

PV array 1: Leicester RWY 04

No glare found

PV array 1: Leicester RWY 06

No glare found

PV array 1: Leicester RWY 10

No glare found

PV array 1: Leicester RWY 15

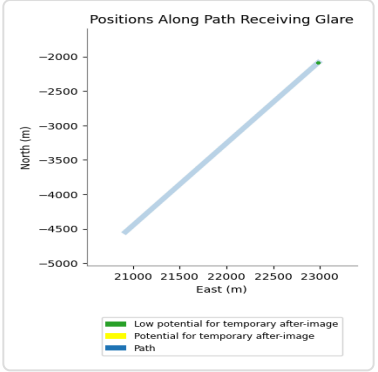
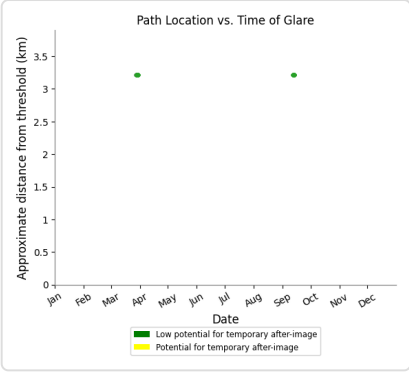
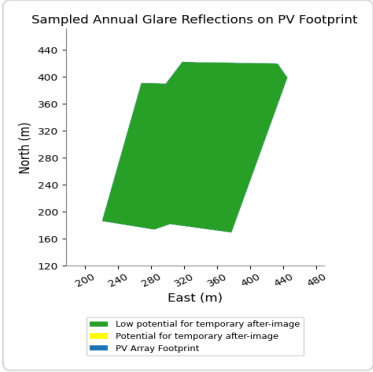
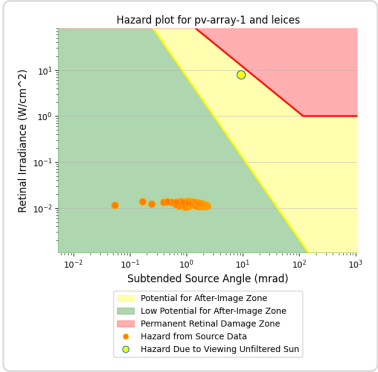
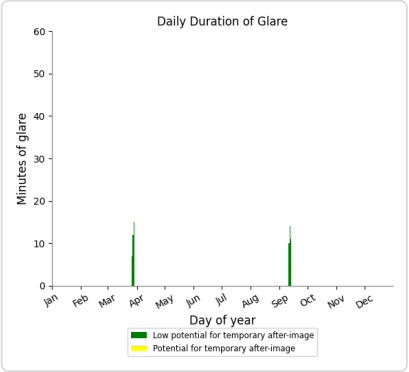
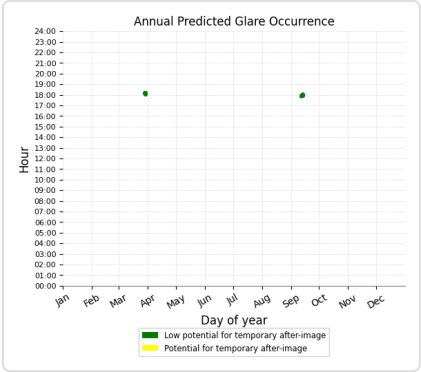
No glare found

PV array 1: Leicester RWY 16

No glare found

PV array 1: Leicester RWY 22

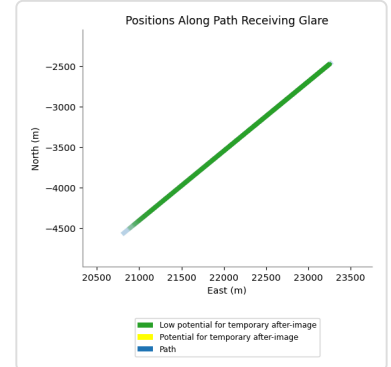
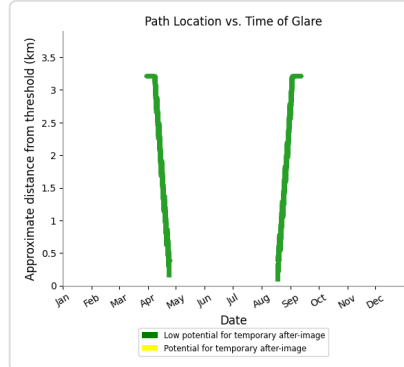
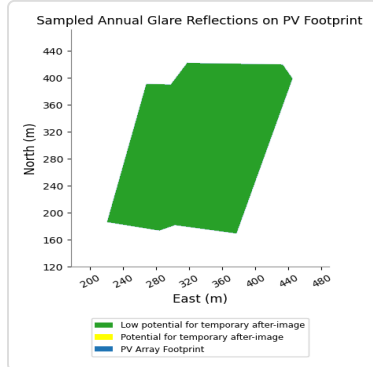
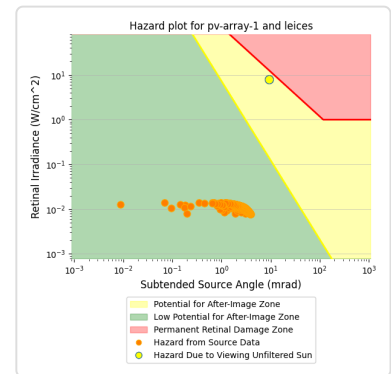
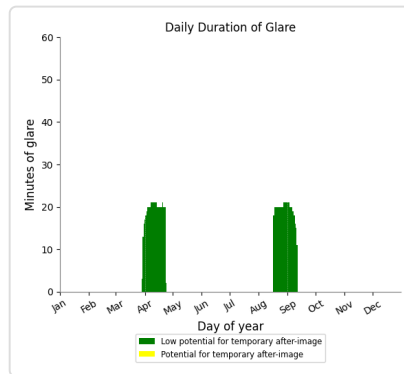
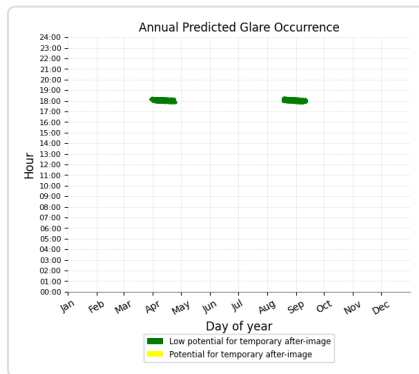
- PV array is expected to produce the following glare for this receptor:
- 69 minutes of "green" glare with low potential to cause temporary after-image.
 - 0 minutes of "yellow" glare with potential to cause temporary after-image.



PV array 1: Leicester RWY 24

PV array is expected to produce the following glare for this receptor:

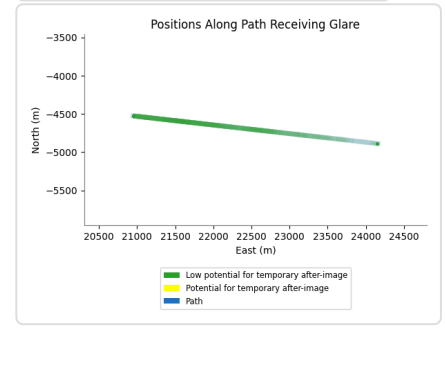
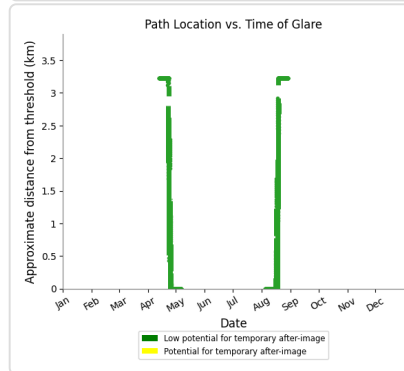
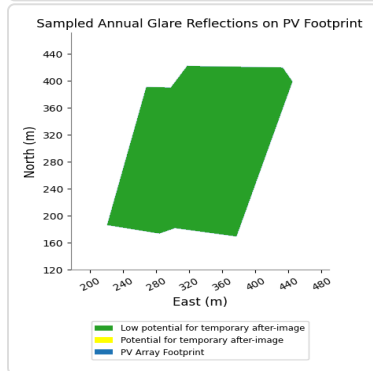
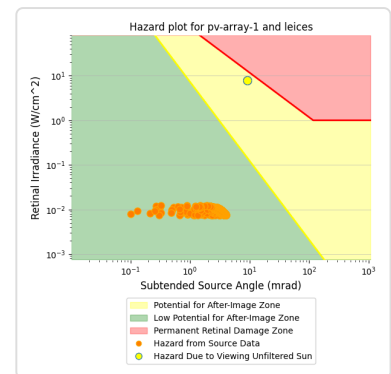
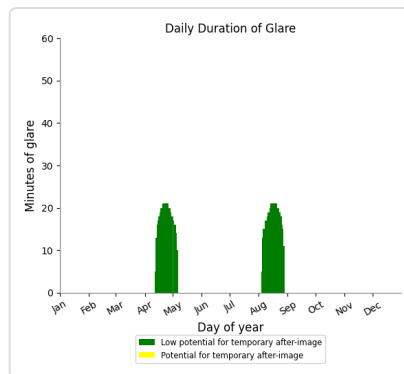
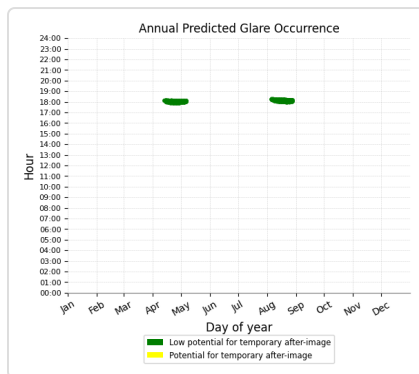
- 997 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.



PV array 1: Leicester RWY 28

PV array is expected to produce the following glare for this receptor:

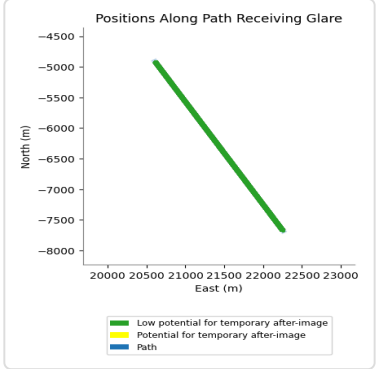
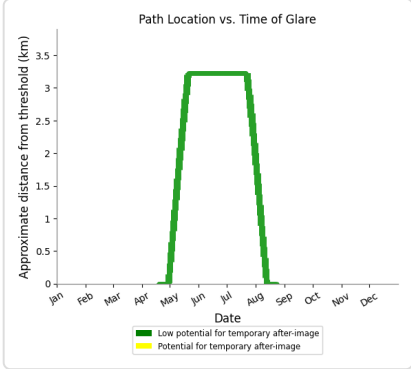
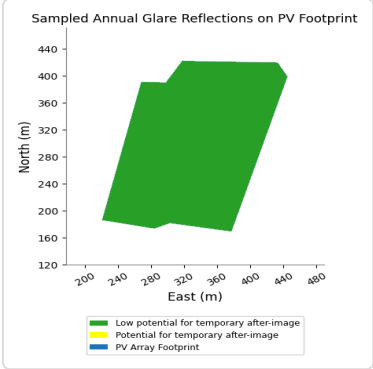
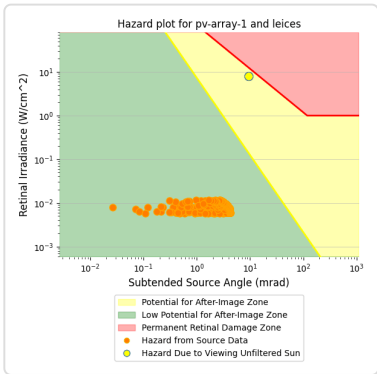
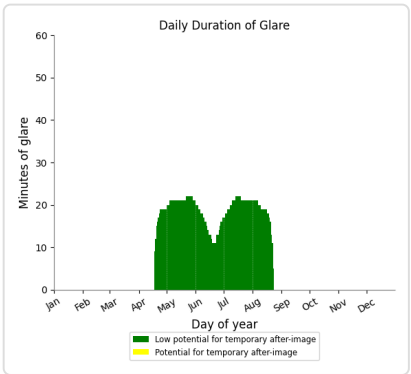
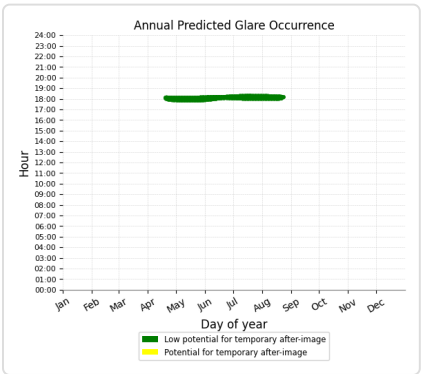
- 886 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.



PV array 1: Leicester RWY 33

PV array is expected to produce the following glare for this receptor:

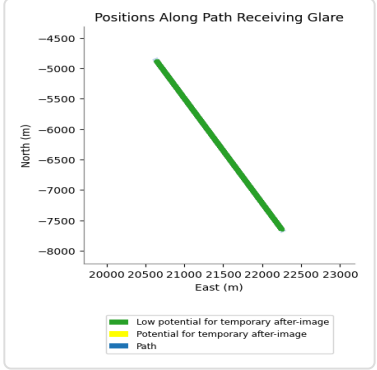
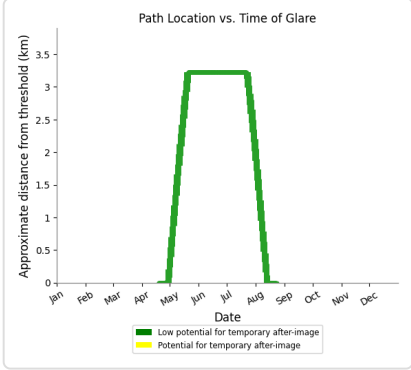
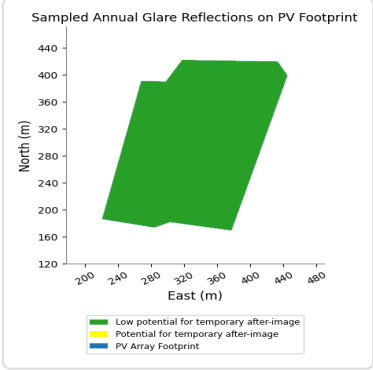
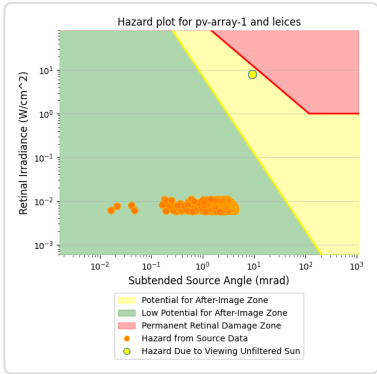
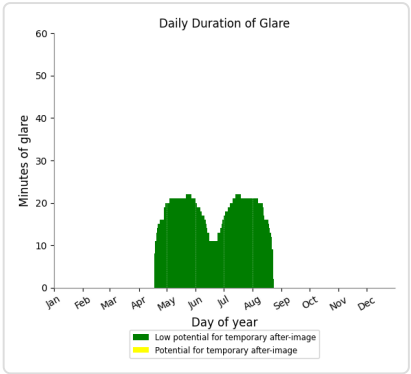
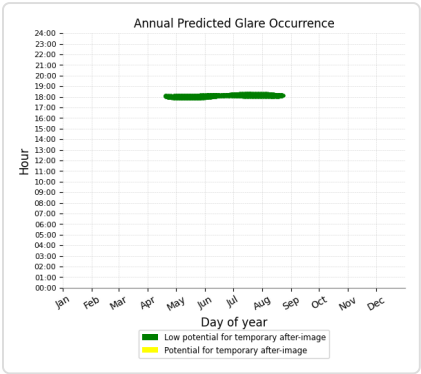
- 2,386 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.



PV array 1: Leicester RWY 34

PV array is expected to produce the following glare for this receptor:

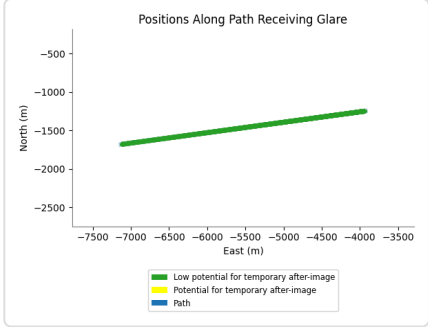
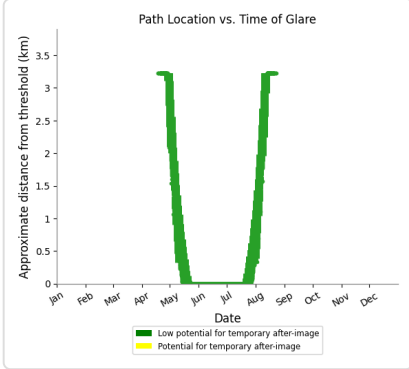
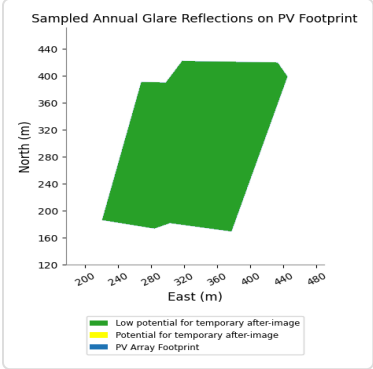
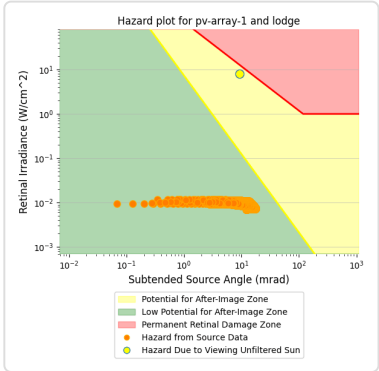
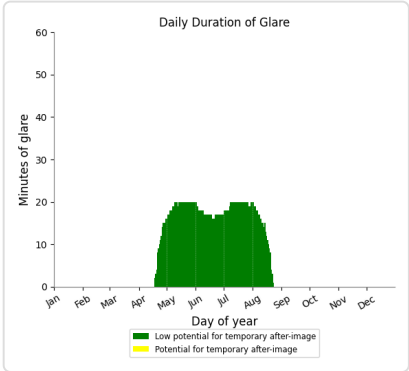
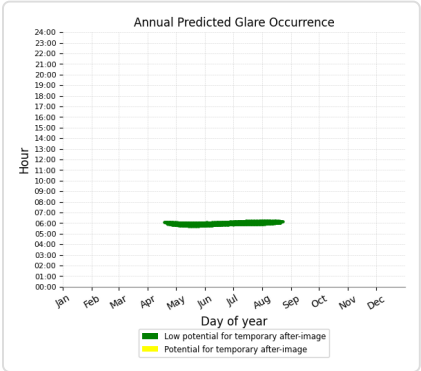
- 2,314 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.



PV array 1: Lodge Farm RWY 08

PV array is expected to produce the following glare for this receptor:

- 2,171 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.



