Visual Representation of Windfarms

Good Practice Guidance

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Prepared for Scottish Natural Heritage, The Scottish Renewables Forum and the Scottish Society of Directors of Planning

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SNH COMMISSIONED REPORT

Summary

VISUAL REPRESENTATION OF WINDFARMS GOOD PRACTICE GUIDANCE
Report No: FO3 AA 308/2
Contractor: horner + maclennan and Envision

BACKGROUND
This guidance is derived from research reported within the publication Visual Assessment of Windfarms: Best Practice, by the University of Newcastle (2002). The sections of this original work concerning visibility maps, viewpoints and visualisations have been updated and refined through a review of current VIA practice, current illustrative methods, consultation with stakeholders and reference to other guidance documents.

The production and use of visual representations forms just one part of the Visual Impact Assessment (VIA) of proposed windfarm developments and, in turn, this forms just one part of the wider Landscape and Visual Impact Assessment within an Environmental Impact Assessment. Yet within the visual analysis process itself, there is a wide range of different tools and techniques that can be used. This Good Practice Guidance advises on the different purposes, uses and limitations of these and sets down some minimum technical requirements.

MAIN FINDINGS

- Visibility maps and visualisations are tools for VIA. They help the landscape architect or experienced specialist assessor to identify and assess potential significant visual impacts, and help the wider audience of an Environmental Statement to understand the nature of these visual impacts through illustration.

- Various software is available to produce visibility maps and visualisations of windfarms. These possess different strengths and weaknesses. In this respect, minimum standards can be defined; however there is no 'one size fits all' solution.

- The choice of visibility mapping and visualisations forming part of a VIA should be based on why they are being produced, how they are to be used, and what information they can provide. This decision should occur in an informed and methodical manner, in consultation with the determining authority and consultees. This process, including the technical specification of visualisations, should also be clearly documented within the ES.

- Different people read visibility maps and visualisations in different ways. This is partly based on their experience and understanding of landscapes and the typical visual impacts of windfarms, and partly from their experience and understanding of how visualisations compare to how a development actually looks once built.

- New method of visibility mapping and visualisations will continue to develop, as will other approaches not included within the scope of this study, such as the use of computer animation and the representation of cumulative impacts. Consequently, it is envisaged that the content of this Good Practice Guidance will require future updating.

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Kay Hawkins	E4environment Ltd
Phil Marsh	spatial data analyst
John Rennilson	Scottish Society of Directors of Planning

In addition, many planners, landscape consultants and windfarm developers participated in the development of this project through contribution to a series of workshops held in September 2004.

Natural Power and Green Power are acknowledged for giving permission to use some of their photography and ES material, and to base hypothetical visualisations on some of their windfarm site data.

This publication builds upon the original findings of the SNH research report - 'Visual Assessment of Windfarms: Best Practice', produced by the University of Newcastle in 2002. It was initially led and developed by John Benson of the University of Newcastle, until John's sudden and extremely sad death in March 2004.

John Benson was a well-respected researcher and consultant at the forefront of this work. He had the ability to see all sides of an issue with great clarity, fair-mindedness and understanding and was a great mentor to all that worked with him. It is hoped that the fruition of this work does his reputation justice. The draft report was developed by John and his colleagues at the University of Newcastle, Karen Scott and Maggie Roe; and then, from December 2004, this work was completed by horner + maclennan and Envision.

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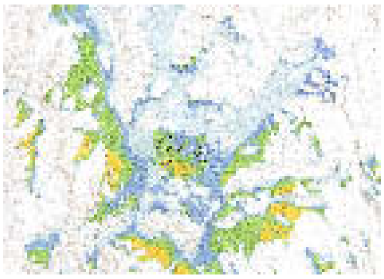
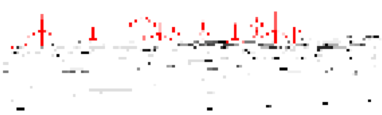
1 Introduction

1 ‘Pictures speak louder than words’. Images are an incredibly powerful medium in conveying information – both positive and negative, and in capturing our imagination. The visual assessment of windfarms, however, involves much, much more than just looking at pictures. It requires detailed site assessment of a visual resource while also considering data on the potential effects of a development.

2 While images are very powerful and useful in communicating information, they can never tell the whole story. They can never replicate the experience of seeing a windfarm in the landscape, whether they are photographs, maps, sketches or computer generated visualisations, and prepared to the highest specification and skill possible. Similarly, however, assessment in the field will be considerably limited without the benefits of technical data such as visibility maps and visualisations that demonstrate the technical aspects of a proposed development.

3 Visual analysis forms just one part of a Visual Impact Assessment (VIA), the process by which the potential significant effects of a proposed development on the visual resource are methodically assessed. In turn, VIA forms just one part of a Landscape and Visual Impact Assessment (LVIA) and the wider process of Environmental Impact Assessment (EIA). All of these processes are directed by specific guidelines and/or legislation, some of which are listed in figure 3 and Appendix i.





4 Detailed information on the process of LVIA, together with a recommended methodology, are provided within the 'Guidelines for Landscape and Visual Impact Assessment' (GLVIA), produced by The Landscape Institute and Institute of Environmental Management and Assessment (2002).

5 The purpose of an EIA is to identify and assess the potential significant effects of a proposed development. Its findings are presented within an Environmental Statement (ES). An applicant will usually appoint specialists to conduct the different studies that make up this report; for VIA, it is usual to appoint landscape architects.

6 A combination of illustrative techniques are used during the VIA process. The most commonly used include computer generated visibility mapping, wirelines and photomontages, together with hand drawn diagrams and sketches. These can show where a proposed development may be seen from and how it may appear in terms of its basic characteristics such as size, pattern and shape.

7 It is important to stress that visualisations, whether they are hand drawn sketches, photographs or photomontages, will never appear 'true to life'. Rather, they are merely tools to inform an assessment of impacts; and, like any tool, their application requires careful use. Interpretation of visualisations always needs to take account of information specific to the proposal and site, such as variable lighting, movement of components, seasonal differences and movement of the viewer through the landscape. Thus visualisations in themselves can never provide the answers – they can only inform the assessment process by which judgements will be made.

How this Good Practice Guidance has been developed

8 This guidance has been prepared by independent consultants acting on the behalf of Scottish Natural Heritage (SNH), the Scottish Society of Directors of Planning (SSDP) and the Scottish Renewables Forum (SRF). It is derived mainly from research reported within the publication 'Visual Assessment of Windfarms: Best Practice' by the University of

Newcastle (2002). This original work has been updated and refined through reference to a range of material and sources, including:

- a review of current VIA practice represented by a range of windfarm ESs;
- a review of current illustrative methods representing a range of interests, experience and expertise;
- advice from participants at three workshops involving the key stakeholders of windfarm developers, consultants and planning officers (the latter also describing key concerns raised by the public); and
- existing guidance (see 'Other sources of information' section).

9 This work was begun by the University of Newcastle in 2003, led by John Benson, and later completed by horner + maclennan and Envision.

Aims and Objectives of the Good Practice Guidance

10 This Good Practice Guidance focuses upon only the Visual Impact Assessment (VIA) element of Landscape and Visual Impact Assessment (LVIA). This process usually requires visibility maps and visualisations that are then used differently by different people for different purposes. Some visualisations will directly inform judgements made within the VIA (and thus guide the scale, location and design of the windfarm), while others will be used for general illustrative purposes. Their common aim, however, is to help inform judgements on the potentially significant effects of a proposed windfarm on the landscape and visual resource.

11 The accuracy of these illustrations is often questioned. Sometimes this is due to unfamiliarity and thus a misunderstanding regarding their specific purpose, and the limitations of visibility maps and visualisations to depict what can actually be seen by the naked eye.

The University of Newcastle (2002) highlighted that photomontages "..can imply a degree of realism that may not be robust, and can seduce even a critical viewer into investing more faith in that realism that may be warranted". Sometimes, their accuracy is questioned simply because there remains considerable variation between how illustrations are presented within ESs, and these different methods have various strengths and weaknesses.

12 The methods used to produce visibility maps and visualisations have developed significantly since the first windfarms were planned in the UK at the beginning of the 1990s. This has been aided by continued effort on the behalf of many consultants, developers, researchers and consultees to try to find more effective ways of representing the effects of windfarms in the landscape. There has also been a progressive change in the availability, cost and capability of computers, software and digital data used to produce computer-generated images. This situation continues to change as new techniques develop.

13 For these reasons, Scottish Natural Heritage in conjunction with Planning Authorities (represented by the Scottish Society of Directors of Planning) and the Scottish Renewables Forum has produced this Good Practice Guidance.

Figure 1: The aims of the Good Practice Guidance

- To advise on the purposes and uses of different visibility maps and visualisations of windfarms, ensuring that their relevant strengths and limitations are better recognised and understood;
- To advise on the various methods of producing visibility maps and visualisations;
- To promote and encourage good practice in the production of computer generated visibility maps and visualisations;
- To ensure that the approaches, methods and techniques used in the production of visualisation tools and illustrations are technically sound and robust and hence carry credibility; and
- To enable the Good Practice Guidance to be easily updated as new methods and techniques become established.

What the Good Practice Guidance is not

14 The Good Practice Guidance is designed to summarise and explain what is feasible, available and reasonable in terms of current good practice in the production of illustrations. However:

- It is not an exhaustive guide to all possible techniques, nor does it prescribe a single method or brand of software;
- It is not intended to be highly prescriptive, nor suggest that there is a 'one size fits all' solution;
- It does not remove the need for consultation, good judgement and the adaptation of tools and techniques for different developments and different locations; and, most importantly,
- It is not intended to inhibit or stifle innovation in the development and use of new approaches, tools and techniques.

15 This guidance specifically applies to onshore windfarms within Scotland; however some of the principles established through this guidance may be relevant to other development types or within other locations. Additional guidance may be developed in the future that builds upon this work, exploring and/or incorporating additional aspects of windfarms, such as cumulative assessment or offshore developments.

16 The production and use of visibility maps and visualisations are but one aspect of a complex interplay of factors considered within the VIA process (and thereby also the EIA process). Hence, it is neither feasible nor appropriate to define a single approach, as agreement requires consultation and site-specific judgements. Rather, this guidance seeks to identify the key factors that need to be considered when making decisions about what is the most appropriate approach for a particular project (as later summarised within figure 35).

17 In addition to computer generated (or computer assisted) visualisations, landscape and architectural design has for centuries been aided by the illustration of proposed change by hand drawn sketches and diagrams. Given that the creation and use of these images is long established, this Good Practice Guidance will not consider these methods in any detail, although they are mentioned in paragraphs 223-228.

18 Methods of visualisation using computer animation and video montage were not included within the scope of this study. This was because:

- These were not assessed within the original study by the University of Newcastle (2002);
- They rarely form an essential part of the ES, but tend to be a supplementary tool; and
- There has so far been insufficient methodical assessment of how these compare against individual built schemes within Scotland.

19 Finally, it should be stressed that the quality of a LVIA depends on much more than just good practice visibility maps and visualisations. These are just tools to inform the assessment process and, even if of a high quality, will not diminish the requirement for a thorough and professional LVIA. Equally, however, it is important to stress that it is extremely difficult to carry out a high quality LVIA without visibility maps and visualisations that meet good practice standards.

Who should use the Good Practice Guidance?

20 This Good Practice Guidance is intended for all those with an interest in the VIA of windfarms.

- For developers, the guidance offers an overview of what is technically available, feasible and reasonable in terms of producing visibility maps and visualisations so that they can be better informed when instructing their consultants and commissioning ESs, as well as discussing proposals with determining authorities and consultees.

- For landscape architects and other specialist consultants, the guidance advises on the technical specifications for a range of visibility maps and visualisations commonly used in VIA practice and advises on their strengths and weaknesses.
- For consultees, the guidance presents recommended standards in terms of the quality and type of visibility maps and visualisations that can be used to inform EIA, and advises on how these should be interpreted and used.
- For officers from planning authorities/ determining authorities, the guidance also presents recommended standards as described above for consultees. It will also inform scoping opinions and assist planning officers and decision-makers in their interpretation and use of visibility maps and visualisations as presented within Environmental Statements.
- This document is not targeted at the general public, given its specialist nature and technical content. However, for those members of the public particularly interested in this subject, the guidance should aid their understanding of what visibility maps and visualisations can and cannot do, and how this information should be interpreted when included within a VIA or ES.

How to use the Good Practice Guidance

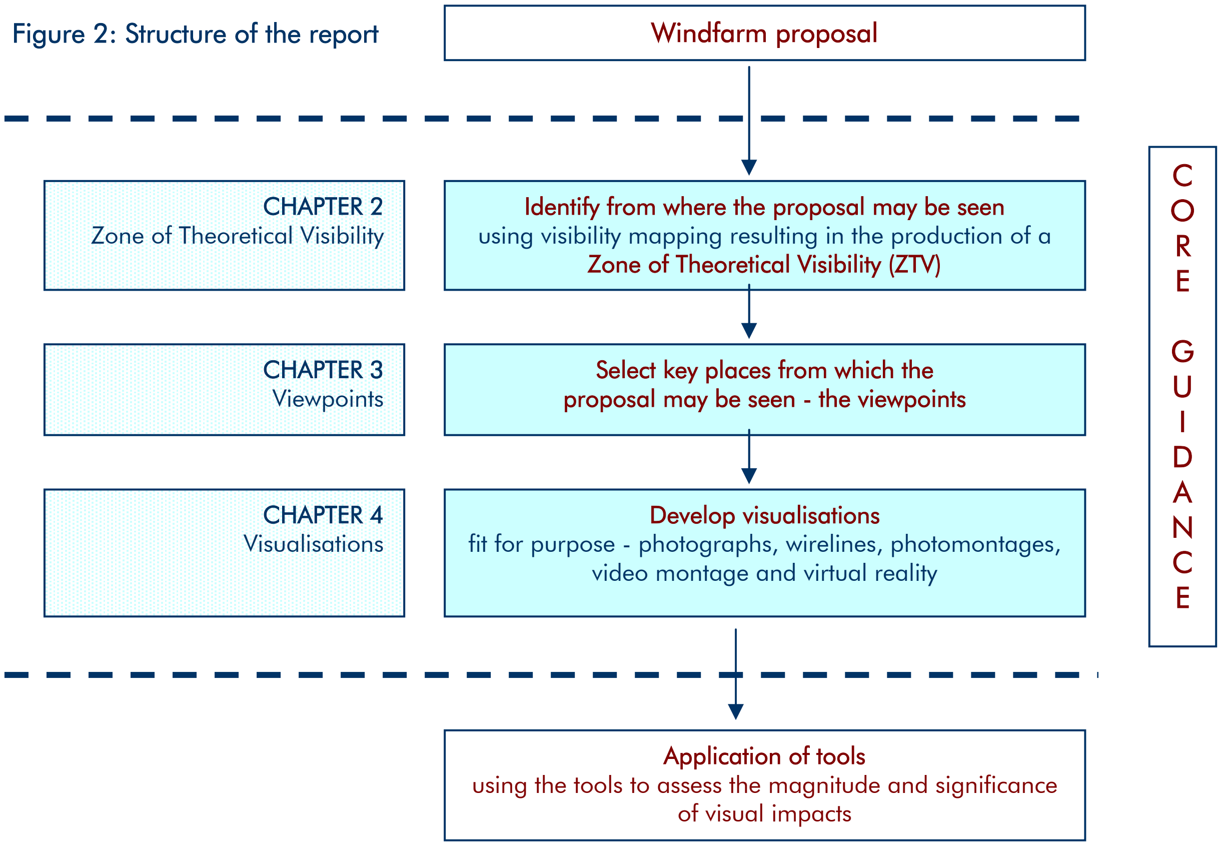
21 The guidance is presented in different sections so that it can be used as a reference tool. Not all of the information contained within the guidelines will be relevant in all circumstances.

22 The main body of this guidance is divided into a series of sections which broadly relate to the stages of a VIA process as shown in the diagram below. It is intended that the loose-leaf format will allow flexibility of use

and future updating of the guidance as new techniques are developed and experience grows.

23 The core of the Good Practice Guidance lies in chapters 2, 3 and 4 where the technical recommendations for different tools and techniques are explained as well as their uses and limitations. Where recommendations are based on complex and/ or detailed technical factors, these are further explained in the technical appendices.

Figure 2: Structure of the report



Glossary of key terms

24 A glossary is included within Appendix ii. However there are a number of key terms used throughout this document that need to be explained at an early stage as follows:

Digital Terrain Model (DTM). This term refers to the way in which a computer represents a piece of topography in 3-dimensions as a digital model. The terms Digital Elevation Model, Digital Ground Model and Digital Height Model are also used and are synonymous.

Landscape and Visual Impact Assessment (LVIA). This is the professional and methodical process by which assessment of the impacts of a proposed development on the landscape and visual resource is undertaken. It comprises two separate and distinct parts - Landscape Impact Assessment and Visual Impact Assessment.

Landscape Impact Assessment. This is the process by which assessment is undertaken of the impacts of a proposed development on the landscape, its character and quality. GLVIA (2002) states that "*Landscape effects derive from changes in the physical landscape, which may give rise to changes in its character and how it is experienced*".

Panorama. An image covering a horizontal field of view wider than a single frame. Panoramic photographs may be produced using a special panoramic camera or put together from several photographic frames. Wirelines and photomontages may also be produced as panoramas. See Appendix B.

Photomontage. A visualisation which superimposes an image of a proposed development upon a photograph or series of photographs. For windfarms, photomontages are conventionally used to illustrate proposed wind turbines within their setting. However tracks and other ancillary structures may also be shown. Photomontages are now mainly generated using computer software.

Significant. This term is used to describe the nature of a change. VIA, LVIA and EIA aim to identify and assess significant effects. For each project, levels of significance will be categorised and defined in relation to the particular nature of the resource and the proposed development.

'Telephoto Photomontage'. A type of photomontage (see above) based on a photograph taken using a telephoto lens (over 50mm when using a 35mm camera).

Visual Impact Assessment. This is the professional and methodical process which is used to assess the impacts of a proposed development on the visual appearance of a landscape and its visual amenity. GLVIA (2002) states that "*visual effects relate to the changes that arise in the composition of available views as a result of changes to the landscape, to people's responses to the changes, and to the overall effects with respect to visual amenity*".

Visualisation. Computer simulation, photomontage or other technique to illustrate the appearance of a development. This term is used within this Good Practice Guidance to include photographs, but not Zone of Theoretical Visibility (ZTV) maps.

Wirelines. These are also known as **wireframes** and **computer generated line drawings**. These are line diagrams that are based on DTM data and illustrate the three-dimensional shape of the landscape in combination with additional elements. For windfarm projects, wirelines usually show just wind turbines. However, some software also allows the representation of additional elements such as access tracks and masts.

Zone of Theoretical Visibility (ZTV). Also known as a **Zone of Visual Influence (ZVI), Visual Envelope Map (VEM)** and **Viewshed**. This represents the area over which a development can theoretically be seen, based on a DTM. The ZTV usually presents a 'bare ground' scenario - that is, a landscape without screening structures or vegetation. This information is usually presented upon a map base.

Visual Impact Assessment (VIA)

25 Visibility maps and visualisations are only tools. Within VIA, they are produced to aid the identification and assessment of significant visual effects.

26 General guidance on assessing significance of effects is contained within the Guidelines for Landscape and Visual Impact Assessment (Landscape Institute & Institute of Environmental Management & Assessment, 2002). Consequently, this document does not include guidance on this topic. Rather, this report focuses on the choice, production and use of visibility maps and visualisations.

Cumulative Landscape and Visual Impact Assessment (CLVIA)

27 As the number of proposed windfarms increases in Scotland, the issue of potential cumulative impacts becomes ever more important. This Good Practice Guidance will not, however, provide specific guidance on cumulative visibility maps and visualisations. This is for two main reasons:

- It is believed that Good Practice Guidance on the visual representation of individual windfarms should be established and adopted before venturing into the more complex arena of cumulative issues; and
- when this study was first commissioned, there was little existing research on the effectiveness of CLVIAs and the respective cumulative impacts of windfarms.

It is hoped, however, that guidance on the cumulative visual representation of windfarms will be produced in the near future. In the meantime, it is recommended that reference be made to the relevant documents listed within the following section and Appendix i.

