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January 17, 2012

Mr. James Upchurch, Supervisor
Coronado National Forest
P.O. Box 4207
Logan, Utah 84323

RE: Comments on Draft Environmental Impact Statement for Proposed Rosemont Mine Plan of Operations

Dear Mr. Upchurch:

Please consider the following document, *"Statement of Concern—Ground-water Resources of the Sonoita Plain"* as an official public comment of the Sonoran Institute pursuant to the National Environmental Policy Act (NEPA) regarding the Rosemont Copper Draft Environmental Impact Statement.

Sincerely,

Luther Propst
Executive Director
The Sonoran Institute

Statement of Concern—Ground-water Resources of the Sonoita Plain

I. Introduction

Purpose -- Recent inquiries of possible effects on ground-water resources underlying the Sonoita Plain, Pima, Santa Cruz, and Cochise Counties, Arizona, suggest a potential for unacceptable declines in ground-water levels owing to flow of water into a pit if a copper mine is constructed at the Rosemont site, northeastern Santa Rita Mountains, AZ. The purposes of this statement are to (1) express this concern to regulators and decision-makers responsible for the permitting process to conduct mining at the site, (2) provide a basis for the concern, and (3) provide estimates of the possible range of effects if copper mining at the Rosemont site has the regional hydraulic effect described in this statement. Investigations pertinent to the issue are summarized below to provide a basis for the conclusion that concern is warranted.

Thesis – The Forest Service's Draft Environmental Impact Statement (DEIS) on the proposed Rosemont Copper Mine inadequately examines the potential impacts to the water resources, both surface and subsurface, of the Sonoita Plain. Extensive, even exhaustive, technical investigations have been conducted on ground-water issues related to extraction of copper ore at the proposed Rosemont Mine. These investigations generally have taken the form of ground-water flow models. Results of the modeling for areas at and near the proposed mine have been detailed, but are deficient in the regard that they do not specify estimated effects of subsurface dewatering in much of the Sonoita Plain, they do not recognize differing lithologies of rocks underlying the mine site and the Sonoita Plain, and they do not acknowledge the possibility or likelihood of confined (artesian) ground-water conditions at the mine site and beneath the Sonoita

Plain. Although abundant geohydrologic information is contained in many of the commissioned reports, very little of the relevant information is summarized in the DEIS (see Postscript). Additional and expanded consideration of the possible regional effects of water draining into the proposed open-pit mine have been suggested by hydrologists Larry Winter, PhD (Professor and Head, Department of Hydrology and Water Resources, University of Arizona), and W. R. Osterkamp, PhD (Research Hydrologist, Emeritus, National Research Program, U. S. Geological Survey). The Forest Service must take into consideration the scientific work of Drs. Winter and Osterkamp and undertake a detailed and rigorous analysis of these potential impacts prior to rendering a decision on this project.

II. Concern

The Sonoita Plain (Appendix 1, map A) is an area of extensive exurban housing, livestock production, agriculture and vineyards, tourism and historic sites, native grasslands, and natural riparian areas. It lies east of the northern Santa Rita Mountains and the site of the proposed Rosemont Mine and includes a portion of Las Cienegas National Conservation Area, Pima and Santa Cruz Counties, northeast of Sonoita (Appendix 1, map A). All human-related activities of the area rely on ground water pumped from wells, and all of the grasslands and water-sensitive bottomlands depend on moisture derived from natural processes of precipitation, streamflow, infiltration, and spring discharge and seepage. Analysis of the geology and hydrology of the eastern flank of the Santa Rita Mountains and areas east of the mine site causes concern that these water sources are vulnerable to decrease or elimination by the excavation of a deep open pit at the site of the proposed Rosemont Mine.

III. Basis for Concern

The maximum projected depth of the open-pit mine will be about 885 m (meters), or 2900 ft (feet). This depth corresponds to an elevation of about 730 m (2400 ft), 670 m (2200 ft) lower than the 1400-m (4600-ft) mean elevation of the central Sonoita Plain. The depth to saturated rocks at the mine site averages about 40 m (130 ft), or an elevation of 1575 m (5170 ft). With decreasing elevation of the land surface from the mine site to the east and southeast, the depth to the zone of saturation increases to a range generally of 30 to 80 m (100 to 260 ft) in the Sonoita/Elgin area. Rocks that may be exposed by excavation at the open-pit mine range from late-Cretaceous and Tertiary-age clastic and volcanic beds to underlying Paleozoic carbonate strata; beds of Paleozoic limestone and dolomite at the mine site dip steeply eastward before flattening to near-horizontal beneath the Sonoita Plain. Although the stratigraphy and structural geology of the Sonoita Plain are inadequately known and understood, many of the volcanic and carbonate rocks to be exposed on walls of an open-pit mine are present at and beneath the Sonoita Plain. If exposure of these rocks causes ground-water drainage into the open pit to a level approaching a lowermost elevation of 730 m (2400 ft), the water resources, especially the ground-water resource, of the Sonoita Plain could be severely compromised.

IV. Estimates of the possible range of hydrologic effects

A deep, open-pit mine causes drainage of the adjacent saturated rocks that it penetrates and can be likened to a water well penetrating the same rocks (Myers, 2007). In either case water flowing from saturated bedrock into the well or excavation creates a "cone of depression", a conical volume of dewatered rock surrounding the well or pit that is deepest at the well or pit wall and declines in depth with distance from the well or mine disturbance. Depending particularly on rock characteristics, the length and intensity of pumping at a well, and the time since an open pit was constructed, the edge of the cone, or the limits of effect, diminishes outward and the cone merges with the top of the pre-existing zone of saturation.

