Comments on: Draft Environmental Impact Statement for the Rosemont Copper Project

A Proposed Mining Operation
Coronado National Forest
Pima County, Arizona

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These comments relate to the meteorological data, observations, and related parameters, that were used by Rosemont consultants as input for air quality and visibility computer forecast models. These models (AERMOD and CALPUFF) were used in an attempt to quantify the impacts of the proposed Rosemont operations upon ambient air quality and visibility. Results from these model forecasts constitute most of the quantitative information presented in Chapter 3 – Section "Air Quality and Climate Change" and Subsection "Visibility" - of the DEIS (pages 158 – 205). It is important to understand and assess the procedures used to collect meteorological observations and to initialize these forecast models. To understand the modeling effort one must refer to two recent reports prepared for Rosemont Copper Company [1,2], as well as numerous technical documents from the EPA, and other sources, that describe details of the models and provide users' guides for applying the models.

I - Background

The proposed Rosemont project area covers a roughly triangular region (approximately 3 x 4 x 4.5 miles) that is located along and east of the northern ridge-line of the Santa Rita Mountains (a sky island, which is mostly Coronado National Forest land, including a wilderness area at higher elevations). The elevation of the Rosemont project area ranges from about 6500 ft to 4500 ft MSL from west to east, with the project area extending east almost to Arizona Scenic Highway 83 (Fig. 1 - top). The project area is located in a region of very complex terrain (meaning: abrupt and significant changes in elevation). This complicated orography makes it extremely difficult to determine the meteorology of the site.

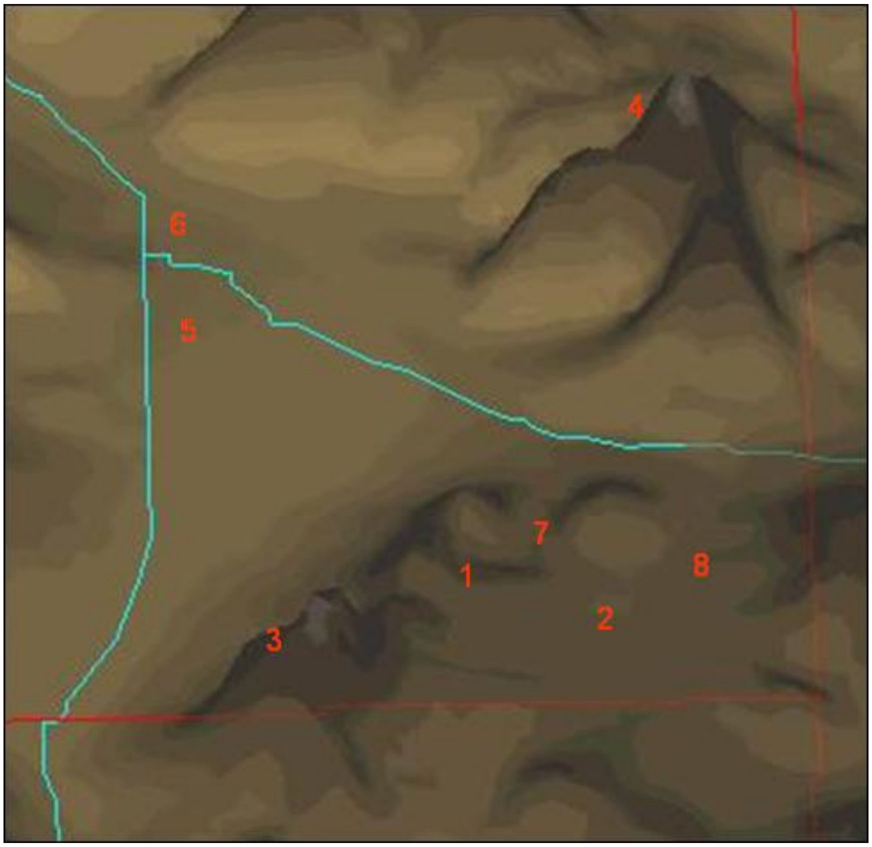

Figure 1 – Top: Contour map showing the Rosemont project area. Bottom: 3-D terrain map, at 1.8 km resolution, that extends from the project area north and westward to Tucson. Red lines are county boundaries; green/blue lines are I-10 and I-19. Red numbers are approximate locations of: 1 – Rosemont project area; 2 – Empire RAWS station; 3 – Hopkins RAWS station; 4 – Rincon RAWS station; 5 – NWS TUS site; 6 – Relocated NWS at U. of A. campus site; 7 – Davidson Canyon; 8 – Cienega Wash and grasslands.

The small-scale (referred to as mesoscale) "weather" at the site will play a large role in determining air quality and visibility at downwind locations ("downwind" depends upon the day-to-day meteorological setting). The 3-D terrain map in Fig. 1 (bottom) has been smoothed to a 1.8 km grid. At this resolution, the Santa Rita Mountains are well-resolved, as are the Cienega watershed and Davidson Canyon. **Barrel Canyon is not resolved at this resolution.** Davidson Canyon is particularly important, since there are a number of residents along the canyon from near the project site northward to Interstate 10. Davidson Canyon ends at Pantano Wash, which winds northwestward through the town of Vail and into the east side of Tucson. Barrel and Davidson Canyons are narrow and steep and will carry most of the precipitation runoff from the project site. They will also be the **principal pathway for cool-air drainage winds** away from the site – see Appendix A. Drainage flows occur over sloping terrain under cool, stable conditions with little or no background wind, typically at night.

Portions of this comment are based upon the author's experiences driving south on Highway 83 to Sonoita, and back to Tucson, about one weekend per month for the past 15 years. The author has personally observed the strong and very gusty winds that occur frequently along the ridge-line just to the east of the Rosemont project area. Some photographs taken by the author have been used in this comment. Estimates of surface parameters made in this comment are based upon personal observations of the site area, both during drives and hikes on public lands near the proposed project area. In writing this comment, I draw upon several decades of experience in observational research, weather and forecasting studies, meteorological field programs, and reviews of hundreds of technical and scientific papers.

II - Meteorological Data and Observations Used in Developing the DEIS

#1 – On-site weather station (elevation 5,350 ft MSL, 2006-2009). Applied Environmental Consultants (hereafter AEC) installed a **single**, Campbell Scientific, Inc. weather observing station on the project area (parameters measured included temperature, differential temperature to 10 m, wind direction, and wind speed). On-site **<u>relative humidity, station pressure, and solar radiation</u>** (all important inputs that had to be **estimated** for the modeling efforts) were **not** measured, nor was precipitation[3], although the DEIS (see p. 303), and other documents, refer to precipitation at the site. The AEC "Data Completeness Tables" actually indicate that a precipitation gauge was added to the station beginning in February 2007), and onsite pan evaporation for 6 months in 2008 (DEIS p. 304)]. Precipitation and evaporation pan data were not mentioned in the monitoring and quality assurance plan[3] (**<u>this plan is dated July 1st 2006; even though the weather station began routine operation April 1, 2006</u>**). The evaporation pan was added in mid-2008, since evaporation data were apparently needed for preparation of the aquifer protection permit application[4,5]. The on-site weather station is located on the west side of the project area, at the approximate center of the proposed mining pit, immediately east of the highest terrain in the project area (i.e., in a location that appears to be sheltered somewhat by terrain blockage of the larger-scale winds, when they are from the northwest to west to southwest).

#2 – Santa Rita Experimental Range (elevation 4,300 ft MSL, 1950-2005). Data used from this site included: temperature and precipitation. This station is located approximately 8 miles southwest of the project area.

#3 – Nogales (elevation 3,560 ft MSL, 1952-2007). Data used from this site included: winds, pressure, temperature, precipitation, and pan evaporation. This station is located approximately 30 miles south-southwest of the project area.

#4 – *University of Arizona (elevation 2,440 ft MSL, 1894-2007).* Data used from this site included temperature, precipitation, and pan evaporation. This station is located approximately 30 miles north-northwest of the project area.

#5 – *Helvetia (elevation 4,300 ft MSL, 1916-1950).* Data were used from this site, even though it has been out of operation for over 60 years, and included temperature and precipitation. This station was located approximately 3 miles west of the project area.

#6 – *Canelo 1 NW (elevation 5,010 ft MSL, 1910-2007).* Data used from this site included temperature and precipitation. This station is located approximately 24 miles south-southeast of the project area.

#7 – *Tucson, National Weather Service (elevation 2641 ft MSL, ~1970-2010).* Data used from this site include surface data and weather conditions made by human observers before 1988 and, since then, by the NWS automated surface observing system (ASOS), including wind and cloud cover data. Upper-air sounding data were used for 2001-2003, and for 2006 to early June 2007. This station is located at Tucson International Airport, approximately 24 miles northwest of the project site.

#8 – *University of Arizona NWS (elevation 2464 ft MSL, June 4, 2007-2008).* Data used from this site were the 5 am MST upper-air sounding data. This upper-air site is located approximately 30 miles north-northwest of the project site. **<u>NOTE – the NWS moved its upper-air sounding site on June 4, 2007, to the University of Arizona campus – the new site is located approximately 7 miles north of the old site.</u>**

III - Assessment of These Observational Sites and Data

#1 – The on-site weather station is located about 4,000 ft east of the south-to north ridgeline of the Santa Ritas and approximately a mile north of a distinct west-to-east ridge. **It is likely that winds, especially from the south to west, are stronger along the western, high-elevation periphery of the project area than those measured at the weather station location below. The varying land-surface character and diverse vegetation on the site support the conclusion that data from a single station CAN NOT characterize this complex site.** Based upon descriptions of observed and documented complexity of the diurnal wind cycle in sloping and canyon terrain (Whiteman, Chapter 11[6]), it is very unlikely that the data from the on-site weather station quantify the meteorological conditions occurring over the approximately 4,800 acres and the 2,000 ft elevation range of the project area (see Appendix A also). Therefore, the following statements from the monitoring protocol document[3] are not accurate:

> "The monitoring sites [for weather and PM_{10}] were selected [to]…….
>
> **Establish the meteorology which will transport and disperse emissions from the proposed facility … The measured meteorological parameters should thus yield representative meteorological emission transport patterns in the vicinity of the proposed facility."**

Meeting these objectives would require installation of a number of weather stations at key locations and at various elevations on the very complex project area. These stations would need to measure **ALL** the atmospheric parameters required for running air quality models. A complete categorization of the project area meteorology would also require that a wind profiler, or tethersonde, be operated onsite. (Soundings from far away in the Santa Cruz watershed can not be merged, in any realistic way, with the onsite surface wind and temperature – see Appendix C.)

#2 – #6 - These sites are mostly west of the Santa Rita Mountains and in the large-mesoscale, meteorological regime of the Santa Cruz River watershed. Canelo, while located south-southeast of the project area, is in the western foothills of the Huachuca Mountains and not in the mesoscale wind circulation regime of the Cienega watershed – Canelo is actually located in the upper watershed of the San Pedro River. Data from other existing observation sites within the Cienega watershed and at higher elevations in the Santa Rita and Rincon Mountains were apparently not considered, or used, by AEC.

#7 – The Tucson NWS ASOS observing equipment are located near the runways at Tucson International Airport (TUS), within the large-mesoscale, meteorological regime of the middle Santa Cruz River watershed. The diurnal wind regime observed at TUS is markedly different than that observed from 2006-2008 at the Rosemont site. (see Appendix B). Cloud cover observations are an important input variable for the AERMOD and CALPUFF models. **However, the cloud cover at TUS is undoubtedly much different than that at the Rosemont project area (as per the lower annual rainfall at TUS, and its greater distance from the Santa Rita Mountains).** The sky islands of southeast Arizona are very effective generators of orogenic clouds (clouds produced by mesoscale wind flows up the mountain slopes – particularly during the warm season).