Other sources of information

28 This Good Practice Guidance should be read in combination with existing guidance for LVIA, VIA, EIA and CLVIA. Existing guidance particularly relevant to the LVIA of windfarms in Scotland is included within the following figure 3:

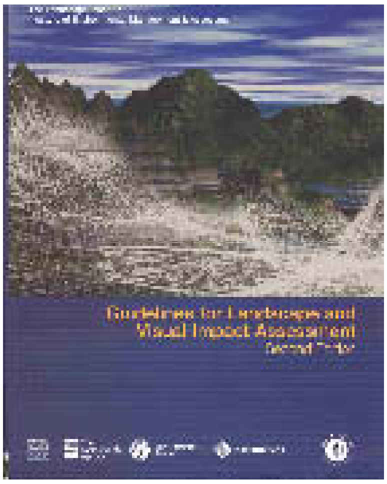


Figure 3: Existing guidance relevant to the LVIA of windfarms

- Landscape Institute & Institute of Environmental Management & Assessment (LI-IEMA). 2002. Guidelines for Landscape and Visual Impact Assessment. 2nd Edition. Spon Press, London.
- Scottish Executive. 1999. Planning Advice Note 58. Environmental Impact Assessment.
- Scottish Executive. 2002. Planning Advice Note 45. Renewable Energy Technologies.
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- Scottish Natural Heritage. 2003. Policy on Wildness in Scotland's Countryside (Policy Statement No 02/03). Available at www.snh.gov.uk.
- Scottish Natural Heritage. 2005. Cumulative Effect of Windfarms. Version 2 revised 13.04.05. Guidance. Available at www.snh.gov.uk.
- Scottish Natural Heritage. 2005. Environmental Assessment Handbook, 4th edition. Available at www.snh.gov.uk.
- University of Newcastle. 2002. Visual Assessment of Windfarms: Best Practice. SNH: Redgorton, Perth.

29 In addition, a number of landscape capacity studies for windfarms have been produced covering different parts of Scotland. For details, refer to www.snh.gov.uk.

30 The Landscape Institute produced Advice Note 01/04 in June 2004 on the 'Use of Photography and Photomontage in Landscape and Visual Assessment'. Further details on the issues raised by this note are included in the Technical Appendices A-E.

2 Zone of Theoretical Visibility

31 The term 'Zone of Theoretical Visibility' (ZTV) is used to describe the area over which a development can theoretically be seen, and is based on a Digital Terrain Model (DTM) and overlaid on a map base. This is also known as a Zone of Visual Influence (ZVI), Visual Envelope Map (VEM) and Viewshed. However the term ZTV is preferred for its emphasis of two key factors that are often misunderstood:

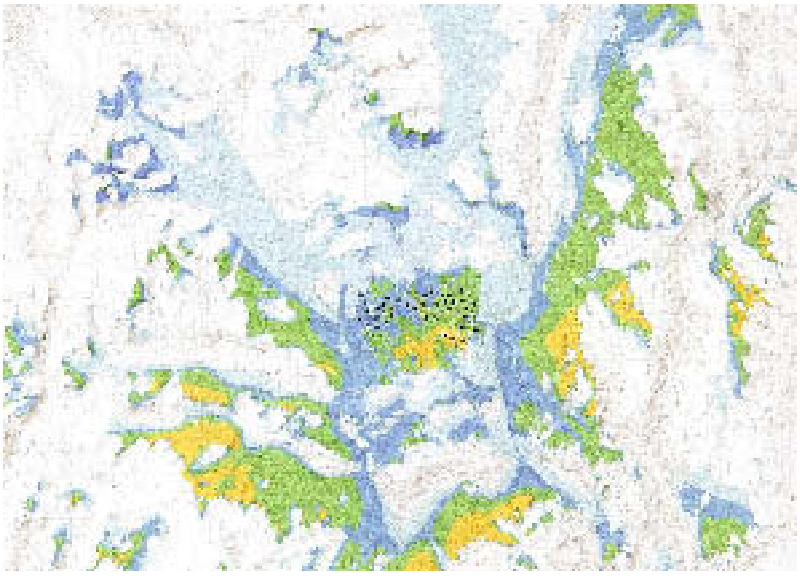
- visibility maps represent where a development may be seen theoretically – that is, it may not actually be visible in reality, for example due to localised screening which is not represented by the DTM; and
- the maps indicate potential visibility only - that is, the areas within which there may be a line of sight. They do not convey the nature or magnitude of visual impacts, for example whether visibility will result in positive or negative effects and whether these will be significant or not.

32 This section of the report highlights the following key issues with regard to ZTVs:

ZTV preparation	• ZTV data • ZTV calculation • Viewer height • Extent of ZTV

Presentation of ZTV information	• Base map • Colour overlays • Visibility bands • Recording ZTV information • ZTV development for a project • ZTV production

Good Practice Guidance Summary



33 ZTVs are calculated by computer, using any one of a number of available software packages and based upon a DTM that represents topography. The resulting ZTV is usually produced as an overlay upon a base map, representing theoretical visibility within a defined study area.

34 Production of ZTVs is usually one of the first steps of VIA, helping to inform the selection of the study area in which impacts will be considered in more detail. ZTVs provide the following information:

- where visibility of a windfarm is most likely to occur;
- how much of the windfarm is likely to be visible (within bands of various numbers of turbines);
- how much of the wind turbines is likely to be visible if separate ZTVs are produced showing visibility up to blade tip height, and visibility up to the hub or nacelle; and
- the extent and pattern of visibility.

In combination with a site visit, possibly with initial wireline diagrams, this information enables the landscape architect or experienced specialist assessor to identify a provisional list of viewpoints, and allows the determining authority and consultees to judge how representative these are and whether they include particularly sensitive vantage points.

35 Importantly, ZTVs indicate areas from where a windfarm may be seen within the study area, but they cannot show how it will look, nor indicate the nature or magnitude of visual impacts.

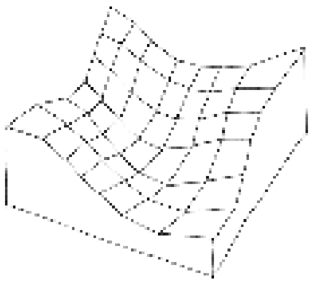
Table 1: Uses and limitations of ZTVs
(numbers in brackets refer to paragraph numbers in text)

USES OF ZTVs	LIMITATIONS
• A ZTV gives a good indication of the **broad areas** from where a windfarm might be seen (31, 34). • A ZTV predicts **theoretical visibility** (31). • A ZTV is a useful **tool** as long as its limitations are acknowledged. • The ZTV can be used to **identify viewpoints** from where there may be significant visual impacts, enabling an assessment to consider these with the aid of visualisations (34). • A ZTV is a useful tool for comparing the relative visibility patterns of different windfarms or different wind turbine layouts (84-85).	• A ZTV is only as accurate as the data on which it is based (49-51). • A ZTV **cannot indicate the potential visual impacts** of a development, **nor show the likely significance of impacts**. It shows potential theoretical visibility only (31, 33). • It is not easy to test the accuracy of a ZTV in the field, although some verification will occur during the assessment of viewpoints. • A ZTV, if prepared to good practice guidelines, will be adequate as a tool for VIA; however is will never be entirely 'perfect' for a number of technical reasons. Most importantly, in order to handle large areas of terrain the DTM data is based on information which does not allow detail to be distinguished below a certain level. There are also differences in the way that the software package 'interpolates' between heights in the calculations made (44-45).

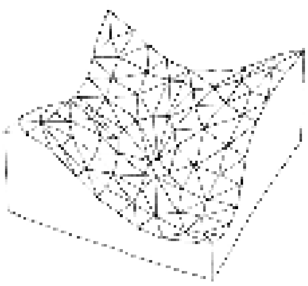
ZTV preparation

ZTV data

36 A ZTV is produced using a computer-based software package. Several of these are commercially available, for example, most windfarm design packages and many Geographical Information System (GIS) packages have this facility. However, operation of even the most user-friendly package requires a high level of expertise and understanding of all the specific features and assumptions applied by the software.



Square grid DTM



TIN

37 ZTV production begins with a Digital Terrain Model (DTM) that represents the ground surface as a mesh of points. This may form a regular grid of squares when seen on plan, known as a Square Grid DTM, or an irregular network of triangles, known as a TIN (Triangulated Irregular Network).

38 A Square Grid DTM is fundamentally incapable of representing terrain features smaller than the cell size, such as a small knoll or outcrop. Such features are either lost between grid points or represented by one point only. A TIN can, in principle, represent finer detail than a Square Grid DTM as it can represent all the detail shown by contours. However, in practice, a Square Grid DTM with a suitably chosen cell size will represent almost as much detail and may interpolate better between contours on less steeply sloped land.

39 Both formats are acceptable. The choice between them is most likely to depend on the software being used and from where the data is sourced. It is common practice for a Square Grid DTM to be chosen if OS data is to be used, while a TIN is used when based on independent and/or detailed survey data, enabling high and low points to be better represented.

40 The Ordnance Survey (OS) supply data in two formats - gridded, which has already been interpolated into a

Figure 4: Comparison digital terrain models

Wireline drawing of OS Panorama DTM at the supplied 50m grid size

Wireline drawing of OS Profile DTM of the same area at the supplied 10m grid size. As would be expected, far more terrain detail is apparent in this DTM. Also, because the source is 1:10,000 contours rather than 1:50,000, the shapes of quite large landscape features are better represented.

Square Grid DTM, and as contours, which is the usual starting point for constructing a TIN.

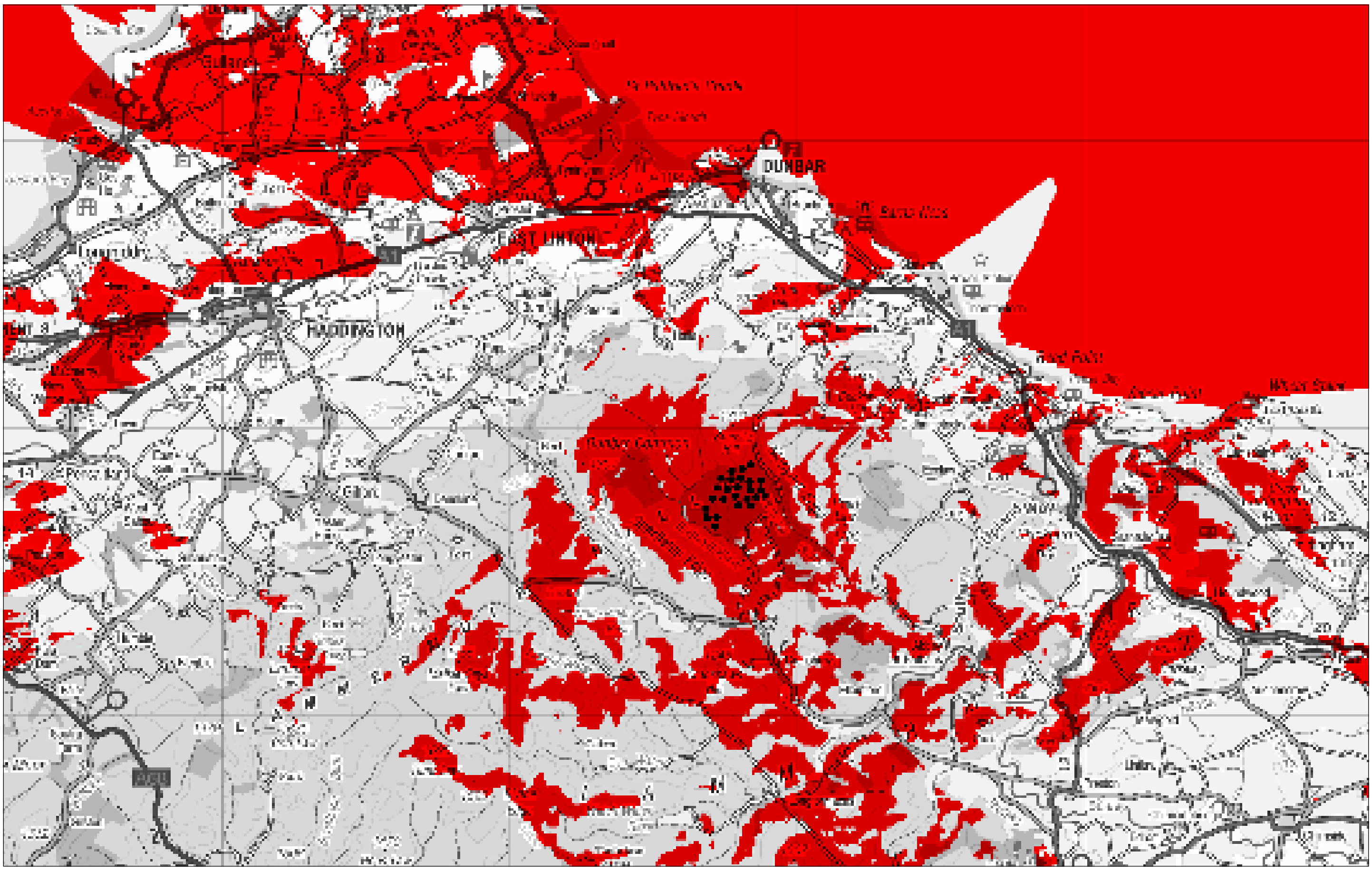
41 The OS Square Grid DTM product, 'Landform Profile', uses a 10m cell size and is interpolated from the contours shown on OS 1:10,000 and 1:25,000 scale mapping. An earlier product, 'Landform Panorama', once temporarily withdrawn, but now re-launched, uses a 50m cell size and is derived from 1:50,000 scale mapping.

42 The 10m Landform Profile DTM provides a more precise representation of topography than the 50m Landform Panorama DTM, as illustrated within figure 4, although, not surprisingly, it is more expensive. Landform Panorama DTM is less precise not only because of the larger cell size, but also because the shape and detail of the 1:50,000 scale contours used as the source data are themselves more simplified than the 1:10,000 scale contours. If Landform Panorama DTM is used, it is important that the resolution at which it is provided is used and the grid is not down-sampled, as shown in figure 5.

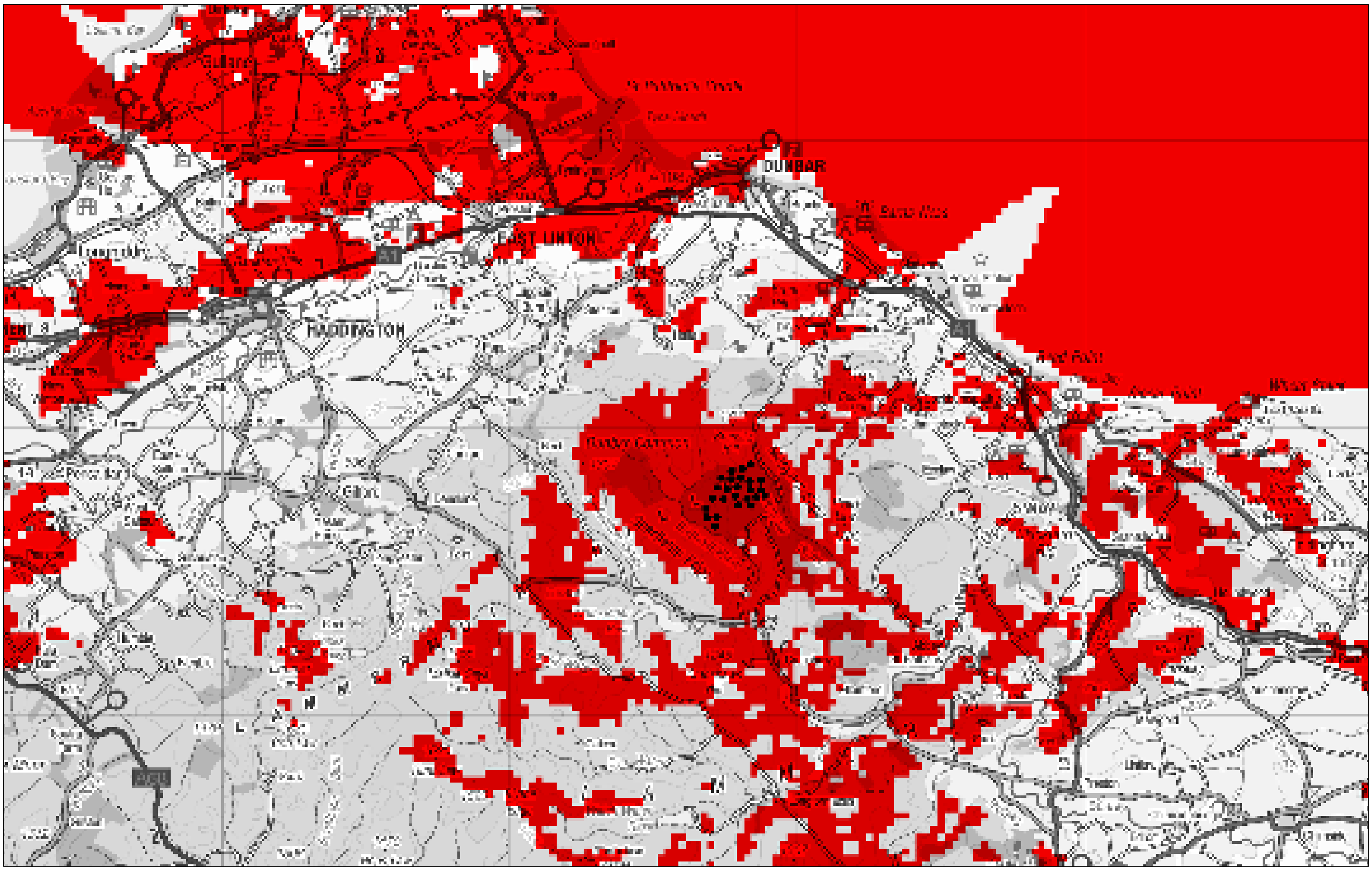
43 OS Landform Panorama DTM is considered an acceptable product, especially if the landform is simple. However the recommended preference is for OS Landform Profile, especially if the terrain is very rugged.

44 Although considered adequate for the purposes of VIA (given that ZTVs are just a tool for assessment), the accuracy of most DTMs is limited and they do not include accurate representation of minor topographic features or areas of recent topography change, such as open cast coalfields, spoil heaps and mineral workings. Known significant discrepancies between the DTM and the actual landform should be noted in the ES text. If survey information on recent topographic change is available, together with the necessary software to amend the DTM, it may be

Figure 5: Comparison of ZTV grid size



ZTV of windfarm based on OS Landform Panorama data at the supplied 50m grid size



ZTV of windfarm based on OS Landform Panorama data with the grid size downsampled to 250m. Some small areas of theoretical visibility are not shown at all, while others are over-represented. (Scale 1:250,000) useful to include it. However, any changes to the DTM should also be noted in the text.

45 The OS provides accuracy figures for each of its data products (expressed statistically as root-mean-square error in metres). Where the DTM is obtained from another source, the expected accuracy can also usually be obtained from the data supplier. These accuracy figures should be stated within the ES. However, non-experts may find it difficult to extrapolate from this a judgement of precision. Therefore it is preferable if these figures are accompanied within the ES by a general statement from the landscape architect or experienced specialist assessor that confirms that the levels of accuracy fall within acceptable limits.

46 An alternative to the OS DTM products is NextMap which offers a grid with a cell size of 5m. This is a Digital Surface Model (DSM) derived from airborne radar data. As its name implies, the grid is a model of the upper surface of the land, including vegetation, buildings and other ground cover. As such, it can provide a good basis for calculating visibility including the effects of such features. A parallel product is also available from the same source which is a DTM with a cell size of 5m or 10m. However, as this is derived from the DSM with ground heights estimated from the height to the top of ground cover, its accuracy is not entirely reliable, except in very open areas.

47 ZTV production also requires data on the locations and heights of the proposed wind turbines. For the purposes of ZTV calculation, it is sufficient to represent each proposed turbine as a single point in space, located directly above the centre of the proposed base of the turbine. The height specified is usually that at either hub/nacelle height or at a blade tip pointing straight up, but can be at any other point on the turbine depending on the ZTV analysis required.

48 It is recommended that separate ZTV calculations are run for the overall height (to blade tip) and for the

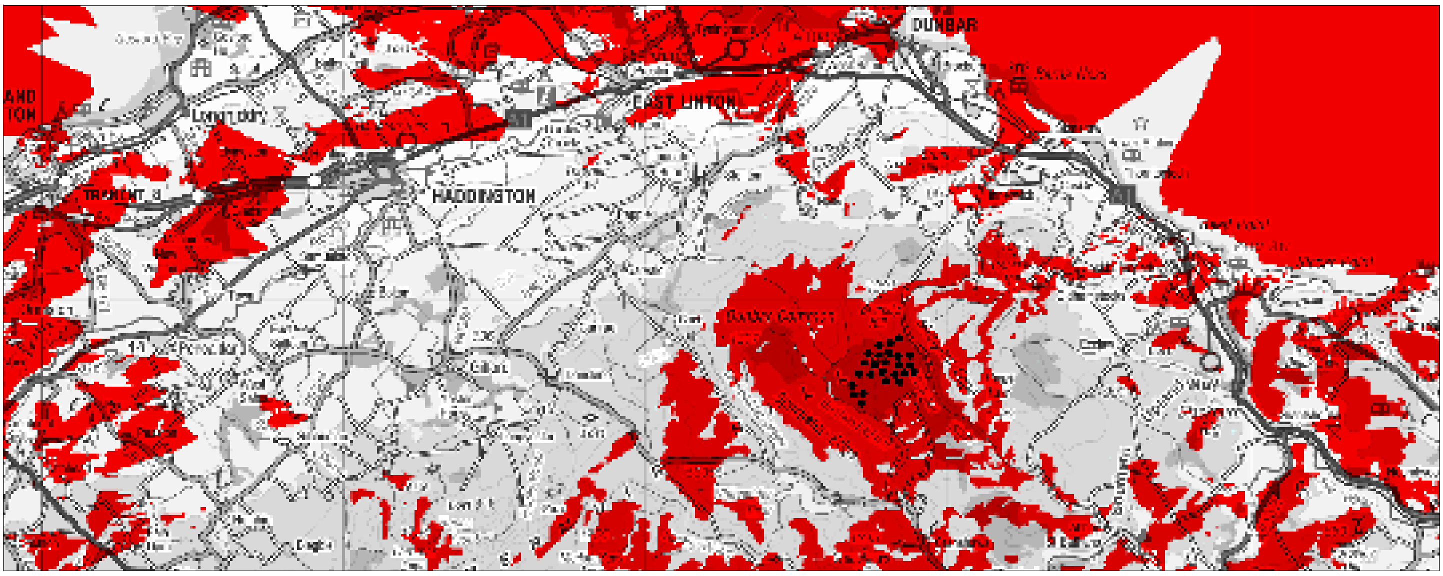
height of the turbine to its hub (representing the nacelle that houses the generator on top of the tower). This is a useful comparison that helps to identify areas where turbine blades may be visible, but not the tower or nacelle. For a single proposed turbine, it can also be useful to run ZTVs with other targets, such as 1m above the ground and at the base of the rotor sweep which, in combination, provide an indication of where almost all the turbine or just the rotor sweep may be visible.

