California
Department of Conservation
California Geological Survey

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MEMORANDUM

DATE: SEPTEMBER 10, 2019

TO: Dan Canfield, Acting Deputy Director
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FROM: Will Harris, Senior Engineering Geologist

SUBJECT: Review of Stipulated Order of Abatement 17-01 as It Applies to the Development of the Particulate Matter Reduction Plan and Airborne Dust Detected on the Nipomo Mesa, San Luis Obispo County, California.

This memorandum has been prepared at your request. It regards ongoing cooperative efforts to mitigate dust in south San Luis Obispo (SLO) County undertaken by the California Department of Parks and Recreation Off Highway Motor Vehicle Recreation Division (Division) and the SLO County Air Pollution Control District (APCD). These efforts are part of the APCD Hearing Board Stipulated Order of Abatement 17-01 (SOA), which was ratified by the Division and APCD and filed with the Hearing Board on May 4, 2018. The SOA also established the Scientific Advisory Group (SAG), a multi-disciplinary team of scientists that assists in the development and review of investigations and documents prepared as part of the SOA.

Setting, Saltation, and the Premise of the Stipulated Order of Abatement

The SOA states the main source of dust detected in the Nipomo Mesa (Mesa) area of south SLO County (south county) is from the off highway vehicle (OHV) riding area of the Oceano Dunes State Vehicular Recreation Area (SVRA), as determined by cited studies and APCD air monitoring stations in the south county.

The 1,400-acre OHV riding area of the Oceano Dunes SVRA lies within 18,000 acres of active dunes along the central California coastline, stretching from the south county into north Santa Barbara County. For seven months of the year, beginning every spring and extending through the early fall (March 1 to October 1), the OHV riding area of the SVRA is reduced from 1,400 acres to 1,000 acres to protect nesting shorebirds.

Also every spring, strong prevailing winds blow from over the ocean, out of the west-northwest, providing the key force that gives shape to the coastal sand dunes. Coinciding with the spring winds, elevated concentrations of airborne PM10 dust (dust particles that are 10 microns or less in diameter) are detected at the APCD's CDF air monitoring station, which is on the southwest edge of the Mesa, about 2.5 miles from the coast (Figure 1).

A distinction not stated but implied in the SOA, and acknowledged by the Division, the APCD, and the SAG, is that PM10 dust that originates from the OHV riding area of the dunes is not derived by vehicles kicking up sand. Rather, like the dunes outside of the OHV riding area, the dust comes from the natural dune-building process called saltation.

In the coastal dunes of Central California, the strong west-northwest prevailing winds push sand, and everything finer than sand, shoreward. Once on shore, the saltation process begins: Sand grains creep and bounce as they are pushed by the wind, forming small ripples. The sand ripples move downwind and as they do, each sand ripple lays down a thin layer of sorted sand as the ripple rolls over the landscape. These layers build on each other, sand ripple by sand ripple, to create the dunes. As the wind pushes the sand ripples along, there is also a turbulence of bouncing sand grains just above the dune surface. As the grains bounce downwind, they dislodge other grains, including dust particles. The dust is then caught up in the wind as the wind blows over the dunes, over agricultural fields and other lands and eventually to the Mesa and beyond.

Dune vegetation not overwhelmed by blowing sand will hamper the saltation process. Where there is more dune-covering vegetation there is that much less dust produced from saltation. Accordingly, the SOA states that the primary mitigation to reduce dust from the OHV riding area of the dunes is vegetation.

The SOA is premised on the principal that OHV activity increases dust emissions from the saltation process (APCD, 2019A). But this difference—how much more dust from the natural saltation process is due to OHV recreation on an open dune of the SVRA—has never been established.

The Lagrangian Model and Development of the PMRP - Ambiguity of SOA-Defined PM10 Baseline Emissions

Condition 2b of the SOA states that the Division will develop a Particulate Matter Reduction Plan (PMRP), and the PMRP is to be “designed to achieve state and federal ambient PM10 air quality standards”

Per Condition 2c, the SOA also stipulates that to achieve the state and federal PM10 standards, development of the PMRP “shall begin by establishing an initial target of reducing the maximum 24-hour PM10 baseline emissions by fifty percent (50%), based on air quality modeling based on a modeling scenario for the period May 1 through August 31, 2013.”

