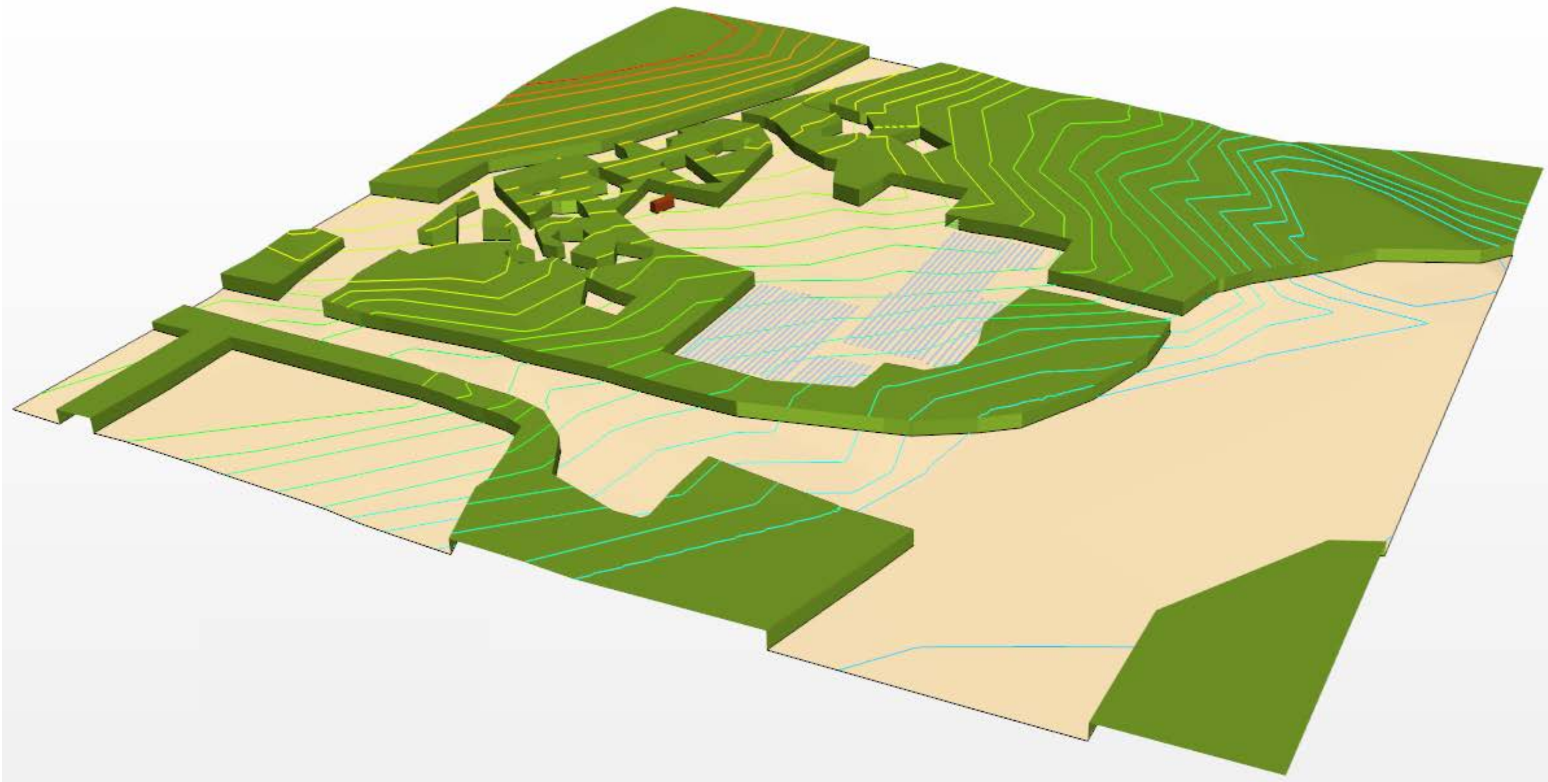
Chelsea & Apple Hill
Solar Projects

Wind Effects Analysis



Value-Driven Solutions

ENGINEERING

Chelsea & Apple Hill Solar Project

CFD Model of Wind Speeds from Tree Removal

1033 & 1035 Willow Road

Bennington, VT 05201

April 11, 2017

M/E Reference 170104.00

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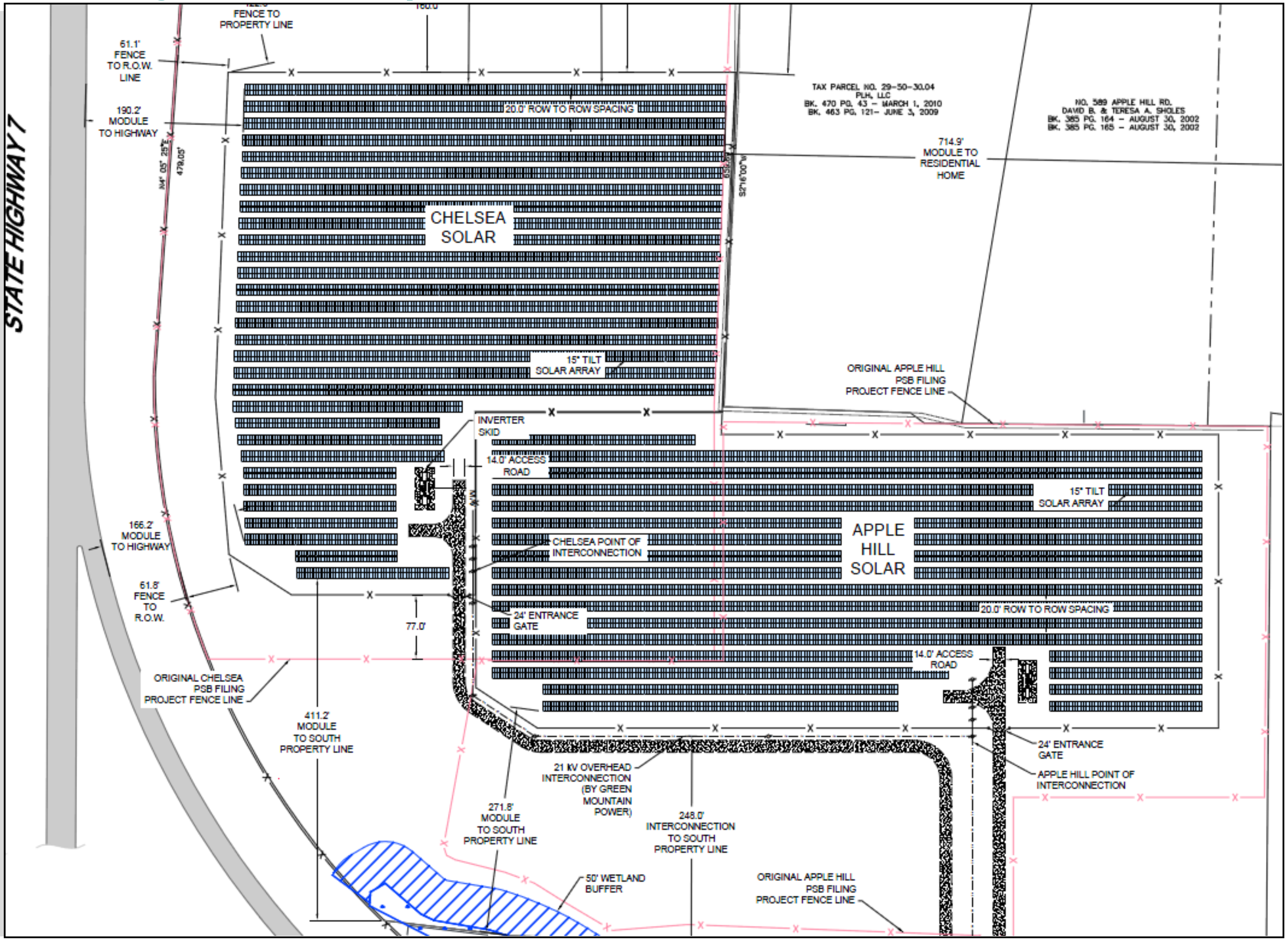
ENGINEERING

Introduction

