative, qualitative value on a scale of 0-10 was used.

Note that the design scenario evaluations conducted by BGC were prepared as one input into the next phase of the overall alternatives development process. As with the initial screening, details contained in this memo should not be construed to represent the entirety of the alternatives analysis or the only considerations in front of the project team.

Table 2-3. TSF design scenarios evaluation.

		Overall Length (mi)	Total Elevation Gain (ft)	Total Elevation Loss (ft)	Tributary Area (ac)	Capital (0-10 scale)	Operating (0-10 scale)	Closure (0-10 scale)	Runout Area (0-10 scale)	Number of People & Structures Affected (order of mag)	Historic Performance of Similar Designs (0-10 scale)	Maximum Height of Embankment (ft)	Starter Embankment Volume (cu yd)	Footprint Area (sq ft)	Raises Volume (cu yd)	Lined Area (sq ft)	Area Outside Footprint Requiring Recontouring (0-10 scale)	Time Required for Reclamation (yrs)
Site Name	**Alternative #**	**Tailings Corridor**			**Stormwater Mngmnt**	**Cost**			**Dam Breach**		**Geotech Stability**		**Dam Fill**				**Reclamation**	
Lower West	1	4.5	1,489	1,807	3,903	4.5	10	6	2	100	6	410	2,913,013	158,131,398	622,001,705	114,492,713	4	3
	2	4.5	1,489	1,807	3,903	2.2	10	6	2	100	5	410	2,913,013	158,131,398	622,001,705	0	4	3
	3	4.5	1,489	1,807	3,903	2.8	10	6	2	100	5	410	3,107,926	158,131,398	622,001,705	28,519,837	4	3
	4	4.5	1,489	1,807	3,752	2.7	1.4	8	2	100	3	410	2,545,798	154,886,953	434,384,199	28,095,461	4	3
(GPO Base Case)	5	4.5	1,489	1,807	4,874	2.1	0.4	8	2	100	0	410	1,888,528	156,340,837	117,743,386	0	4	3
	6	4.5	1,489	1,807	4,555	3.5	0.2	2	5	100	8	410	0	139,376,171	0	0	4	1
BGC B	1	35.7	4,225	5,378	13,915	10	3.6	6	1	1000	6	308	2,613,064	273,168,160	213,622,188	245,606,730	6	3
	2	35.7	4,225	5,378	13,915	4.9	3.6	6	1	1000	5	308	2,613,064	273,168,160	213,622,188	0	6	3
	3	35.7	4,225	5,378	13,915	7.9	3.6	6	1	1000	5	308	2,823,805	273,168,160	213,622,188	143,899,626	6	3
	4	35.7	4,225	5,378	13,708	7.8	1.2	8	1	1000	3	312	2,707,208	268,541,368	312,841,387	141,381,701	6	3
	5	35.7	4,225	5,378	12,987	4.6	0.5	8	1	1000	0	285	2,604,339	251,458,307	97,425,061	0	6	3
BGC C (Donnally Wash)	1	28.9	5,352	5,849	36,594	7.2	6.2	6	3	10	6	505	3,439,324	197,969,974	373,231,534	166,257,479	6	3
	2	28.9	5,352	5,849	36,594	3.7	6.2	6	3	10	5	505	3,439,324	197,969,974	373,231,534	0	6	3
	3	28.9	5,352	5,849	36,594	4.6	6.2	6	3	10	5	505	3,727,561	197,969,974	373,231,534	39,391,720	6	3
	4	28.9	5,352	5,849	38,820	4.8	1.9	8	3	10	3	545	3,727,561	216,183,011	519,713,388	36,814,342	6	3
	5	28.9	5,352	5,849	36,419	3.6	0.6	8	3	10	0	482	4,419,573	181,838,944	119,391,645	0	6	3
Pinto Valley	1	13.7	4,880	3,973	0	0	0.1	1	10	1	10	0	0	0	0	0	10	1
San Manuel (Mammoth)	1	55.9	5,439	5,391	0	1.4	0.2	1	10	1	10	0	0	0	0	0	10	1
Casa Grande	1	59.0	1,113	2,820	0	1.4	0	1	10	1	10	0	0	0	0	0	10	1
Carlota	1	10.8	3,939	3,029	22,780	6.7	2.6	6	8	10	6	699	1,327,322	206,496,498	155,187,517	178,034,098	1	3
Upper Arnett	1	8.1	2,266	1,575	3,364	3.4	0.3	2	5	1000	8	830	0	102,851,150	0	0	5	1
Whitford	1	3.3	1,582	862	7,855	3.2	0.2	2	6	100	8	860	0	120,805,401	0	0	5	1
Hewitt	1	8.8	3,960	3,513	5,277	3.6	0.3	2	3	100	8	870	0	117,509,880	0	0	5	1
Silver King	1	1.1	1,120	105	3,743	2.7	0.2	3	1	1000	8	970	0	102,613,088	0	0	5	1

2.4. Design Scenarios Discussion

2.4.1. Existing Open Pit Alternatives

The Casa Grande existing pit is insufficient to provide storage for the life of the mine and it is the farthest pit from the West Plant Site.

The Pinto Valley mine is currently in operations, with published proven and probable reserves, and a stated intent to extend operations.

The San Manuel pit has potential capacity to store all the PAG tailings, but not the total volume of tailings.

2.4.2. Dry Stack TSF Alternatives

The dry stack alternatives provide favorable stability and concurrent reclamation opportunities, and have relatively low capital costs; however, they are relatively expensive to operate. Operating costs are reduced when the site is close to the plant facilities, such as Silver King. The Whitford and Upper Arnett sites are also reasonably close.

2.4.3. Thickened TSF Alternatives

The Carlota site has the advantage of being located on an existing brownfield site. Current topography was not publicly available for the site and the topography used for the drawings was measured before mining operations began.

The case considered in the GPO, referred in this analysis as Lower West Scenario 5, offers relatively low capital costs. However, upstream constructed tailings dams have relatively less stability than centerline and downstream facilities.