An important characteristic of the NWS ASOS cloud sensors is that **they do not detect clouds above 12,000 ft AGL**[7,8]. Major airports have the ASOS cloud observations augmented by human observers, but this is not the case at TUS. Thus, regardless of the actual cloud cover, if there are no clouds detected below 12,000 ft AGL at TUS, the sky condition is reported as "clear." **The cloud cover data used in the development of the air-quality model forecasts and the EIS were incomplete and not representative of the actual project area. Since there were no solar radiation data taken on site, the only way to improve the cloud information is to use closer observations, which do exist and which do include solar radiation data.**

#8 – Tucson NWS upper-air sounding data (also see #7). The NWS takes upper-air soundings twice a day in Tucson, at 5 am and 5 pm MST. These soundings, from 2006 – 2008, were used as key input to the air quality models run by AEC. The EPA suggests using the closest NWS upper-air data, relative to the site being evaluated, for air quality modeling, **even though data from the upper-air station may not actually be representative of the site/project area being evaluated**. Given the complex terrain in and near the Rosemont project, the difference in elevation between the sites (more than 2,700 ft), and the distance of the TUS sounding sites from the Santa Rita Mountains, the upper-air data used in the modeling efforts were not likely to be representative of the site below 700 mb (i.e., approximately 10,000 ft MSL). **This limitation makes the mixing depths, and other parameters, computed within the AERMOD model unreliable.**

There is an additional, **serious problem** with the upper-air data used in the DEIS air quality modeling. The NWS has been implementing a program to modernize its upper-air program during recent years. The program is known as the Radiosonde Replacement System (RRS)[9]. This program implemented new hardware and software systems in early June 2007 for obtaining and processing upper-air data at Tucson. Further, the upper-air balloon launch site was moved at this time from a location near the runways at TUS to a new site on the University of Arizona campus. **These changes result in a flawed, heterogeneous upper-air data set that was used by AEC as they ran the AERMOD air quality forecast model.**

The upper-air balloons are currently launched from the roof of a three storey building that has higher buildings surrounding it from the northwest to the northeast. The surface character of the launch site was changed from essentially open desert to an urban setting, with irrigated vegetation - see Fig. 2. The near-surface data have been impacted by this change, particularly the low-level winds. As an example, consider observed surface winds at launch time of the upper-air sounding for 5 am MST on 17 December, 2011. At the current NWS launch site on campus the wind was from 155 degrees at 6 mph; at the old airport launch site the wind was from 122 degrees at 25 mph with gusts to 37 mph; and at a weather station within the Cienega watershed (located approximately 7 miles east-southeast of the Rosemont project area) winds were from 120 degrees at 15 mph with gusts to 23 mph. The upper-air sounding data indicate wind speeds less than 25 mph to a height of approximately 1400 m (~4590 ft) AGL – indicating a substantial perturbation of low-level winds, apparently caused by the nearby, tall buildings on the University of Arizona campus.

Figure 2 - Satellite image (left) showing the barren, flat terrain around the Tucson airport. The former NWS launch site was to the northwest of the "A." Aerial photograph (right) of the current NWS location on campus. The current NWS launch site for upper-air soundings is on the roof the building in center and is just beneath the "National Weather Services" label.

The upper-air sounding instrumentation package was also changed in June 2007. (The Vaisala RS80, MicroART sonde and processing system were replaced by the Microsonde MKII-A-GPS RRS sonde and processing system.) Information regarding the NWS Radiosonde Replacement System (RRS) can be found at: http://www.ua.nws.noaa.gov/rrs_overview.htm

There have been serious problems with data from the new instrument package, including flawed RH measurements (**RH data are very important within the CALPUFF model**). When temperatures are hot, extreme dry layers above the surface are frequently indicated erroneously. The slow recovery time of the humidity sensor leads to sounding data that are too dry. This "too dry in low levels" problem was first detected by NWS personnel in the Western Region. The NWS instruction manual for operators of the RRS system describes the low humidity, and other, problems with the new MKII-A-GPS sonde. See the RRS Users Manual[9] Chapter 13 (the low RH problem is discussed in 13.8.1).

http://www.ua.nws.noaa.gov/Documents/RWS%20Build%202.1%20User%20Manual.pdf

The slow response of the humidity sensor can also lead to situations where lagged-response to dry layers aloft produces data that are too moist. These errors are not systematic and thus **can not** be bias-corrected. A consistent and homogeneous three-year period of sounding data, preceding these system changes, should have been used in the Rosemont project air-quality modeling. Staff at AEC were apparently **unaware** that these significant changes in the NWS upper-air program at Tucson had occurred in June 2007.

IV – On Site Meteorological Monitoring and Quality Assurance Project Plan

The EPA[19, 20] provides detailed guidance for on-site meteorological monitoring and quality assurance for the data obtained. In particular, EPA guidance for meteorological monitoring[20] states explicitly (see pages 8-25 and 8-26) that (**emphasis** added):

> "These [Quality Assurance] procedures should provide quantitative documentation to support claims of accuracy and should be conducted by persons **independent of the organization responsible for the collection of the data and maintenance of the measurement systems**."

> "**Regular and frequent routine checks of the monitoring system are essential** to ensuring high data retrieval rates. These should include visual inspections of the instruments for signs of damage or wear, inspections of recording devices to ensure correct operation and periodic preventive maintenance. ….Also crucial to achieving acceptable valid data retrieval rates is the regular review of the data … This review should be performed **weekly**…."

The meteorological monitoring was conducted by AEC, and they prepared a quality assurance plan[3] for the on-site weather station and its data. The project responsibilities for the meteorological data are presented in Table 1.1 (p. 10) of this plan. AEC was identified as being responsible for maintenance of site equipment and for coordinating data collection with Rosemont Copper (then identified as Augusta Resources) on-site personnel. The on-site equipment was to be routinely checked for proper operation by Augusta Resources personnel.

The responsibilities were therefore dispersed inside and outside of AEC, and routine and frequent checks of the weather station operation were obviously not made during late 2006 and early 2007, indicating that the quality assurance plan was NOT followed. This is made clear by the AEC AERMOD report[1] (p. 8) which states:

"The data base, however, is not continuous as data between December 2006 and February 2007 were lost due to a data logger malfunction…."

Hourly data from the on-site weather station indicate that the system failed at 1700 MST on 22 December, 2006. The system was not repaired and functional again until 1600 MST on 13 February, 2007. The **seven weeks** of data lost were replaced by **duplicating** the data obtained on-site from December 2007 to February 2008 to fill the long data void, **thus compromising the scientific integrity and validity of the three-year meteorological data base that was used to drive much of the air quality modeling work.**

There were other significant problems with the AEC Quality Assurance procedures. The six-month audits (see first EPA quote above) of the meteorological data were done internally by AEC staff, who could hardly be considered **"independent"**. Finally, it seems strange that data gathering began on-site on April 1, 2006, three-months prior to the date of the AEC quality assurance plan.

V - Nearby Surface Observational Data That Were Not Considered

There is a meteorological, surface observation station within the Cienega watershed. This station is part of a cooperative, multi-agency, network of Remote Automated Weather Stations (RAWS)[10]. Both the **Forest Service** and the **Bureau of Land Management** are partners in this interagency program – see

http://raws.fam.nwcg.gov/index.html

where the following description of the program is given (**emphasis** added):

"REMOTE AUTOMATED WEATHER STATIONS (RAWS)

There are nearly 2,200 interagency Remote Automated Weather Stations (RAWS) strategically located throughout the United States. **These stations monitor the weather and provide weather data that assists land management agencies with a variety of projects such as monitoring air quality**, rating fire danger, and providing information for research applications. Most of the stations owned by the wildland fire agencies are placed in locations where they can monitor fire danger. RAWS units collect, store, and forward data to a computer system at the National Interagency Fire Center (NIFC) in Boise, Idaho, via the Geostationary Operational Environmental Satellite (GOES)..."

The basic RAWS sensor suite includes a rain gauge; anemometer; wind vane; air temperature and relative humidity sensor; fuel stick to measure fuel temperature; and an instrument to monitor the battery voltage of the data logger or data collection platform (DCP). Also included at the RAWS stations near the Rosemont project area are a barometer; a fuel moisture sensor that may be combined with the fuel temperature stick; and a pyranometer to monitor global solar radiation (which indicates total cloud cover and thickness). The **Empire RAWS station** is located in the Cienega watershed approximately **7 miles east-southeas**t of the Rosemont project area. The station is at 31.780N 110.635W at an elevation of 4650 ft MSL. Surface data are available from this station beginning in 1988 through the current time. The Empire station is the closest surface observing site to the Rosemont project area and is within the same watershed and meteorological regime as the project area (see photo, Figure 3). **Observations from this station should have been incorporated in the air quality modeling for the EIS.**

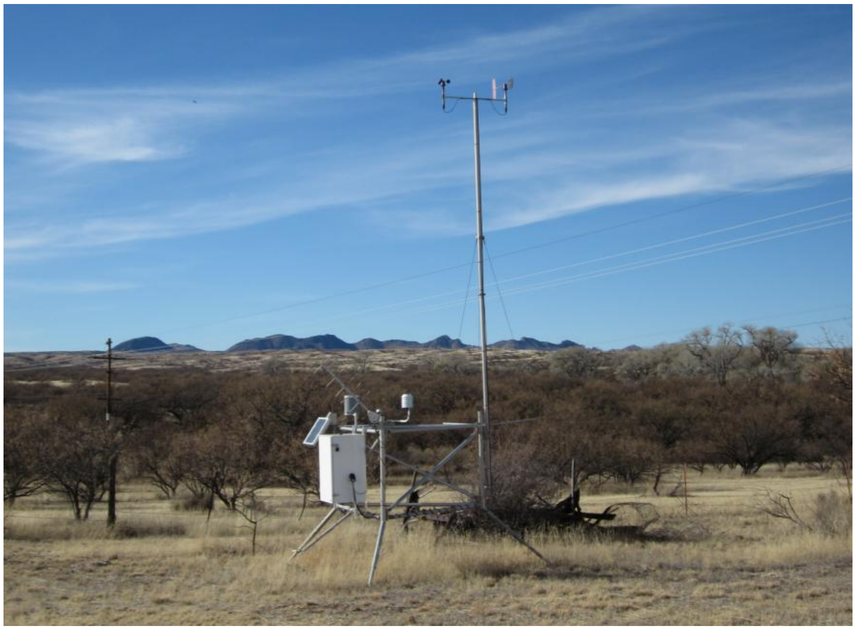

Figure 3 - The RAWS surface meteorological station at Empire, approximately 7 miles east-southeast of the Rosemont project area. This photograph (by R. Maddox) was taken looking to the west-northwest. The Rosemont project area lies along and east of the line of dark peaks at the horizon, and extends approximately from the northern-most to the southern-most peaks.

The **Hopkins RAWS station** is located on Mt. Hopkins, near the Hubble telescope, approximately 13 miles south-southwest of the Rosemont project area. The station is at 31.675N 110.880W at an elevation of 7,120 ft MSL. Surface data are available from this station beginning in 2001 through the current time. The **Rincon RAWS station** is in the Rincon Mountains approximately 28 miles north-northeast of the Rosemont project area. The station is at 32.206N and 110.548W at an elevation of 8,240 ft MSL and within an **Arizona Class I area**. These two stations provide the only surface–based meteorological observations near the project area that are at higher elevations than the weather station on the Rosemont site (5,350 ft MSL). Because the terrain is very complex near the project area (e.g., the elevation of Mt. Wrightson, approximately 11 miles south-southwest of the project area, is 9,453 ft MSL), **it is important to include the surface observations from these two stations in the air quality and visibility modeling (CALPUFF) for the EIS.**

VI - AERMOD Forecasts

The AERMOD[11, 12] model was used by AEC to predict air quality in the region immediately surrounding the Rosemont project area. AERMOD (plus, several associated models/programs, e.g., AERMET[13] and AERSURFACE[14]) is a steady-state, plume model that can account for sloping terrain (albeit in a very simple way for downslope winds). **Steady state** means that the meteorological conditions remain constant in time through each hour, before being reset with the next hour's data. This model predicts the evolution of a plume of pollution as it moves away from the project area for one hour. AERMOD is designed to estimate **near-field (less than 50 km - approximately 30 miles)** concentrations[14]. The model uses the **on-site weather data (wind and temperature)**, plus the **5 am Tucson NWS upper-air sounding** data. The model also uses **mixing depth** calculations (the depth of what is called the boundary layer) from an associated program and stability estimates based on both the differential temperature data on-site and the upper-air data from Tucson. Additionally, the user (in this case AEC) must specify the **surface roughness length** (how smooth and uniform the land surface and its vegetation are), the **albedo** (the amount of solar radiation reflected by surface conditions at the site, expressed as the ratio of reflected to total radiation - the albedo is high over light-colored surfaces, e.g., snow and sand, but lower when there is considerable green vegetation), and the **Bowen**

ratio (the ratio of surface sensible heat flux to latent heat flux) – the Bowen ratio is small during wet periods (e.g., the summer monsoon) and becomes large as evaporation from the soil becomes very low (e.g., during the pre-monsoon months, April, May, and June, which are hot and very dry).

