VISIBILITY MAPPING FOR WINDFARM DEVELOPMENT – THE SCOTTISH BORDERS

A study to investigate areas where the development of windfarms is likely to be most visually intrusive in the Scottish Borders

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The contract report has been scrutinised by a fully qualified and experienced senior staff member of the Macaulay Institute and approved by the Executive Chairman or Chief Operating Officer of MEL . It is a confidential report between MEL and the client.

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EXECUTIVE SUMMARY

The aim of this project is to undertake geographic modelling of factors required to produce "prospecting maps" for wind turbines. This is to aid the Scottish Borders Council in directing developers to potentially suitable sites before the preparation of planning proposals for developments.

The objectives of the project were defined as follows:

- Prepare visibility maps for the Scottish Borders to show the areas of land upon which a wind turbine would be visible from residential property. The assumed height of turbine to be 100 m to tip of blade. The extent of the area of interest was the Scottish Borders area plus a buffer zone of 2.5 km beyond its boundaries. The maps were to use the Ordnance Survey's (OS) 1:250,000 scale raster base map (Ordnance Survey 2003a).
- The maps were to be colour coded to show the distance from the nearest observer with ranges having increments of 2.5 km (2.5, 5.0, 7.5 and 10 km).
- One set of maps was to be prepared, showing visibility from settlements.
- A second set of maps was to be prepared, that accounts for all residential properties.
- For each set, calculations will be made using two observer heights, 1.8 m to represent adult head height and 5.0 m to represent views from a first floor window.
- For each observer height two elevation models were to be used. One would be the OS 1:50,000 scale Digital Terrain Model (DTM) data (Ordnance Survey 2003b), at a 50 m x 50 m resolution as the main input, and the same resolution for the output. The second would use a Digital Elevation Model (DEM), based on the DTM but adjusted to account for woodland. Natural, semi-natural and plantation woodland was identified using the Land Cover of Scotland 1988 (LCS88) dataset (MLURI, 1993). These areas were "raised" by the addition of 20 m to ground level at that location. Areas of scrub woodland were also identified and were raised by 5 m.

These objectives resulted in eight maps showing the visibility of potential wind turbines in the Scottish Borders region.

The main settlements in the area were identified using a dataset provided by Scottish Borders Council. Other individual and outlying properties were identified by using OS AddressPoint data (Ordnance Survey 2003c). Commercial properties and businesses were excluded. The number of properties was in excess of 50,000 and reduced to just over 9,500 by using "residential foci". These foci are defined as representing all properties within a 100 m radius. This was considered not only expedient from the point of view of performing the calculations but also appropriate given that the number of occupants at any one property was unknown and that multiple properties share the same coordinates in many cases (i.e. they represent flats or tenements). It was this dataset that was input as 'observers' into the visibility calculations.

Data on properties that lay outside the boundaries of Scottish Borders were not available from the Council. Therefore, the LCS88 data set was used to identify settlements and residential foci in the buffer zone. The LCS88 data set did not extend into England and so additional settlements were identified from the OS raster data (Ordnance Survey 2003a).

The visibility of the landscape was calculated in a similar way to the calculation for zones of visual influence of wind turbines used for planning applications. The results of each calculation were then classified according to distance from each observer in 2.5 km radii up to a maximum of 10 km. The classification makes no statement as to the relative number of observers able to see a given location, merely that it can be seen by at least one observer. The results of the analysis were overlaid on the Ordnance Survey 1:250,000 scale raster backdrop (Ordnance Survey 2003c) to show the contours and major field boundaries.

It was found that, in the particular situation of the Scottish Borders, the use of the 5 m observer height resulted in only minor differences in the pattern of visibility. The use of an adjustment for vegetation, while a relevant method, resulted in little change to the pattern of visibility in the Scottish Borders. While there are some differences between the results of the classifications, these are hard to identify by casual observation of the maps. Therefore, it is suggested that it adds little to a strategic-level study and such a technique should be reserved for specific studies where relevant.

To obtain a full impression of the visibility within the limits viewing radii, the equivalent maps of visibility from the main settlements and the visibility from the residential foci should be considered together. The digital data are also provided to Scottish Borders Council.

1. INTRODUCTION

This report represents the culmination of research conducted at the request of Scottish Borders Council following correspondence between Mr. Jim Knight and Dr. Jonathan Ball. The aim of the research was to provide the Council with a strategic-level planning tool to assist with assessing the potential visual impact of windfarm development proposals.

2. OBJECTIVES

The aim of the work was to produce maps to aid the Scottish Borders Council in directing developers to potentially suitable sites prior to the preparation of proposals for the development of windfarms. To achieve this, Scottish Borders Council requested that the following work be carried out:

- Prepare visibility maps for the Scottish Borders Council area to show the areas of land upon which a wind turbine would be visible from residential property.

- Two sets of calculations were to be conducted. One set to derive the visibility from the main settlements in the area and the second to repeat the visibility calculations but account for all residential properties, including those not within the main settlement boundaries.

- The extent of the area of interest beyond to include a buffer of 2.5 km outside the Scottish Borders boundary.

- Account should be taken of the visibility from first floor windows to make some allowance for property with more than one storey.

- A further refinement that was requested during the project was to perform the calculation using both a Digital Terrain Model (DTM) and a model that takes some account of the presence of vegetation.

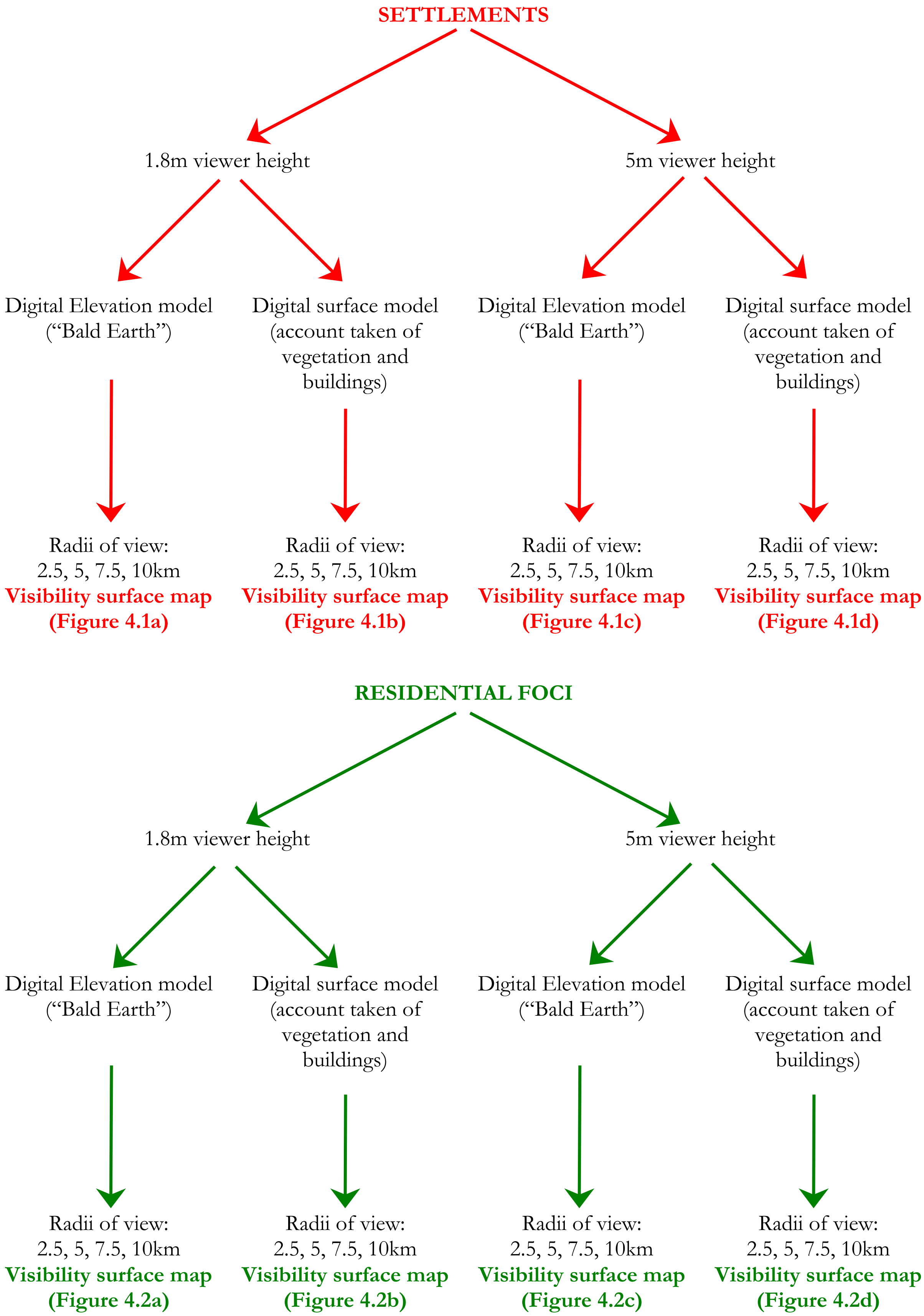
In total a set of eight calculations of visibility were necessary to meet the objectives listed.

