SUBSIDENCE MONITORING & MANAGEMENT PLAN

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1 INTRODUCTION

Subsidence at the Resolution Copper (RC) project is predicted to occur in a typical slow and gradual process from approximately year 6 when the cave from the underground mining is expected to reach surface. This gradual subsiding of the surface and growth of the subsidence bowl will then occur as mining continues through its estimated 40-year life of the project and in a much smaller and slower capacity for a number of years after mining has ceased.

The dimensions, rate of change, the relative horizontal & vertical displacements of the subsidence footprint have been analyzed and disclosed in the Environmental Impact Statement (EIS) through the use of an explicit finite-difference program (*FLAC3D)* that employs an industry accepted and well established caving algorithm to simulate large scale rockmass deformation and displacements.

There are a number of areas of importance that occur in and around the proposed mining operation that will receive particular attention in this monitoring and management programme. RC is committed to protecting and preserving these areas.

- *Apache Leap*
- *Queen Creek & Devils Canyons*
- *Highway US -60*

Additionally, Resolution Copper will maintain public access to the Oak Flat Campground (and area comprising approximately 50 acres and 16 developed campsites) as long as it is safe, with safety determined by compliance with Mine Safety and Health Administration (MSHA) regulations and guidance. Resolution will allow continued public access to Oak Flat Campground after the land exchange has been completed and the parcel is privately owned by Resolution Copper. The duration and extent of access would be determined by compliance with MSHA safety requirements. Based on subsidence impacts predicted in the EIS, public access is expected to continue for more than thirty years and may never be restricted.

This monitoring and management plan will outline the methodologies and strategies to ensure that the impact of subsidence is continuously monitored, managed and communicated throughout the life of the mine and thereafter.

2 Overall Strategy for Subsidence Monitoring & Management

- Subsidence Monitoring Methodology
  - Will be subdivided into multiple phases of instrumentation installations and will be subjected to time dependencies as the mining progresses with subsequent growth in the surface subsidence footprint.

- Subsidence Management Methodology
    - Will use the predictions from the EIS subsidence impact analysis (Itasca, July 2017) on surface subsidence for the RC operation in conjunction with actual field measurements obtained from the various instrumentation. A graphical comparative tracking tool will be used to measure and track actual data to modeled data. This will provide valuable early trends and projections on subsidence progression and rates of growth, which in turn will allow for early mechanism understandings and if required, implementation of any mitigation strategies.

3 Monitoring Methods & Instrumentation

Surface subsidence at RC will be monitored using a number of different methods and instrumentation types using proven technology and best practice as seen throughout the industry. As such, methods and instrumentation may change over time. The frequencies of measurement recommended in the relevant phases represent a best initial estimate on how caving and the associated subsidence will progress. When caving commences and data starts becoming available, adjustments may be made on the monitoring frequency based on actual subsidence behavior to ensure that the data is fully representative of conditions.

The table below is a list of what is proposed, and the primary purpose and encompasses the entire subsidence monitoring window period from pre to post mining activities (Phase 1 through to 6).

Instrumentation/Monitoring Method	Purpose/Reasoning
InSAR (Interferometric synthetic aperture radar)	Measure changes in surface displacements (primary vertical sense with lateral calibration to other instruments) across a very large area.
Aerial Photogrammetry (Drone Technology)	Measure vertical & lateral (using targets in the field) displacements through 3D point cloud analysis of the surface. Furthermore, it also provides high definition images for observational analysis of subsidence behavior.
Robotic Prism Network using a Total Survey Station	Monitoring of survey prisms anchored to the surface at strategic points to validate the relative displacements captured through InSAR & Photogrammetry analyses.
LIDAR (Light Detection & Ranging)	Terrestrial laser scanning of important features like “Apache Leap” where steep rock faces are monitored for toppling/rotational type of displacements.

TDR's (Time Domain Reflectometers)	Monitor shallow to deep seated subsurface rockmass deformations and assist in tracking of cave propagation to surface in Phase 2. TDR's are limited in that they can only provide area/ location of ground movement and not magnitude.
Open Holes	Track & monitor the propagation of the cave to surface using simple borehole camera and/or weighted probe.
Cave Smartmarkers & Beacons with Detectors	Monitor cave growth, propagation and flow of material in the cave and sensitivities to draw
Wireless Wireless In-Ground Monitoring ("Geo4Sight")	Monitor shallow to deep seated subsurface rockmass deformation with magnitude and direction ability.
Inclinometers	Monitor near surface to ~ 250m (max) rockmass displacements. Limited to depths of ~ 250m and cannot tolerate high levels of rockmass deformation. Plan to use early on in phase 3 as a means to validate the Geo4Sight deformation interpretations. Can be phased out later in the monitoring programme.
Soil Extensometers (Multi-Point)	Monitor superficial (1-2m below surface) lateral displacements of overburden materials. Particularly useful close to areas of concern/importance as they are very sensitive and provide a high degree of accuracy.
Surface Monuments (Concrete Lock Blocks)	Monitor vertical, but primarily the lateral surface displacements (direction & magnitude) for calculating the angular distortion for any selected area.
Crack Mapping	Field observations of subsidence induced tension crack formation. Survey measurements of location, length, aperture and vertical offset. This monitoring should be started soon after breakthrough (Phase 3 onwards) and observations can be done initially using the photogrammetry images to identify onset and followed by field measurements and installation of "crackmeters" to monitor growth and trends.