Accordingly, and at the request of the Division, the Desert Research Institute (DRI) developed a Lagrangian Stochastic Particle Dispersion Model (Langrangian model) to meet the air quality modeling requirement of the SOA and inform the development of the PMRP.

The SOA does not explain why the May 1 through August 31, 2013 timeframe was specified, but presumably it is because an extensive assortment of meteorological, air quality and dust emission potential data were collected in the dunes in the spring and summer of 2013 by the Division and DRI. Those data were incorporated into the Lagrangian model.

Additionally, the APCD’s CDF air quality monitoring station is incorporated into the Lagrangian model, as is another APCD station called Mesa 2, which is 2¼ miles southeast of CDF (Figure 1). These stations were integrated into the model so that the output of PM10 dust concentrations at CDF and Mesa 2 under different modeling scenarios can be predicted and ideally verified by actual PM10 concentration measurements that were recorded at the stations. That said, the amount of meteorological data available was insufficient, which prevented the model from making direct comparisons of model predicted PM10 values with actual air quality monitoring data collected during SOA-defined 2013 timeframe (Division, 2019).

Despite the sophistication of the Lagrangian model and the breadth of data that informed it, it became clear as the Division reviewed the model runs and began preparation of the SOA-required PMRP that the SOA condition 2c term, “maximum 24-hour PM10 baseline emissions,” was unclear, even within the May 1 through August 31, 2013 timeframe.

Most fundamentally, the specific record of 24-hour PM10 measurements to use is not specified in the SOA. The record of the CDF air monitoring station appears to be a logical choice given its location and given that violations of state and federal 24-hour PM10 standards were measured there, as noted in the SOA. Also, the highest 24-hour PM10 concentration measured at CDF occurred on May 22, 2013, which is within the SOA’s specified timeframe (PMRP, June 2019). But even if the CDF record is used, the SOA does not specify how to parse PM10 data from within the stated 2013 timeframe. Should the highest recorded 24-hour PM10 measurement be used? Should an aggregate of high PM10 days be used? This is not clear.

Of additional concern is that the CDF location is simply one point near the southern boundary of the Mesa area. The APCD did not have in 2013, nor does it have now, an air quality monitoring station that is more central to the Mesa that could also be used to model and verify an SOA-mandated “baseline” and mitigation benefits. In other words, while the 2013 air quality record of the CDF station could be used to achieve the intent of the SOA, improvements marked at the CDF location do not necessarily indicate air quality has improved elsewhere on the Mesa.

To address this concern, the Division examined the output of the Lagrangian model from the standpoint of dust produced by saltation—specifically the mass of dune dust that becomes airborne under different wind and mitigation scenarios, measured in metric tons per day. In that way, meteorological parameters from the SOA’s specified 2013 timeframe could be used to determine a pre-mitigation dust production baseline, and various proposed measures to suppress saltation in the dunes could be incorporated into the model to determine overall reduction in the mass of dust from the dunes. This approach has significant shortcomings, however, because estimates of the mass of dust produced under various scenarios are entirely within the Lagrangian model. There is no field instrument capable of verifying the overall mass of dust produced by the dune saltation process.

Moving Forward with SOA Baseline Emissions Definition Unresolved

Resolution of these concerns has not been definitively reached. Regarding the use of the 2013 CDF station record and how to define “24-hour PM10 baseline emissions,” the APCD indicated it preferred that the CDF 2013 record be examined, suggesting that “the top ten highest emission days, or even an average of all ‘wind event days’ as defined by some reasonable metric” be used “to determine an aggregate baseline in place of a single-day baseline” (APCD, 2019A). Yet the APCD cited uncertainty, stating, “Whether the existing SOA allows for an aggregate baseline is not entirely clear” (APCD, 2019A).