- M/E Engineering has prepared a Computational Fluid Dynamics (CFD) study to evaluate the wind conditions for the proposed Chelsea Solar and Apple Hill Solar Projects.
- The purpose of this report is to show how wind speeds will be affected at an adjacent private property if a large area of trees is removed to make space for the proposed solar projects.

Existing and Proposed Tree Line Conditions

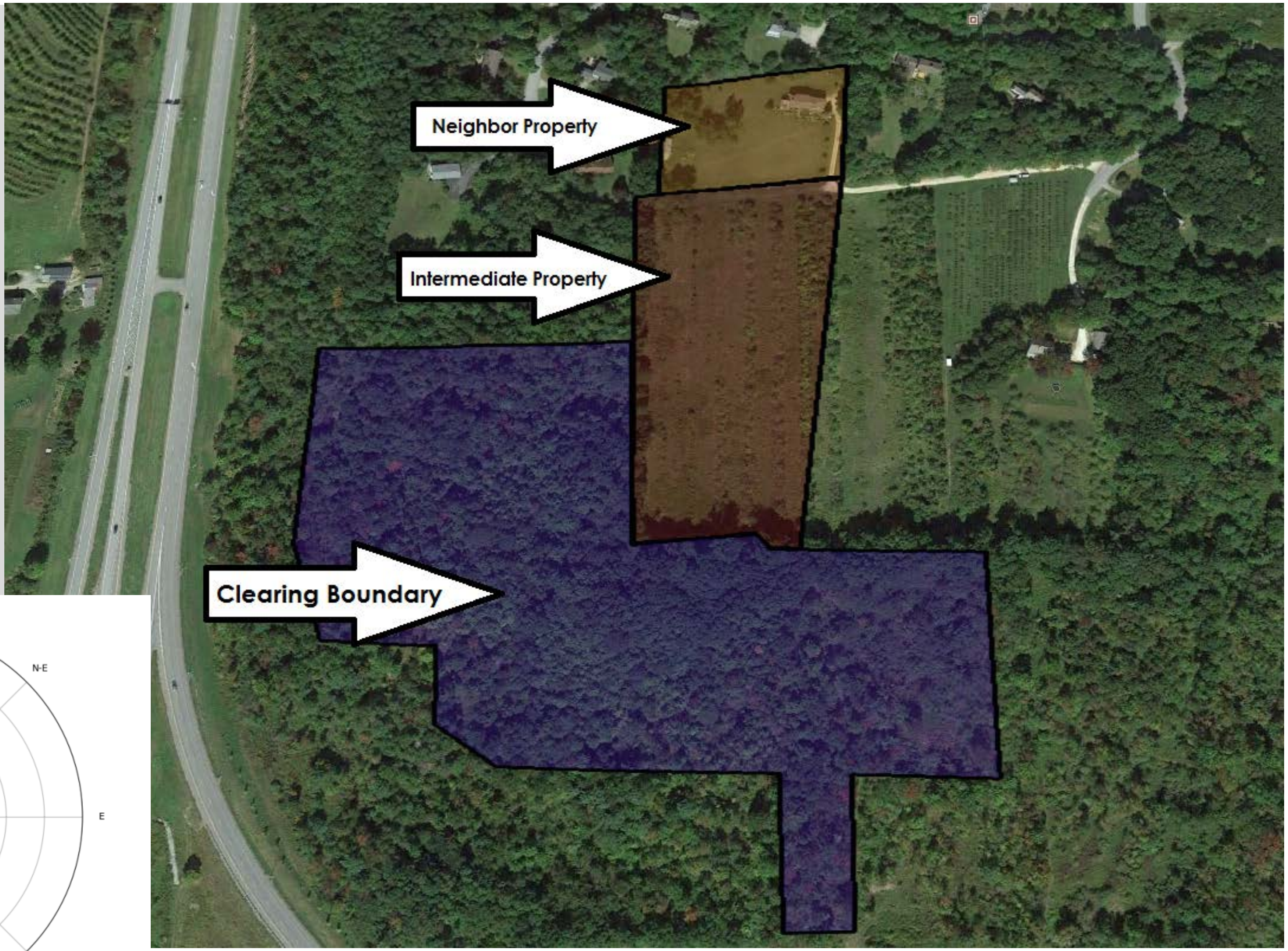
- Location of the proposed Chelsea Solar and Apple Hill Solar Projects

