Hecate Energy
Cider Solar Farm

Appendix 8-B Glare Hazard Analysis

(Appendix B ForgeSolar Reports is provided on a CD)

Glare Hazard Analysis

Cider Solar Farm Project
Towns of Oakfield and Elba
Genesee County, New York

April 1, 2021

Prepared for:

Hecate Energy Cider Solar LLC

Prepared by:
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Rochester, NY 14614

Sign-off Sheet

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Reviewed by:

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Name / Title Katie Hogue, Aviation Planner

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Executive Summary

Stantec Consulting Services, Inc. (Stantec) utilized the web-based ForgeSolar glare hazard analysis program to analyze the potential for glare from the proposed Cider Solar Project (Project), a 500-megawatt (MW) utility-scale solar powered electric generating facility located in Genesee County, New York. The Project will include photovoltaic (PV) solar panels mounted on a racking system to maximize solar energy capture and electric generation of the array. The Project Site encompasses 4,650 acres in a rural area located approximately four miles to the north of the City of Batavia.

Based on the solar array parameters provided and the current site design, glare is not predicted from the Project for pilots landing at two airports and one heliport located in the vicinity of the Project, including the Pine Hill Airport, Genesee County Airport and the Troop A Headquarters heliport. The results of the ForgeSolar analysis determined that glare from the Project is not predicted to occur for drivers of vehicles on roadways or for residences in and adjacent to the Project.

Abbreviations

AGL	Above Ground Level
deg	degrees (0 is due north, 180 is due south)
DNI	Direct Normal Irradiance
FAA	Federal Aviation Administration
FP	Flight Path (landing path from threshold to two miles out)
ft	feet
kW	kilowatt
kWh	kilowatt hour
m	meters
mi	mile
min	minutes
mrad	milliradian
MW	megawatt
MSL	Mean Sea Level
OP	Observation Point (e.g. control tower, vehicle location)
PV	Photovoltaic

Glossary

Correlate Slope Error with Surface Type – Yes/No	Correlates the slope error value based on the surface material type; default value is 8.43 milliradians (mrads).
Eye Focal Length (m)	Typical distance between the cornea and the retina of the human eye, default is 0.017, though some sources indicate that the typical length is 0.022.
Glide Slope (deg)	Angle at which the plane approaches the runway during landing (default is 3 degrees [deg] from horizontal).
Maximum Tracking Angle (deg)	Rotation limit of panels in either direction. Full rotation is 2*maximum tracking angle. E.g. maximum tracking angle of 60 deg indicates full panel rotation range of 120 deg.
Resting Angle (deg)	Angle modules return to after maximum angle is reached.
Observation Point	A specific location, such as a control tower or vehicle, from which an observer might experience glare.
Ocular Transmission Coefficient	Related to the ability of the eye to transmit light, set by at 0.5 by Forge Solar.
Offset angle of module (deg)	Additional tilt/elevation angle between the tracking axis and the panel.
Orientation of Tracking Axis (deg)	Azimuthal position of tracking axis measured clockwise from true north. Tracking systems in the northern hemisphere are typically oriented near 180 deg. Tracking systems in the southern hemisphere are typically oriented near 0 deg.
Peak DNI (W/m^2)**	This value is set at 1,000 by ForgeSolar and is the amount of solar radiation per unit surface area by a surface perpendicular to the sun's rays in a straight line from the direction of the sun at its current position in the sky.
Pupil Diameter (m)	Typical pupil diameter for observer, default is 0.002 meters (m).
PV Array Axis Tracking	Panel tracking mode, if any. Panel can be set to track along one (single) or two (dual) axis tracking. This parameter affects the positioning of the panels at every time step when the sun is up.
PV Array Panel Material	Surface material of panels, including use of anti-reflective coating (ARC). Options include: smooth glass without ARC, smooth glass with ARC, light-textured glass without ARC, light-textured glass with ARC, and deeply textured glass.
Rated Power (kW)	Power rating of the solar array - used to estimate the energy output per year of the array (optional).
Slope Error (mrad)	Accounts for beam scatter of sunlight on the array. Default is 8.43 mrads but the value may be adjusted based on the panel material type.
Subtended Angle of Sun (mrad)	The angle above horizontal at which the viewer observes the sun, default value is 9.3 mrad.

CIDER SOLAR FARM

GLARE HAZARD ANALYSIS

Introduction

Threshold	The physical beginning of the runway. Aircraft are typically expected to be 50 ft above ground at this point.
Time Interval (min)	Time step intervals used by the program for analyses. Default is set to analyze for glare at every one minute interval throughout the year.
Timezone	Time zone difference from Greenwich Mean Time at the location of the analysis.
Tilt of Tracking Axis (deg)	The elevation angle of the tracking axis upon which panels rotate (e.g. torque tube), measured from flat ground. 0 deg implies the axis is on level, flat ground. Values between 0 and 30 deg are typical.
Vary Reflectivity	Varies panel reflectivity with sun position at each time step.
Maximum Downward Viewing Angle (deg)	The angle extending downward from the horizon indicating the maximum downward viewing angle from the cockpit. Used to determine whether glare is visible by the pilot along the flight path. Default is 30 degrees.

Sources:
Ho, Clifford, K., Cianan A. Sims, Julius E. Yellowhair. 2015. Solar Glare Hazard Analysis Tool (SGHAT) Users Manual v. 2H. Sandia National Laboratories.

ForgeSolar – PV Planning & Glare Analysis. https://www.forgesolar.com/

**Source: http://www.3tier.com/en/support/solar-prospecting-tools/what-direct-normal-irradiance-solar-prospecting/

1.0 INTRODUCTION

On behalf of Hecate Energy Cider Solar LLC Stantec completed a glare analysis for the Project. The Project will include photovoltaic (PV) solar panels mounted on a racking system to maximize solar energy capture and electric generation of the array. The Project Site encompasses 4,650 acres. The glare analysis determined the potential for glint/glare from the PV solar panels to affect pilots and airport operations, residents in the area, and drivers passing through. The Project is located in south central Genesee County, New York (**Figure 1**), approximately four miles of the City of Batavia.

ForgeSolar is an interactive tool that provides a quantified assessment of (1) when and where glare will occur throughout the year for a prescribed solar project and (2) potential effects on the human eye at locations where glare occurs. ForgeSolar originated as the Solar Glare Hazard Analysis Tool (SGHAT), developed and maintained by Sandia National Laboratories. The public no longer has access to SGHAT due to national security concerns; however, one of the original developers of SGHAT has developed and maintains the commercially available ForgeSolar program based on the code and algorithms developed for SGHAT. ForgeSolar includes many enhancements compared to SGHAT, which was originally developed for airport use, and ForgeSolar is capable of analyzing not only potential glare to airports, but to drives along a continuous stretch of roadway instead of at isolated points. Numerous other enhancements in data entry options accommodate large utility scale projects. Therefore, ForgeSolar is currently the standard tool used for utility-scale solar projects.

Glare can occur from the reflection of sunlight on the PV solar panels of utility-scale solar-powered electric generating facilities. While PV solar panels absorb direct sunlight, some reflection can occur when the panels are directed close to horizontal, which predominately occurs during sunset and sunrise when the incidence angle of the panels is highest, as depicted in **Figure 2** below.

ForgeSolar employs an interactive Google map for site location, mapping the proposed PV array(s), and specifying observer locations, vehicular travel routes, or flight paths. Latitude, longitude, and elevation are automatically recorded through the Google interface, providing necessary information for sun position and vector calculations. Additional information regarding the orientation and tilt of the PV solar panels, reflectance, environment, and ocular factors are entered by the user.

If glare is found, the tool calculates the retinal irradiance and subtended angle (size/distance) of the glare source to predict potential ocular hazards ranging from temporary after-image to retinal burn. The results are presented in a plot that specifies when glare will occur throughout the year, with color codes indicating the potential ocular hazard.

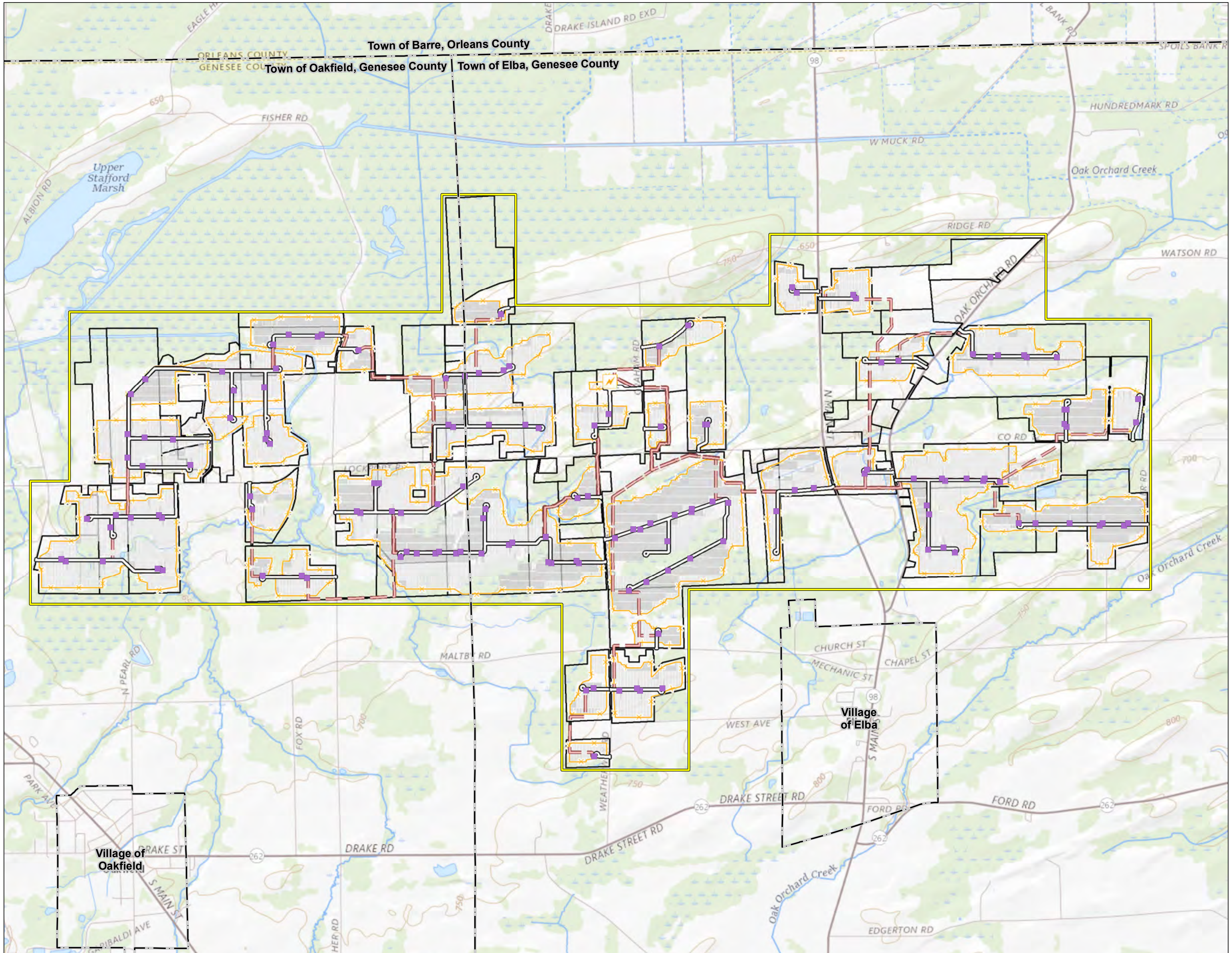
This glare study analyzes potential glare for pilots of planes landing at two airports and one heliport in the vicinity of the Project (**Figure 3**). Glare analyses were conducted for drivers of vehicles at 5-ft above ground level (AGL) (cars and small trucks) and 9-ft AGL (semi-truck) viewing heights on 16 roadways adjacent to the PV panels (**Figures 4-9**, **Table 1**). Roadways were analyzed for glare from arrays in close proximity to panel blocks, and therefore not every roadway was analyzed for every panel block.