ZTV calculation

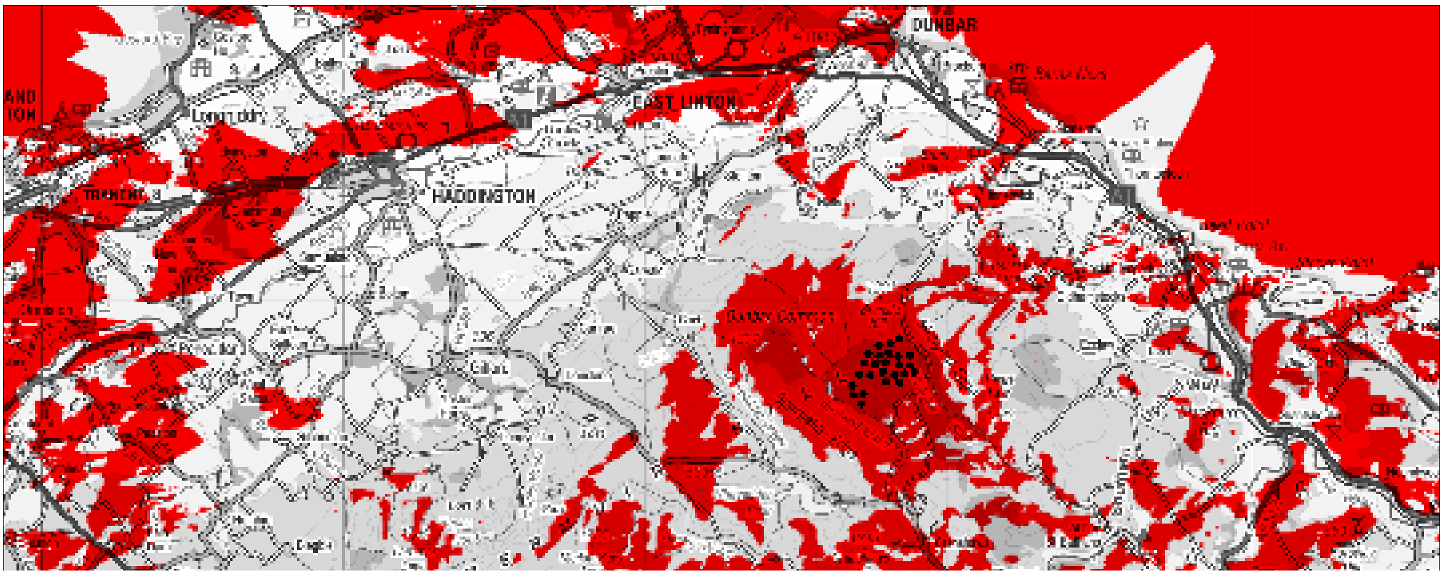
49 In principle, all ZTV software packages are similar, but variations in the detailed routines (algorithms) used for each mean that slight variation in results may be produced by different packages using the same data. Most differences stem from different choices in the shape of the ground surface that the software assumes to exist between the grid points in the DTM and tend to result in insignificant discrepancies. Some software packages offer both a standard and 'fast' option for ZTV calculation. 'Fast' implies the use of mathematically approximate methods in order to speed up the computation, which tends to result in greater errors. It is recommended that this is only used to obtain a quick, provisional result which will be later superseded by a more comprehensive calculation. It is also important, that users of ZTV software ensure that they are clear about the technical limitations inherent in their chosen package.

50 Visibility is affected by earth curvature and the refraction (bending) of light through the atmosphere, particularly at greater distances, as shown on figure 6. Therefore this effect should be included in the ZTV calculation as its absence will tend to overestimate visibility. Appendix F treats this issue in more detail and includes a table of the vertical difference introduced by earth curvature and refraction with distance. At 10km, the vertical difference is enough to

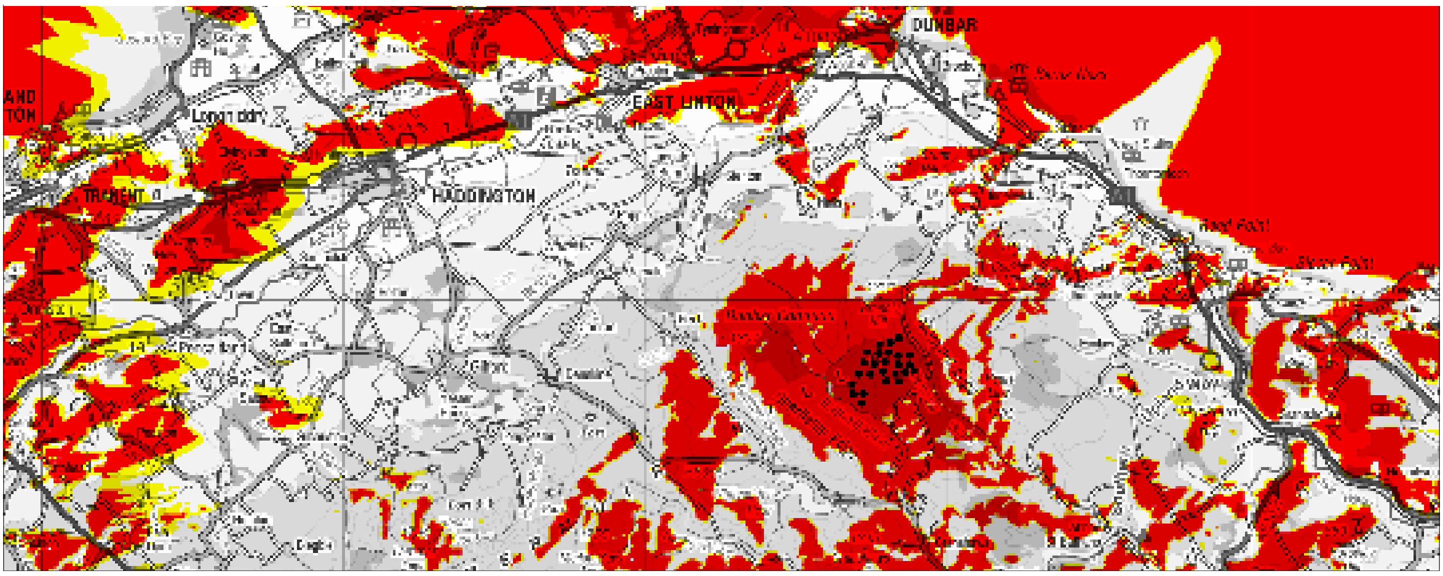
Figure 6: The effects of earth curvature upon a ZTV



a: ZTV of windfarm including effects of earth curvature and atmospheric refraction



b: ZTV of windfarm without earth curvature or refraction



c: Above images superimposed. The yellow areas indicate areas from which the windfarm would not be theoretically visible but which are shown as visible on the ZTV map without earth curvature or refraction. The areas principally affected are naturally those with more distant views. Depending on the shape of intervening topography, these areas can be quite large. (Scale 1:250,000) hide a single storey house and it increases more rapidly thereafter.

51 These limitations, inherent in the data and in the method of calculation should always be acknowledged and, if possible, quantified. Note that these limitations may either over or under-represent visibility. As a general rule, ZTVs should be generated to err on the side of caution, over-representing visibility. There are no defined thresholds for this allowance; rather, judgements will need to be made based on professional expertise in this field.

52 A ZTV usually represents visibility as if the ground surface was bare; that is, it takes no account of the screening effects of intervening elements such as trees, hedgerows or buildings, or small scale landform or ground surface features. The ZTV also does not take into account the effects of weather and atmospheric conditions in reducing visual range. In this way, the ZTV can be said to represent a 'worst case scenario'; that is, where the windfarm could potentially be seen given no intervening obstructions and favourable weather conditions (while accepting that the DTM data can sometimes understate visibility at the very local level). To understand how this might be affected by typical visibility conditions within a particular area, Met Office data on visibility conditions can be obtained.

53 Some software does allow the use of more sophisticated datasets, enabling some screening effects to be taken into account. Examples are the application of data which applies different 'thickness' to various land uses such as forestry and urban areas, and the use of digital surface data obtained from laser-based aerial surveys which represent the tops of vegetation and buildings. At present, for most projects, this data does not make a considerable difference to the pattern of visibility, while tending to be very expensive; therefore, its use should be limited to specific projects where the benefits will be notable.

Care needs to be taken when assessing this kind of information, as its accuracy is limited by data availability and the constant change in landscape conditions. The results will also be closely tied to the specifications used, for example the height of trees; as a consequence, these should be noted within the ES.

54 In some situations, it might be useful to map other characteristics such as the number of wind turbines seen against the skyline or what proportion of the horizontal field of view is likely to be occupied by the visible part of a windfarm, known as the 'horizontal array angle'. This information is particularly useful for considering the impact of a very large windfarm or several windfarms where they would be seen together within panoramic views. However, for most windfarms, the width of view can usually be more simply judged by considering the distance to the development in combination with wireline diagrams from specific viewpoints.

55 Any analyses that calculate characteristics other than simple visibility over base ground should be produced in addition to bare ground visibility, not as an alternative to it. Although these currently have various limitations as described above, improvement and development of this kind of data is likely to occur in the future.

Viewer height

56 As the ZTV calculates the number of wind turbines visible at each of a number of points just above the ground, a measure of viewing height is required. Often this is set at 1.5–2 metres. The rationale for this height is usually given as relating to viewer height and/or camera height to maximise correlation between the ZTV and visualisations. However, although viewer height is an important element of the ZTV calculation, the error inherent in the DTM is of about the same magnitude (1.5 metre RMS error for Landform Profile, 2.5 metre RMS error for Landform

Panorama). Consequently, it is recommended that the viewer height adopted should try to both avoid errors arising from DTM and inaccuracy close to a viewpoint, for example due to local undulations, as well as taking into account the typical height of a viewer. To satisfy these criteria, it is recommended that a standard viewing height of 2 metres is used.

Extent of ZTV

57 As previously discussed, a ZTV map illustrates locations within a study area from where a development is potentially visible. However, just because a development can be seen, it does not automatically follow that this will result in significant visual impacts. This creates a circular process of decision-making. That is: the distance of a ZTV should extend far enough to include all those areas within which significant visual impacts of a windfarm are likely to occur; yet the significance of these visual impacts will not actually be established until the VIA has been completed; and the VIA process needs to be informed by the ZTV. As part of this cycle of assessment, the recommendations given within Table 2 below act as a starting point. However, the actual extent required may need to be adjusted inwards or outwards according to the specific characteristics of a landscape and/or proposed development. It is advised that determination of the extent of the ZTV should be discussed and agreed with the determining authority and consultees.

Figure 7: Process of determining ZTV extent

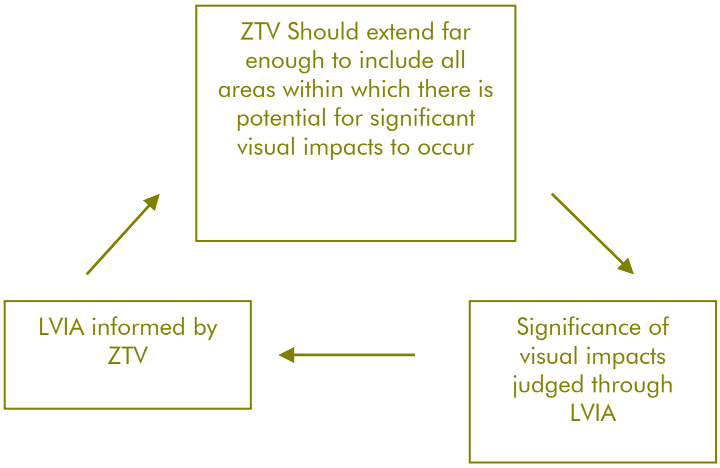


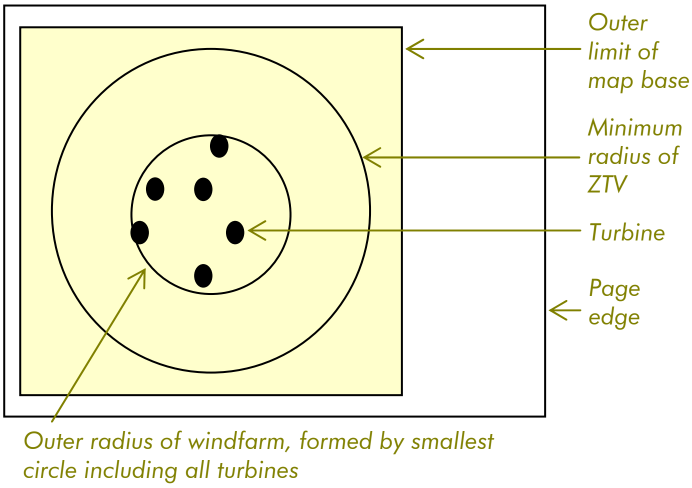
Table 2: recommended distance of ZTV

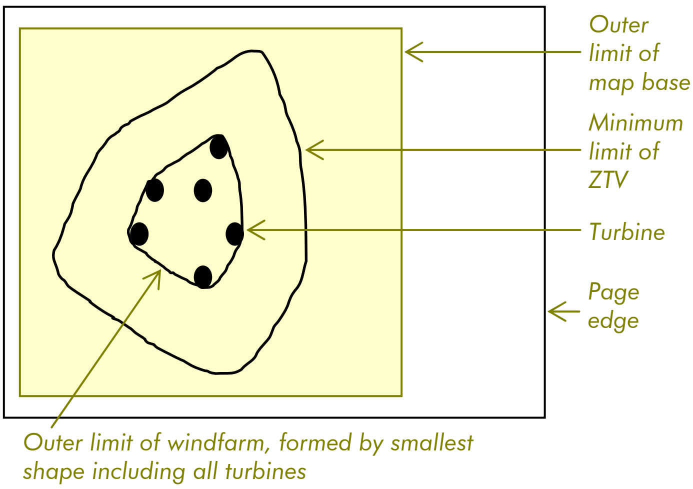
Height of turbines including rotors (m)	Recommended ZTV distance from nearest turbine or outer circle of windfarm (km)
up to 50	15
51-70	20
71-85	25
86-100	30
101-130*	35*

*These figures are based on recommendations within 'Visual Assessment of Windfarms: Best Practice' (University of Newcastle, 2002). * This category was recommended by the late John Benson, based on experience and extrapolation of evidence presented within the publication cited above.*

58 The extent of a ZTV is typically defined as a distance from the outer turbines of a windfarm. This can be to the nearest turbine or as incorporated within a specific shape, as shown below. The most suitable option will usually depend on the layout of the windfarm.

Figure 8a and 8b
Measuring the extent of a ZTV

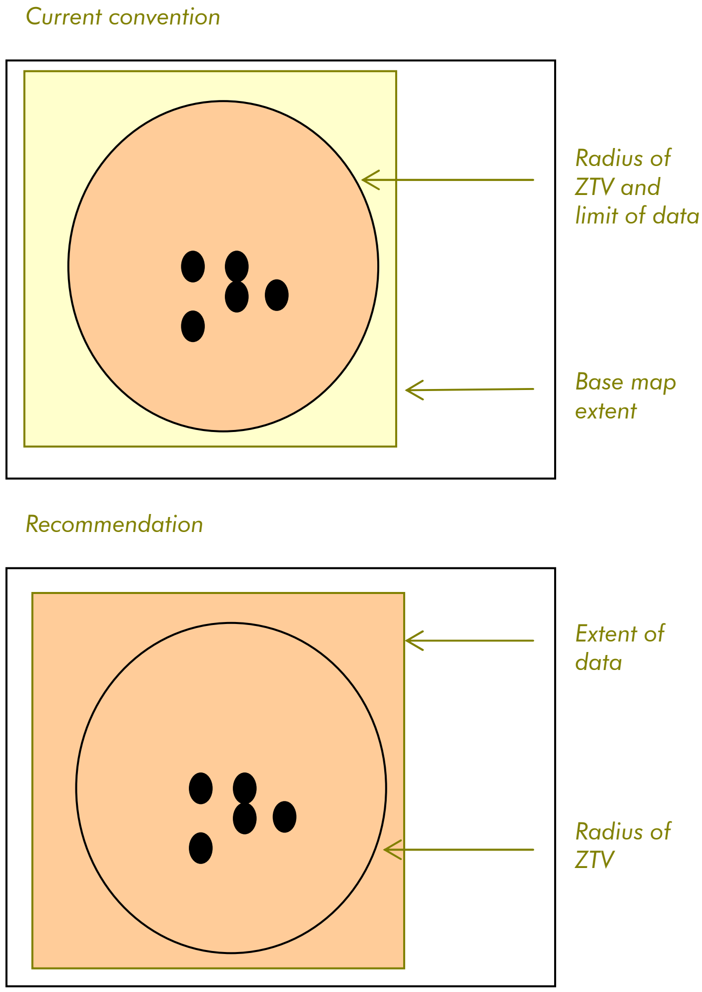




59 If a windfarm is very small and concentrated in layout, typically 5 wind turbines or less, it may be reasonable to measure the extent of the ZTV from the centre of the site. However this should always be agreed with the determining authority and consultees.

60 ZTV information is often shown as stopping at the outer radius of the ZTV and not the edge of the map base, unlike other information usually presented within a LVIA such as landscape character and landscape designations. This cut-off can appear slightly irrational upon a rectangular base map, seeming to imply that visibility ceases at a defined distance (although it is acknowledged that, when considering cumulative visibility from multiple developments, limiting data to this boundary may improve clarity of the separate ZTVs). Consequently, it is recommended that a ZTV overlay for an individual windfarm should extend to the border of the map that includes the recommended ZTV distance.

Figure 9a and 9b
Presentation of ZTV information



61 Table 2 provides recommended distances for ZTV data. These are based on turbine height. However this is just one factor which affects potential visibility and, as discussed previously, the ZTV distance may need to be adjusted up or down depending on the specific environmental conditions and landscape context in addition to the nature and scale of the proposed development.

62 The recommendations within Table 2 are based upon the total height of a turbine to blade tip. However it is important to understand that visibility of turbine blades and turbine towers differs. At close distances, turbine blades often seem more noticeable than the towers due to their movement; while at far distances, the turbine towers are usually more prominent because of their greater mass, and may actually be the only element visible at very great distances. This creates a slightly odd situation; that is, the categorisation of visibility to blade tip at far distances, while turbine blades might not actually be visible at these distances. However, the reality is that the categories of turbine height used in Table 2 act only as a 'yard stick', and similarly defined categories based on tower or hub height would likely provide the same recommendations. The only notable discrepancy might be if a wind turbine was unusual in its proportions, for example having a high hub with a smaller than usual rotor diameter. However the difference of visibility that would occur in these circumstances at far distances is unlikely to be significant; and, even if it were predicted as being significant, the difference could be accommodated by adjusting the ZTV as discussed in paragraph 61above, as part of the usual process of confirming ZTV extent for a specific scheme.

63 For turbines between 53 and 85 metres total height, the University of Newcastle (2002) reported that it was not possible to identify the taper of a turbine tower or identify nacelle detail at distances over 10km. They

also reported that blade movement could be detected up to15km in clear conditions, or where there was a strong contrast between the rotors and the sky, but that a casual observer may find blade movement unnoticeable beyond 10km. These observations highlight that visibility of the different aspects of wind turbines will vary. However most new wind turbines are of heights much greater than those on which these observations are based and, unfortunately, it was not within the scope of this study to carry out site assessment of more recently built, taller wind turbines on which additional guidance could be based.

64 Some practitioners have suggested that, as it usually becomes difficult to see turbines clearly when over 30km away, extending a study area further than this is unlikely to ever be necessary. Although there is obviously some validity to this argument, it is nevertheless the case that some exceptional visibility conditions occur at times in Scotland. Combined with the fact that some key vantage points in Scotland, such as the tops of mountains or hills, are of very high sensitivity in terms of scenic value, some windfarms could clearly be seen at certain times from very sensitive locations at great distances away. This means it is feasible that, in exceptional circumstances, visibility of a windfarm or windfarms could result in significant effects beyond 30km. This highlights the importance of determining ZTV extent in agreement with the determining authority and consultees for a specific project.