Projected excavation activity at the Rosemont Mine site and available geologic and hydrologic information from the mine area were applied to this simple concept by W. R. Osterkamp, Research Hydrologist, Emeritus, U. S. Geological Survey, to construct a conceptual model covering the area of the Rosemont Mine eastward through the Sonoita Plain (Appendix 1, maps B, C, D). Simplifying assumptions of the conceptual model included confined (artesian) conditions for carbonate rocks at the mine, unconfined to partially confined conditions for carbonate rocks under the Sonoita Plain, hydraulic connectivity of carbonate strata between the mine site and the Sonoita Plain, no complicating effect by geologic structures (faults, folds, fractures, joints, etc.), and a linear relation between elevation of the top of the zone of saturation or the potentiometric surface and distance from the open pit to limiting topographic (Appendix 1, map A) and ground-water divides (Appendix 1, maps C, D) of the Sonoita Plain. Without doubt the hydrology of the area is more complex and more fully artesian than these simplifications represent, and development of a more accurate model is essential. Nonetheless, application of known geologic and hydrologic conditions to the model suggests an effect, possibly a “worst-case” scenario, of water-level or potentiometric-surface decline of up to 300 m (980 ft) in the Sonoita area and 200 m (660 ft) in the Elgin area; declines in ground-water levels owing to drainage into the open pit potentially could occur as far as 40 kilometers (25 miles) to the east and southeast of the mine.

To test results suggested by the conceptual model, an independent analysis was conducted by Larry Winter, University of Arizona. The analysis differed from the conceptual model by computing the size and shape of the cone-of-depression. The computations were based on the Theis equation, which can provide drawdown estimates at various distances from a mine. Application of the Theis solution requires simplifying assumptions of a high degree of geologic uniformity in a saturated, confined aquifer. Available information indicates that the first assumption is not met – the geology is quite complex -- and that the second assumption is reasonably valid – artesian conditions, relative to the Paleozoic carbonate rocks, are either in place or nearly so.

Dr. Winter's analysis yielded families of curves describing the size and shape of the cone of influence assuming a range of rock properties, especially transmissivity (the ability of rocks to convey water through them). Although he made several simplifying assumptions in conducting the analysis "that may not strictly apply in this case", and that the analysis "is probably conservative", Dr. Winter summarized results for drawdown at a distance of 10 kilometers (6 miles) from the mine to vary between 0.5 and 15 m (1.6 and 50 ft). Explanations given by Dr. Winter included:

> *Assuming no mistakes were made in the arithmetic or parameterizations (always a possibility), these rough calculations indicate that a drawdown of about 5-10 m might be expected at a distance of 10 km from the open pit. This is a significant amount of water, although not enough to dry up most water supply wells.*
>
> *Given the material heterogeneities found in many karst systems, it is possible that much greater drawdowns could be observed at some locations. Only a more detailed model could show that.*

Given the regional importance of groundwater in Southern Arizona, a regional groundwater study seems in order. The place to start is with a better parameterization of this simple Theis model and evaluate a range of scenarios based on T, Q, and R. (For elaboration on the comments of Dr. Winter, with explanation of the Theis equation and symbols used, see Appendix 2.)

The conceptual model of Dr. Osterkamp, based on physical conditions and observations of the Sonoita Plain, and the pressure-head drawdown (Theis equation) computations of Dr. Winter are different approaches to estimate ground-water declines caused by dewatering of rocks at the open pit. The magnitudes of effects estimated using the two approaches differ, but both suggest likelihood that significant water-level declines much greater than was identified by the Rosemont DEIS may be induced by ground-water drainage of geologic formations at the mine site.

V. Previous Investigations

A review of water use in the Sonoita Plain (Naeser and St. John, 1996) identified a disparity between the rate of exurban development and the ground-water resource needed to support the development. Principal conclusions of the review were that (1) the subsurface is the only available source of water for environmental and human needs, (2) the occurrence of ground water is neither uniform or predictable throughout the Sonoita Plain, (3) inadequate hydrologic assessments for developments may cause water scarcity for property owners and a disruption of ground-water recharge, and (4) disturbance to the hydrologic system, such as drought or excessive ground-water withdrawals, will exacerbate previous overdrafts.

Extensive technical investigations by consultants, including hydrologic studies, have been commissioned by the Rosemont Copper Company. Among several reports describing the geology, ground-water hydrology, proposed surface-water and ground-water monitoring, and expected reactions of the regional hydrologic systems to open-pit copper mining, Montgomery and Associates (2009) prepared *Groundwater flow modeling conducted for simulation of proposed Rosemont Pit dewatering and post-closure*. The report provides a detailed analysis of expected effects to the local ground-water reservoir owing to proposed copper mining before, during, and after mine construction, and gives quantitative results of temporal changes to the ground-water reservoir in the mine vicinity based on numerical modeling. Although descriptions of local and regional geology are provided, the analysis generalizes the effect of mining to all rocks without specifying that near-surface rocks, clastics and volcanics, likely have transmissivities different from the underlying carbonate rocks. Acknowledged is the extensive fracture permeability that is present for most rocks at the mine site, but potentially variable effects of dewatering owing to lithologic differences of the rocks to be penetrated by the pit, particularly carbonate beds, is disregarded. Implicit in the analysis is that ground water is unconfined throughout the system. This assumption differs from that of the conceptual model of Dr. Osterkamp and of the hydraulic model of Dr. Winter; it is probably incorrect relative to the carbonate beds.