3. METHODOLOGY

The main tools that were used in this work were Geographic Information Systems (GIS) functions provided by ESRI's ArcGIS 8 suite of software, with the output compatible with ArcView 3.2 for use within the Council.

A "Visual Receptors" approach was adopted for this project. Visual receptors are sites and areas from which people are exposed to views of the landscape. These can include a number of different points such as roads, significant landmarks and historic sites, but in this study restricted in accordance with the requirements of Scottish Borders Council to views from residential properties. A summary of the calculations and output is presented in Figure 3.1.

Figure 3.1: Summary of Outputs



3.1. Assumptions

In keeping with the current trends in windfarm development, the height of turbines was assumed to be 100 m to tip of the rotor arc, although it is recognised that proposals for turbines may include taller structures.

The Guidelines on Landscape and Visual impact Assessment (GLVIA - The Landscape Institute and The Institute of Environmental Management and Assessment, 2002) recommends an observer eye height of 1.8 m (Appendix 7, Guidelines on computer-based techniques for landscape and visual impact assessment). This was used in the calculations to represent the height of an observer at ground level. The Scottish Borders Council also requested that some account be taken of visibility from first floor windows. For this purpose the same calculations were re-run with an observer height of 5 m to provide an approximate representation of a 1.8 m observer standing at first floor level. It is accepted that many buildings in urban centres will have windows higher than 5 m but an approximate "first-floor threshold" was deemed appropriate, as it encompasses the vast majority of residential property. Visibility calculations from higher stories were not requested and were therefore not considered.

3.2. Core Data

The final mapping used The Ordnance Survey 1:250,000 scale colour raster backdrop (OS 2003a).

The analysis used the Ordnance Survey (OS) 1:50,000 scale Digital Elevation Model data (OS 2003b), at a 50 m x 50 m resolution as the main input, and the same resolution for the output.

Key to the calculations were the data on settlements and residential properties. These data were obtained from four sources:

1. The boundaries of the main settlements, provided by Scottish Borders Council.
2. Ordnance Survey Address-Point (OS 2003c) data for postcodes appropriate to the Scottish Borders area, which was used in preference to the dataset of the postcode centroids supplied by The Scottish Borders Council.
3. Land Cover of Scotland 1988 (LCS88) dataset (MLURI, 1993) to identify properties in the buffer zone, outside the data covered by that provided by Scottish Borders Council.
4. Ordnance Survey 1:250,000 scale colour raster backdrop (OS 2003a) to supplement data for England in the absence of other available sources.

3.3. Identification of Residential Properties

The calculations involving residential properties raised three particular issues:

1. The poor availability and/or high cost of grid coordinates for all residential properties.
2. The large number of properties, presenting practical difficulties for computation.
3. The superimposition of many residential properties (*i.e.* within single 50 m x 50 m cells) leading to a high level of redundancy in the visibility calculations.

In response to the first issue, The Scottish Borders Council provided a dataset of the centroids of the postcodes. However, it was decided that this was not suitable for the visibility calculations because the centroids bore little relationship to the actual location of the properties. The centroids were positioned centrally to the area covered by a given postcode. The same postcode identifies a number of properties and is not predominantly based on areal units. Therefore, in rural locations, the area covered by any given postcode is considerably larger than in urban areas, leading to very poor correspondence between the coordinates of the postcode centroid and residential properties.

This problem was overcome by rejecting the dataset of postcode centroids in favour of the OS Address-Point dataset. However, the OS Address-Point dataset did not specifically differentiate between residential property and other property types. A set of all postcodes that covered the Scottish Borders area was used from which a sub set was created that represented the residential properties. This was determined by excluding those properties that included the following types of data: Department Name, PO Box Number, Organisation Name. It was accepted that this may include some businesses but would exclude the majority. The number of properties was in excess of 50,000, which was reduced to just over 9,500 by using "residential foci".

The "residential foci" dataset contained foci of residential properties to represent all properties within a 100 m radius. In other words, there was a minimum separation of the foci of 100 m. The residential foci reduced the redundancy of visibility calculations from flatted properties with identical sets of coordinates and conjoined or closely neighbouring properties. It also had the effect of reducing the influence of the residual business properties that would not have been excluded by the initial filtering process. The residential foci were then used in the calculations and, given the strategic and indicative nature of this study, such an approach was considered appropriate. One residential focus approximates, in this case, to five residential addresses. The actual number of properties that are represented by any given residential focus will be higher in the settlements and lower in the more sparsely populated rural areas.

Where OS data were unavailable to Scottish Borders Council, substitutes were used. The area in question was the buffer zone around the outside of the Scottish Borders Council boundary. The LCS88 dataset was considered to be sufficiently accurate for these purposes, partly because of the strategic and indicative nature of the study, and partly because the original data from which urban areas in the LCS88 dataset were derived was OS data. However, the LCS88 dataset only covered Scotland. The area of the buffer zone south of the border was covered by manually digitising urban areas in the OS Raster backdrop to complete the data for the buffer zone.

3.4. Calculation of Visibility

Visibility was calculated from the observer locations to a target of height 100 m for each raster cell in the DEM.

Large features, such as areas of woodland and tall buildings, can have a significant impact on studies of visibility. If such features are to be accounted for in the preparation of Zones of Visual Influence (ZVIs), adjustment for their height must be made in the Digital Elevation Model ("bald earth") to create a Digital Terrain Model ("canopy layer"). At the time of writing extensive coverage for the United Kingdom of digital surface models does not exist. Most current commercially available data are for parts of England and Wales. However, there are alternative methods of deriving digital surface models where direct radar measurement does not exist.

The Land Cover of Scotland 1988 (LCS88) dataset (MLURI, 1993) was used to identify areas of woodland and type of woodland. The LCS88 dataset has a total of 1327 classes into which the land cover of Scotland has been classified. Of these, 126 are primary features and the remaining 1201 classes represent areas that are classified as being combinations (or 'mosaics') of the primary features. For this study, the land cover codes whose dominant class denoted the presence of woodland were used to identify relevant areas. Areas that are classed as woodland (broadleaved, coniferous or mixed) were given a height of 20 m. Areas that are identified as low scrub woodland were given a height of 5 m. While many tree species can reach heights greater than 20 m, this limit was considered as an appropriate first approximation in the absence of site-specific surveys.