65 It has been suggested that the ZTV radius should also depend on the number of wind turbines in a development. In purely technical terms, visibility extent is not actually dependent on the number of turbines, as a single 100m turbine would technically be as visible as 100 x 100m turbines from a set distance. However a larger windfarm would obviously be more noticeable, particularly as the eye tends to be attracted to groups or patterns when it might otherwise miss a

single element. So although the guidance included in Table 2 above would be applicable for most windfarms and should be used as the 'starting point' for ZTV production, it may be acceptable to adopt a reduced study area for a smaller development and it may be advisable to explore a wider area for a larger windfarm. This should be agreed in consultation with the determining authority and consultees.

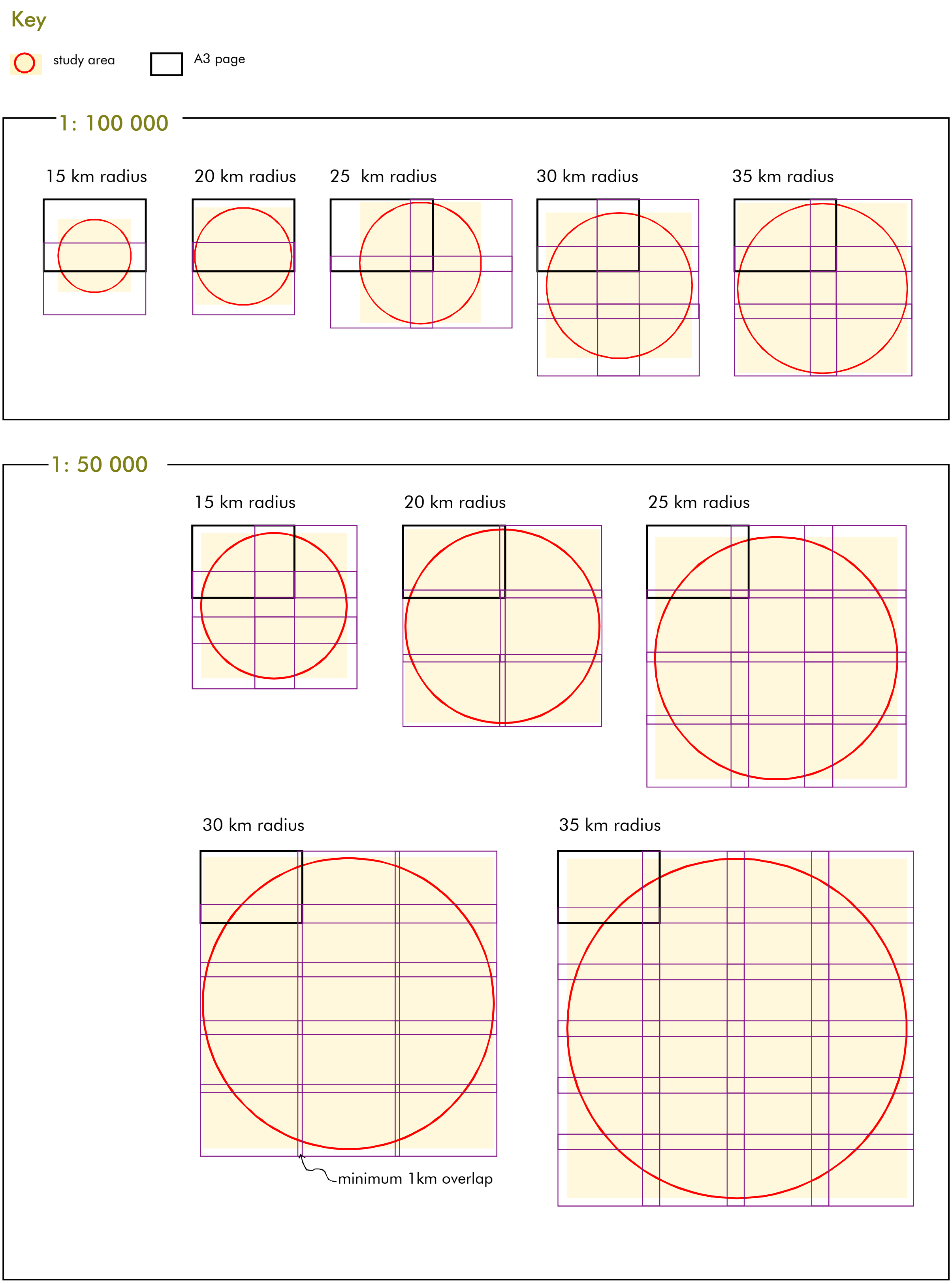
Presentation of ZTV information

Base map

66 A ZTV should be superimposed on a clearly legible base map at a recognised standard scale, such as the Ordnance Survey (OS) 1:50,000. For an ES in A3 format (420 x 297mm), showing a ZTV extending from a site up to a 30km radius, a scale of 1:250,000 will be required to fit a single page. At this scale, the ZTV can only provide an overview and thus another more detailed ZTV is required for use as a working tool for VIA, consultation and design. This should be provided on a 1:50,000 OS base (copied at either 1:50,000 or 1:100,000) to be able to illustrate sufficient detail, as shown in figure 10a and b. However a ZTV at this scale obviously results in a much larger map as detailed within Table 3. Conventionally, this is presented as either a single fold-out plan or as separate A3 sections (with minimum 1km overlaps).

67 Single maps are usually clearer as they show the whole study area on one sheet, but they may be more difficult to handle and require folding and insertion within a wallet in the ES. Separate A3 maps will divide the study area, and possibly the site, into sections, so a supplementary and overlapping site-centred map may also be required. Although, a high number of sheets may be required to cover an entire study area in this way, as shown in figure 11, not all of the study area may require detailed coverage if the ZTV overview identifies that large areas within the study area would

Figure 11: Overlap of A3 sheets to illustrate ZTV coverage



have no visibility of the proposed development at all. Conversely, for particularly sensitive areas, it may be useful to produce large-scale enlargements (representing the information used by the assessor when zooming in on the ZTV on a computer screen) in order to examine small areas of theoretical visibility.

Table 3: Size of ZTV at various scales and to fit standard paper sizes

ZTV extent (from single point)	Size of single map				Number of A3 separate sheets*	
	1:100,000		1:50,000		1:100,000	1:50,000
	Image size	Paper size	Image size	Paper size		
15km	300x300	A2	600x600	A0	2	6
20km	400x400	A2	800x800	A0	2	6
25km	500x500	A2	1000x1000	-	4	12
30km	600x600	A0	1200x1200	-	6	15
35km	700x700	A0	1400x1400	-	6	24

68 For a ZTV to be clear and legible when overlain with colour shading, the base map needs to be in greyscale. This is to prevent confusion of overlays, for example a yellow overlay upon blue coloured lochs will appear as green, and this could be confused with woodland (figure 12). To maximise legibility, it is also important that the base map is of a high quality resolution and not too light or dark.

69 Each individual wind turbine should be clearly marked upon the ZTV, usually shown as a small circle or 'dot', depending on the base map against which it has to be distinguished. Although it is recommended that the ES includes a map that shows individual turbine numbers and their grid coordinates, and that the ZTV should include reference to this map, it is best not to include this information on the ZTV itself in order to keep this map as clear as possible.

70 It is recommended that viewpoint locations (numbered) also be shown on the ZTV, although it is important to

label these carefully to avoid obscuring vital ZTV information. This requirement is discussed further in paragraph 114.

71 For ease of legibility it is recommended that the ZTV show concentric rings to indicate different distances from the proposed development, for example 10, 20 and 30 km. However, the areas encircled by these rings should not be shaded or coloured as this may imply a direct relationship between distance and relative visibility or visual impact that would be misleading. To maintain legibility, the number of rings should also be limited.

72 Where ZTVs need to show potential visibility of different components of the wind turbines, this should be clearly explained as follows:

- a ZTV 'to blade tip' shows potential visibility of any part of a wind turbine up to its highest point (but not all of the wind turbine would necessarily be seen);
- a ZTV 'to hub' or 'to nacelle' shows potential visibility of any part of a wind turbine up to the height of its hub or nacelle (but not all of the wind turbine tower would necessarily be seen); and
- Comparison between ZTVs to blade tip and nacelle/hub allows identification of those areas from which the turbine towers might not be visible, but the blades (or part of these) would.

Colour Overlays.

73 Areas of potential visibility should be illustrated by a colour overlay. This should be slightly transparent so that the detail of the underlying map can be seen. Transparency within most software is expressed as a percentage – the amount of colour dots to clear space per unit area. The level of overlay transparency chosen should ensure that the detail upon the base map remains clearly discernible and no single colour appears more prominent than another.

74 If a range of colours is to be used, the shades and tones should be chosen carefully. Darker colours tend to read as portraying greater visibility than lighter colours whilst several colours of similar tone tend to convey information of equal importance. Using different shades of only one colour should generally be avoided as the distinctions between bandings usually appear merged and this can also imply a gradation of impacts represented by the decreasing shades that is misleading (figure 13a).

75 Legibility of a ZTV map tends to decrease with greater numbers of colours. For this reason, 7 colours should typically be the maximum used on any one map. It is recommended that these are bright and strongly contrasting as is illustrated within the scheme shown in figure 13b.

76 When selecting the colour palette to be used on a ZTV, it is important to consider how the colours would be seen by different viewers. One of the most important considerations is how the same colour will be represented differently according to the specification of different computer screens and/or printers. It is recommended that practitioners always print out draft copies to check that any discrepancy between these still produces a clearly legible map, and then print out the final copies on the same printer.

77 When choosing a colour palette, it is also important to consider colour blindness. It is estimated that around 7-8% of males and 0.4-1% of females in Britain have some form of colour blindness. To them, legibility of maps depends on the type of colour blindness they have, the shade and brightness of the colour, and on the contrast and combinations of colours used. This requires careful consideration and is not just a simple issue of avoiding the juxtaposition of red and green.

78 While it would be useful to specify a standard range of colours consistently legible to colour blind people, it is impossible to develop this without also standardising

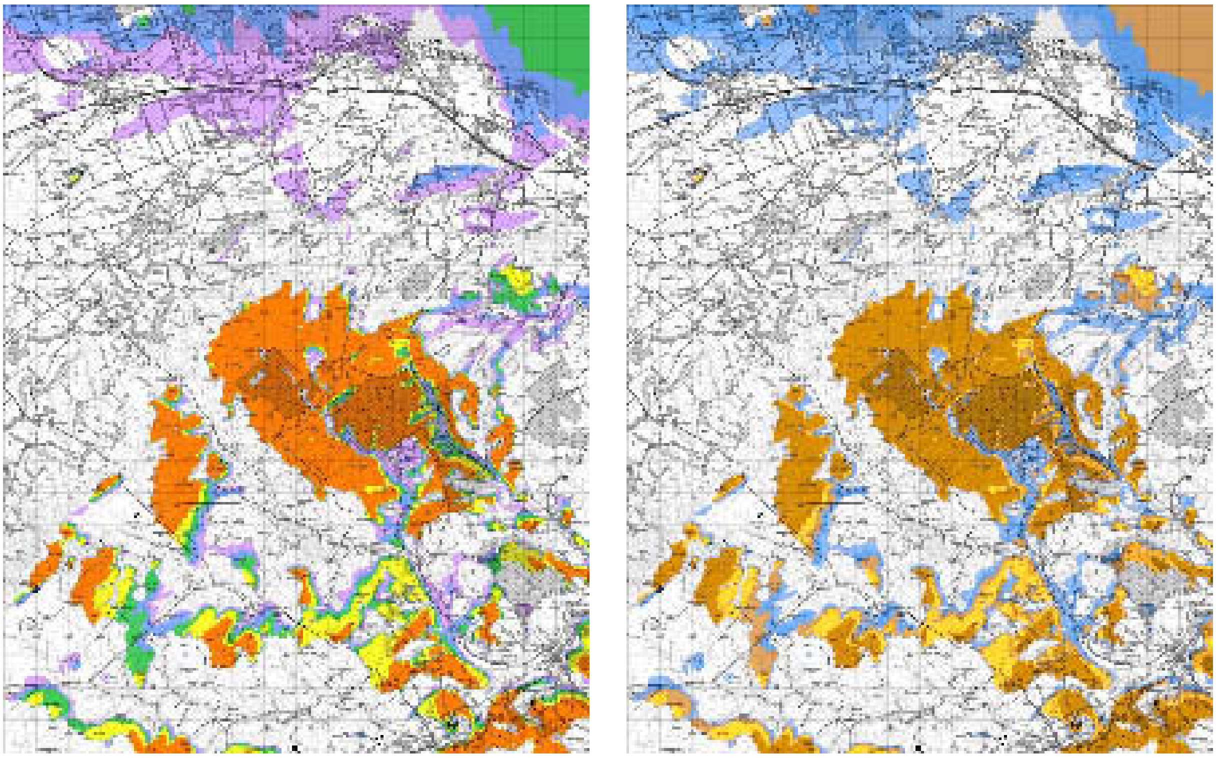
Figure 14: Colour blindness

There are various web-based tools which help map makers to devise a palette of colours which are readable for the majority of the population and have colour charts which compare normal vision with various types of colour blindness.

ZTV maps should be checked for colour blindness legibility for instance by running them through a web based tool like Vischeck (www.vischeck.com) This allows any image to be shown as it would appear for people with the three main types of colour blindness. It can be downloaded or used online.

computer screens and colour printer reproduction. Thus, as an alternative, it is recommended that individual maps shown within each ES are checked for colour blind legibility using a quick clarification tool, for example as described within figure 14.

Figure 15: The effect of colour choice on ZTV clarity for colour blind people



The map on the left shows a possible colouring of a ZTV in five bands. The version on the right has been processed to simulate the effect of red/green colour blindness on these colours. (Carried out using the Photoshop filter distributed by Vischeck.com.) The blue and violet bands are difficult to distinguish, as are the orange and green bands. This map would not be easily readable by a person with red/green colour blindness.

Visibility bands

79 The theoretical visibility of different numbers of wind turbines (within a single development, or different windfarms within a cumulative ZTV) is usually distinguished upon a ZTV as different coloured bands. It is important to highlight that these bands differentiate between the visibility of different numbers of wind turbines as a tool for assessment. They are in no way intended to imply that greater numbers of turbines will necessarily result in higher levels of visual impact. These bands are particularly useful for

identifying potential viewpoints where the visibility of the windfarm varies considerably within an area.

80 The number of visibility bands should be high enough for each band to represent just a small range of turbine numbers, whilst low enough to avoid the need for too many colours which can appear confusing. For example, with 30 turbines, it is better to have 6 bands each covering 5 turbines (1-5, 6-10, etc) rather than 3 bands of 10 turbines which would provide limited resolution, or 10 bands of 3 turbines which would appear confusing. As mentioned in paragraph 75, it is recommended that no more than 7 colour bands should be used upon a ZTV.

81 Where equal banding is impossible (for example 11 turbines), then the widest band size chosen should apply to the lower end of the scale – for example 1-3, 4-5, 6-7, 8-9, 10-11, as greatest resolution is then retained where visibility is furthest.

82 For a small windfarm, an alternative to different coloured bands representing the visibility of turbine numbers, is to produce numerous ZTVs that each represent visibility of an individual turbine or individual group of wind turbines. This is a very useful tool for designing turbine position where a variable landform strongly affects visibility. The downside is the need to overlay or compare numerous ZTV maps. For anyone with access to a software package such as Photoshop, a high number of ZTVs can be better managed as transparent layers upon the same base. The various layers, representing visibility of different wind turbines or groups, can then be turned on and off to illustrate various visibility scenarios. However, production of maps in this format will inevitably need to occur only as a supplement to paper copies within an ES to ensure accessibility of this information for all.

Recording ZTV information

83 It is vital within an ES to include information on all the key assumptions made in ZTV production, and to summarise these within the VIA. This should include the following information:

	Table 4: Information on ZTV production to be provided
1	The DTM data from which the ZTV has been calculated, including original cell size and whether this has been sampled down.
2	Confirmation that it is based on a bare ground survey, or provision of information on the specifications of additional land use data if this has been incorporated.
3	The viewer height used for the ZTV.
4	Confirmation that earth curvature and light refraction has been included.
5	The extent of the ZTV overlay as a minimum distance from the development, in addition to the frequency of any distance rings shown.
6	The numbers of wind turbines represented for each colour band.
7	The 'target height' used for the turbine and whether this is to hub or blade tip.
8	Confirmation that the ZTV software does not use mathematically approximate methods (see para 49).

ZTV development for a project

84 ZTV maps are very useful as a tool for comparing alternative turbine layouts, turbine numbers and turbine heights as a scheme develops. This also means that it is important to consider how they will be used throughout the entire VIA and EIA process, as well as how they are presented in the ES. This is because, as the design of a windfarm develops, the ZTV specification may need to change. For example, it may seem sensible to have 6 separate bands of 11 turbines for a 66 turbine windfarm and 6 separate bands of 9 turbines for a 54 turbine windfarm. But if a particular windfarm is reduced in size from 66 to 54 wind turbines it is important to keep the original bands

(that is 1-11, 12-22, 23-33, 34-44, 45-55, 56-66) even though there would not be any visibility shown for the highest band. Otherwise, it is impossible to directly compare the relative visibility of the original proposal and the revised windfarm. Sometimes there may be reasons why this practice is difficult, for example if amendment to a scheme would result in either too few or too many bands. In these situations, a judgement needs to be made regarding the most appropriate banding. If this involves amendment of the original range, it is useful to include an additional ZTV showing this range within the ES appendices.

85 Similarly, if an extension to an existing windfarm is proposed, it is recommended that the original range of bands is retained and supplemented by additional bands of the same interval to represent the additional turbines. For example, if the original ZTV bands were for 1-5, 6-10, 11-15 and 16-20 turbines, the proposed extension should have a ZTV that shows additional bands 21-25 and 26-30 turbines etc.

ZTV production

86 Where a ZTV map forms part of an ES, it should be accessible by all members of the public and thus should be produced on paper. However, as discussed in paragraph 82, in some cases it will be useful for the developer to provide the determining authority and consultees with a digital version in addition to the paper map. This also allows them to enlarge the ZTV on screen or focus in on particular areas of concern, making for a more flexible product. Production of this additional information will require agreement by the developer.

87 It has been suggested that ZTV information could also be made publicly accessible on developers' websites. However there are issues of map licensing and file sizes that are difficult to overcome, in addition to the difficulty in ensuring high quality resolution on a website, and the alternatives such as multiscale

mapping (for example streetmap.co.uk and getamap.co.uk) require very specialised (and expensive) hosting arrangements. A potential disadvantage of this to the developer is also that they have reduced control over the use and quality of any printed outputs.

Table 5: GOOD PRACTICE GUIDANCE SUMMARY

ZONE OF THEORETICAL VISIBILITY

	Paragraphs in report	Minimum requirements	Preferred requirements
ZTV data	41-45	OS 50m Panorama data if simple landform, OS 10m Profile data if rugged terrain.	OS 10m Profile data.
	44-45	Describe inherent limitations of data and methods of calculation.	
	52-53	Use bare ground data.	In specific circumstances, datasets may be useful where there are likely to be significant screening effects, for example by vegetation or buildings, produced in addition to the bare ground ZTV; Obtain data on visibility conditions in the area to help interpretation of visibility data.
	48 54-55 72	ZTVs should be produced for both total height of turbines to blade tip and hub/nacelle height.	In specific sensitive situations, ZTV should also show proportion of turbines visible and/or numbers upon the skyline.
	50	Earth curvature should be included in ZTV calculation.	
	50	The refraction of light should be included in ZTV calculation.	
	56	ZTV based on viewer height of 1.5 – 2.0m.	Viewer height of 2.0m
	57 61-65 71	ZTV extent to comply with Table 2 subject to consultation and agreement with determining authority and consultees.	Aid legibility by showing concentric circles upon ZTV map at defined distances such as 10, 20 and 30km, whilst avoiding confusion of lines.
	58	Distances on which the ZTV is based should be measured from the nearest turbine or the smallest circle containing all the turbines of the site unless otherwise agreed with the determining authority and consultees.	
	59	For developments of 5 turbines or less, the ZTV can be calculated from the centre of the site.	
	60	ZTV overlay should extend to the edge of the map base containing the study area.	