PV array 1: Lodge Farm RWY 26

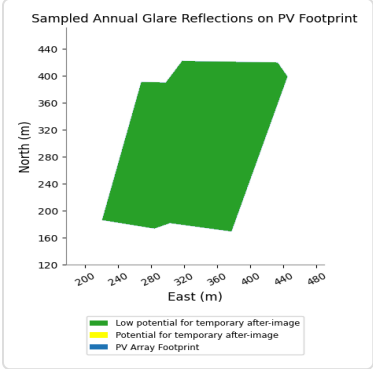
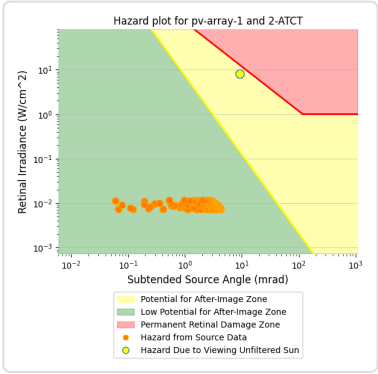
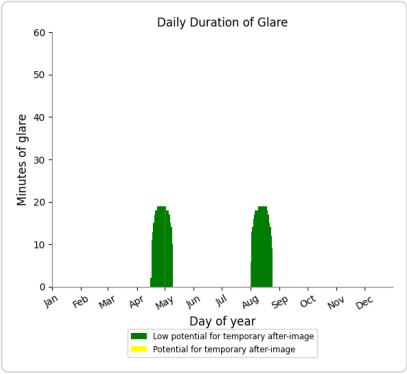
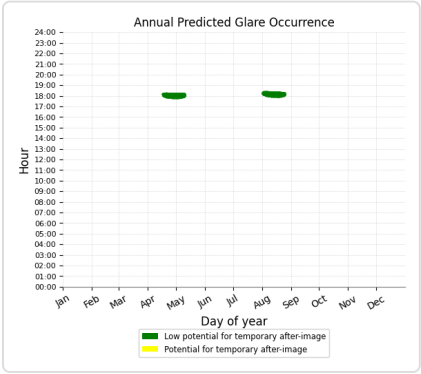
No glare found

PV array 1: 1-ATCT

No glare found

PV array 1: 2-ATCT

- PV array is expected to produce the following glare for this receptor:
- 789 minutes of "green" glare with low potential to cause temporary after-image.
 - 0 minutes of "yellow" glare with potential to cause temporary after-image.



PV array 2 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)
FP: East Midlands RWY 09	0	0
FP: East Midlands RWY 27	0	0
FP: Leicester RWY 04	0	0
FP: Leicester RWY 06	0	0
FP: Leicester RWY 10	0	0
FP: Leicester RWY 15	0	0
FP: Leicester RWY 16	0	0
FP: Leicester RWY 22	84	0
FP: Leicester RWY 24	767	0
FP: Leicester RWY 28	567	0
FP: Leicester RWY 33	1492	0
FP: Leicester RWY 34	1439	0
FP: Lodge Farm RWY 08	1344	0
FP: Lodge Farm RWY 26	0	0
OP: 1-ATCT	0	0
OP: 2-ATCT	446	0

PV array 2: East Midlands RWY 09

No glare found

PV array 2: East Midlands RWY 27

No glare found

PV array 2: Leicester RWY 04

No glare found

PV array 2: Leicester RWY 06

No glare found

PV array 2: Leicester RWY 10

No glare found

PV array 2: Leicester RWY 15

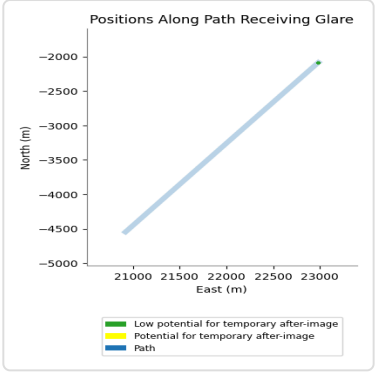
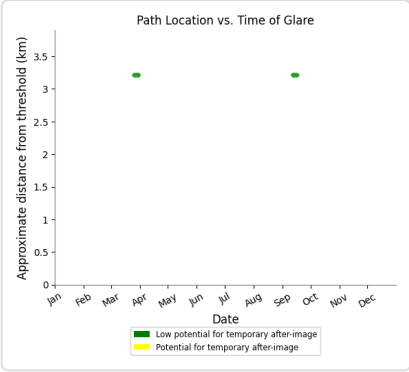
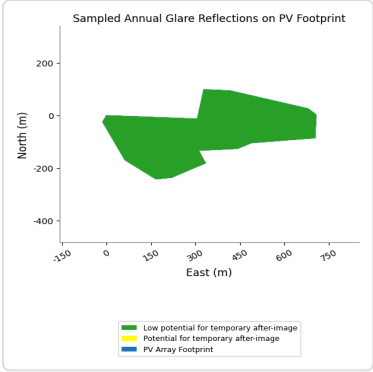
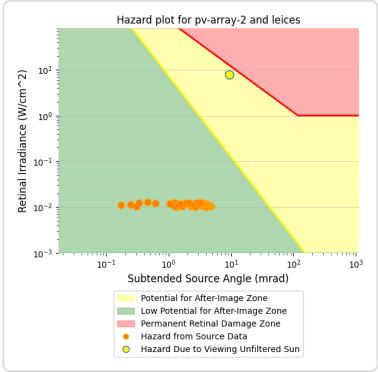
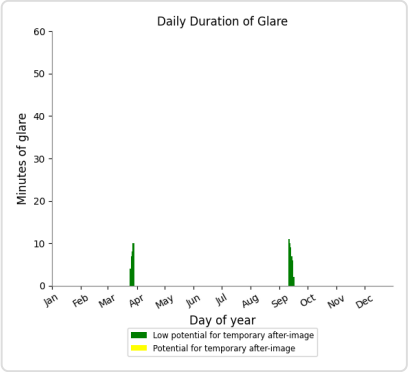
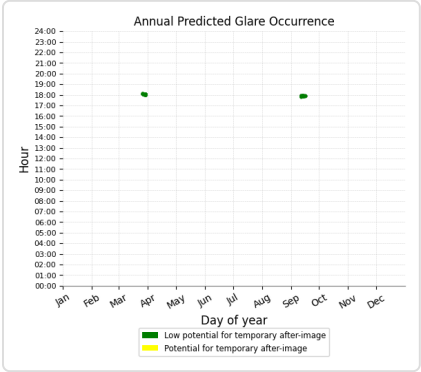
No glare found

PV array 2: Leicester RWY 16

No glare found

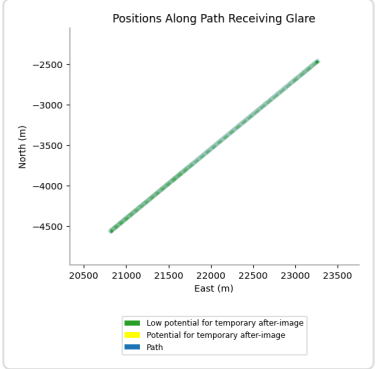
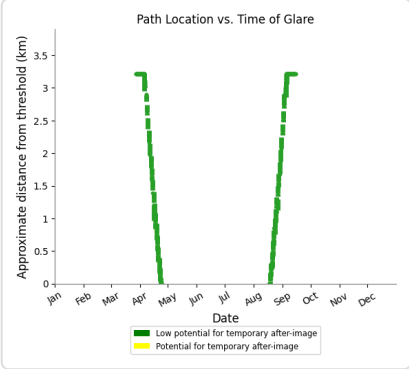
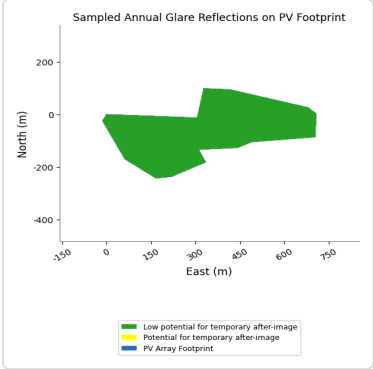
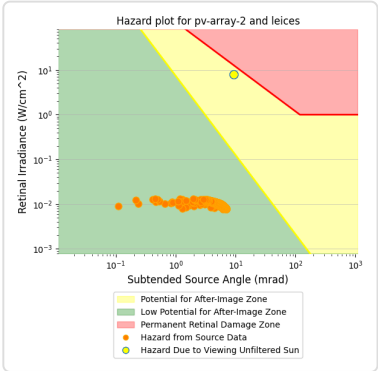
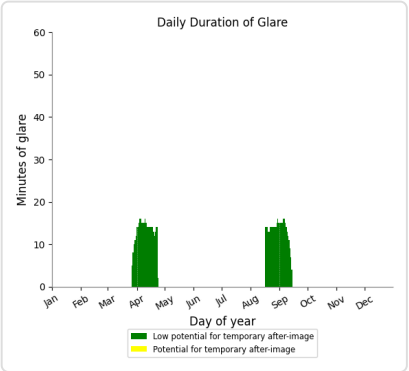
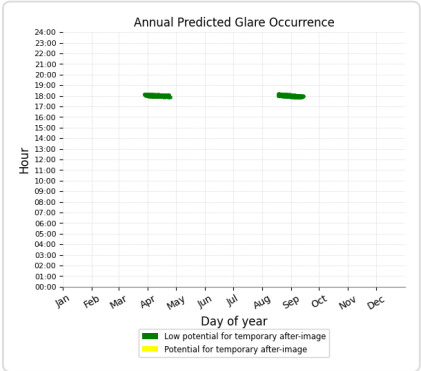
PV array 2: Leicester RWY 22

- PV array is expected to produce the following glare for this receptor:
- 84 minutes of "green" glare with low potential to cause temporary after-image.
 - 0 minutes of "yellow" glare with potential to cause temporary after-image.



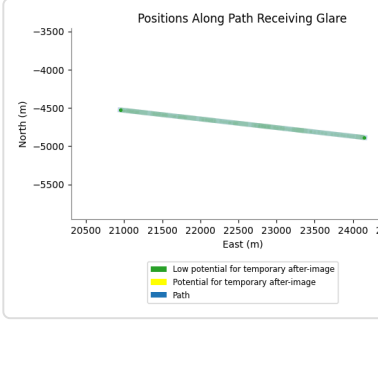
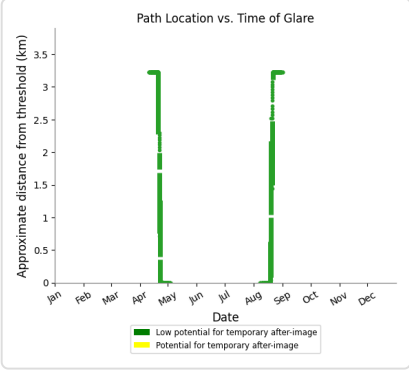
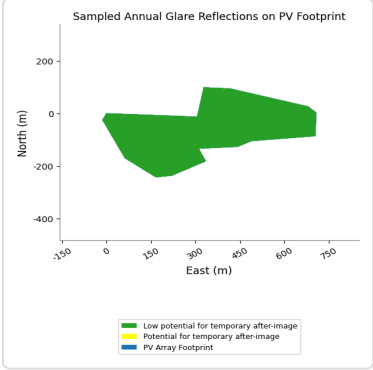
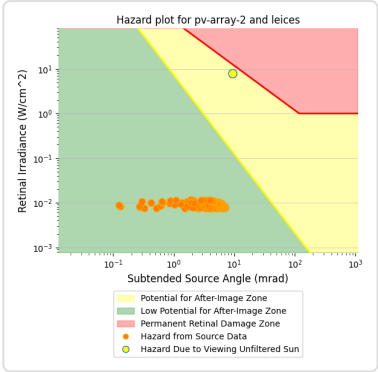
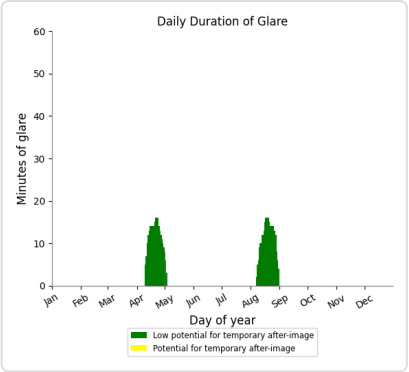
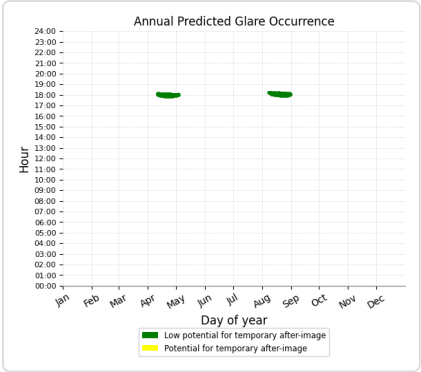
PV array 2: Leicester RWY 24

- PV array is expected to produce the following glare for this receptor:
- 767 minutes of "green" glare with low potential to cause temporary after-image.
 - 0 minutes of "yellow" glare with potential to cause temporary after-image.



PV array 2: Leicester RWY 28

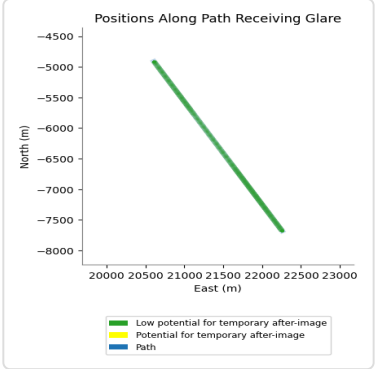
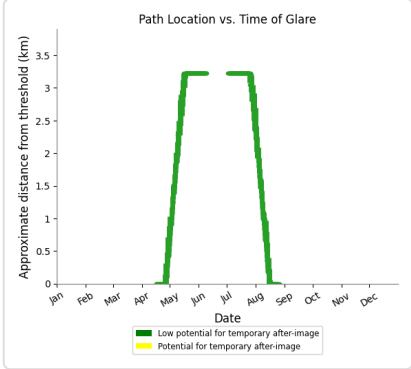
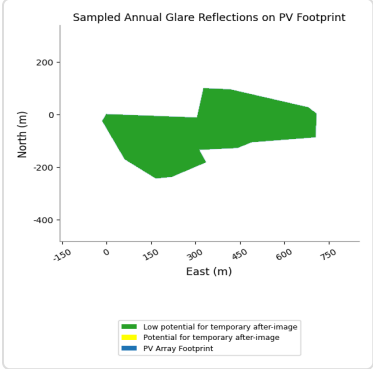
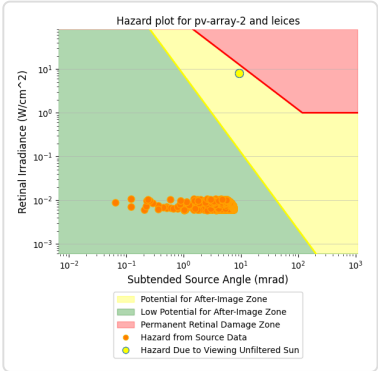
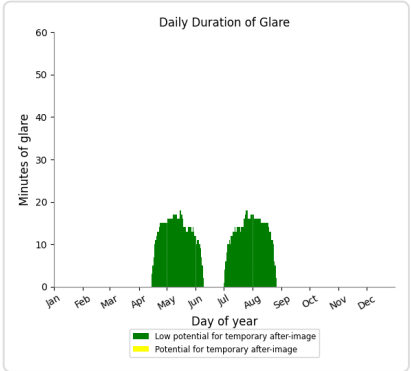
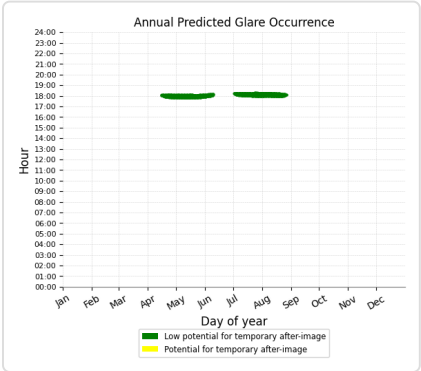
- PV array is expected to produce the following glare for this receptor:
- 567 minutes of "green" glare with low potential to cause temporary after-image.
 - 0 minutes of "yellow" glare with potential to cause temporary after-image.



PV array 2: Leicester RWY 33

PV array is expected to produce the following glare for this receptor:

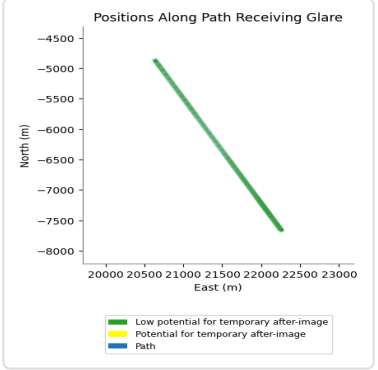
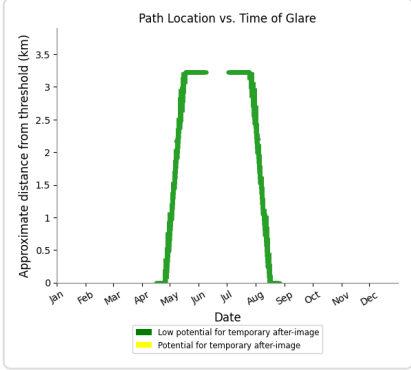
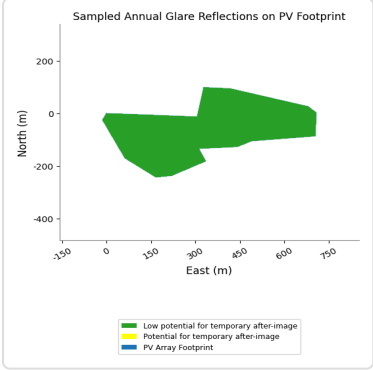
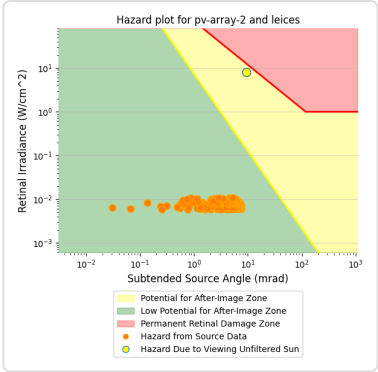
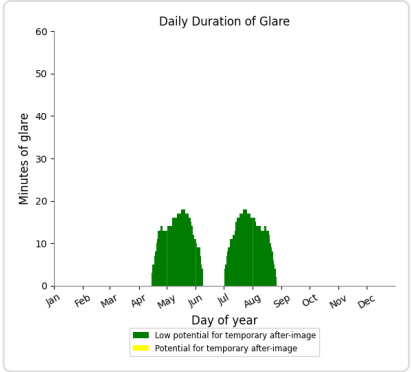
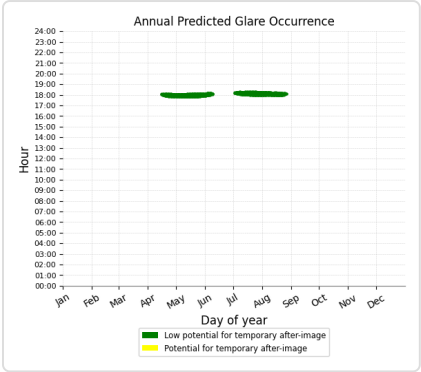
- 1,492 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.