Additionally, when the Division asked whether the SOA’s “24-hour PM10 baseline emissions” term refers to PM10 concentrations as measured at CDF or refers to PM10 emitted from the Oceano Dunes SVRA as measured in mass (e.g., pounds or tons), the APCD, in consultation with the California Air Resources Board (CARB), indicated the SOA’s “PM10 baseline emissions” term refers to mass (Canfield, 2018). By contrast, the SAG appears to contradict this position, stressing that PM10 concentrations from air quality monitors such as CDF and Mesa 2 be used to validate Lagrangian model runs and recommending that additional PM10 and meteorological monitoring be conducted east of the SVRA “to investigate other potential contributions to regional PM10 levels not related to ODSVRA, such as sea salt, marine microorganisms, or agricultural field operations” (SAG, 2019A).

Because these discrepancies regarding SOA's "24-hour PM10 baseline emissions" term have not been resolved (and because of SOA-required time constraints), the Division prepared the PMRP based on runs of the Lagrangian model that used several 24-hour baseline scenarios and several 2013 timeframes. In its approval of the Division's June 2019 Draft Particulate Matter Reduction Plan (DPMRP), the APCD acknowledged the DPMRP's necessarily broad approach, noting that "the SOA allows for 'adaptive management'" (APCD, 2019B).

<u>Draft PMRP - Using Alternate Scenarios to Define 24-Hour PM10 Baseline Emissions and Estimate the Effectiveness of Existing, Proposed, and Hypothetical Mitigations</u>

In the DPMRP, the following scenarios were used to define the SOA's "24-hour PM10 baseline emissions" term:

1. The averaged 24-hour PM10 concentration value based on the number of days within the SOA 2013 timeframe where the measured, 24-hour PM10 concentration at the CDF station equaled or exceeded the California 24-hour PM10 standard.
2. The highest 24-hour PM10 concentration recorded during the SOA 2013 timeframe. That occurred at the CDF monitoring station on May 22, 2013.
3. The single day with the maximum Lagrangian-modeled 24-hour PM10 emissions level, predicted in metric tons per day. Based on meteorological and dust emission potential data collected in the dunes in 2013, this day is also May 22, 2013.
4. The ten days with the highest Lagrangian-modeled emissions levels, predicted as mass and measured in metric tons per day.

The DPMRP notes that due to Lagrangian model and meteorological data limitations, actual PM10 measurements from CDF cannot be used under SOA baseline Scenarios 1 and 2. Consequently, model-predicted CDF PM10 concentrations were used as surrogates for actual CDF measurements. For Scenario 1, that meant 22 days where the state PM10 standard was exceeded at CDF had to be reduced to 20 days and the actual averaged PM10 concentration value was lowered by 11%. For Scenario 2, the actual PM10 concentration measured on May 22, 2013 was lowered by 6.5% (Division, 2019; DRI, 2019).

The Division has already placed approximately 132 acres of dust mitigation measures in the dunes. To determine the effectiveness these measures have thus far achieved in reducing downwind dust, the Division examined Lagrangian model runs using SOA baseline Scenarios 1 and 2 (with the caveats noted above). Additionally, using SOA baseline Scenario 4 as a guide, the Lagrangian model was run to identify the 10 highest emission days in 2013 (measured as mass) and then predict the PM10 concentrations at CDF on those days. These modeled PM10 concentrations were then averaged and used as a baseline. Of note and akin to the modeled baselines created for Scenarios 1 and 2, this modeled average was 6% higher than the actual average determined from CDF PM10 measurements (DRI, 2019).

The results, summarized in Table 5-6 of the DPMRP, indicate the Division's dust mitigation measures placed in the dunes to date have reduced saltation dust emissions by approximately 26%, regardless of the caveated scenarios used to define the SOA baseline. However, these reduction amounts are only measured within the Lagrangian model itself, as it is presently configured and informed by 2013 data. While it is clear that the 132 acres of dust mitigations measures already placed in the dunes significantly minimize saltation within those 132 acres, their effect on actual PM10 measured at CDF or elsewhere on the Mesa has not been demonstrably quantified.