The AERMET meteorological preprocessor derives hourly mixing heights based on the morning upper-air sounding and the surface meteorology, including **available solar radiation using the limited ASOS observations from NWS TUS**. The model is then run every hour, so that under light winds, the pollution does not move very far from the site. In reality, of course, a long period of stable drainage flow could move a pollution plume considerable distances (particularly down Barrel and Davidson Canyons). The AERSURFACE interactive program allows the user to estimate albedo, Bowen ratio, and surface roughness. This program is quite versatile and allows the user (AEC in this case) to make various decisions concerning a specific site **to be certain that the best values of these important parameters are used**.

Grosch and Lee[15] noted that: "… modeled design concentrations can vary substantially due to normal ranges of variations in the albedo, Bowen ratio, and surface roughness length." Their study of the sensitivity of AERMOD predicted concentration changes caused by changes in the albedo, Bowen ratio, and surface roughness length, they found changes in predicted design concentrations of 1.5, 2.6, and 160 respectively, with the model being most sensitive to changes in surface roughness. Their data were from studies conducted for a relatively flat and simple site in Kansas. **The specification of these parameters is extremely important, if the user wants to obtain the most realistic design concentrations from the models.**

The AERSURFACE program allows the user to partition complex sites, such as the Rosemont project area, into sectors to allow more precise specification of the surface characteristics. **This was not done by AEC**. The surface parameters also vary by season. Generalized seasonal definitions can be used, or the user can specify seasons, if the site climatology indicates that typical U.S. season definitions do not apply. However, the table below (from the Rosemont Copper Company revised AERMOD modeling report[1]) indicates that AEC used the **most simple, default options** from AERSURFACE and did not determine more accurate, site-specific conditions – **this is a serious flaw within the AEC modeling effort, given the very complex surface character of the Rosemont project area.**

Table 5.1 Surface Characteristics used in the AERMOD Modeling

Surface Characteristic *	Spring	Summer	Autumn	Winter
Albedo	0.25	0.25	0.25	0.25
Bowen Ratio	2.88	3.76	5.70	5.70
Surface Roughness	0.153	0.153	0.153	0.152

* Generated by AERSURFACE, dated 08009
Center UTM Easting (meters): 522896.0; Center UTM Northing (meters): 3521802.0; UTM Zone: 12, Datum: NAD83
Study radius (km) for surface roughness: 1.0
Airport? N, Continuous snow cover? N
Surface moisture? Average, Arid region? Y, Month/Season assignments? Default
Late autumn after frost and harvest, or winter with no snow: 12 1 2
Winter with continuous snow on the ground: 0
Transitional spring (partial green coverage, short annuals): 3 4 5
Midsummer with lush vegetation: 6 7 8; Autumn with un-harvested cropland: 9 10 11

Table 1 – Surface characteristic values used by AEC[1] in their air quality modeling efforts.

The table indicates that **generalized, U.S. seasons** were used. Note that the U.S. spring is considered a transitional season with greening occurring during March, April, and May (the lowest Bowen ratio is specified for spring - **this implies that spring is the wettest season at the site**); June, July, and August are considered as having lush vegetation and an increased Bowen Ratio.

Given the climatology of the site, using these season definitions was grossly in ERROR. The albedo has been set to a constant 0.25 throughout the year – implying that the surface character does not CHANGE during the year. This is certainly not accurate and is another gross error.

The summer monsoon season (July, August, September) brings a strong greening, as the grasses come to life (note that the site has several grazing leases in effect). The summer monsoon is not **"arid"** as was specified by AEC. Actually summer monsoon rainfall at the Rosemont site (July, August, and September) has been comparable with the average precipitation for those months at: Milwaukee and St. Louis, and only slightly

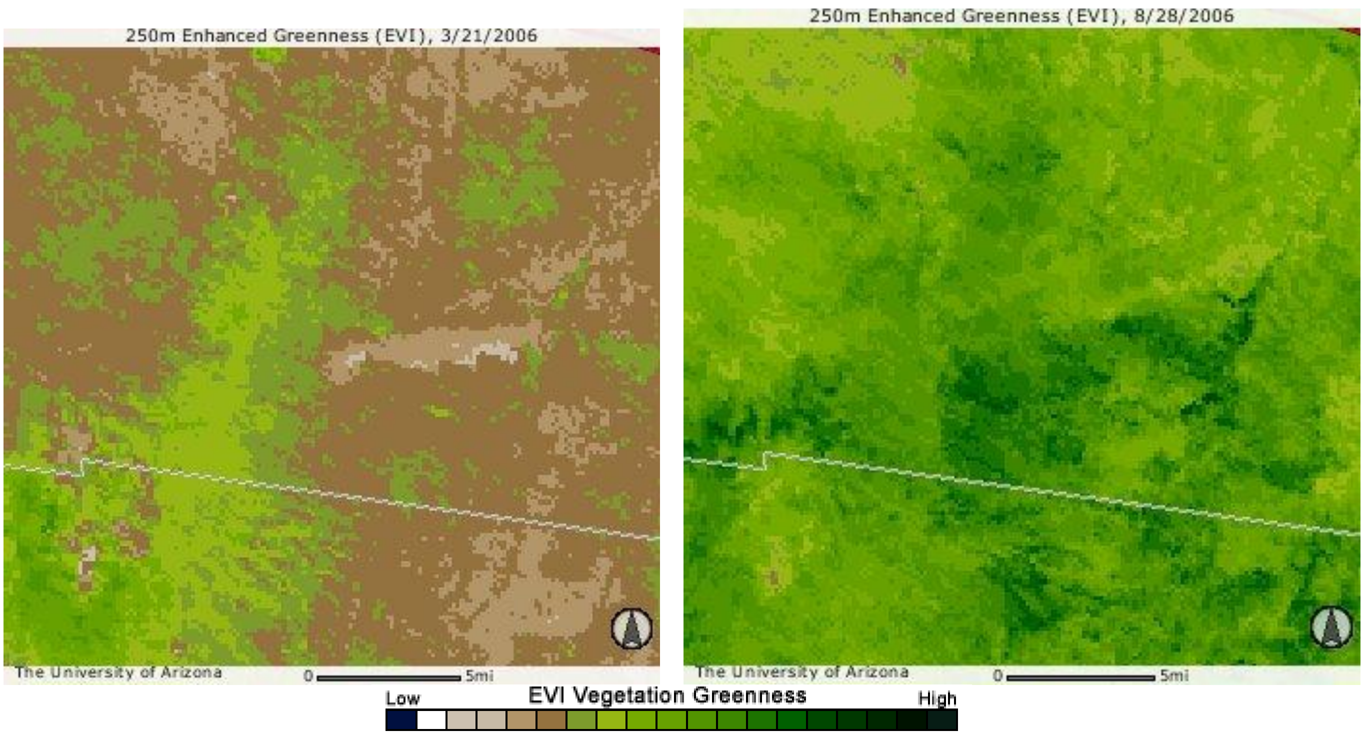

Figure 4 - Vegetation greenness (EVI) from satellite. Left – March 2006. Right – August 2006.

less than Houston. Thus, the albedo certainly changes through the course of an annual cycle. The high-resolution satellite images of the enhanced greenness index (i.e., vegetation index) shown in Figure 4 contrast late March 2006 with late August 2006 (the first year considered in the AEC AERMOD modeling work). The Rosemont site is at the center of these images. The monsoon grasslands have undergone spectacular change from the brownness of the winter and spring months.

The changes in greenness captured in the photographs of Figure 5 show the substantial land surface changes that occur as the monsoon season ends during late September and October – changes that have not been properly recognized, nor accounted for, in the flawed air quality modeling work reported in the DEIS. **Note that the documents related to the proposed Rosemont project employ a subtle, visual subterfuge. There are no photographs of the site shown in the documents that were taken during the verdant greenness of the monsoon season.**

Figure 5 - Photographs of a wash (taken by R. Maddox) in September 2007 (top) and in November 2007 (bottom). This location is approximately three miles south of the Rosemont project area.

Figure 6 (from reference 4) shows monthly average precipitation for the weather stations identified as being near the project area by Rosemont consultants. The "averages" for the Rosemont site are only for the period February 2007 through March 2009; whereas, the other curves are for 30-year averages. July and August rainfall at all the other sites (including Rosemont) is more than twice that at Tucson, U of A. The substantially lower monsoon rainfall in the lower-elevations of the Tucson area indicates that relative humidity and cloud information from the NWS TUS surface observations, and soundings, are **not representative** of conditions at the site (RH was not measured at the site by AEC). All of these data indicate that the meteorological seasons at the project site should essentially be defined as:

1) **pre-monsoon** (Spring) - hot and very dry April, May, and June
2) **monsoon** (Summer) – slightly cooler, very wet and very green – definitely not ARID as entered by AEC
3) **extended fall/winter** - cool to cold and moderately dry October through March.

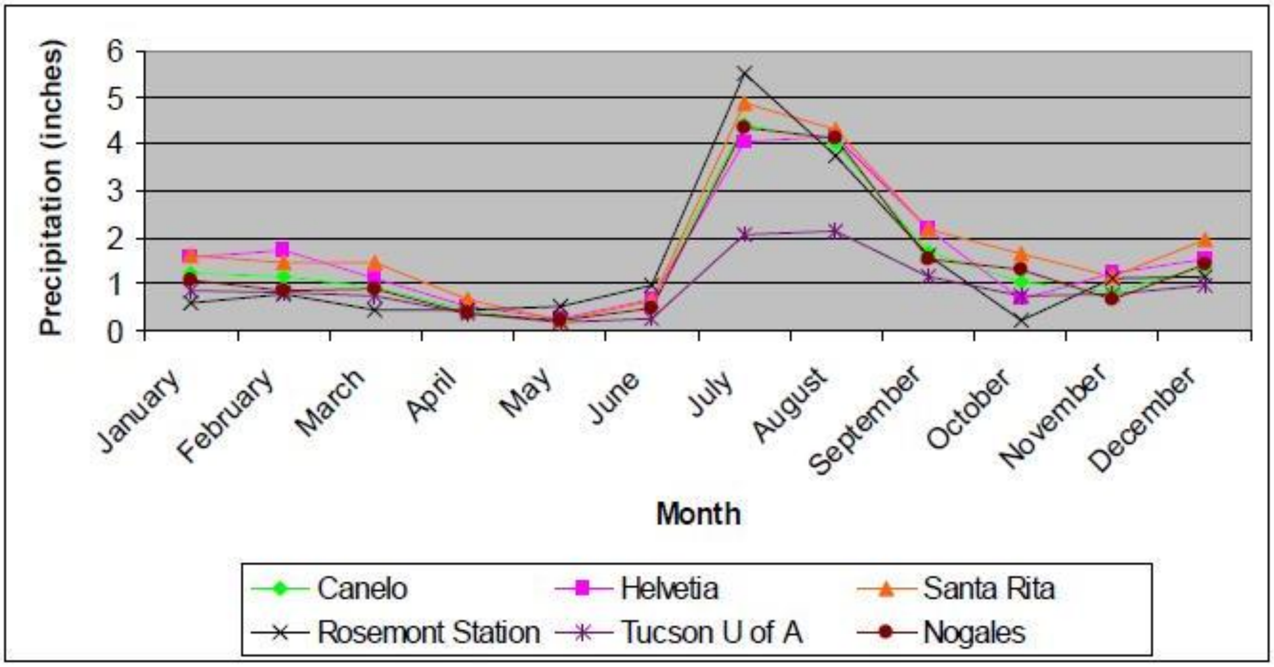

Illustration 3.01 Average Monthly Precipitation

Figure 6 - Average precipitation at the Rosemont site and several stations near the project area (from reference 4).

