December 19, 2023

Memo: <u>Reply to Comments from APCD and CDPR on SAG Proposed Emissivity Grids Document of June 21, 2023</u>

From: Scientific Advisory Group (SAG)

To: Jon O'Brien, California Department of Parks and Recreation
Karl Tupper, San Luis Obispo Air Pollution Control District

Cc: Sarah Miggins, California Department of Parks and Recreation
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On June 21, 2023, the Scientific Advisory Group (SAG) forwarded a document[1] to the San Luis Obispo Air Pollution Control District (APCD) and the California Department of Parks and Recreation (CDPR) entitled "***SAG Recommendations for Establishing Emissivity Grids to be used in Modeling of Pre-Disturbance Conditions and Future Excess Emissions Reduction***." ADCP undertook a review of that proposal and provided extensive constructive comments[2], which were forwarded to the SAG on August 1, 2023. CDPR commissioned personnel from the Desert Research Institute (DRI) to undertake a separate review on their behalf[3], which was forwarded to the SAG on or about August 30, 2023. The CDPR (DRI) review includes commentary regarding potential modeling challenges associated with the proposed emissivity grid and also responds, item-by-item, to the issues listed in the APCD review document. Below is the SAG response to both review documents according to major issues identified. The SAG extends our gratitude and thanks to both APCD and CDPR for their thoughtful input and insightful suggestions.

Before proceeding with our reply, it is important to note that several important developments have transpired since the original proposal was submitted in June, 2023. **First**, a discussion between personnel from APCD, CDPR, and SAG yielded agreement that the focus of immediate efforts regarding the Stipulated Order of Abatement (SOA) should be on modeling mass emissions from the ODSVRA and not on updating the emission-dispersion model used for the purposes of predicting (and retrodicting) PM_{10} concentrations at established monitoring stations. The outcome of those discussions is summarized in a SAG memo[4] dated September 14, 2023.

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[1] https://storage.googleapis.com/slocleanair-org/images/cms/upload/files/SAG%20Memo_Emissivity%20Grids%20for%20Future%20Modeling%20of%20Excess%20Emissions%20-%2020230621Rev1.5.pdf
[2] https://storage.googleapis.com/slocleanair-org/images/cms/upload/files/Revised%20Comments%20on%20SAG%20proposal%20on%20emissivity%20grids.pdf
[3] https://storage.googleapis.com/slocleanair-org/images/cms/upload/files/DRI%20Comments_SAGAPCD_excess_emiss_memos_08-30-2023.pdf
[4] https://storage.googleapis.com/slocleanair-org/images/cms/upload/files/SAG%20Memo%20-%20Summary%20of%20Exec%20Discussion_Sept%2014%202023.pdf

Second, the 2023 ARWP[5] process has been completed, receiving conditional approval[6] from the San Luis Obispo Air Pollution Control Officer (APCO). The 2023 ARWP discusses at length the specific needs for mass emissions modeling to satisfy the conditions of Section 3.b. of the SOA (revised 2022), which refers to 'excess emissions' beyond 'naturally occurring' conditions. Given that the 2023 ARWP recently received conditional approval, many of the issues that were noted in the APCD review of the June proposal with reference to terms in the conditional approval of the 2022 ARWP are no longer relevant (and need not be discussed herein).

Third, at the October in-person SAG meeting, which included representatives from APCD and CDPR, many issues regarding the proposed emissivity grid were discussed. Consensus was reached on all issues, and these will be noted below.

Fourth, the SAG has developed a revised version of the original June 21 proposal that responds to many of the comments from APCD and CDPR (DRI). The revised proposal[7] (dated December 19, 2023) is intended to accompany this memorandum, and for the sake of expediency the reader will be referred to relevant sections and figures when appropriate.

1. **Emissivity Zones** – There is concurrence that the ODSVRA should be divided into distinct emissivity zones, as proposed in the June document and reiterated in the December document. This zonation will supplant the previous modeling approach, which used a spatial interpolation scheme to derive a continuously varying emissivity grid. Zonation simplifies the modeling effort (eight distinct sub-regions rather than a multitude of 20 m by 20 m grid cells) and more realistically accommodates the statistical uncertainty and local variability in the PI-SWERL data (refer to discussion in Appendix II of December document). Figure 17 in the December document shows the proposed zonation. DRI correctly notes that the implementation of a zonal approach will decrease the fidelity inherent to an interpolated grid, which has been used previously to reverse-track the location of highly emitting cells that contribute to large PM_{10} concentration at downwind receptor sites. **The SAG notes the following:**
    a. most highly emitting locations were identified in earlier modeling exercises and to large degree have been mitigated, so there is less need to identify 'hot spots';
    b. the Lagrangian Particle Dispersion model will need to be recalibrated and is now of secondary importance given the focus on excess mass emissions rather than PM_{10} concentrations; and
    c. there is no easy way to develop a representative interpolation grid that incorporates PI-SWERL measurements from multiple campaigns (across several years). Prior interpolation grids were developed for 2013 and 2019 separately, with substantially different results.