Presentation of ZTV	82,86	Present ZTV maps in paper form.	Production of ZTV maps in paper and digital form, with varying visibility bands distinguished as separate layers upon a base map that can be interrogated using imaging editing software or GIS.
	66	Overview ZTV map at 1:250,000 based on 1:250,000 OS map	
	66-67	Detailed ZTV map(s) at 1:100,000, based on a 1:50,000 OS map. Where these are provided as separate sheets there should be an overlap of at least 1km between neighbouring maps (numbered and keyed). There may also need to be an overlapping site-centred map.	Detailed ZTV map(s) at 1:50,000, based on a 1:50,000 OS map. Detailed ZTV mapping covering specific areas at a more detailed scale where there are particularly sensitive visibility issues.
	68	The base map should be very clear and printed in 'greyscale'.	
	69	Each individual turbine should be clearly marked upon the ZTV. Reference should be made to a plan contained within the ES which shows the individual turbine numbers and grid coordinates.	
	73	Colour overlays upon the ZTV map representing visibility should be partially transparent and allow clear visibility to the underlying base map.	
	75	For legibility, a maximum of 7 colours/ shades should be shown overlaid upon a ZTV map.	
	74-76	Colours for overlays should be bright and strongly contrasting. Their choice should take into account typical variation in computer screen and printer reproduction, and consider legibility for colour blind persons.	
	75 79-82	If visibility bands are used, there should be a maximum of 7 bands and, if equal banding is not possible, the widest range should apply to the lower end of the scale.	If varying visibility is distinguished, it is useful to also produce this information digitally, arranged as separate layers upon a base map in imaging editing software or GIS.
	83	Information on the data and assumptions that have been used during the ZTV production as in Table 4. This information should be included within the VIA (or referenced appendices).	
	84-85	Maintain the format of the ZTV map throughout the VIA process if possible, so that comparisons can be made as the scheme develops.	Include ZTVs representing design development within appendices of VIA.
	69	The location of viewpoints (numbered) should be shown on the ZTV.	

3 Viewpoints

88 The term viewpoint is used within Visual Impact Assessment (VIA) to define a place from where a view is gained and represents specific conditions or viewers (visual receptors). During the VIA process for a proposed windfarm, a number of viewpoints are chosen in order to assess:

- the existing visual resource;
- the sensitivity of this resource to windfarm development;
- the proposed design (incorporating mitigation measures to minimise any adverse impacts); and
- the predicted appearance of the final proposed development.

This section of the Good Practice Guidance will address the selection of viewpoints and the information that should be provided for them.

89 It is important to stress that viewpoint assessment forms just one part of VIA. Because of the 'powerful' nature of viewpoint images and the widespread recognition of some of the locations from where these are taken, there is often over-emphasis of their role. But VIA also includes assessment of the following:

- the extent and pattern of visibility throughout the study area (thus considering those areas from where a windfarm will not be seen, as well as those areas from where it may);
- views of the proposed windfarm from areas of potential visibility other than the selected viewpoints; and
- sequential views.

90 The viewpoints used for VIA must be carefully selected to be representative of the range of views and viewer types that will experience the proposed development. They should also form part of the "description of aspects of the environment likely to be significantly

affected by the development" (PAN58 , paragraph 65).

91 In addition to representative viewpoints, specific viewpoints may also be chosen for their importance as key viewpoints within the landscape. Examples are local visitor attractions, settlements, routes valued for their scenic amenity, or places with cultural landscape associations. These will be supplementary to the range of representative viewpoints and will usually be identified through consultation with the planning authority and SNH, although they may be confirmed also by local people and special interest groups at public meetings and/or exhibitions.

92 The following issues regarding viewpoints are considered within this section of the Good Practice Guidance:

Selection of viewpoints	• Number of viewpoints • Viewpoint siting

Use of viewpoints

Recording viewpoint information

Good Practice Guidance summary

Table 6: Uses and limitations of viewpoints
(numbers in brackets refer to paragraphs in text)

USES OF VIEWPOINTS	LIMITATIONS
• Carefully chosen viewpoints enable representation of a diverse number of views within a study area. • Carefully chosen viewpoints enable representation of a diverse number of viewers who experience the landscape in different ways (90,98, Table 7). • Viewpoints enable consultees to assess specific views from important viewpoints for example tourist attractions, mountain tops and settlements (91, 101). • By considering a range of views at different viewpoints, the designer can consider how the windfarm image varies in appearance, informing design development (100). • Views from numerous viewpoints can be assessed to determine sequential effects that occur as one moves through the landscape. • By assessing viewpoints in combination with ZTV maps, it is possible to consider the potential pattern of visibility for a windfarm in 3 dimensions.	• Whilst the choice of viewpoints is very important, it must be remembered that VIA should also be based on other aspects. An over-heavy emphasis on viewpoint selection and assessment may create the erroneous assumption that this is the only aspect of VIA (89). • There may be a tendency to focus on the particular characteristics of specific viewpoints, rather than considering these as being just broadly representative of a wider area. Consequently, it is usually inappropriate to make design modifications to change the visual effects of the proposed windfarm from a single viewpoint. This is because this may have negative 'knock-on' effects a small distance away or from other viewpoints. Rather, a more holistic approach should be adopted that considers the overall windfarm image from separate viewpoints in relation to the design objectives. • A point, and thus viewpoint, is by its very nature static whilst views tend to be experienced on the move as well as when stationary. • Some viewpoints may be difficult to access and require lengthy walks to reach them. As a result, some people might not be able to assess the viewpoint on site. They will therefore need to rely on the landscape architect or experienced specialist assessor’s assessment and visualisations to indicate predicted visual effects. • On account of the limitations of DTM data, several provisionally identified viewpoints may need to be visited before finding a location that is suitable to be a VIA viewpoint. • Information on the exact location and conditions of individual viewpoints is required to be able to create accurate visualisations (111-112). • Some requested viewpoints might be judged inappropriate due to unacceptable health and safety risks (99).

Selection of viewpoints

93 Viewpoints are initially selected as being those places from where a proposed development is likely to be visible and would result in significant effects on the view and the people who see it (receptors). This is informed by the ZTV and other maps, fieldwork observations, and information on other relevant issues such as access, landscape character and popular vantage points. This data enables a provisional list of viewpoints to be developed that can be later refined through further assessment, consideration of provisional wireline diagrams and discussions with the determining authority and consultees such as SNH. Interested members of the public may also advise on sensitive local vantage points at public meetings and/or exhibitions held by the applicant.

94 It is important to stress that, even though a ZTV is very useful in focusing upon those areas with potential visibility of a proposed development, the ZTV is only one source of information used to inform the selection of viewpoints. Over-reliance on a ZTV to highlight viewpoints can result in over-concentration on open locations with the greatest visibility of a site, often far from the proposed development. This may be at the expense of potential viewpoints where visibility is less extensive, but from where views of the site are more typical.

95 Nevertheless, during early consultations regarding the provisional list of viewpoints, it is useful if the determining authority and consultees are provided with a copy of the ZTV. In certain circumstances, a selection of provisional wireline diagrams may also be helpful to give an impression of possible impacts from viewpoints. It is important to highlight, however, that the LVIA information that will accompany the visualisations within the final ES, and thus inform their interpretation, will not usually be available at this early

stage. Consequently, a degree of caution should be exercised when circulating wirelines during this period.

96 During the initial stages of VIA, viewpoint wirelines are used to inform the design development of the proposed windfarm. Some of these viewpoints will be described and assessed within the main ES report; however others may ultimately be omitted, for example because they show very similar results to another viewpoint. Nevertheless, details regarding these original viewpoints should be included within the ES appendices if they have informed the design process. Likewise, during the VIA process, it may be found that some of the originally identified viewpoints will not actually have a view of the windfarm due to local screening or changes to the windfarm design. These should also be documented within the ES.

97 The issues discussed above regarding the selection of viewpoints highlight that a flexible approach needs to be adopted. This also reflects the iterative nature of VIA and the way in which parties will gradually become more familiar with a site and proposed development. Consequently, the developer must be aware that additional or alternative viewpoints may need to be considered throughout the VIA process if more information is required by either the landscape architect or experienced specialist assessor, or the determining authority and consultees.

98 The range of issues that influence the selection of viewpoints is listed in Table 7 below. The aim is to choose a representative range of viewpoints from where there is likely to be significant effects.

Table 7: Views and viewers to be represented through choice of viewpoints	
View type	• **Various landscape character types** (separate and combinations of type) • **Areas of high landscape or scenic value** - both designated and non designated, for example National Scenic Areas, Areas of Great Landscape Value, Gardens and Designed Landscapes, Search Areas for Wild Land, tourist routes, local amenity spaces • **Visual composition**, for example focused or panoramic views, simple or complex landscape pattern • **Various distances** from the proposed development • **Various aspects** (views to the north will result in a very different effect to those facing south) • **Various elevations** • **Various extent of windfarm visible,** including places where all the wind turbines will be visible as well as places where partial views of turbines occur • **Sequential** along specific routes
Viewer type	• **Various activities,** for example those at home, work, travelling in various modes or carrying out recreation • **Various mode of movement,** for example those moving through the landscape or stationary

99 The assessment of viewpoints should not involve unacceptable risks to health and safety – either to the LVIA assessor or to others who may wish to later analyse the viewpoint assessment on site, such as staff from the determining authority and consultees, or the general public. Examples of these situations could include viewpoints from motorways, railway lines, scree slopes or cliffs.

100 Viewpoints within the local area immediately surrounding the windfarm are particularly useful to understand and develop the windfarm layout and design.

101 In addition to representative viewpoints, specific viewpoints may also be important as key viewpoints

within the landscape, for example local visitor attractions, scenic routes, or places with cultural landscape value.

102 In identifying viewpoints, it is important to consider whether a cumulative Landscape and Visual Impact Assessment (CLVIA) is also required as part of the ES. If it is, the choice of all viewpoints should be informed by the cumulative ZTV as well as the individual ZTV. Although it is possible to add supplementary viewpoints as part of a cumulative VIA, it is preferable to use the same viewpoints for both the individual and cumulative VIA to enable direct comparisons to be made. Likewise, it is also useful to choose viewpoints already used for other windfarm LVIAs in the surrounding area. The use of these may allow direct comparisons and also assist the determining authority, consultees and the general public who are already familiar with these viewpoints. It is hoped that further guidance on CLVIA may be provided in the future.

103 As the VIA progresses, it is useful to consider how the appearance of the windfarm from the separate viewpoints would be best illustrated within the ES. Further information on the choice of visualisations is included within the section of chapter 4 on 'Presentation of Visualisations', paragraphs 242 to 265.

104 The reasons for selection or omission of viewpoints recommended by consultees, should be clearly justified and documented within the ES.

Number of viewpoints

105 The number of viewpoints for separate projects will vary greatly depending on how many are required to represent likely significant effects from the range of views and viewers of a development as listed in Table 7. As mentioned previously, the initial list of provisional viewpoints, will be high. This is necessary to enable identification of the required viewpoints

during the early stages of the VIA, and to ensure no key viewpoints have been omitted. This process will involve the production of numerous wirelines too, as one will need to be produced for each viewpoint and for every layout and design option.

106 After reducing the number of viewpoints down to only those that are required to represent potential significant effects on views and viewers, it is common for there to be around 10- 25 viewpoints within a VIA in Scotland. However, this number will vary depending on the specific circumstances of a proposal. It is important to highlight that over-provision of viewpoints can be as unhelpful as under-provision. This is because an excessive number of viewpoints, for example including those that do not have significant impacts, may distract attention from the smaller number of viewpoints where impacts are significant. Additionally, a high number of viewpoints will also require more time to be assessed by the determining authority and consultees and result in a more expensive ES (in time, computing effort and graphic production) – both for the developer and people that wish to purchase the report. As a consequence, an appropriate balance must be struck through the VIA consultation process in terms of providing sufficient, but not excessive, numbers of viewpoints.

Viewpoint siting

107 Following agreement on the general location of viewpoints through consultation, the selection of the precise viewpoint site should be considered carefully. If, on visiting a potential viewpoint, it is apparent that there will be no view of the proposed development, for example due to localised screening, this location should be amended or withdrawn.

Figure 16: Deliberate positioning of distracting or screening features within a photograph

a:

b:

c:

d:

e:

f:

These photographs were all taken within 50m of each other and all show essentially the same distant view of an existing windfarm, with only the foreground detail differing. **a** shows the view seen adjacent to a house. **b** is from the public road immediately outside the house. **c**, **d**, **e** are successively more open views from the same road. **f** is from the road verge adjacent to the tree visible in the middle of **a**.

If the purpose of the viewpoint is to illustrate the view from one specified important view, one window in a house perhaps, then it should include whatever foreground obstruction happens to be in the view, as in **a** above. Otherwise, if a viewpoint is to represent potential views from a locality, then it should be as unobstructed as possible, as in **f** above.

108 The siting of viewpoints needs to balance two key factors:

- the likely significance of impacts; and
- how typical or representative the view is.

For example, in choosing a viewpoint along a stretch of main road, the magnitude of impacts may be greater along one section, but the likelihood of focusing on the view, that is its sensitivity, greater in another, for example at a lay-by. In all cases, judgement needs to balance these factors and this decision-making process must be documented. Most importantly, the location chosen must avoid the view of the windfarm being misrepresented by the inclusion of atypical local features, such as a single tree in the foreground, as illustrated in figure 16. Where this has mistakenly occurred, the viewpoint location should be revised and the photographs retaken. Conversely, it is also unacceptable to wander too far from the most prominent viewpoint in order to avoid typical foreground objects, for example moving into a neighbouring field when the view is intended to be from a road, in order to avoid the inclusion of the roadside fence or hedgerow.

Use of viewpoints

109 Viewpoints are used within VIA as sample locations from where to assess the existing visual resource, the design and siting of the proposed development, and potential visual impacts. Further information on their use is included within the Guidelines for Landscape and Visual Impact Assessment produced by the Landscape Institute and Institute of Environmental Management and Assessment (2002).

110 Viewpoints are primarily used for carrying out VIA. However, it is usually considered expedient to record elements of the landscape assessment at the same time, especially in relation to the landscape experience, as there is often significant overlap

between landscape and visual impacts. Where this takes place, however, it is very important to distinguish clearly between the information used for the VIA and that recorded for the Landscape Impact Assessment (LIA) to avoid confusion between the two.

Recording viewpoint information

111 It is important to record the field conditions in which a viewpoint is assessed, including information as listed in Table 8 below.

Table 8: Viewpoint information to be recorded

no	Viewpoint	Specification required
1	Precise location	12 figure OS grid reference, measured in the field, ideally using GPS or a large-scale map.
2	Viewpoint altitude and Viewing height	Viewpoint altitude in metres above Ordnance Datum (m AOD) (May be better interpolated from map or DTM than relying on GPS height). Viewing height in metres.
3	Nature of view	Horizontal field of view (in degrees).
	Conditions of assessment	
4	Date of assessment	
5	Time of assessment	
6	Weather conditions and visual range	

112 This information is essential to allow others to visit precisely the same viewpoint and make on-site checks or assessment. It also helps others to understand the conditions under which professional judgements have been made.

113 As part of VIA, viewpoint assessment will involve recording baseline conditions 360° around the viewpoint. However, most attention will be paid to the main focus of the view and its setting, the direction of the proposed windfarm, and any other existing and proposed developments.

114 All viewpoints should be numbered and their location shown upon separate maps as follows:

i The ZTV overview map(s) based upon a greyscale 1:50,000 OS base. The viewpoints should be marked using discrete symbols and numbering to avoid obscuring or confusing the ZTV information.

ii The detailed ZTV map(s) based upon a greyscale 1:50,000 OS base. The viewpoints should be marked using discrete symbols and numbering to avoid obscuring or confusing the ZTV information.

iii A detailed map extract on each viewpoint visualisation sheet which indicates the location and direction of the view on a 1:50,000 or 1:25,000 OS base map (although not necessarily the proposed windfarm), potentially reduced to another 'standard' scale, to enable those assessing the view on site to locate themselves in relation to local landscape features.

115 Viewpoint numbering needs to be clear. It is recommended that the original viewpoint numbers are retained right up until the point at which all the viewpoints are finalised and agreed and the VIA has been completed, to keep track of which viewpoints have been added or withdrawn during the VIA process. At this point they can be re-numbered in a continuous and more logical manner. Where material developed during the early stages of the VIA process information is included within the ES and its appendices, to show the development of the VIA, this should show both the original and new numbering so these can be easily cross-referenced.

116 To ease legibility, viewpoint numbering should follow a clear system. Some people number viewpoints in order of distance from a development, which is useful

when considering the effect of distance on impacts, while others number a windfarm in relation to how it tends to be experienced, such as from key routes, leading to isolated vantage points, which is useful when considering sequential impacts. Alternatively, numbering in a set direction, such as clockwise, may be the most appropriate method in terms of being clearly objective and transparent. Of these options, all are acceptable as long as the system chosen is clear and described within the VIA.

Table 9: GOOD PRACTICE GUIDANCE SUMMARY

VIEWPOINTS			
	Paragraph in report	Minimum requirements	Preferred requirements
Selection of viewpoints	90 93	Choice of preliminary viewpoints to be based on likely significant effects and the ZTV, landscape character and landscape experience. The justification for these viewpoints (in terms of what they represent or illustrate) should be stated.	
	93	Assess each preliminary viewpoint against ZTV and wirelines.	
	93, 95 97, 103	Consult on viewpoint choice with determining authority and consultees. Requests for comments should be accompanied by a list of the proposed viewpoints, justification for their inclusion/removal and a ZTV (also cumulative ZTV if relevant).	Wireline diagrams may also be provided for each preliminary viewpoint to inform the consultation process.
	96, 103	Include information on all preliminary viewpoints, whether they are subsequently abandoned or not. Information on those that have been dropped should be included within an appendix to the final LVIA/ ES report.	
	97	Adopt an iterative approach to viewpoint selection. Further/ alternative viewpoints may need to be assessed later in the VIA process if particular sensitivities become apparent.	
	98 101	Select viewpoints to represent different view types and viewer types as listed in Table 7. Specific viewpoints that are important viewpoints of the landscape, for example designated sites and visitor attractions, and from which impacts are likely to be significant, should also be included.	
	102	Consider whether a Cumulative LVIA will be necessary. If so, viewpoint selection should also be informed by the Cumulative ZTV. Cumulative assessment should occur at every viewpoint that cumulative visibility occurs.	If other LVIAs have been carried out in the study area, it may be useful to use some of the same viewpoint locations.

Selection of viewpoints (continued)	105 106	The number of viewpoints should be based on the number needed to represent likely significant visual effects within the range of views and viewer types listed in Table 7.	
	107 108	Determine viewpoint siting and orientation to represent typical views that are likely to result in significant visual effect within an area and reflect the key existing foci. Very localised screening/ distracting elements should be avoided if these are atypical of the area.	
Use of viewpoints	109	Consult GLVIA for use of viewpoints	
	110	Distinguish between aspects of VIA and LIA at viewpoints	
Recording viewpoint information	111-114	Number all viewpoints. Record information on each viewpoint and the conditions of assessment as listed in Table 8.	
	114	Viewpoint locations should be shown on the ZTV maps.	
	114	For each viewpoint, a plan showing its detailed location and direction upon the visualisation figures. This should be at 1:50,000 or 1:25,000, based on OS base maps of these scales	
	115-116	Viewpoints should be numbered in a logical order	

4 Visualisations

117 Visualisations are illustrations that aim to represent an observer's view of a proposed development (figure 17). At the moment, visualisations of windfarms most commonly comprise photographs, computer generated wireline diagrams and photomontages. However the range and use of different visualisations will change over time.

118 Visualisations are very powerful in communicating information – 'Pictures speak louder than words'. This means that people often jump to the visualisations within an ES to gain an impression of a scheme, in a way that they rarely adopt for other specialist information. However, it is important to stress that visualisations in fact represent just one source of data that informs a VIA.

119 A considerable amount of debate on visualisations in the past has revolved around making them 'true to life'. However, it must be stressed that this is impossible. Visualisations, whether they are hand drawn sketches, photographs or photomontages can never exactly match what is experienced in the field. Thus, in contrast, this guidance concentrates on how visualisations should be produced to be most effective as a tool to inform the assessment of impacts. Ideally this assessment would always occur on site, where the visualisations can be compared to the 'real life' view. However, it is acknowledged this is not always possible. It is important to stress that, whatever the circumstances, interpretation of visualisations will always need to take account of information specific to the proposal and site, but which cannot be shown on a single 2-dimensional image, such as variable lighting, movement of turbine blades, seasonal differences and movement of the viewer through a landscape. Therefore visualisations in themselves can never provide the answers, only inform the assessment process by which judgements are made.

120 The production of computer generated wireline diagrams to inform viewpoint assessment by landscape architects and experienced specialist assessors on site has generally involved little dispute, and independent assessors have found in the past that the judgement of impacts based upon these has been largely accurate (University of Newcastle, 2002). However the presentation of photomontages to illustrate visual impacts to a wider audience within ESs has often been a contentious issue. Partly, this has been because the method, format and quality of these visualisations has varied considerably between ESs as different methodologies have been explored and adopted, but also because the decision-making process behind their choice has not always been clear.

121 It is important to highlight that this Good Practice Guidance tackles this issue from first principles – that of what, why, how and for whom visualisations are produced. Thus, while it builds upon the findings of the report 'Visual Assessment of Windfarms: Best Practice', by the University of Newcastle (2002) (see Introduction and paragraphs 8-9), this guidance is not based on adopting certain methods simply out of convention.