The TSF alternatives at Lower West, BGC-B, and BGC-C, which include earthfill and tailings embankments with downstream construction, have the advantage of being relatively stable as compared with upstream construction (assuming similar and competent foundation conditions). The capital cost of implementing the earthfill downstream construction method is relatively high because the overall dam volume is larger when compared with centerline and upstream constructed dams.

The design scenarios that include downstream construction using tailings as the dam construction material offer a lower capital cost than those using borrowed earthfill. These offer a middle ground between the upstream constructed dam using tailings as the dam fill, and the downstream constructed earthfill alternatives.

The cost of lining the tailings impoundment is relatively low compared to the other tailings capital expenditures, however if an over-liner drain is included the capital cost would increase. This should be considered in analyzing lined alternatives. Lining of the area beneath the PAG tailings only may offer a capital savings, but the efficiency should be further evaluated.

2.5. Screened Design Scenarios

The 24 potential design alternatives were presented and discussed with the EIS project team during alternatives workshops in July 2017. Following discussions with the EIS project team, these 24 conceptual design scenarios were then further screened down to 11 design scenarios, summarized below and in Table 2-4. Design scenario cross-sections are provided in Figures 2-1 through 2-3.

The Lower West site includes:

- The GPO base case, including thickened tailings, upstream dam construction with cyclone tailings, segregated PAG and non-potentially acid generating (NPAG) tailings disposal, and a fully unlined facility (Lower West Scenario 5 shown in Table 2-4).
- Modified GPO, including additional thickening of the PAG tailings, downstream dam construction, segregated PAG and NPAG tailings disposal (split stream), partially lined where the PAG tailings are placed (Lower West Scenario 3 in Table 2-4).
- Modified GPO including tailings center line dam construction method, segregated PAG and NPAG tailings disposal, partially lined where the PAG tailings is placed (Lower West Scenario 7 in Table 2-4).

The BGC-C site includes:

- Earthfill downstream dam construction, whole tailings disposal (mixed PAG and NPAG tailings), and a fully lined facility (BGC-C Scenario 1 in Table 2-4).
- Earthfill downstream dam construction, split-stream PAG and NPAG tailings disposal, partially lined where the PAG tailings are placed (BGC-C Scenario 3 in Table 2-4).
- Earthfill centerline dam construction, whole tailings disposal (mixed PAG and NPAG tailings), and a fully lined facility (BGC-C Scenario 6 in Table 2-4).
- Tailings centerline dam construction, split-stream PAG and NPAG tailings disposal, and a fully unlined facility (BGC-C Scenario 7 shown in Table 2-4).

The Carlota site includes:

- Using the existing Heap Leach Pad (HLP), for thickened tailings disposal, including earthfill downstream dam construction, whole tailings disposal (mixed PAG and NPAG tailings), and a fully lined facility (Carlota Scenario 1 in Table 2-4).

The Upper Arnett site includes:

- Filtered tailings, including whole tailings disposal (mixed PAG and NPAG tailings), and an unlined facility (Upper Arnett Scenario 1 in Table 2-4).

The Silver King site includes:

- Filtered tailings, including whole tailings disposal (mixed PAG and NPAG tailings), and an unlined facility (Silver King Scenario 1 in Table 2-4).

San Manuel site includes:

- Use of the existing depleted open pit, with disposal of 100% of the PAG tailings, but not the NPAG tailings (San Manuel Scenario 1 in Table 2-4).

Table 2-4. TSF design scenarios.

Site Name	Scenario	New TSF	Existing Open Pit	Existing HLF	Wet (Whole) 100% NPAG/PAG	Wet (Split Stream) 85% NPAG, 15% PAG-lined	Filtered (Whole)	Earthfill Downstream	Tailings Downstream	Tailings Upstream	Earthfill Centerline	Tailings Centerline	100% Unlined	Lined Under PAG Tails Only	100% Lined
		Disposal Facility			Tailings Deposition			Embankment					Containment		
Lower West	5 (GPO base case)	X				X				X			X		
Lower West	3	X				X		X						X	
Lower West	7	X				X						X		X	
Lower West	1	X			X			X							X
BGC-C	3	X				X		X						X	
BGC-C	6	X			X						X				X
BGC-C	7	X				X						X	X		
Carlota HLP	1			X	X			X							X
Upper Arnett	1	X					X						X		
Silver King	1	X					X						X		
San Manuel (only for PAG tailings)	1		X			X							X		

3.0 COMPARISON OF TSF ALTERNATIVE DESIGN SCENARIOS

As described in the previous section, 11 potential TSF alternative design scenarios were identified during the alternatives development meetings on July 5 and 6. The six locations associated with these alternatives, along with the land surface management, are shown on Figure 3-1 and Figure 3-2; the regional geology and footprints of the alternatives are shown on Figure 3-3; and an aerial photo with footprints of the alternatives are shown on Figure 3-4.

A qualitative and quantitative comparative study was performed for all the TSF alternatives identified, as described below.

3.1. Qualitative Comparison

A qualitative comparison was used for the six (6) TSF site locations (Lower West, BGC-C, Carlota, Upper Arnett, Silver King and San Manuel). The criteria factors for comparison are presented in Table 3-1 and described as follows:

1. Mineral Resource - Established mineral resources or reserves would be a constraint to disposal of tailings at that location.
2. Geological Constraints - Stable, relatively watertight formations (i.e., geologic containment) are preferable for tailings facilities. Fault systems may require detailed investigations, and poor geological conditions may require additional consideration during design and construction.
3. Distance from West Plant Site - The shorter the distance from the mill, the lower the relative cost of access roads, pipelines and pumping. In addition, the project footprint is reduced with a shorter pipeline or conveyor length.
4. Topographic Relief - Containment is affected by topographic relief and can minimize dam construction material requirements, improve aesthetics, reduce environmental impacts and provide an inherently safe facility.
5. Basin Capacity - Basin capacity accounts for the opportunity to optimize tailings storage using site topography, and for the potential expansion of the facility. Flat topographic slopes require more containment structures, while steep valley slopes provide natural barriers allowing for optimized designs.
6. Hydrogeological Barrier - The use of a geomembrane as a hydrogeological barrier can detain or reduce the seepage from the foundation to the PAG tailings and minimize tailings oxidation.