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[5] https://storage.googleapis.com/slocleanair-org/images/cms/upload/files/2023ARWP_ProvFinal_20231004_lowres.pdf
[6] https://storage.googleapis.com/slocleanair-org/images/cms/upload/files/2023-10-18%20Conditional%20Approval.pdf
[7] https://storage.googleapis.com/slocleanair-org/images/cms/upload/files/SAG%20Memo_Emissivity%20Grids%20for%20Future%20Modeling%20of%20Excess%20Emissions%20-%2020231219.pdf

2. **Pooled Data and Emissivity Power Relations** – There is concurrence that the data for each of the management zones identified in Figure 17 should be pooled across all years of available data (2013 through 2022 and beyond). This issue is discussed on page 31 of the December document. It was also agreed that **the median (rather than the mean) is the most robust statistic of central tendency to use in the development of emissivity power relations** given the highly skewed nature of the data distributions (see page 28 and 29). DRI notes that this will have implications for the emission-dispersion model, which will need to be recalibrated and refined given that it currently ingests emissivity relations based on mean values. However, modeling convenience is not a valid justification for avoiding the use of a more statistically robust parameter (i.e., the median). DRI also questions whether the use of the mean better captures the magnitude of the emission process because it better accounts for the "high tail of the distribution that generate high emissions for high values of u_*." It is not evident that this argument has credence since:
    a. Both the median and mean are influenced by large values in the distribution, albeit the median less so than then mean;
    b. Large values of emissivity are typically statistical outliers, perhaps due to local placement of the PI-SWERL instrument (see page 43 and 44), and therefore may not be representative of the general tendencies in the distribution; and
    c. As long as there is consistency in using the median for developing emissivity relations for both the pre-disturbance and 'current' scenarios, there is no danger of not treating large values of u_* correctly in the modeling for purposes of assessing excess emissions.

3. **Sample Bias: Campaign-Weighted Emissivity Medians** – Both APCD and DRI expressed reservations about the fact that there are spatial-temporal biases in the PI-SWERL data, specifically with some measurement campaigns (e.g., 2013_09, 2019_05) having many more measurements than other campaigns (e.g., 2014_10; 2016_03, 2022_05). Each of these campaigns had different spatial coverage with only the 2013 and 2019 campaigns having comprehensive coverage of the entire ODSVRA. DRI suggests that the data be 'normalized' in some fashion to one selected year (e.g., 2013 or 2019) for purpose of evaluating the pre-disturbance and 'current' scenarios. It is not clear what the advantage of this scheme might be, except that there will be a common basis in which to understand changes from year-to-year (i.e., all values are reported in "2013 emissivity units"). Perhaps this suggestion was intended to assist in the development of an interpolated grid, but in either case, **the SAG does not see the benefit of normalizing to a 'standard' year of measurements** because the spatial bias is not resolved. A sensitivity analysis might be interesting to undertake, as recommended by DRI, presuming that adequate resourcing is available. The more germane issue, discussed at length in the APCD review, is that given the unequal sample size of the measurement campaigns, simply pooling all the data will skew the results (i.e., the median or mean) to those years with greater numbers of samples. If one year has inordinately large emissivity values and that measurement campaign was extensive, then the pooled global median (across all years) will be skewed slightly toward the higher values. **The SAG notes the following:**
    a. As long as the same medians are used to develop emissivity relations for both the pre-disturbance and 'current' scenarios, any skewness in the data pooling will be irrelevant

because the objective (at this juncture) is to evaluate excess mass emissions (i.e., a relative difference value) rather than actual mass emission or concentrations (i.e., an exact value);