Interpretations developed from a ground-water flow model independent of that of Montgomery & Associates were submitted to Rosemont Copper Company by the consulting firm, Tetra-Tech, Tucson, AZ (2010). Assumptions used in a finite-difference model, MODFLOW, to simulate ground-water movement for up to 1000 years in the mine vicinity, Davidson Canyon, and the Cienega Creek Basin were similar to those applied by Montgomery & Associates: extensive fracture permeability, unconfined ground-water conditions, and pit excavation into relatively homogeneous bedrock. Separate model results were not obtained for near-surface clastic and volcanic rocks as opposed to the underlying limestones and dolomites (carbonate rocks), and results were not extended to the east and southeast into the central Sonoita Plain. Because assumed conditions of geology and ground-water hydraulics for the Montgomery & Associates (2009) and Tetra Tech (2010) models were similar, results were similar.

Hydrogeology of the Santa Rita Rosemont Project Site, a consulting report by Tom Myers, PhD (2007), was commissioned by the Pima County Board of Supervisors. The study was a reconnaissance analysis of surface- and ground-water fluxes, and of the water balance of the mine area. Although Dr. Myers recognized that the open pit could affect the regional ground-water resource, focus was largely on areas near the mine site. Using a conceptual model similar to that used by Dr. Osterkamp, Dr. Myers concluded that mine excavation could *lower the regional water table by up to 1500 feet. This would create a drawdown cone which would draw water from the regional groundwater similar to pumping from a large diameter well. This substantial drawdown may draw groundwater from a significant distance if the adjoining aquifers are hydraulically connected to the bedrock aquifer of the pit.*

A Draft Environmental Impact Statement (DEIS) for the Rosemont Mine describes anticipated effects of the mining operations on ground-water quantity and quality. Discussion of ground-water issues within the DEIS is strongly weighted toward monitoring and protection of ground-water quality at the mine site and seepage of water from mine spoils (p. 32); no attention is given to possible reduction of ground-water levels east of the mine, nor does the DEIS provide summary results of the Montgomery & Associates, Tetra Tech, or Myers reports for areas other than in the vicinity of the proposed mine. The DEIS acknowledges that west of the Santa Rita Mountains, in the Santa Cruz River Valley, the mine facility could adversely affect ground-water availability to public and private wells, especially in the communities of Sahuarita and Green Valley; household water supplies may be reduced (p. vii, 13). According to the DEIS (p. vii, 13), ground-water availability to private and public wells east of the proposed open-pit mine may be reduced "in the vicinity of the open pit"; no mention is provided concerning the influence that the open pit might have on the ground-water resource further to the east and southeast in the Sonoita Plain.

VI. Recommended Actions by the Forest Service

To ensure that discharge of water into the pit of the proposed Rosemont Mine does not have immediate and long-term effects on ground water of the Sonoita Plain, a variety of studies is necessary. It is recommended that before approval is provided by the Forest Service for advancement of mining activities, detailed and independent investigations be conducted throughout potentially affected areas of the Sonoita Plain, Pima, Santa Cruz, and Cochise Counties, Arizona (Appendix 1, map A). The results of these investigations should be peer-reviewed by impartial experts in the fields of geology, hydrology, biology and ecology, and economics prior to submission of results of the studies to the Forest Service and other regulatory agencies. The investigations should include but not be limited to:

Geology

Geologic mapping of rocks exposed at the surface and characterization of subsurface stratigraphy, and geologic mapping of structural features including faults, folds, fracture patterns, and rock jointing. Geologic mapping of the above is possible through the use of previously published geologic maps, water-well logs and related data, and aerial photography and imagery.

Hydraulic Properties of Water-bearing Rocks

Characterization of hydraulic properties of saturated rock types underlying the Sonoita Plain; these properties in particular should include transmissivity, storage capacity, determination of hydraulic gradients for unconfined aquifers and the potentiometric surface for confined aquifers, and rates/velocities of ground water flowing through rocks underlying the Sonoita Plain. A starting point for determining these properties is the use of previously published geologic maps, water-well logs and related data, and aerial photography and imagery, but these sources will need to be supplemented by the drilling of test wells at suitable sites, determination and logging of rock types penetrated, and aquifer tests of the wells.

Ecological Analyses of the Sonoita Plain and Adjacent Hills and Mountains

The Sonoita Plain, including Las Cienegas National Conservation Area, has one of the last remaining relatively natural grassland ecosystems of the semiarid American Southwest. Components of the ecosystem include four rare habitat types (native desert grassland, riparian/wetland, mesquite bosque, and oak woodland) as well as moist-bottomland stands of the bunchgrass, sacaton, diverse riparian-zone plants, and numerous invertebrates, reptiles, amphibians, and fish dependent on intermittent-to-perennial flows of streams draining the Sonoita Plain. Many fauna are listed as endangered (lesser long-nosed bat, Huachuca water umbel, Gila chub, Gila topminnow, Southwestern willow flycatcher, and jaguar) or threatened (Chiricahua leopard frog), and all rely on water supplied as spring flow or seeps, generally emanating from carbonate rocks exposed in bounding mountains and hills that define the limits of the Sonoita Plain area (Appendix 1, map A). A lowering of water levels owing to dewatering of rocks at the mine site could adversely affect these plants and animals, and an analysis of the magnitude of the effect is mandatory.