Table 3-1. Qualitative comparison of the Tailings Storage Facilities sites.

Factor	Site 1 Lower West	Site 2 BGC C	Site 3 Carlota HLP	Site 4 Upper Arnett	Site 5 Silver King	Site 6 San Manuel
Mineral Resource	None	None	Possible	None	Possible	Depleted
Geological Constraints	None Identified	Moderate	High	Moderate	None Identified	High
Distance from Plant Site	Close	Close-Far	Close	Close	Close	Far

Factor	Site 1 Lower West	Site 2 BGC C	Site 3 Carlota HLP	Site 4 Upper Arnett	Site 5 Silver King	Site 6 San Manuel
Topographic Relief	Fair	Good	Excellent	Fair	Good	Nonexistent
Basin Capacity	Fair	Good	Good	Fair	Fair	Good
Hydrogeological Barrier	Yes	Yes	Yes	No	No	No

Lower West

The land management of the area falls under the US Forest Service. There are no known ore bodies in the area. Regional geology data shows the site to be on moderately to strongly consolidated conglomerate and sandstone, with no visible major faults, and there are no identified geological and hydrogeological constraints for this scope level.

The site is approximately 5 miles from the West Plant site (straight line distance – mill to center basin). The topographic relief is fair due to low to flat slopes on the containment surface. The basin capacity is fair because this site has the capacity to store tailings production for present reserves and can be raised to meet future storage demands. Due to the natural topography, significant effort in design and construction may be needed for future raises.

BGC- C

The property's surface management falls under the Bureau of Reclamation, Bureau of Land Management, and Arizona State Land Department. There are no known ore bodies in the area. Regional geology data shows the site to be on unconsolidated to weakly consolidated alluvial fan, terrace and basin floor deposits, but no major faults were identified. As a result, there are moderate geological and hydrogeological constraints associated with potential foundation preparation involved in this area.

The site is approximately 18 miles from the West Plant site (straight line distance – mill to center basin). The topographic relief is good due to almost uniform flat slopes on the containment surface. The basin capacity is good because this site has the capacity to store tailings production for present reserves and can potentially be raised to meet future storage demands.

Carlotta Heap Leach Pad (HLP)

The surface management of the area falls under the US Forest Service. There are possible ore bodies in the area, southwest of the site limits.

Regional geology data shows the site to be located on a complex geological area, comprised of fine grained intrusive rocks and diverse pyroclastic rocks to moderately and strongly consolidated conglomerate with sandstone deposits. No visible major faults were noted but a network of small local faults trending downstream to lower elevations was observed on regional geologic maps. The geology at this location of this site results in high geological and hydrogeological constraints.

The site is approximately 8.7 miles from the West Plant site (straight line distance – mill to center basin). The topographic relief is excellent due to very steep valley slopes that can optimize containment surface. The basin capacity is good because this site has the capacity to store tailings production for present reserves and can be easily raised to meet future storage demands.

Upper Arnett

The surface management of the area falls under the US Forest Service. There are no known ore bodies in the area.

Regional geology data shows the site to be on granitic and sedimentary bedrock with no visible major faults but few clusters of local fault systems. The geological and hydrogeological constraints are considered moderate.

The site is approximately 6.2 miles from the West Plant site (straight line distance – mill to center basin). The topographic relief is fair due to overall flat and wavy slopes on the containment surface. The basin capacity is good because this site has the capacity to store tailings production for present reserves and can be raised to meet future storage demands.

Silver King

The surface management of the area falls under the US Forest Service. The area shows some mining activity in the past but there are no known remaining ore bodies in the area. Regional geology data shows the site to be located on porphyritic to equigranular granite to diorite, with no visible major faults. As a result, there are no identified geological and hydrogeological constraints.

The site is approximately 1.9 miles from the West Plant site (straight line distance – mill to center basin). The topographic relief is good due to steep slopes on the containment surface. The basin capacity is good because this site has the capacity to store tailings production for present reserves and can be raised to meet future storage demands.

San Manuel

This site is privately owned and not owned by RCM. The ore bodies at this site are known to be depleted. Regional geology data shows the site to be on porphyritic biotite granite and sedimentary bedrock. There is a high angle fault in the area and because San Manuel is an open pit, further data is needed to evaluate hydrogeological constraints. Due to the high angle fault and necessary review of hydrogeological conditions, the geological and hydrogeological constraints for this scope level are considered high.

The site is approximately 49.1 miles from the West Plant site (straight line distance – mill to center basin). The topographic relief is non-existent in this site because it is a depleted open pit.

The basin capacity is good because this site has the capacity to store tailings production for present reserves and PAG tailings will be placed.

3.2. Quantitative Comparison

A quantitative comparison of the 11 design scenarios at the six alternative site locations, is shown in Table 3-2 below.

Table 3-2. Quantitative comparison of TSF design scenarios.

