Evaluating Secondary Effects of Dust Controls on Emissions and Air Quality using Computational Fluid Dynamic Modeling

The secondary effects on emissions and air quality from the foredune restoration project are expected to be significant based on scientific arguments made by the Science Advisory Group, but quantification of the added benefits to air quality needs to be carried out.

The current mass emission/dispersion modeling being undertaken to estimate the effect of implementing dust controls to lower mass emissions and improve air quality is not sufficiently sophisticated to take into account the changes in flow that will result from changes in the surface as the foredune develops.

We suggest that DRI undertake a measurement and modeling effort within the framework and budget of our current contract with Parks to develop a Computational Fluid Dynamics model that can be used to evaluate how the evolving foredune will modulate the boundary-layer flow (wind speed, direction, and surface shear velocity) over the foredune area, in the lee of the foredune area, and in synergy with the re-vegetation areas that lies east of the foredune restoration area.

The methodological approach will be to use the open-source finite volume toolbox openFOAM as the basis for developing the flow model. Dr. Eden Furtak-Cole has extensive experience with this software having previously used it to model flow in urban street canyons in Hong Kong and other applications as well. He will be the principle developer of the model working with others in the DRI team who bring expertise in modeling (J. Mejia) and wind erosion and dust emissions (J. Gillies, V. Etyemezian). The goal will be to use the model to evaluate how the flow is changed by the developing foredune and subsequently use this information to inform CALMET in terms of wind speed, wind direction, and surface shear over and in the lee of the foredune. The changes in flow will subsequently affect the mass emissions (reduce wind shear by an established fractional reduction for the affected grid cells), and provide a more realistic wind field for the particles that are being dispersed by the wind.

To develop the modeling inputs will also require some measurements be made in the field in the established foredune areas of the Park to parameterize boundary conditions (e.g., vertical wind speed profiles, horizontal flow gradients in the lee of select dunes). We will also need access to the Digital Elevation Maps (DEMs) from Arizona State University's UAV photogrammetric program to (digitally) construct the topography of the evolving foredune as well as a DEM of the mature foredune that has been used as a model for the fully-evolved foredune that is being restored.

Benefits that can arise from this work are: 1) a means to provide more realistic estimates of the aerodynamic roughness lengths (z_0) for different areas of the ODSVRA. This parameter plays a critical role in CALMET in the estimation of wind shear (which drives dust emissions), and at present its representation in CALMET remains simplistic; 2) better estimates of shear velocity based on topographic position on the dunes and in their lee, which will also provide better estimates of emissions.

We envision that this model could be developed in the next 8 months and refined with incorporation of the field-measurement based parameterizations by summer 2021.