Due to the complexities of the Lagrangian model and the limitations of data used to inform the model, it is not possible to accurately determine how many acres of additional mitigations are necessary to achieve the SOA condition 2c target of a 50% reduction in dust from baselines defined according to the four scenarios listed above. Nonetheless, by simplifying some of the modeling efforts (and caveating the output with limitations), DRI estimated that an additional 369 acres of proposed and hypothetical mitigations within the OHV riding area of the dunes may be necessary to comply with the SOA (DPMRP, 2019). This would bring the total mitigations in the dunes to 501 acres, most of which are/would be in the OHV riding area.

From Lagrangian model runs that use Scenario 4, above, as SOA baseline, the Division's DPMRP presents the effect 501 acres of mitigations would have on saltation dust emissions from (1) all of the SVRA dunes, and (2) just the dunes within the 1,000 acre OHV riding area (Table 5-8, DPMRP, 2019). Using a baseline defined as the average (arithmetic mean) of model-predicted PM10 mass for the 10 highest modeled PM10 emission days, there would be an estimated 38% reduction in dust emission mass from all of the dunes, and a 49% reduction in dust emission mass if only saltation from the 1000 acre OHV riding area is modeled. Note, greater dust reduction is modeled in the OHV riding area because it is a smaller area of dust emission overall, and most of the actual mitigations (101 acres) and proposed/hypothetical mitigations (369 acres) are within the OHV riding area.

Finally, the DPMRP examines the effect 501 total acres of dust mitigation measures would have on PM10 concentrations at CDF using SOA baselines according to Scenarios 1 and 2 (as caveated above), and according to the model-predicted 2013 CDF record for the ten highest PM10 emission days identified per Scenario 4, above.

As presented in Table 5-9 of the DPMRP, 501 total acres of saltation-inhibiting mitigations are predicted to reduce an SOA baseline defined according to caveated Scenarios 1 and 2 by 50% and 32%, respectively. For the ten highest PM10 emission days identified per caveated Scenario 4, the mitigations are predicted to reduce CDF 24-hour PM10 concentrations as measured on those days by 32%.

Limitations of the Lagrangian Model and PM10 Baseline Scenarios Defined by the Model

The Lagrangian model is informed by meteorological, air quality and dust emission potential data collected in the dunes in the spring and summer of 2013. That said, any computer model used to simulate real world conditions is based on numerous assumptions. For example, despite its extensiveness, the meteorological dataset still created constraints that limited the model's ability to use actual CDF measurements in defining an SOA "baseline." Consequently, approximations of 2013 CDF PM10 values that were as much as 11% different from actual values were used in the model rather than the actual recorded 2013 values.

Additional assumptions in DRI's Lagrangian model are listed in Section 3.4 of the DPMRP, such as assuming uniformity of dust emission potential between points in the dunes where measurements for dust potential were taken. Likely the most significant and inexact assumption is that mitigations incorporated into the Lagrangian model are 100 percent effective at preventing saltation-derived dust (Division, 2019).

The process to determine the accuracy of model assumptions, and therefore the model, is called validation. Validating a model is performed by comparing model-predicted data with data collected by apparatus measuring real-world phenomena, such as temperature, wind speed, or PM10 dust concentrations. Accordingly, if a model generates data that cannot be compared to like data measured in the physical world, the model cannot be validated.

As stated earlier, there is no instrument that measures the overall mass of dust produced by the dune saltation process. In the context of the SOA, that means an SOA baseline that is defined by a Lagrangian model run that predicts saltation-derived PM10 mass from all of the dunes cannot be validated. Validation becomes even more remote when defining an SOA PM10 mass baseline from a smaller prescribed area within the dunes, such as the OHV riding area.

