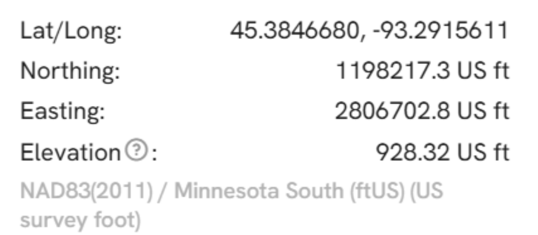
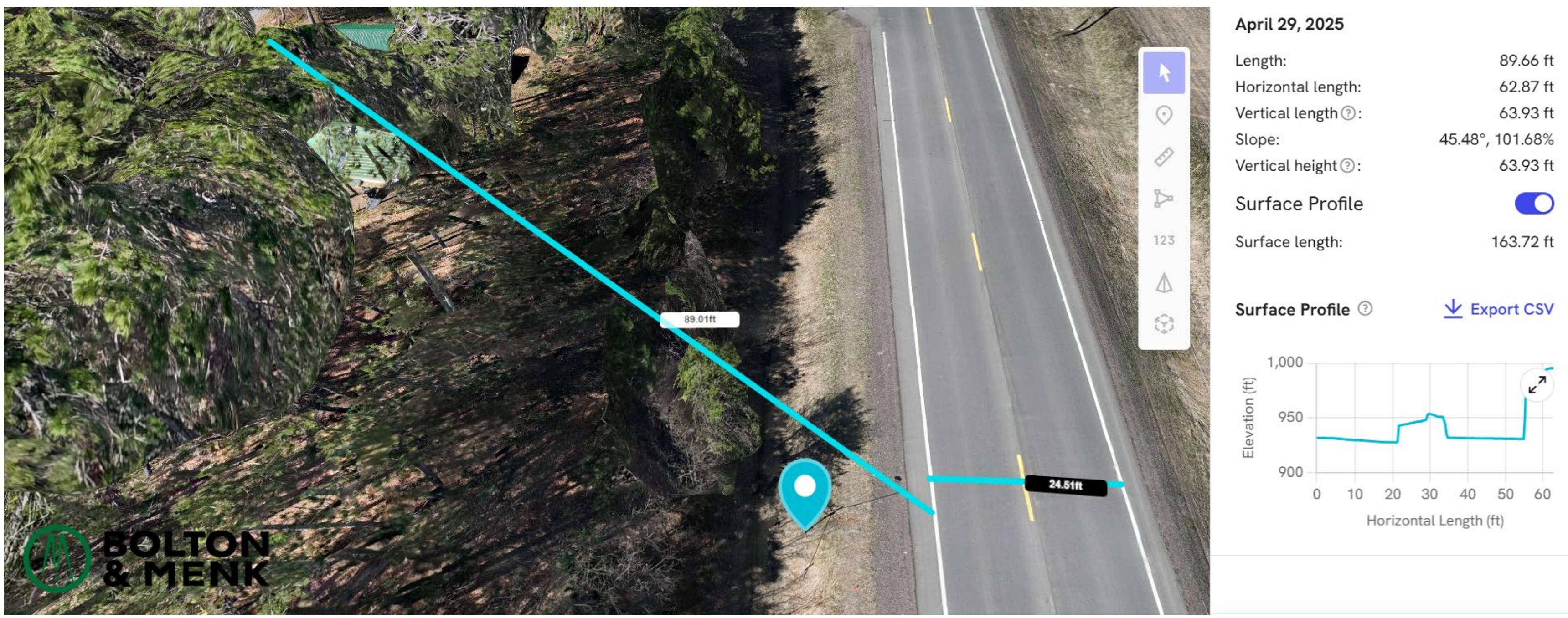
Technical Specification for Shadowcast Model

Data Product of Clear Roads Project 23-04, “Using Vegetation Management Practices Near Roads to Leverage the Benefits of Solar Radiation”. Created by Bolton & Menk, Inc.

Overview:

This Excel workbook is designed to model and approximate the effects of roadside vegetation and other structures on solar radiation reaching road surfaces. It integrates site-specific inputs, vegetation characteristics, and solar position calculations to estimate shading effects and energy loss due to obstructions.





How to Use this Workbook

As you update the values in the "Setup" table, the workbook is automatically set to update the solar calculations. However, to get updated outputs for a shadowcasting scenario, you must refresh queries using the data tab. This allows for a series of more complicated computations to take place at a single time and keep the workbook from crashing.

Functionality:

The workbook supports dynamic updates via "Data > Refresh All" to recalculate shading and energy metrics based on updated inputs. Queries and formulas utilize the 'Params' table to simulate shading effects and quantify energy losses due to vegetation and terrain. Outputs include weekly and monthly summaries of shaded road proportions and net solar energy received.

Use Case:

Designed for transportation and environmental professionals to assess solar exposure and shading impacts on roadways. This workbooks supports planning and evaluation of vegetation management strategies to optimize solar gain and road safety, and is meant to be used to help communicate why vegetation management practices can help sustainable operations.

Setup Sheet

Contains five single-row input tables. Use the images below to assist with the example Setup page, based on study site CR-03. This is based on drone imagery taken on April 29, 2025. The sheet is protected, but does not require a password.

Site Conditions:

a. Site Name (descriptive only)
b. Latitude – reported in decimal degrees
c. Longitude – reported in decimal degrees
d. Elevation – reported in feet above sea level
e. Time Zone – this is the hour difference between local time and UTC.