This dataset can be considered to be stable with respect to forestry based on a number of assumptions:

- There is unlikely to have been a wholesale change in land use from forestry to open pasture or arable land.
- Given the general changes in silvicultural practices since the late 1980s and the location of the area of interest, it is unlikely that significant areas of woodland will have been clear felled.
- Where thinning and harvesting have taken place, it is assumed that sufficient trees remain, or sufficient replanting has taken place for the woodland to continue to obscure views

The woodland heights were then added to the DEM to produce a new model, which was used as the DEM in the visibility calculations.

3.5. Radii of Viewing Limits

The purpose of this study was not to investigate the total visibility of the area from residential properties but to try to take account of the potentially decreasing intrusiveness of developments with increasing distance from an observer. This effect is not accounted for in the conventional ZVI.

Representatives of the Scottish Borders Council requested that three radii be used to represent the distances at which a windfarm development might be considered to be most intrusive. These were 2.5 km, 5 km and 10 km. It was decided to introduce a fourth radius of 7.5 km to provide a slight refinement to the analysis by using increments of the smallest radius. The radii of viewing limit were calculated from each residential focus or from the perimeter of the main settlements.

It is acknowledged that a wind turbine, with a height of 100 m to the tip of the rotor arc would potentially be visible from considerably greater distances but a calculation of total visibility was not requested.

4. RESULTS

The maps are presented in two sets of four as follows (see Figure 3.1):

Set one:

1. Visibility from main settlements, viewer height 1.8 m, no adjustment for vegetation (Figure 4.1a)

2. Visibility from main settlements, viewer height 1.8 m, DTM adjusted for vegetation (Figure 4.1b)
3. Visibility from main settlements, viewer height 5 m, no adjustment for vegetation (Figure 4.1c)
4. Visibility from main settlements, viewer height 5 m, DTM adjusted for vegetation (Figure 4.1d)

Set two:
1. Visibility from residential foci, viewer height 1.8 m, no adjustment for vegetation (Figure 4.2a)
2. Visibility from residential foci, viewer height 1.8 m, DTM adjusted for vegetation (Figure 4.2b)
3. Visibility from residential foci, viewer height 5 m, no adjustment for vegetation (Figure 4.2c)
4. Visibility from residential foci, viewer height 5 m, DTM adjusted for vegetation (Figure 4.2d)

After discussion with the client it was decided to drop any classification of the data according to viewer numbers and to represent the data in terms of distance from the observer.

The data are also provided in a digital format to enable reproduction at different scales.

Figure 4.1a: Visibility from main settlements (observer height 1.8m, no adjustment to DTM)

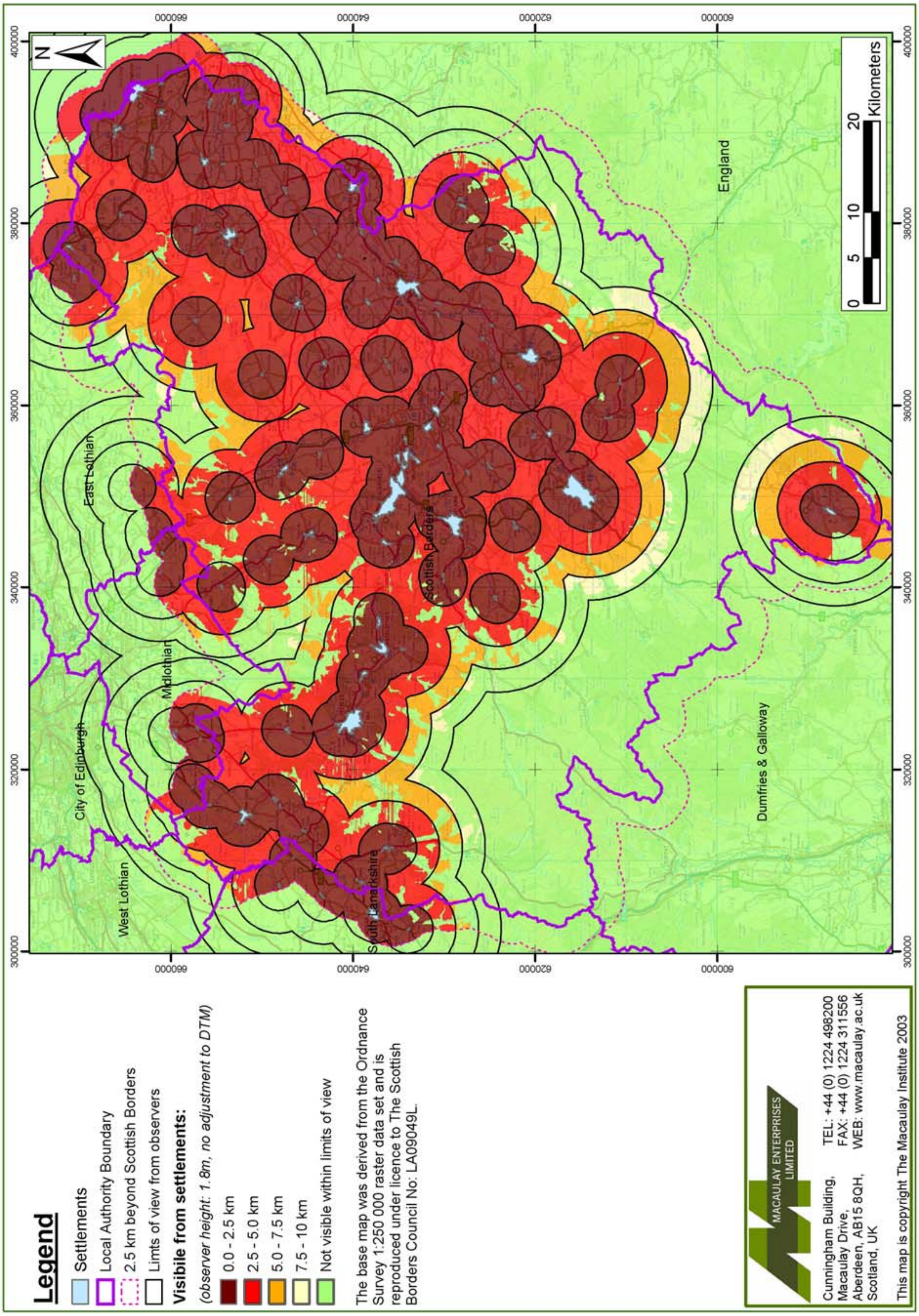


Figure 4.1b: Visibility from main settlements (observer height 1.8m, DTM adjusted to account for trees)