That said, Lagrangian model runs that use calculated PM10 mass values to predict PM10 concentrations at specific locations, like the CDF air quality monitoring station, could allow for model validation. To make the validation credible, however, would require more than one or two PM10 monitoring points. And those added monitoring locations would have to have been operational in 2013 so that their PM10 concentration records could be used to compare with model predictions that are based on meteorological and dune dust emission potential data collected in 2013. Unfortunately, those added stations do not exist. Also, as it stands, simply trying to correlate more than one day of predicted high PM10 mass values to just the CDF location has proven difficult, as discussed and presented in Section 4.4.1 and Table 4-3 of the DPMRP: While one model-predicted high emission day coincides with a day when the actual PM10 concentration at CDF was high (May 22, 2013), others do not. Further, as noted above, the Lagrangian model as currently configured and informed cannot use actual CDF PM10 concentration measurements as baseline input for the model.

Discussion – Impracticability of a Model-Defined Baseline, Unaccounted PM10 Sources, and Evaluating Historical and Current Dune Vegetation Coverage

The shortcomings of the Lagrangian model are not the fault of the model nor its designers, DRI. Rather, the inability of the model to appropriately define a PM10 baseline according to condition 2c of the SOA indicates (1) that the meteorology and physical environment of the south county are very complex, making accurate and practically-modeled simulation of the environment for the purposes of the SOA unrealistic, and accordingly, (2) that condition 2c of the SOA, which requires that a model be used to define a PM10 baseline, is also unrealistic.

From the review of the model runs, the development of the DPMRP, and in receiving subsequent input from the SAG and APCD, there appears to be inherent confusion regarding the term “baseline” in the context of the SOA and, more importantly, in the context of dust from dune saltation as measured on the Mesa.

First, if a model defines a PM10 baseline, and confirmation that modeled mitigations can achieve a targeted reduction from that baseline only in terms of a measurement calculated within the model, then it remains an open question as to whether actual mitigations will have a measureable effect on actual PM10 concentrations measured in the field. In other words, it is ill-advised to design mitigations based on model-determined estimates of PM10 mass when the model can’t be informed by actual measurements of PM10 mass. As stated earlier, there is no field instrument capable of verifying the overall mass of dust produced by the dune saltation process.

Second, many sources contribute to PM10 as measured at CDF, which means each source is a certain percentage of the whole. Certainly dust from dune saltation is in the measured PM10 concentrations, but how much relative to other sources is unknown. While the percentage of dust that is from dune saltation may be large, it is not 100% of 24-hour dust measured at CDF. Yet conditions 2b and 2c of the SOA assume that for each day when state and federal 24-hour PM10 standards are exceeded, 100% of dust measured on the Mesa is from dune saltation for all of the 24 hours in that day. The strong, west-northwest winds that blow every spring are not constant. They rise in strength in the late morning or early afternoon and typically peak between 2:00 and 5:00 PM before dying out for the day. And these winds blow not just over the dunes but over all of the south county, including agricultural fields, dirt roads, vacant lots, and construction sites, all of which contribute to PM10 detected on the Mesa. Marine salt, which registers as PM10, also contributes; its percentage of Mesa PM10 has been calculated as high as 25% (APCD, 2010). Phytoplankton also contribute to PM10 in the south county (CGS, 2018). The Scripps Institution of Oceanography is currently leading efforts to quantify this marine source in dust collected in the dunes and on the Mesa. While a record of PM10 measurements made on the Mesa could be used to determine a “maximum 24-hour PM10 baseline” related to dune saltation, the baseline would have to also account for these temporal and contributing-source variables for the baseline to be appropriately representative. However, in the context of the SOA and the shortcomings of condition 2c, attempting to quantify these variables would not be practical.

Further complicating the picture is the APCD/SOA perceived principal that OHV recreation increases the potential for dunes to emit dust via the saltation process (APCD, 2019). This implies that state and federal PM10 exceedances detected on the Mesa are not attributed to saltation throughout the dunes. It doesn’t even imply the exceedances are due to saltation within the seasonally-reduced 1000 acre OHV riding area. Instead, only a percentage of the saltation-derived dust generated from within the OHV riding area is responsible for creating the PM10 exceedances detected on the Mesa. And that percentage exists because, according to this principal, OHV recreation on an open sand dune increases the potential for dust to be generated via the natural saltation process. This is problematic because that proportional amount of extra saltation dust due to OHV recreation has never been establish, and it is not clear how this amount, if it was determined, could be correlated to PM10 measured on the Mesa.