122 This section of the Good Practice Guidance considers the selection, creation, use and presentation of visualisations and will highlight the following key issues:

Key issues affecting visualisations	
Photography	• Objectives • Field of view • Choice of camera • Choice of film • Choice of lens • Time of day, direction of sun and weather • Information to record at each photo location
Photographic post-processing	• Scanning • Panorama construction • Turbine Image • Image enhancement
Wirelines	• Use of wirelines • Data • Geometrical properties • Drawing style
Photomontage	• The use of photomontages • Rendering of photomontages • Accuracy of match to photography • Accuracy of lighting • Associated infrastructure and land use change
Other visualisation techniques	• Wirelines superimposed on photographs • Coloured 3D rendering • Hand drawn illustrations • Animation
Choice of visualisation	
Presentation of visualisations	• Presentation for different audiences and uses • Combinations of visualisations • Viewing distance • Information to provide • Paper and printing • Exhibition display
Good Practice Guidance summary	

Key issues affecting visualisations

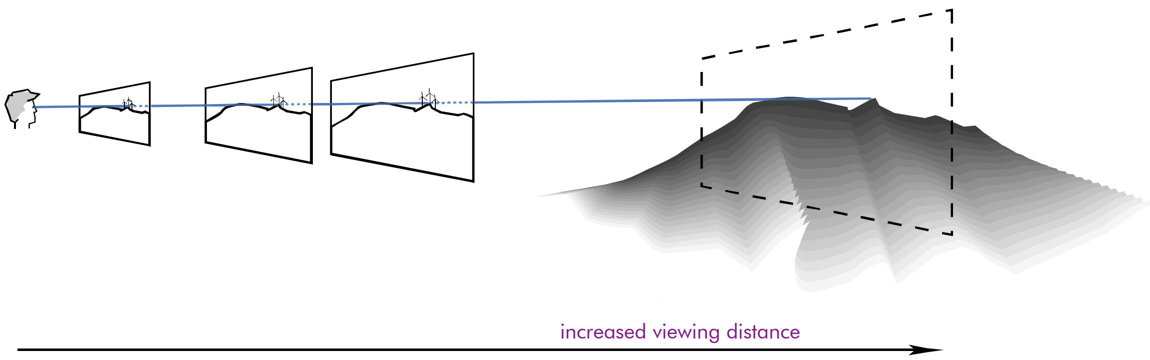
123 Photographs are important visualisations, not only in their own right, but also as a component of other visualisations such as photomontages. Photography is discussed in some detail in this section and also within the Technical Appendices. To understand how photographs represent what we see, it is important to first highlight that the eye is not directly sensitive to the outlines of objects or details in a scene. Instead it relies upon a degree of contrast to make those edges, and therefore the objects they define, visible. Thus there is always a trade-off between detail and contrast. This effect is replicated in photography, where visual representation on screen or the printed page is affected by the resolution of the image (to ensure that sufficient detail is captured) and contrast in the image (to ensure that the detail is visible). A key limitation of photographs in replicating the visual experience is that it is generally impossible to reproduce the full contrast range visible in a scene to the human eye. This means that while, on a bright day outdoors, we may experience a brightness ratio of 1000:1 between the brightest and darkest shades, a good quality computer monitor is only likely to achieve a ratio of about 100:1 and a printed image is only likely to manage 10:1.

124 Having chosen a specific camera, the key factors that determine the size of a visualisation are the selected field of view and viewing distance. These factors should be determined on the basis of being able to clearly represent the key characteristics of a view while the visualisation can be viewed comfortably. The resulting image also requires to be large enough to show sufficient detail.

125 It is important that visualisations are viewed at the correct 'viewing distance' – that is the distance between the eye and the image that directly relates to the visualisation calculations and image size, as shown in figure 18. In the field, the correct viewing distance

is easy to establish, as a viewer can adjust the position of a hand-held visualisation until it appears to correspond with the scene beyond. Very simply, if the photograph is held too close to the eye, the elements in the scene will appear too big; if it is held too far away, the elements will appear too small; and there is only one distance at which the photograph will match the real scene (the correct viewing distance). Unfortunately however, this direct correlation between the printed visualisation and real view is not possible if the viewer is not in the field at the viewpoint location; it is in these circumstances that use of the correct viewing distance is crucial if the visualisation is to be viewed and assessed correctly. The geometrical principle of correct viewing distance is explained in more detail within Appendix A.

Figure 18: The relationship between image size, viewing distance and the 'real-life' view



Using a standard paper size, a projected wind farm image will be smaller at a shorter viewing distance, and larger at a further viewing distance. However if held at the correct viewing distance they will be seen as being the same size. This represents a direct mathematical relationship between the eye and the image of the subject (the landscape).

A key issue is whether this viewing distance is comfortable for the viewer and if this is likely to be used correctly.

126 Not only must the viewing distance be correct, but it must also be set at a comfortable distance. For material printed in an ES and intended to be hand held, this should be between 300mm and 500mm, although a distance between 400mm and 500mm is recommended as a "comfortable viewing distance for

larger images at either A4 or A3 [and presumably larger] held at arm's length " (University of Newcastle, 2002). It also allows easier comparison with the real-life view on site as shown in figure 35.

127 Field of view is discussed in further detail within the section of this chapter on photography, paragraphs 135-144, and within appendices A and D. Although it would be convenient to be able to recommend a standard field of view to be used for all visualisations, analysis on site and of existing ESs suggests that no such standard can be established. Rather, the recommended horizontal and vertical field of view will vary, depending on what is required to illustrate the key characteristics of the visual resource and the key components of the proposed development. In some cases, the recommended horizontal field of view may conveniently fit the dimensions of a single photographic frame. More commonly, however, this requires a panorama photograph (discussed further in paragraphs 172-175 and Appendix B). In most cases, the recommended vertical field of view will conveniently fit within a single frame height (horizontal or vertical orientation); however, in exceptional circumstances, multiple vertical images could also be required in this dimension.

128 In the past, people sometimes doubted the technical accuracy of photos and photomontages as they didn't seem to compare well to the scale of landscape features when directly compared on site. As discussed within the sections on image size (paragraphs 129 and 248) and viewing distance (paragraphs 125-126 and 255-256), while the visualisations were mathematically correct, they were often produced in a format that could not be used comfortably, and thus tended to be used incorrectly. People sometimes assumed that this deficiency would be corrected by taking photographs with a telephoto lens or equivalent. However, as discussed within the section on choice of lens (paragraphs 150-158) and

illustrated in figure 21, it is important to realise that a longer lens length does not necessarily result in a larger or clearer image; rather, the key factors directly influencing this are image size in direct relation to viewing distance and field of view (assuming good quality resolution and contrast).

129 The image height and width will relate to the viewing distance and vertical and horizontal field of view chosen. However, if a short viewing distance and a small vertical field of view is selected, the resulting image may not be large enough to show sufficient detail. To avoid this situation, the University of Newcastle (2002) stated that "an image height of approximately 20 cm is therefore to be preferred". However, following the University of Newcastle's own recommendations in terms of a minimum viewing distance of 300mm and the use of a 50mm equivalent camera lens, the maximum vertical height of an image generated from a horizontal format photograph (landscape format) would be 140 mm. Once cylindrical projection (discussed in Appendix B) is applied this is further reduced to 135mm at the edges and may be further reduced if the image was cropped in scanning. Thus, while an image height of approximately 200mm is recommended, an image height over 130mm is considered acceptable.

130 Visualisations are complementary to ZTVs and vice versa and neither can be interpreted satisfactorily without the other. While a ZTV shows where a proposed windfarm will or will not theoretically be seen (subject to surface screening) and the number of wind turbines (or parts of turbines) likely to be seen from any location, it cannot indicate what the windfarm will look like. A visualisation, on the other hand, simulates the appearance of the windfarm from a particular location, but gives no indication of whether this is characteristic of views over a wider area or peculiar to a specific site. Used carefully together,

a ZTV and a set of visualisations can provide information on all of these aspects.

131 The choice of visualisations for a specific viewpoint will depend on a number of factors described within the sections on choice and presentation of visualisations, paragraphs 232 to 265.

Table 10: Uses and limitations of visualisations
(numbers in brackets refer to paragraphs within main text)

USES OF VISUALISATIONS	LIMITATIONS
• Visualisations give an impression of the appearance of a proposed windfarm (117). • Applied carefully in the field, a visualisation can be used as a tool to help assess the likely visual impact at that point. • Visualisations can aid development of the windfarm layout and design (188). • Presented carefully, visualisations can help illustrate to a 'lay' audience the location and nature of a proposed windfarm (and may be the basis on which this audience will assess a project). • Wirelines provide objective data, while photomontages present an illustration of visual impacts that incorporates artistic interpretation. (186, 236-237).	• Visualisations provide a tool for assessment, an image that can be compared with an actual view in the field; they should never be considered as a substitute to visiting a viewpoint in the field (204). • Neither photographs nor visualisations can convey a view as seen in reality by the human eye. It is very difficult to represent contrast upon the printed page. (119, 134, Appendix C). • Visualisations are only as accurate as the data used to construct them (189-191). • Visualisations can only represent the view from a single location and the ZTV and site visits must be used to determine whether or not it is typical of a wider area. • Visualisations are inherently limited in the field of view and detail they can represent. • Visualisations with very wide panoramic fields of view can be difficult for some people to use and interpret, while visualisations with narrow fields of view may appear to present insufficient context (Table 15 and 135-144). • Visualisations should be used in combination with other VIA tools, including a ZTV (130). • Visualisations presented upon paper cannot convey the effect of turbine blade movement (119).

Photography

Objectives

132 Photography has two main roles in EIA. One is as a simple record and aide-mémoire of site visits and on-site assessment work. The other, on which this guidance focuses, is in producing visual material for inclusion in an ES.

133 Photography for presentation in conjunction with wirelines or other visualisations, or as the basis for photomontage, requires high quality specification. This is because the perspective geometry of the resulting photographic image is necessary in order to use a computer program to generate an image with exactly matching perspective. This in turn implies considerable care in the selection and use of appropriate photographic equipment and supplies.

134 Representing landscape conditions through photography (and thus photomontages) has its limitations and, while some of these effects can be ameliorated and/or compensated for by using presentation techniques discussed in the following section, other effects are less easy to counteract. One of the most significant difficulties of photographing windfarms, in contrast to other types of development, is that they often appear on the skyline where there is little contrast between the light-coloured turbines and a light-coloured sky. In these circumstances, while the human eye can distinguish, in bright outdoor light, a contrast range of around1000:1 or more (the brightness ratio of the lightest to darkest elements in the scene), a picture of the same view taken with a camera and shown on a computer screen will have a ratio of only about 100:1. This range of contrast is reduced to as low as 10:1 when printed on paper.

Field of view

135 The term 'field of view' is used to describe the height and width of a view as represented by an image. These constitute the horizontal field of view and vertical field of view and are expressed as angles in degrees. (The terms 'angle of view', 'included angle' and 'view cone angle' are equivalent but can be ambiguous in some contexts.)

136 There have been suggestions that the horizontal field of view shown in visualisations could be linked to the physical limits naturally seen by a human eye. However it is difficult to derive definite parameters in this way, as a human has an extreme horizontal field of view of about 200°, yet only the 6-10° that falls on the central part of the retinas of the eyes will be in focus at any one time. Thus a viewer moves their eyes and head around to see a view over a wide area. Further information on this subject is included in Appendix C.

137 As viewers typically direct their attention over different widths of view, the size of photograph required to represent a view will vary for different projects and viewpoints, depending on the key characteristics of a view that need to be included within the image (defined by the landscape architect or experienced specialist assessor on site), and the extent of the proposed windfarm which needs to be included.

138 Occasionally this information can all be incorporated within a small field of view, as discussed below, that may conveniently fit within one single photographic frame (representing 39 degrees using a 50 mm lens on a 35mm camera). More commonly for open landscapes in the UK, however, a series of frames will be required that are joined together to form a panorama image. Panorama construction is discussed in further detail in paragraphs 172-175 and Appendix B.

139 Although a viewer will move their eyes and head around a field of view, a central point can be identified, based on the key focus or foci of the view (existing and proposed) and where the eye typically 'rests'. This should also be determined by the landscape architect or experienced specialist assessor on site while carrying out the VIA so that the visualisations can be centred on this.

140 To ensure that the photographs taken for each viewpoint (which may be taken by someone other than the landscape architect or experienced specialist assessor) are able to accommodate the required horizontal field of view, it is recommended that a panorama is taken from each viewpoint that includes the entire width of open view. This may be 360° for some viewpoints. For certain viewpoints, especially where there is a high vertical dimension to the view, as in mountain areas or close to vertical features (including proposed or existing turbines), it will also be advisable to prepare a panorama comprising of vertical 'portrait' frames.

141 For the narrow horizontal field of view contained within a single frame, the differences in geometry between single frame and panorama are not marked (see Appendix B for more details). Nevertheless, photographs should be clearly identified as either single frame or panorama if a mix of the two types is used. Figure 19 shows the comparison between a panorama and a single frame view of the same scene. The panorama includes context missing from the single frame view. The single frame is slightly wider than the equivalent central portion of the panorama. This is because the image scale increases with horizontal distance from the centre of the image in the case of a single frame, whereas it is constant in the case of a panorama.

142 In the section on visualisations (7.5) within 'The Visual Assessment of Windfarms: Best Practice' (2002), the

University of Newcastle recommends that "a full image size of A4 or even A3 for a single frame picture, giving an image height of approximately 20cm, is required to give a realistic impression of reality". During the early stages of developing this Good Practice Guidance document, John Benson of the University of Newcastle explained that this recommendation derived from the need to promote larger sized visualisations to enable sufficient detail, clarity and longer viewing distances than conventionally used at that time, rather than promoting a particular field of view that would limit visualisations to single photographic frame dimensions or paper sizes. He acknowledged that this push to produce taller images and longer viewing distances, and the assumption that these would be limited to A3 page sizes, meant that the implications of accommodating the required horizontal field of view was not sufficiently considered at the time. Indeed, in 2002, few developers had submitted panorama images at the recommended viewing distances and image height, although a few had produced what they termed as 'enlarged photomontages' that happened to include just a single photographic frame and fitted an A3 page.

143 It has been suggested by some that familiarity with the traditional proportions of a single frame photograph (3:2) or television screen (4:3) means that these proportions of image might be preferred by the general public instead of a panoramic image. However, there is ever-increasing use of 'unconventional' formats in communication, eg 'wide-screen' computers and televisions, and common use of image software such as photo stitching to produce panorama photographs at home. So familiarity presents fairly weak grounds on which to base field of view criteria. By contrast, defining the field of view in terms of the specific characteristics of the visual resource and development proposal provides criteria that can be continuously applied in a transparent and methodical manner.

144 The field of view is one of two factors that determine how large a visualisation image will be when presented on paper (Table 14 and 15); the other being the viewing distance. It is likely that there will always be pressure to keep viewing distances low to limit paper size on wide panoramas, and to use longer viewing distances for larger images in order to take advantage of the greater levels of detail possible. These issues are discussed further in the section on Presentation of Visualisations, paragraphs 242 – 265.

Choice of camera

146 To take photographs for visualisations, the choice of camera and lens represents the first of a series of judgements that must be made in terms of choosing the most appropriate photographic equipment and processes. All these will determine the quality of the final images in the printed ES. This is discussed further in Appendix B. The geometry of the image must be known and be able to be matched on a computer and the detail captured must be sufficient to produce a reasonable image quality as finally printed.

147 In general, a high quality camera is required to produce satisfactory results for ES purposes because the lenses need to be of high quality both in terms of resolving power (the ability to capture detail) and in freedom from distortion. For film cameras, the minimum standard should be a good-quality 35 mm SLR, with manually adjusted focus and exposure settings, and with a range of good-quality fixed focal length lenses. For digital cameras, the ideal is again a SLR with a range of good-quality fixed focal length lenses. The use of compact zoom digital cameras is not recommended due to the distortion these create.

147 The construction of panoramic photos requires accurately levelled photographs. To achieve these, a tripod is absolutely essential, as is a spirit level, to set the camera accurately so that it is not tipped up or down, or to either side. Special tripod heads for

panoramic work are available. These have a built-in spirit level, levelling screws and an indexing mechanism to allow the direction of view to be set in fixed increments. These are quite expensive but can speed up photographic work and simplify subsequent panorama construction.

148 Panoramic cameras are available, which can shoot a panorama onto a long length of 35mm film or a whole roll of 120mm roll film. While appealing at first sight, these are generally less practical than the use of a sequence of frames taken on an ordinary film or digital camera and subsequently spliced together. Panoramic cameras are discussed further in Appendix B.

Choice of film

149 Choice of camera film is important for non-digital work. The grain and resolving power of the film will affect the quality of the finished images and the detail represented in them. Very fast film (ISO 400 and above) should be avoided, except when it is vital that photography has to be done in very poor lighting conditions, as these films tend to have a coarser grain structure than slower films and poorer resolution in low-contrast parts of the image. Rather, a good quality ISO100 film (or ISO 200 on days with poorer light) from a reputable manufacturer is recommended. Good quality amateur film is generally satisfactory and does not have the requirement for refrigerated storage that many professional films have. Very slow film (below ISO 100) can prove difficult to use on-site and, although its very fine grain structure can produce superb results, exposure times need to be quite long on all but the brightest of days, which sometimes results in blurring of grass and leaves in the wind. Colour print film is a better choice than slide film as a source for scanning, because it retains more detail in shadows than is often the case with transparencies.

Choice of lens

150 The camera lens forms an image of the scene in front of the camera on film or on a digital sensor. The longer the focal length of the lens, the larger will be the scale of the image. For good quality lenses, substantially free of distortion, the perspective is exactly the same. This issue is discussed further in Appendix D.

151 As a longer focal length lens projects a larger scale image of the scene on to the film or sensor, any element in the scene will, therefore, cover more film grains or pixels and will be captured in more detail than would be the case with a shorter focal length lens. However, because the scale of the image is larger, but the film frame size or sensor size remains the same, it is also true that a smaller field of view (and thus context of a view) is captured. There is therefore inevitably a trade-off between the field of view and the resolution of detail as shown in figure 21. The use of a longer lens does not mean that an image, or elements within the image, will necessarily appear larger. Rather, this is a function of the field of view and viewing distance applied as discussed in paragraphs 124 and 125.

Figure 20

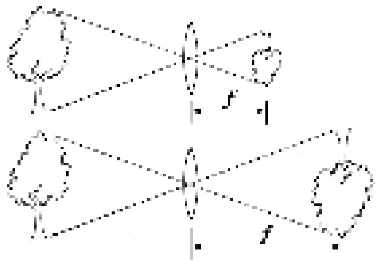


Image size is directly proportional to focal length.

152 With 35mm film, a 50mm focal length lens has been found to be a good compromise (Landscape Institute & Institute of Environmental Management & Assessment, 2002). It does not present the very finest detail visible to the human eye, but nevertheless captures much of it and is sufficient for most purposes (see Appendix C). A longer focal length lens will capture more detail, but only at the expense of reducing the vertical field of view and therefore loss of foreground and sky. A shorter length lens would result in the converse – a larger field of view, but with reduced detail.

153 To increase the amount of foreground and sky visible, photographs may be taken in 'portrait' format. This is

particularly useful where there is a strong vertical component to a view, for example where there are steep mountains, or where wind turbines would appear very close to the viewer.

154 Appendix D includes a table that lists the various field of view dimensions that result from taking photographs with lens of varying focal length.

155 There are very specific circumstances where a telephoto lens may be useful to illustrate a windfarm; for example where this would appear in the far distance and against the sky. In these situations, it is difficult for a photograph to adequately show the presence of turbines against the sky, due to the difficulties of the photo picking up the contrasts of shade between the sky and the turbines as discussed previously in paragraph 134. In these circumstances, some compensation for the restricted range of shades may be possible with the provision of additional detail as provided by a photograph taken with a telephoto lens. However it is important to realise that the viewing distance for this telephoto view when printed will be much further than for the more conventional photographs based on the use of a 50mm lens (or equivalent) and thus may be difficult to view easily. In addition, a telephoto view will usually omit contextual information and thus should only be provided in addition to a 50mm lens (or equivalent) view for the same viewpoint.

156 The following photographs (figures 22a-22c) of the existing Dun Law windfarm show a comparison of effect using alternative lens lengths for an image of the same size but requiring varying viewing distance.

157 1If using a telephoto lens to take pictures, it is important that this is of a fixed length. For, while zoom lenses are convenient for general photographic use in allowing the view to be framed up in the camera, rather than by subsequent cropping, they are always an optical compromise. Their resolving power

is never as good as their equivalent fixed focal length lens and some geometrical distortion is almost always introduced into the image. The latter usually varies with focal length setting (see Appendix D). Also, other than setting a zoom lens at its upper or lower focal length limit, it is impossible to set it precisely to a given focal length, resulting in variations in focal length between viewpoints and difficulties in matching computer generated images.

158 Most digital cameras have a sensor area smaller than a 35mm film frame (although this is likely to change in time). So, although the image size will be the same for any given focal length, the digital camera has a smaller field of view. The only sensible solution to this problem is to use a shorter focal length lens, often a 28 mm lens, in order to achieve the required coverage. Even with a very good lens, this will introduce a small amount of barrel distortion (see Appendix B), which may be acceptable or can be corrected with appropriate image processing software. The use of a compact zoom digital camera is not recommended.