Given the potential suggested by the models for significant drawdown of the zone of saturation through time and many kilometers from the mine, there are major biological risks that need to be recognized and assessed prior to a decision on mine approval. The obvious element concerns surface-water loss and reduction of riparian-zone area, such as along Empire Gulch (Appendix 1, map A). Congress was clear when it established Las Cienegas National Conservation Area that protection of wildlife and riparian areas was one of its key purposes: *In order to conserve, protect, and enhance for the benefit and enjoyment of present and future generations the unique and nationally important aquatic, wildlife, vegetative, archaeological, paleontological, scientific, cave, cultural, historical, recreational, educational, scenic, rangeland, and riparian resources and values of the public lands described in subsection (b)…there is hereby established the Las Cienegas National Conservation Area of the State of Arizona (HR 2941, 2000).*

In addition to significant risk to the biological and heritage values of Las Cienegas National Conservation Area, there is a less obvious and far more serious risk to all of the eastern slopes of the Santa Rita Mountains, Davidson Canyon, the Sonoita Plain, and beyond. It concerns the ability of the trees and shrubs to grow as the ground-water level drops. The roots of many of the key species will be unable to reach adequate moisture to sustain growth, and the species eventually will die out. With the prediction of increasing drought owing to regional climate change, the loss of ground-water will certainly exacerbate a situation that does not appear to have been considered.

The hydrological models vary in how extreme the effect might be, but in all of them the ground-water loss over time will have the effect of reducing the density of vegetation that allows so much wildlife to flourish in this haven of biological diversity. In the worst-case scenario, the effects will likely be evident within a few years, with diminished diversity of plants, and as drawdown continues, the forests eventually will disappear over large areas. It is even possible that, in 50 years, the Santa Rita Mountains and areas to the east will be barren.

For these reasons alone, it is critical that more detailed models be developed, so that more precise predictions can be made, and decisions about the environment based on them. Avoidance of these dire effects is essential to prevent the total loss of basic habitat, corridor habitat, and thousands of species of animals including birds. For much of the report, the question of water and its significance for the whole habitat has been practically ignored except in relation to stream beds, washes, and water for human consumption. Yet, for the region to remain the habitat for wildlife and the recreation center for residents and tourists alike, the big picture of water loss needs critical attention.

Economic Impact

An economic analysis of the implication of projected ground-water drawdown, including but not limited to the costs associated with springs, streams, and wells drying out; and aquifer storage decreasing. These costs can be measured in terms of changes to personal income, personal property, business income, business property, Tucson Water drinking water costs; fiscal impacts; local/regional economic development; and ecosystem services values.

Modeling of Ground-water Impacts Owing to Possible Dewatering by an Open-pit Mine

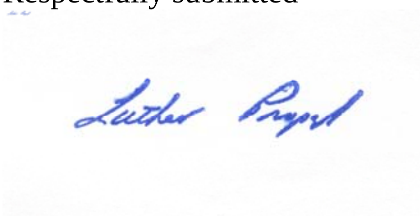
Results of the ground-water flow models developed and submitted to Rosemont Copper Company by Montgomery & Associates (2009) and Tetra Tech (2010) are detailed and based on comprehensive data. Many of the conclusions presented in the two reports appear valid and should not have been disregarded. Other conclusions, owing to the use of inappropriate assumptions (especially unconfined ground-water conditions and homogeneous lithologies), are suspect and should be retested before being used to support the inference that bedrock dewatering by an open pit will cause minimal effect to the ground-water reservoir beyond the immediate vicinity of the proposed mine.

Based on results of the geologic and hydrologic (hydraulic) investigations recommended above, modeling of ground-water movement beneath the Sonoita Plain should be conducted that is similar in approach but more detailed and validated than that conducted by Dr. Winter. Thus, the preliminary modeling results and information obtained to characterize the geology and hydrology of the Sonoita Plain should be used to develop a conceptual model of the area that is based on more substantial information than was available for the conceptual model proposed by Dr. Osterkamp or the hydraulic-model results computed by Dr. Winter. Furthermore, the improved hydrologic and conceptual models should be combined to generate families of drawdown curves, similar to those advanced by Dr. Winter, that yield indications of the range of likely effects to the regional water-table and potentiometric-surface configurations that may result by aquifer dewatering at the mine site. Input data for generating these curves should include aquifer-characteristics information transmitted in consultants' reports such as those of Montgomery & Associates (2009) and Tetra Tech (2010). These curves should reflect changes in land-surface and spring-discharge elevation with distance east of the mine site, and should be constructed to yield change with time.

Topographic Analyses of the Sonoita Plain

The results of the geologic and hydrologic (hydraulic) investigations and modeling need to be combined with investigations of surface features including regional slopes, occurrences of springs and seeps, and stream reaches of intermittent to perennial flow. The objectives would be to anticipate how ground-water gradients and the potentiometric surface of the Sonoita Plain will be altered, the degree to which springs and seeps of the Sonoita Plain will be affected, and the degree to which yields of wells currently drawing water from rocks underlying the Sonoita Plain will be reduced by dewatering at the mine pit.

Respectfully submitted



Luther Propst, Executive Director
The Sonoran Institute
Tucson, AZ

References

106th Congress of the United States of America, Second Session, 2000, HR 2941, An Act to Establish the Las Cienegas National Conservation Area in the State of Arizona.

Montgomery and Associates, Inc., 2009, Groundwater flow modeling conducted for simulation of proposed Rosemont Pit dewatering and post-closure: Consultant’s report prepared for Rosemont Copper Company, Tucson, by Errol L. Montgomery and Associates, Inc.

Myers, Thomas, 2007, Hydrogeology of the Santa Rita Rosemont Project site: Consultant’s report prepared for Pima County Board of Supervisors, C. H. Huckelberry, County Administrator, 30 p.