PV array 2: Leicester RWY 34

PV array is expected to produce the following glare for this receptor:

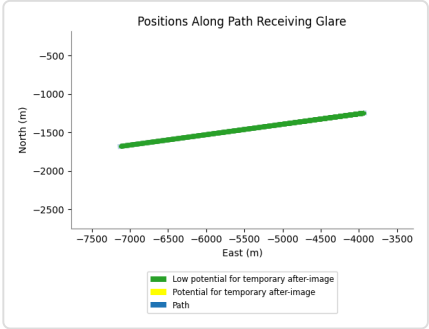
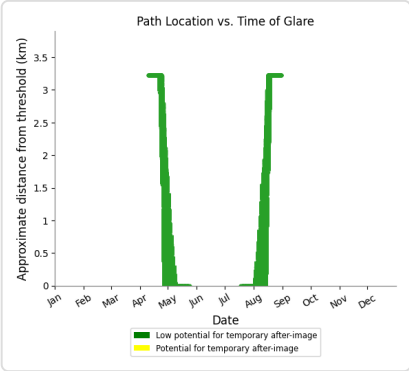
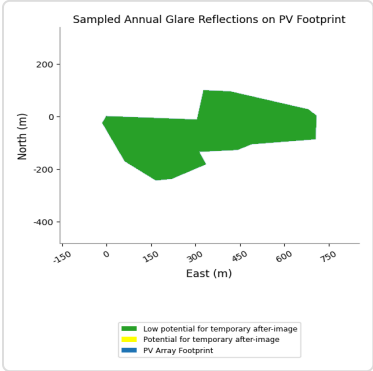
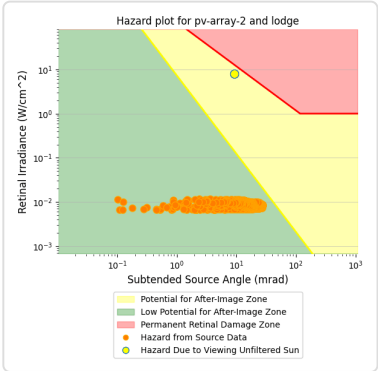
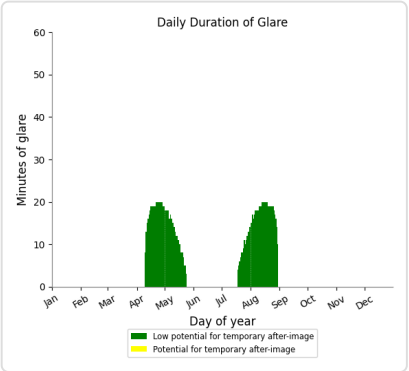
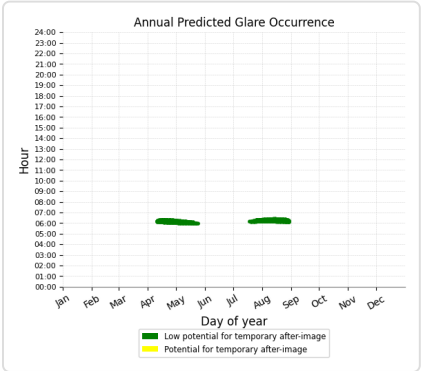
- 1,439 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.



PV array 2: Lodge Farm RWY 08

PV array is expected to produce the following glare for this receptor:

- 1,344 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.



PV array 2: Lodge Farm RWY 26

No glare found

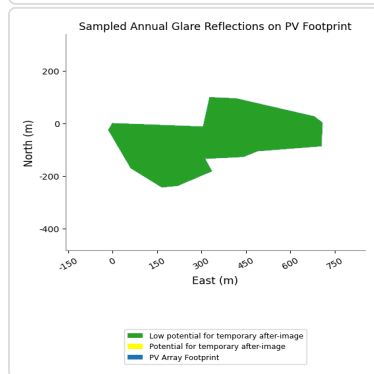
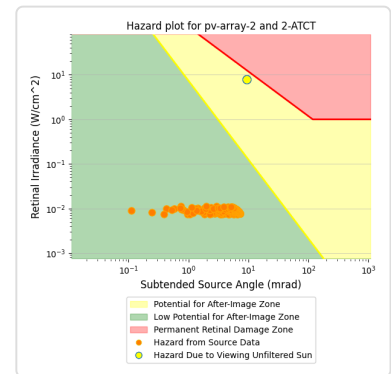
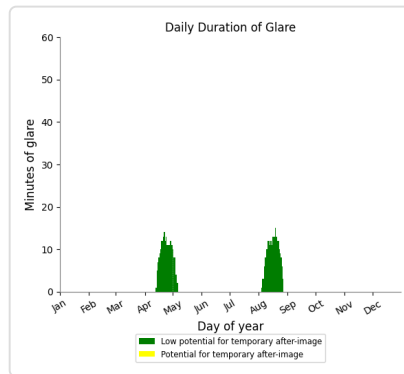
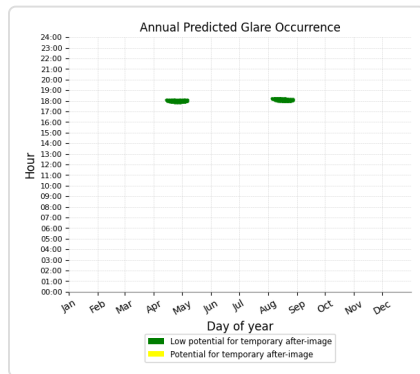
PV array 2: 1-ATCT

No glare found

PV array 2: 2-ATCT

PV array is expected to produce the following glare for this receptor:

- 446 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.



Assumptions

- Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
- Glare analyses do not automatically account for physical obstructions between reflectors and receptors. This includes buildings, tree cover and geographic obstructions.
- Detailed system geometry is not rigorously simulated.
- The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actual values and results may vary.
- The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.
- Several V1 calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results for large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare.
- The subtended source angle (glare spot size) is constrained by the PV array footprint size. Partitioning large arrays into smaller sections will reduce the maximum potential subtended angle, potentially impacting results if actual glare spots are larger than the sub-array size. Additional analyses of the combined area of adjacent sub-arrays can provide more information on potential glare hazards. (See previous point on related limitations.)
- Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
- Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
- Refer to the **Help page** for detailed assumptions and limitations not listed here.



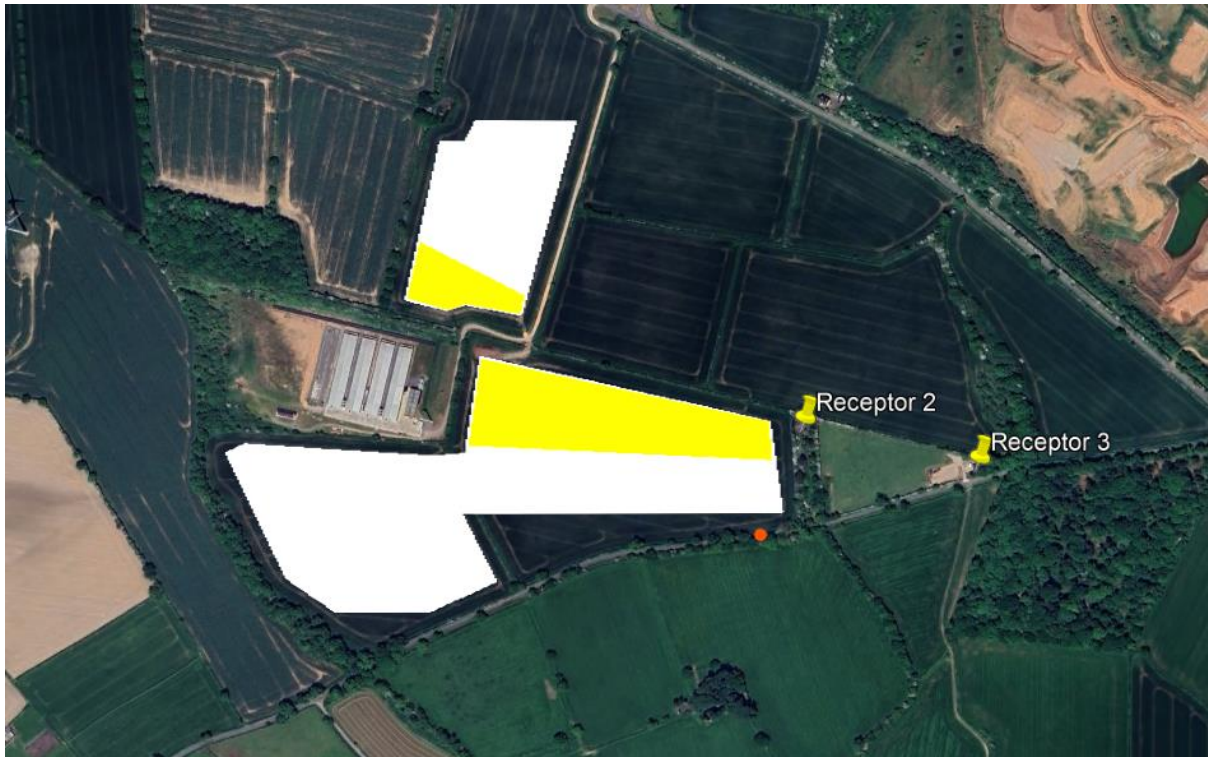
Appendix E: Visibility Assessment Evidence