Introduction

The analysis also included a determination of potential glare to viewers at 857 structures, primarily residences, as well as some sheds, barns and commercial buildings in the vicinity of the Project using a 25-ft AGL viewing height which is a conservative viewing height for one and two story structures (**Figures 4-18, Appendix A**). The analyses were separated into six blocks of arrays due to program limitations on the size of subarrays[1] and the analyses conducted for each block considered the structures most likely to see glare from the array; not all structures were analyzed for all panels. All airports, roadways, and structures were analyzed using 9-ft and 12-ft AGL panel heights to illustrate the range of impacts depending on the final height of the panels and trackers. **Table 2** indicates which roadways were analyzed with which block.

It should be noted that a 'resting angle' of 60 degrees was used for the panels in the analysis. If a resting angle of 0 degrees (panels facing straight up) is used in the analysis, the program moves the panels to 0 degrees instantly once the sun drops below 60 degrees in either direction. This results in the panels facing straight up during sunrise and sunset, under which conditions the program predicts extensive green and yellow glare. Panels should therefore not be returned to a 0-degree position prior to sunset and should be in place at 60 degrees to the east prior to sunrise (See Figure 1 - Incidence Angle diagram).

[1] Subarrays, as shown in Figures 4, 5 and 6 in Appendix A, can be no larger than 25 acres in size to allow ForgeSolar to produce the most accurate results.



Stantec

Legend

- Project Area
- Municipal Boundary

Proposed Project

- Collection Substation
- Inverter
- PV Panel Array
- Collection Line
- Fence Line
- Access Road
- Project Site

N

0 3,000 6,000 Feet

(At original document size of 11x17)
1:36,000

Notes
1. Coordinate System: NAD 1983 StatePlane New York West FIPS 3103 Feet
2. Data Sources: NYS Office of ITS GPO, NYS Civil Boundaries, 2018
3. Background: USGS Topo Basemap - The National Map (Web Map Service); Data refreshed May, 2020.

Project Location
Towns of Elba and Oakfield
Genesee County, NY

Prepared by AS on 2021-03-30
TR by XX on 2021-03-30
IR by NL on 2021-03-30

Client/Project 190502038 REVA
Hecate Energy Cider Solar LLC
Cider Solar Farm

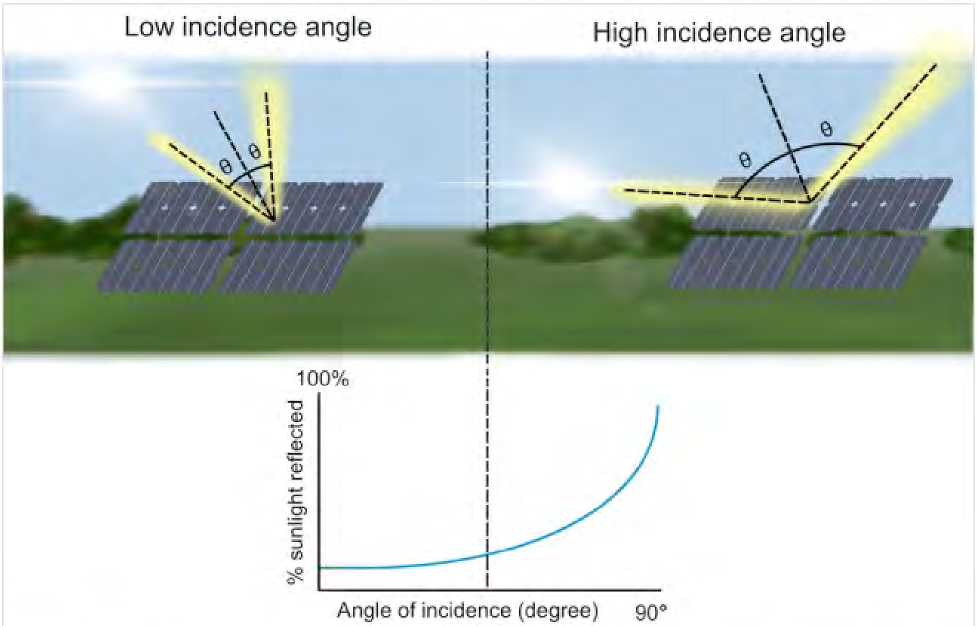
Figure No.
1

DRAFT

Title
Proposed Cider Solar Farm

U:\190502038\03_data\gis\mxd\Figure_1_Proposed_Cider_Solar_Farm.mxd Revised: 2021-04-01 By: astapleton

Figure 2. Reflectivity differences between low and high incidence angles.



PV panel reflectance depends on incidence angle between panel normal (i.e. facing) and sun position. Large incidence angle yields more reflected sunlight.

Source: ForgeSolar 2020.

The arrays used in the analysis program were drawn to encompass the outer extent of the proposed arrays shown in **Figure 1** in order to be conservative in the glare analysis by analyzing more area than the panels will actually occupy.

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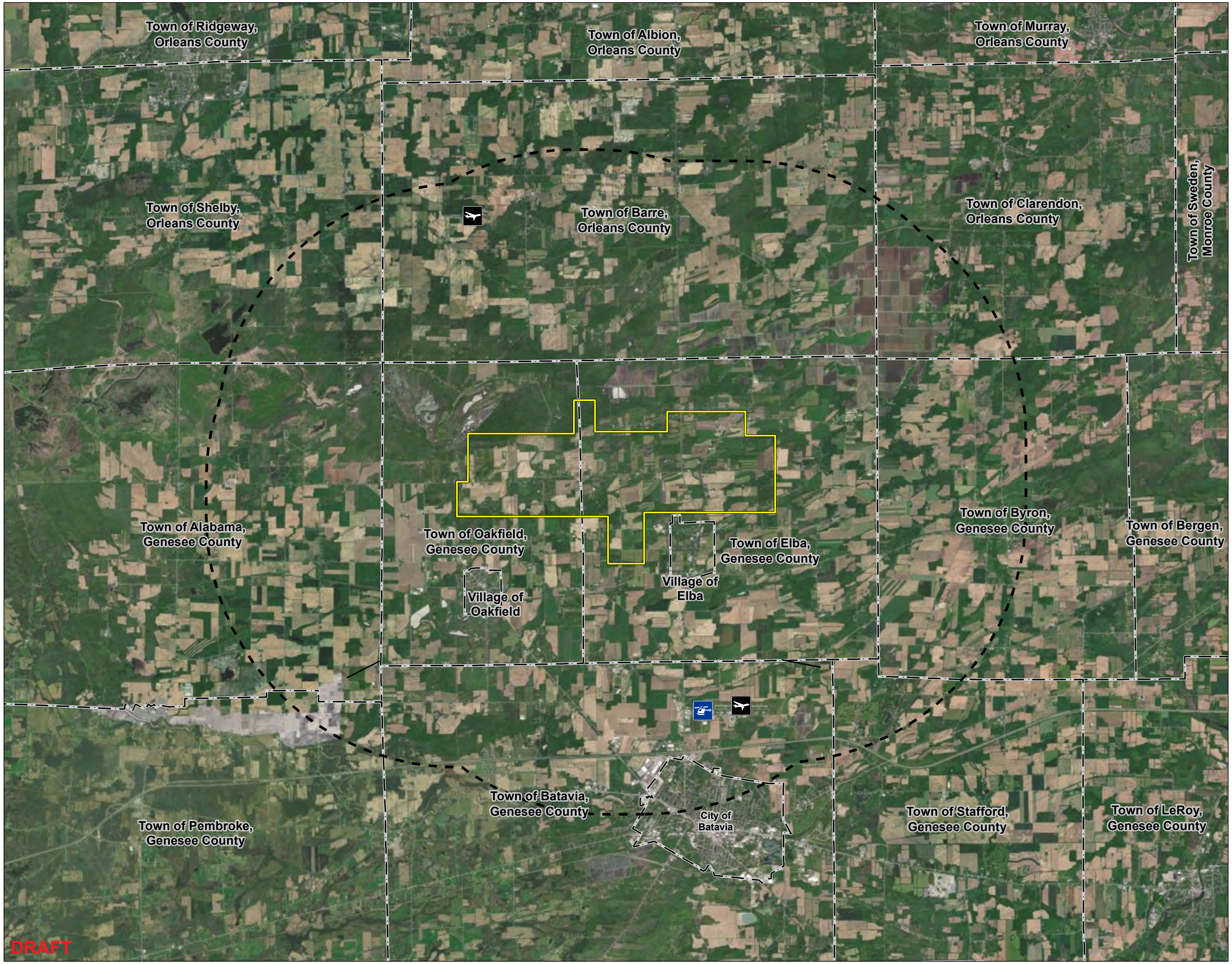
Table 1: Roadways included in Forgesolar Analysis