In its review of an initial draft of the PMRP, the APCD stated, “The goal is to get emissions down to what they'd be in the absence of OHV activity, not to reduce emissions to zero” (APCD, 2019). This is a mutually-agreed tenet. But to achieve this goal, the theory that OHV recreation increases the potential for dunes to emit dust via the saltation process must be tested and from that a relatively accurate fraction of overall saltation dust from the OHV riding area must be determined. However, trying to incorporate this fraction into the construct of the SOA is not feasible because of the noted deficiencies in practical application of the SOA. Ultimately, another evaluation metric, such as dune-based PM10 measurements downwind of the OHV riding area that could be incorporated into a modified Lagrangian model, will be needed to parse out and mitigate for this saltation-dust fraction.

In the meantime, the most conservative approximation is to assume the extra OHV-saltation dust fraction is negligible. In this way, the dust emission potential of the OHV riding area can be evaluated from the standpoint of open sand, where saltation occurs, and vegetative cover, where saltation is minimized. Early this year, the California Geological Survey (CGS) conducted an analysis of dune vegetative cover within the OHV riding area that compared 1930’s aerial imagery, which essentially predates sand dune OHV recreation, to 2010 imagery, which predates the installation of vegetation and other projects specific to APCD/SOA-related dust mitigation efforts. That analysis determined there was a nearly an 80-acre loss of saltation-mitigating vegetation within the riding area (CGS, 2019). At present, approximately 101 acres of vegetation and other measures have been placed within the OHV riding area as part of the Division’s APCD/SOA mitigation efforts (Division, 2019). That indicates the Division’s recent saltation-preventing dust mitigation efforts within the OHV riding area exceed the natural vegetative cover of this area of the dunes by more than 20 acres, a 25% improvement from natural conditions. Additionally, the same CGS report (CGS, 2019) presents information from an earlier analysis that showed native dune plantings undertaken by the Division beginning in 1982 added nearly 200 acres of vegetation to the open dune sheets east of the OHV riding area (and closer to the Mesa). Combined, the acreage data show the Division has already reduced the potential to emit saltation-derived dust to a level far lower than what has existed naturally.

Conclusions and Recommendations

Based on this review of findings from the Lagrangian modeling efforts and summary of the development of the DPMRP, it appears the SOA in its current form is not workable. Specifically, conditions 2b and 2c of the SOA assign parameters that cannot accurately depict "24-hour PM10 baseline emissions" related to saltation-derived dust from the OHV riding area of the dunes.

Additionally, and to the intent of the SOA, the Division's mitigation efforts to inhibit the potential for saltation-derived dust to be emitted from the dunes, as quantified by acreage of vegetation and other mitigations placed in the OHV riding area and elsewhere in the dunes, indicate the dust emission potential has been reduced to below naturally-occurring levels. This of course implies that the effect OHV activity has on the potential for dunes to emit saltation-derived dust is negligible. Determination of this effect has not been quantified.

A logical next step, in collaboration with the SAG and APCD, would be to conceptually design a field investigation to quantify that percentage of saltation-derived dust from the OHV riding area that is due OHV recreation. It should be noted that implementing this investigation may entail closing off small areas of the OHV riding area (3 acres or less) so that no OHV recreation occurs on these areas for up to a year. Once the effect is quantified from such an investigation, appropriate additional mitigations, if necessary, can be implemented to achieve the APCD's stated goal "to get emissions down to what they'd be in the absence of OHV activity, not to reduce emissions to zero" (APCD, 2019).

Please feel free to contact me should you have any questions.