Standard Time (UTC offset)								
Z-TIME	GUAM (+10)	HAWAII (-10)	ALASKA (-9)	PACIFIC (-8)	MOUNTAIN (-7)	CENTRAL (-6)	EASTERN (-5)	ATLANTIC (-4)

f. Road Direction and Bearing – selected from a list of cardinal directions. Bearing is calculated from the pre-determined list of values, and can be overwritten using values ranging from 0° to 180°.
g. Road Width – the fogline-to-fogline width of pavement being maintained, reported in feet.
h. Vegetation Presence (descriptive only)
i. Pavement Type (descriptive only)

Example of Site Conditions:

The latitude, longitude, elevation are shown in a table in the upper right image. The road width is approximately 24.5 feet.

Existing Conditions A & B:

Characteristics of the road shoulder to the right ("A") and left ("B") of the road bearing shown in "Site Conditions":

a. Height of Canopy Above Road Surface (ft) –the average height of canopy along the corridor being assessed. Note that only the height above the pavement is important.
b. Thickness of Growth and Sunlight Blocking Effect – the approximate amount of direct light able to break through canopy. Direct light is the most impactful to pavement temperature.
c. Distance from Canopy Edge to Near Fog Line (ft) – the average horizontal distance from the edge of the canopy to the edge of the maintenance area. Note that this isn't the distance to the nearest standing vegetation or the distance to the tallest tree trunks. This is best evaluated by drawing a line in 3D space between the nearest portions of the shade-casting canopy and the edge of the pavement, then determining the horizontal distance covered between those points.
d. Terrain Shadow Elevation (°) – the average angle of elevation for topographical features (hills, road cuts, buildings, etc.) which serve as permanent, unchangeable aspects of the landscape that block sunlight. This parameter is measured as the average angle from the horizontal at the road surface to the top of the terrain feature.
   In the workbook, this parameter acts as a filter for potential solar radiation. Where a terrain shadow is included, sun exposure from that road shoulder which lies below the selected elevation is ignored. This should be considered when interpreting the Monthly and Weekly Outcome Summaries.

Example of Existing Conditions:

The image below shows an image taken by drone of the shaded study site CR-03 which demonstrates height of canopy above road surface (shown as "Vertical length"), distance from canopy edge to near fog line (shown as "Horizontal length"), as well as site conditions for road width. Note the Surface Profile shows the elevation at the near fog line. As horizontal length increases, the line passes over a short stand of vegetation which we ignore, then another gap before reaching the high portion of the canopy edge.

If the study site had a crest of hills to the south, Shoulder A would include a Terrain Shadow Elevation. Consider the hill crest height (H) relative to the road surface elevation being 300 feet, and a horizontal distance (D) of approximately 1 mile away. To determine an appropriate terrain shadow angle (θ):

$$Tan(\theta) = \frac{H}{D},$$

$$\theta = Tan^{-1}\left(\frac{800}{5{,}280}\right) = 9.57°$$

If the study site were located along a road cut with 20 ft height and 45 ft from the edge of the roadway:

$$Tan^{-1}\left(\frac{20}{45}\right) = 26.6°$$

Proposed Conditions A & B:

Apply the same input types to create a proposed condition for comparison purposes.

a. Increasing Canopy Height and Sunlight Blocking Effect, or decreasing Distance to Near Fog Line. Making these adjustments could be used to simulate growth of a stand of trees and will result in more shade being cast on the road surface.
b. Decreasing Canopy Height and Sunlight Blocking effect, or increasing Distance to Near Fog Line. Making these adjustments could be used to simulate the thinning of existing vegetation, removal and replanting of a stand of vegetation, and/or the expansion of a maintained clear zone.

Example of Proposed Conditions:

For illustrative purposes, the example uses a scenario where tree canopy is proposed to be cleared back to 100 ft from the pavement edge and thinned to a "Moderate," approximately 50% sunlight blocking effect.

Monthly & Weekly Outcome Summary:

At the bottom of the Setup sheet provides estimated solar energy metrics including total unobstructed energy and incident energy on the pavement under existing and proposed conditions. These values assume clear sky conditions. The color-coded values demonstrate how much energy is being blocked by roadside vegetation. The net energy on the road's surface accounts for the full road width, where the shaded portion is affected by canopy and the unshaded canopy receives the full potential energy under clearsky conditions.

The Weekly Outcome Summary provides greater temporal detail in order to show the gradual change of solar radiation throughout meteorological winter. The "Shaded Proportion of Road" reports the minimum daily shade coverage (the shortest shadow) estimated to take place during that week. If shaded proportion is 100%, the road surface is expected to receive no direct sunlight during that week. The "Daily Average Net Energy" and "Daily Average Potential Energy" are the sums of average hourly radiation per day within the week being assessed. The net value is effected by canopy characteristics, whereas the potential value would be representative of unimpeded sunlight.

Example of Outcomes:

In the example, the Monthly Summary shows that December is a dramatically impacted month by the adjacent vegetation. Inspecting the Weekly summary shows that the full month is entirely shaded based on existing conditions. Since the sunlight blocking effect is set to 95%, the full shade conditions still provides 5% of the sun's energy. As the season goes on, there are instances of the sun reaching portions of the road's surface, raising the net energy. By week 3 of February, minimum shadow lengths are reaching nearly the entire road surface.

Under the proposed conditions, these near-fully exposed conditions can be achieved an entire month earlier in Week 3 of January. This is due both to the increased setback and the 50% porosity canopy allowing more direct sunlight to reach the pavement. It's also noteworthy that under the proposed conditions there are no portions of the winter where the entire road is shaded for the entire day. In fact, more than half of the road is exposed to uninhibited sunlight at some point of the day all through December.