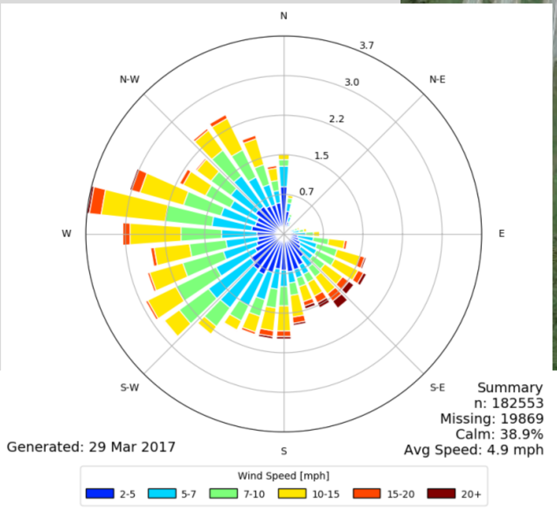


2017-02-16 Chelsea Apple Hill Site Plan Set.pdf

Existing and Proposed Tree Line Conditions

- Scope: Shown is a google maps image of the clearing boundary, intermediate property and the neighbor property. This image shows the trees as they are before the solar project.





Chelsea - Apple Hill Solar Project.kmz

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Model Parameters

CFD Parameters

- STAR-CCM+ 12.02.010
- Turbulence, velocity and temperature profiles are applied.
- Implicit unsteady, K-Ω, Detached Eddy solvers are used

Input Parameters

- 3D topology
  - USGS Bennington Quadrangle
  - 7.5 minute series
  - Contours from National Elevation Dataset, 2014
- Wind speed of 25 mph at the ground level is used and a ambient temperature of 50 °F at the ground level (both cases).
- Trees tops are 45 feet above ground level
- Tree boundaries taken from *Chelsea - Apple Hill Solar Project.kmz* (Google Earth).

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Case 1: 25 mph Winds from South – Existing Condition

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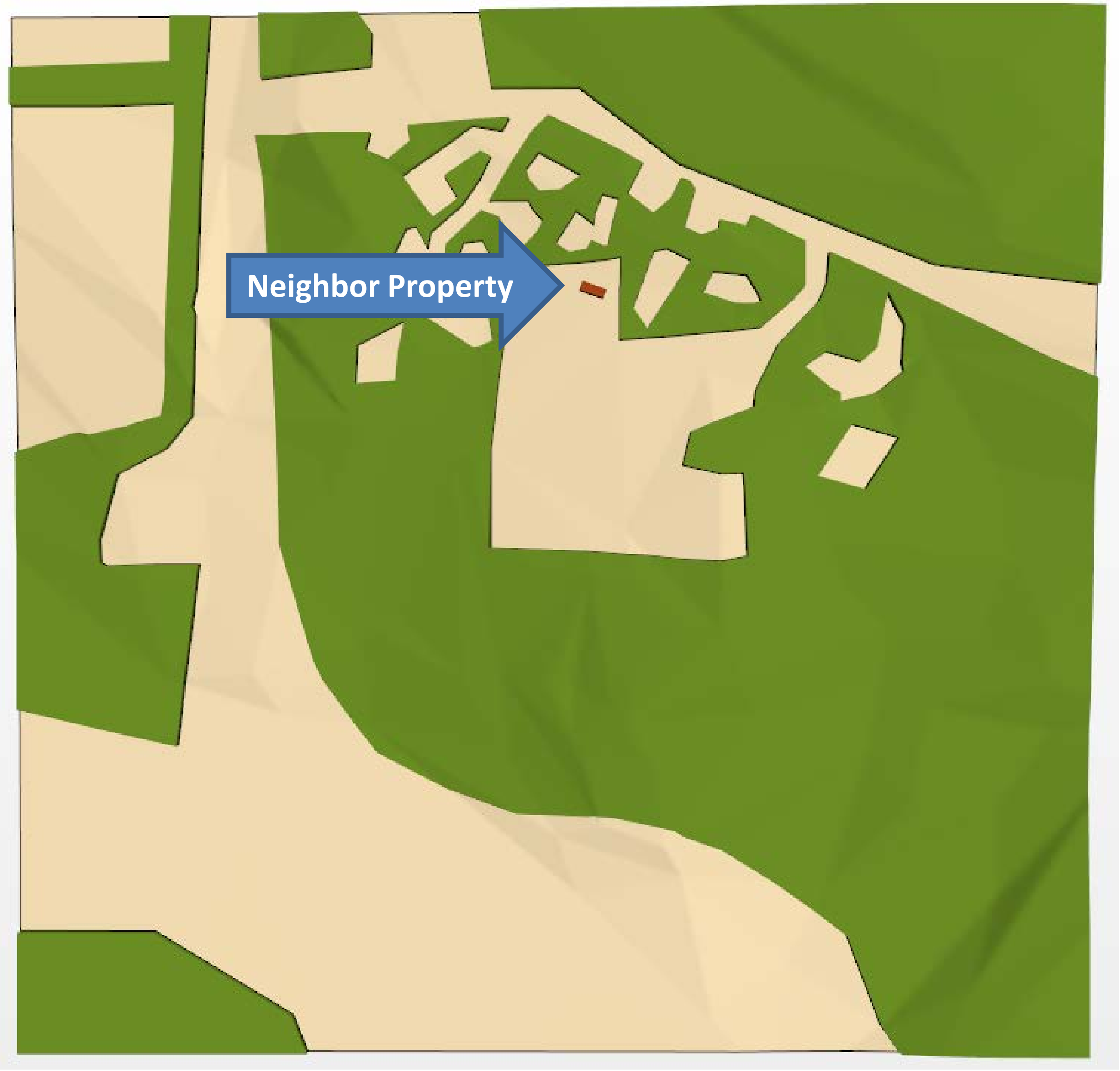
- Plan View Geometry