Respectfully submitted,

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Attachment: Figure 1 – Oceano Dunes SVRA and Vicinity

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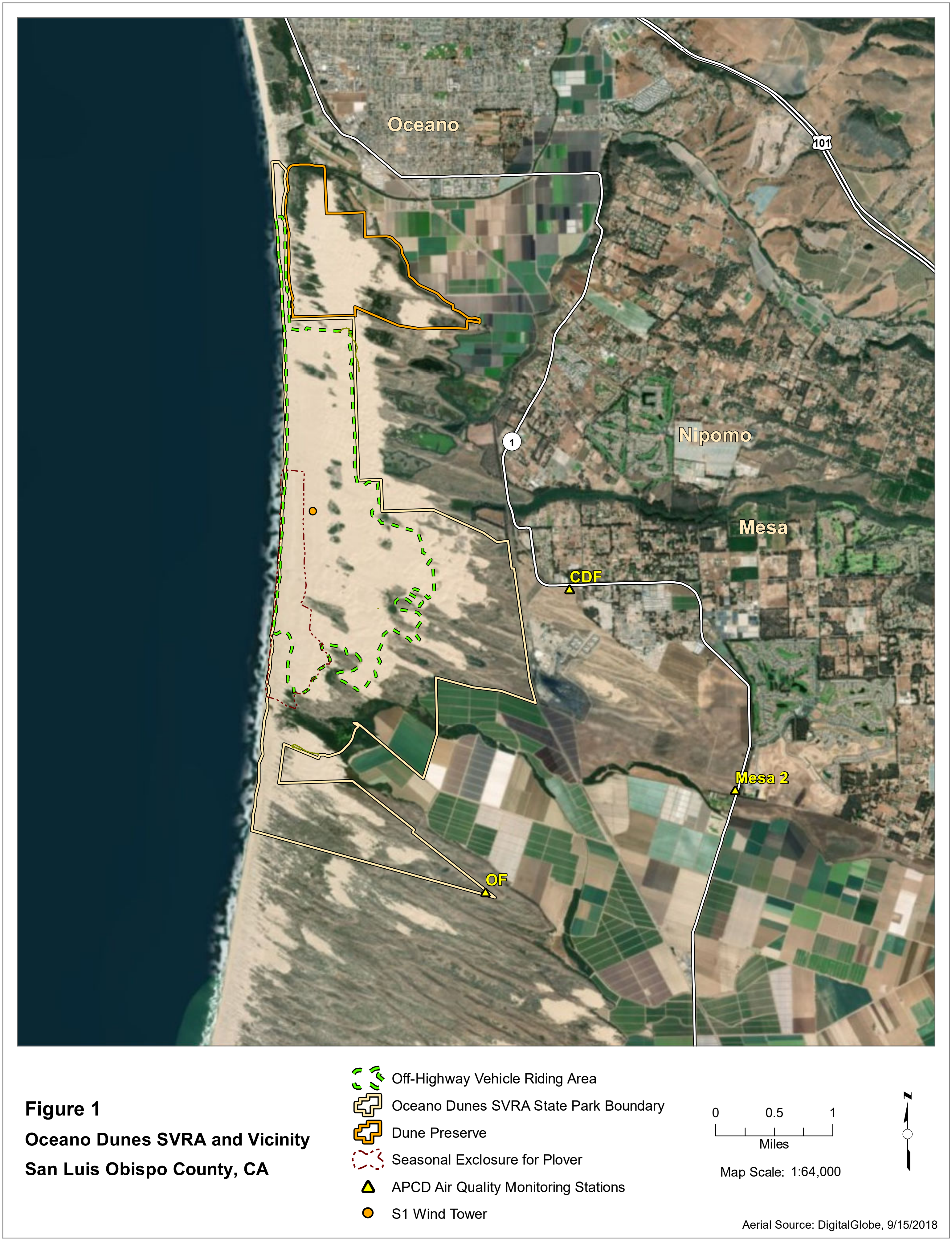

Figure 1

Oceano Dunes SVRA and Vicinity

San Luis Obispo County, CA