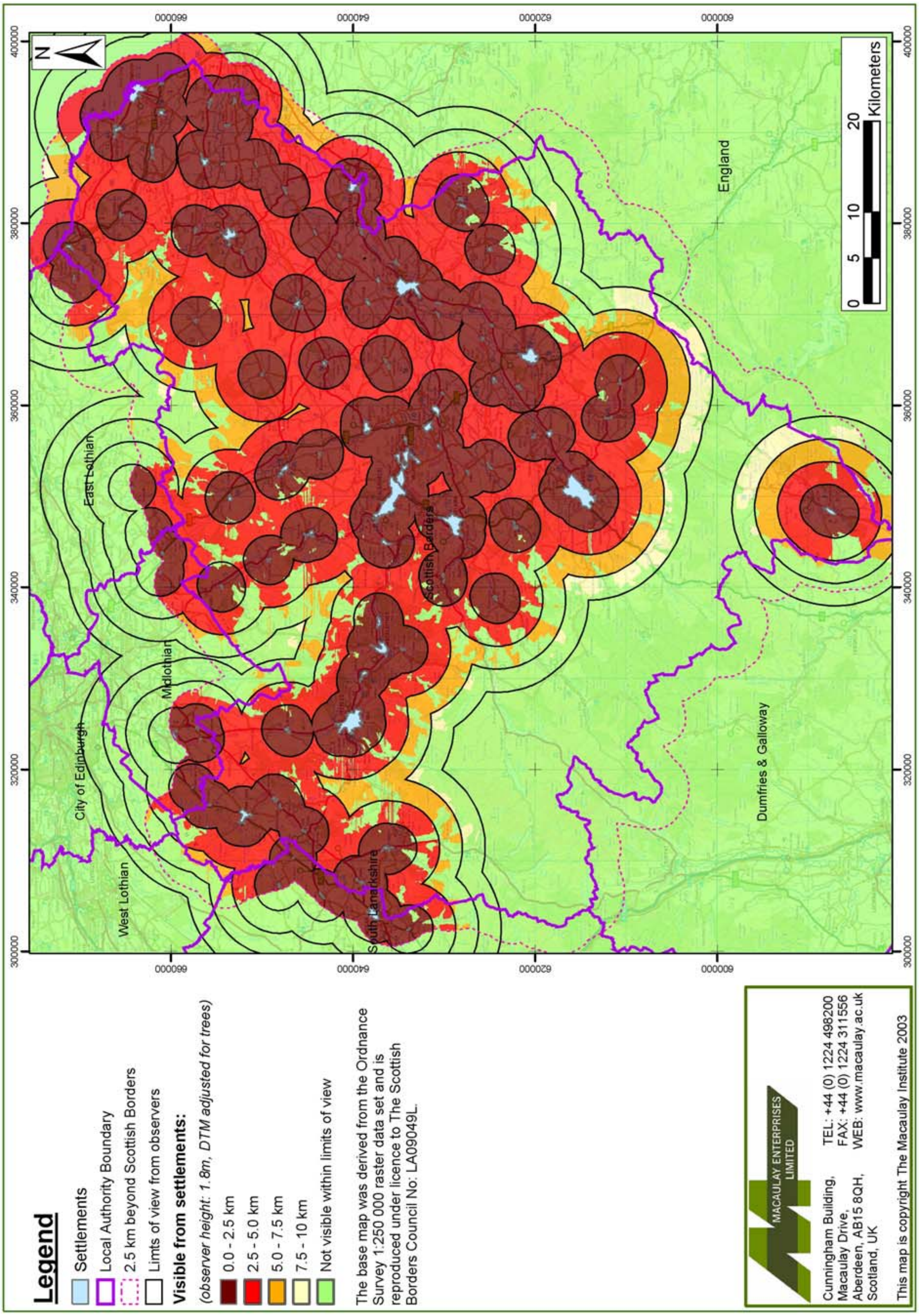


Figure 4.1c: Visibility from main settlements (observer height 5 m, no adjustment to DTM)

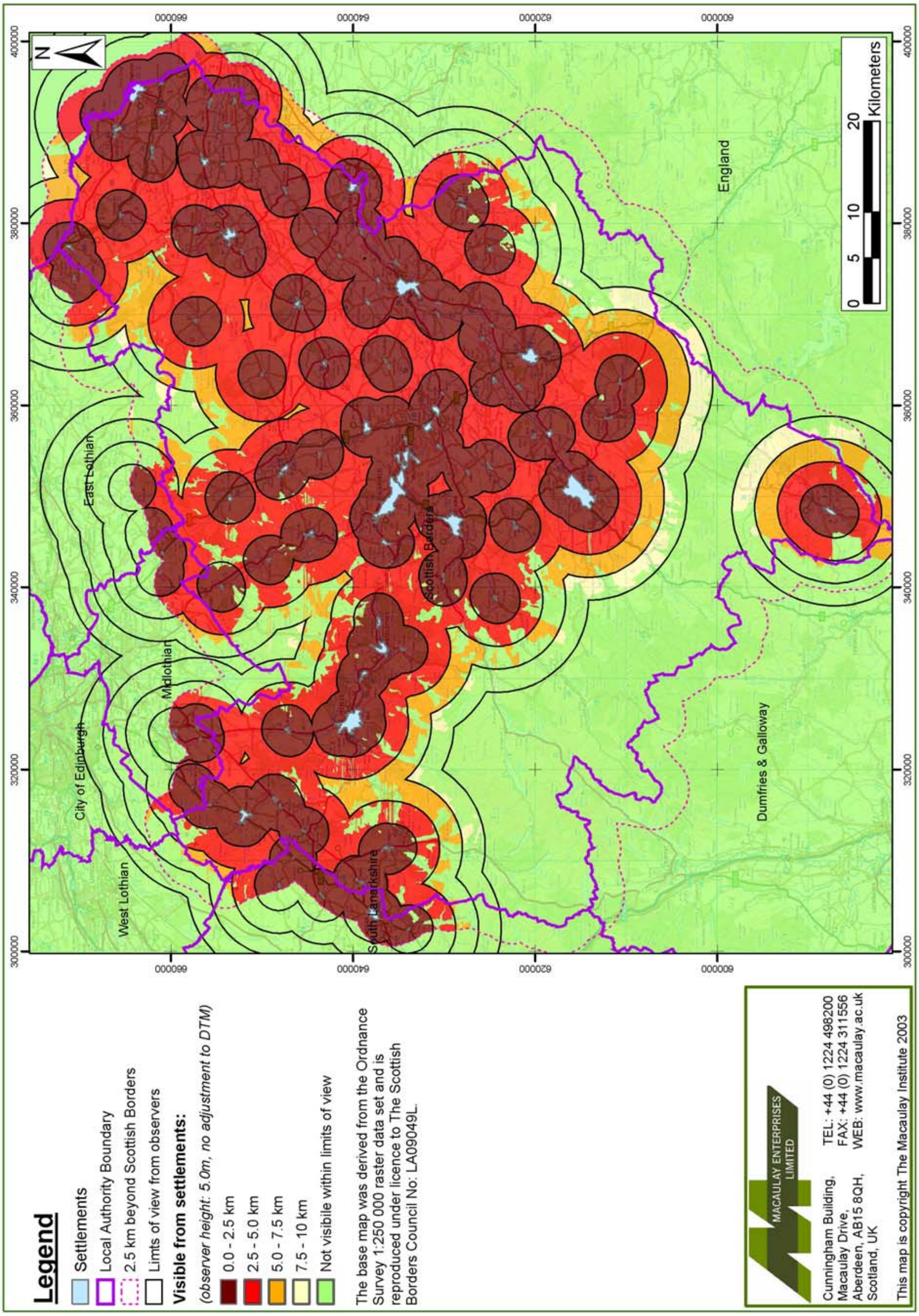


Figure 4.1d: Visibility from residential foci (observer height 5 m, DTM adjusted to account for trees)