4 Subsidence Monitoring

Subdivided into 4 discrete caving related progression events and 6 phases of instrumentation and monitoring (Figure1)

Zones for Phased Monitoring & Instrumentation Installation

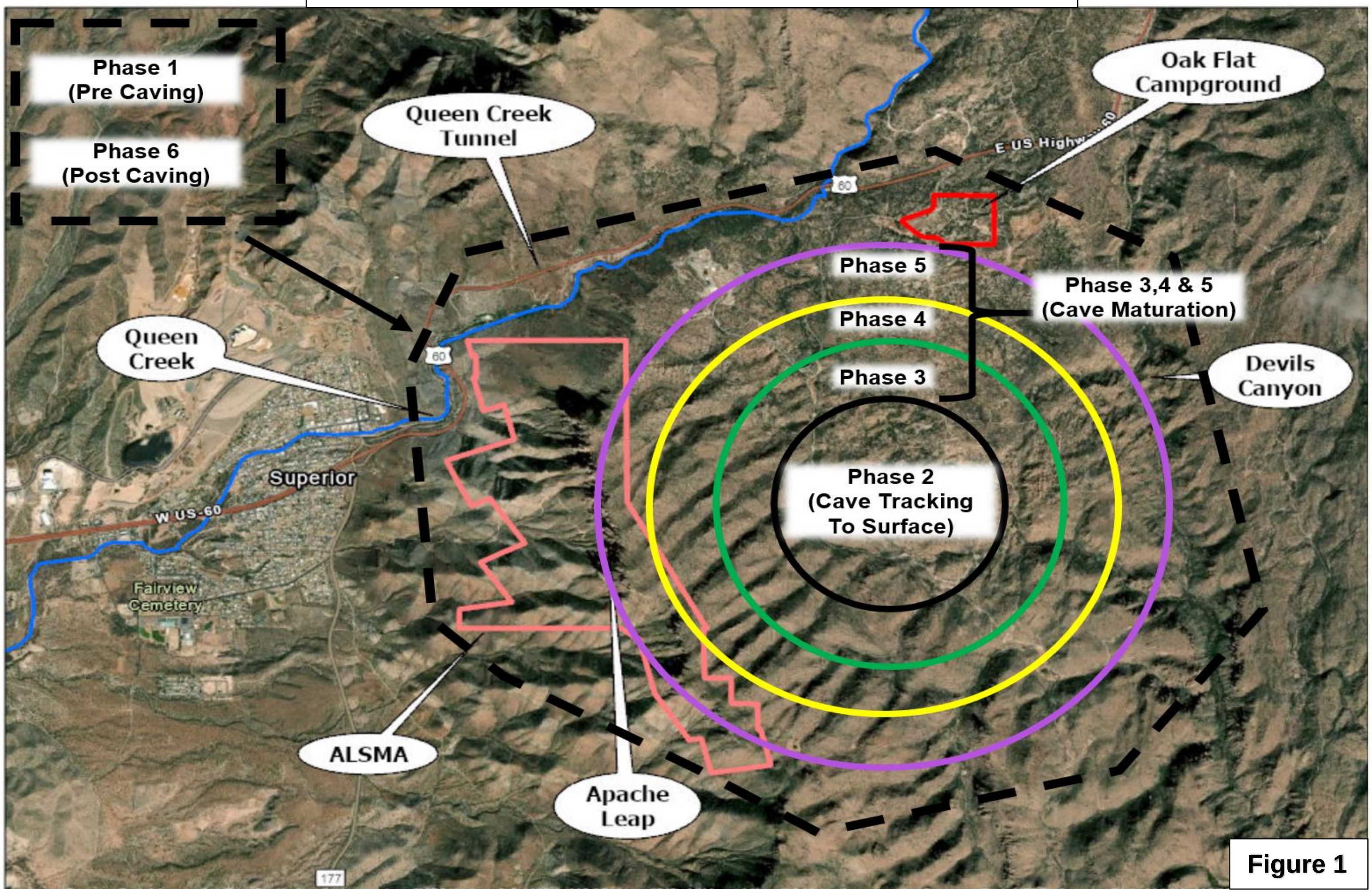

Figure 1

4.1 Pre-Caving (Phase 1)

This phase supplements baseline data readings of the entire area encompassing all the features/areas of particular interest as indicated in the figure above (Figure 1). Phase 1 will establish if there are any observable displacements that might be occurring in the absence of mining and if there are any seasonal fluctuations that are evident. It also allows for the establishment of fixed ground control targets and system calibration for future data processing and monitoring. Due to the very steep and high cliffs that comprise Apache Leap, in addition to the InSAR monitoring, this phase will also include terrestrial LIDAR to monitor for any pre-mining toppling/rotational displacements of the rock faces.