b. Invoking a weighting scheme as suggested by APCD (or normalization scheme as suggested by DRI) would be complex and may undermine the credibility of the results when communicated to the public; and
c. Use of a weighting scheme that reduces the influence of large measurement campaigns will concurrently increase the influence of small measurement campaigns, which is an undesirable outcome given the level of uncertainty associated with small sample sizes. In effect, a small sample that may be inordinately large or small will contribute to the median statistic in a manner that inordinately skews the results but with much less statistical confidence attached to the small sample. Consider, for example, a measurement campaign with only 8 samples, such as the NRA measurements in 2015. Following the APCD recommendation, this campaign would have the equivalent weight as the campaigns in 2013 (n = 143), 2019 (n = 152), and 2022 (n = 160). This seems unreasonable given that the 8 sampling points in 2015 were taken in very close proximity and not distributed across the entire ODSVRA.

Both APCD and CPDR (DRI) suggest interesting ways to either 'weight' or 'artificially replicate' the campaign specific data in order to address the bias issue. **After considerable discussion about this issue at the SAG in-person meeting, it was decided to avoid any normalization or weighting schemes.** Such schemes are complex to implement with uncertain outcomes and effects, and it is not immediately evident whose responsibility it would be to undertake such an exercise. Instead, the preferred strategy is to continue with future PI-SWERL measurement campaigns so that the large number of samples over multiple years and covering the entire area of the ODSVRA will lead to stable statistical representation despite potential sampling bias in any one measurement campaign that may yield inordinately large or small emissivity values. In effect, larger and larger sample sizes will tend toward stable values of central tendency while also characterizing the tails of the distribution faithfully. The upcoming 2024 measurement campaign will be a comprehensive and extensive effort designed strategically to mitigate some of the temporal versus spatial variations, as recommended by APCD, and it will also increase the size of the sample significantly. The APCD also suggests examining some of the data from the Plover Exclosure area that were collected in earlier campaigns while that area was seasonally opened to OHV riding. This analysis is ongoing and will be reported on at a later date.

4. **Threshold Wind Speed** – APCD requested clarification on what values of threshold wind speed (or threshold shear velocity) are to be used in the DRI model. A response was provided in the CDPR (DRI) review document, but no specifics were offered. The options are to use a single value for the entire ODSVRA or to assign different values to each of the management zones. DRI notes that the assignment of a threshold wind speed is necessary in the model to identify periods in wind events when there is no saltation (and hence dust emission), but that this is "not a critical issue that will have a significant effect on model predictions that will influence management decisions or impact the decision to evaluate the condition of excess emissions." **The SAG notes the following:**

a. The threshold condition for initiation of particle motion depends, to first order, on grain size (as represented by Bagnold's equation and many others), but there are many other factors to consider including grain mineralogy (density), particle shape, packing geometry, topographical slope, surface roughness (e.g., ripples, footprints, tire tracks, etc.), surface moisture conditions, presence of chemical and biological crusts, fluid (air) density as a function of temperature and humidity, boundary layer turbulence, and atmospheric stability (buoyancy);
b. There is a long history of investigation into initiation of particle motion, and assigning a single value to a sand surface even under tightly controlled wind-tunnel conditions with well-sorted particle mixtures is a complex endeavor;
c. Determining a value of threshold wind speed using the PI-SWERL data may not align well with values of threshold wind speed from meteorological towers and saltation sensors, so there will be ambiguity;
d. Initiation of particle motion during periods of intermittency is a second-to-second process, meaning that during any period of time there can be periods of active transport and periods of quiescence, which presents a challenge for defining a threshold condition in a model that uses time steps of tens of minutes or an hour; and
e. Even though dust emission is strongly tied to the intensity of saltation of sand-sized particles, there can be dust releases from the ODSVRA sand surfaces without continuous saltation, due to winnowing of fines residing on the surface. So, the threshold for saltation of sand-sized particles may not coincide with PM_{10} emission events especially at low wind speeds when there is intermittent transport.