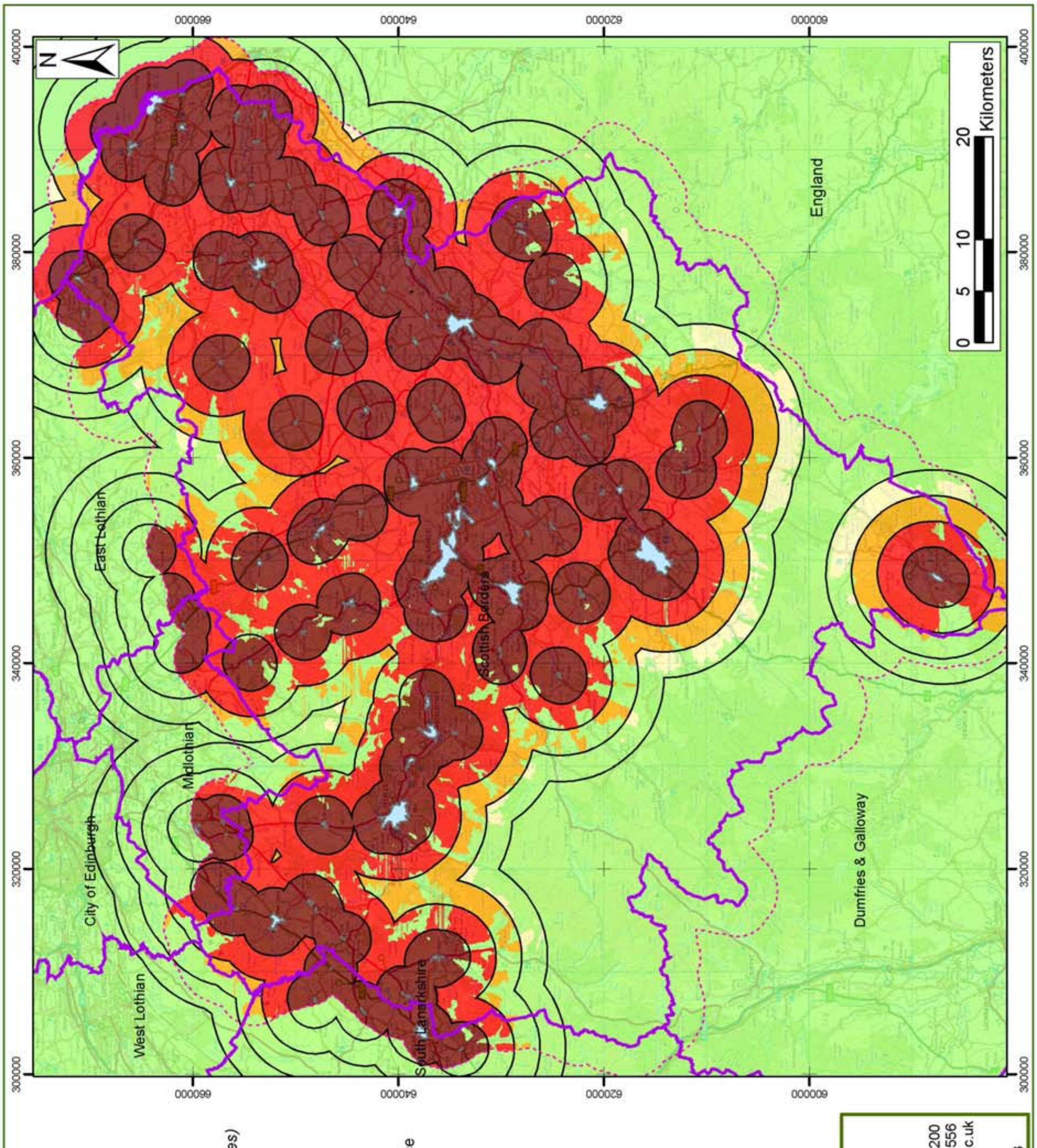


Figure 4.2a: Visibility from residential foci (observer height 1.8 m, no adjustment to DTM)

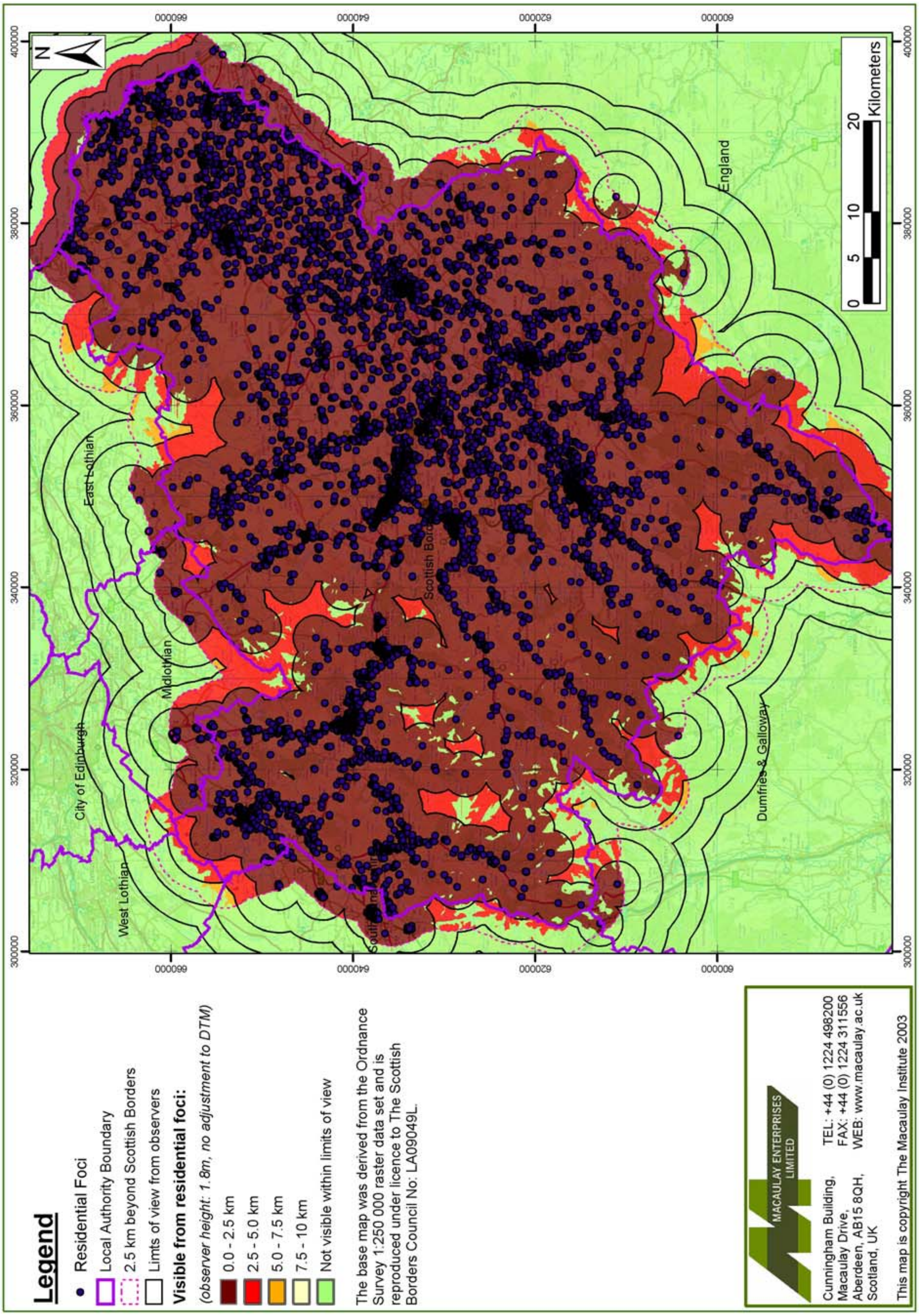


Figure 4.2b: Visibility from residential foci (observer height 1.8 m, DTM adjusted to account for trees)