Route Name	Blocks Including Route in Analysis
Albion Road	4
Lockport Road	3,4,5,6
Lakeside Park Road	5
Fisher Road	3,4,5
Snyder Road	1,3
Maltby Road	1,3,4
West Avenue	1
Graham Road	6
Ridge Road	6
Quaker Hill Road	2,6
Oak Orchard Road	2,6
North Byron Road	2,6
Miller Road	2
Barrville Road	2
Luddington Road	2
Drake Street Road	1



Stantec

Legend

Project Area

5-mile Study Area

Existing Features

Municipal Boundary

Airport

Heliport

N

0 1 2 Miles

(At original document size of 11x17)
1:126,720

Notes

1. Coordinate System: NAD 1983 StatePlane New York West FIPS 3103 Feet
2. Data Sources: Airports: U.S. Department of Transportation, Federal Aviation Administration-Aeronautical Information Services.
3. Background: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Project Location
Towns of Elba and Oakfield
Genesee County, NY

Prepared by AS on 2021-XX-XX
TR by XX on XXXX-XX-XX
IR by XX on XXXX-XX-XX

Client/Project
190502038 REVA

Hecate Energy
Cider Solar Farm

Figure No.
3

DRAFT

Title

Airports Within 5 Miles of the Cider Solar Farm
Map 1 of 1

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2.0 METHODS

The parameters used for the analyses are listed in **Table 2** below. "Default" indicates the default parameter value set by ForgeSolar and is considered the most conservative value for the parameter. "Chosen" parameters were selected to perform the most conservative analysis with respect to glare potential. "Provided" parameters are Project specific information provided by the client.

2.1 SOLAR ARRAY

The location of the solar array and array parameters used for the analyses are based on information provided by Hecate Energy Cider Solar LLC. The analyses described below were conducted using 9-ft and 12-ft panel heights above ground level. A detailed description of each parameter is provided in the Glossary.

Table 2: Solar Panel Parameters Used for the Glare Analysis

Parameter	Value Used	Default, Chosen or Provided?
Axis tracking	Single	Provided
Tracking Axis Tilt (deg)	0.0	Provided
Tracking Axis Orientation (deg)	180.0	Provided
Tracking Axis Panel Offset (deg)	0.0	Default
Maximum Tracking Angle (deg)	60.0	Provided
Resting Angle (deg)	60.0	Provided
Rated Power (kW)	Not Used	NA
Vary reflectivity?	Yes	Default
Panel material	Smooth glass with Anti-Reflective Coating	Provided
Timezone offset	-5	Based on site location
Subtended angle of sun (mrad)	9.3	Default
Peak DNI (W/m^2)	1,000	Default
Ocular transmission coefficient	0.5	Default
Pupil diameter (m)	0.002	Default
Eye focal length (m)	0.017	Default
Time interval (min)	1	Default
Correlate slope error with surface type?	Yes	Default
Slope error (mrad)	8.43	Default

2.2 AIRPORT APPROACH PATHS

Two airports and one heliport were included in the glare analyses for this Project. Approach paths were analyzed for all runways in all directions available to pilots. Helicopters were analyzed hovering 500-ft above the heliport, since heliports do not have approach paths. These hover locations are shown as Observation Point (OP) 1 for blocks 1, 4, 5 and 6 and OPs 67 and 59 for blocks 2 and 3, respectively in the ForgeSolar output in **Appendix A**.

2.3 ROADWAYS AND PROPERTIES LOCATED ADJACENT TO THE SOLAR ARRAYS

This analysis included potential glare to vehicles travelling on 16 roads in the vicinity of the Project (**Table 1**). The Forgesolar program sets the default viewing angle of the array at 50 degrees from the driver's direct line of sight (when looking forward). The Federal Aviation Administration (FAA) has determined that glare beyond 50 degrees from the line of sight will have no impact on the viewer[2].

Potential glare to drivers was evaluated for both passenger vehicles and semi-trucks, where the passenger vehicles were assumed to have a maximum viewing height of 5-ft AGL while the viewing height for drivers of semi-trucks was assumed to be a maximum of 9-ft AGL. The location of the roadway routes analyzed are shown as blue-green route lines on **Figures 4-9, Appendix A**.

The analyses for each of the six array blocks were run four times, once for 5-ft car heights and once for 9-ft truck heights, with each vehicle height analyzed for 9-ft, and 12-ft AGL panel heights. Structures and airports were also analyzed for both panel heights.

Potential glare to viewers from 857 structures in the vicinity of the Project was also analyzed at 25-ft AGL viewing heights.

2.4 FORGESOLAR RESULTS PRESENTATION

The web-based ForgeSolar program was used to analyze glare potential in one-minute increments throughout the year. The program identifies the three following types of glare (no color indicates no glare predicted):

GREEN - Low potential for temporary after-image.
YELLOW - Potential for temporary after-image.
RED - Potential for permanent eye damage.

[2] Rogers, J. A., et al. (2015). Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach, Federal Aviation Administration (link)

3.0 GLARE ANALYSES RESULTS

3.1 AIRPORT APPROACH PATHS

Glare is not predicted for either of the two airports analyzed and their combined four approach paths for the Pine Hill and Genesee County Airport, or for helicopters hovering 500-ft above the Troop A Headquarters Heliport, depicted in **Figure 2**, at any time of the day, any time throughout the year, based on the input parameters described above. Results are shown for each of the approach paths in the ForgeSolar reports in **Appendix B**.

3.2 CONTROL TOWERS

There are no air traffic control towers associated with any of the airports included in this analysis and therefore no glare impacts to air traffic control operations are anticipated.

3.3 ROADWAYS AND PROPERTIES LOCATED ADJACENT TO THE SOLAR ARRAYS

Glare is not predicted for drivers along the 16 roadways analyzed (**Table 1**) that are adjacent to the Project area. The potential for glare for a range of driver conditions was evaluated for viewing heights of 5-ft (cars and small trucks) and 9-ft (semi-trucks). Glare is also not predicted for the 857 structures analyzed at 25-ft viewing heights as shown in **Figures 4-17, Appendix A**. Glare is not predicted for pilots landing at the Genesee County Airport or the Pine Hill Airport, or for helicopters hovering 500 feet above the Troop A Headquarters heliport as shown in **Figure 3** above.

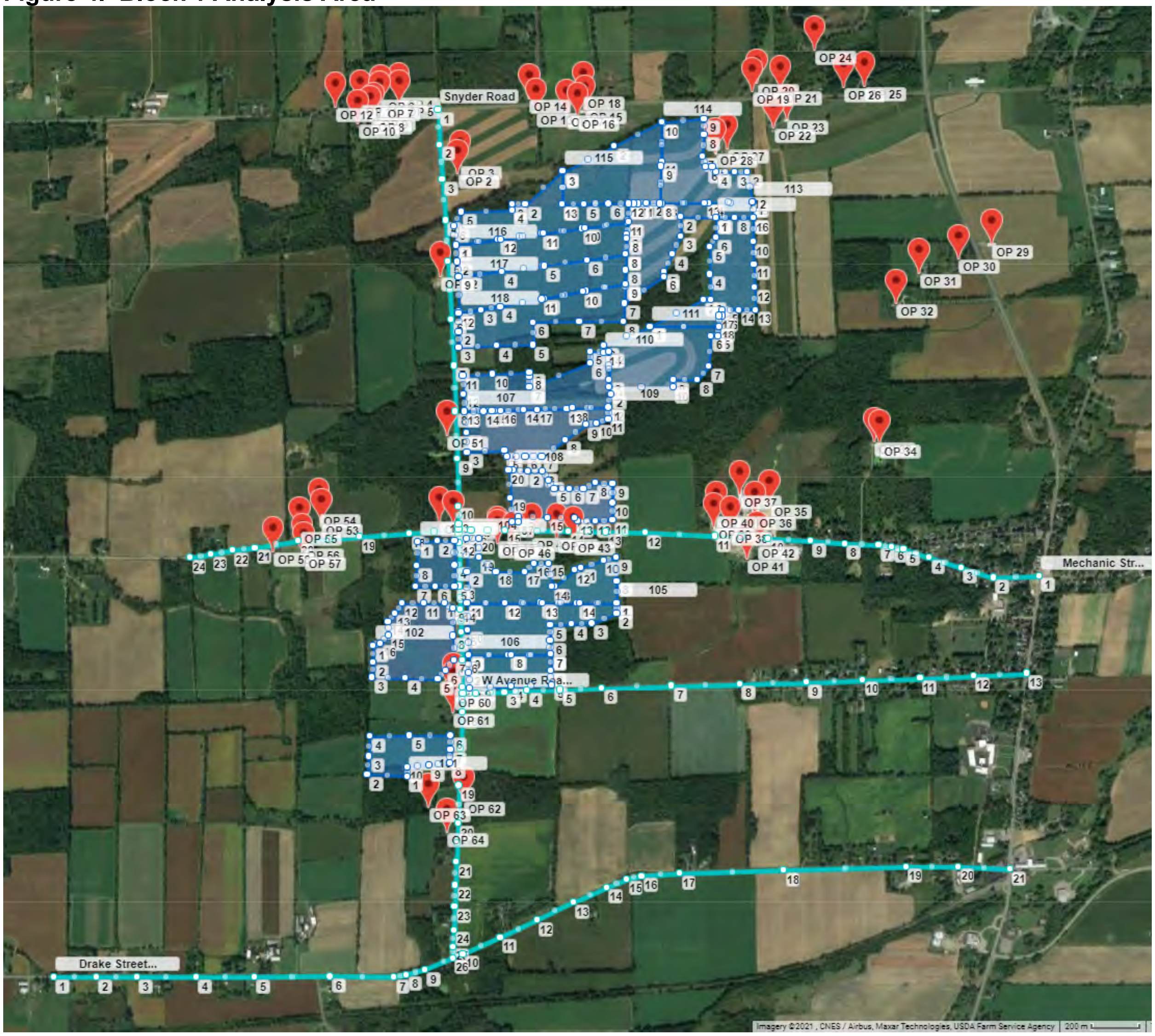
4.0 CONCLUSIONS

Based on the solar array parameters provided, glare is not predicted for planes landing in both available directions at the two airports and one heliport located within 10 miles of the Project. Glare is not predicted for drivers of vehicles on 16 roadways adjacent to the Project area, at 5-ft (cars and small trucks), 9-ft (semi-trucks) viewing heights. Glare is also not predicted for 857 structures with 25-ft viewing heights.