Naeser, Robert, and St. John, Anne, 1996, Water use and the future of the Sonoita Valley, *In* Tillman, Barbara, Finch, D. M., Edminster, Carl, and Hamre, Robert (eds.), The Future of Arid Grasslands: Water Resources Research Center, University of Arizona, Tucson, p. 186-200.

Tetra Tech, 2010, Regional groundwater flow model, Rosemont Copper Project:

Consultant's report prepared for Rosemont Copper Company, Tucson, Tetra Tech Project No. 114-320874.

Partners and Concurrent Voices to this Statement of Concern

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Postscript

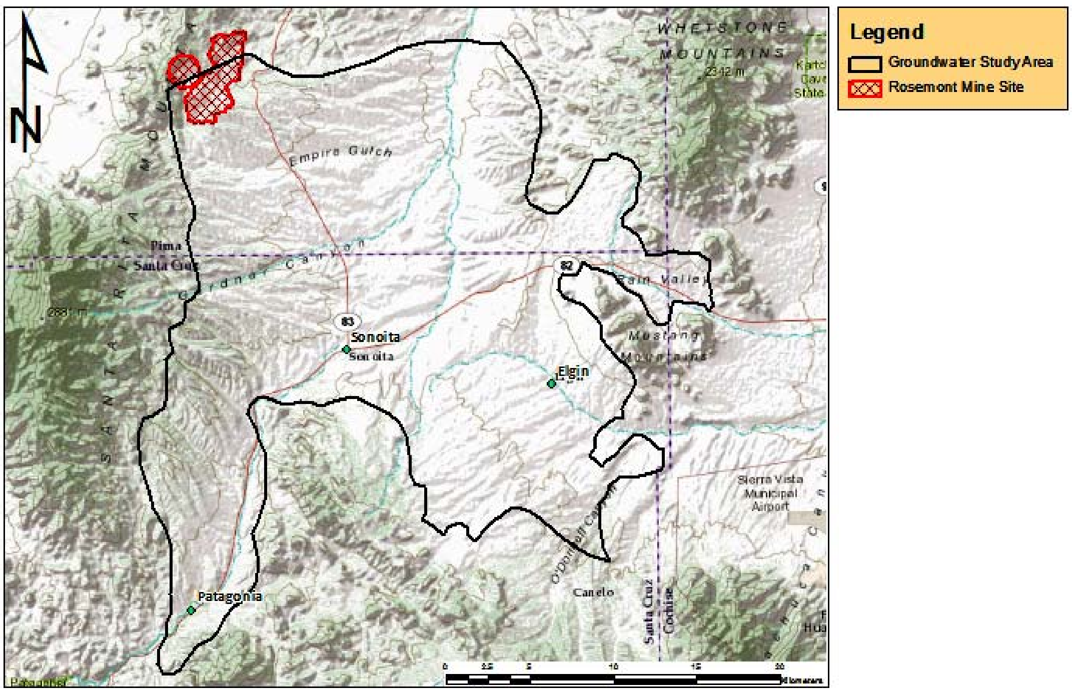
As submitters of this Statement, we contend that the DEIS does not adequately convey available ground-water information regarding the proposed Rosemont Mine. Relative to the issues of concern addressed by this Statement, the DEIS notes only that for Issue 3A, East Side Groundwater Availability, "The proposed open-pit mine may reduce groundwater availability to private and public wells in the vicinity of the open pit. Household water availability may be reduced." This simple statement (page vii) disregards virtually all of the technical input that was provided to Rosemont Copper Company by consultants commissioned by the company. Examples are:

Detailed, albeit inadequate, analysis of flow modeling is contained in a report submitted to Rosemont by Montgomery & Associates (2009). The Montgomery report (p. 2) states that *Model projections indicate groundwater level drawdown will be limited to the area in and around the Rosemont project and into Davidson Canyon with no projected drawdown at Cienega Creek.* Montgomery & Associates do not specify a limit of influence in Davidson Canyon, but at its mouth at Cienega Creek, Davidson Canyon is about 24 km (15 miles) northeast of the mine site, a distance reasonably considered beyond the mine vicinity.