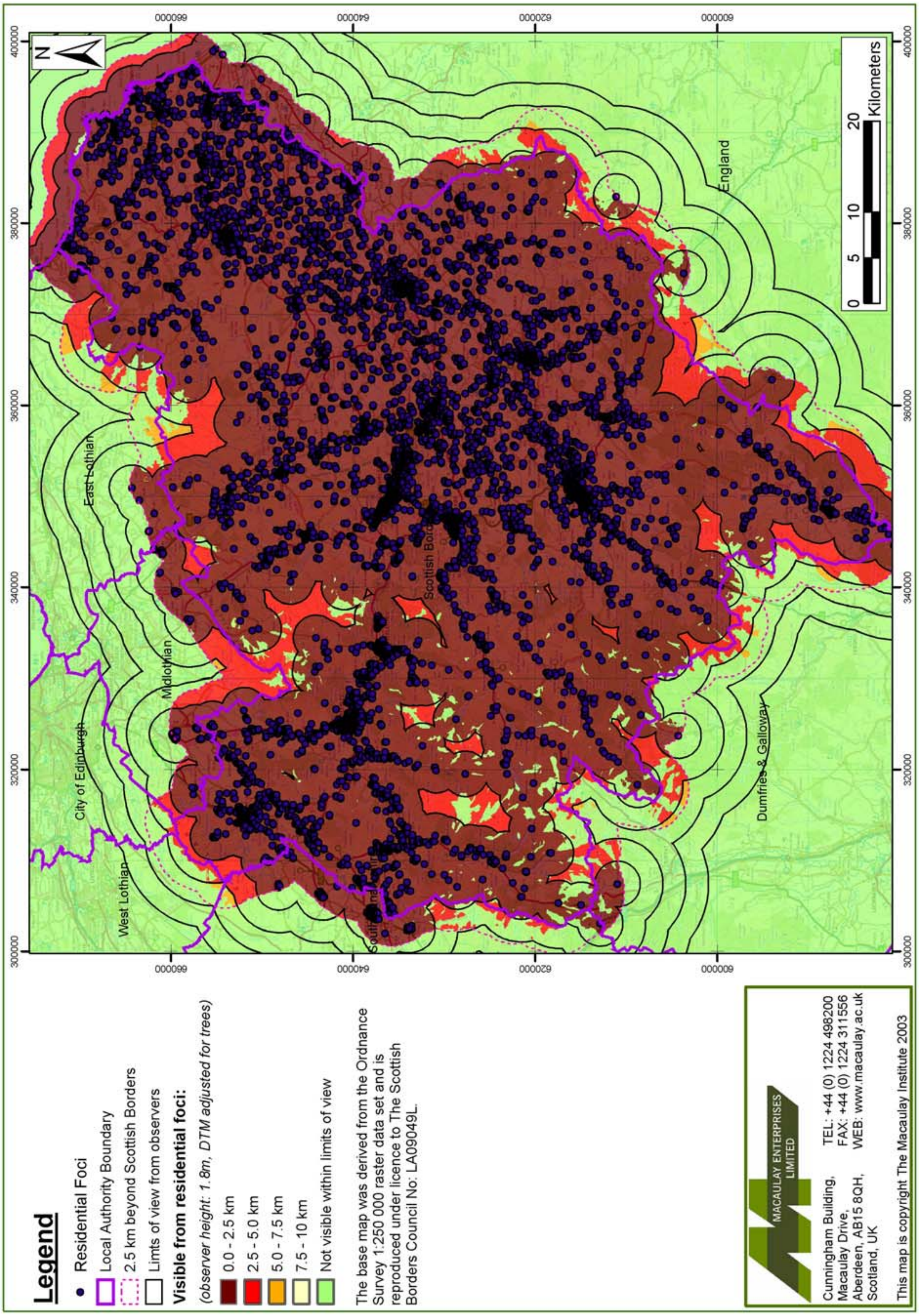


Figure 4.2c: Visibility from residential foci (observer height 5 m, no adjustment to DTM)

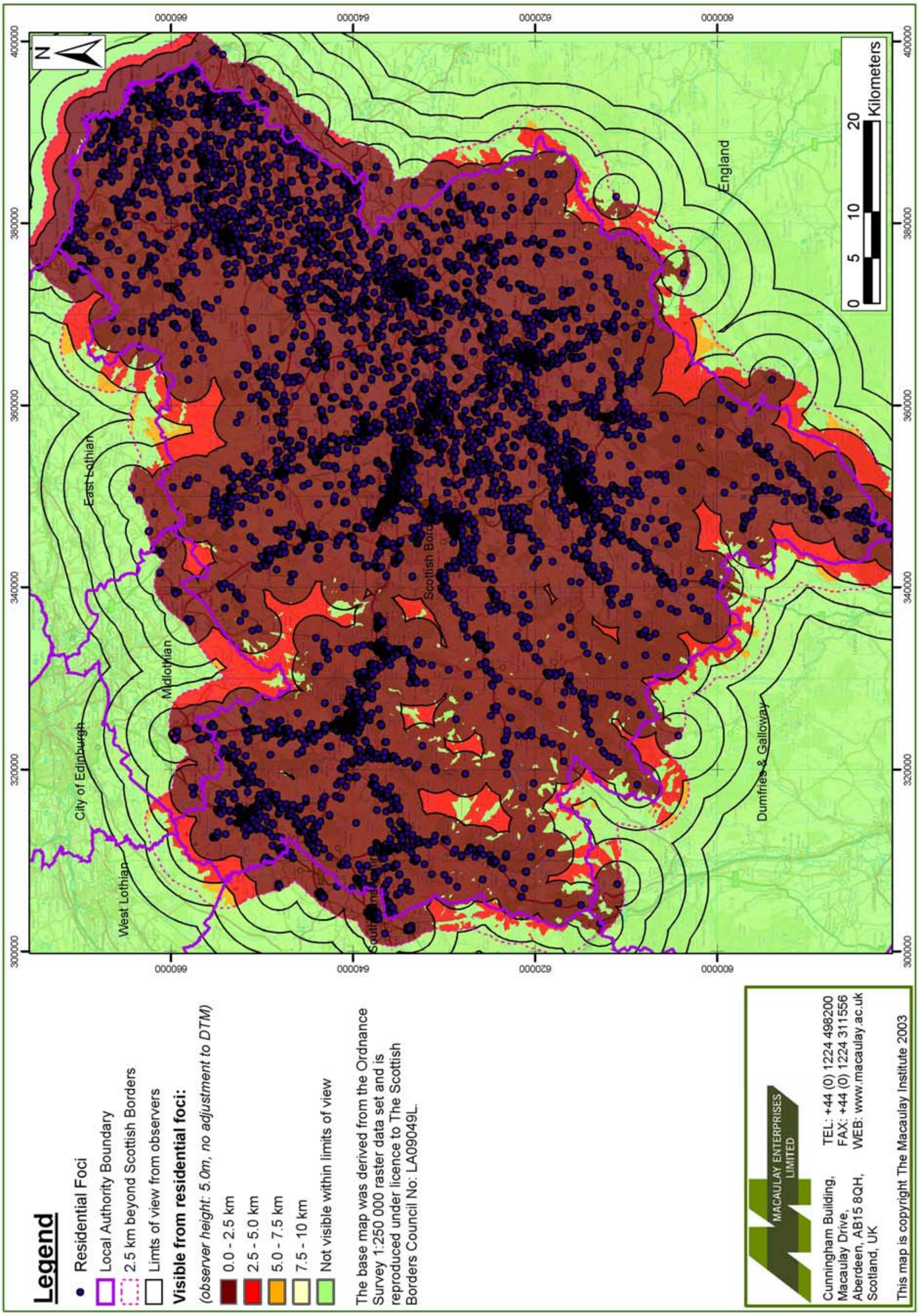
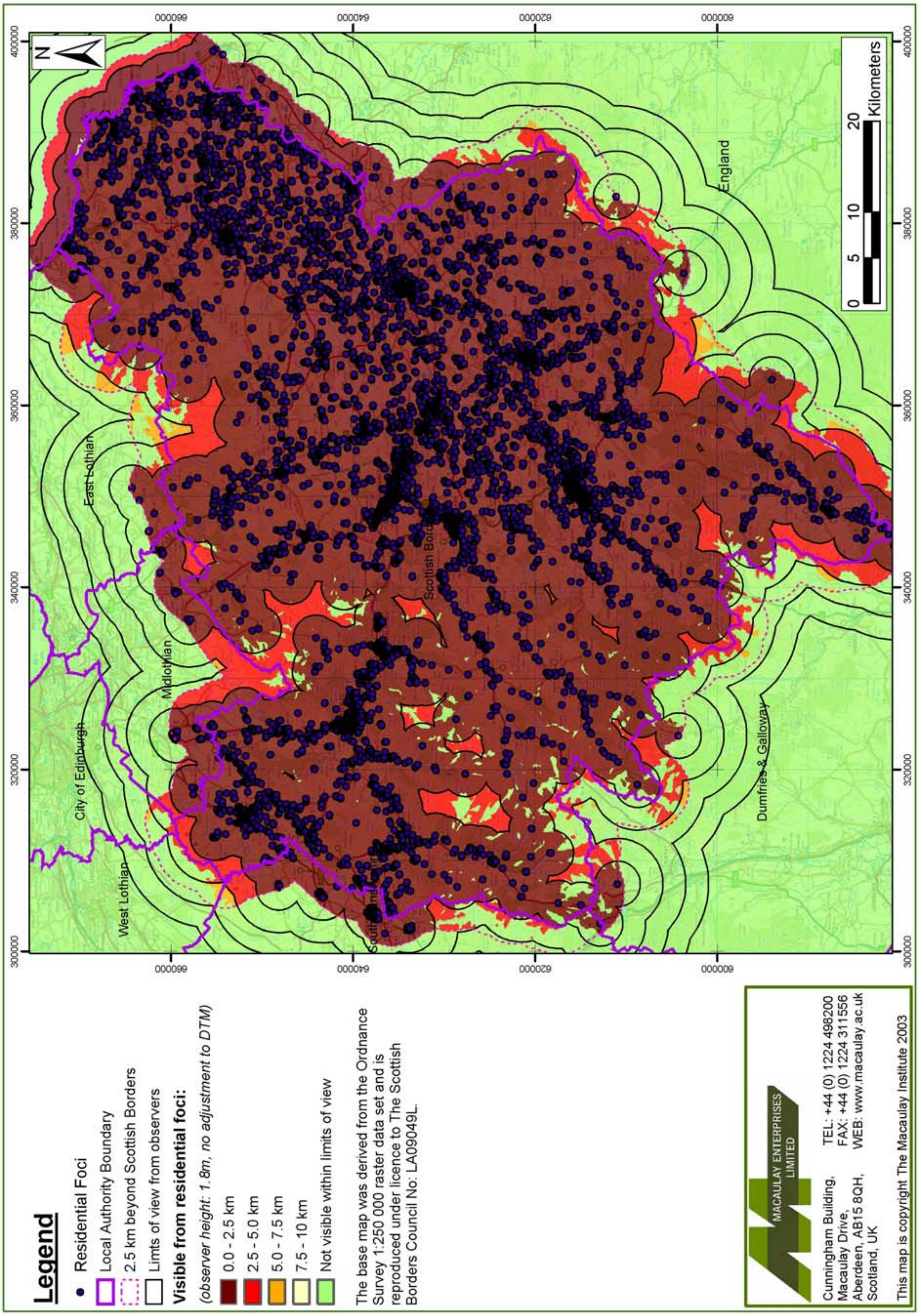