Site Name	Design Scenario	Description	Straight line distance - mill to centre basin (miles)	Tailings storage capacity at Year 45 (million yd^3)				Embank. earthfill volume (million yd^3) at Year 45	Storage / dam ratio	Maximun height of embankment (feet)	Facility footprint area (acres)	Impoundment lined area (acres)	Watershed area (acres)		Tailings transport system length (miles)	Elevation difference mill to ultimate embankment elevation (feet)	Ultimate embankment elevation (feet)
				NPAG Cycloned coarse sand	NPAG	PAG	Total tailings						Impounded NPAG/PAG watershed area (acres)	Diverted watershed area (acres)			
Lower West	5 (GPO base case)	Tailings u/s, split stream, 100% unlined	5.0	287.6			1321.8	6.2	213.5	557.7	3591.0			1096.2	8.7	444.9	2805.1
	3	Earthfill d/s, split stream, lined only PAG			1179.1	142.4	1321.5	462.7	2.9	557.7	4062.5	669.9	3219.1	1096.2		444.9	2805.1
	7	Tailings c/l, split stream, lined only PAG		318.8	891.2	142.4	1352.4	50.6	26.7	557.7	3544.8	669.9	2443.9	1096.2		444.9	2805.1
BGC C	1	Earthfill d/s, whole tailings, 100% lined	18.0		0.0	0.0	1331.7	376.6	3.5	505.2	4533.7	4760.4	4533.7	30411.8	33.1	625.3	2624.6
	3	Earthfill d/s, split stream, lined only PAG			1221.7	147.0	1368.7	423.1	3.2	538.1	4876.8	998.1	4008.1	30411.8		651.6	2598.4
	6	Earthfill c/l, whole tailings, 100% lined			0.0	0.0	1322.5	214.0	6.2	495.4	4129.8	4979.5	3327.6	30411.8		612.2	2637.8
	7	Tailings c/l, split stream, 100% unlined		244.7	950.6	147.8	1343.0	52.7	25.5	475.7	4429.1		3406.9	30411.8		651.6	2598.4
Carlotta HLP	1	Eartfill d/s, whole tailings, 100% lined	8.7		0.0	0.0	1339.8	237.7	5.6	754.6	3543.1	379.4	3044.4	17878.4	16.7	-719.8	3969.8
Upper Arnett	1	Whole tailings, 100% unlined	6.2		0.0	0.0	1192.0			935.0	2526.6			891.6	7.8	-719.8	3969.8
Silver King	1	Whole tailings, 100% unlined	1.9		0.0	0.0	1181.1			1197.5	21.2			8221.3	1.6	-703.4	3953.4
San Manuel (PAG tailings only)	1	PAG volume required: 104.87 Mm3	49.1	Only PAG (Y1 to Y45)			137.5							3373.1	55.7	382.5	2867.4

Based on quantitative comparison information shown on Table 3-2, the main advantages and disadvantages are discussed below for each site and alternatives:

Lower West Site

The Lower West site is the closest proposed thickened tailings storage facility (compared with BGC-C (Peg Leg) and Carlota), located approximately 5 miles northwest from the West Plant (straight line distance). This short distance from the plant decreases costs related to access roads, pipelines, and pumping. In addition, potential environmental impacts are reduced due to a shorter pipeline length, and reduced interference with wildlife and the local habitat.

This site has the smallest watershed area (1096.2 acres). A small watershed minimizes potential run-on and runoff, diversion and spillway costs and reduces the quantity of runoff that in contact with tailings. This site is also located at a lower elevation compared to the plant location (elevation difference between 360 feet and 460 feet), which reduces pumping costs.

Specific characteristics for the Lower West alternative design scenarios are described below:

- Lower West Scenario 5 (GPO base case) is attractive because it has the highest storage/dam ratio of 213.5 (relatively low embankment earthfill volume, approximately 6.2 million cubic yards), and it would be an unlined facility; both aspects significantly reduce the capital cost. The disadvantages of this alternative are: the permitting process might require more effort due to the historical poor performance of upstream dam construction method, and the potential for acid water and metals to mobilize into the environment via seepage because the facility is unlined.
- Lower West Scenario 3 is attractive because the dam downstream construction method is considered the most accepted construction method, from a dam stability perspective, and the PAG tailings are encapsulated with a liner at the northeast corner of the facility, simplifying the environmental permitting process. The main disadvantage is the high cost related with the highest earthfill dam volume (462.7 M yd^3), which results in a low storage volume/dam volume ratio of 2.9. However, using dam construction material sources within the TSF limit increases the tailings storage capacity and minimizes haulage costs and access roads construction.
- Lower West Scenario 7 has a storage/dam ratio increase from 2.9 to 26.7, reducing the capital cost as compared with Lower West Scenario 3. As a disadvantage, the dam stability for Alternative 7 relies on the operational control of tailings cycloning and coarse tailings compaction during dam raises.

BGC-C Site (“Peg Leg”)

The BGC-C site is the farthest proposed thickened tailings storage facility (when compared with Lower West and Carlota thickened TSFs), located approximately 18 miles southwest from the West Plant (straight line distance). This distance increases the cost related to access roads, pipelines, and pumping.

The site is located at lower elevation relative to the plant location (elevation difference between 590 feet and 624 feet), which will reduce the overall pumping costs. This site has a larger watershed area (30,411.8 acres), which would increase water management requirements.

Specific characteristics for the BGC-C (Peg Leg) alternatives are described below:

- BGC-C Scenario 1 and Scenario 3 both involve earthfill dams, and downstream construction, where Scenario 1 is fully lined to store the combined PAG and NPAG tailings, and Scenario 3 is partially lined at the south corner to store the PAG tailings. Scenario 3 has the advantage of isolating the PAG tailings in a specific area of the facility, while Scenario 1 will have the PAG tailings spread along the entire facility. Cost differences between Scenario 1 and Scenario 3 can be seen as a balance between the reduction of earthfill material and increase in liner area for Scenario 1, and an increase of earthfill material and a decrease in liner area for Scenario 3.
- BGC-C Scenario 6 is an optimization of Scenario 1, where the construction method was changed from earthfill downstream construction to the earthfill centerline construction method. The result is a storage/dam ratio increase from 3.5 to 6.2, reducing the capital cost when compared with Scenario 1.
- BGC-C Scenario 7 is an optimization of Scenario 3, where the construction method was changed from earthfill downstream construction to the tailings centerline construction method, and fully unlined. The portion of the PAG tailings disposal and the dam construction method remains the same for both as downstream construction method. The result is a storage/dam ratio increase significantly from 3.2 to 25.5, reducing the capital cost when compared with Scenario 3.

Carlota Site

The Carlota thickened tailings storage facility includes earthfill dams to be constructed using the downstream method, and the facility will be fully lined. It is located approximately 8.7 miles northeast from the West Plant. The advantage of this site is good topographical containment with a storage/dam ratio of 5.6 when compared with the others downstream construction alternatives, where the ratios range from 2.9 to 3.5.