APPENDIX A

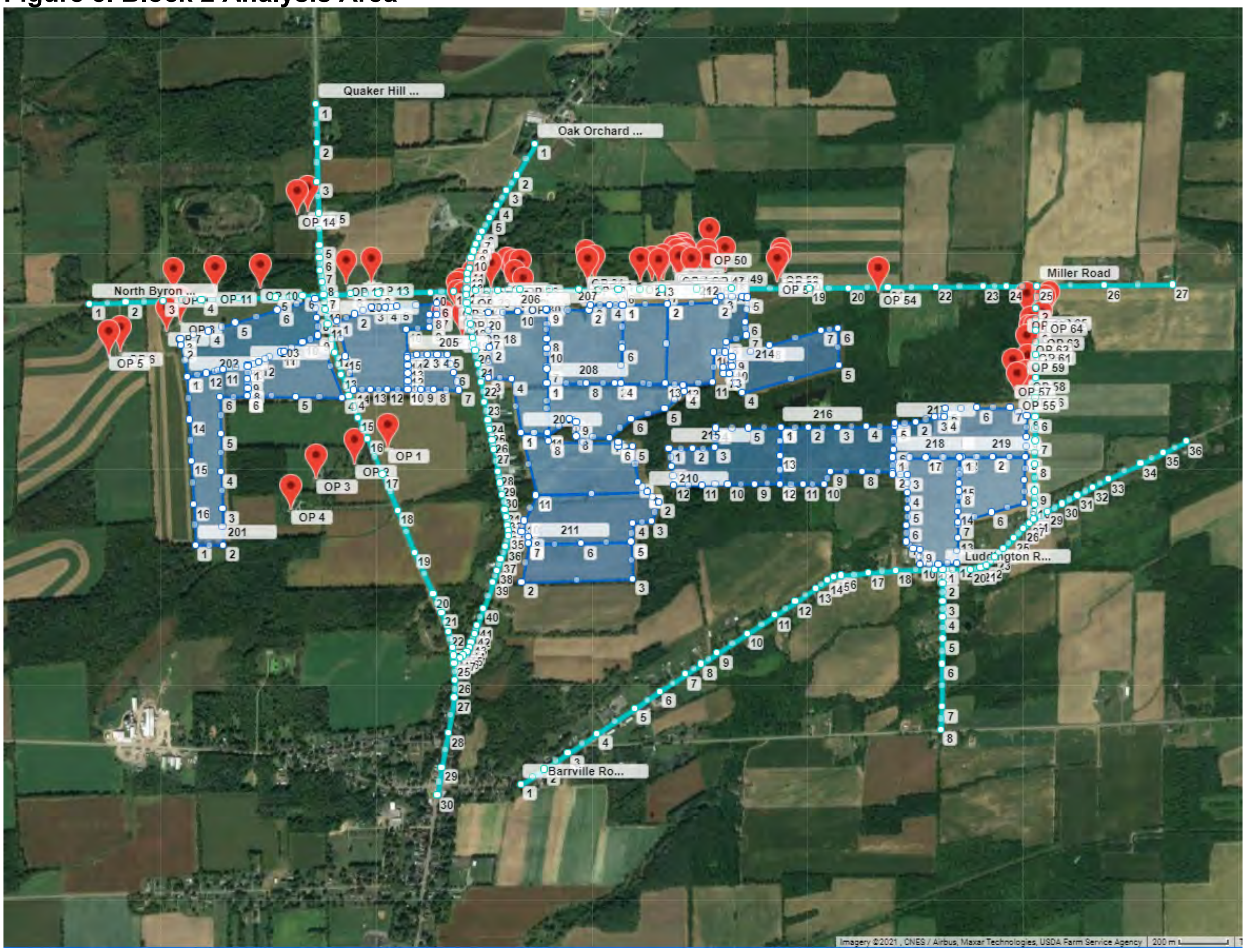
Forgesolar Figures

Figure 4. Block 1 Analysis Area*



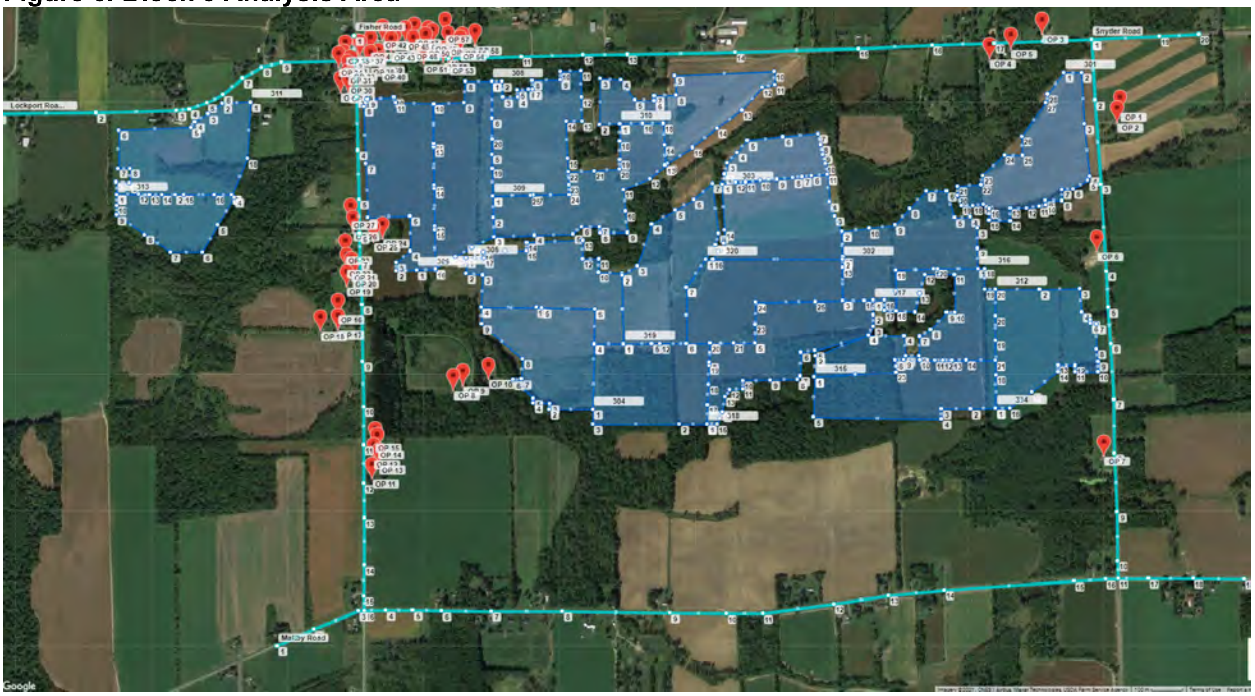
*Red markers indicate structures, turquoise lines indicate roads and blue polygons indicate PV arrays.
Source: ForgeSolar, Google Earth Imagery, September 2018.