Area/Zone/Phase	Monitoring Type	Frequency
Hatched Black Line (Regional Area with +/- 100m beyond the focus areas)	InSAR (Satellite Imagery)	2 x Annually
Apache Leap	LIDAR (Terrestrial)	2 x Annually

4.2 Caving to Surface (Phase 2)

During this phase the Cave has been initiated through production undercutting and steady state caving is achieved when the cave starts to propagate to surface. The modelling results from ITASCA suggests that it will be around year 6 when the cave reaches surface. Resolution will actively monitor the cave propagation rate, boundaries and track the cave geometry in this phase. This phase also allows for the refinement of exclusion zone boundaries and the timing of their implementation based on expected breakthrough of the Cave.

Note: This is also the time that the phase 3 monitoring network will be installed at least 6 months before expected cave breakthrough.

Area/Zone/Phase	Monitoring Type	Frequency
Polygon - Hatched Black Line (Regional Area with +/- 100m beyond the focus areas)	InSAR (Satellite Imagery)	2 x Annually
Apache Leap	LIDAR (Terrestrial)	2 x Annually
Solid Black Circle (Phase 2)	Cave Network Smart Markers/Beacons with Detectors	Continuously

	Time Domain Reflectometry Coaxial Cables	Continuously (Real-Time OR set at minute/hour reporting intervals)
	Micro-Seismic System	Continuously (Real-Time Data Acquisition with auto processing of events)
	Open Holes	Quarterly
	Aerial Photogrammetry (Drones) for Image & Point Cloud creation	2 x Annually Monthly for 3 months just prior to cave breakthrough
Solid Green Circle (Phase 3 – Baselining Data)	Inclinometers	Quarterly
	Wireless In-Ground Monitoring (“Geo4Sight”)	Continuously (Real-Time Remote Data Acquisition)
	Soil Extensometers (Multi Point)	Continuously (Real-Time Remote Data Acquisition)
	Surface Monuments (Concrete “Lock Block” Targets)	As Per Photogrammetry Schedule Handheld GPS Confirmations – Quarterly
	Robotic Total Station Prism Network	Initial cycle every 6 hours
	Crack Mapping	Quarterly Only to commence once HCr (Critical Hydraulic Radius) is achieved during cave undercutting phase

4.3 Cave Maturation after Breakthrough (Phase 3, 4 & 5)

These 3 phases of monitoring are tied to the gradual radial outward growth of the subsidence footprint as the cave matures. The ITASCA model (2017) will be used as a

guide as to when the various phases of instrumentation installations are required and the estimated duration of the monitoring within each phase.

The reason for the multi-phased approach in this stage of cave maturation is to ensure that monitoring data is maintained as instruments will be gradually damaged and destroyed with increased deformation as the subsidence bowl enlarges.

The instrument types and monitoring methodology in all these phases will largely be duplicated with some minor field adjustments being made in terms of depth and dip of the subsurface instrumentation.

Area/Zone/Phase	Monitoring Type	Frequency
Polygon - Hatched Black Line (Regional Area with +/- 100m beyond the focus areas)	InSAR (Satellite Imagery)	2 x Annually
Apache Leap	LIDAR (Terrestrial)	2 x Annually
(Phase 3 – Green Circle) **Req'd (est) - Year 6 to 10** (Phase 4 – Yellow Circle) **Req'd (est) - Year 10 to 25** (Phase 5 – Purple Circle) **Req'd (est) - Year 25 to 40 (LOM)**	Inclinometers Wireless In-Ground Monitoring (Geo4Sight) Aerial Photogrammetry (Drones) for Image & Point Cloud creation Soil Extensometers (Multi Point) Surface Monuments (Concrete "Lock Block" Targets Robotic Total Station Prism Network Crack Mapping	Monthly Continuously Monthly (Adjust to bi-weekly if acceleration or anomalies observed- applies to Phase 3, 4 & 5) Continuously As Per Photogrammetry Schedule Continuously (Start with a ~ 6 hour cycle & adjust as required) Initially using aerial images from photogrammetry on same schedule/frequency. After onset of cracks. Quarterly (Phase 3), Monthly (Phase 4 & 5)

4.4 Post Caving (Phase 6)

This phase is characterized by time dependant compaction of the broken material within the mobilized zone of the cave. This compaction of material results in residual subsidence or “creep” which can occur over several years in the former mobilized zone, however the incremental changes or rate of subsidence reduces rapidly in an exponential fashion. Industry case studies indicate that a conservative estimation for full residual creep decay is in the order of 15 years. Another important aspect to note here is that historic post mining subsidence data gathered from San Manuel (large caving operation located in Arizona that ceased underground operations more than 20 years ago) revealed that the lateral extent of the fracture zone boundary remained static with the subsequent material compaction (time dependent creep) all occurring within the mobilized zone of the cave.