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Residential Receptors

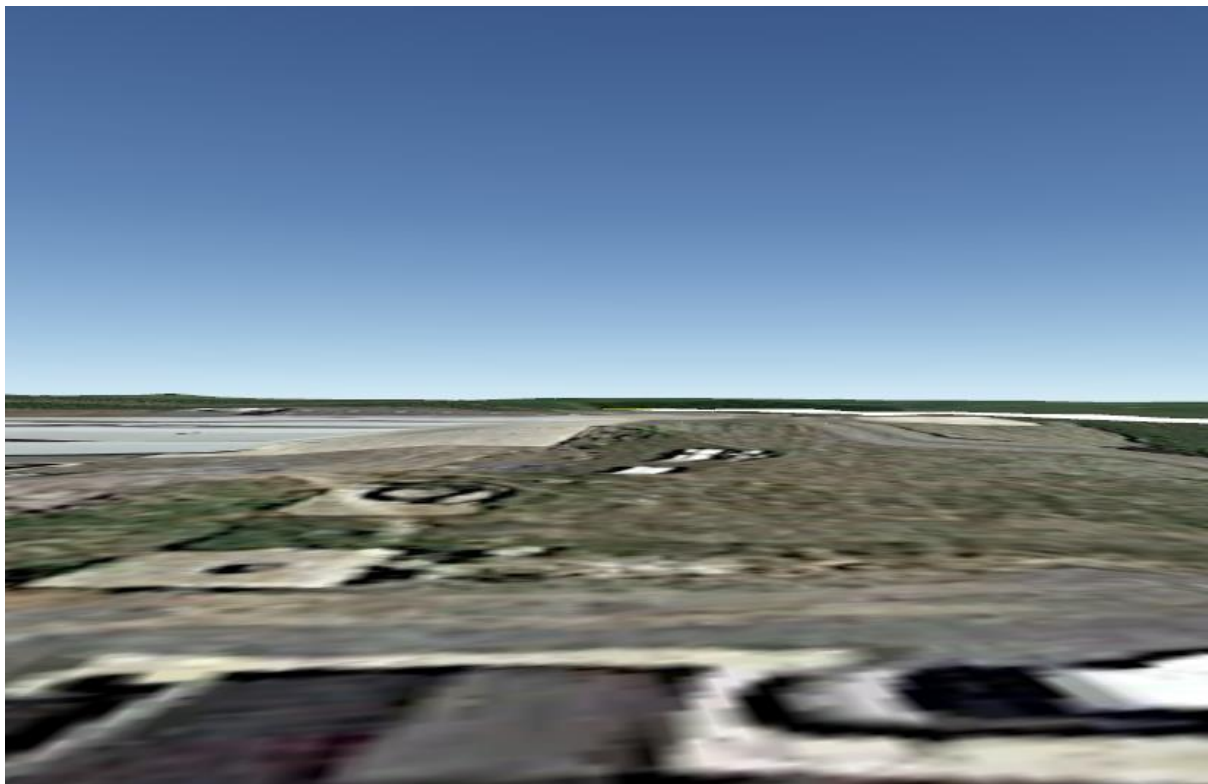
Receptors 2 and 3



Receptor 5



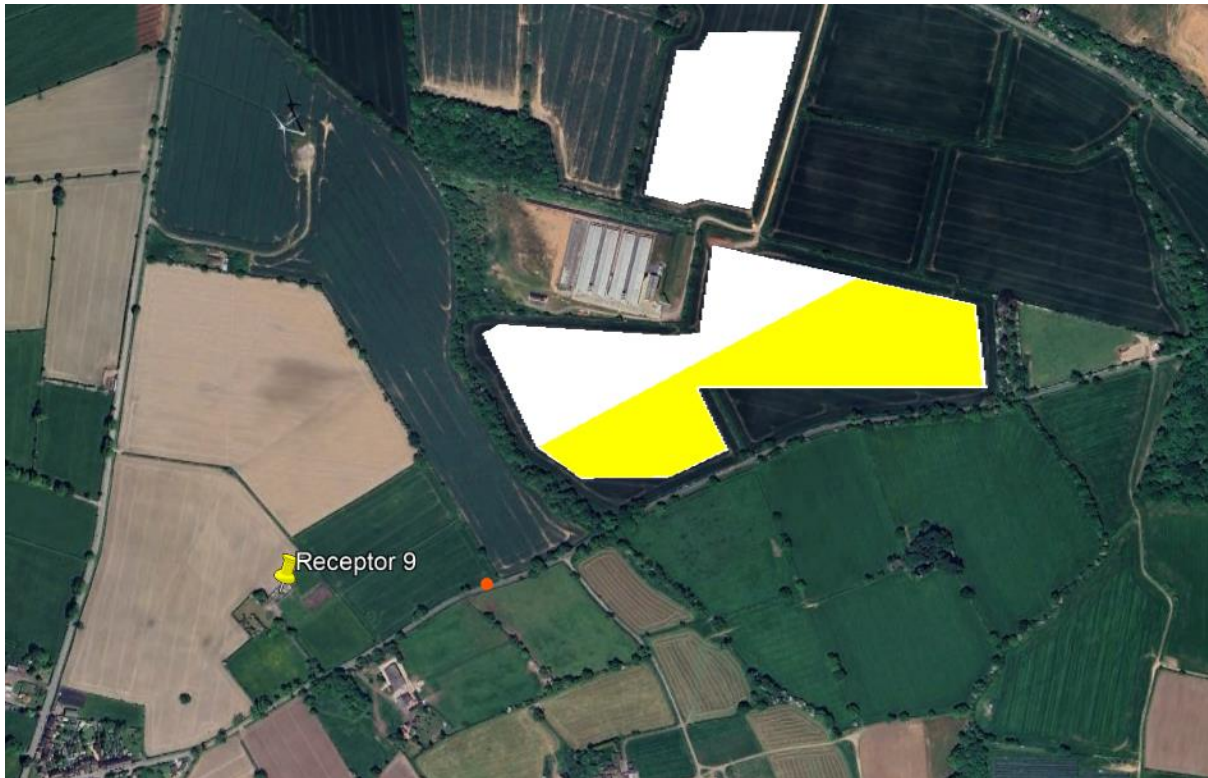
Receptor 7



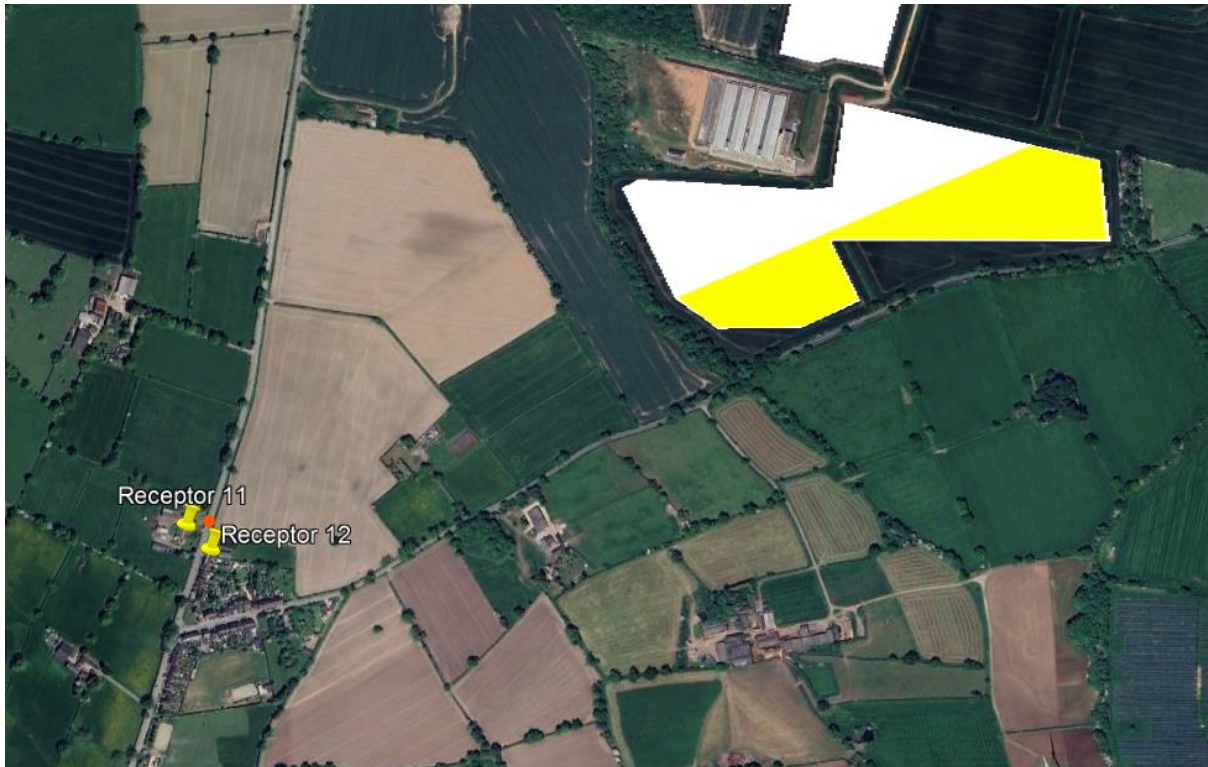
Receptor 8



Receptor 9

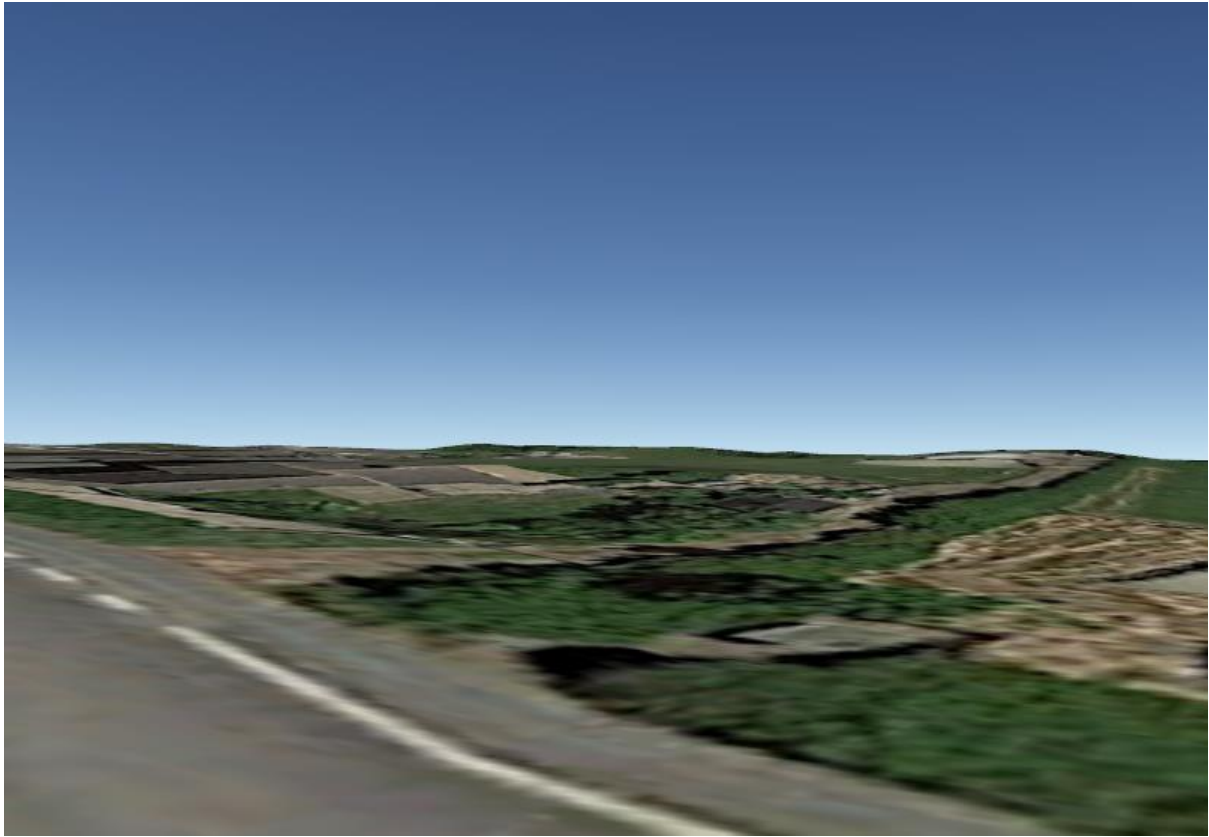


Receptors 11 and 12

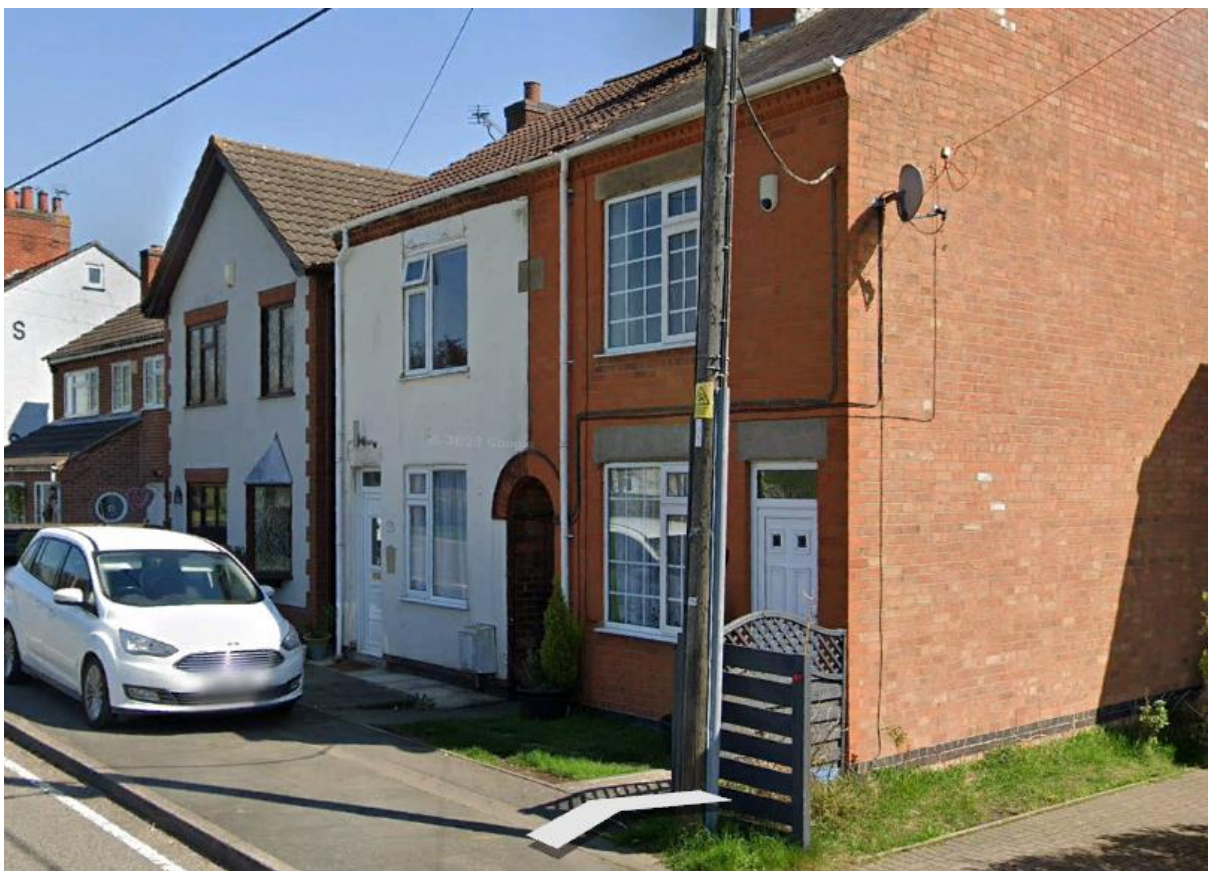
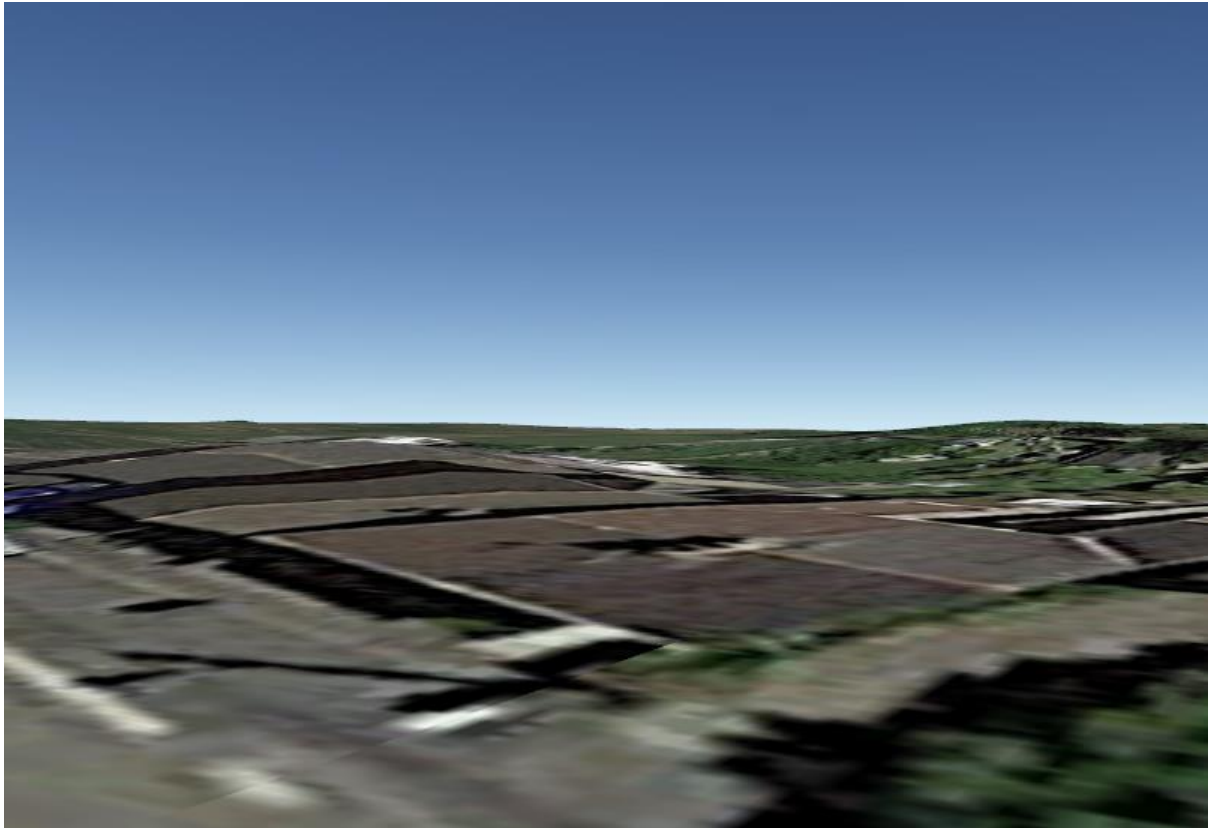