Figure 5. Block 2 Analysis Area*



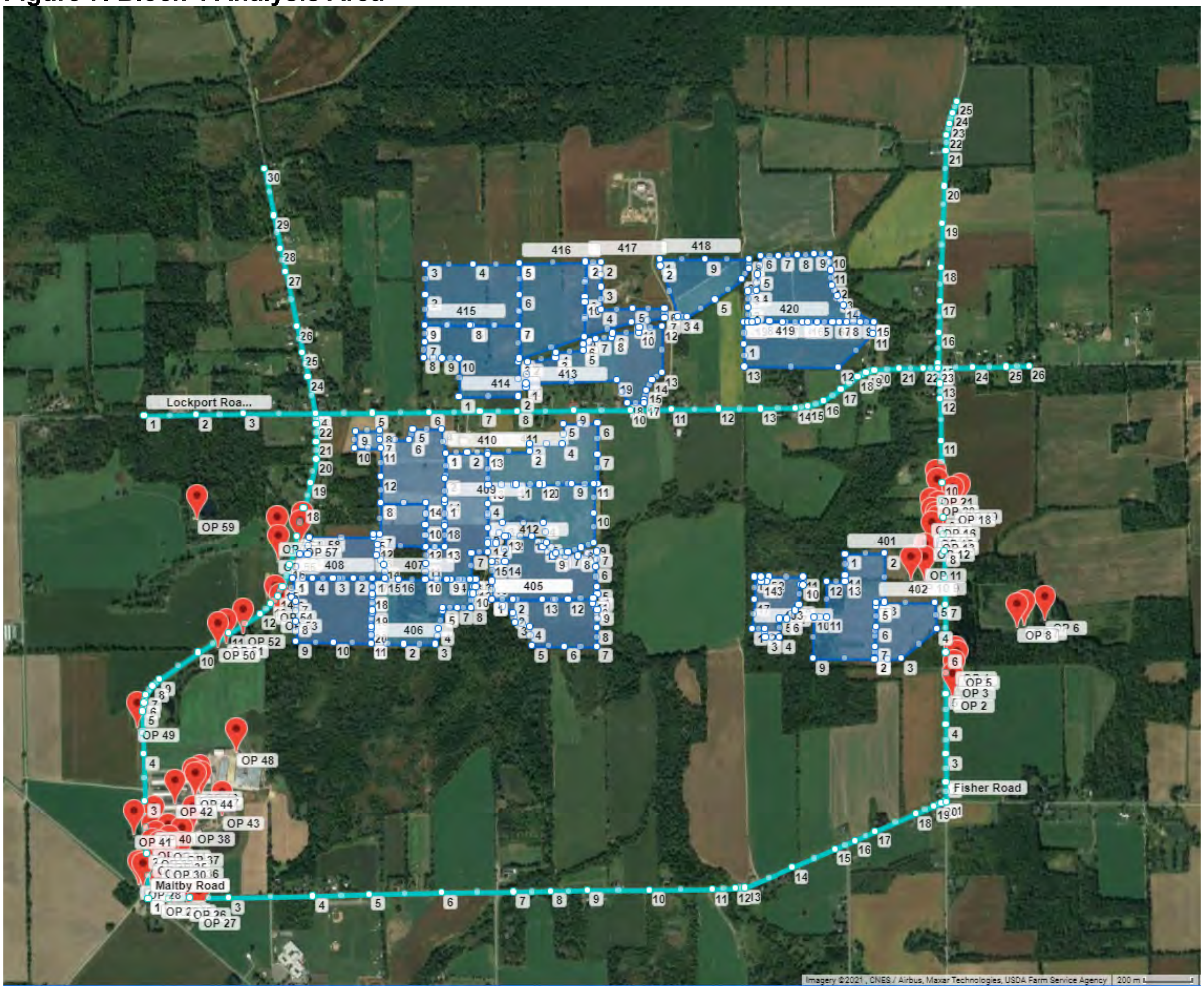
*Red markers indicate structures, turquoise lines indicate roads and blue polygons indicate PV arrays.
Source: ForgeSolar, Google Earth Imagery, September 2018.

Figure 6. Block 3 Analysis Area*



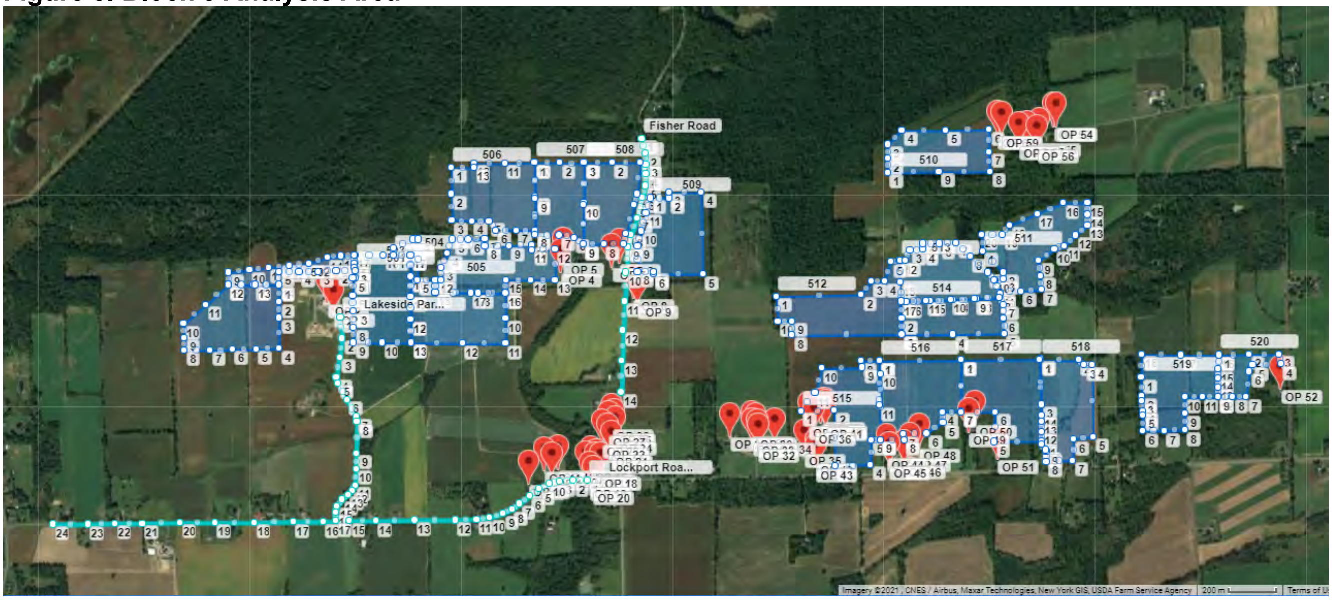
*Red markers indicate structures, turquoise lines indicate roads and blue polygons indicate PV arrays.
Source: ForgeSolar, Google Earth Imagery, September 2018.

Figure 7. Block 4 Analysis Area*



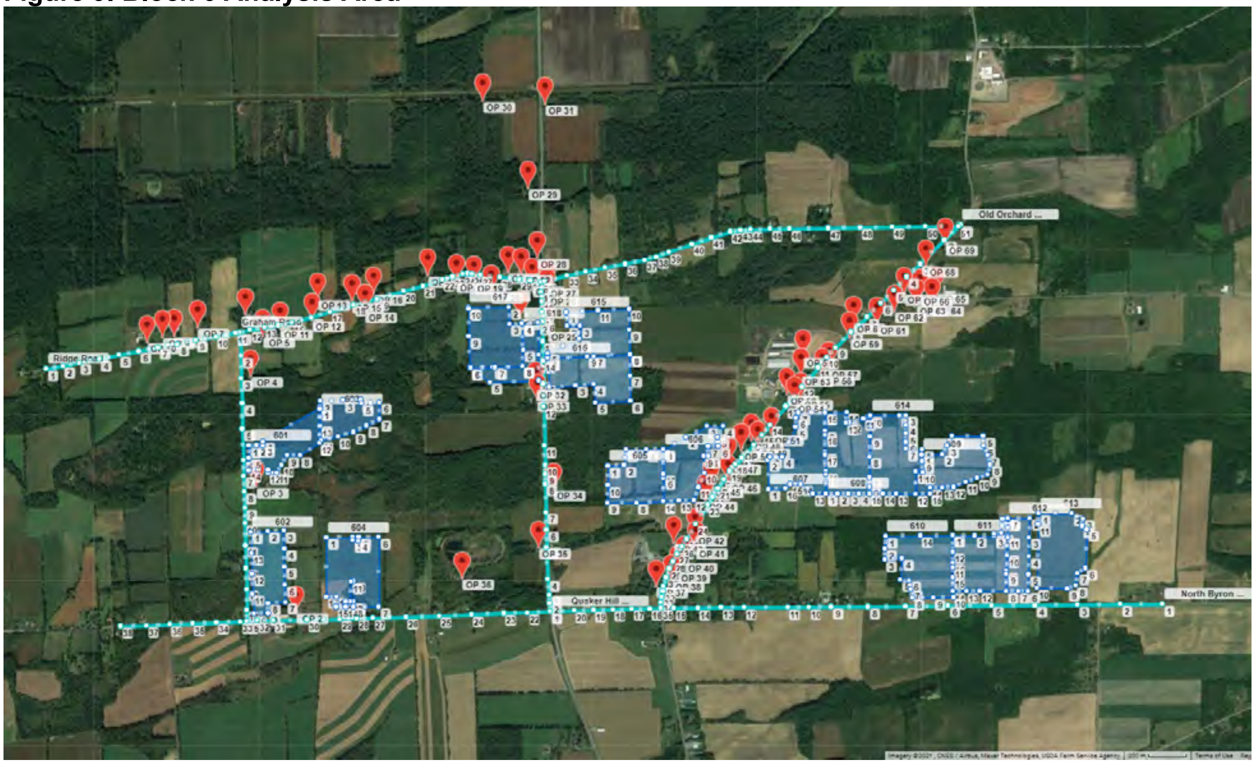
*Red markers indicate structures, turquoise lines indicate roads and blue polygons indicate PV arrays.
Source: ForgeSolar, Google Earth Imagery, September 2018.