Rather than pursue all these complexities in detail, and given the continuously evolving nature of the sand dunes and open sand surfaces in the ODSVRA, **it is recommended that a single value of threshold wind speed be assigned to the entire park** rather than each of the eight (8) management zones separately. The precise value used for threshold wind speed should be informed by the predicted values from Bagnold's equation (based on average grain size) as well as empirical data from the meteorological towers, saltation sensors, and PM_{10} instruments. **It seems that DRI is in the best position to conduct such an analysis, given their role in collecting and assessing the field data. A short report to CDPR, APCD, and the SAG regarding a recommendation (or set of alternative recommendations) would be most welcome in order to bring clarity to this issue of threshold wind speed for purposes of modeling.**

5. **Emissivity of Recently Closed Areas** – The APCD expressed 'surprise' that the emissivity values for the Foredune Restoration Area (FRA) and the Plover Exclosure (PE) are less emissive than other non-riding areas (i.e., NRA North, NRA Central, NRA South) despite the FRA and PE being closed for only a few years whereas the other non-riding areas have been closed for much longer periods (or not having had OHV traffic in recent memory). Although the validity of the PI-SWERL measurements is not called into question, there is concern that there may sampling bias—in other words, the measurements in 2022 may be inordinately small relative to other years, in a manner similar to the 2013 being inordinately large. It is indeed the case that the 2022 measurements skew to the low side of the emissivity range (see Figures 3, 7, and 8), but there is no obvious explanation for why this was the case. The FRA and PE measurements were conducted on September 26-30, 2022 following a lengthy dry

period (Sept 10 recorded only 0.04" and there was no reported rain prior to that dating back to April 22), which suggests that the sand surface would have been quite dry. The sand surface in the ODSVRA should have been highly emissive at that time. Other factors must have been at play (e.g., textural sorting; surface roughness effects), but they remain a matter of conjecture. Another set of measurements in the NRA Central was taken on May 16-20, 2022, and these were preceded by rain events on April 21 (0.4") and April 22 (0.12"). Presuming some residual moisture effects from these rain events persisting through to mid-May would imply that the sand surface should have been less emissive than times when there were significantly long dry periods prior to measurements being taken. Figure 3 (December document) shows that the May 2022 median emissivity was greater than measurements in October 2019 (no rain for 4 months prior) and October 2015 (no rain for 1 month prior), whereas the significance tests reported in Figure 4 show that the May 2022 are not significantly different from any of the other campaigns except August, 2013 (and of course, the FRA and PE measurements in September 2022). It is difficult to argue, therefore, that (i) the May 2022 measurements are inordinate and that all of the 2022 measurements have low emissivity because of 2022 being a dry year; and (ii) the low emissivity values for the FRA and PE measurements in 2022 are due to a temporal effect (given that conditions were dry, which would generally yield higher emissivity). In other words, low values in the FRA and PE appear to be due to a spatial zonation effect, and as noted by DRI, the measurements are real and not easily ignored.

There are, of course, implications for assessing excess emissions, as recognized by APCD. The September 2022 emissivity values in the FRA and PE will be applied to the 'current' landscape scenario, as mandated by the APCO Conditional Approval letter for the 2022 ARWP and reiterated on the first page of the APCD review document. But the SAG has recommended that the FRA and PE values not be applied to the pre-disturbance scenario for reasons discussed at length in the December document (pages 34-35). The FRA and PE areas in the pre-disturbance scenario are to be assigned emissivity values based on measurements in the NRA Central spanning the period 2013-2022 (see page 20 of December document), which are greater than those used for the FRA and PE in the 'current' landscape scenario. APCD finds this objectionable and recommends that the emissivity values for the FRA and PE areas be applied to both the current and pre-disturbance scenarios. **The SAG finds no compelling scientific reason to do so.**

The APCD and CDPR (DRI) review documents suggest that there may be some value in exploring west-east trends in the data to explain the low emissivity values in the FRA and PE, which are close to the beach where larger particle sizes are expected. A cursory analysis was conducted with mixed results, as reported in Appendix II of the December document. This line of inquiry will not be pursued further for reasons articulated in Appendix II, and agreed to in the SAG in-person meeting.

6. **Emissions at High Shear Velocities** – The SAG first identified the fact that curves of one of the emissivity power relations intersects (i.e., crosses over) another curve at large values of shear velocity that extended beyond the bounds of the data used for the regressions (i.e., greater than 0.61 ms^{-1}). The APCD has appropriately expressed concern with this, suggesting that it is "unreasonable" for a non-riding area to be more emissive than a riding

area at high shear velocities. As the CDPR (DRI) review notes, there are no data to support either position, and it is certainly possible that a sand surface not affected by OHV riding could become more emissive, at higher wind speeds, than a sand surface that has been influenced by OHV riding. The APCD suggestion to use linear extrapolation of the power law above a shear velocity of 0.61 ms^{-1} is an interesting one, but there are no data to verify the accuracy of these extrapolated linear segments. Moreover, the approach does not solve the 'cross-over' issue, which was the motivation for the suggestion because the NRA North curve still intersects the RA Central-South curve. Without additional data at high shear velocities it seems unwarranted to invoke an extrapolation scheme that ostensibly 'corrects' the basic power law curves when there is no identifiable scientific 'problem' to correct for.