Road Receptors

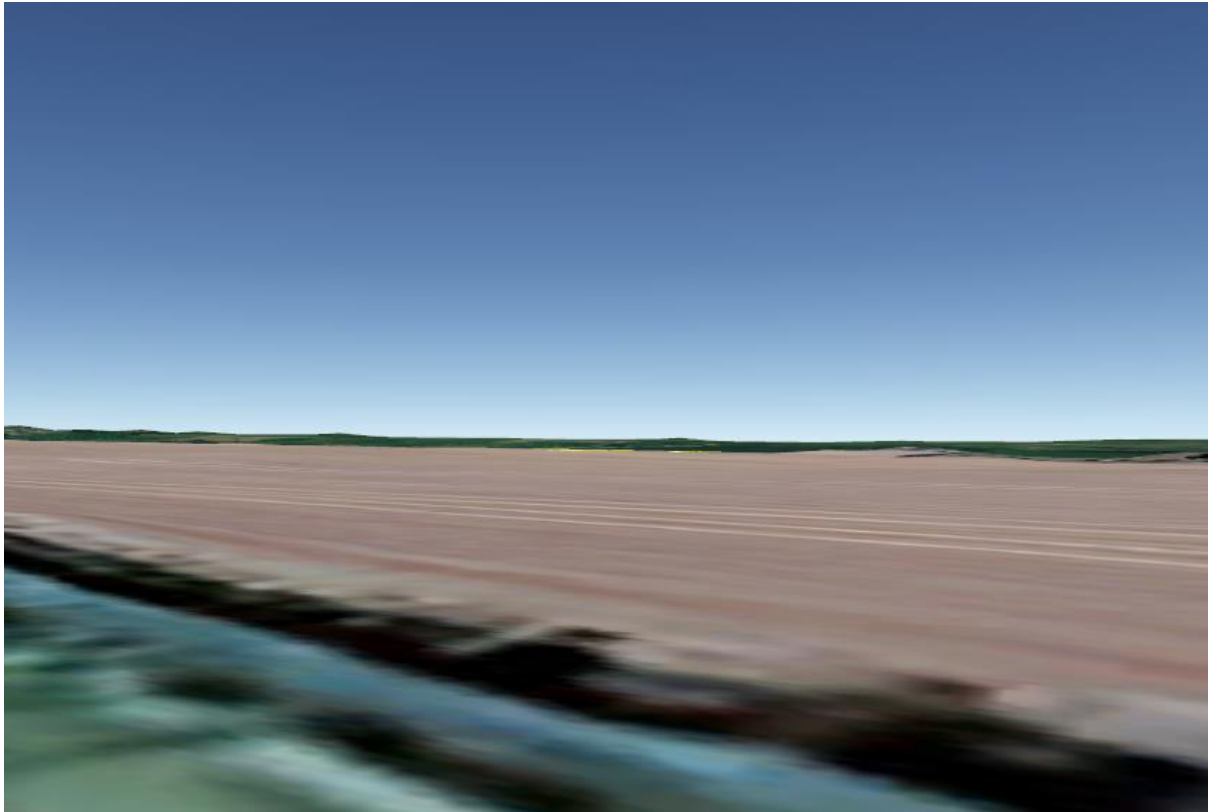
Receptor 1



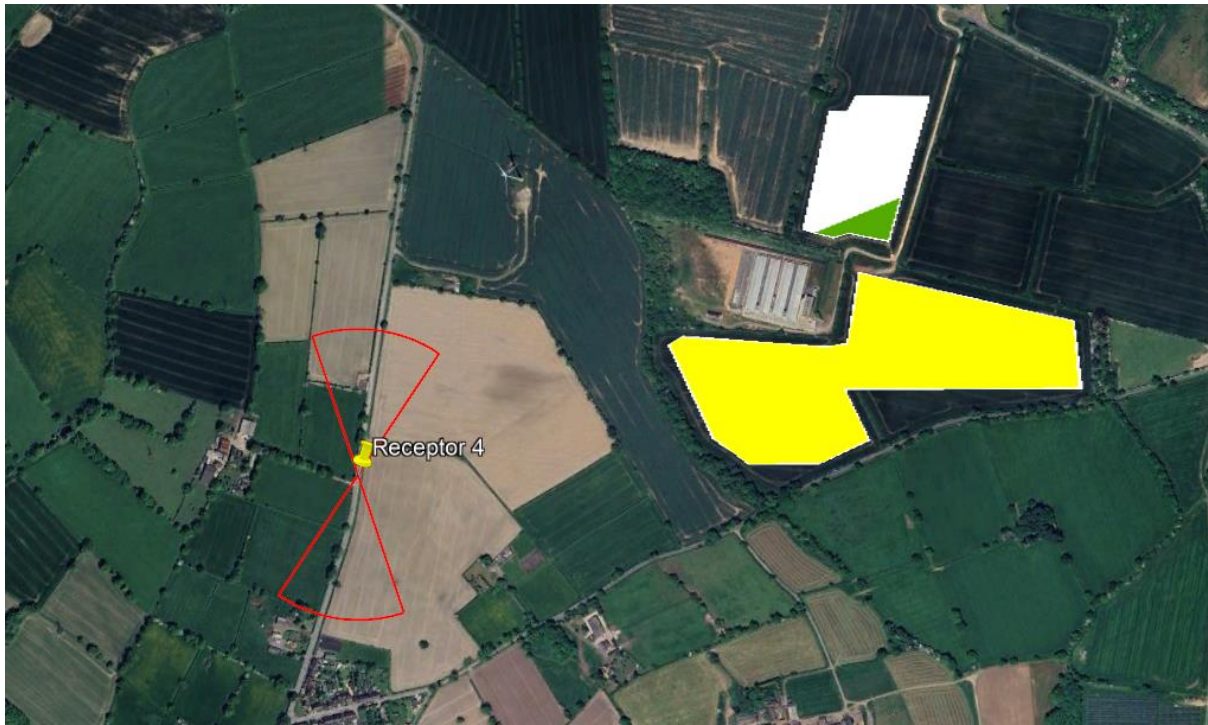
Receptor 2



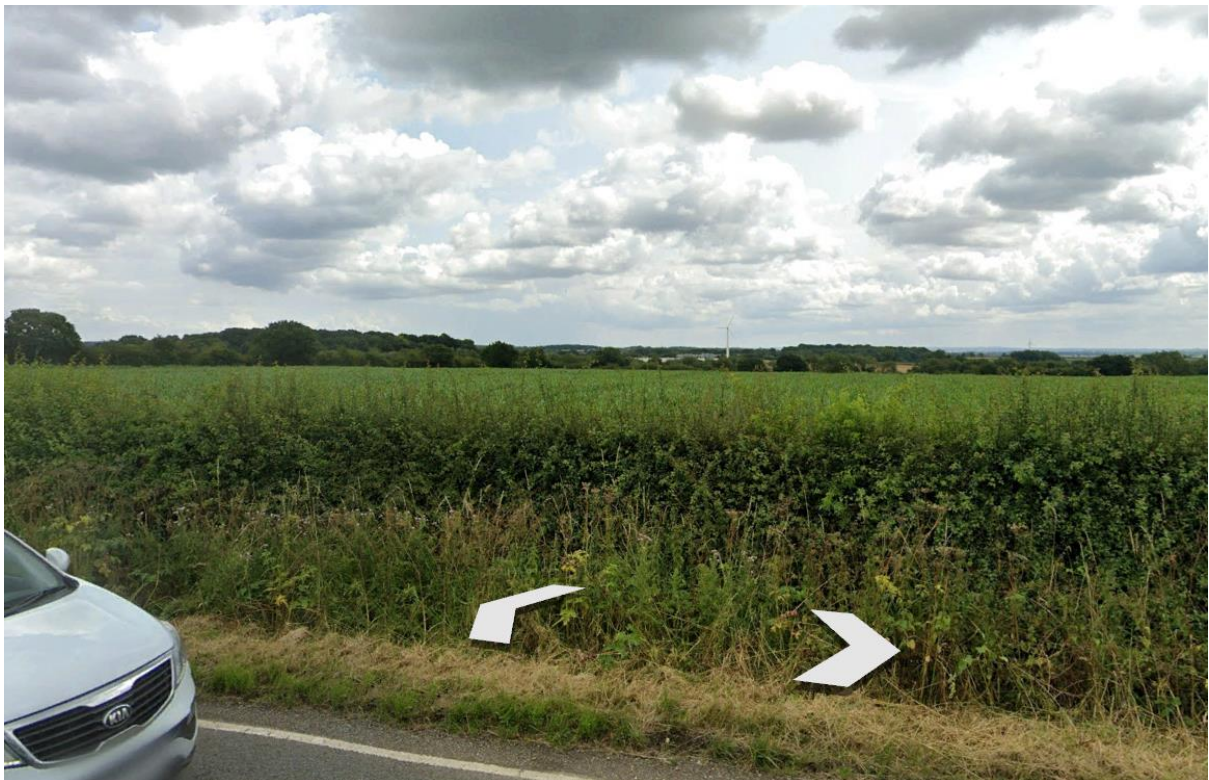
Receptor 3



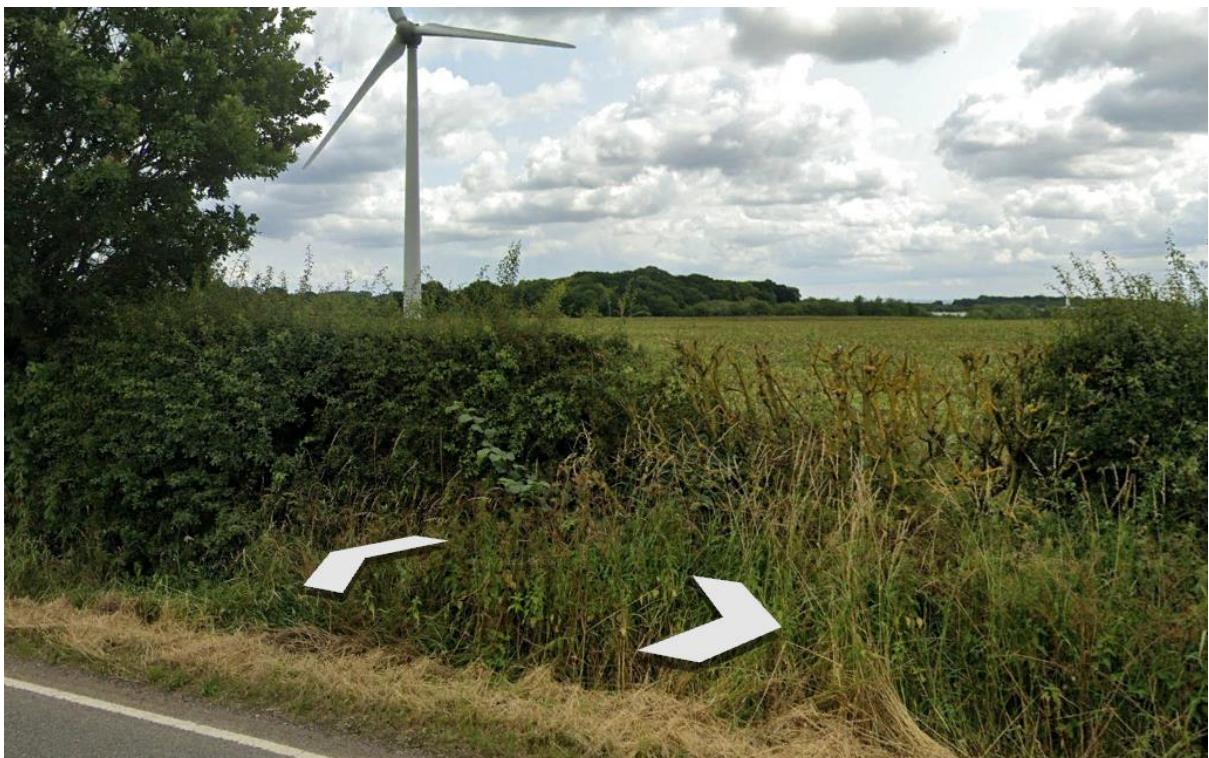
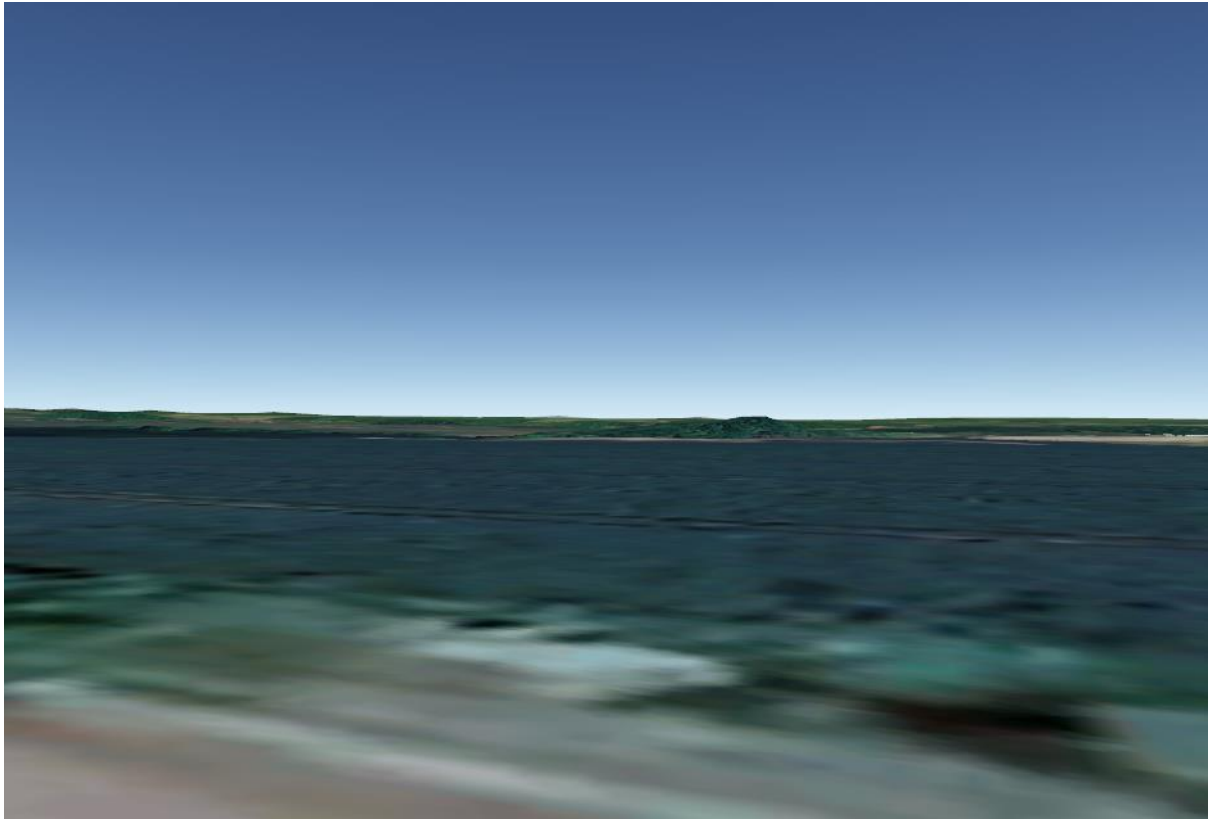
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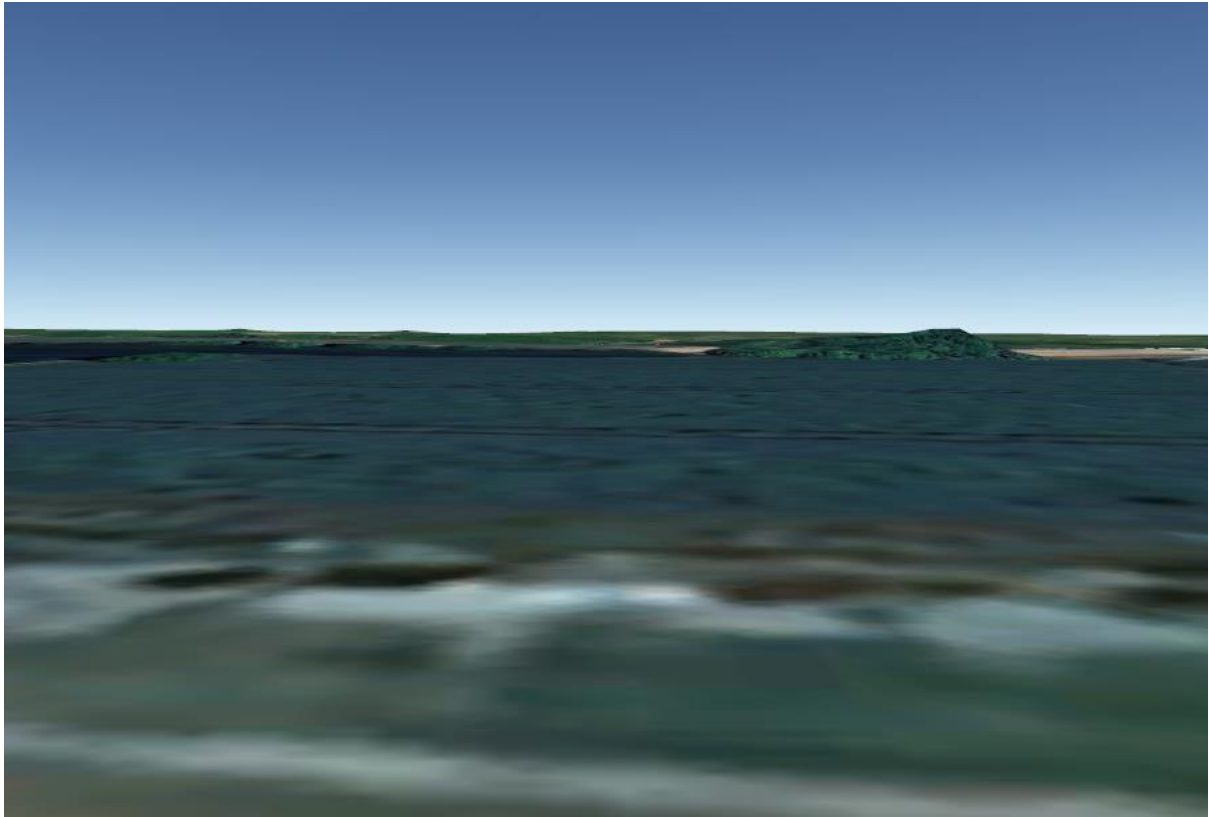
Receptor 5



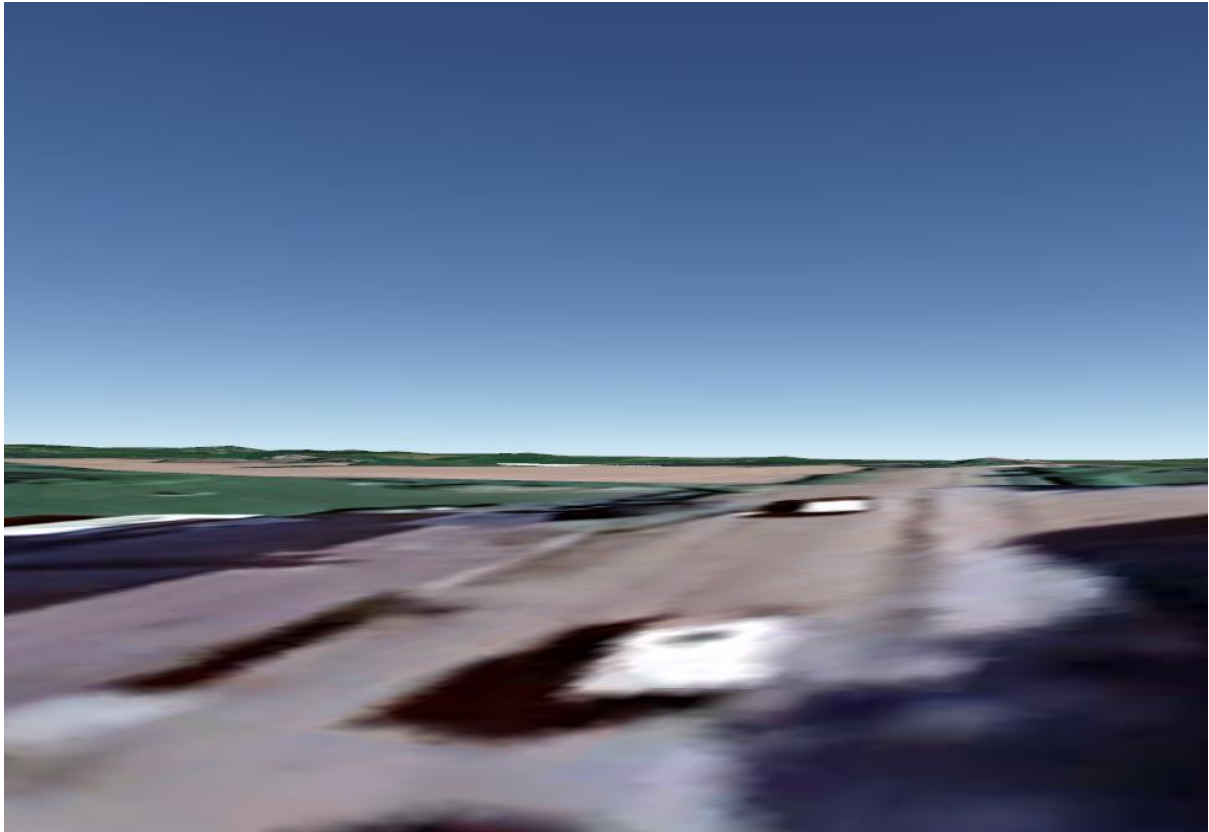
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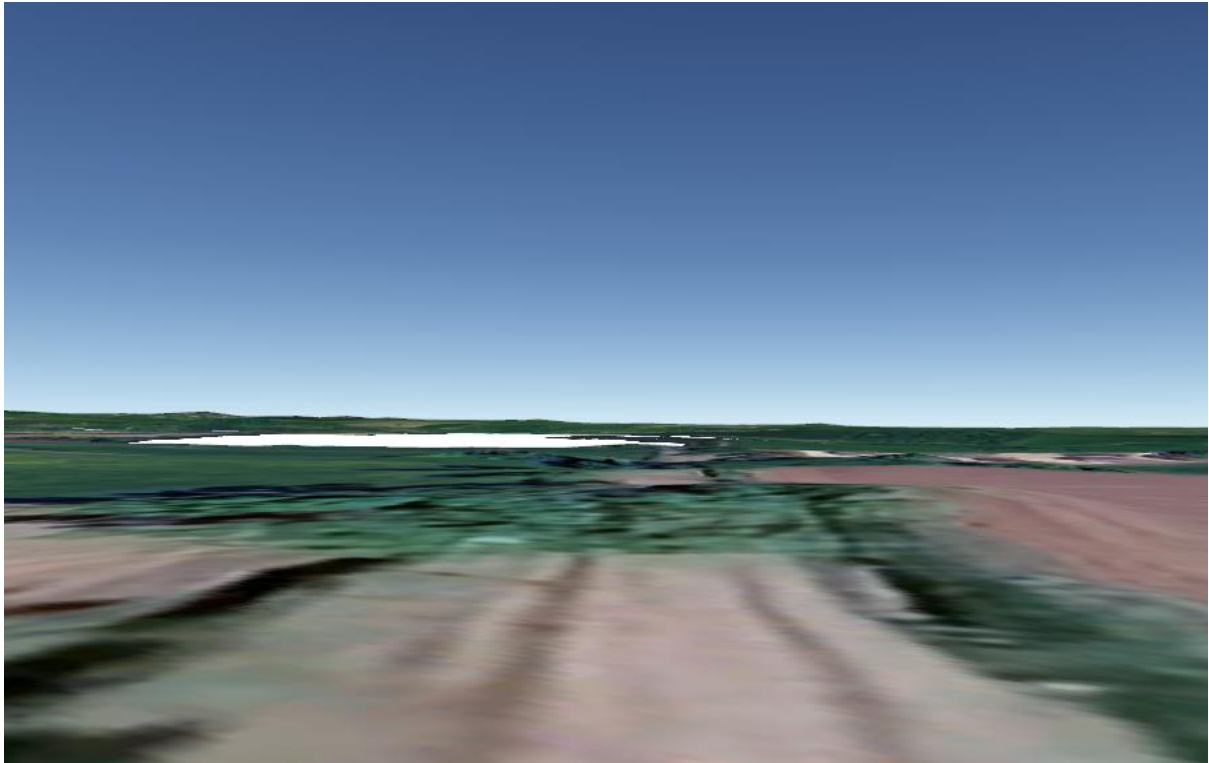
Receptor 7



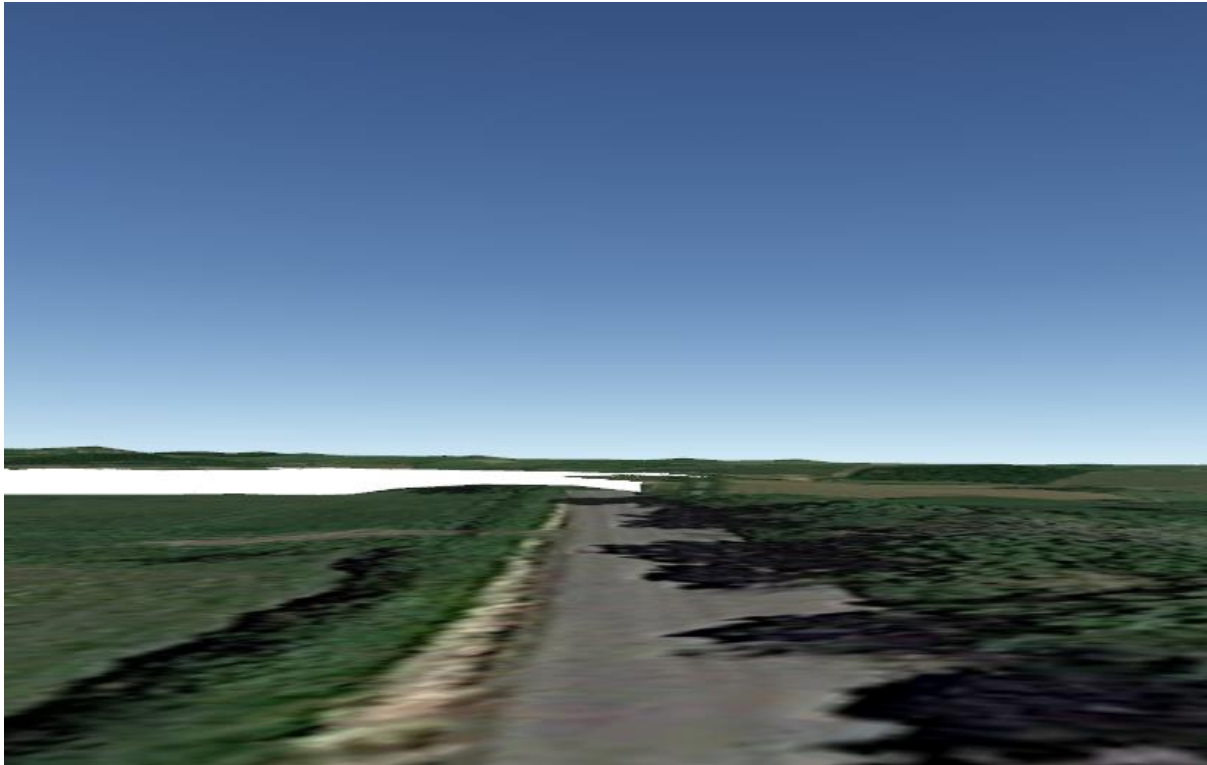
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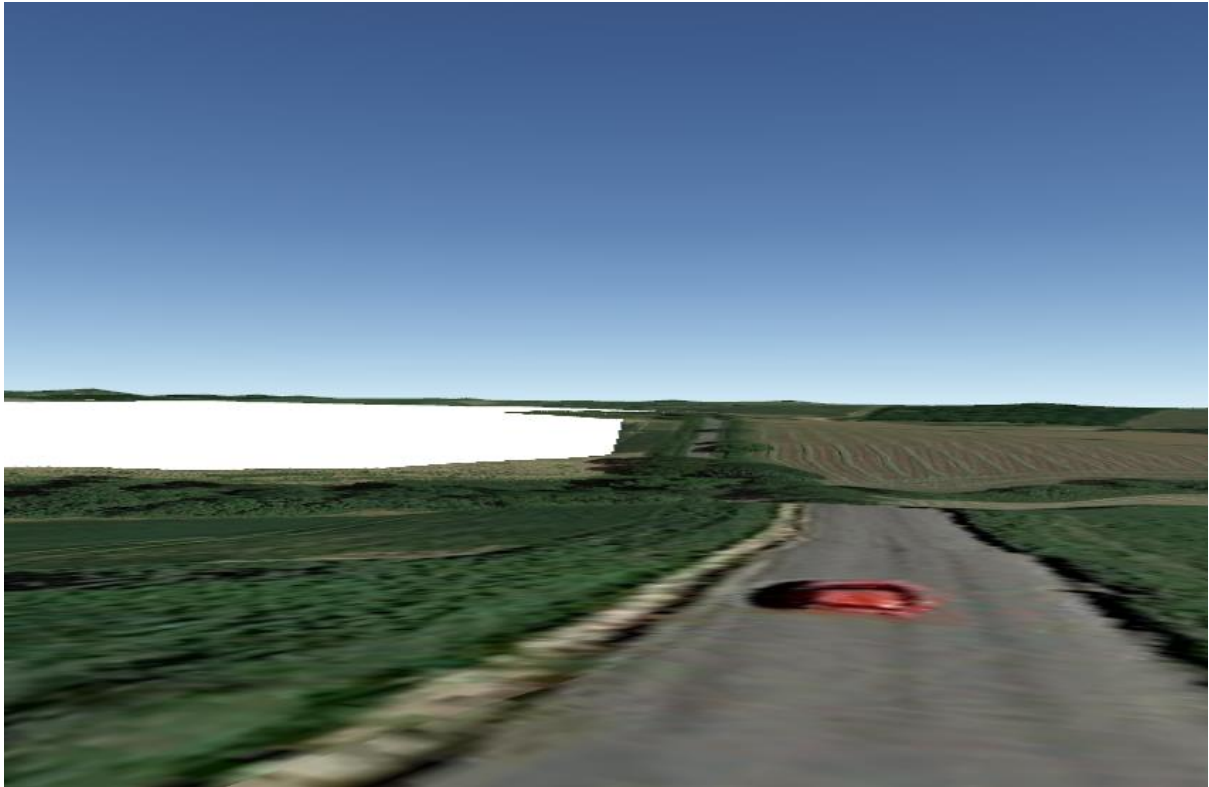
Receptor 11