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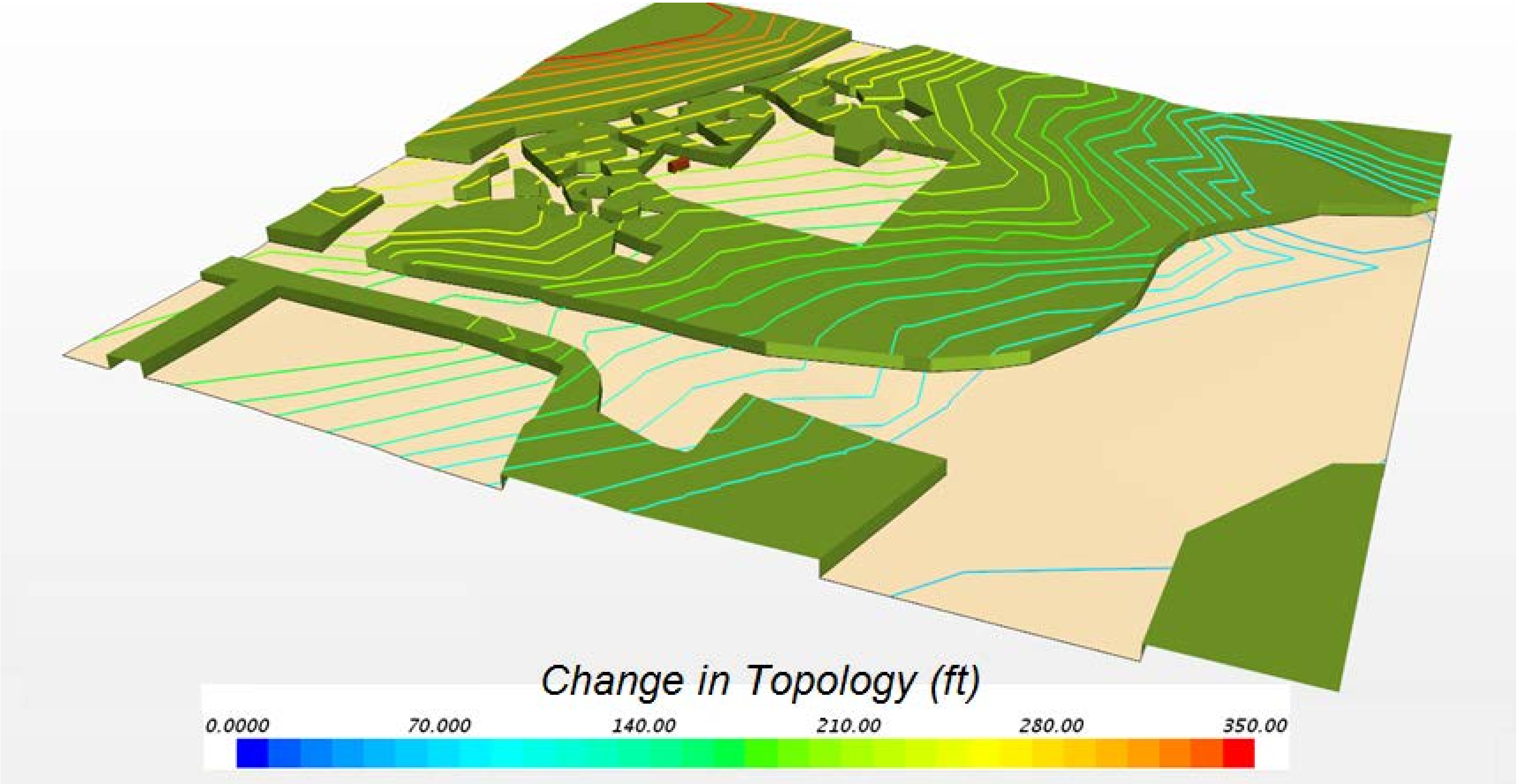
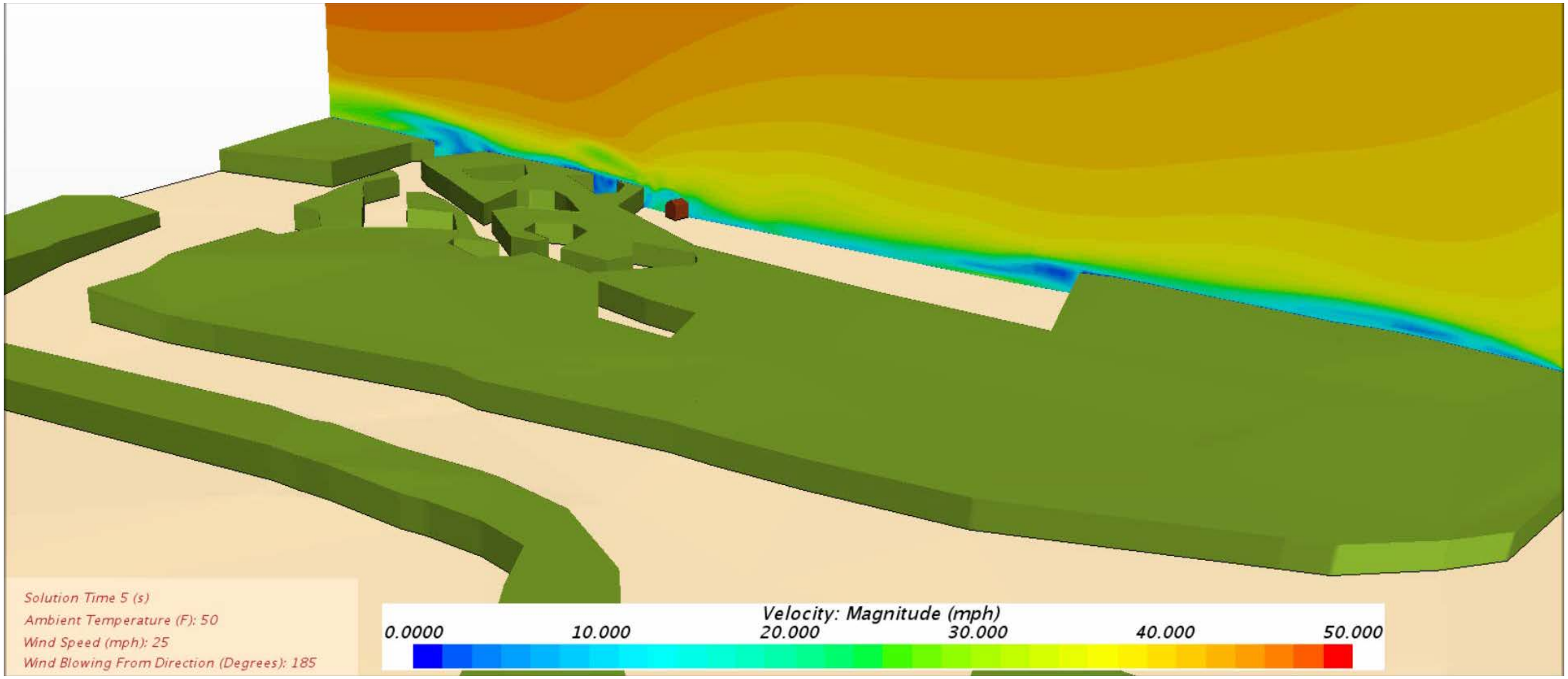