Figure 4.2d: Visibility from residential foci (observer height 5 m, DTM adjusted to account for trees)



5. DISCUSSION

In each case, for settlements and residential foci, four different viewer scenarios were investigated: eye-level while standing/first floor level/with and without woodland height data. Increasing the observer height can be anticipated to increase the observers' visibility of the landscape, while taking trees into account can be expected to reduce the extent of the land visible. This was found to be the case, although the differences are small in the case of this study for Scottish Borders and are hard to identify on the maps.

Figures 5.1a and 5.1b compare the scenario with the least visibility and the scenario with the greatest visibility from the point of view of windfarm development. The difference between the two calculations is approximately 1.5%. It is probable that this limited difference is a result of the height of the turbines, as the turbines are much taller than the trees. The situation is similar for the visibility from residential foci.

Figure 5.1a: Histogram for calculation of visibility from settlements (landscape least visible – best case scenario for windfarm development)

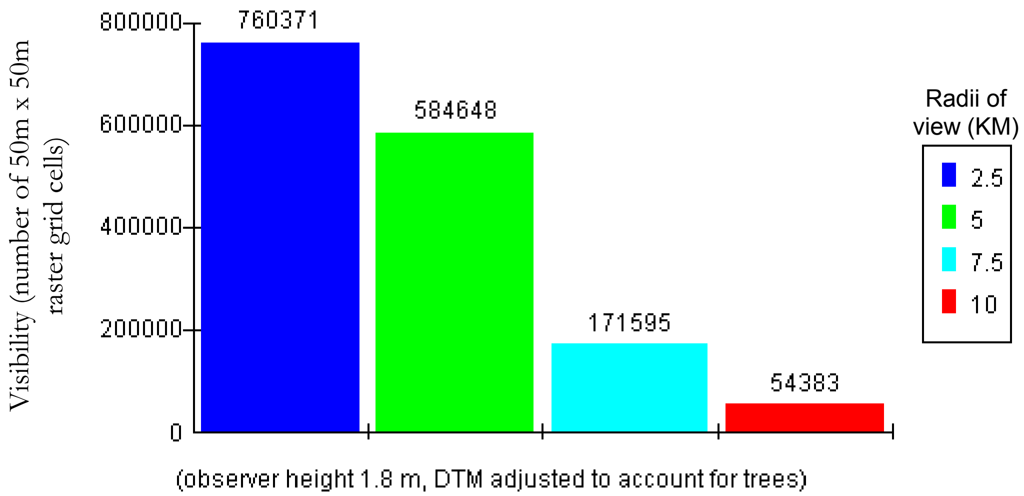


Figure 5.1b: Histogram for calculation of visibility from settlements (landscape most visible – worst case scenario for windfarm development)