However, there is a related issue that arises from this observation of curve cross-over outside the range of the regression fit. Specifically, it is important to know how often wind speeds during dust events are likely to exceed an upper shear velocity threshold defined by the limits of the regression exercise (i.e., greater than 0.61 ms^{-1}). If such extreme wind events are very rare, then the cross-over issue is only of marginal importance. DRI performed a preliminary analysis (see the CDPR-DRI review) showing that the frequency of hourly exceedances of this threshold is less than 0.04 (4%) for a 60-day simulation period (discussed in Mejia et al., 2019). DRI concludes that "the likelihood of hourly wind speed estimates exceeding 16 ms^{-1} [at a height of 10 m at S1, which corresponds to a value roughly equivalent to a shear velocity of 0.61 ms^{-1}], and biasing the emission estimates from the DRI emission and dispersion model are limited." **SAG accepts this analysis but recommends that a more detailed assessment be performed based on the 10 highest emissions days for the period May 1 through August 31, 2013 (as per the SOA) to understand how frequently wind speeds exceed the upper threshold established by the PI-SWERL limitation (and regression curves), and what impact this might have on emissions calculations.** Nevertheless, the SAG sees no compelling reason to adjust the recommended emissivity power relations proposed in the December document (Table 3; Figure 20), regardless of the cross-over issue, in a manner recommended by APCD to extrapolate the curves. This decision was also supported after discussion at the October SAG in-person meeting.

7. **Curve-Fitting and Parameter Estimation** – APCD presents several interesting ideas with regard to potentially improving the emissivity power relations. These are fully described in their review document and will not be summarized here, nor will they be acted upon at this time. The following consensus decisions were reached at the SAG in-person meeting in October:
    a. A simple power law relation will be fitted to the three paired values (emissive flux; shear velocity) from the PI-SWERL measurements using non-linear regression. Adding a fourth point to the regression process based on a threshold shear velocity does not alter the three-point results to any significant degree, and the marginal changes have negligible impact on emissions calculations overall. Moreover, there is inherent uncertainty to all the PI-SWERL measurements as well as uncertainty with defining an exact threshold shear velocity, and these combined errors likely lead to uncertainty that is greater than any marginal benefit gained by including a fourth point in the regressions. Nevertheless, **the SAG believes it may be worth exploring**

other curve-fitting options in order to verify that the three-point power relations are optimal.

b. **The preferred software for performing the curve-fitting exercise should be SigmaPlot (or equivalent) and not Excel**. Excel uses an algorithm that converts data values to logarithms and then applies linear least-squares regression in logarithmic space for sake of computational speed and efficiency. Unfortunately, minimizing the squares of deviations in logarithmic space introduces a bias that favors low values in the data distribution, leading to relatively poor curve fits at large emissivity values when the logarithms are reverted back to standard data values. This is clearly not ideal for the objective of understanding dust emissions, which are more pronounced at high wind speeds (where curve-fitting accuracy is most essential). SigmaPlot and other statistical software does not convert the original data to logarithms but rather uses an algorithm that iteratively fits a non-linear curve to the original data. This ensures that the squares of deviations from the curve are minimized across the entire range of the data set, thereby yielding a better fit at large shear velocities. The proposed emissivity power relations shown in Table 3 and Figure 20 of the December document all have R^2 values better than 0.999.

The SAG reiterates its thanks to personnel from APCD and CDPR for undertaking a thorough review of the June 21, 2023 document. We believe we have addressed all concerns, either by altering the original proposal (as reflected in the revised document dated December 19, 2023) or by way of explanation in this memo.

We remain open and receptive to further suggestions leading to improvements.

Respectfully,

The Scientific Advisory Group

Bernard Bauer (Chair), Carla Scheidlinger (Vice-Chair), Mike Bush, Jack Gillies[8], Jenny Hand, Leah Mathews, Ian Walker

[8] Dr. Gillies was not included in the discussions and writing of this memorandum because of a potential conflict of interest. He was a co-author of the CDPR (DRI) review document that provided feedback on the June 21, 2023 document that dealt with the proposed emissivity grid, so it is not appropriate for him to participate in a formal response to a review that he co-authored.