Based on this information, RC will continue to monitor the subsidence, any trends and potential impacts on key areas and infrastructure at the intervals below.

As mentioned, because the drop off in subsidence is very rapid after mining has ceased, the use of regional aerial monitoring techniques such as InSAR in combination with reduced LIDAR targets and frequency of measurements is sufficient to track any future subsidence growth or trends.

Area/Zone/Phase	Monitoring Type	Frequency
Hatched Black Line (Regional Area with +/- 100m beyond the focus areas)	InSAR (Satellite Imagery)	2 x Annually
Apache Leap	LIDAR (Terrestrial)	Annually (Increase frequency dependent on data trends obtained from InSAR)
Phase 3, 4 & 5	All remaining functional remote monitoring equipment used in Phase 3, 4 & 5	Quarterly data with threshold triggers

5 Subsidence Management

The monitoring plan outlined in the preceding section and the data obtained from the various instrumentation will be a fundamental input source in the overall management of subsidence. Tracking against predicted states of subsidence will provide insights into trends and will allow for projections and implementation of early mitigation measures, if required.

The data combined with the numerical model predictions disclosed in the EIS (Assessment of Surface Subsidence Associated with Caving Resolution Copper Mine Plan of Operations, July 17, 2017, Ref# 2-5605-01: 17R25) will be used as a basis for comparison to actual field measurements and associated subsidence profiles. An explanation of the process and the steps follow.

5.1 Subsidence Management Methodology, Triggers Levels and Associated Actions

- Figure 2 is a plot of the building damage criterion (combination of angular distortion & horizontal strain) at year 40 (end of mining life) and as depicted by the hatched black lines, all the areas of specific importance and focused attention are located at various distances from the modelled centre of crater (CoC).