The actual meteorological "seasons" at the site are very much different than those used in the modeling effort by AEC; however, they could have been specified within AERSURFACE, but were not. Using the data tables in AERSURFACE User's Guide[13,14] and the actual seasons at the project area, as well as considering the transitions from shrubland to grassland that occur spatially and seasonally on the site, it appears that the Bowen ratio for season 1 (Spring) would be approximately 6-10; for season 2 (the wet monsoon period) approximately 0.5 -1.0; and for the extended fall/winter season approximately 4-6. The actual Bowen ratios used by AEC are seriously flawed. Similarly, it is likely that on-site albedos range from about 0.15 to 0.25 during the annual cycle. The surface roughness values used by AEC are also NOT reasonable and that they should range from about 0.05 to 0.30 during the course of the seasonal cycles. See Table 2 of estimated, more realistic, values below. **These are very significant differences from the AEC assigned values, given the sensitivity of model results produced by changes in these parameters, as reported by Grosh et al.[15].**

Surface Characteristic	Spring (April, May June)	Summer – monsoon (July, August, September)	Fall/Winter (October through March)
Albedo	0.18 to 0.25	0.15 to 0.20	0.20 to 0.25
Bowen Ratio	6 to 10	0.5 to 1.0	4 to 6
Surface Roughness	0.05 to 0.15	0.1 to 0.3	0.1 to 0.15

Table 2 – Estimates by R. Maddox of seasonal surface characteristics of the Rosemont site. These estimates are based upon personal observations of the project area and application of AERSURFACE guidance.

The use of AERMOD, as described in AEC documents, indicates that the modeling effort was not designed properly with respect to the actual surface conditions, and the observed "seasonality" of the Rosemont project area. A single, simple weather station was assumed to represent the meteorology of a very complex and large project area. This was very likely an invalid assumption. The modeling effort was not sectorized to account for the different character of the terrain and land surface of the project site, e.g., mountain ridge-line west portion, sloping steeply down across grasslands with trees. The observations used in this modeling effort were highly flawed and inhomogeneous. Further, nearby observations were not included in AEC's analyses of conditions at the site (see Appendices B, C, and D). **The AEC AERMOD report and the model results are so seriously flawed that they can not be used to provide scientific support for the report's conclusions. Agencies evaluating the DEIS can not be confident of the scientific analyses and conclusions that have been based on the AERMOD modeling effort.**

VII - Extended Modeling of Visibility Impacts at Arizona Class I Areas

The revised CALPUFF modeling report[2] prepared by AEC presents very limited details regarding this modeling effort. Some of the information in this report is inaccurate. Several references are given in the report but there is **no listing of references**, requiring the interested reader to chase down the documents cited. The reference to Scire, 2000 on p.8 is apparently a reference to Scire et al.[16]. This is poor technical writing and reporting. The description of nearby Class I areas (p. 2) and the **1994** Map of Arizona Class I areas (p. 4) refer to Saguaro National Monument. Saguaro became a **National Park** back in 1994. The staff at AEC was apparently not aware of the important changes that have occurred at Saguaro.

It is not clear why the AERMOD model, rather than CALPUFF, was used to assess air quality and visibility in the Saguaro National Park East Class I area. Because of AERMOD's steady-state meteorology and 1-hour forecast period it is not really appropriate for application to Saguaro National Park East, which is 35 to 45 km away. Because hourly average wind speeds are used in AERMOD, there would be relatively few days when wind speeds and directions would transport pollution plumes from the site into the Park. **Results should be provided for Saguaro National Park East from the CALPUFF, four-dimensional, extended period model forecasts, as well as those already given from AERMOD.**

The CALPUFF model is a transport model that advects "puffs" of pollution in 4-dimensions. CALPUFF is driven by hourly output from CALMET[16], a 4-dimensional, meteorological prediction model. CALMET can be driven by forecasts from more sophisticated, mesoscale meteorological prediction models, such as MM4 or MM5, or the CSUMM. (It should be noted that while these were state-of-art models a decade or so ago, they have been supplanted by much improved and much higher resolution mesoscale forecast models.) CALMET can also be driven by only meteorological observations, or it can be driven by a combination of model-produced, pseudo-observations blended with actual, real-world observations. The third option was used by AEC to produce the hourly inputs for CALPUFF.

Although the EPA prefers that the modeling be done using data from the most recent 5 year period, the agency will accept a shorter three year period of analysis when mesoscale models are used. AEC used easily available MM5 forecast data for the years 2001, 2002, and 2003 to drive CALMET. The forecasts produced by CALMET/CALPUFF were for a completely different three-year period than were the AERMOD forecasts, introducing yet another uncertainty into the air quality evaluations. The CALPUFF forecasts were all made using the MM5 (PSU/NCAR) model, but with significantly different configurations. The forecasts for 2001 and 2003 were made on a 36-km grid; whereas, the 2002 forecasts were made on a 12-km grid. Thus, the model "observations" used as input for CALMET were also an inhomogeneous data set. It is an EPA regulatory requirement that the acceptability of the three years of MM5 prognostic data be established through demonstration of statistical comparisons with observations of winds aloft and surface observations [GAQM-Section 9.3(c)[19]]. **There is no indication within the CALPUFF report that such comparisons of the MM5 predictive, pseudo-observations were made with the actual observations from southeast Arizona that were used by AEC.**

Kimbal-Cook et al.[17] have evaluated the 2002, 12-km MM5 forecasts. They note that the forecasts were better for winter than summer; over the Southwest the amplitude of the summer, diurnal temperature cycle was consistently underestimated by the model forecasts; in the Southwest the humidity was "greatly overestimated" in summer; and finally, the model forecasts produced excessive amounts of summertime rainfall over the Southwest. The authors also point out that the over-forecast of rainfall can have "serious repercussions" for air-quality modeling, due to excessive "wash out" of pollutants. **Even at 12-km resolution the forecasted low-level winds were not particularly good due to small-scale terrain effects.** All of these problems were likely worse at the coarser model grid spacing used for 2001 and 2003.

Figure 7 presents two contour maps showing terrain as resolved in the 2001 and 2003 MM5 simulations (left) and in the 2002 MM5 simulations (right). At 36 km resolution (left), the forecast model has resolved none of the important orographic features within or near to the Rosemont project area (red "1"). **The Catalina, Rincon, and Santa Rita mountains do not exist in the model terrain field. It is important to note that Anderson[20] states that use of the 2001 and 2003 36 km MM5 model forecasts is not appropriate for air quality modeling over the intermountain West.** At 12 km resolution (right, all the red numbers correspond to features identified similarly on Fig. 1) the Santa Rita Mountains are crudely detected and spatially shifted to the south and east. The Cienega watershed is barely detected. **Barrel and Davidson Canyons, which will be the primary pathway for stable, nighttime drainage flow away from the Rosemont site, are not present at either resolution.** The internal software within CALMET includes parameterized functions to attempt to adjust the lower-level, model forecast winds for complex terrain (downslope winds only), but the results can only have a limited effect, given such crude inputs from the MM5 forecasts.

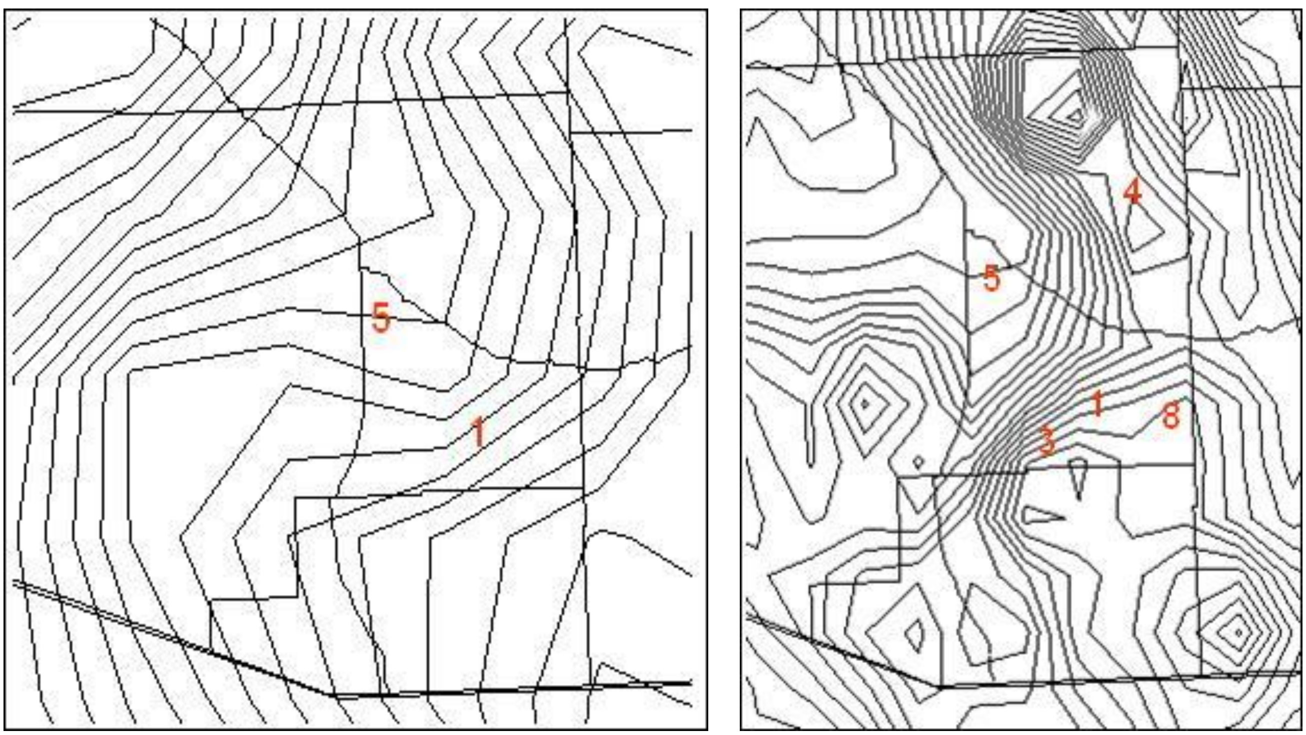

Figure 7 – Southeastern Arizona terrain as resolved by 36 km MM5 (left) for 2001 and 2003 forecasts, and by 12 km MM5 (right) for the 2002 forecasts. Red numbers correspond to the same numbers and approximate locations shown on Figure 1. Contour intervals are at 50 m in both panels.