A disadvantage of this site is that it would hold a relatively large watershed (17,878.4 acres), which increases the water diversion costs. This site is located at higher elevation in relation to the West Plant location (approximately 722 feet above the West Plant elevation), which increases pumping costs.

San Manuel Site

The San Manuel PAG tailings storage facility is composed of a depleted open pit. It is located approximately 49.1 miles south from the West Plant (straight line distance). Advantages of this site are: the open pit allows for a ready-to-go storage space; no dam construction would be necessary for only PAG tailings; good aesthetics and reduced environmental impact (pending further review of hydrogeological data of pit).

A disadvantage of this site is that it is very far away from the plant site, which adds costs associated with the transportation and management of tailings.

Filtered Tailings Dry Stack Sites

Two filtered tailings stacks were considered for further analysis at the Silver King and Upper Arnett sites.

Due to the need to convey or truck filtered tailings, it is beneficial to have the facility relatively close to the plant site. The Silver King filtered tailings stack is located approximately 1.9 miles northwest from the West Plant site. The Upper Arnett filtered tailings stack is located approximately 6.2 miles south from the West Plant site.

Both facilities would be unlined with the assumption that the dry stack would not release seepage, or have very limited seepage.

The advantages of dry stack facilities, when compared with conventional and thickened TSFs, include:

- Stack can be built anywhere on level ground or against a hillside
- Higher water recovery for use in the plant is particularly important in arid climates
- Less risk of catastrophic failure and tailings runout
- Limited earthfill borrow material is required
- Progressive reclamation and closure of the facility
- Less embankment footprint area, since the filtered tailings are denser
- Potential seepage to groundwater is reduced.

Some of the disadvantages of dry stack include:

- Higher capital and operating costs
- Oxidation of PAG tailings can create high concentrations (but low volumes) of seepage water
- Exposed areas of the stack can generate fugitive dust.

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BGC ENGINEERING INC.
per:

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Reviewed by:

Mike Henderson, PE
Principal Geotechnical Engineer

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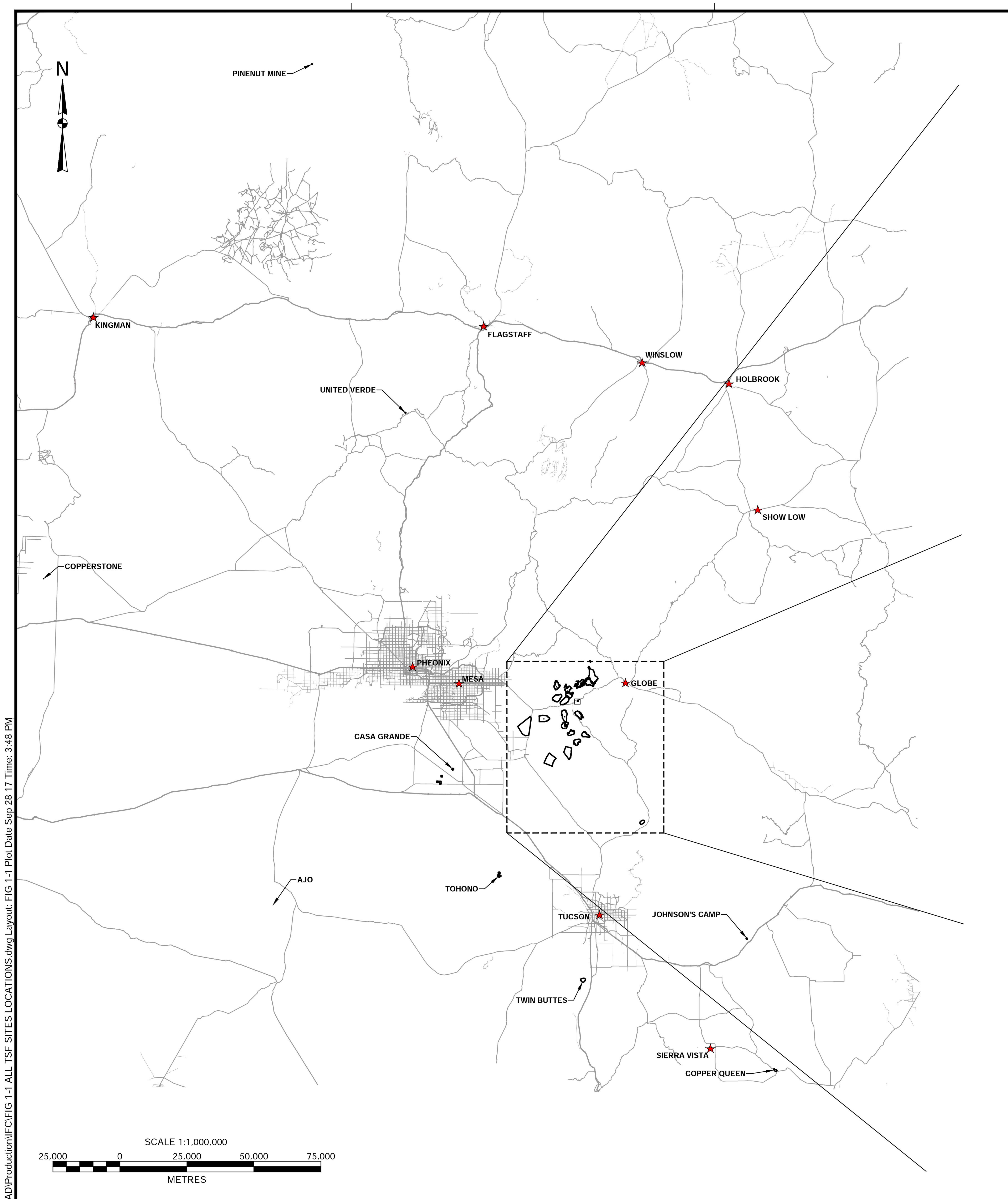
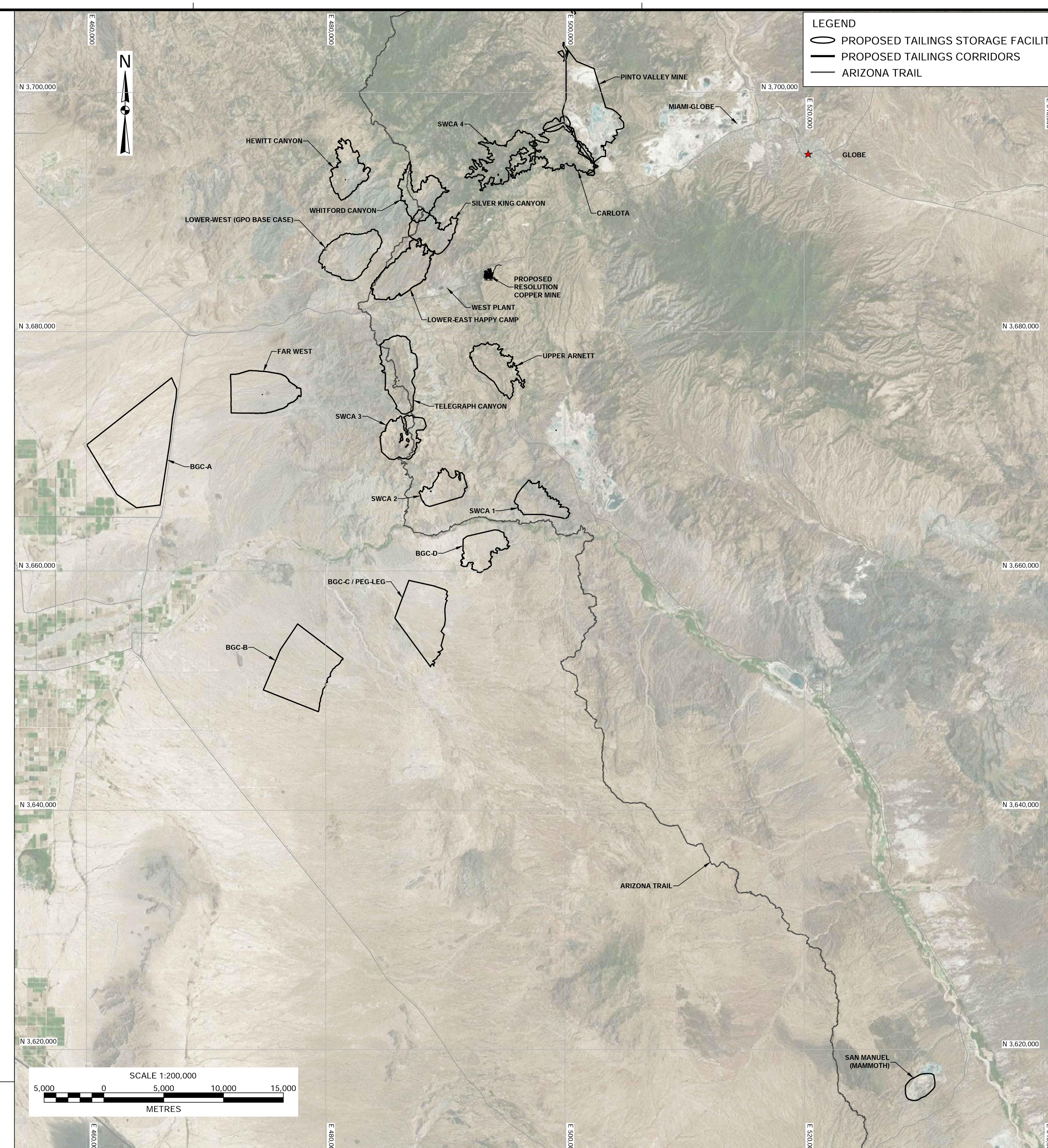
REFERENCES