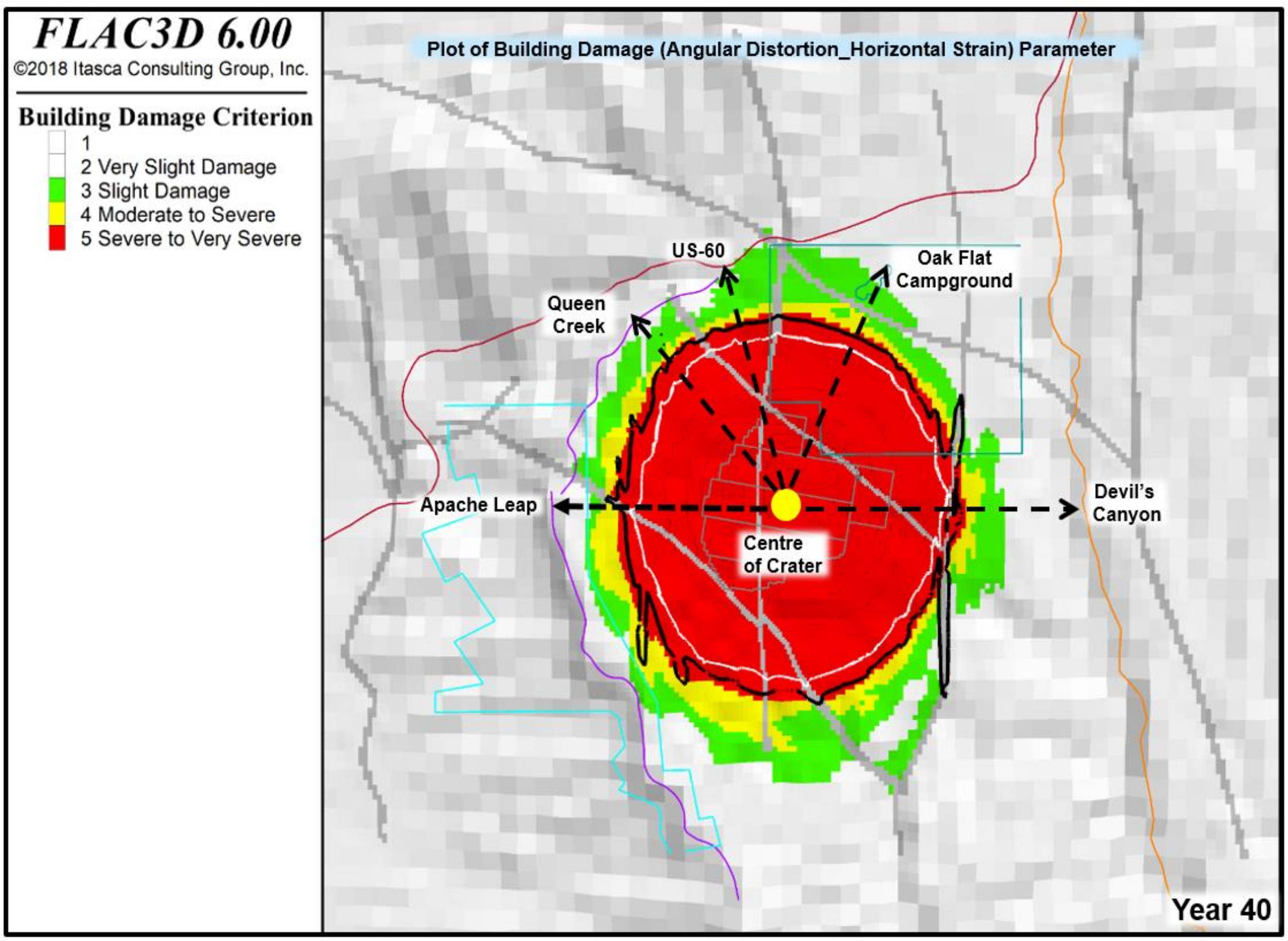

Figure 2

Angular distortion, β, is the ratio of the differential settlement (Δ or δ) between 2 points divided by the distance (L) between them, and horizontal strain (Ɛh) is simply the deformation change that occurs due to an applied force divided by the original length of a body. These concepts are illustrated in a graphical sense in Appendix A. The mining induced subsidence naturally creates the differential imbalance resulting in the body distortion which in turn generates various strain gradients with tension cracks and scarps ultimately appearing as a surface expression.

For each section line shown in Figure 2 between the center of the crater and the point of interest (Apache Leap SMA, Devil's Canyon, US60, Queen Creek, Oak Flat Campground, or others) plots would be generated for each year for the selected deformation parameter to track the subsidence impact over time. As an example, the plot shown in Figure 3 with a final state prediction (Year 40) is for Apache Leap.

- The values associated with the Y axis and the 3 deformation zones as reflected in Figure 3 are in direct reference to the industry accepted building damage plot (Modified after Harrison, 2011). Since there is no true static state in nature, with or without mining influences, the condition shown represents a trend to a negligible state. Furthermore, based on what can be practically measured and derived from the field instruments, a conservative limit has been selected at the upper boundary of the “slight damage” zone from which exceedances are to be measured from.
    - Base Trigger Limit = 0.2 % Angular Distortion & 0.1 % Horizontal Strain
- The Trigger Action Response Plan Levels 1, 2 & 3 will generate certain actions depending on the amount of subsidence deviation, expressed in terms of percentage exceedance. (See Figure 4 for Examples)
    - Percentage Exceedance = Actual – Distance X / Distance Y
        - Actual (Field Data) = Distance from the Centre of the Crater (CoC) to the intersection point along the base trigger limit line.
        - Distance X (Model) = Distance from the CoC to where the modelled condition intersects the base trigger limit line.
        - Distance Y (Model) = Distance from “distance X” intersection point along the base trigger limit line to the point of impact of the area in consideration.
- TARP levels indicated in Figure 3 represent levels of deviation tolerances from the modelled condition. Level 1 = 0 - 30%, Level 2 = 31% to 60%, Level 3 = >60%, and the actions associated with each level are commensurate to the level condition, with level 1 being the lowest and level 3 requiring more stringent actions/mitigation measures.

Modelled Damage Criterion Plot – Centre of Crater to “Apache Leap Special Management Area”

(Note: Used Apache Leap in this example, but Queen Creek, Devils Canyon, US 60 Hway, Oak Flat, etc…are all treated in exactly the same way)