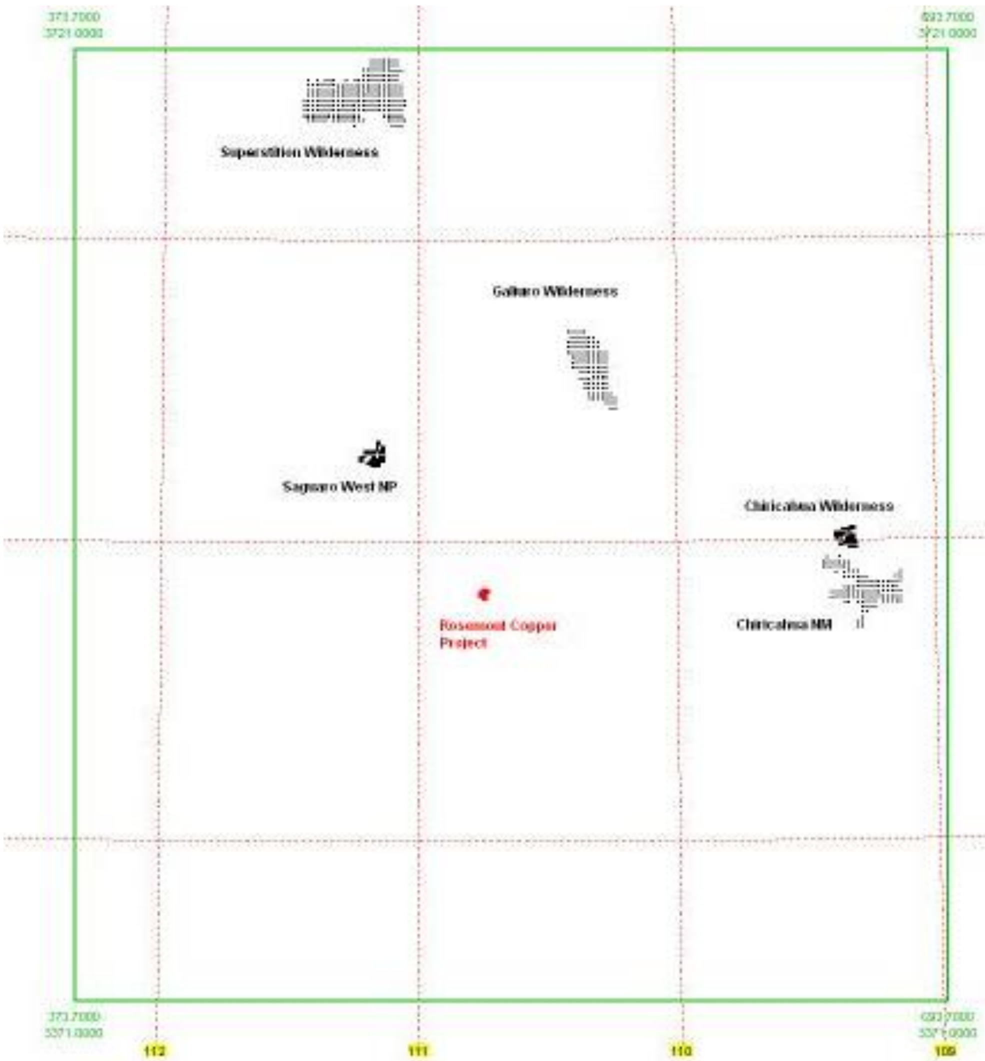

Figure 8 - The CALMET modeling domain (from reference 2).

The CALMET process applied by AEC "blends" actual meteorological observations with the three years of crude-resolution, model forecasts. The CALMET model domain used is shown above and is 350 km (~215 miles) by 320 km (~200 miles). The grid-mesh used was 5 km. Given the complex terrain involved, a grid mesh of no more than 1 km would have been needed to capture on-site, near-site, and Barrel and Davidson Canyon winds and pollution plumes. Such high-resolution modeling can be done for complicated air quality assessments.

The meteorological observations from Tucson (TUS), Davis-Monthan AFB, Nogales, and Douglas-Bisbee were blended with the model forecast data (problems with cloud cover data from the NWS ASOS stations were covered in Sect. III). Table 4.1 (CALMET Parameter Settings) in the AEC CALPUFF report[2] provides information on the weighting-function settings used to blend the small number of actual observations with the MM5 model predicted conditions, both aloft and at the surface. The TUS upper-air data were weighted equally (i.e., averaged) with the model-predicted values at a distance from TUS of 100 km, and the model values were used as the "observation" beyond 200 km. The data from the four surface stations used were weighted equally with the model forecast of surface conditions at a distance of 50 km, and the model forecast was used as the surface "observation" at distances beyond 100 km. [The actual weighting of the surface observations is more complicated near Tucson, since data from both Davis-Monthan AFB and TUS (separation less than 10 km) were used.] Regardless, large portions of the CALMET modeling domain were driven mostly, or entirely, by the crude-resolution MM5 model forecasts. **This is why the demonstration of "acceptability" of the model forecast data by comparison with actual observations is so important.**

There are a number of additional, 24-hour, NWS observing sites within the modeling domain that were not used, for unknown reasons. These include Safford, Casa Grande, and Phoenix. Surface data are also available from the University of Arizona (Atmospheric Science building) and Ft. Huachuca (Army). Precipitation observations were used only from 7 sites (NWS TUS, and 6 NWS cooperative stations), although there are numerous cooperative stations (many of which report the required hourly precipitation data) throughout southeastern Arizona – again, the reason for these omissions are not known. Finally, the interagency, RAWS observation program was described earlier. The RAWS stations actually provide more complete data, with respect to the meteorological input required within CALMET, than any of the other stations. **None of the RAWS data were incorporated into CALMET.** The map below shows the RAWS stations located within the CALMET modeling domain. The RAWS data should have been used in the CALPUFF/CALMET visibility modeling – note that there are several RAWS stations in or near Class I areas.

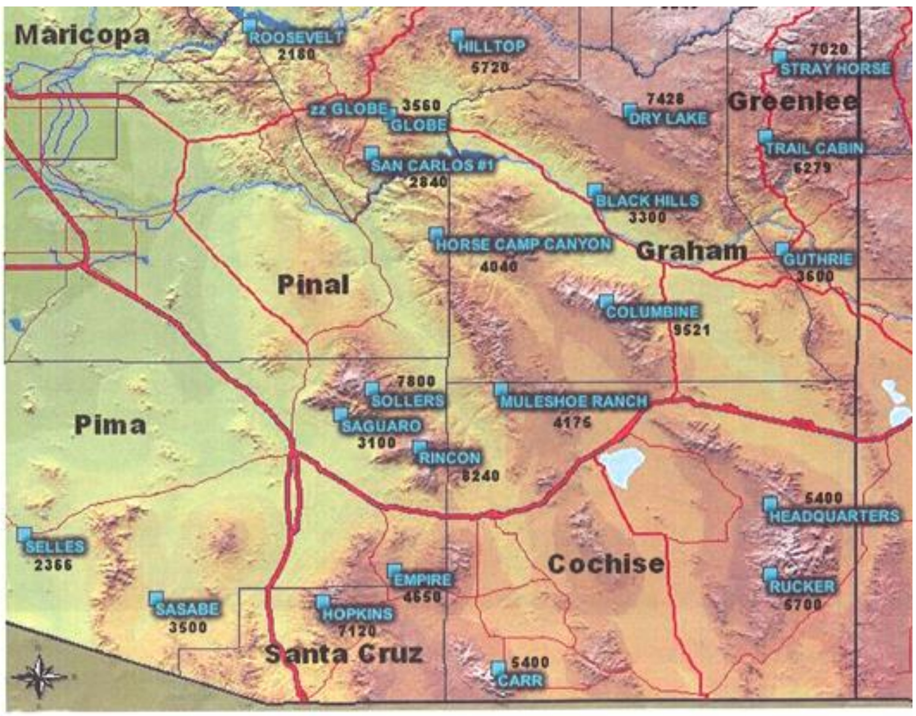

Figure 9 - Current RAWS meteorological observation stations in southeast Arizona. All sites have observations beginning in 2000 or earlier with the exceptions of Sells (2002 – note that station name is not spelled correctly), Hopkins (2001), Saguaro (2002), Stray Horse (2002). Globe 3560 is not in operation and Roosevelt ceased operation in 2009. Six of these stations are within, or very near, to Arizona Class I areas.

<u>The omission of the RAWS, and other available station, data is a serious flaw.</u>

<u>Given these serious input problems, the results from CALMET and CALPUFF can only be considered as crude and likely flawed estimates of what might actually occur, if the Rosemont mine were to go into operation. These results can not be considered as precise predictions of expected conditions during mine operations and the error bars are potentially quite large.</u>

In 2003 the EPA[18] provided a number of cautions for potential users of air quality forecast models. These cautions are relevant to the modeling effort that was done for the Rosemont project area, and are repeated below (from page 455 – **emphasis** added):

> "The extent to which a specific air quality model is suitable for the evaluation of source impact depends upon several factors. These include:
>
> (1) The meteorological and topographic complexities of the area…..
>
> (3) the technical competence of those undertaking such simulation modeling…
>
> (5) the detail and accuracy of the data base, i.e., …[the] meteorological data.
>
> Appropriate data should be available before any attempt is made to apply a model. A model that requires detailed, precise, input data should not be used when such data are unavailable……
>
> Areas subject to major topographic influences experience meteorological complexities that are extremely difficult to simulate…..
>
> Models are highly specialized tools. Competent and experienced personnel are an essential prerequisite to the successful application of simulation models. The need for specialists is critical when the more sophisticated models are used or the area being investigated has complicated meteorological or topographic features. **A model applied improperly, or with inappropriate data, can lead to serious misjudgments regarding the source impact or the effectiveness of a control strategy**…"

These EPA guidelines and cautions were not adequately considered or addressed within the air quality modeling efforts conducted for Rosemont Copper Company. Pollutant concentrations forecast by the air quality models, as configured and run for the Rosemont project area, undoubtedly have large uncertainties that are not quantified. Information presented in the DEIS can not be assumed to mean that planned Rosemont activities would actually be in compliance with applicable Federal laws.

REFERENCES

1 – **Revised AERMOD Modeling Report to Assess Ambient Air Quality Impacts.** Applied Environmental Consultants, April 4, 2011, 42 pp plus 2 Appendices of 6 pp and 41pp.

2 – **Revised CALPUFF Modeling Report to Assess Impacts In Class I Areas.** Applied Environmental Consultants, Inc., April 4, 2011, 26 pp. plus an Appendix of 22 pp.

3 – **Monitoring Protocol and Quality Assurance Project Plan for Conducting Ambient PM_{10} and Meteorological Monitoring for the Proposed Rosemont Copper Mine – Pima County, Arizona.** Applied Environmental Consultants, July 1, 2006, 83pp.

4 – **Aquifer Protection Permit Application, Volume 1 – Rosemont Copper Company.** Tetra Tech, February 2009, 1506 pp.

5 – **Rosemont Copper Project Design Storm and Precipitation Data/Design Criteria.** Carrasco, Joel (Tetra Tech), Technical Memorandum, April 7, 2009, 24 pp.

6 – **Mountain Meteorology – Fundamentals and Applications.** Whiteman, C. David, Oxford University Press, 2000, 355 pp.

7 – **ASOS: Automated Surface Observing System – Guide for Pilots.** NWS publication online at: www.nws.noaa.gov/os/brochures/asosbook.shtml Last updated July 2011.

8 – **Sky Condition.** NWS publication online at: www.nws.noaa.gov/asos/sky.htm Date unknown.

9 – **Radiosonde Replacement System (RRS) Workstation User Guide for RWS Software Version 2.1.** U.S. Dept. of Commerce, NOAA, NWS, March 2011, PDF available only online, 312 pp.

10 – **A Review of the Forest Service Remote Automated Weather Station (RAWS) Network.** Zachariassen, John, et al., 2003, General Technical Report RMRS-GTR-119, 163 pp.

11 – **AERMOD: Description of Model Formulation.** Cimorelli, Alan J. et al., 2004. EPA-454/R-03-004, 91 pp.

12 – **AERMOD Implementation Guide.** AERMOD Implementation Workgroup, 2009. Environmental Protection Agency, 20 pp.

13 – **User's Guide for the AERMOD Meteorological Preprocessor (AERMET).** U.S. Environmental Protection Agency, EPA-454/B-03-002, 252 pp.

14 – **AERSURFACE User's Guide.** U.S. Environmental Protection Agency, EPA-454/B-08-001, 2008, 24pp.