Time of day, direction of sun and weather

159 Key environmental factors affecting the quality of a photograph are the angle of the sun, the direction of the sun and the level of humidity (creating haze, cloud or rain). If a photograph is taken in fine conditions, the most important issue tends to be the direction of the sun, although low light can emphasise the vertical element of the landscape. Conventional wisdom states that the sun should be behind the photographer for the best lighting in a scene. In practice however, having the sun directly behind the camera can make some landform shapes less apparent and side lighting often gives the best impression of the topography. Looking directly into the sun, especially in the winter when it is low in the sky, is to be avoided, unless sunset views need to be illustrated.

160 Whilst it is appropriate to consider a range of weather conditions in the VIA, the viewpoint photographs should be taken in weather, visibility and lighting conditions that would allow operational wind turbines to be captured on a photograph (which requires greater light intensity, clarity and contrast than when viewed with the naked eye). This is more likely to be achieved by maximising the contrast between the turbines and their background. This requires taking account the effect of lighting, background and turbine colour as shown in Table 11 below. Table 11 indicates how the optimal lighting will also vary with turbine distance. The actual distance will depend on the brightness of the light, the focal length of the lens used and the resolution of the film and printing technology.

161 It is rarely possible to achieve the desired photographic contrast in grey and overcast conditions, unless the turbines would be back-lit or in shadow. Land with heavy snow cover gives a background similar to brightly lit clouds and can present similar problems in achieving the required contrast.

Table 11 - Best weather and lighting for photographing turbines

Turbines	Background	Weather	Ideal lighting
Near/ middle distance	land	Bright sunshine	Front or side lit
	sky	Blue sky, bright sunshine	Front or side lit
		Cloudy, bright	Back lit or in shadow
		Dark storm clouds, bright sun	Front or side lit
Distant	land	Bright sunshine	Front lit
	sky	Blue sky, with clouds	Back lit or in shadow
		Cloudy, bright	Back lit or in shadow
		Dark storm clouds, bright sun	Front lit

Source: Kay Hawkins, E4environment Ltd and Phil Marsh

162 Realistically, it is not always possible to arrange for the photography from each viewpoint to be taken under ideal conditions when there is a tight project timescale. However, photographic expeditions should be planned (by reference to weather forecasts, web cams and local information) as far as is practical to coincide with good conditions, with visits to viewpoints to the east of the site in the morning, and to the west in the afternoon.

163 With wide panoramas, a variation of light across the image is inevitable. The critical issue is to ensure good lighting of both the proposed development site, and the key characteristics and features within the surrounding landscape that are most likely to be affected by the proposed windfarm. Where a panorama is to be produced from a series of frames spliced together, it is important to choose an exposure setting (shutter speed and aperture) that is appropriate for the most important part of the scene and to apply that exposure setting to all frames within the panorama.

164 Whatever the weather and light conditions, the minimum requirement is for photographs to clearly show the proposed windfarm site and its context and, if they are to be used as the basis for photomontage, they should be able to have wind turbines clearly illustrated upon them.

Information to record at each photo location

165 To assist with the construction of visualisations back in the office or studio, the photographer should keep a record of important information about the viewpoint location, equipment used etc, as listed in Table 12. This information is best recorded in a photo log for each photo point. The records of information within this log may be made by separate assessors and photographers on different days and, as a consequence, should be sufficiently comprehensive for both parties to understand the conditions under which

all visits occurred. Some of this information needs to be included on the final visualisation (see Table 16). Some photographers find it helpful to record the shutter speed and aperture settings used and, in the case of a digital camera, the ISO setting used (although this is usually all recorded in the EXIF data associated with each frame).

166 It can also be useful to take a photograph recording the position of the tripod location in relation to local features such as a cairn or signpost. This can be helpful both during the production of the visualisations and in the event that the location has to be re-visited.

Table 12 - Information to be recorded at each photograph location (in addition to viewpoint information listed in table 8)

- Camera type (SLR, digital)
- Lens focal length (for example 50mm)
- Film speed (for example 100 ASA)
- Frame numbers as read off the camera (although these may need to be calibrated with the negative numbers which may be different)
- Spacing between the frames (for example 30 degrees for 50mm shots)
- Compass bearings to distinctive elements in the view that will assist with the scaling and placement of the turbines (plus sketch of the view with these elements marked if appropriate).

Source: Kay Hawkins, E4environment Ltd

167 For compass bearings, it is more accurate to use a sighting compass, as bearings to within 0.5 degrees can be measured. However, sighting compasses do not have the variation adjustment (to compensate for the difference between grid and magnetic north). There is less risk of mistakes if the bearings are recorded in the photo log and recalculated back in the office to allow for the appropriate number of degrees deviation. Significant deviations in the compass bearings will be caused by nearby metal objects

(including passing vehicles) and, if this is a possibility, it should be noted.

Scanning

168 Assuming that all photographic preparation work will be carried out digitally for ES work, the next step in the process is to import the images into a computer system. With a digital camera, this is very straightforward and is done directly, with no risk of image degradation. However, with a film camera, a scanning stage is required. Scanning should be carried out using negatives rather than prints, as they retain a greater range of contrast than can be represented on photographic paper.

169 It is possible for an experienced professional to adequately scan from negatives on a relatively inexpensive flatbed scanner. Some of these will come with a range of settings for different film stocks while others will require some experimentation to obtain the best results. A true optical scan resolution of 2400 ppi (points per inch) is adequate for most purposes, giving a 3400 x 2267 pixel image from each 35 mm frame.

170 It is, however, difficult to keep the film as scrupulously dust-free as is desirable when scanning, and it is extremely laborious work. Both of these factors make it an attractive proposition to have the film scanned professionally. Many photographic processors offer this service and will provide a CD-ROM and a set of prints as a packaged service, which should ensure a good standard of cleanliness. However the quality of the scanning varies considerably. In particular, detail is often lacking in very light or dark areas of the image, so that features obvious on prints are hard to pick out on the scans. It is worth having test scans done before committing valuable photography to any of these services. Also, some cropping can occur and it can be difficult to ascertain precisely how much, which makes the calculation of, and scaling to, a chosen viewing distance difficult to achieve.

171 Although digital photography and scanning from 35mm negatives both produce digital photographic images, they are different. In the case of a digital camera, the sensor is accurately centred on the axis of the camera lens, so that the optical centre of the photographic image falls exactly in the centre of the digital image area. With scans from film, no matter how accurately it is done, there is always some residual misalignment, which is compensated for by slightly cropping the image. Because of this, the optical centre of the photographic image is not certain to accurately fall in the middle of the digital image, which means that some image processing operations cannot be reliably applied to them.

Panorama construction

172 Photographic frames are projected onto a plane surface to correspond to the plane of the film or sensor on which the image was first captured. A panorama involves the projection of frames onto part of a cylinder (see Appendix B for a discussion of these issues). It is possible to take a series of frames and to find the overlap point between each adjacent pair and then to splice them together. In this case, however, the frames correspond to a series of facets rather than a smooth cylinder. In consequence, straight lines, such as kerbs or rooflines, which run from frame to frame, appear to kink sharply at the panel joins. It is possible to improve this by using many very narrow panels, but cumbersome to do so.

173 A number of software packages are available to take a series of separate frames and combine them into a single panorama (software to do this often comes on the CD accompanying a new digital camera). Most of these programs attempt to do the whole operation automatically by trying to find matching elements in adjacent frames where they overlap. They also remap the image mathematically so that it forms a smooth cylindrical panorama and blend out any mismatches

in colour between frames. Unfortunately, even with the best software, the ability to carry out the image matching operation is not entirely reliable. Some programs allow the user to manually over-ride the splicing; others do not and will produce images unacceptable for professional use in an ES. There is always some residual mismatch at the joins between adjacent frames and the usual solution is for the overlap area to be blurred, to hide the artefacts created by the slight mismatch. Naturally, this also destroys valuable detail. As a consequence, the finished panoramas are never as geometrically accurate as ones which are created carefully using manual tools and therefore should not be used as the base image for photomontages.

174 Tools are available as plug-ins to image processing software which facilitate the creation of panoramas manually. Each frame should ideally first be corrected for any barrel distortion in the image (this step can only be done satisfactorily with an image from a digital camera as it must be applied symmetrically with respect to the optical centre of the photographic image). A remapping operation is then required to convert the planar geometry of the photographic frame to a cylindrical image. Once overlapped and spliced, the geometry will match consistently across adjacent frames without the kinks apparent without correction. Finally, the colours of each frame can be adjusted to achieve a uniform colour balance across the entire panorama.

175 In theory, as long as the component images used to construct a panorama cover the scene with no gaps, it would be possible to splice them together. In practice, some overlap is required. There are two main reasons for this:

- Some minimum overlap is necessary to see the same detail on two adjacent frames in order to align them accurately; and

- it is often useful to have some scope to choose which of a pair of adjacent frames is used as the source for a particular part of the image, for example to compensate for the effects of changing lighting or moving cloud shadows, to remove the effects of vegetation moving in wind or to remove moving vehicles.

Too much overlap, on the other hand, will increase the work involved in splicing panoramas. In general the overlap should be somewhere between one quarter and one half of the width of an individual frame.

Turbine image

176 The turbines shown on a visualisation should represent reasonably faithfully the shape of the intended turbines for a project. Ideally, they should be based upon detailed line drawings of the actual turbines proposed; but they should at least have the correct hub height and rotor diameter. This will allow the proportions of the turbines to be understood from the visualisation as well as confirm actual visibility. Some practitioners prefer to depict all turbines with the rotors set to have one blade pointing straight up, whereas others prefer these set at random angles, helping to simulate more realistically the fact that the turbine blades will be moving. The disadvantage of setting blades at random angles is the risk of 'losing' turbines behind the landform because the blade angle happens not to put a tip high enough in its arc to be seen. On the other hand, having all the blades at the same angle can produce a very 'regimented' effect that appears less realistic. Consequently it is recommended that, for all 'working' copies of wireline diagrams, turbines are always shown with one blade positioned straight upwards, while photomontages, as illustrations, can show turbines at random positions. However, even accepting the more illustrative quality of photomontages, it should be ensured that all the wind turbines that could potentially be seen from a

viewpoint are shown within the image, even if their highest blades are on the diagonal.

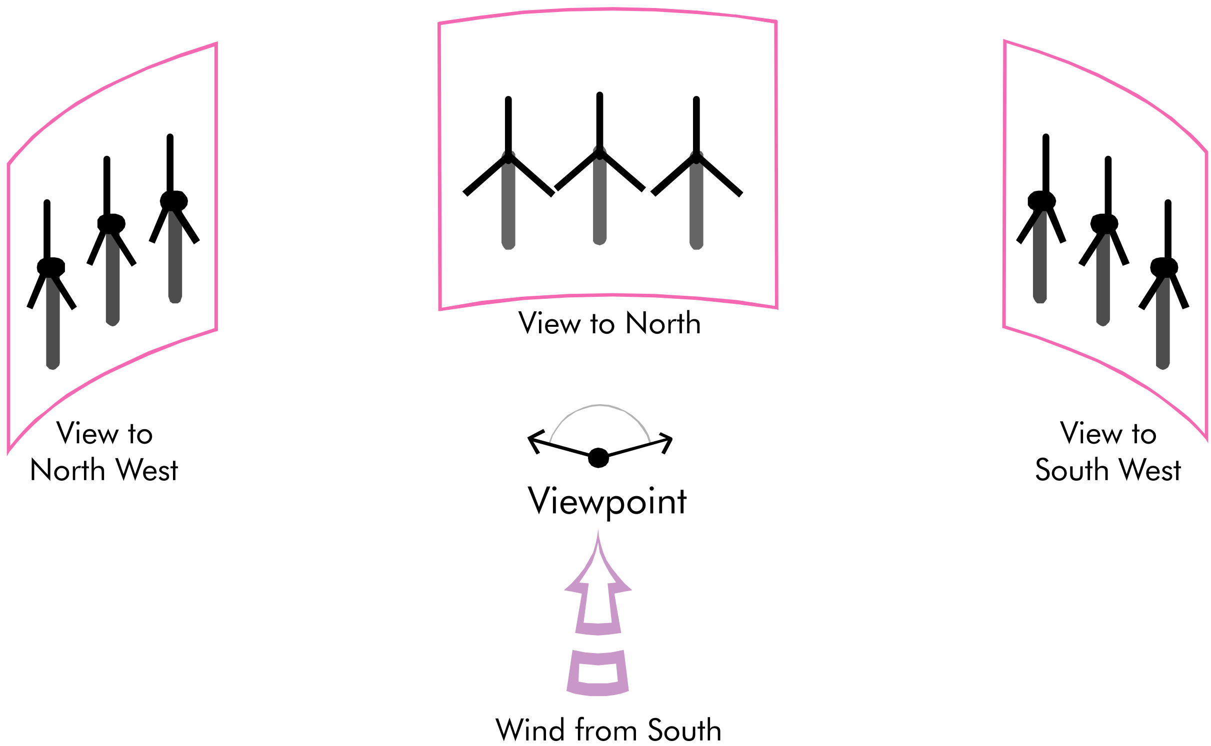
177 Turbines can be shown in three different ways:

- Every turbine individually facing the viewpoint;
- Every turbine facing the same direction, but this varying between viewpoints so that the ones in the centre always face forwards towards the viewpoint; and
- Every turbine facing the direction of the prevailing wind at each viewpoint.

178 Some software can only show the turbines facing the viewpoint as it uses a 2-dimensional representation of the turbine, but most offer a choice. It is often stated that a wind turbine is most visible when seen 'face on', and therefore this should be represented as the 'worst case scenario'. However, when 'face on', the wind turbine image can actually appear more simple and comprehensible than when it is seen at an oblique

Figure 23: Variable direction of wind turbines

Turbines all facing into the wind, as would be seen from the viewpoint



angle, so the latter can actually result in similar levels of impact. The key issue to highlight here, once again, is that visualisations are tools, and that they can only represent the likely effect of a development at a particular time. Thus, the most important objective should be to present an honest representation that informs the viewer's prediction of how the turbine rotors would appear in different conditions.

179 To meet this objective, the first option for turbine direction listed in paragraph 177 above is not recommended; this is because this image would in reality rarely occur over a wide horizontal field of view and would thus appear improbable. Both the second and third options are acceptable. The presentation of turbines facing the prevailing wind will tend to create the most realistic image throughout an ES. If all the wind turbines face the same way, but in an alternative direction, this is equally accurate. However the choice of direction may be questioned where there are numerous windfarm developments visible over a wide field of view and the choice of direction seems to favour illustration of one windfarm more than another.

Image enhancement

180 Enhancement of images is an inherent part of photographic production. Photo processing involves judgements - there is no process by which a 'pure' photo can be produced without the application of human decision-making, from exposure timing to the specification of the camera, and whether this is applied manually or automatically.

181 Although enhancement, for example to maximise clarity, has traditionally occurred within the photographic darkroom, this practice has often raised concern with regards to producing digital photographs and photomontages. This may be because it is difficult to quantify the level of enhancement in a way that is easy to understand, raising the suspicion that an image has been 'doctored', and is consequently

Figure 24: Various levels of image sharpening

Digital photograph contrast enhanced and colour balanced

Sharpened for printing

Grossly over-sharpened

Figure 25: The effect of colour balancing an image

Digital photograph as taken

Blue cast removed by colour balancing

Contrast and brightness enhanced

misleading. In reality there is no way to avoid a photograph being 'doctored' as this is an integral part of photograph and photomontage production. The only way to ensure that this is to acceptable standards, is to require the use of extreme care by a suitably experienced professional. The extent of enhancement must also be limited to that which would conventionally occur in a darkroom to improve the clarity of an image, not change its essential character. For example, it is important that any enhancement, such as sharpening elements within a view, is carefully balanced throughout an image, not just the wind turbines; otherwise other features may seem less prominent in comparison.

182 Sharpening an image slightly can also help fine detail visible in the field, be visible on printing. This operation works by identifying areas of high contrast in the image, which correspond to the detail we see, and locally further increasing the contrast so that the detail becomes more apparent. However this operation must be applied carefully as over-sharpened images can result in a hard dark line that appears at the skyline and a corresponding light edge to the sky above it, while miniscule details can appear unrealistically prominent and fussy (see figure 24).

183 It is also helpful to sometimes adjust the brightness and contrast of an image so that, for example, no detail is unnecessarily lost in deep shadow, while also ensuring that the sky does not bleach out to white or pale grey as the shadows are lightened. Colour balance across the whole image sometimes needs adjustment, even if the photography was taken in good conditions, to remove unwanted colour casts (see figure 25). These operations are available in photographic image processing software and are techniques similar to those used within a conventional darkroom. They do not change the content of the image.

184 Conversely, if changes are made to sky colour alone, which is sometimes done to ensure that turbines are visible, the content of the image is effectively changed. This approach should therefore only be employed if there is no other practical alternative and targeted enhancement is clearly noted adjacent to the affected images. In these circumstances, it may be advisable to ensure that the original photographs are available, if required, to demonstrate the degree and nature of the enhancement that has taken place. However, as discussed in paragraphs 180-181above, it must be understood that even the original photographs will have been enhanced to some extent through standard photo processing.

Wirelines

Use of wirelines

185 Wirelines are computer generated line drawings, based on a digital terrain model (DTM), that indicate the three-dimensional shape of the landscape in combination with additional elements. They are a valuable tool in the windfarm VIA process as they allow the assessor to compare the position and scale of the turbines within the wireline to the existing view of a landscape.

186 Wirelines are particularly useful to the landscape architect or experienced specialist assessor as they strictly portray objective data. This means that, by comparing wirelines with a view on site, the assessor can make clear and transparent judgements on the likely visual impacts in a variety of environmental conditions, safe in the knowledge that the wirelines have not been subject to manipulation that cannot be quantified. They can also reveal what would be visible if an existing screening element, for example vegetation or a building, is removed.

187 It is important to highlight that wirelines are not intended to portray a 'true to life' visualisation of a

proposed windfarm. Rather, their use in VIA relies on interpretation that is based on experience of the visual impacts of windfarms and how these typically compare to the representation of a windfarm within wireline diagrams.

188 Wireline diagrams are extremely valuable in the windfarm design process, as they are relatively quick and easy to produce, so that many sets will usually be generated as a windfarm layout evolves. The benefit of these wirelines is that, not only do they clearly convey the overall windfarm image that results from the layout and siting, but they also show how this is affected by the position of individual wind turbines, that can be easily identified and re-positioned in an attempt to improve the effect. The assessor will usually identify individual turbines using computer software. However, for the benefit of the ES reader, it is essential to include some wirelines within the appendices that have individual wind turbines numbered. This aids understanding of the design process, as documented with reference to individual turbine numbers, and also enables further mitigation measures in relation to individual turbines to be discussed more easily. A limitation, however, is that individual numbers for wind turbines may change during the design process, as wind turbines are added and removed. Consequently, when comparing recent wirelines to those produced in the early days of a project, some number correlation may be required.

Data

189 The accuracy of a wireline depends on the accuracy of the data used to create it. In general, this data will be the same as that used for calculation of the ZTVs, commonly the OS Landform Panorama or Landform Profile DTM products. See paragraphs 41-44 for a fuller discussion of these issues.

190 It is important that, for each project, sufficient DTM data is used to enable the full landform background to

the turbines to be seen and thus easily matched to a view on site or photographs of the existing landscape. For some views, DTM data may need to extend further than the LVIA study area because the distant horizon extends beyond this limit.

191 The quality of Landform Panorama varies widely across the country, largely reflecting the variable quality of the contours on the OS 1:50,000 scale First Series mapping which was used as a source in the late 1980s. Some narrow ridges and peaks are in particular not well represented and can produce wireline diagrams that do not closely resemble the scenes they are supposed to depict. In these cases, it is worth using the Landform Profile DTM, which is usually a better representation of the landform even if downsampled to 50 m simply for use as a 'patch' to repair the Landform Panorama DTM. In a few situations, the Landform Profile DTM may be found to give a poor representation of small but important local landform features. Some of the data, such as NextMap, now available using radar or laser based aerial survey techniques may be appropriate in this situation for critical viewpoints.