- Topology – Change in elevation

Case 1: 25 mph Winds from South – Existing Condition



- Animation: Velocity Profile – Elevation View Looking East – Wind Speeds Higher at Higher Elevations

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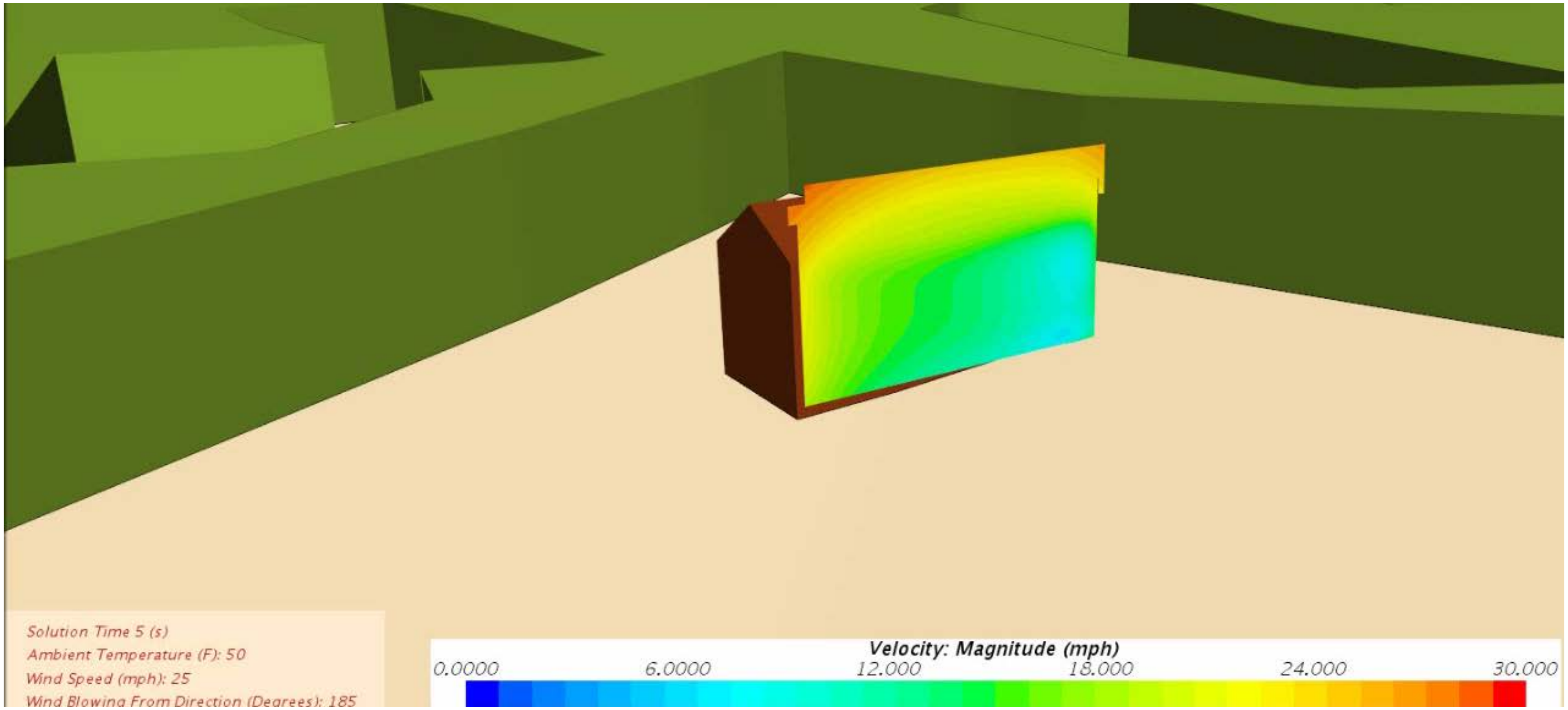
Case 1: 25 mph Winds from South – Existing Condition

- Animation: Velocity Streamlines – Velocity From South to North – Looking East

Case 1: 25 mph Winds from South – Existing Condition



- Velocity – Imaginary Plane in front of Private Neighbor Property
- Average Velocity on Plane (26 mph)
- Max Velocity on Plane (30 mph)