Figure 8. Block 5 Analysis Area*



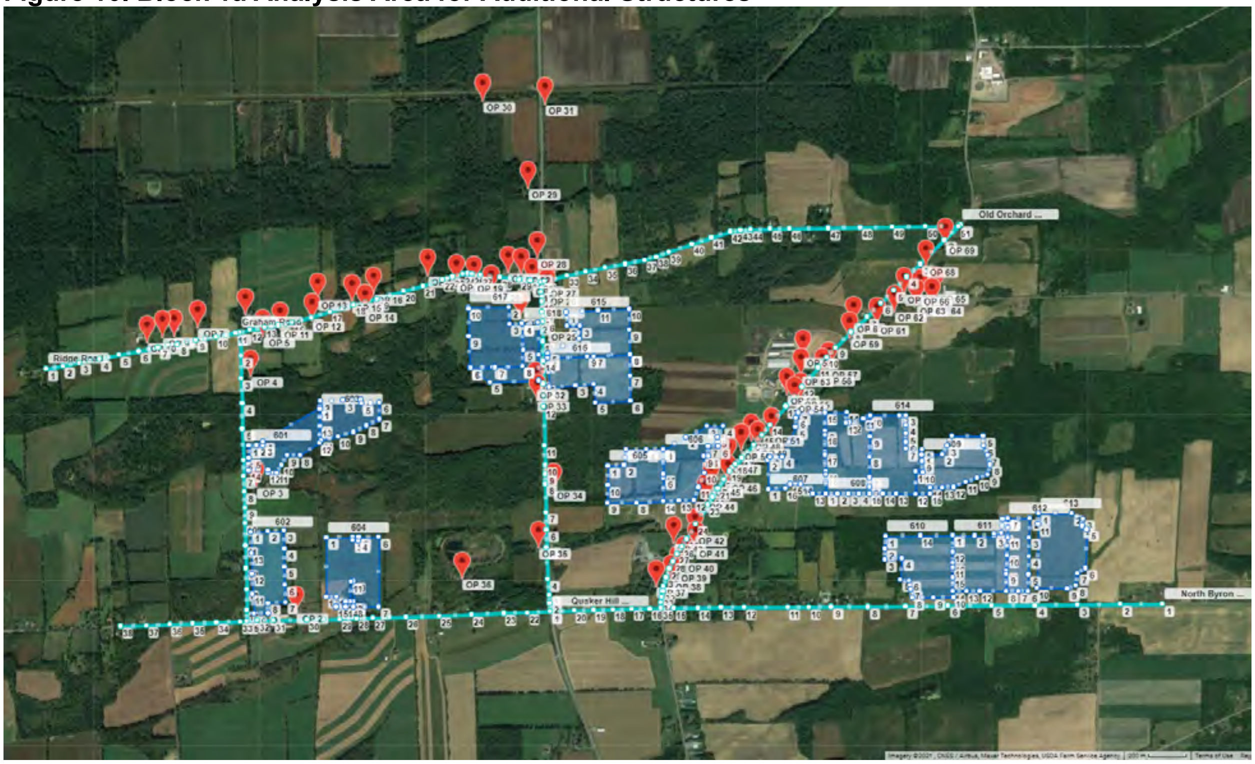
*Red markers indicate structures, turquoise lines indicate roads and blue polygons indicate PV arrays.
Source: ForgeSolar, Google Earth Imagery, September 2018.

Figure 9. Block 6 Analysis Area*



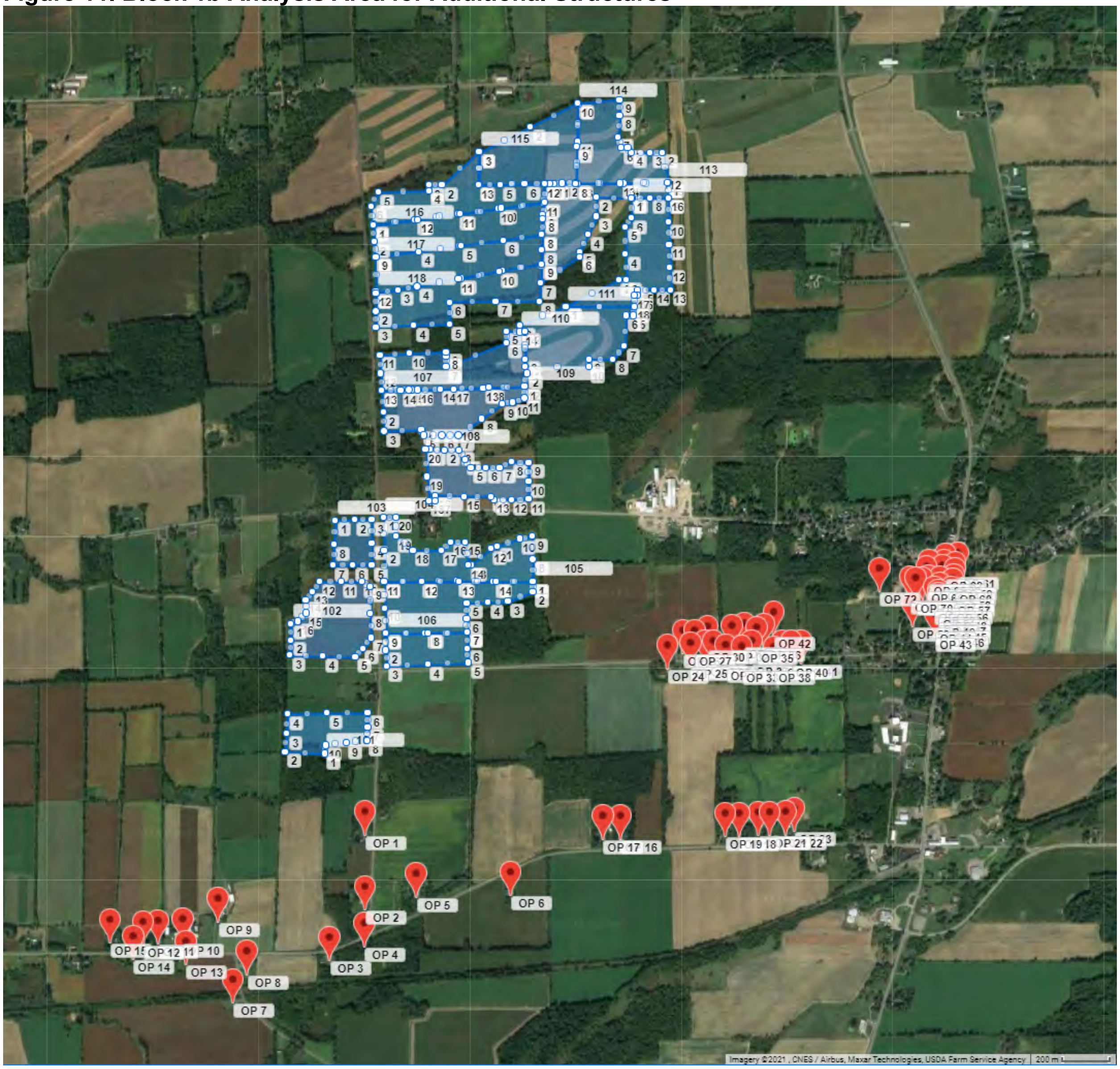
*Red markers indicate start and structures, turquoise lines indicate roads and blue polygons indicate PV arrays. Source: ForgeSolar, Google Earth Imagery, September 2018.

Figure 10. Block 1a Analysis Area for Additional Structures*



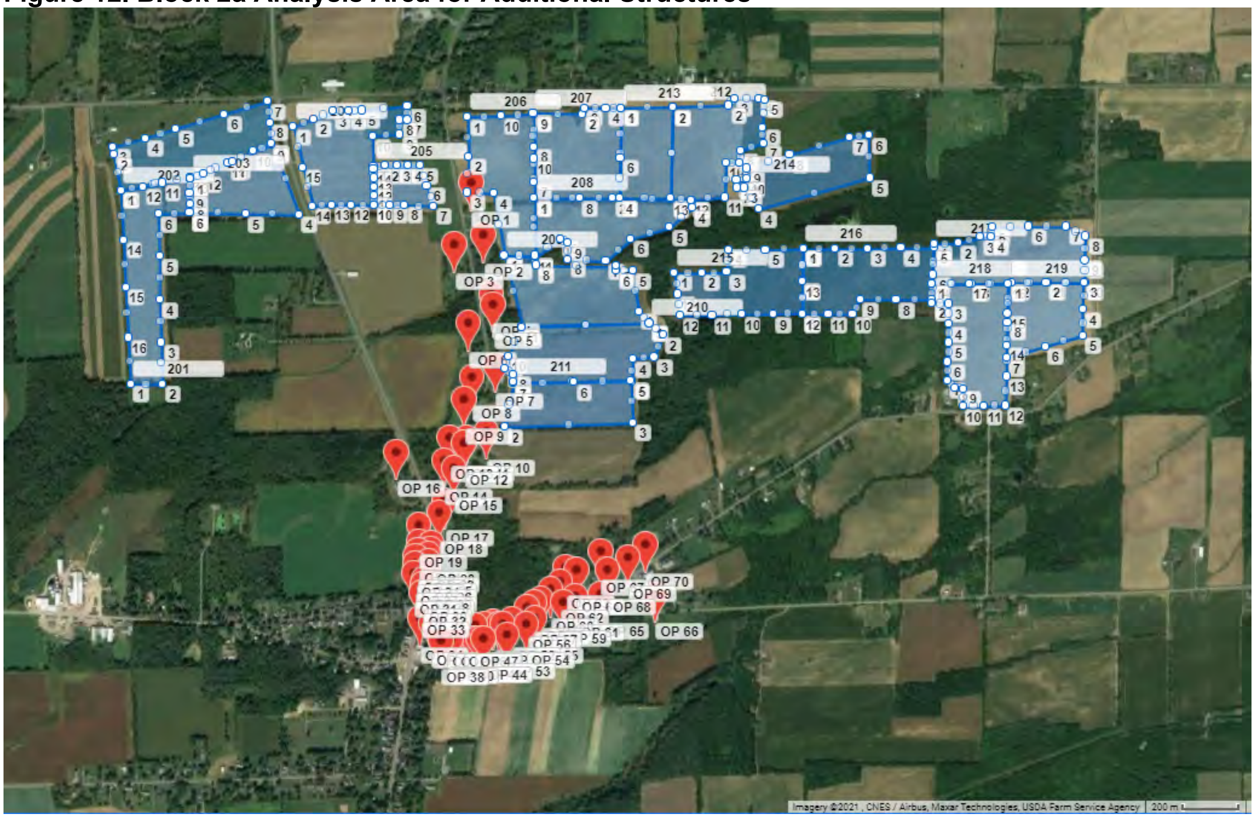
*Red markers indicate structures and blue polygons indicate PV arrays. Source: ForgeSolar, Google Earth Imagery, September 2018.