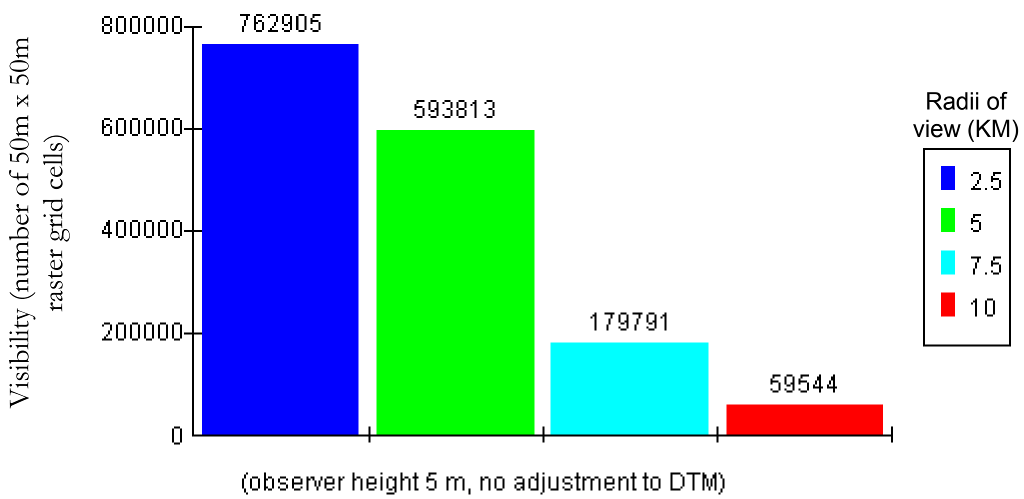
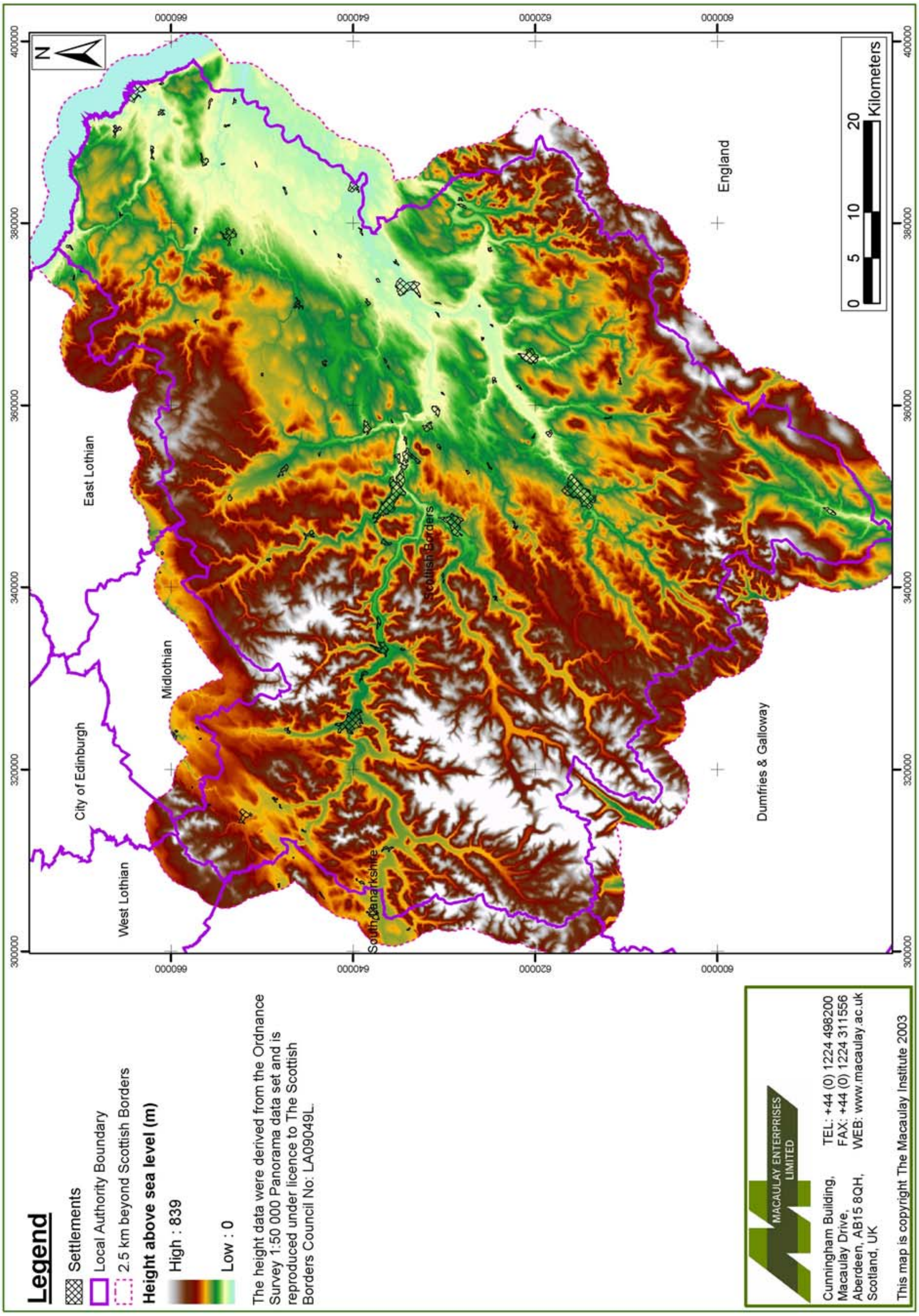


Figure 5.2: Location of settlements in relation to high ground



The visibility from the residential foci is much higher than that from the settlements. This is to be expected because there is a spread of residential properties across most of the region and well beyond the limits of the settlements. Areas that are not visible, within the limits of the radius of view, for the calculations using the residential foci can also be assumed to be hidden from view from the settlements. This is because the residential foci include the settlements.

There are some areas that are not visible from the settlements, within the limits of view, but are visible from some residential foci. These areas coincide with high ground where the terrain hides the uplands from the settlements, which are predominantly found in the lower lying areas (Figure 5.2). This does not mean that a windfarm development would not be visible in these locations. It shows that development in these areas will affect fewer people (those represented by the residential foci). One such area lies to the southwest, along the border with Dumfries and Galloway. Most of this area is beyond the maximum (10 km) viewing limit imposed on this study, and therefore might be visible from the settlements. However, it is expected that the effect of distance will cause some reduction of the visual impact.

6. LIMITATIONS

The output of the calculations is limited by the viewing radii used, which reflects the intended purpose of this study. It cannot be concluded that, because an area is not marked as visible, development at such a location will not be visible from residential properties. This is because of the limits of radius of view chosen by Scottish Borders Council. The maps are intended to show the locations where the visual impact of a windfarm might reasonably be considered unacceptable due to the high intrusiveness of the turbines, while not precluding the visibility and potentially lower levels of intrusiveness of turbines at greater distances from residential properties. This approach was intended to address the simplicity of the conventional ZVI, which makes no account of the potentially decreasing intrusiveness of a development with increasing distance.

A further limitation in the process was that it was not possible to identify and exclude properties that are uninhabited but still retain a valid postcode. However, these represent a very small proportion of the total number of residential properties and an even smaller proportion of the residential foci.

When considering the outcomes, it should also be noted that the results are only relevant from the perspective of the area of interest (i.e. residential properties within Scottish Borders local authority boundary). Areas that are marked as of low, or zero, visibility may be highly visible from residences in neighbouring districts.

It should also be noted that areas coded on the maps as being not visible within the limits of view (green) can only truly be considered to be not visible where they lie within the limits of view boundary. Areas outside the boundary automatically default to "not visible" because they are beyond the viewing radius.

Finally, the assessment of visibility does not include consideration of views of turbines with respect to the skyline, irrespective of distance of view.

7. CONCLUSIONS

Using an observer height of 5 m to simulate views from first floor windows appears to have a minor impact upon the outputs from the mapping process. It is therefore suggested that this approach only be used in more detailed, specific (i.e. not strategic) calculations of visibility.

The concentric radii of view gives a refinement, when used with a conventional ZVI map, that makes some account of the influence of distance on the degree of visual intrusiveness of a potential site. However, this is a strategic-level study and the merits of each windfarm proposal will need to be investigated individually. This study does not obviate the need for a landscape assessment.

The maps showing visibility from residential foci and the main settlements should be used together to gain a full picture of the likely visual impact of developments in an area.

8. POSSIBLE FUTURE WORK

1. The boundaries of the Scottish Borders Council district could be extended to include a suitably sized buffer zone, incorporating parts of the neighbouring districts. This would allow greater use to be made of the study with regard to visibility of developments within Scottish Borders Council district by residential properties in neighbouring areas.

2. The areas could be re-categorised according to population density. A link could be made to work already existing within Scottish Borders Council by Heidi Goodship (Scottish Neighbourhood Statistics Project) to code each residential focus according to the appropriate population density in that area.

3. The outcomes of this study could be used in conjunction with data such as wind-speed and land ownership to identify locations that could be of interest to developers. The most desirable combinations of areas, in terms of cumulative impact, for development could then be determined so that developers can be encouraged to investigate those areas first.

9. REFERENCES

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