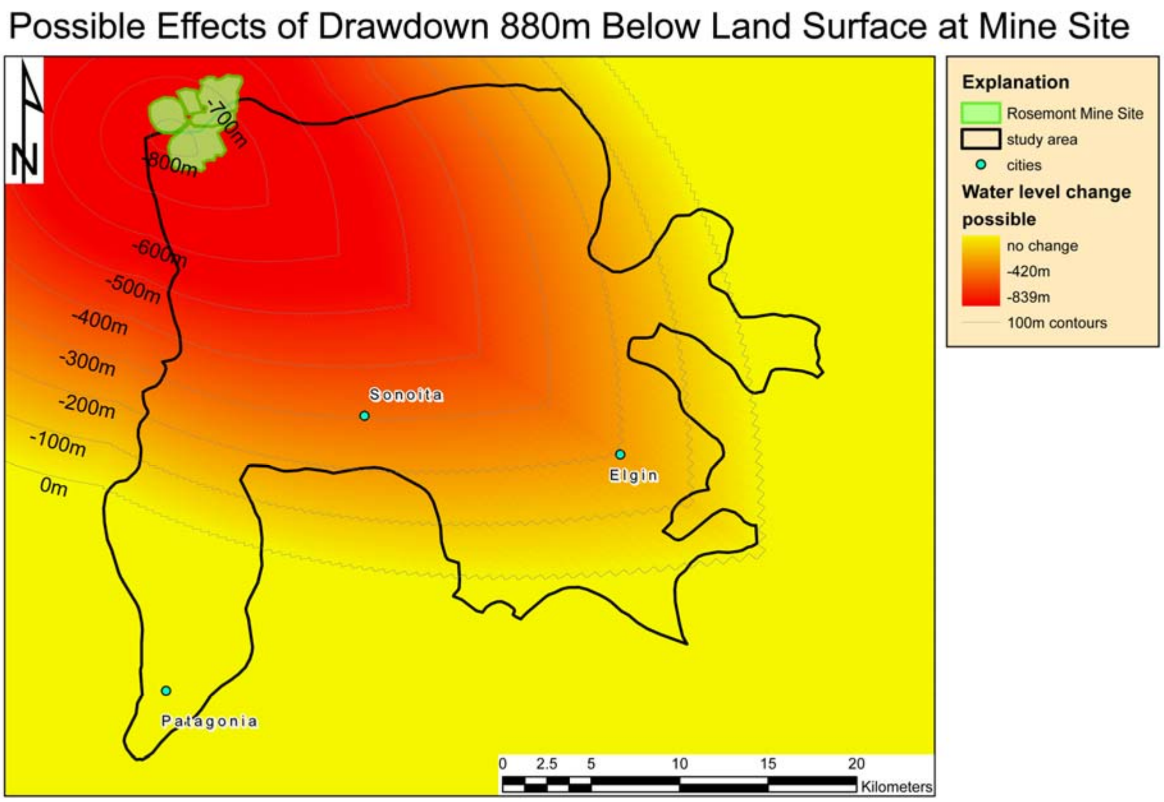
A report by Tetra Tech (2010, p. 1) warns that *Dewatering of the proposed Open Pit will result in groundwater levels being lowered to approximately 3,020 feet above mean sea level (amsl), which is about 2,200 feet below the pre-mining water level in the immediate Project area. The projected bottom of the pit is 3,050 feet amsl. Dewatering the pit will create drawdown in the regional groundwater system, propagating outward. Drawdown will be most dramatic in the vicinity of the Open Pit, the effects of which will* *decrease with increased distance from the pit. Although partial recovery of water levels within the pit area are anticipated following the cessation of dewatering, water levels are anticipated to take hundreds of years to reach a new equilibrium condition*. The DEIS selectively mentions that water-level decline is expected in the vicinity of the pit, but other potential problems suggested by the Tetra Tech passage are ignored.

As shown above, the Tetra Tech report (2010) predicts a temporal effect lasting hundreds of years, and model results reported by Montgomery & Associates (2009) indicate that decreased water levels outward from the open pit may persist in excess of 100 years. No indication of the time that water-level decline will persist is apparent in the DEIS.

Appendix 1. – Unpublished maps of the Sonoita Plain area showing A: relief and cultural features of the study area, the Sonoita Plain (the area within the closed black line) (extracted from ESRI GIS software, scale 1:280,000, 2010), B: potential reductions in water-surface or potentiometric-surface elevation based on the conceptual-model analysis of W. R. Osterkamp, C: depth to water in wells of the Sonoita Plain, and D: interpolated, or generalized, water levels of the Sonoita Plain based on well data of map C.

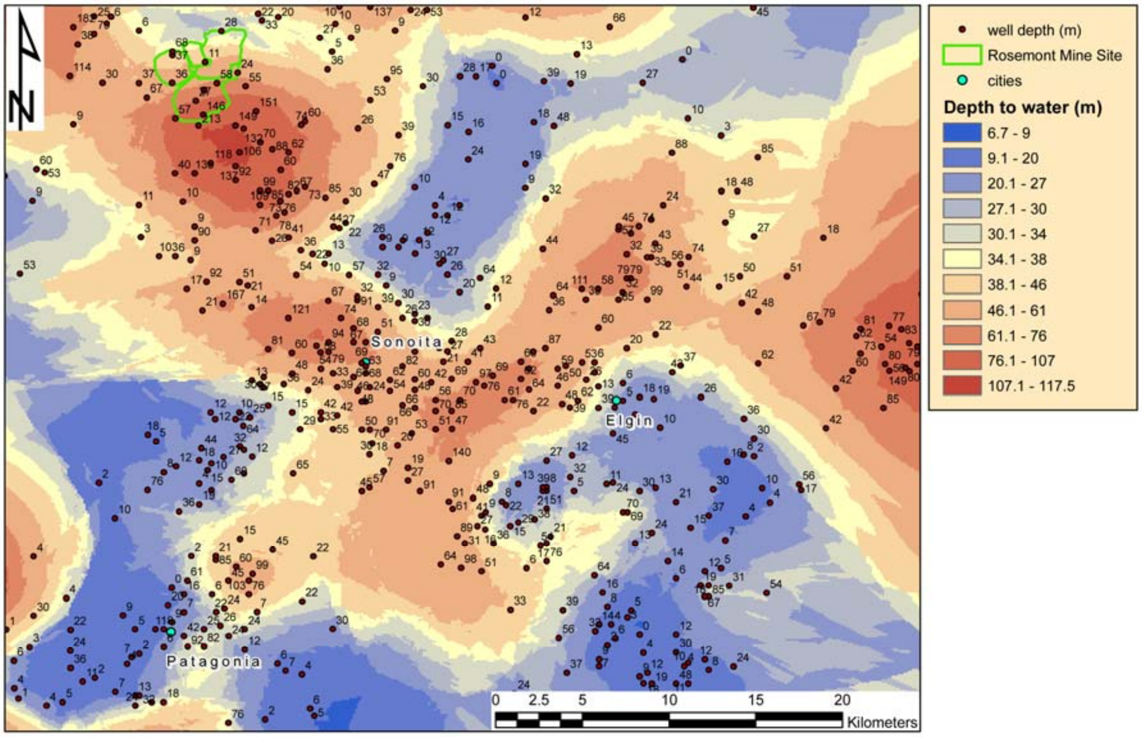


A.