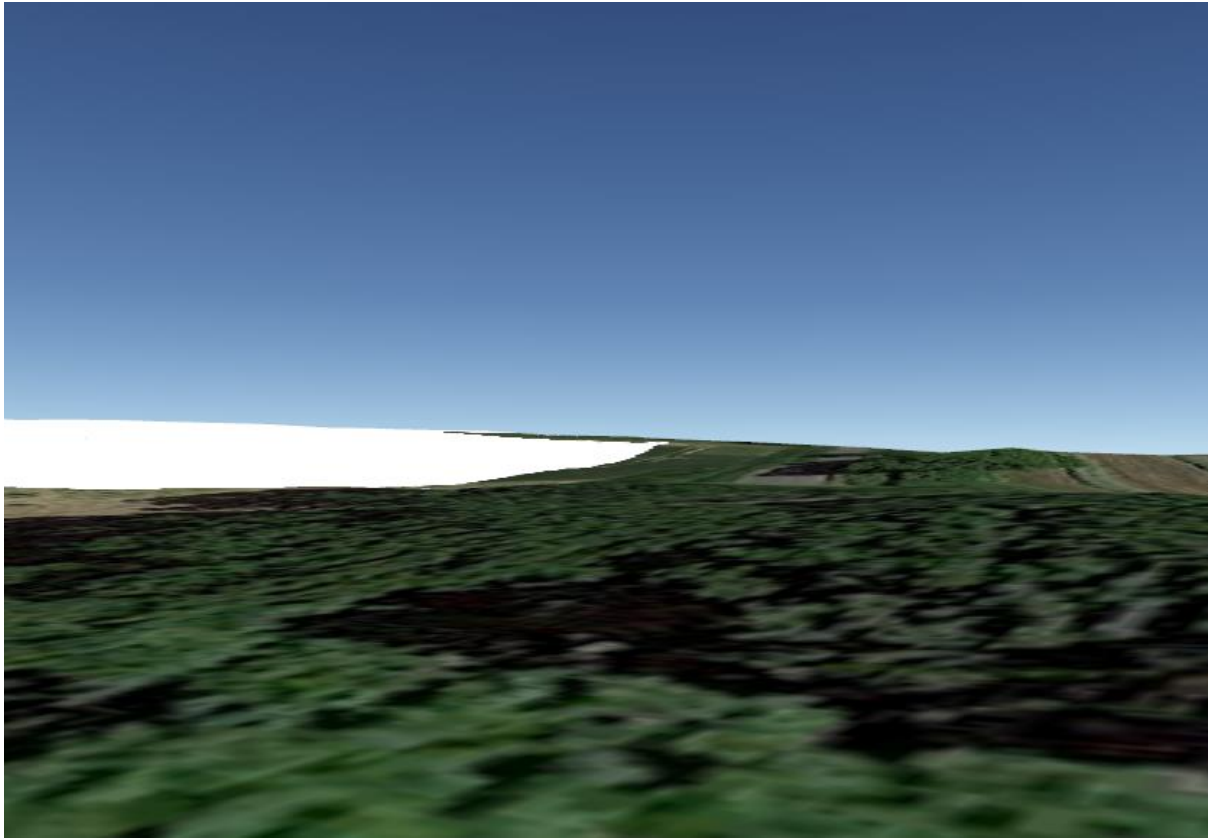
Receptor 12



Receptor 13

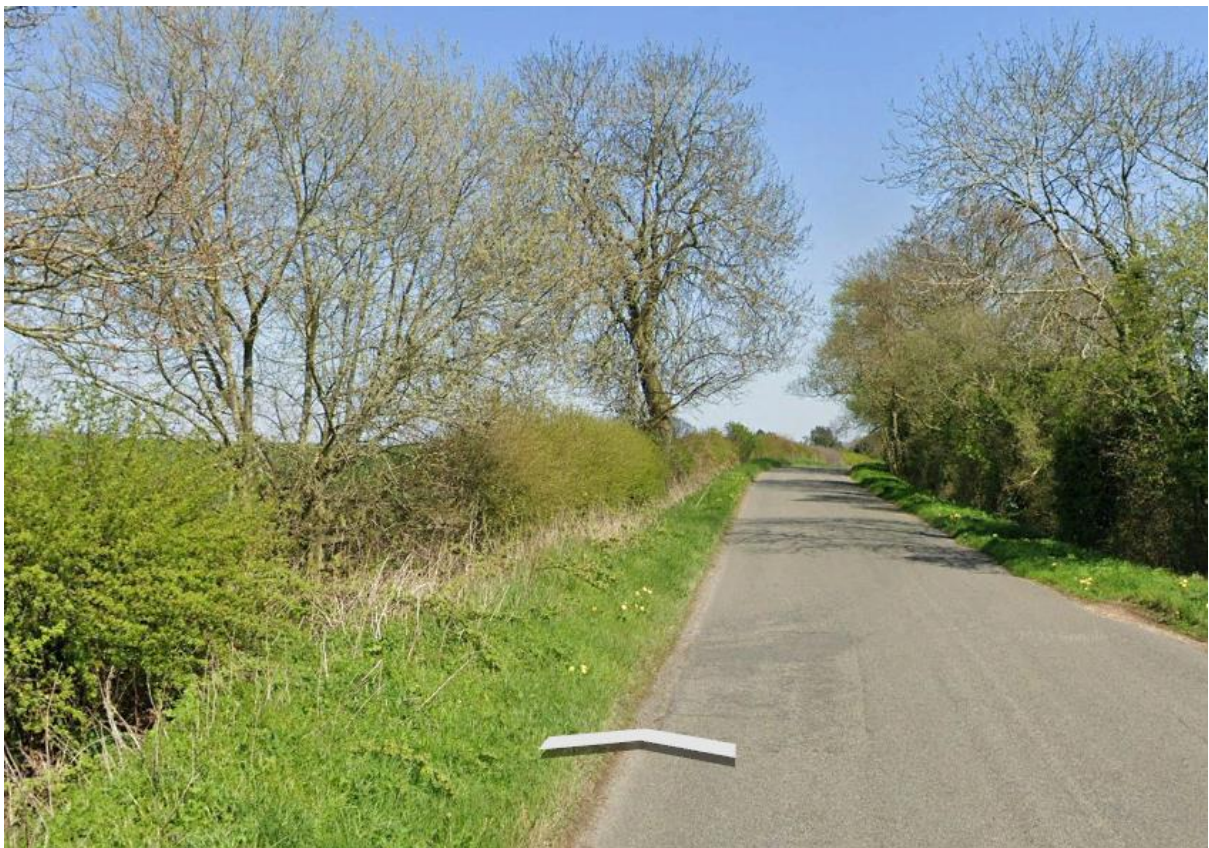
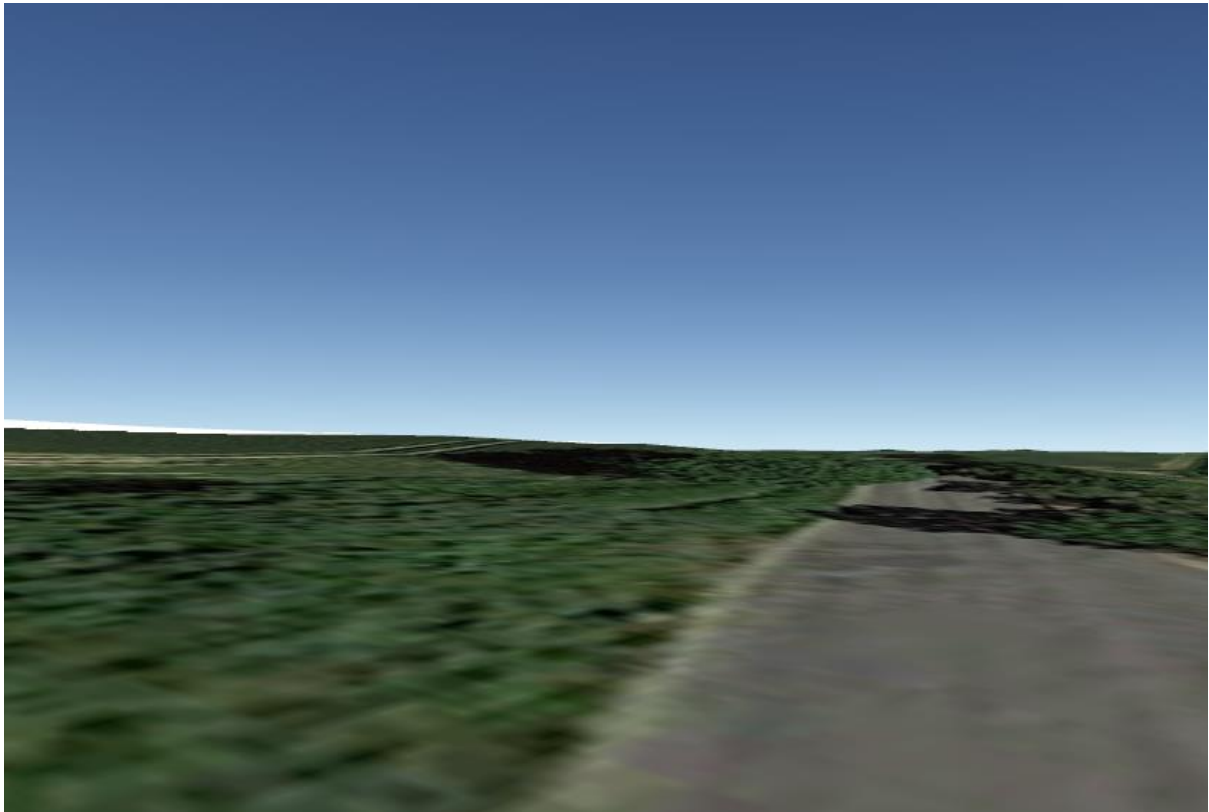


Receptor 14

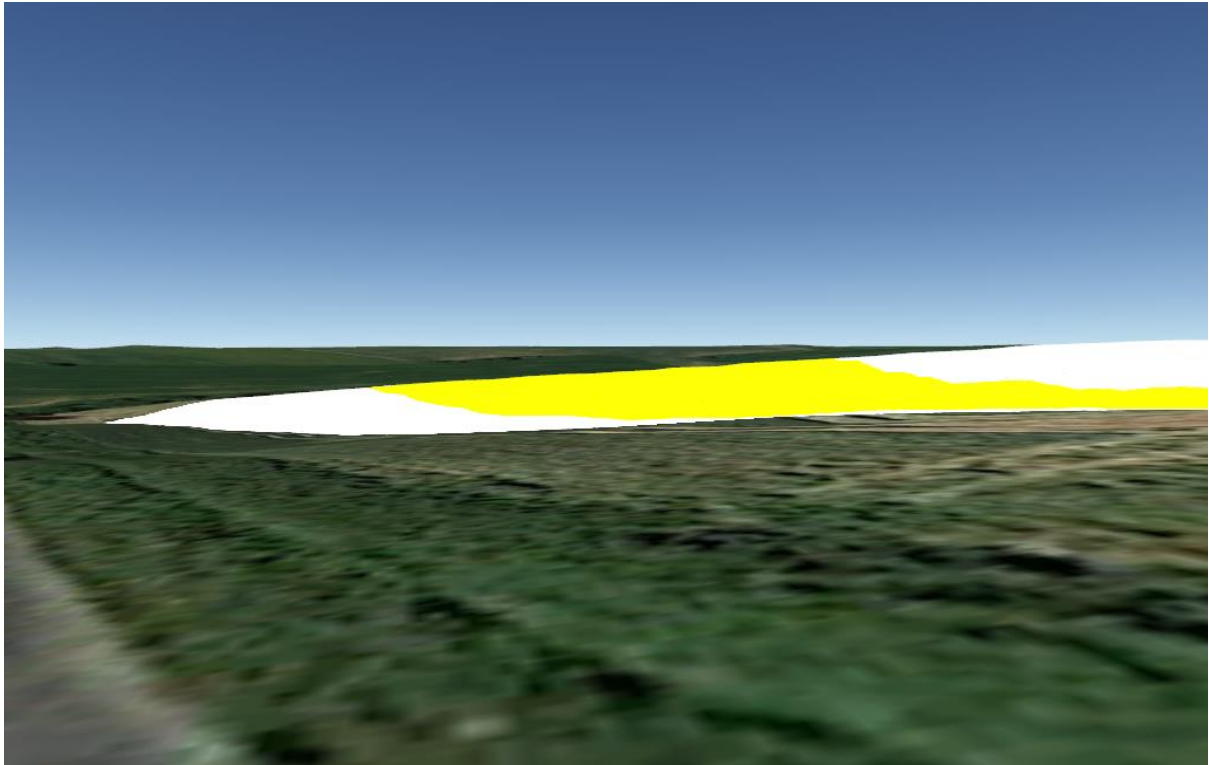


Receptor 15

Looking east

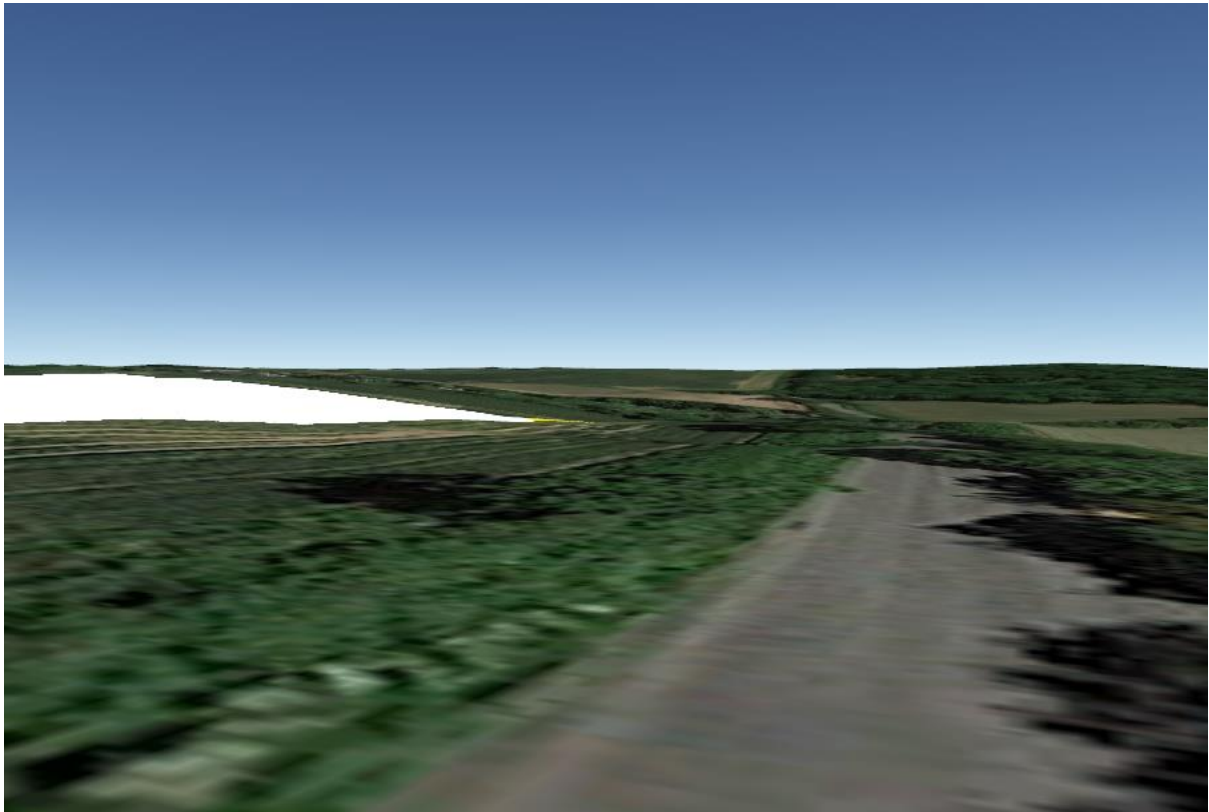


Looking west

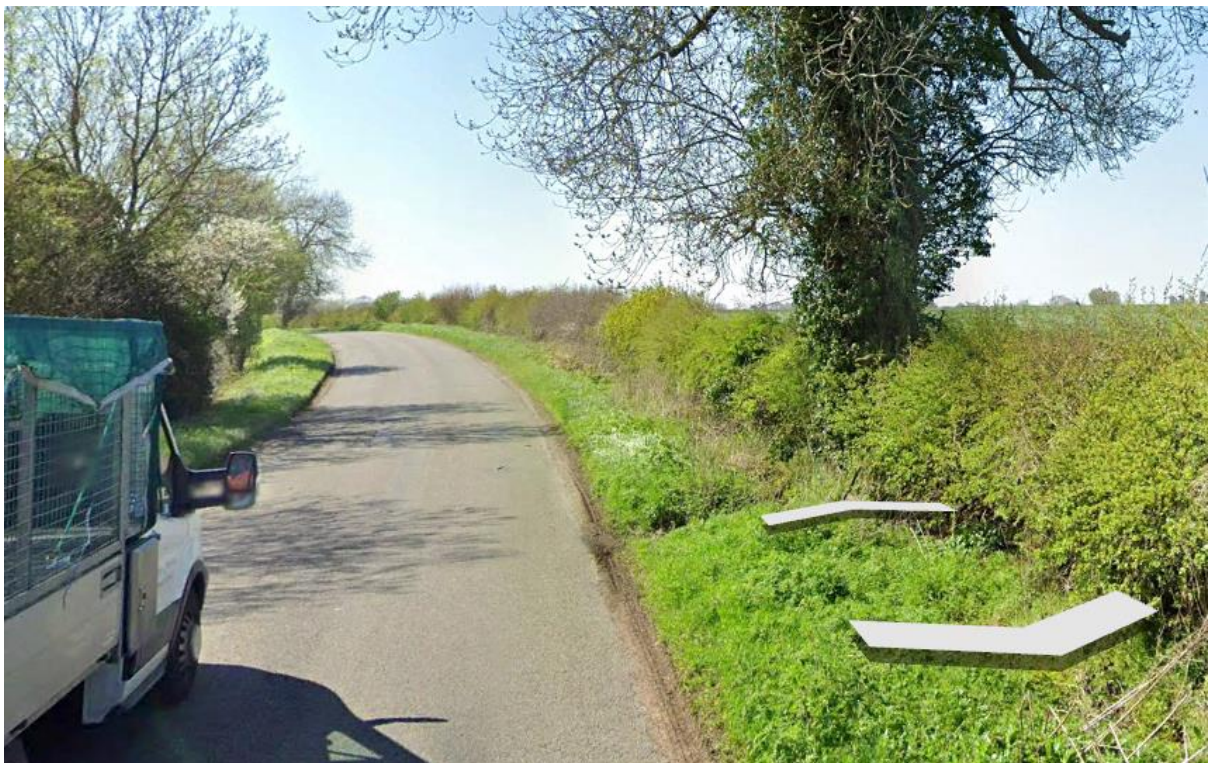
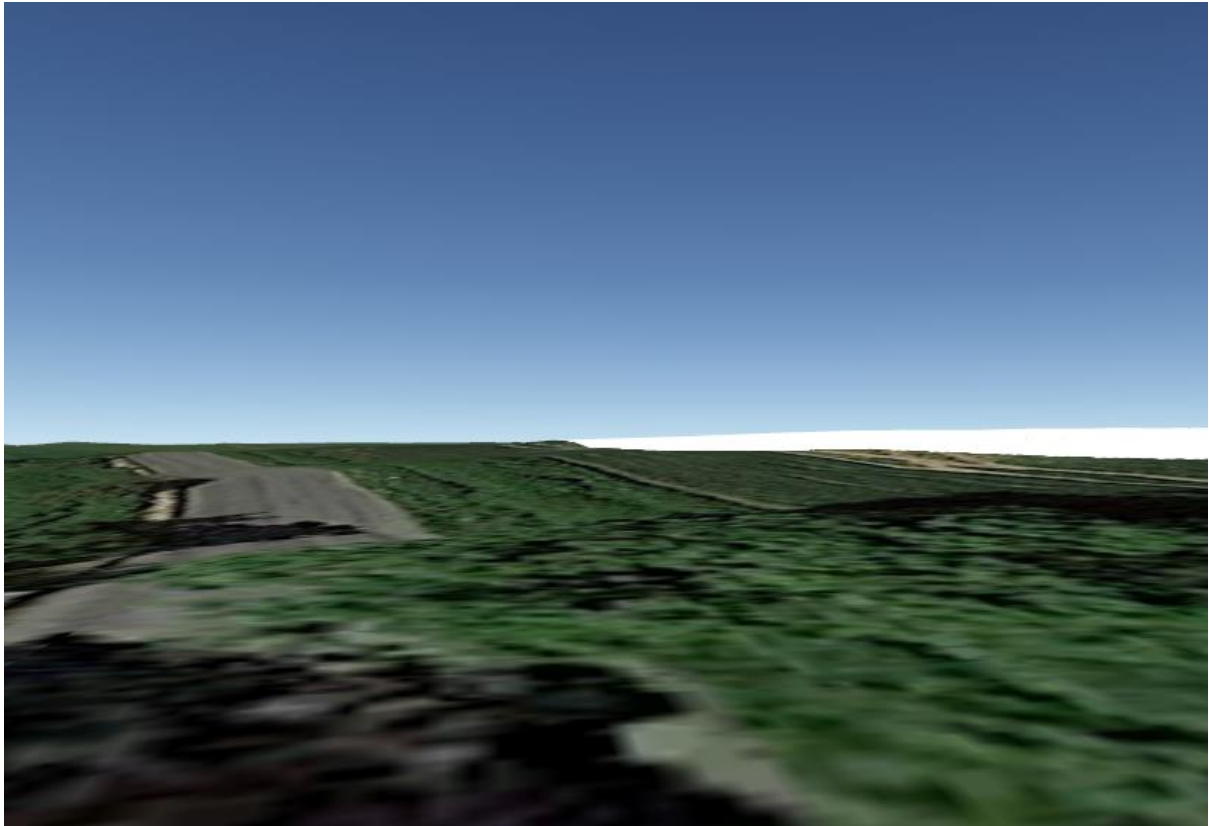