Figure 11. Block 1b Analysis Area for Additional Structures*



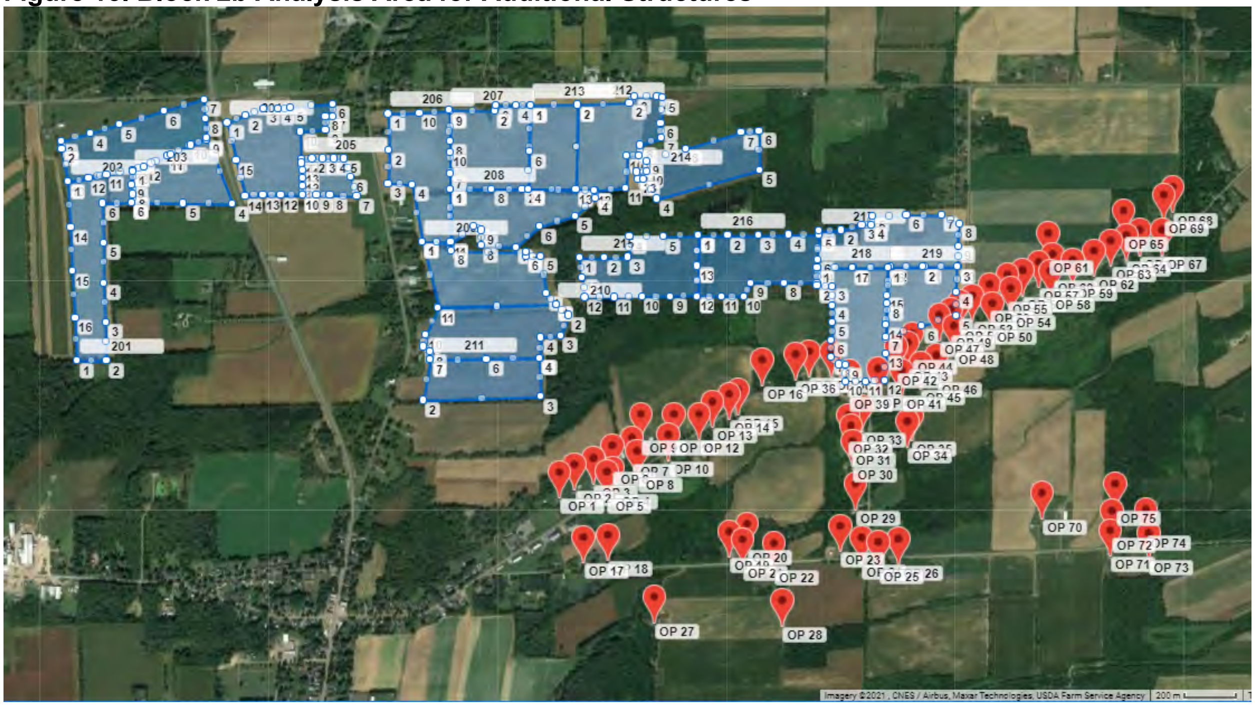
*Red markers indicate structures and blue polygons indicate PV arrays. Source: ForgeSolar, Google Earth Imagery, September 2018.

Figure 12. Block 2a Analysis Area for Additional Structures*



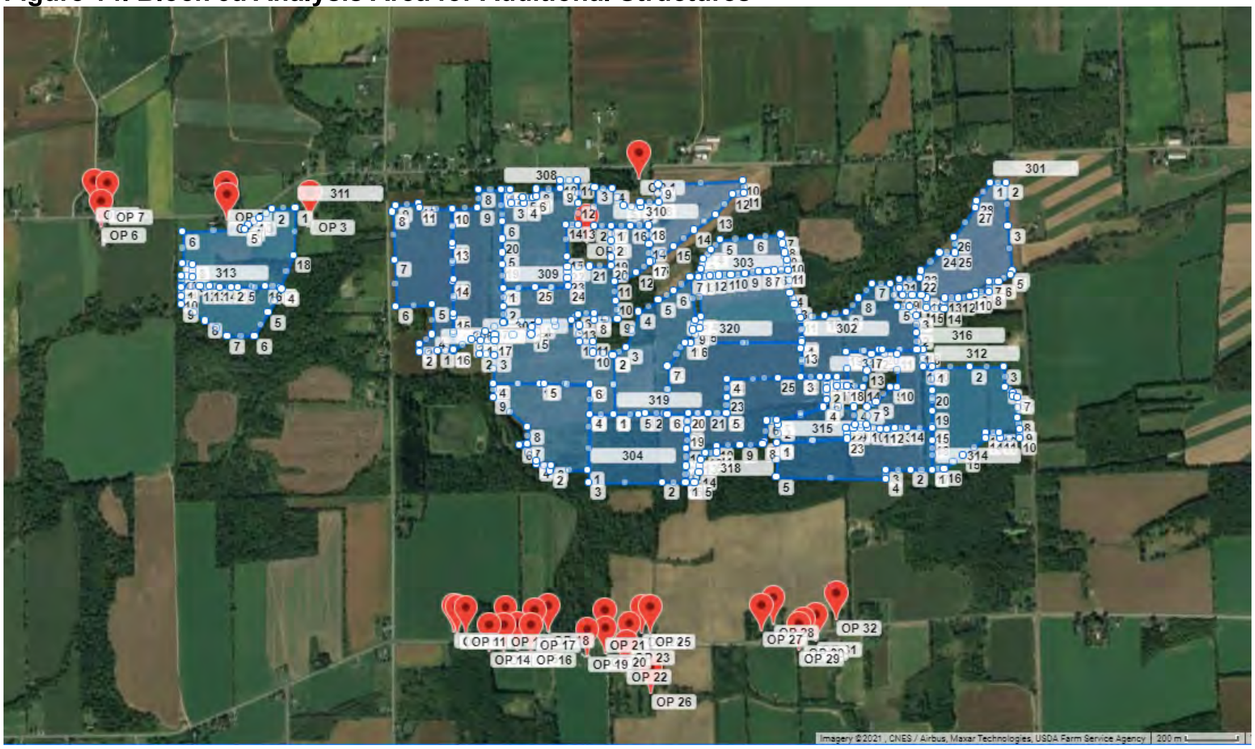
*Red markers indicate structures and blue polygons indicate PV arrays. Source: ForgeSolar, Google Earth Imagery, September 2018.

Figure 13. Block 2b Analysis Area for Additional Structures*



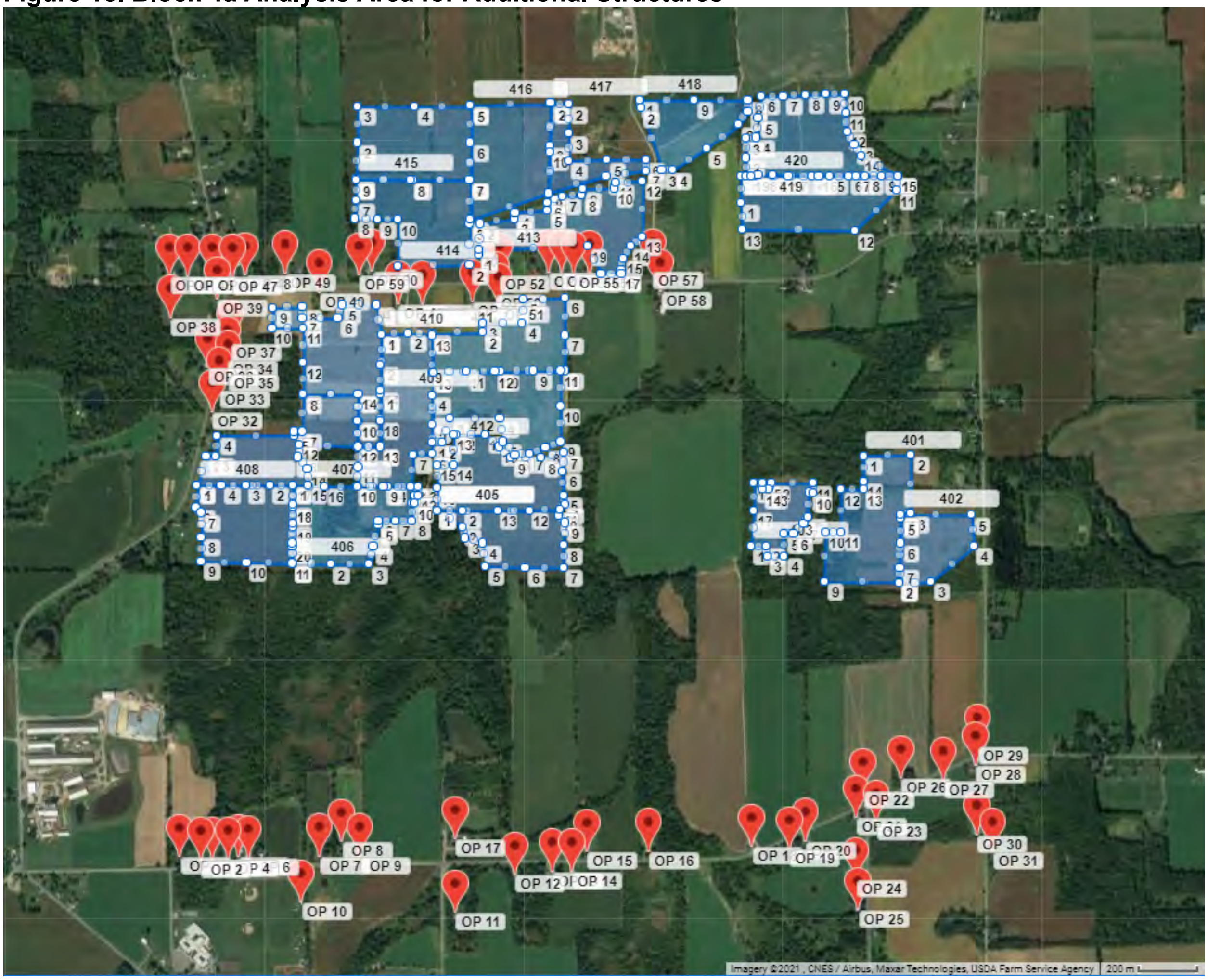
*Red markers indicate structures and blue polygons indicate PV arrays. Source: ForgeSolar, Google Earth Imagery, September 2018.