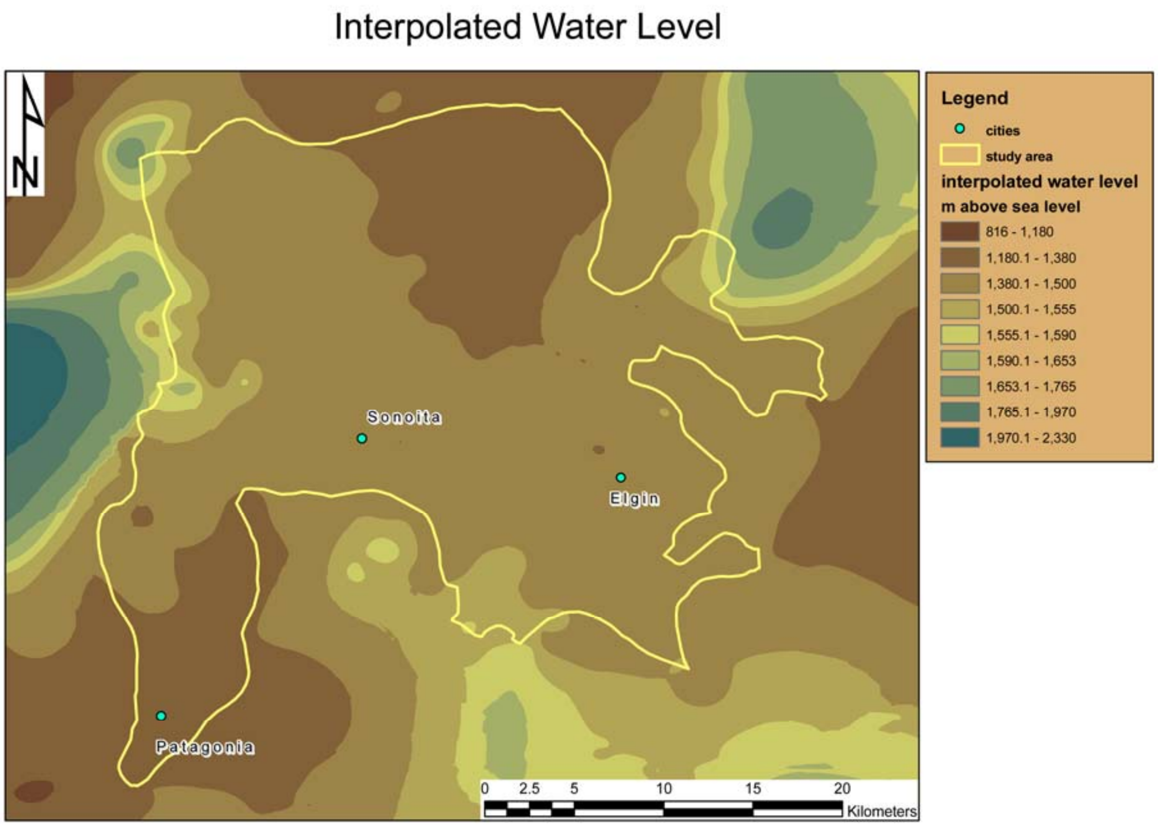

Possible Effects of Drawdown 880m Below Land Surface at Mine Site
Explanation
Rosemont Mine Site
study area
cities
Water level change possible
no change
-420m
-839m
100m contours
-700m
-800m
-600m
-500m
-400m
-300m
-200m
-100m
0m
Sonoita
Elgin
Patagonia
0
2.5
5
10
15
20
Kilometers

B.

Current interpolated depth to water below land surface



C.


Interpolated Water Level
N
Legend
cities
study area
interpolated water level
m above sea level
816 - 1,180
1,180.1 - 1,380
1,380.1 - 1,500
1,500.1 - 1,555
1,555.1 - 1,590
1,590.1 - 1,653
1,653.1 - 1,765
1,765.1 - 1,970
1,970.1 - 2,330
Sonoita
Elgin
Patagonia
0 2.5 5 10 15 20
Kilometers

D.

Appendix 2. – Theis drawdown analysis of Larry Winter, PhD, University of Arizona

Estimates of drawdown due to an open pit at the Rosemont mine site

From: Larry Winter   11/28/11

I made a quick estimate of pressure head drawdown at distances up to 50 km from a pond at the bottom of a site like the proposed Rosemont Mine. The estimate is based on the Thiem Equation, which is the simplest setting for a steady-state solution to Darcy's Law governing groundwater flow. The purpose of the calculation is to see whether further study is in order to determine if a mine pond *could* significantly affect water pressure in Sonoita.

Bottom-line. Estimated drawdowns for typical parameter settings are 1-10 m at 10 km, which is not negligible. Given the high degree of heterogeneity that may be found in the parent karsts, detailed regional modeling may be required to investigate the hypothesis carefully. Assuming the well model (mine pond) and transmissivity estimates are approximately correct, a mine pond could significantly affect water pressure in Sonoita

Model. The Theis solution is a basic means for calculating groundwater drawdown at a distance, *r*, from a well (the mine pond). The drawdown due to a well losing water at a rate *Q* (measured in m^3/s) is

$$h(r) - h_0 = [Q/2\pi T]\ln(r/R) \qquad (1)$$

The pressure head at a distance *r* is $h(r)$, and $h - h_0$ ($h_0 > h$), is the drawdown at *r*. The background hydraulic head for the region, h_0, is the height in meters to which water would rise naturally in the absence of pumping or other disturbance, and *R* is the radius of the well's influence, i.e., the distance away from the well where the pressure head attains the background level, h_0. The drawdown is inversely proportional to the regional transmissivity, *T*, whose units are m^2/s.