Case 1: 25 mph Winds from South – After Proposed Tree Removal

Case 2: 25 mph Winds from South – After Proposed Tree Removal

- Plan View Geometry

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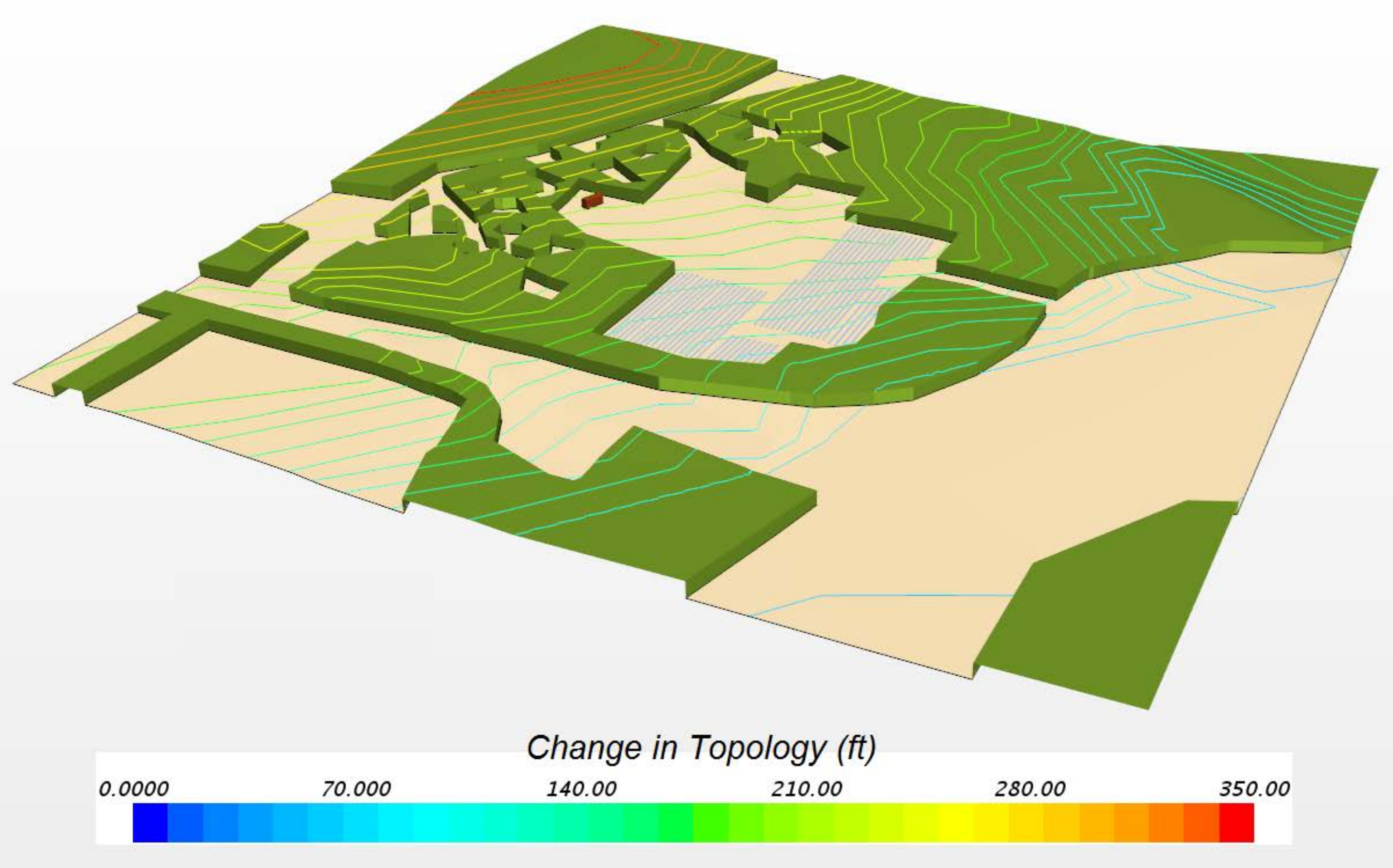
Case 2: 25 mph Winds from South – After Proposed Tree Removal



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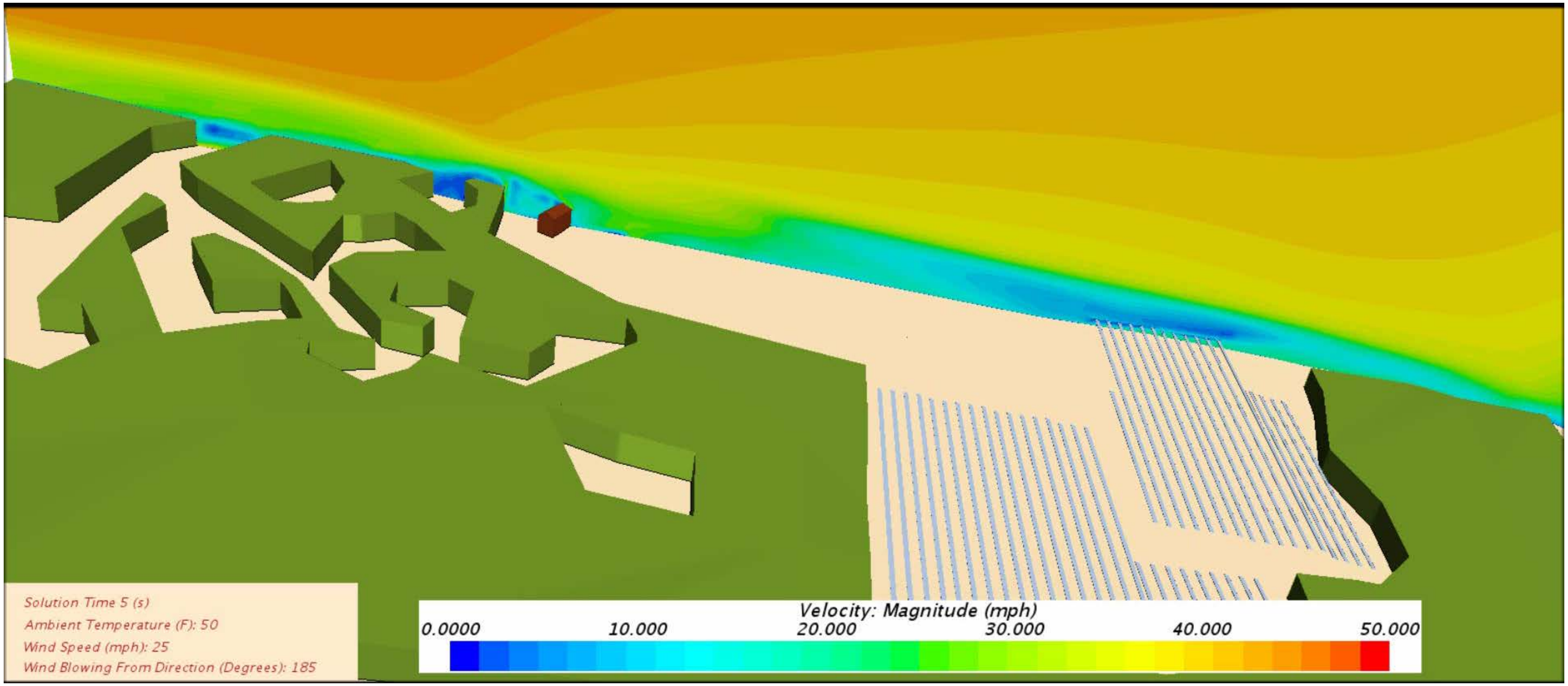
Case 2: 25 mph Winds from South – After Proposed Tree Removal