Receptor 16

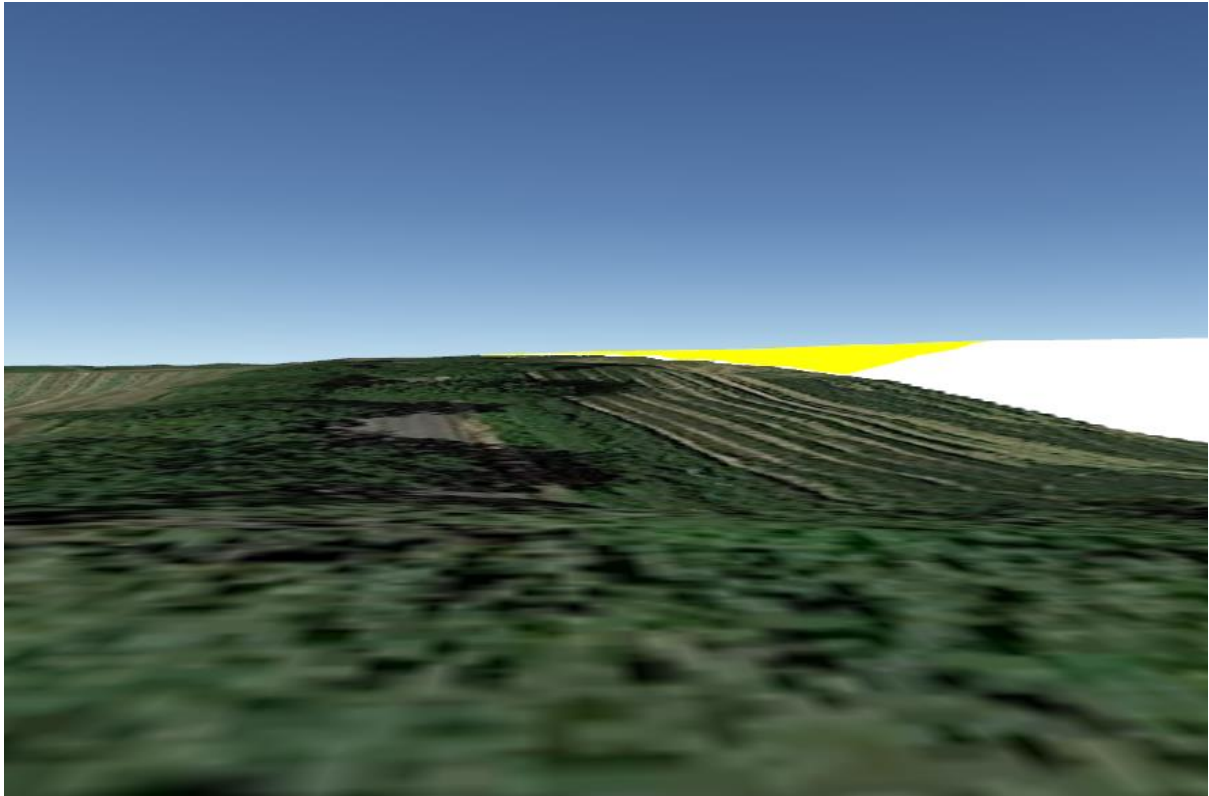
Looking east



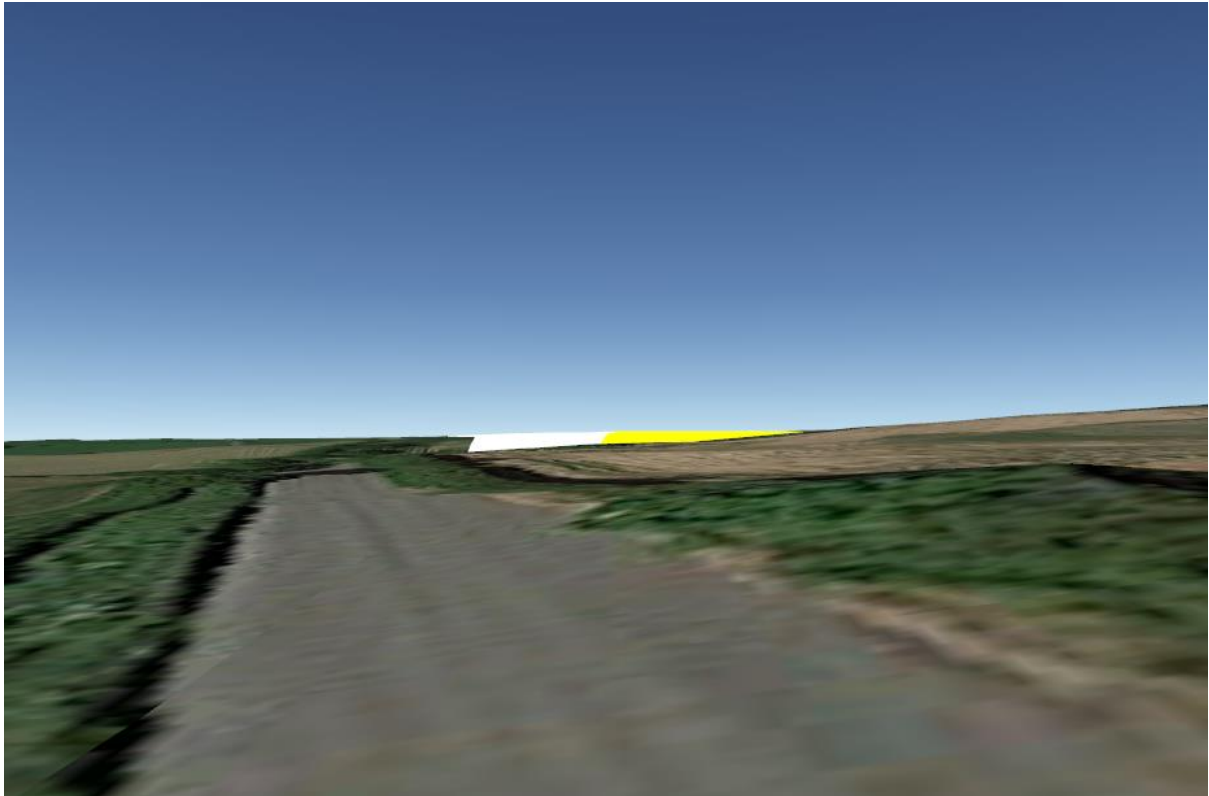
Looking west



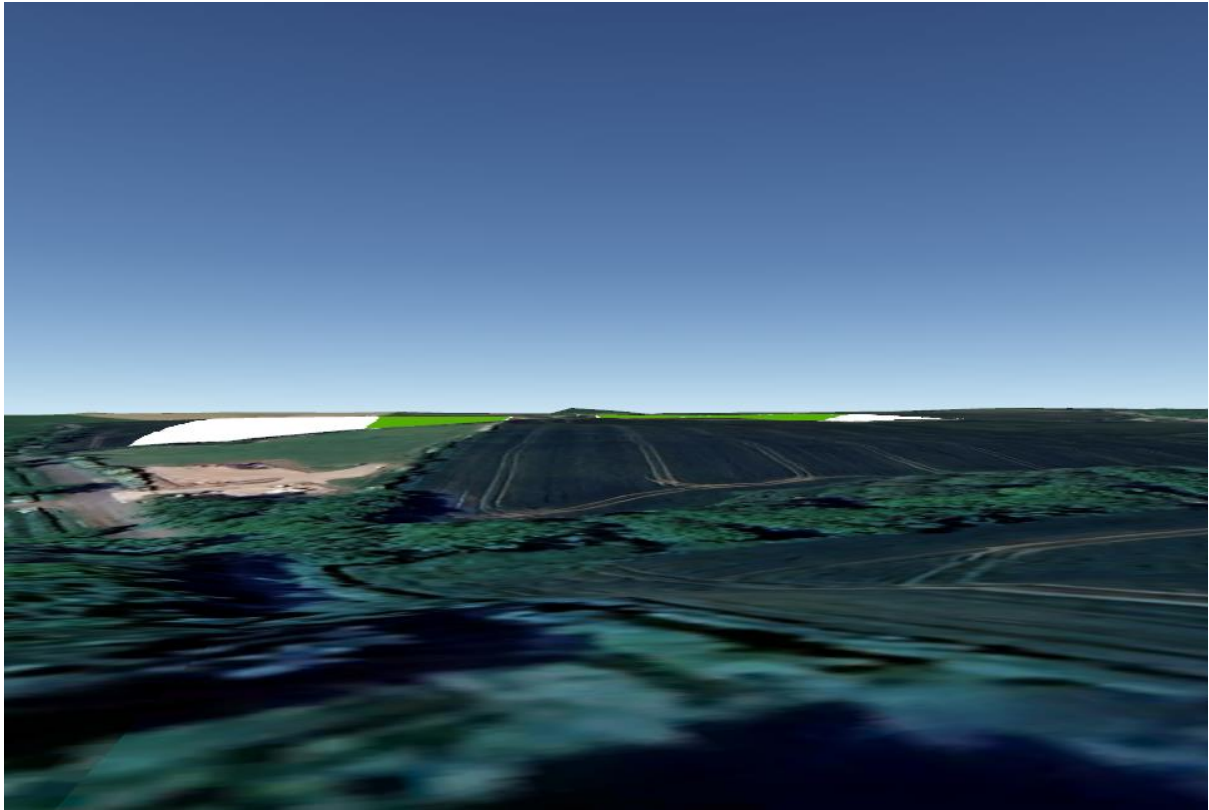
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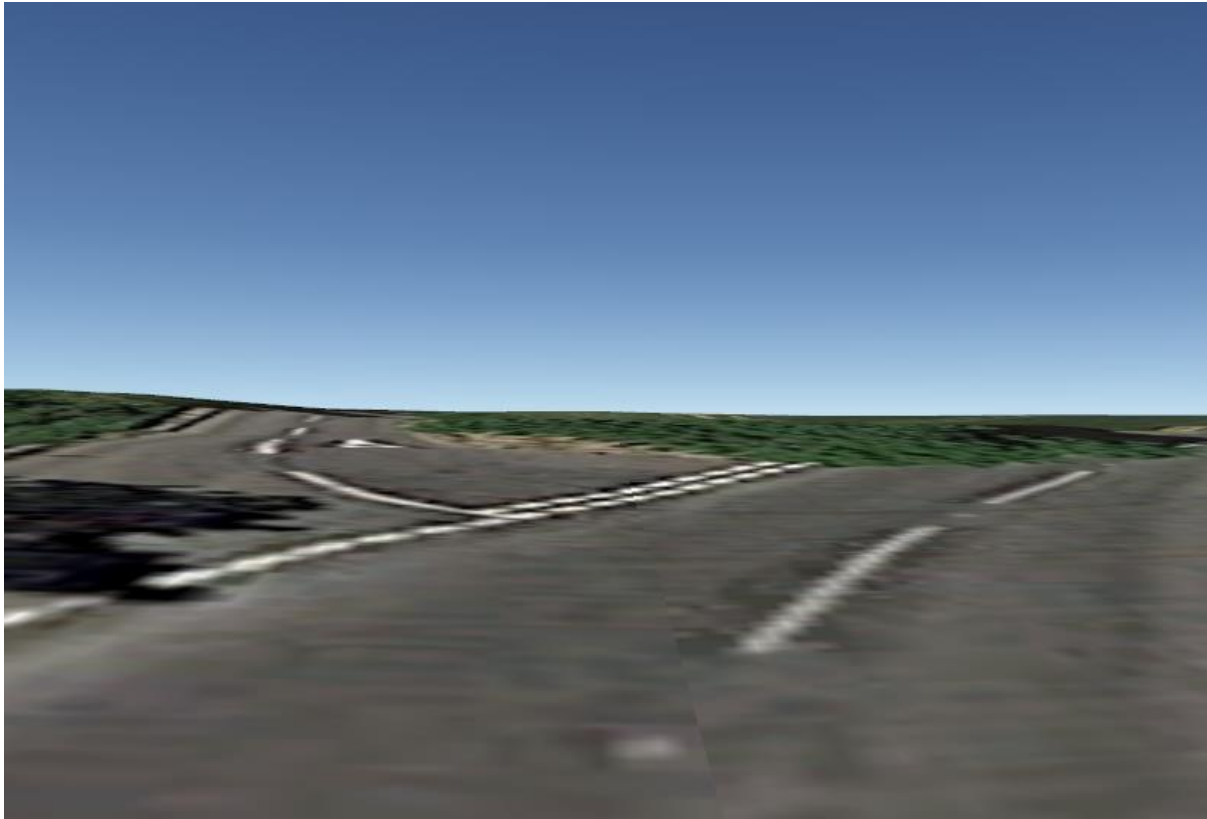
Receptor 18



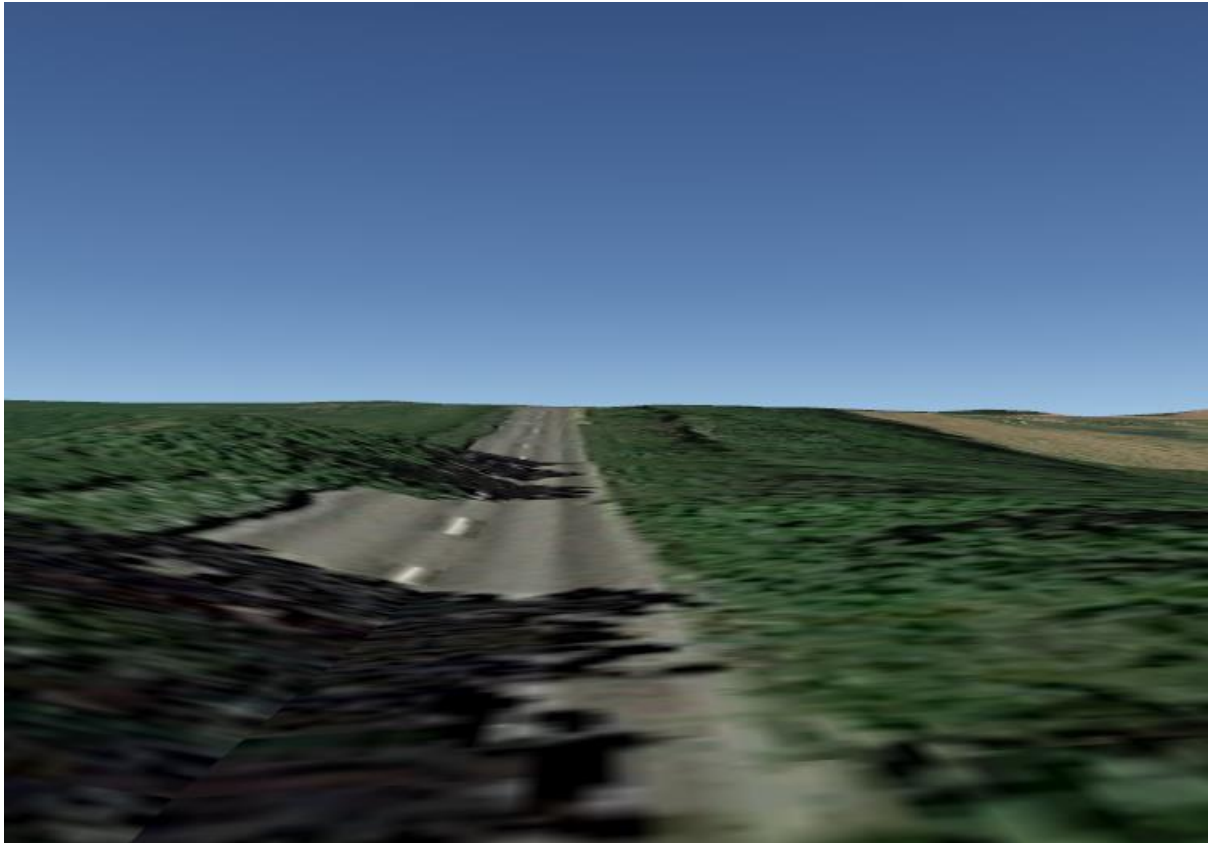
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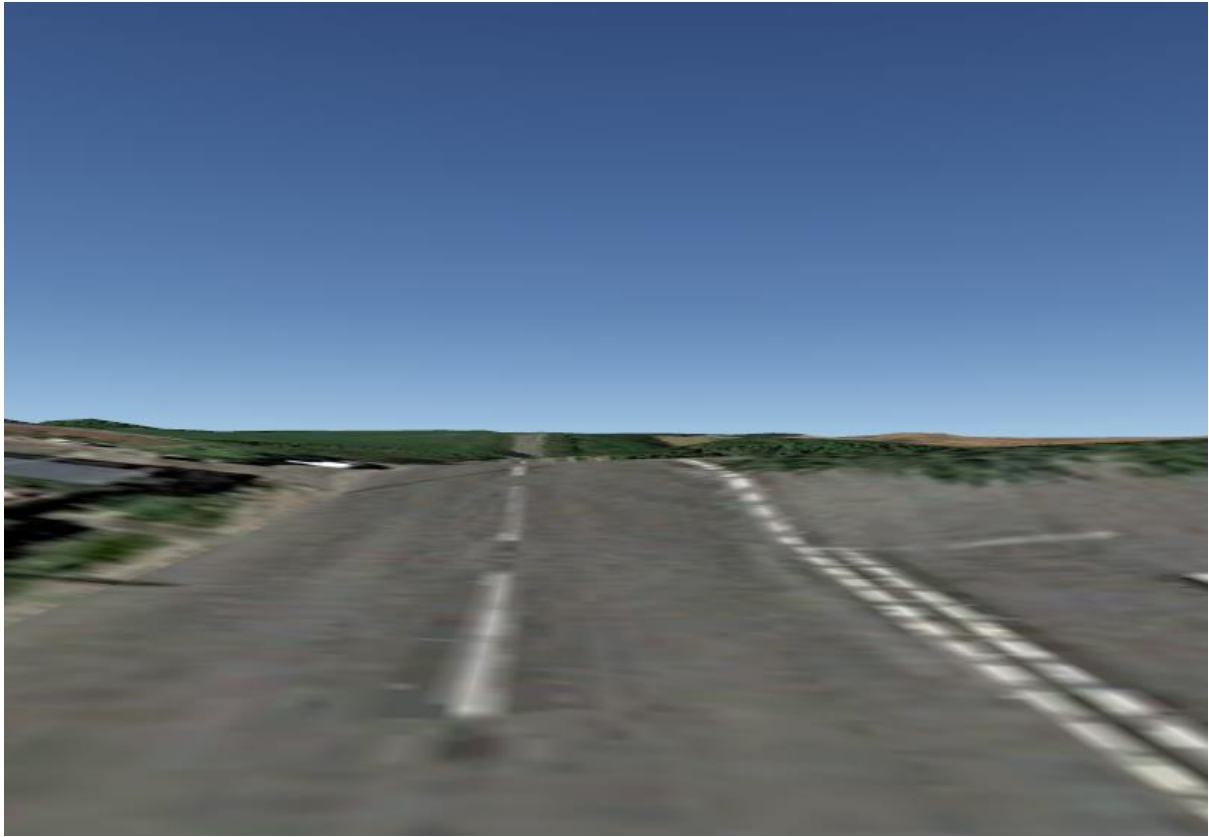
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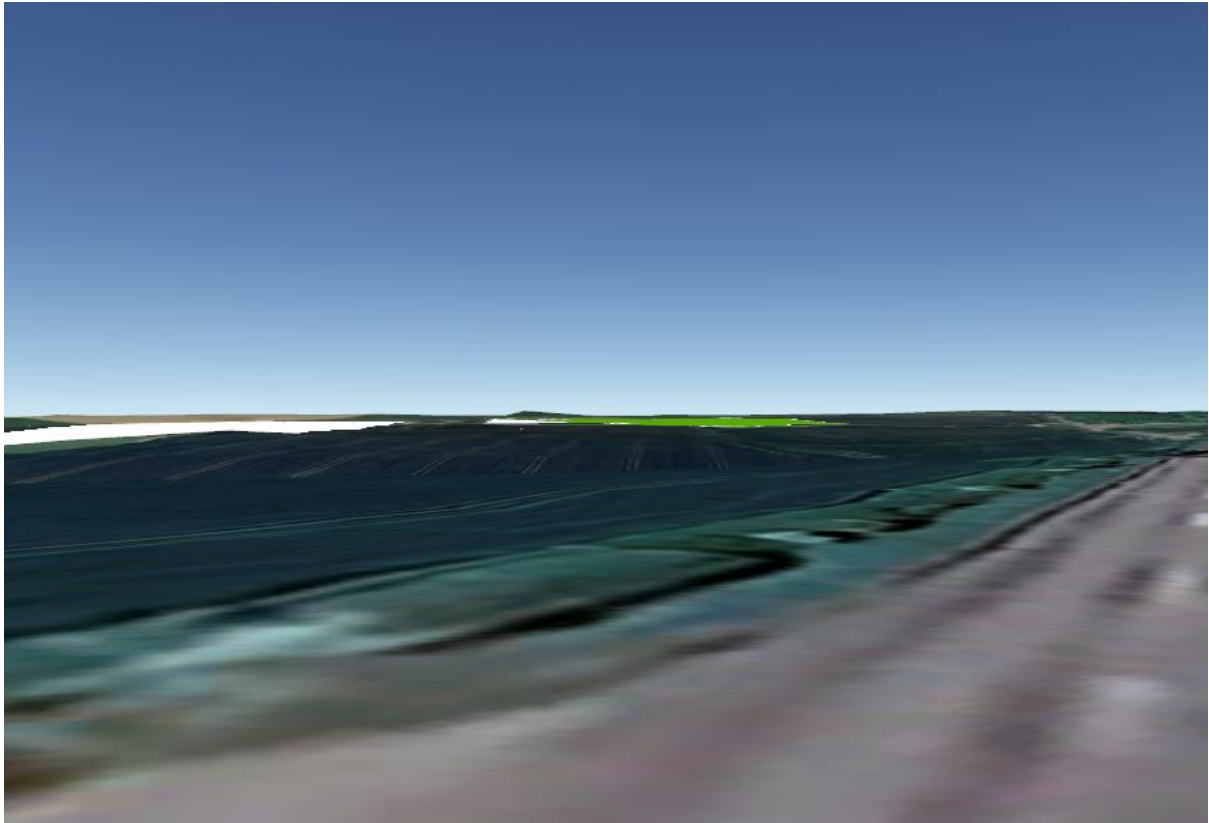
Receptor 21