The Theis solution is based on assuming a high degree of uniformity in a saturated, confined aquifer. See a standard hydrology text for details. The necessary uniformity assumptions may be a bit strong for a karst system, but the point of this exercise is just to gauge feasibility.

Parameters. The values of the parameters in this model can be found in databases of the NWS and USGS. Since the current exercise is only meant to indicate risk, rough estimates of parameters are used here based on experience.

Transmissivity. Transmissivity, $T = Kd$, is the product of hydraulic conductivity, *K*, with aquifer thickness, *d*. I used conductivities, K = 1, 2 and 3 m/day, which could be a little slow and aquifer thickness, d = 50 m, which might be a little thick.

Hence, T = 50, 100, and 150 m2/day. Also we consider T = 1000 m^2/da, which is a typical high transmissivity value in the Tucson basin.

Pond losses (the well rate). Average pan evaporation for Tucson is approximately 1/3 inch/day or 0.008382 m/day. The surface area of an open-pit mine pond is about 250,000 m^2 based on the areas of the ponds at the Kennecott pits outside Green Valley.

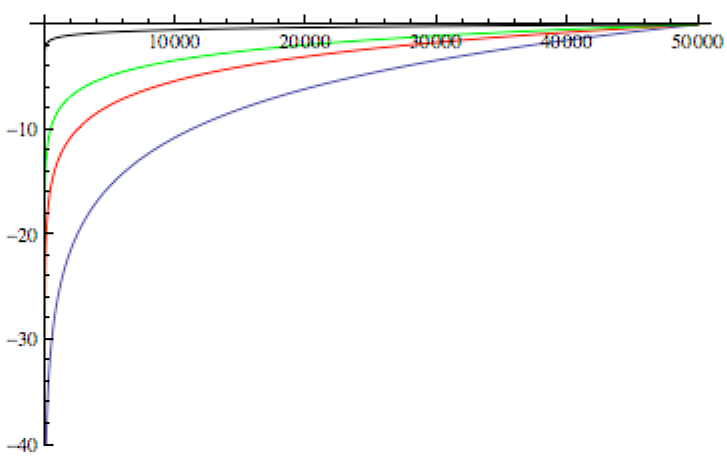
Hence, Q = 200 m^3/day. I also used Q = 100 and 500 m3/day.

Radius of influence. I used a range R = 30, 40, of 50 km. The radius of influence doesn't have a large effect.

Location of an affected site. I used *r* = 10 km, which is about the distance from the mine site to Sonoita, when evaluating impacts on domestic wells.

Results. Results of solving eqn (1) are given for two kinds of scenarios: (1) varying *T* while holding other factors constant, (2) varying *Q* while holding other factors constant.

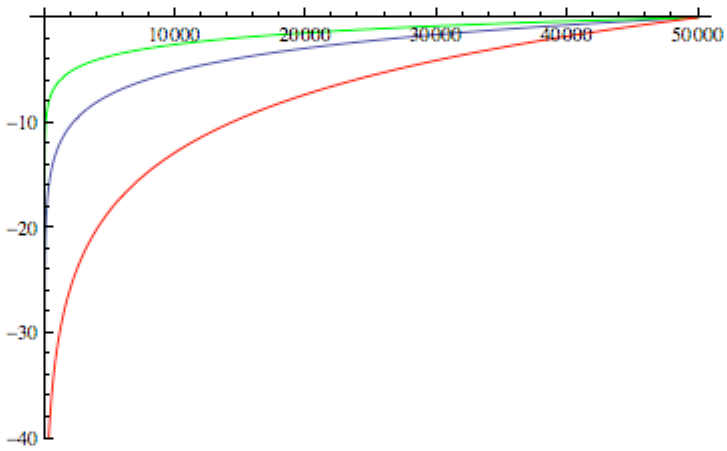
(1) The following figure indicates drawdowns at various distances, *r*, from the pond for 3 levels of *T*: *T* = 50 (blue), 100 (red), 150 (green), and 1000 (black) m. *Q* = 2000 in all scenarios. The vertical axis is drawdown in meters. At *r* = 10 km the drawdown ranges from approximately -0.5 to -15 m.



r
h - h0

(2) The next figure indicates the effects on drawdown of *Q* = 1000 (green), 2000 (blue), and 5000 (red) m3/day, also at various distances. Here *T* = 100 m2/day. Drawdown is approximately -2m to -15m at a distance of *r* = 10 km.

r
h - h0



Discussion. Assuming no mistakes were made in the arithmetic or parameterizations (always a possibility), these rough calculations indicate that a drawdown of about 5-10 m might be expected a distance of 10 km from the open pit. This is a significant amount of water, although not enough to dry up most water supply wells.

The Theis solution is based on a number of simplifying assumptions that may not strictly apply in this case. If anything, it is probably conservative. The parameterizations of *Q* and *T* are extremely rough, and improved estimates might make a difference. In particular, *T* ~ 100 m could be an order of magnitude too small.

Given the material heterogeneities found in many karst systems, it is possible that much greater drawdowns could be observed at some locations. Only a more detailed model could show that.

Given the regional importance of groundwater in Southern Arizona, a regional groundwater study seems in order. The place to start is with a better parameterization of this simple Theis model and evaluate a range of scenarios based on *T*, *Q*, and *R*.