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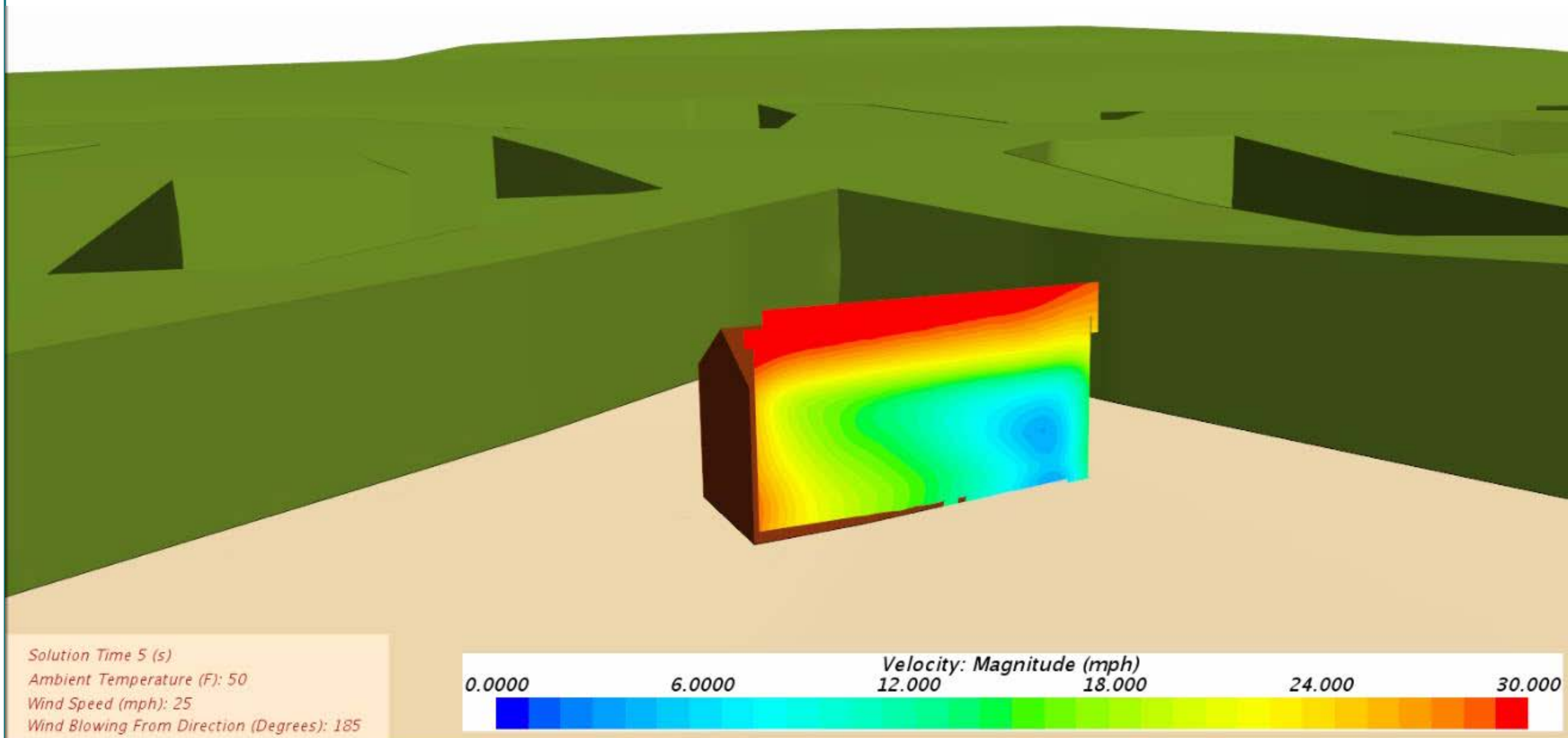
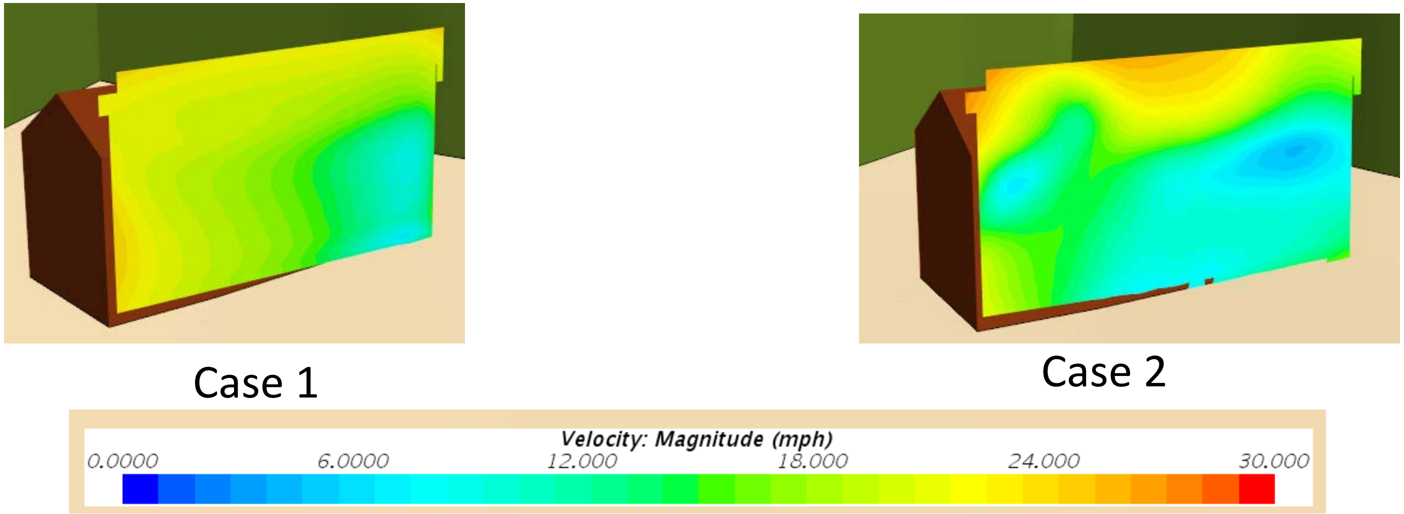