15 – **Sensitivity of the AERMOD Air Quality Model to the Selection of Land Use Parameters.** Grosch, Thomas G., and Russell F. Lee, 1999, 10 pp in *Ecology and the Environment*, Vol. 37, 1112 pp.

16 – **A User's Guide for the CALMET Meteorological Model (Version 5).** Scire, Joseph H. et al., 2000, Earth Tech Inc., 332 pp.

17 – **Annual 2002 MM5 Meteorological Modeling to Support Regional Haze Modeling of the Western United States (Draft Final Report**). Kemball-Cook, Sue et al., 2005, ENVIRON International Corp. and University of California Riverside, 70 pp.

18 – **40 CFR Part 51 Appendix W.** Environmental Protection Agency, 2003, 507 pp.

19 – **Guidelines on Air Quality Models.** Environmental protection Agency, no date, continually updated.

20 – **Use of prognostic Meteorological Modeling Data for the CALMET/CALPUFF Modeling System: Alternatives.** Anderson, B. A., USEPA Region 7, presentation 2005, R/S/L Modelers Workshop.

APPENDIX A – Complexity of Near-Site Winds and Movement of Pollution

Detailed terrain maps indicate that nighttime drainage winds from the project area (particularly the pit, the plant facilities, and the roads to/from the dry stack tailing piles and waste rock dump) will be channeled down Barrel Canyon and then along Davidson Canyon. During extended periods of stable conditions, the drainage and pollution may reach Vail and the Pantano Wash, possibly affecting both east Tucson and Saguaro National Park East. The diurnal cycle of solar insolation, sun angles, surface heating, and the very complex terrain along Barrel and Davidson Canyons will interact to produce extremely complicated, four-dimensional wind patterns. In addition to the generally northeast to northward drainage winds down the canyons, small-scale drainage winds will flow down the sides of the canyons, and likely lift the pollution plume from the site slightly aloft within the canyons. After sunrise, heated slopes on western portions of the canyons produce upslope winds and possible surface fumigations (rapid increases in the concentrations of pollutants). If the stable flow regime continues into afternoon, heated eastern slopes may also be fumigated. Whiteman[6] (Chapter 12) discusses the extreme difficulties of assessing new-source, air pollution impacts in complex terrain. The simplified figure below illustrates fumigation of a canyon slope during the morning.

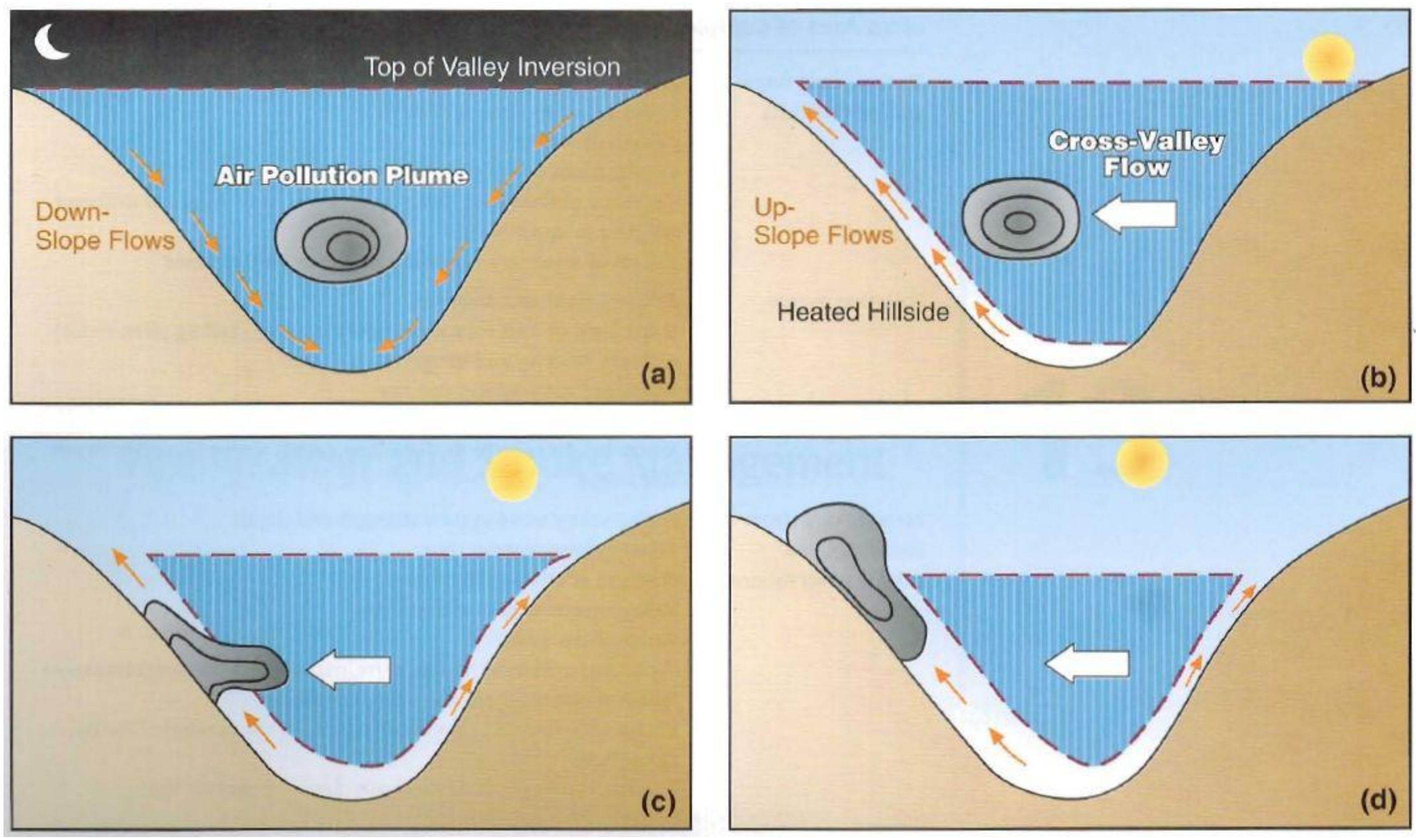

Figure A-1 – Small-scale, cross-canyon flows producing fumigation by a pollution plume on the west slope of a canyon after sunrise (from Whiteman[6]). Mesoscale, down-canyon winds are not shown.

The only way to assess how Rosemont operations could affect air quality from the proposed site through Barrel and Davidson Canyons, north to Pantano Wash and Saguaro National Park East would be to run a nested, very-high resolution forecast model. The model would require additional surface observations on-site, as well as in the canyons and wash. The surface data would have to be enhanced with observed winds aloft data measured by several low-level wind profilers.

APPENDIX B – Wind Roses From at and Near the Rosemont Site

Figure B-1 shows a wind rose from the meteorological station installed at the project area by AEC.

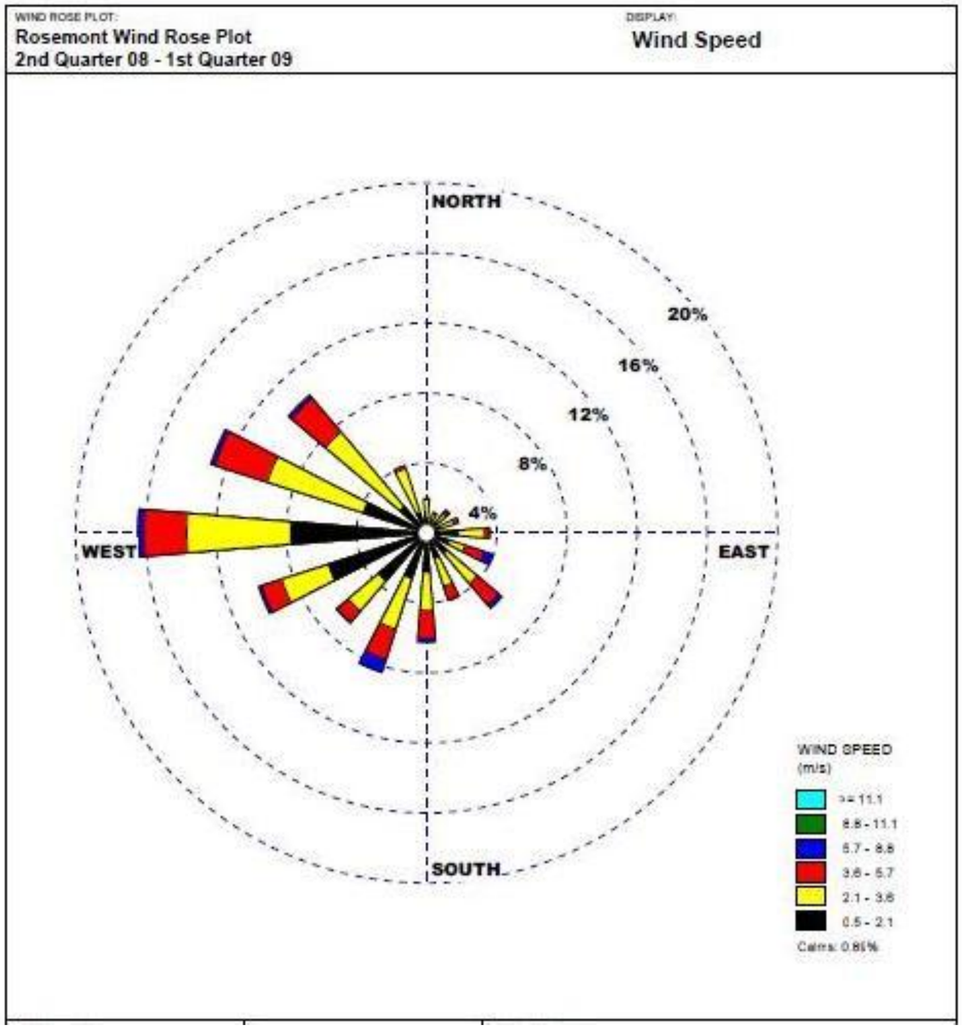

Figure B-1 – Wind rose from the Rosemont weather station for the period April 2008 through March 2009.

This is the only wind rose available from the site that includes 365 days of consecutive data. Wind roses are constructed using hourly average, winds without consideration of the gustiness of the winds. Within the EPA recommended air quality models an algorithm computes the turbulence based on the surface data and the constructed vertical profile of winds aloft. **This is problematic since it is unlikely that the algorithms within AERMOD and CALPUFF can accurately reproduce the gusty character of the winds in the area in and near the Rosemont site because of the complexity of the terrain interactions with the large-scale winds. It is the gustiness of the local winds that pick up and disperse particulate matter from surfaces**, such as the proposed tailing piles at Rosemont. The wind rose for Rosemont indicates no hourly average wind for the year plotted exceeded 8.1 m/s (~18 mph). The winds at the site's weather station occur predominantly from the northwest through south-southeast. A substantial majority of the wind speeds are less than 3.6 m/s (~ 8 mph), principally due to light drainage winds during the late afternoon and nighttime hours. The frequency of light winds may also be influenced by the terrain blockage to the immediate west and south of the weather station.