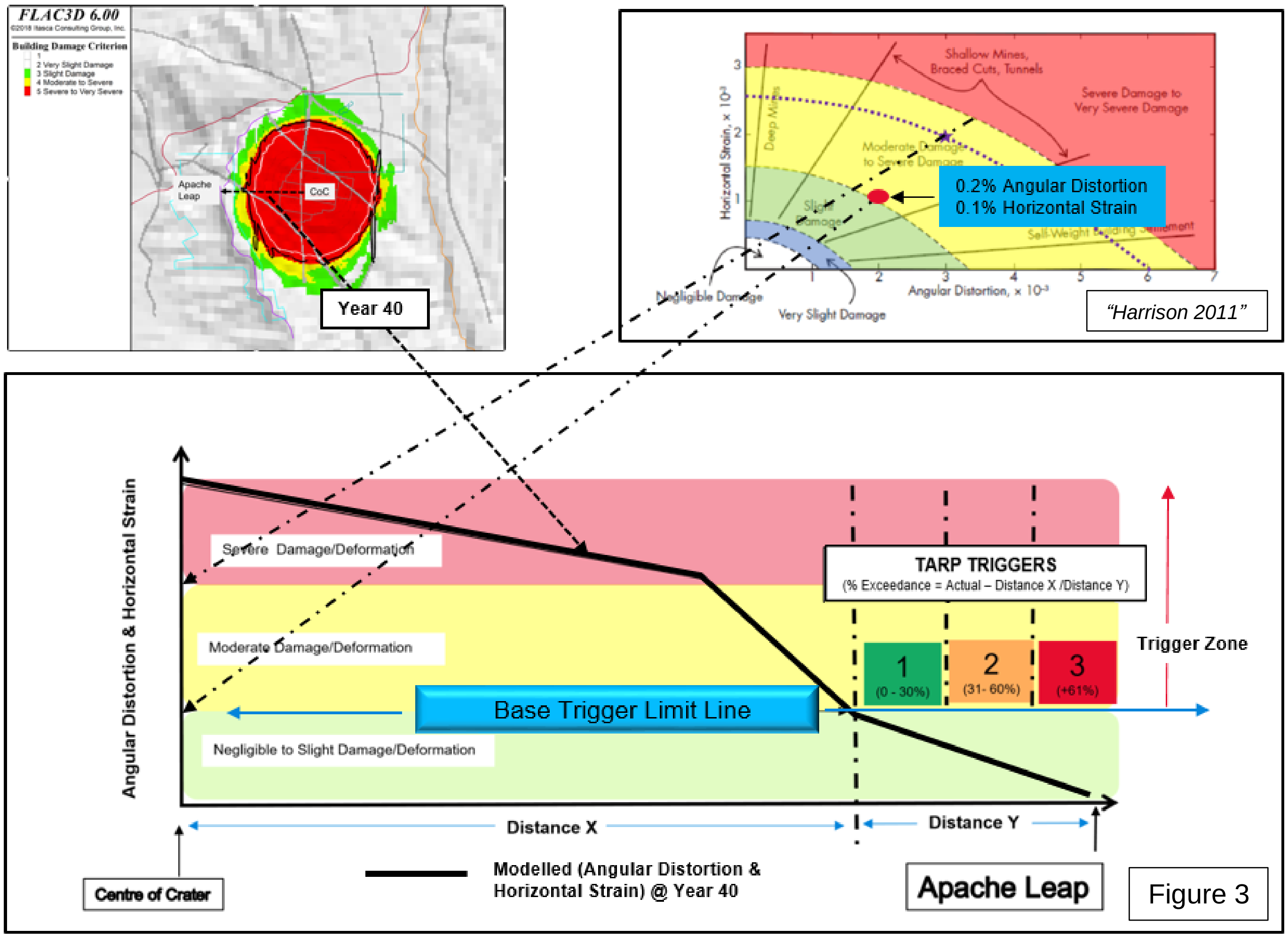

Figure 3

- Using this approach and applying the percentage exceedance methodology as a means to evaluate potential risk of impact, plots would be generated from the field monitoring data and plotted against the year from the modeled data plots (Figure 4) and each area of interest (Queen Creek, Apache Leap SMA, Devil's Canyon, etc...).
- If there is a “step out” or deviation in the subsidence profile during the course of the mining life, and after implementation of early levels (1 and 2) in the trigger action response plan (TARP) and the deviation is not resolved, then mining would be suspended if potential impact is projected for the areas of interest. Note that the percentage exceedance will increase year upon year, even if there was no increase in the original offset distance, which is a function of the percentage exceedance calculation. As such the plan incorporates a strong focus on early monitoring and mitigating potential issues early to avoid the potential for mining disruptions.
- Figure 4 below is an example plot, showing the modeled subsidence condition at year 20 (blue line) and hypothetical data outcomes from field measurements plotted for the area of interest (in this case, Apache Leap).
- Note that as per “measured example 1” in Figure 4 if the actual falls below the modelled condition and therefore no actions are needed and mining continues as planned.
- The associated actions that apply to the TARP levels1, 2 & 3 are listed in table1.