Resolution Copper Mining. May 9, 2016. General Plan of Operations – Resolution Copper Mining. Document prepared for US Forest Service review and approval.

FIGURES





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TITLE: 30 TSF SITE LOCATIONS		
SCALE: 1:200,000	FIGURE No.: 1-1	REV.: A

X:\Projects\1704 SWCA Environmental Consultants\CAD\Production\IFC\FIG 1-1 ALL TSF SITES LOCATIONS.dwg Layout: FIG 1-1 Plot Date Sep 28 17 Time: 3:48 PM

ALTERNATIVES 1 & 2 FOR LOWER WEST, BGC_B AND BGC_C TSF SITES

ALTERNATIVE 3 FOR LOWER WEST, BGC_B AND BGC_C TSF SITES

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X:\Projects\1704 SWCA Environmental Consultants\CAD\Production\IFC\FIG 2-1 THROUGH 2-3- DAM SKETCHES.dwg Layout: DAM SKETCHES 2-1 Plot Date Sep 20 17 Time: 10:39 PM

ALTERNATIVE 4 FOR LOWER WEST, BGC_B AND BGC_C TSF SITES

ALTERNATIVE 5 FOR BGC_B AND BGC_C TSF SITES

ALTERNATIVE 5 FOR LOWER WEST

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DRAWN BY: DG	CHECK DRAWING: JC	BGC ENGINEERING INC. AN APPLIED EARTH SCIENCES COMPANY	PROJECT: RESOLUTION COPPER PROJECT EIS TAILINGS DISPOSAL ALTERNATIVES DEVELOPMENT
DESIGN BY: JC	CHECK DESIGN: MH/NE		TITLE: DAM SKETCHES (2 OF 3)
LEAD ENGINEER: MH	APPROVAL DATE: 09/22/17	CLIENT: SWCA	SCALE: 1:200,000 / FIGURE No.: 2-2 / REV.: A
PROJECT MANAGER: MH	APPROVAL DATE:		

THIS BAR MEASURES 100 mm AT FULL SIZE. ALL SCALES REFERENCED TO FULL SIZE.