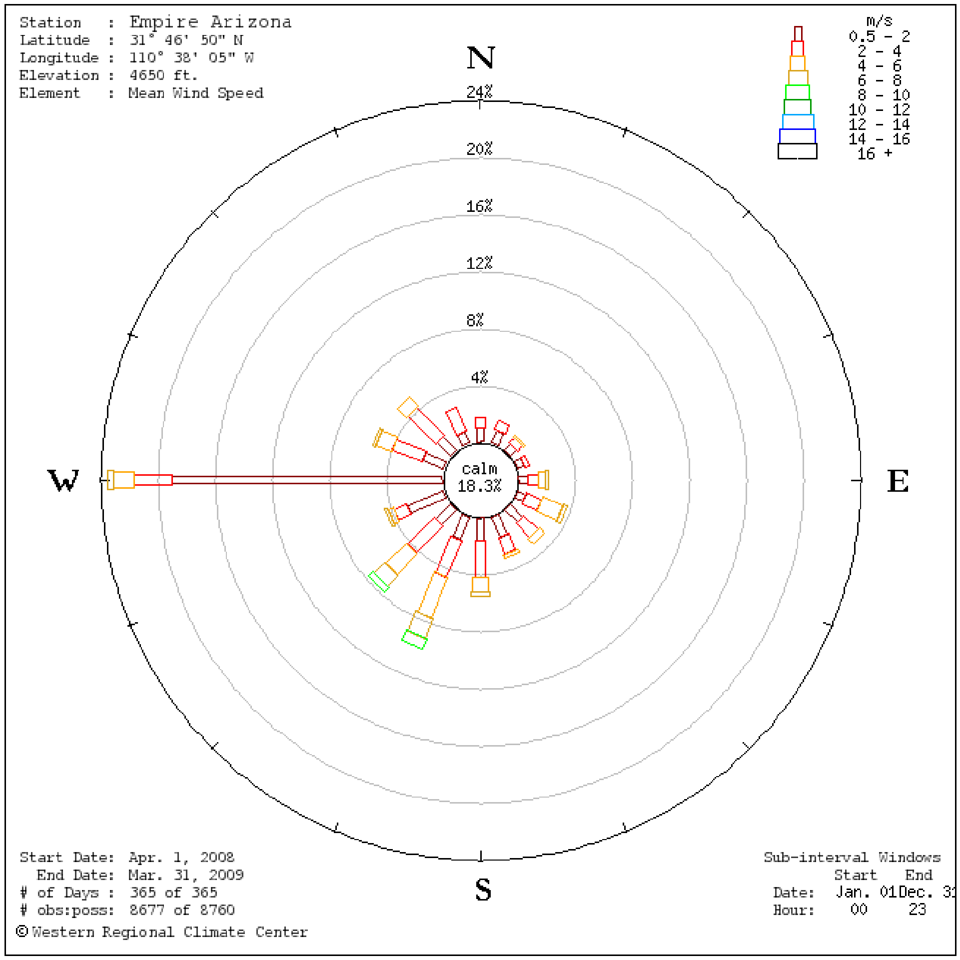

Figure B-2 – Wind rose from the Empire RAWS station for the period April 2008 through March 2009.

A wind rose for data from the Empire RAWS station (approximately 7 miles east-southeast of the Rosemont project area and at about the same elevation as the eastern periphery of the project area) is shown above. The winds at this weather station near Rosemont show a very strong westerly peak, with a secondary peak from the southwest to south-southwest. It is within this secondary peak that the strongest hourly average winds occur at Empire (8 to 10 m/s, or ~18 to 22 mph). The winds at Empire are somewhat stronger than those at the Rosemont site during windy conditions (see Appendix C).

Figure B-3 shown below is the wind rose for the same period from the Hopkins RAWS station (located about 13 miles south-southwest of the Rosemont site, at an elevation 1770 ft higher than the Rosemont on-site weather station). This station is the next nearest observation site with a full-range of meteorological observations. Note that winds, as would be expected at a higher surface elevation, are considerably stronger than those at Empire and Rosemont. Winds are predominantly from the west to west-northwest, with a secondary peak from the east. Strongest winds occur within this easterly flow regime. At Hopkins there were 14 hours during the year considered with hourly average speeds greater than 17.6 m/s (~39 mph) and 4 hours with average winds greater than 21.2 m/s (~47 mph). The Hopkins wind rose illustrates well the complexity and variability of surface winds over the very complex terrain near the site and the Santa Rita Mountains.

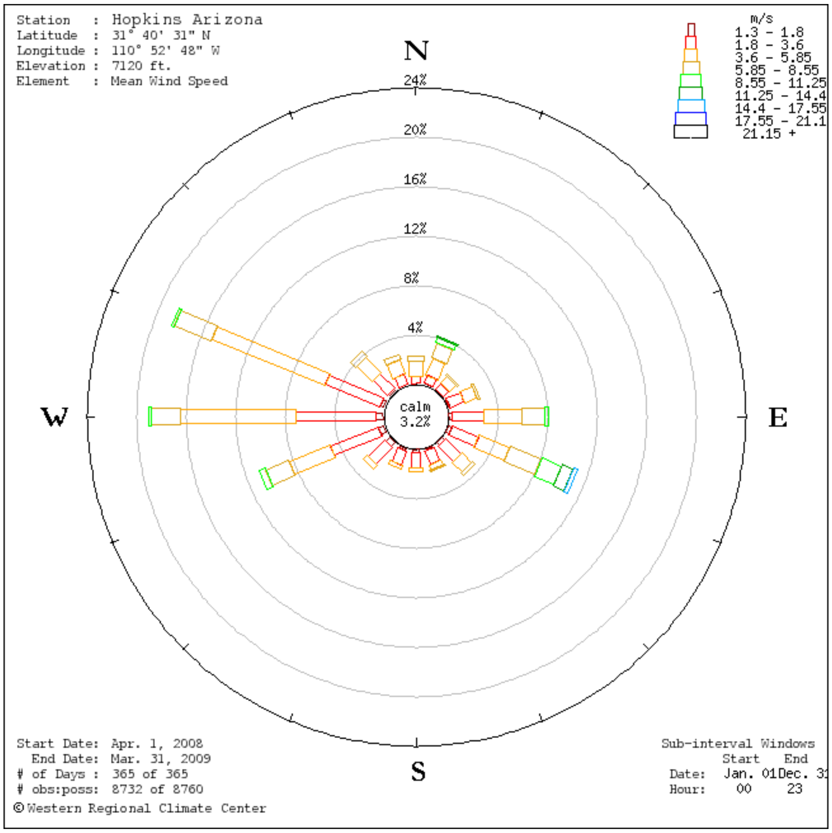

Figure B-3 – Wind rose from the Hopkins RAWS station for the period April 2008 through March 2009

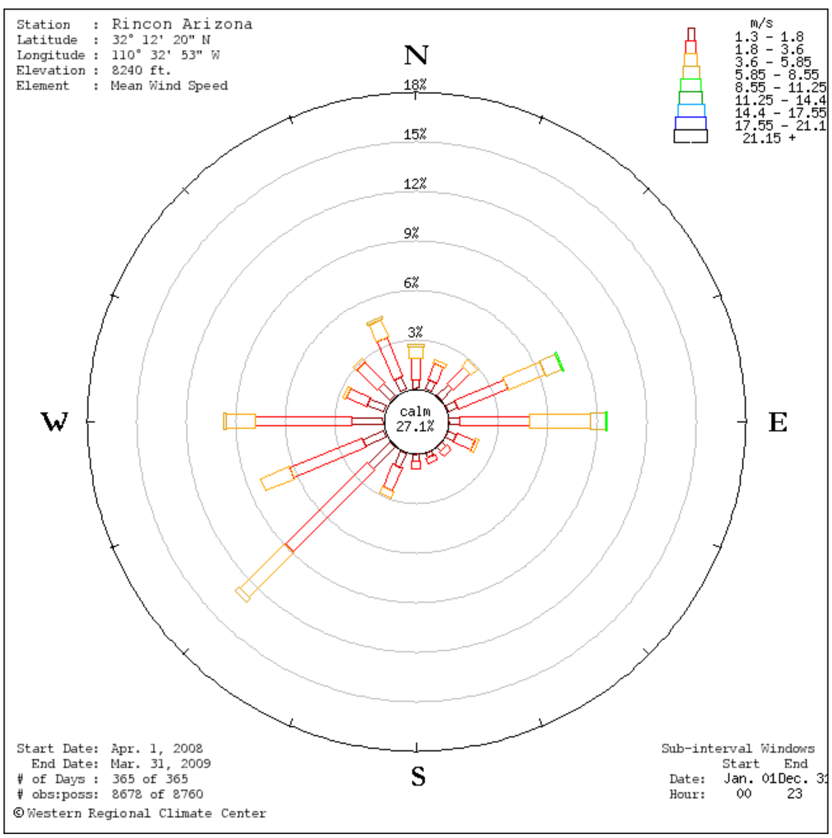

Figure B-4 – Wind rose from the Rincon RAWS station for the period April 2008 through March 2009.

Figure B-4 shown above is the wind rose for the same period from the Rincon RAWS station (located about 28 miles north-northeast of the Rosemont site, at an elevation 2890 ft higher than the Rosemont on-site weather station). This station is the closest observation site with a full-range of meteorological observations located in an Arizona Class I visibility area. Note that winds, as would be expected at a higher surface elevation, are considerably stronger than those at Empire and Rosemont, but are not as strong as those observed at Hopkins. Winds are predominantly from the southwest to west, with a secondary peak from the east to the east-northeast. Strongest winds occur within this easterly flow regime. At Rincon there were 19 hours during the year considered with hourly average speeds greater than 8.6 m/s (~ 19 mph). The Rincon wind rose also illustrates well the complexity and variability of surface winds near the Rosemont site.

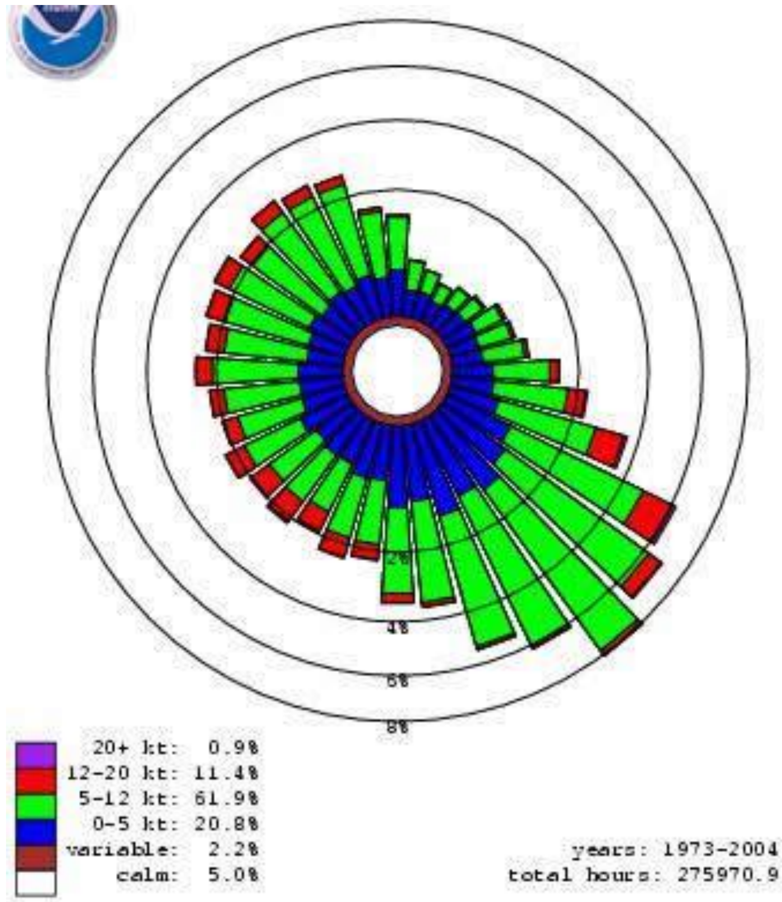

Figure B-5 – Wind rose from Tucson (TUS) NWS observations for the period 1973 through 2004.