Annual Tracking Example – Measured vs Modelled

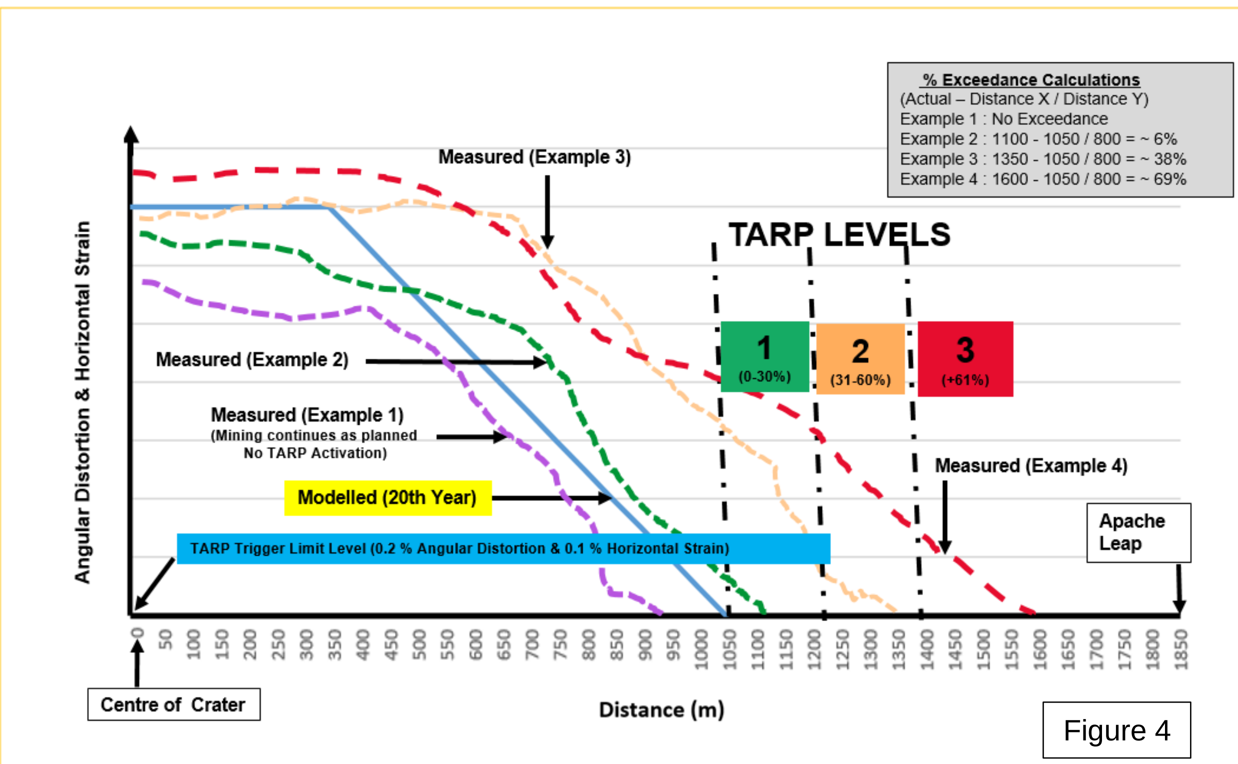

Figure 4

6 Reporting to USFS

For reporting to the USFS, all the subsidence data will be compiled and submitted in a format (TBD) that will capture the pertinent issues such as data observations, instrumentation and system status, data trends and tracking behavior.

Phase	Frequency
Phase 1 (Pre-Caving)	Annually
Phase 2 Caving to Surface)	2 x Annually
Phase 3, 4 & 5 (Cave Maturation after Breakthrough)	Quarterly
Phase 6 (Post Caving)	2 x Annually (First 10 years after Mining Cessation) Annually (Year 11+ after Mining Cessation)

7. Subsidence Trigger Action Response Plan (Table 1)

TRIGGER LEVEL	THRESHOLD/CONDITION DESCRIPTION	ACTIONS
1	Actual subsidence plotted against the modelled is in **excess of the prediction state with a percentage exceedance greater than 0 and up to 30%**	1) RC to confirm the instruments are all functioning correctly and providing data on the intervals as required. 2) RC to conduct an internal data validation exercise to check on the data integrity and interpretations 3) The site Geotechnical Engineer must inform the Mine Manager of the outcome following the interrogation of the data. 4) RC Management to inform USFS of the subsidence exceedance condition 5) A field investigation to be conducted by a RC Geotechnical Engineer to assess and document the surface conditions specifically in the zone where the subsidence exceedance has occurred. 6) Geotechnical Engineer and Planning Engineer to check on production schedule and draw compliance and notify Production Manger to correct if deviations are noted. 7) Increase monitoring frequency and continue to track for any further deviations.
2	Actual subsidence plotted against the modelled is in **excess of the prediction state with a percentage exceedance greater than 30% and up to 60%**	1) RC to confirm the instruments are all functioning correctly and providing data on the intervals as required. 2) RC to conduct an internal data validation exercise to check on the data integrity and interpretations. 3) RC to engage with an external and independent person/organization to conduct a similar instrumentation and data integrity review. 4) The site Geotechnical Engineer must inform the Mine Manager of the outcome following the interrogation of the data. 5) RC Management to inform USFS of the subsidence exceedance condition. 6) A field investigation to be conducted by a RC Geotechnical Engineer to assess and document the surface conditions specifically in the zone where the subsidence exceedance has occurred. 7) Geotechnical Engineer and Planning Engineer to check on production schedule and draw compliance and notify Production Manager to correct if deviations are noted. 8) Mining sequence and draw schedule to be altered to reduce potential further expansion or exceedance of the footprint by targeting production that would locate furthest from the surface feature of concern. 9) Add instrumentation (to fill any possible data gaps or improve sensitivity) and further increase monitoring frequency and continue to track for any further deviations.
3	Actual subsidence plotted against the modelled is in **excess of the prediction state with a percentage exceedance of greater than 60%**	1) RC to immediately confirm the instruments are all functioning correctly and conduct an immediate data validation exercise to check on data integrity. 2) RC Geotechinical Engineer to immediately inform the RC Mine Manager on the condition observed. 3) RC Management to notify the USFS of the situation within 24hrs of having conducted the internal data validation. 4) All production (cave related drawpoint activities) to cease immediately. 5) Investigation to be initiated immediately to throroughly review the condition and identify possible causes for the exceedance level in the subsidence profile. 6) Investigation will determine the next steps, implement remedial measures as required and determine the options if restart of the cave production is possible at this time.