X:\Projects\1704 SWCA Environmental Consultants\CAD\Production\IFC\FIG 2-1 THROUGH 2-3- DAM SKETCHES.dwg Layout: DAM SKETCHES 2-2 Plot Date Sep 28 17 Time: 4:24 PM

ALTERNATIVE 6 FOR BGC_C TSF SITE

ALTERNATIVE 7 FOR LOWER WEST AND BGC_C TSF SITES

THIS BAR MEASURES 100 mm AT FULL SIZE. ALL SCALES REFERENCED TO FULL SIZE.

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PROJECT MANAGER: MH	APPROVAL DATE:

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CLIENT: SWCA

PROJECT: RESOLUTION COPPER PROJECT EIS TAILINGS DISPOSAL ALTERNATIVES DEVELOPMENT		
TITLE: DAM SKETCHES (3 OF 3)		
SCALE: 1:200,000	FIGURE No.: 2-3	REV.: A

X:\Projects\1704 SWCA Environmental Consultants\CAD\Production\IFC\FIG 2-1 THROUGH 2-3- DAM SKETCHES.dwg Layout: DAM SKETCHES 2-3 Plot Date Sep 20 17 Time: 7:44 PM

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TAILINGS CORRIDORS

TSF ALTERNATIVE	LENGTH	
TSF ALTERNATIVE	km	miles
SILVER KING	2.6	1.6
UPPER ARNETT	12.5	7.8
LOWER WEST, ALTERNATIVE 7	14.0	8.7
BGC_C (PEG LEG), ALTERNATIVE 7	53.2	33.0
CARLOTA	26.8	16.6
SAN MANUEL	89.6	55.7

NOTES:
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3. PROJECTION IS UTM NAD 83 ZONE 12.
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CLIENT: SWCA

PROJECT: RESOLUTION COPPER PROJECT EIS TAILINGS DISPOSAL ALTERNATIVES DEVELOPMENT

TITLE: TSF'S LOCATION AND PROPOSED TAILINGS CORRIDORS LAND MANAGEMENT

SCALE:	FIGURE No.:	REV.:
1:200,000	3-1	A

X:\Projects\1704 SWCA Environmental Consultants\CAD\Production\IFC\FIG 3-1 TSF SITES LOCATIONS.dwg Layout: FIG 3-1 Plot Date Sep 20 17 Time: 10:16 PM

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3. BASE TOPOGRAPHIC DATA BASED ON SRTM DATA, DATED FEBRUARY 2000. CONTOUR INTERVAL IS 50 m.
4. PROJECTION IS UTM NAD 83 ZONE 12.
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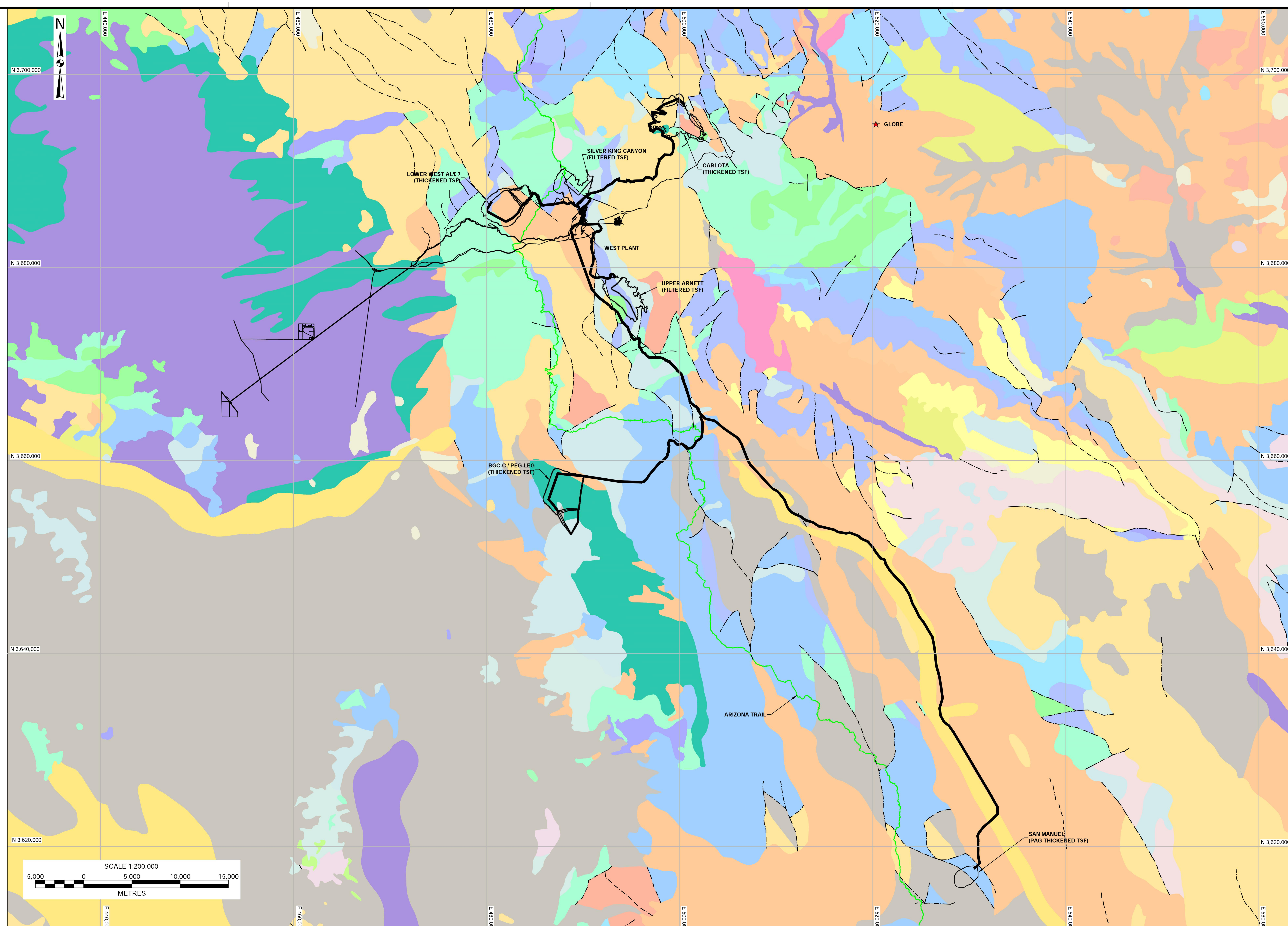
CLIENT: SWCA