Finally, a long-term (30 years) wind rose is shown above in Figure B-5 for the NWS observations at Tucson International Airport. The wind speeds are in kt (10 kt is ~5 m/s or 11 mph). The predominant wind direction observed at TUS is **from the southeast** – which highlights the difficulties involved in using an upper-air sounding from the different flow patterns that dominate the large and broad Santa Cruz watershed. Winds from other directions are about equally distributed, except for the minimum from the northeast. Strongest speeds occur from the southeast quadrant. **The wind roses in this Appendix illustrate clearly that the complex flow regimes that characterize the Rosemont, and nearby areas, can't be defined by a single surface observation on the large and strongly-sloped site.**

APPENDIX C – Detailed Wind Data From Rosemont and Empire

The following two tables compare wind data from the Rosemont on-site weather station with data from the RAWS weather station at Empire (about 7 miles east-southeast of the Rosemont station and at an elevation that is 700 ft lower than the Rosemont station). The tables present hourly wind data from July 2006 and March 2007. Shown are the maximum hourly average wind (direction and speed) for each site, for each day of the month. The time of the maximum hourly wind is also shown for each day. For Empire, the maximum gust observed each day and its time is also shown (gust data are not available for Rosemont). Wind directions for the maximum hourly wind are in **"blue"** if the directions differ by 30 degrees or more. (If the direction difference were 30 degrees, an AERMOD forecast parcel of air at a distance of 50 km would be displaced by 25 km – i.e., significant differences in the small scale directions of the wind, if input to AERMOD, result in forecast air parcels traveling significantly different paths). Wind speeds for the maximum averaged hour are in **"red"** if the speeds differ by 1.5 m/s or more. A speed difference of 1.5 m/s results in a position difference, after an hour forecast, of 5.4 km. If the times of the hourly average maximum winds observed differed by 6 hours or more the times are in **"green."** Different timing of the strongest winds would again lead to different AERMOD forecasts of where the pollution and dust leaving the site would end up and what the concentrations would be.

Rosemont winds July 2006				Empire winds July 2006					
Day	MHW Dir	MHW Sp	time	Day	MHW Dir	MHW Sp	time	Max Gust	time
1	264	4.8	2	1	118	5.4	14	10.3	15
2	249	5.2	18	2	268	4.0	14	7.6	21
3	252	5.0	19	3	289	4.0	19	8.0	16
4	238	5.3	17	4	122	6.7	21	13.0	22
5	123	5.3	11	5	116	5.4	10	8.0	13
6	198	4.2	8	6	106	4.5	22	8.0	14
7	300	6.6	16	7	310	5.8	17	12.5	15
8	314	4.0	12	8	296	3.6	17	7.2	18
9	248	5.1	23	9	288	4.0	17	8.0	18
10	260	6.6	7	10	228	4.0	6	8.0	19
11	305	5.2	9	11	310	3.6	17	8.0	19
12	253	6.5	4	12	219	4.9	1	8.9	2
13	244	6.0	3	13	110	5.4	18	19.7	18
14	273	5.5	2	14	339	4.0	11	11.2	21
15	89	4.7	16	15	107	5.8	23	12.1	23
16	265	5.4	18	16	207	5.8	19	13.0	18
17	275	5.3	21	17	138	4.0	14	9.4	20
18	258	6.8	19	18	245	4.9	18	10.3	16
19	263	5.4	16	19	119	5.4	8	9.8	13
20	308	4.1	24	20	300	4.0	21	8.0	22
21	67	5.0	15	21	84	5.4	16	10.7	16
22	109	8.0	11	22	114	7.2	11	13.0	13
23	131	5.3	10	23	62	8.9	15	19.2	16
24	258	6.8	23	24	57	1.8	14	6.3	14
25	268	7.5	20	25	150	6.7	16	11.6	16
26	268	5.2	2	26	290	5.4	15	9.8	16
27	243	5.1	2	27	280	4.5	17	10.3	4
28	278	5.6	3	28	22	4.0	12	8.9	5
29	263	5.3	24	29	186	3.6	3	7.2	7
30	279	5.2	2	30	228	3.1	5	5.4	4
31	304	5.0	4	31	267	4.5	16	8.9	16

Rosemont winds March 2007				Empire winds March 2007					
Day	MHW Dir	MHW Sp	time	Day	MHW Dir	MHW Sp	time	Max Gust	time
1	306	7.0	21	1	323	3.6	16	7.6	16
2	301	4.9	1	2	308	5.4	12	9.8	16
3	138	4.7	24	3	30	5.8	11	10.7	14
4	120	10.7	11	4	102	9.8	10	15.6	12
5	128	6.1	12	5	124	6.3	2	11.2	1
6	296	4.9	19	6	325	4.0	5	7.2	5
7	318	3.5	14	7	289	3.6	17	8.9	16
8	294	5.7	6	8	310	4.9	17	8.9	16
9	314	3.3	13	9	316	3.1	17	6.3	18
10	313	3.8	12	10	267	5.4	14	10.7	16
11	48	3.6	14	11	320	5.4	16	10.3	17
12	128	6.0	10	12	110	5.8	10	8.9	13
13	247	4.2	24	13	305	5.8	15	12.1	14
14	241	4.0	1	14	322	4.0	17	8.0	16
15	312	4.6	22	15	319	2.7	16	7.2	15
16	116	5.6	12	16	126	5.4	12	8.0	12
17	261	5.8	23	17	271	5.4	19	18.8	17
18	261	6.8	5	18	223	5.8	17	9.8	17
19	276	5.2	22	19	195	5.8	11	10.7	11
20	277	5.8	15	20	274	6.3	16	13.9	17
21	192	7.7	12	21	194	11.6	11	21.1	10
22	121	7.7	11	22	129	8.0	16	17.0	16
23	280	4.5	14	23	213	5.8	14	12.1	2
24	303	3.2	23	24	222	4.5	2	7.2	3
25	302	5.3	23	25	110	3.1	14	8.5	14
26	273	4.1	23	26	300	4.9	17	8.9	17
27	305	9.2	24	27	205	11.2	16	18.3	20
28	312	8.1	1	28	309	5.4	16	9.8	17
29	306	3.6	14	29	319	4.5	22	9.8	23
30	329	3.5	16	30	311	5.8	15	9.4	15
31	304	5.9	20	31	310	3.6	18	6.7	18

Finally, the maximum daily gusts measured at Empire indicate that the **local area winds around the Rosemont site are very gusty (maximum gusts during a day tend to be 2 to 3 times the speed of the maximum hourly wind)**. It is very unlikely that the turbulence algorithm within AERMOD accurately captures the turbulence of the wind flow at and near the Rosemont site – this is very important because it is the turbulence and its strength that would lift and transport particulates (dust) away from the Rosemont tailing piles. The tailing piles would be on the east (lower) side of the project area, where winds are likely somewhere between those observed at the Rosemont pit versus those observed at Empire.

To summarize the difference in the wind observations – during July 2006 the maximum observed hourly wind speeds differed by 1.5 m/s or more on 35% of the days. The direction differed by 30 degrees or more on 65% of the days, and the time of the maximum hourly averaged wind differed by 6 hours or more 48% of the days. During March 2007 the maximum observed hourly wind speeds differed by 1.5 m/s or more on 35% of the days. The direction differed by 30 degrees or more on 35% of the days, and the time of the maximum hourly averaged wind differed by 6 hours or more on 55% of the days. During easterly wind periods the speeds tend to be stronger at the higher elevation Rosemont weather station; whereas, south to southwest winds tend to be stronger at the Empire weather station. In March 2007 the strongest wind gust at Empire (21.1 m/s) was approximately twice as strong as the maximum hourly wind observed at Rosemont (10.7 m/s) during the nearly three years of observations taken at the site. **These data further indicate the extreme variability and gustiness of the winds in the complex terrain in and near the Rosemont and substantiate the need for observations from different locations on the project area.**

APPENDIX D – Comparison of Winds From TUS Upper-Air Data With Hopkins RAWS Data

The two tables below show winds observed at 5 am MST during July 2006 and March 2007 at both the Hopkins RAWS station (located approximately 32 miles south of TUS) and the **now closed** NWS upper-air site at TUS. The Hopkins RAWS observing site is at an elevation of 2170 m MSL. A comparison is made here with the free-air data taken at TUS at ~ 2135 m MSL (i.e., the morning 5 am MST upper-air data that are used in both the AERMOD and CALPUFF models). The models combine the surface temperature and surface wind (either observed or MM5 predicted) with the TUS sounding data (from ~24 miles away) to produce an estimated vertical profile of meteorological parameters over the Rosemont site

The wind directions have been highlighted in "blue" when there is a directional difference between the two observations of 30 degrees or more. The speeds have been highlight in "red" when there was a speed difference of 1.5 m/s or more. During July 2006 the directions of the observed winds differ by 30 degrees or more on 50% of the days (the largest difference in wind directions was 137 degrees on 28 July), and the speeds differ by 1.5 m/s or more on 60% of the days (the largest speed difference in July was 6.7 m/s the morning of July 17th). During March 2007 the directions of the observed winds differ by 30 degrees or more on 47% of the days (the largest difference in wind directions was 174 degrees on March 4th), and the speeds differ by 1.5 m/s or more on 40% of the days (the largest speed difference in March 2007 was 12.0 m/s the morning of March 4th). **These data indicate the extreme variability of the winds in and above the complex terrain near the Rosemont site.** Upper-air sounding data from TUS can not be realistically blended with the surface observations from Rosemont to produce an accurate vertical profile of meteorological conditions over the project area. **<u>These data also substantiate the need for observations from different locations on the project area, as well as wind and temperature data from aloft above the site.</u>**

Hopkins RAWS 5 am wind elevation 2170 m MSL July 2006			TUS 5 am sounding JULY 2006 data from approx. 2135 m MSL		
Day	Dir	Speed	Day	Dir	Speed
1	304	3.6	1	350	2.5
2	16	7.2	2	345	3.5
3	275	2.7	3	20	1.5
4	66	2.2	4	345	3.0
5	56	6.7	5	55	5.0
6	211	1.3	6	195	3.5
7	95	4.9	7	110	7.0
8	90	1.8	8	125	1.5
9	47	2.2	9	315	1.5
10	292	3.6	10	280	3.5
11	26	4.5	11	355	4.0
12	306	1.8	12	345	4.5
13	290	5.4	13	325	6.0
14	309	5.4	14	315	7.5
15	78	5.4	15	60	2.0
16	93	4.5	16	105	6.0
17	106	1.8	17	10	7.5
18	111	3.6	18	15	2.0
19	111	4.0	19	95	4.0
20	90	4.9	20	80	3.5
21	99	6.7	21	50	4.5
22	103	9.8	22	115	10.0
23	84	4.5	23	135	6.5
24	66	2.2	24	85	4.0
25	278	1.3	25	310	3.5
26	350	3.1	26	320	6.5
27	8	3.6	27	15	6.0
28	277	4.0	28	140	1.0
29	295	1.8	29	275	6.0
30	309	2.2	30	999	99.0
31	238	3.6	31	235	7.5

Hopkins RAWS 5 am wind elevation 2170 m MSL March 2007			TUS 5 am sounding March 2007 data from approx. 2135 m MSL		
Day	Dir	Speed	Day	Dir	Speed
1	327	3.1	1	325	5.5
2	279	4.9	2	310	5.5
3	143	2.2	3	15	6.0
4	276	4.0	4	90	16.0
5	92	6.3	5	119	8.5
6	303	4.5	6	280	4.0
7	291	1.8	7	345	2.5
8	285	5.8	8	325	3.5
9	287	2.2	9	305	2.5
10	312	2.7	10	265	2.0
11	24	4.5	11	999	99.0
12	123	8.5	12	90	7.5
13	290	5.8	13	280	6.5
14	289	5.4	14	285	4.5
15	287	5.4	15	310	6.0
16	74	2.7	16	75	4.5
17	92	3.1	17	125	3.0
18	290	5.8	18	310	6.0
19	240	2.2	19	215	8.0
20	287	5.4	20	245	4.5
21	259	5.8	21	220	16.5
22	106	7.6	22	180	13.5
23	102	4.5	23	170	6.5
24	281	1.8	24	245	3.5
25	103	4.9	25	145	6.0
26	292	4.9	26	280	3.0
27	242	5.8	27	235	7.5
28	284	6.3	28	290	5.0
29	19	13.4	29	50	6.5
30	283	4.5	30	285	5.5
31	279	3.1	31	20	4.0