Figure 14. Block 3a Analysis Area for Additional Structures*



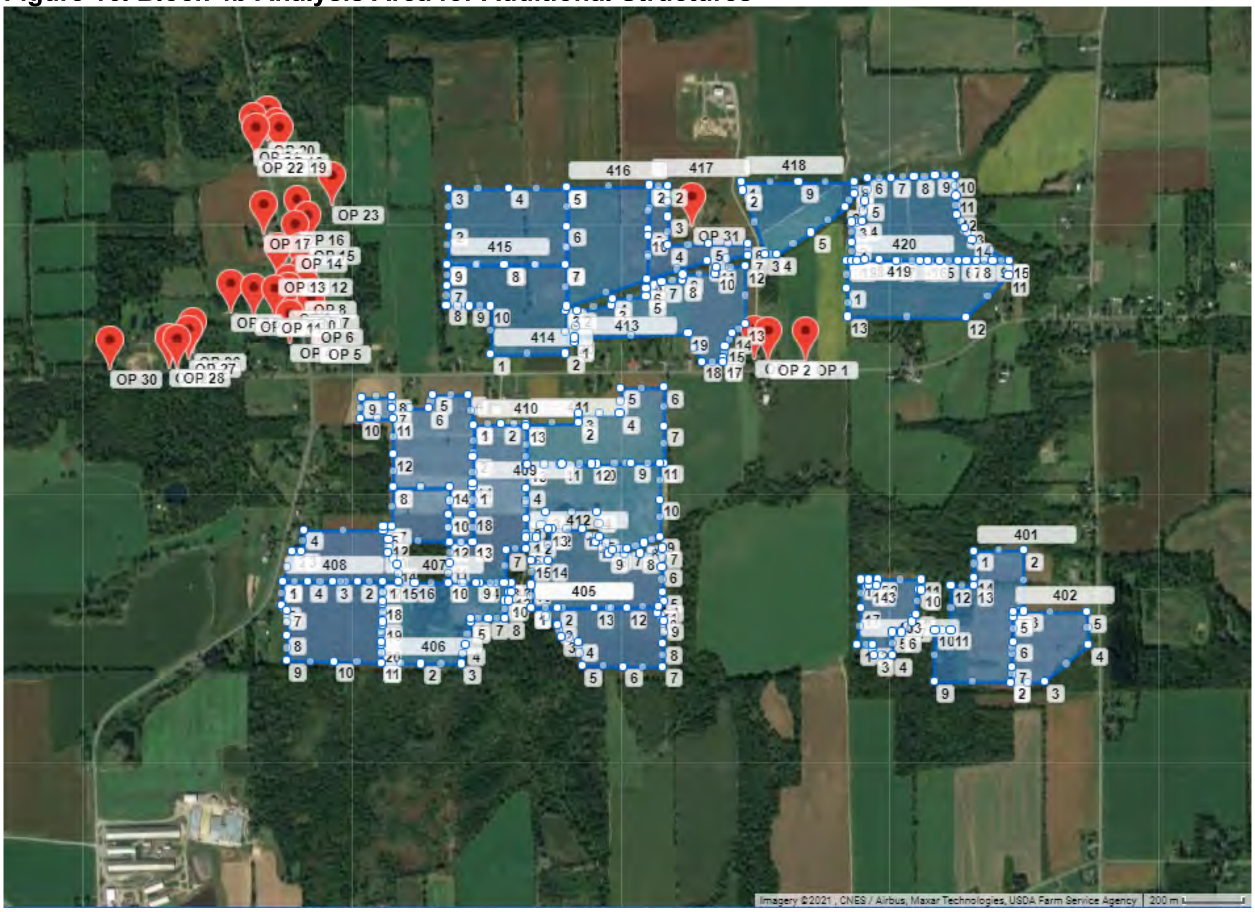
*Red markers indicate structures and blue polygons indicate PV arrays. Source: ForgeSolar, Google Earth Imagery, September 2018.

Figure 15. Block 4a Analysis Area for Additional Structures*



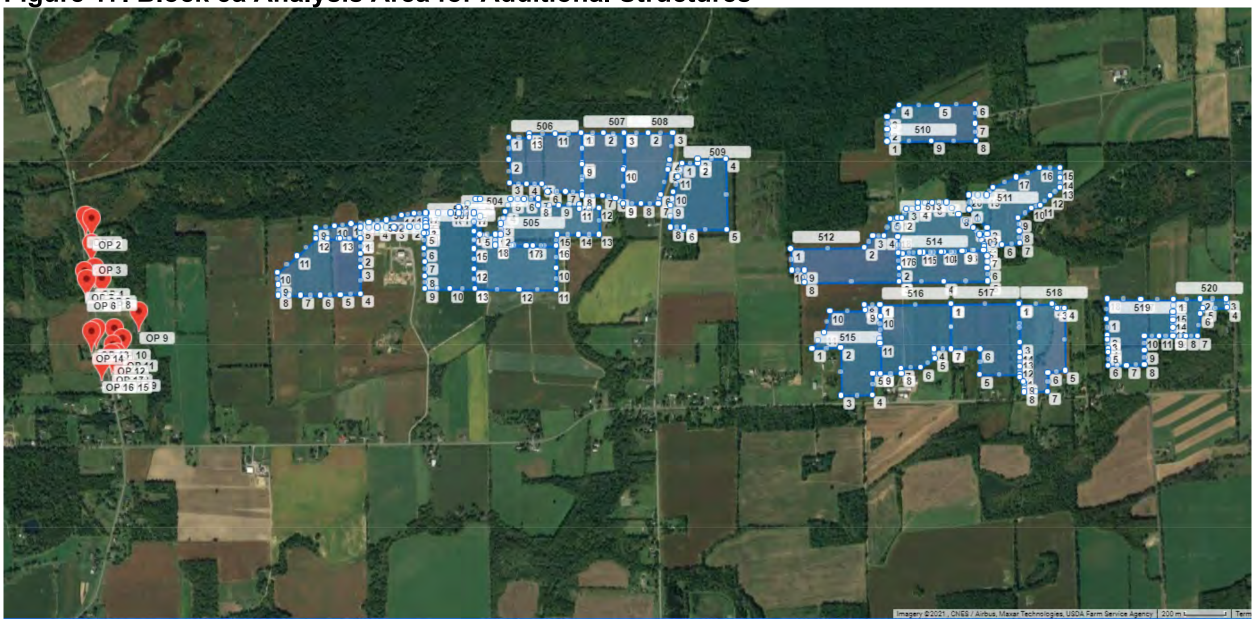
*Red markers indicate structures and blue polygons indicate PV arrays. Source: ForgeSolar, Google Earth Imagery, September 2018.

Figure 16. Block 4b Analysis Area for Additional Structures*



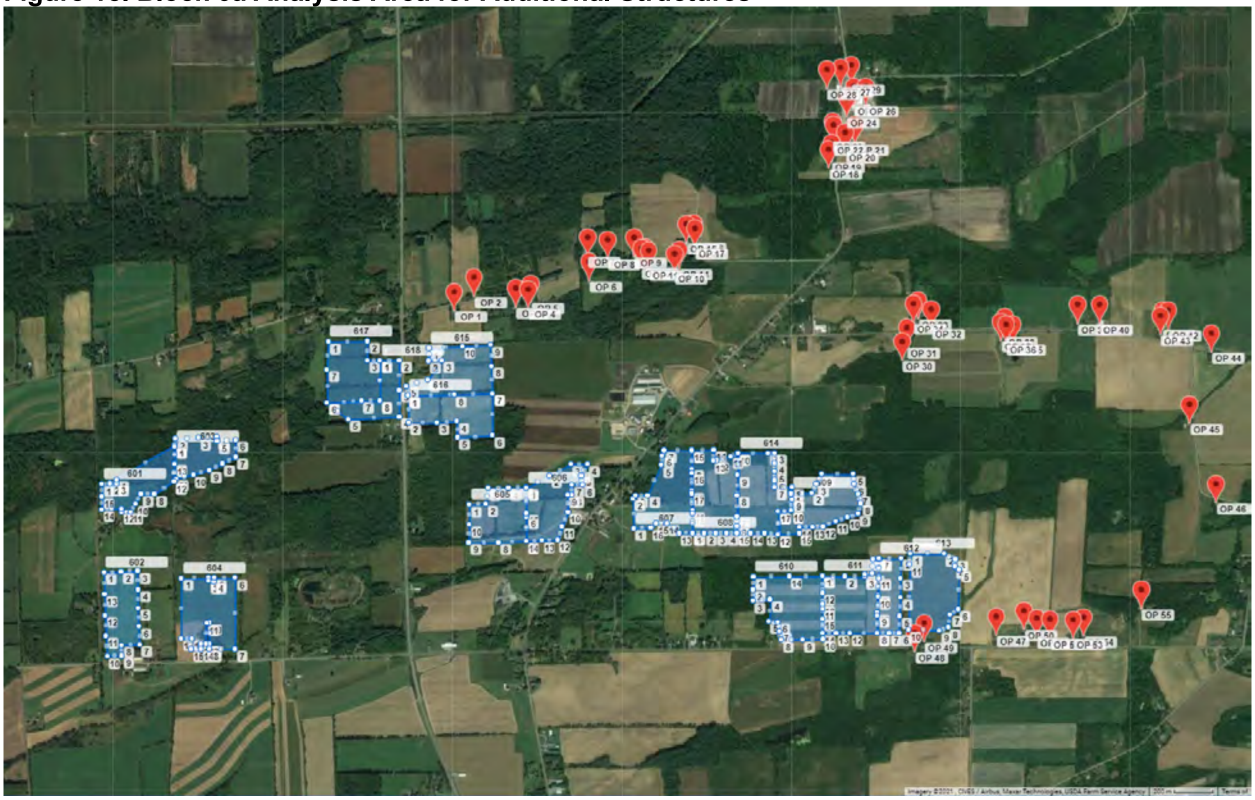
*Red markers indicate structures and blue polygons indicate PV arrays. Source: ForgeSolar, Google Earth Imagery, September 2018.

Figure 17. Block 5a Analysis Area for Additional Structures*



*Red markers indicate structures and blue polygons indicate PV arrays. Source: ForgeSolar, Google Earth Imagery, September 2018.

Figure 18. Block 6a Analysis Area for Additional Structures*



*Red markers indicate structures and blue polygons indicate PV arrays. Source: ForgeSolar, Google Earth Imagery, September 2018.