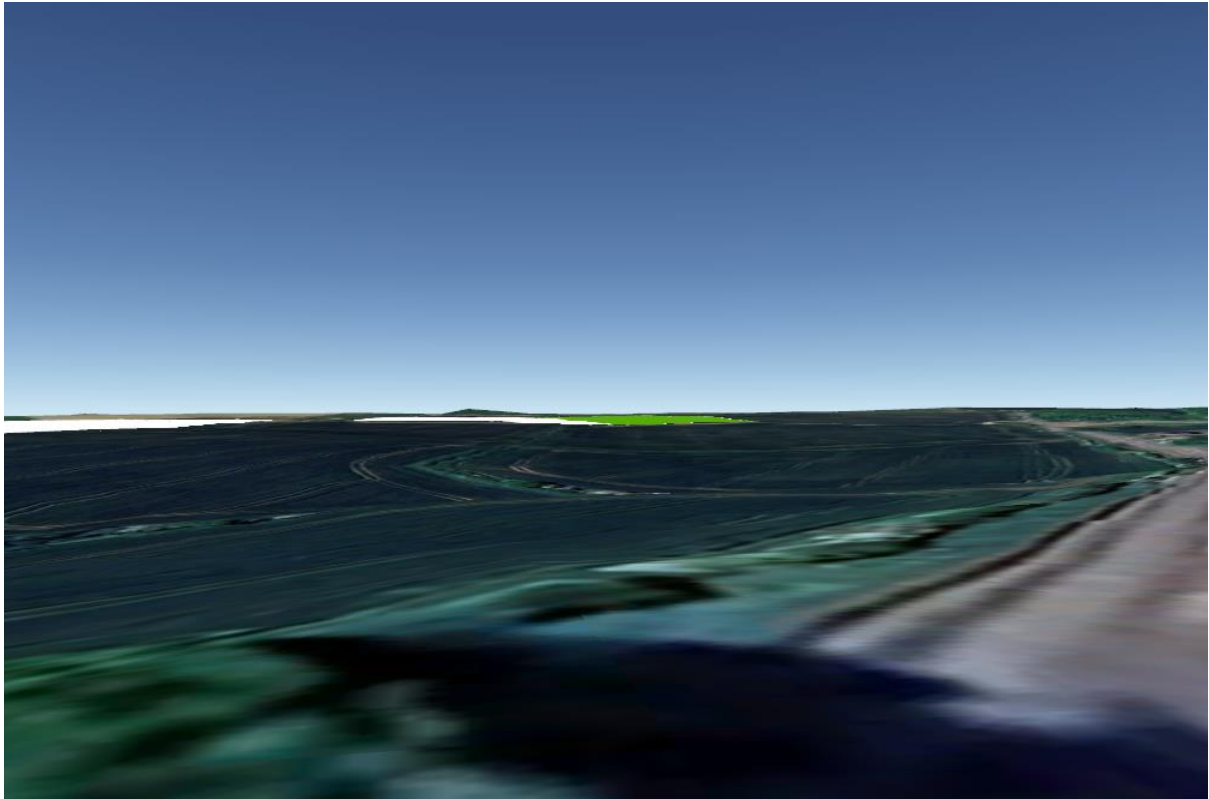
Receptor 22



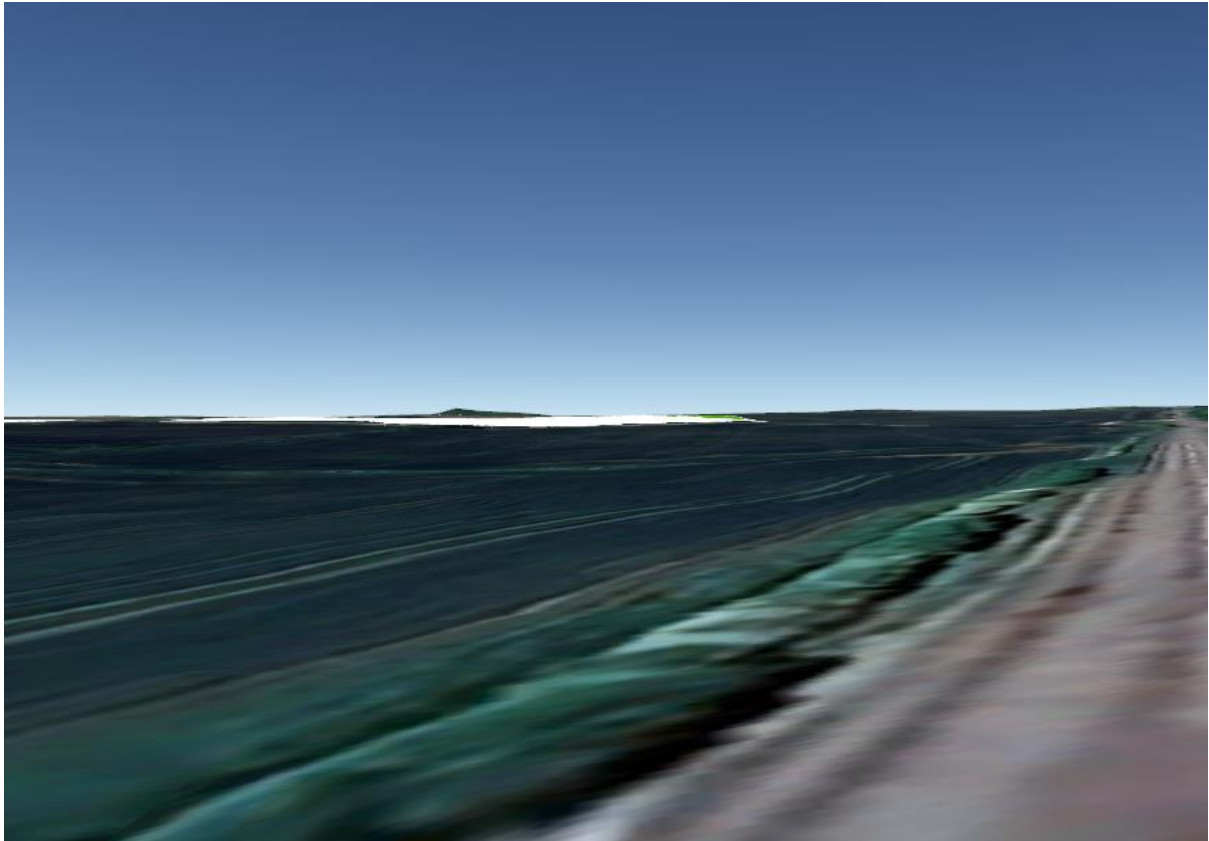
Receptor 23



Receptor 24



Receptor 25



Aviation

Leicester Airport Air Traffic Control Tower



Solar Module Glare and Reflectance Technical Memo



Technical Notification

TITLE: SunPower Solar Module Glare and Reflectance

AUTHORS: Technical Support

APPLICATION: Residential/ Commercial

SCOPE: SunPower Modules

SUMMARY:

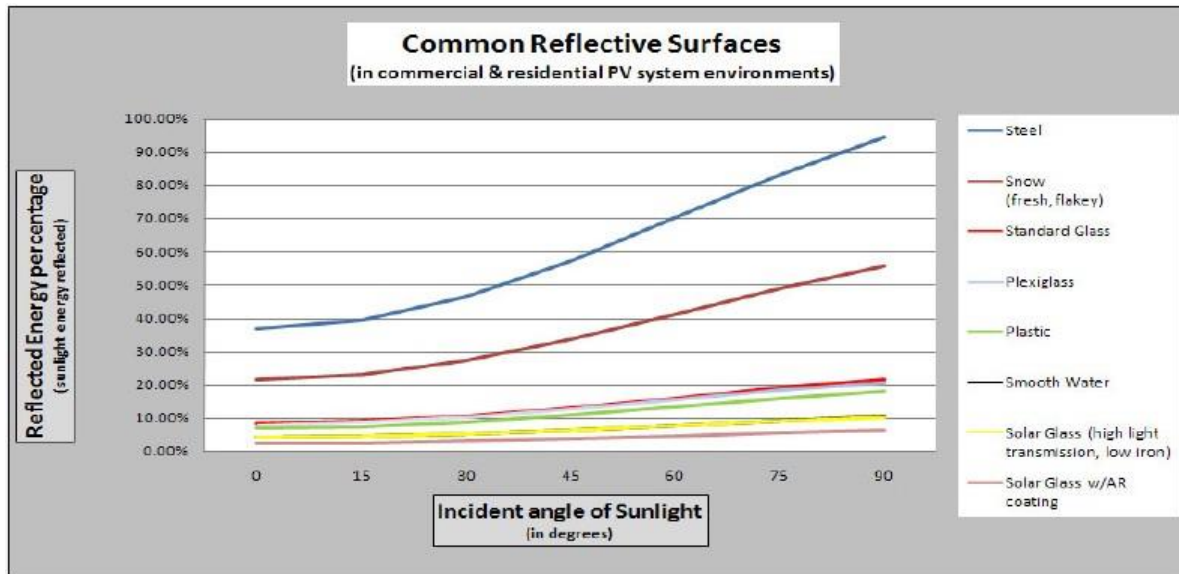
The objective of this document is to increase awareness concerning the possible glare and reflectance impact of PV Systems on their surrounding environment.

The glare and reflectance levels from a given PV system are decisively lower than the glare and reflectance generated by the standard glass and other common reflective surfaces in the environments surrounding the given PV system. Concerning random glare and reflectance observed from the air: SunPower has several large projects installed near airports or on air force bases. Each of these large projects has passed FAA or Air Force standards and all projects have been determined as "No Hazard to Air Navigation". Although the possible glare and reflectance from PV systems are at safe levels and are usually decisively lower than other standard residential and commercial reflective surfaces, SunPower suggests that customers and installers discuss any possible concerns with the neighbors/cohabitants near the planned PV system installation.

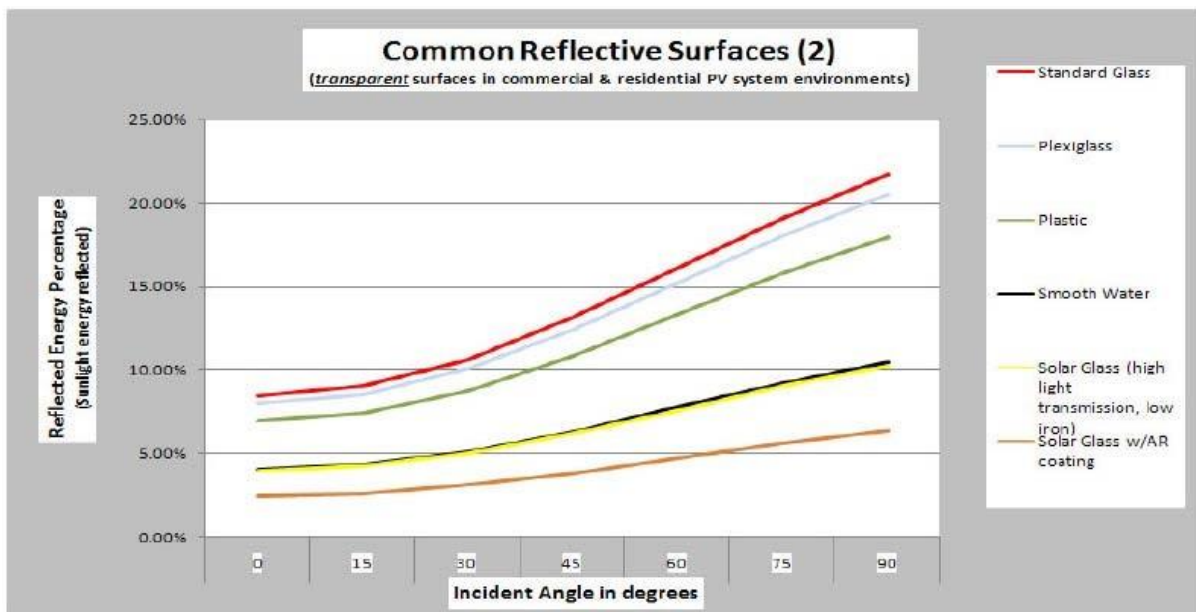
DETAILED EXPLANATION:

In general, since the whole concept of efficient solar power is to absorb as much light as possible while reflecting as little light as possible, standard solar module produces less glare and reflectance than standard window glass. This is pointed out very well in US Patent #6359212 which explains the differences in the refraction and reflection of solar module glass versus standard window glass. Solar modules use "high-transmission, low iron glass" which absorbs more light, producing small amounts of glare and reflectance than normal glass.

In the graph below, we show the reflected energy percentages of sunlight, of some common residential and commercial surfaces. The legend and the graph lists the items from top to bottom in order of the highest percentage of reflected energy.



It should be noted that the reflected energy percentage of Solar Glass is far below that of a standard glass and more on the level of smooth water. Also, below are the ratios of the common reflective surfaces:



Light beam physics resolves that the least amount of light is reflected when the beam is the normal, in other words, least light energy is reflected when the beam is at 0 degrees to the normal. The chart below is a result of light beam physics calculations:

Common Reflective Surfaces (in surrounding environments for PV systems)		Incident angle in degrees						
		0	15	30	45	60	75	90
Material Reflectivity (percent of incident light reflected)	Steel	36.73%	39.22%	46.34%	57.11%	70.02%	83.15%	94.40%
	Snow (fresh, flakey)	21.63%	23.09%	27.29%	33.63%	41.23%	48.96%	55.59%
	Standard Glass	8.44%	9.01%	10.65%	13.12%	16.09%	19.10%	21.69%
	Plexiglass	8.00%	8.54%	10.09%	12.44%	15.25%	18.11%	20.56%
	Plastic	6.99%	7.46%	8.82%	10.87%	13.33%	15.83%	17.97%
	Smooth Water	4.07%	4.35%	5.14%	6.33%	7.76%	9.22%	10.47%
	Solar Glass (high light transmission, low iron)	3.99%	4.26%	5.03%	6.20%	7.61%	9.03%	10.26%
	Solar Glass w/AR coating	2.47%	2.64%	3.12%	3.84%	4.71%	5.59%	6.35%

(Note: Index of refraction values may vary slightly depending on suppliers and reference documentation. The values for the above calculations are averages or single values obtained from the list of references for this document).

Important reference – “Stipples glass”: In addition to the superior refractive/reflective properties of solar glass versus standard glass, SunPower uses stippled solar glass for our modules. Stippled glass is used with high powered telescopes and powerful beacons and lights. The basic concept behind stippling is for the surfaces of the glass to be textured with small types of indentations. As a result, stippling allows more light energy to be channeled/ transmitted through the glass while diffusing the reflected light energy. This concept is why the reflection of off a SunPower solar module will look hazy and less-defined than the reflection from standard glass, this occurs because the stippled SunPower glass is transmitting a larger percentage of light to the solar cell while breaking up the intensity of the reflected light energy.

SUMMARY/ACTION REQUIRED:

The studies, data and light beam physics behind the charts and graphs prove beyond a reasonable doubt that solar glass has less glare and reflectance than standard glass. The figures also make it clear that the difference is very decisive between solar glass and other common residential/commercial glasses. In addition, not to be lost in the standard light/glass equations and calculations, the SunPower solar glass is stippled and has a very photon-absorbent solar cell attached to the back side, contributing two additional factors which results in even less light energy being reflected.

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