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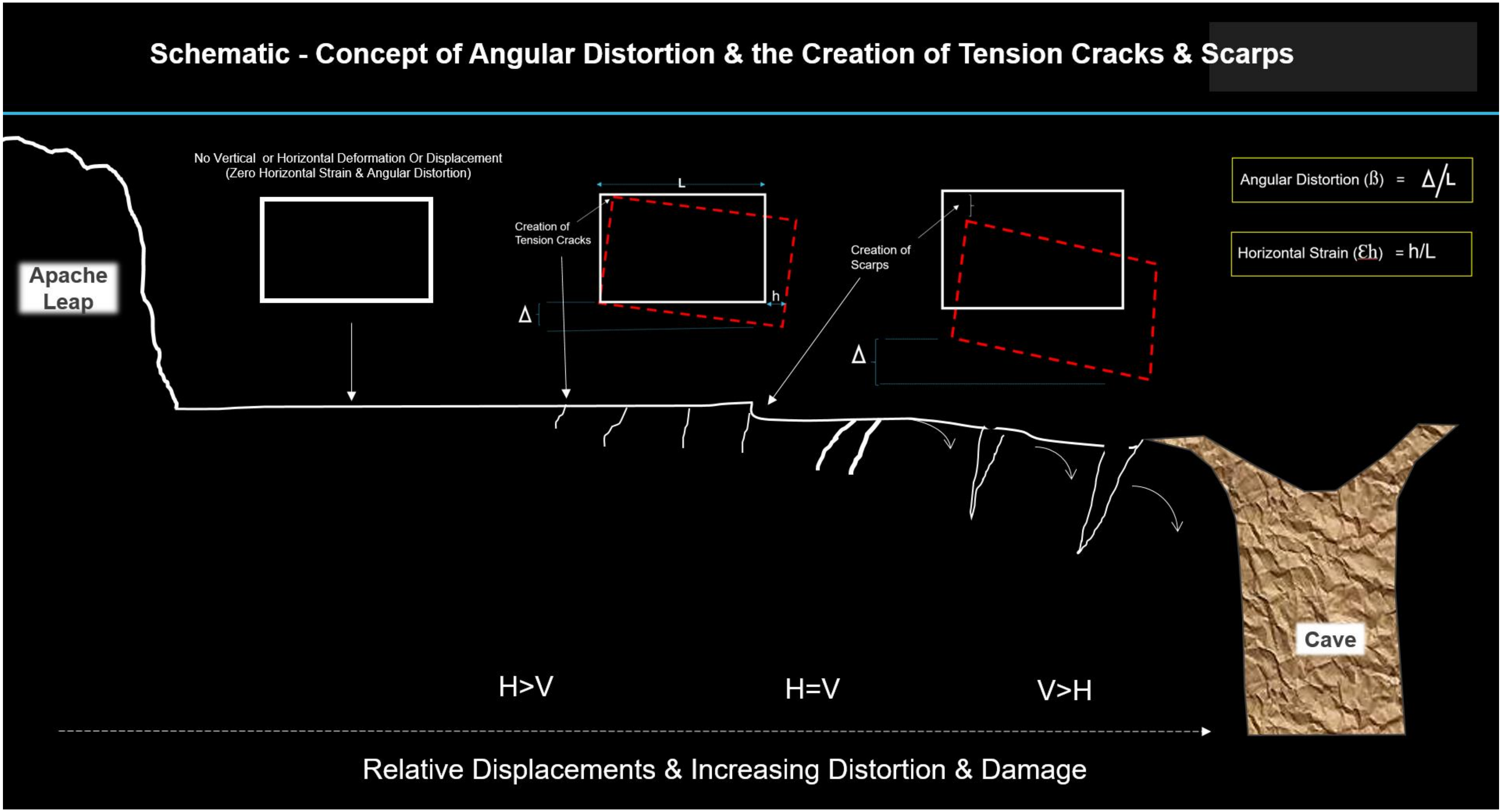
8. Schematic of Angular Distortion Concept (Appendix A)



Victoria Boyne

From: ResolutionProjectRecord
Subject: FW: [External] Subsidence Monitoring Plan - Next Step/Plan of Attack
Attachments: RC SMP_Final_ Aug 20_2020.pdf

From: Peacey, Victoria (RC) <Victoria.Peacey@riotinto.com>
Sent: Thursday, August 20, 2020 5:13 PM
To: Chris Garrett <cgarrett@swca.com>
Cc: Rasmussen, Mary C -FS <mary.rasmussen@usda.gov>; Donna Morey <dmorey@swca.com>
Subject: RE: [External] Subsidence Monitoring Plan - Next Step/Plan of Attack

EXTERNAL: This email originated from outside SWCA. Please use caution when replying.

Hello Chris and Mary – For your review and consideration, please see the attached updated subsidence monitoring and management plan in response to comments (and consistent with the responses submitted on August 6, 2020).

Thanks,

Vicky Peacey
Senior Manager Permitting and Approvals

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