PROJECT: RESOLUTION COPPER PROJECT EIS TAILINGS DISPOSAL ALTERNATIVES DEVELOPMENT

TITLE: TSF'S LOCATION AND PROPOSED TAILINGS CORRIDORS LAND MANAGEMENT

SCALE:	FIGURE No.:	REV.:
1:100,000	3-2	A

X:\Projects\1704 SWCA Environmental Consultants\CAD\Production\IFC\FIG 3-2 TSF SITES LOCATIONS - ENLARGED.dwg Layout: FIG 3-2 Plot Date Sep 20 17 Time: 10:34 PM



LEGEND

- PROPOSED TAILINGS STORAGE FACILITY
- PROPOSED TAILINGS CORRIDORS
- FAULT

GEOLOGY LEGEND

LBL.	CLR.	UNIT
Jg		Jurassic granitic rocks
Jgc		Glen Canyon Group
Jm		Morrison Formation
Js		San Rafael Group
Jsv		Jurassic sedimentary and volcanic rocks
JTR		Jurassic and Triassic sedimentary and volcanic rocks
Jv		Jurassic volcanic rocks
KJo		Orocopia Schist
KJs		Cretaceous to Late Jurassic sedimentary rocks with minor volcanic rocks
Kmv		Sedimentary rocks of the Late Cretaceous Mesaverde Group
Ks		Cretaceous sedimentary rocks
Kv		Early Tertiary to Late Cretaceous volcanic rocks
MCA		Mississippian, Devonian, and Cambrian sedimentary rocks
MZPZ		Jurassic to Cambrian metamorphosed sedimentary rocks
P		Permian sedimentary rocks
PPA		Permian to Pennsylvanian sedimentary rocks
PZ		Paleozoic sedimentary rocks
Q		Quaternary surficial deposits, undivided
Qm		Late and middle Pleistocene surficial deposits
Qo		Early Pleistocene to latest Pliocene surficial deposits
Qr		Holocene river alluvium
QTb		Holocene to middle Pliocene basaltic rocks
QTs		Early Pleistocene to late Miocene basin deposits
QTv		Holocene to middle Pliocene volcanic rocks
Qy		Holocene surficial deposits
Tb		Late to middle Miocene basaltic rocks
Tby		Pliocene to late Miocene basaltic rocks
Tg		Middle Miocene to Oligocene granitic rocks
Ti		Middle Miocene to Oligocene shallow intrusions
TKg		Early Tertiary to Late Cretaceous granitic rocks
TKgm		Early Tertiary to Late Cretaceous muscovite-bearing granitic rocks
TRc		Chinle Formation
TRcs		Shinarump Conglomerate Member, Chinle Formation
TRm		Moenkopi Formation
Tsm		Middle Miocene to Oligocene sedimentary rocks
Tso		Oligocene to Paleocene[?] sedimentary rocks
Tsv		Middle Miocene to Oligocene volcanic and sedimentary rocks, undivided
Tsy		Pliocene to middle Miocene deposits
Tv		Middle Miocene to Oligocene volcanic rocks
Tvy		Pliocene to middle Miocene volcanic rocks
TXgn		Tertiary to Early Proterozoic gneissic rocks
water		water
Xg		Early Proterozoic granitic rocks
Xm		Early Proterozoic metamorphic rocks
Xms		Early Proterozoic metasedimentary rocks
Xmv		Early Proterozoic metavolcanic rocks
Xq		Early Proterozoic quartzite
Yd		Middle Proterozoic diabase
Yg		Middle Proterozoic granitic rocks
Ys		Middle Proterozoic sedimentary rocks
YXg		Proterozoic granitic rocks

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3. GEOLOGY MAPPING BASED ON "GEOLOGIC MAP OF ARIZONA (2000)" PUBLISHED BY THE ARIZONA GEOLOGIC SURVEY (HTTP://WWW.AZGS.AZ.GOV/SERVICES_AZGEOMAP.SHTML). FULL LEGEND AVAILABLE AT HTTP://DATA.AZGS.AZ.GOV/GEOLOGIC-MAP-OF-ARIZONA/.
4. PROJECTION IS UTM NAD 83 ZONE 12.
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LEAD ENGINEER: MH	APPROVAL DATE: 09/22/17
PROJECT MANAGER: MH	APPROVAL DATE:

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AN APPLIED EARTH SCIENCES COMPANY

CLIENT: SWCA

PROJECT: RESOLUTION COPPER PROJECT EIS
TAILINGS DISPOSAL ALTERNATIVES DEVELOPMENT

TITLE: TSF'S LOCATION AND PROPOSED TAILINGS CORRIDORS
GEOLOGY

SCALE:	FIGURE No.:	REV.:
1:200,000	3-3	A

X:\Projects\1704 SWCA Environmental Consultants\CAD\Production\IFC\FIG 3-1 TSF SITES LOCATIONS.dwg Layout: FIG 3-3 Plot Date Sep 20 17 Time: 8:27 PM

SCALE 1:200,000

5,000 0 5,000 10,000 15,000

METRES

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CLIENT: SWCA

PROJECT: RESOLUTION COPPER PROJECT EIS
TAILINGS DISPOSAL ALTERNATIVES DEVELOPMENT

TITLE: TSF'S LOCATION AND PROPOSED TAILINGS CORRIDORS
AERIAL PHOTO

SCALE:	FIGURE No.:	REV.:
1:200,000	3-4	A

X:\Projects\1704 SWCA Environmental Consultants\CAD\Production\IFC\FIG 3-1 TSF SITES LOCATIONS.dwg Layout: FIG 3-4 Plot Date Sep 20 17 Time: 7:58 PM