- Velocity – Imaginary Plane in front of Private Neighbor Property
- Average Velocity on Plane (27 mph)
- Max Velocity on Plane (34 mph)

Conclusions and Observations

Concerning the Neighbor Property – Case Comparison

- Shown below are the velocities from a direct wind (from the south) of 25 mph
- ***<u>Case 1: 25 mph Winds from South – Existing Condition</u>***
  - Average Velocity on Plane (26 mph)
  - Max Velocity on Plane (30 mph)
- ***<u>Case 2: 25 mph Winds from South – After Proposed Tree Removal</u>***
  - Average Velocity on Plane (27 mph)
  - Max Velocity on Plane (34 mph)



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Conclusions and Observations

Conclusions

Bottom Line: The clearing of trees for the proposed solar panels at the Chelsea and Apple Hill project sites will have very little effect on the wind speed and intensity on or around the neighbor's property.

- The physics of how wind behaves as it transitions from a wooded area to a field area are as follows:
  - Wind is disturbed by trees (or solar panels) because they present an irregular obstacle to flow. This normally causes an increase in turbulence and a decrease in speed immediately down-wind from the trees.
  - As the wind flows out into an open field, the wind velocity starts to become more uniform after some distance – this is called the "*reattachment distance*" or the "*recirculation zone*".
  - After the reattachment distance is reached, the wind starts to reestablish a velocity profile similar to before the influence of trees (or solar panels). The growth of this more uniform velocity profile is the beginning of what is referred to as a "*fully developed flow*" zone.

Conclusions and Observations

Conclusions (continued)

- The reattachment distance in this case appears to occur in the adjacent field upwind from the neighbor’s property, regardless of whether the trees are cleared or not. This is consistent with experimental studies that show a reattachment distance of 2 to 5 times the height of the trees. Fully developed flow is established before the neighbor’s house in both model cases and average wind speeds are nearly identical.

- Although solar panels are shorter than the surrounding trees, they are much less porous, exhibit regular spacing and are situated in such a way as to form multiple rows of inclined planes.

- The combined effects above make the comparison between stands of trees and solar panels approximately equal from a wind velocity and turbulence standpoint.

Conclusions and Observations

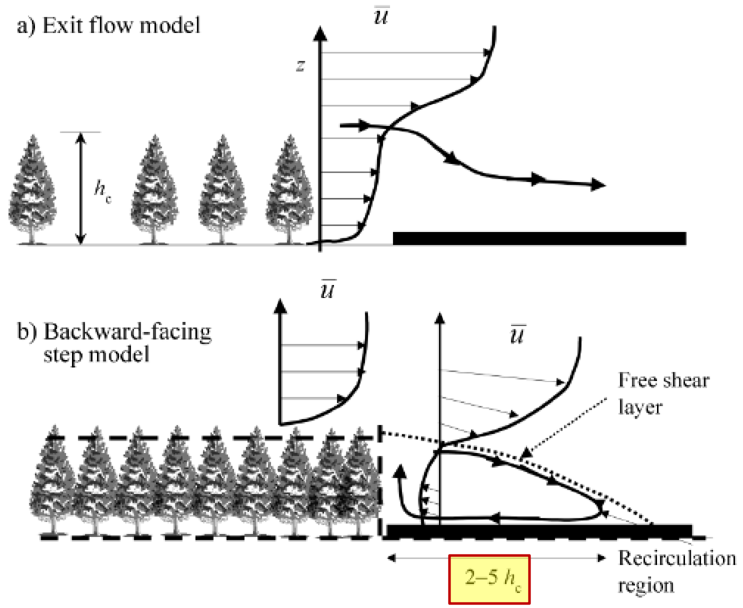

FIG. 1. Two conceptual models for the structure of turbulence near forest edges. (a) The exit flow model in which the mean flow near the edge retains its canopy-turbulence state. (b) The backward-facing step (BFS) flow model in which a recirculation zone dominates the turbulence near the edge. The "fingerprints" of these two models on the flow statistics at the edge are shown in Table 1. The thick arrows indicate expected mean flow streamline while the thin arrows indicate the local velocity. The dashed line indicates the free-shear interface delineating a potential recirculation zone. Variables are: h_c, canopy height; z, height from the ground; and $\bar{u}$, mean longitudinal velocity.

sitions were quantified by changes in the so-called momentum roughness length (z_{om}), but rarely considered the explicit vertical geometry (or morphology). Transitions from a tall-forested canopy with a canopy height (h_c) on the order of 10 m to a forest clearing with a vegetated cover height on the order of 10 cm cannot ignore the vertical dimension imposed by the forested canopy on the bulk flow near the edge.

profile was established at some $5h_c$ from the edge (Raynor 1971).

Here we argue that this conceptual framework, especially in the exit region, may not be general near tall and dense forest edges. For densely forested canopies, the flow may actually share several attributes with the so-called backward-facing step (BFS) flow schematically shown in Fig. 1 and qualitatively com-

Conclusions and Observations

Reference:

INVITED FEATURE

Ecological Applications
Vol. 18, No. 6

Ecological Applications, 18(6), 2008, pp. 1420–1435

THE STRUCTURE OF TURBULENCE NEAR A TALL FOREST EDGE: THE BACKWARD-FACING STEP FLOW ANALOGY REVISITED

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