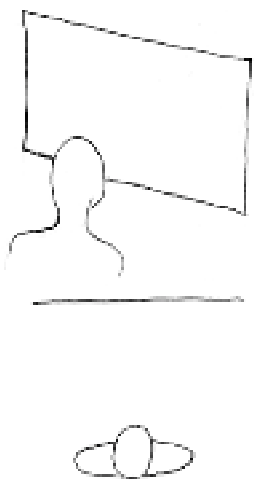


Figure 26a: Planar perspective

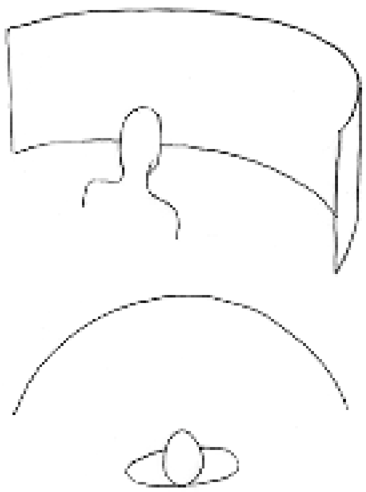


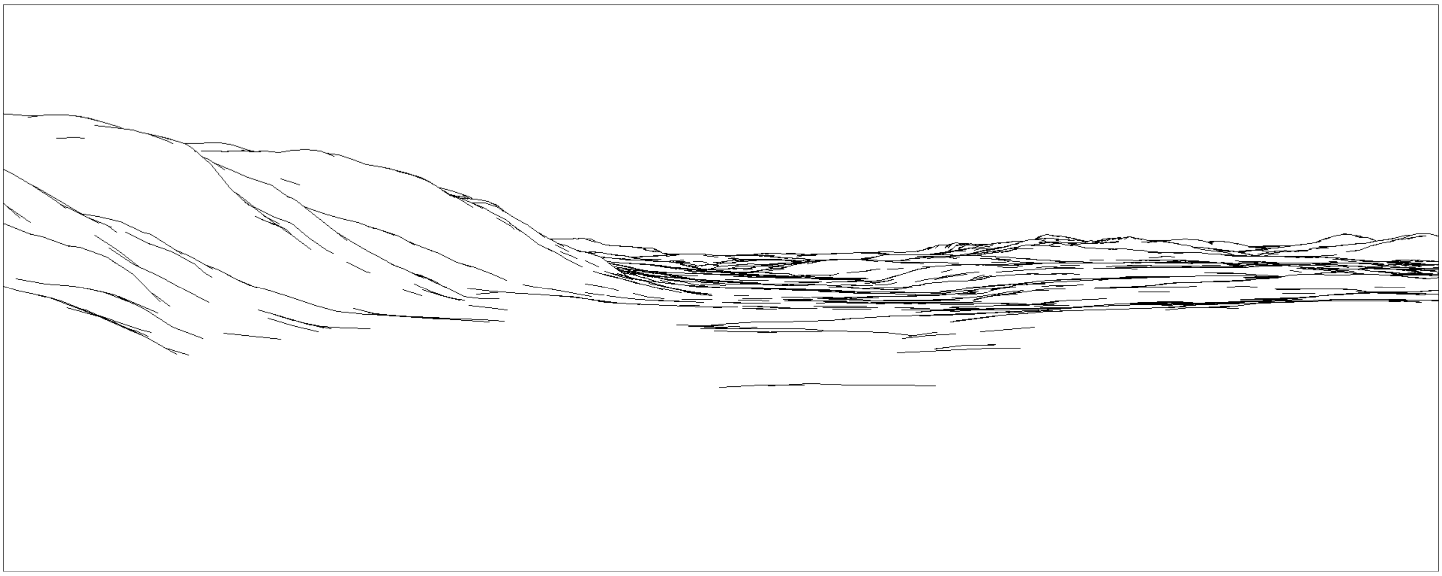
Figure 26b: Panoramic perspective

Geometrical properties

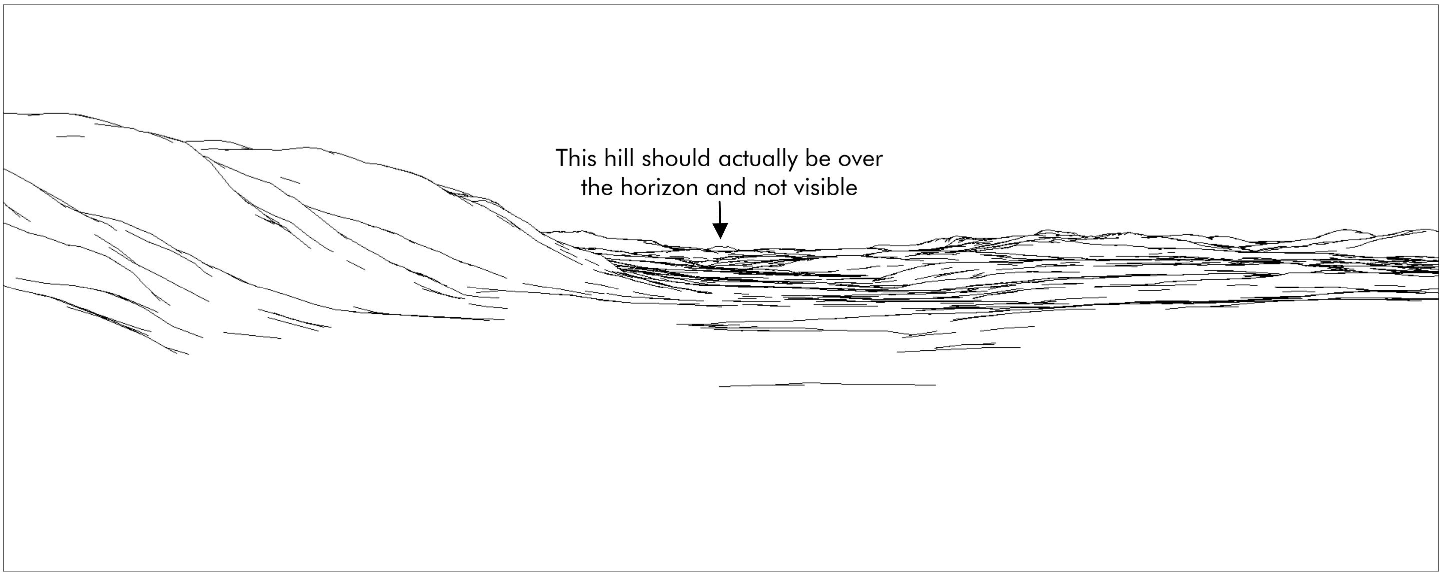
192 As is the case with photographs and photomontages, most wirelines used in windfarm ES work are panoramas. Some software packages can produce true cylindrical panoramas directly; others will produce panoramas, but approximate them as a series of planar panels, generally with an option to specify how many panels are used. Provided that the individual panel width is kept to 20° or less, an acceptable match to a photographic panorama is usually achievable.

193 Some software cannot produce panoramas at all, only simple planar perspectives. The horizontal field of view can generally be specified (sometimes indirectly as an equivalent notional focal length) and will often allow very wide angles to be used. It is however very

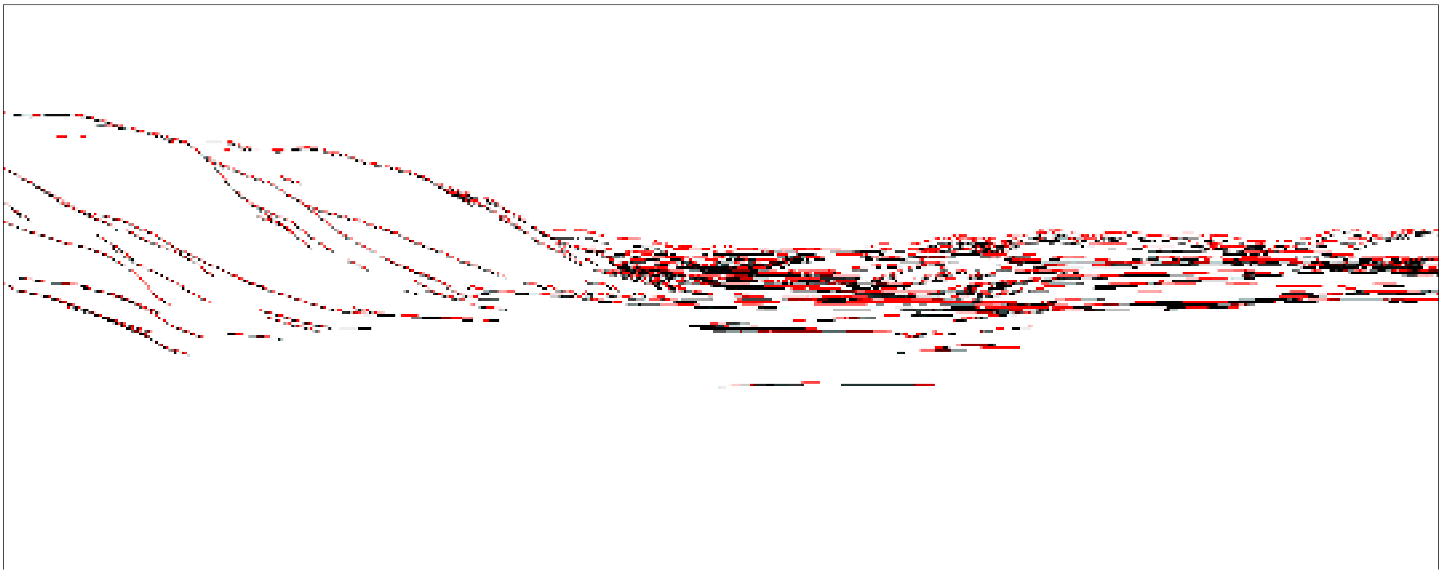
Figure 27: The effect of earth curvature on wireline composition



Wireline image of DTM including effects of earth curvature and atmospheric refraction



Wireline without earth curvature or refraction



Above images superimposed. The version with no curvature is shown in red. Note that distant hills are wrongly placed on the image and also some geographical features are shown which in reality are over the horizon. The image without earth curvature would be impossible to superimpose satisfactorily on a photograph.

important to bear in mind that a planar perspective is not the same as a panorama (there is more detail on this topic in Appendix B). Panoramas can always be approximated with software like this by generating a series of panels that approximate to the required perspective, and then splicing them together in the way that would be done with photographs.

194 Software packages designed for depicting areas of terrain usually include the effect of earth curvature, whereas general-purpose CAD packages most often do not. As pointed out in paragraph 50, the effect of earth curvature increases rapidly with distance from the viewpoint and has a profound effect on the resulting view (figure 27). Wirelines constructed without earth curvature will at best be a poor match to photographs, and at worst will be seriously misleading, as they show features in the distance which in reality would be hidden below the horizon (see Appendix F).

Drawing style

195 Wirelines consist of little more than simple line-drawings of the DTM and the windfarm. However, there are a range of graphic styles used to depict these which can affect the clarity and legibility of the finished image. A number of options are acceptable; however it is important that the same format is used within a single ES.

196 The DTM is most commonly drawn as a mesh seen in perspective. While this is a faithful depiction of the landform as represented by the DTM, it can often result in the more distant parts of the scene becoming unreadable as the grid lines get closer together, eventually merging into solid colour. An alternative, offered by some packages, is to draw only the outline of the topographic features in the scene, approximating to the lines one might draw as a sketch of the scene (figures 28a and 28b). While this approach results in a less cluttered image and one

similar to that which might be hand drawn by a landscape architect or experienced specialist assessor, it can sometimes make the shape of some features harder to understand in three dimensions. A few packages offer a further option of drawing the outlines and also putting in the mesh in a different colour or lighter shade. While the options available within separate software packages may limit choice, it is worthwhile trying alternatives to see which works best for a particular project.

197 Colour is useful to highlight the wind turbines in contrast to the landform lines or mesh, especially in distant views where the effect of merging lines noted above often occurs and where some turbines may only just be visible against the landform. It is sometimes argued that this unnecessarily draws attention to the windfarm but, as the purpose of the diagram is to depict the geometrical relationship between the windfarm and landform, this is not a compelling argument. There are a number of options, such as those listed below and shown in figures 28a and28b.

- Green turbines on a black DTM;
- Red turbines on a black DTM;
- Black turbines on a grey DTM;
- Blue turbines on a grey DTM; and
- Grey turbines on a green DTM.

198 Using the same colour and/or shade for the turbines and DTM grid is not recommended due to the lack of distinction between them, as already discussed. However, all the other options listed above, and potentially others too, are acceptable with the caveat that care must be taken to ensure that the type of colouring does not produce an illusion that the turbines are closer than the landform on which they are sited.

199 Varying colours of turbines can be used to distinguish separate windfarms within a view or existing turbines from proposed wind turbines planned as an extension.

200 Turbines can also be numbered, as mentioned in paragraph 188, so that the individual turbines visible can be directly referred to a layout plan also showing turbines numbered. Unless the windfarm is a very small development, however, this information will usually take up a large amount of space upon the wireline image and, similar to any other labelling, may reduce clarity and distract from the wireline image itself. Consequently, it is generally preferable to label duplicate wirelines within an appendix (just a selection of key viewpoints may suffice). This labelling may need to be done manually, depending on the software used.

201 Features other than wind turbines, can also be modelled into the wireline, depending on the software being used. In this way, existing landscape features can be shown, such as pylons or distinctive buildings, which will help direct comparison with the photograph of the existing view (as long as these do not obscure the wind turbines). In addition, other elements of the windfarm development can be shown, such as the route of access tracks. Inclusion of reference objects, such as field boundaries can help the process of matching the perspective and the photograph during photomontage preparation (although these will usually not be desired in the final wireline used in the ES).

Photomontage

The use of photomontages

202 The basic concept of photomontage is simple; it combines a photograph of an existing view with a computer-rendered image of a proposed development. In this way, photomontages are used to illustrate the likely view of a proposed development as would be seen within a photograph (not as it would appear to the human eye in the field). However, it is important to stress that, although the scale, siting and geometry of photomontages are based on technical data, the other qualities of the image are open to judgements, albeit professionally informed, similar to a hand-drawn illustration. In addition, as already discussed in the section on photography in paragraph 134, photomontages are subject to the same limitations as photographs for representing existing windfarms; that is, that it is difficult to replicate their visibility to the human eye in the field because a printed image cannot replicate the same range of contrast. This is of particular importance when trying to see light-coloured structures at a distance against a background of similar colour and brightness.

203 Photomontages are not generally required by the landscape architect or experienced specialist assessor to carry out VIA. Instead, they will normally use wirelines while carrying out site assessment, to ensure their judgements are based on objective data, as described in paragraph 186 (although, in addition, they will usually consider all information available). However photomontages can help illustrate the visual impacts that have been assessed within the VIA to an audience that is less familiar with windfarm developments, the particular landscape in question and/or how windfarms typically appear in a landscape in comparison to their representation by wireline diagrams.

204 Although photomontages are based on a photo of the existing landscape, it is important to stress that they should never be considered as a substitute to visiting a viewpoint in the field. This is because they are only a tool for assessment. They provide a 2-dimensional image that can be compared with an actual view of the landscape to provide information, such as the scale of a proposed development, but they cannot convey other qualities of the landscape experience that can only be appreciated in the field.

205 Given the limitations of depicting turbines in photos or photomontages of the landscape (as discussed in paragraph 134), their production will usually be of most value for views within 15km of a windfarm site for turbines up to 130 metres high to blade tip. However this will depend on the specific windfarm design and environmental conditions and, consequently, this parameter should usually be discussed and agreed with the determining authority and consultees.

Rendering of photomontages

206 In order to address the difficulty of representing windfarms clearly within photos, it is common practice to exaggerate the prominence of the turbines to ensure that they stand out in the finished photomontage, as discussed previously in the section on photography image enhancement (paragraphs 180-184). When done poorly, this results in a level of visibility unwarranted by the conditions seen in the photograph. However, where done sensitively, this can improve the clarity of an image, comparable to the conventional processing of photographs within a darkroom. Consequently, as for the section of this guidance on photography, is recommended that the rendering of photomontages is acceptable if carried out extremely carefully by a suitably experienced professional. As a guide, the degree of enhancement should be limited to that which would conventionally occur in a

darkroom to improve the clarity of an image, without changing the essential character of the image. The nature of the enhancement should also be noted within the ES.

207 Where a project involves an extension to an existing windfarm, it has sometimes been the case that existing turbines have been 'painted out' in the photo of existing conditions and re-montaged back so that the images of both existing and proposed turbines match. This effectively changes the record of baseline conditions. Consequently, once again, this practice is not recommended if it can be avoided; however it is acceptable under exceptional circumstances, where carried out with extreme care by an experienced professional and noted within the ES.

208 Most importantly, enhancement and rendering cannot compensate for photographs that have been taken in poor light or weather conditions, for example the blue colouring of white skies because of cloud conditions at the time of the assessment. In these circumstances, the photos should ideally be retaken. Neither should enhancement be used as a way of making turbines appear visible within a photomontage for a viewpoint that is actually so far from the proposed development that existing turbines would not be visible within a photograph. In these circumstances, it would be better to represent the likely visibility of the development using wirelines.

Accuracy of match to photography

209 In order to create a photomontage, the geometry of the overlain rendered image of the windfarm must exactly match that of the base photography. That is, the viewpoint location, height and direction of the view must be identical, as must the horizontal field of view, and both the panoramic photograph and the rendered image must be true cylindrical panoramas.

210 The most reliable method of obtaining this accurate match is to generate a wireline image that matches the photograph. If the wireline can be accurately overlaid onto the photograph, then the fit is good. However, where there are few landform features, this process may require the matching of specific structures identified and mapped on site.

211 A GPS position, taken when the photography was carried out, is almost always sufficient for windfarm applications (viewpoint location errors usually manifest as a mismatch in the horizontal position of elements in the photograph and wireline and are always more apparent in closer objects or landscape elements). If it is impossible to obtain a simultaneous match on both near and distant landform features, then the viewpoint position is incorrect and will need to be either re-measured on site or worked out through iteration, depending on the magnitude of the discrepancy and the presence of identifiable objects in the scene.

212 Matching of photographs and wirelines can usually be satisfactorily achieved through knowing the exact location of the viewpoint and windfarm and then adjusting the direction of view to align distinctive features shown within these images. In certain landscapes, where there are few distinctive topographic features, it is necessary to use man-made features such as masts, pylons or buildings in addition. Even when features of these types are clearly visible in photographs, it is often difficult to identify them on the map. If it is anticipated that use will have to be made of built features, then it is worth noting these while taking the photographs and taking compass bearings towards them with a good quality sighting compass. Once identified, these features can be added to the computer model used to create the wirelines and then be treated as alignment aids like topographic features.

213 Note that it is not sufficient to take a compass bearing of the camera's direction of view and then to assume

that this will be sufficient to set the correct direction for a matching wireline.

214 Adjustments should be made until a satisfactory match between topographic features in the wireline and the photograph are achieved across the whole width of the panorama to ensure that there are no errors of scale. If this cannot be achieved, then the fields of view do not exactly match and the parameters must be adjusted further. It is often the case that a small rotation needs to be applied to the panorama to compensate for residual errors in levelling the camera.

215 Once a satisfactory match has been achieved, it is then possible to use the parameters for the wireline as perspective parameters for rendering the turbines for photomontage. Many packages combine wireline and rendering and some also include the facility to overlay the wireline on the photograph while adjusting parameters. However, the best quality is usually obtained using a separate computer program designed for high-quality rendering. Note that most rendering programs do not include the effect of earth curvature, so it may well be necessary to make vertical adjustments to the turbine positions accordingly before rendering.

216 The rendered windfarm should be overlaid on the photograph using a matched wireline for reference, to ensure that the position is correct.

Accuracy of lighting

217 The lighting model used to render windfarm images for photomontages should be a reasonably faithful match to the lighting visible in the base photograph. Consequently it is recommended that the date and time that the photographs were taken should be recorded by the photographer/assessor to enable an exact sun direction to be calculated although, in practice, so long as the direction of light is correct to

within about 10 degrees, a convincing match can be obtained.

218 The effect of light and shade on wind turbines is an important aspect of their visual character and should be represented well. There may be a conflict between achieving realistic lighting and ensuring that the windfarm is clearly visible on the completed photomontage, and thus it will usually be a matter of professional judgement to achieve a satisfactory compromise based on an understanding of lighting conditions and experience of windfarm visibility.

Associated infrastructure and land use change

219 Windfarm proposals include elements other than wind turbines, typically including tracks, borrow pits, cabling and a substation. Additionally, a windfarm development may be both directly and indirectly responsible for vegetation and land use change. If these elements are likely to result in significant impacts, either individually and/ or collectively, they should be included in photomontages if possible, as shown in figure 29.

220 Some of these elements may be difficult to model well, particularly changes in vegetation. In these circumstances, it may be necessary to render them directly onto the photomontage, guided by a wireline or other computer generated image to ensure that the positioning, perspective and scale of these elements is correctly represented.

Figure 29: Representation of land use change (in addition to wind turbines) using photomontage

a: Photograph of existing conditions

b: Photomontage showing proposed land use change in association with windfarm

Other visualisation techniques

Wirelines superimposed on photographs

221 One difficulty of comparing separate wirelines and photographs, is that it is often difficult to interpret the exact spatial relationship between elements in the two images. One alternative is to present the wireline superimposed upon the photograph as shown in figure 30. This is almost a hybrid between a wireline and a photomontage. It has the advantage that the time consuming rendering stage of photomontage construction is avoided; however, in order to achieve a satisfactory superimposition of wireline on photograph, it is still necessary to achieve a quality of perspective match equal to that required for photomontage.

Coloured 3D rendering

222 Wireline diagrams are not suitable for depicting all the works that may be associated with a windfarm, both individually and collectively, for example forestry works, access tracks and borrow pits. One solution, short of a full photomontage, is to use a coloured computer rendering of the scene. This can represent the additional features required, whilst retaining much of the abstract simplicity of a wireline diagram. These techniques are not widely used and different rendering packages offer different facilities, so it is difficult to make firm recommendations on this practice at this stage.

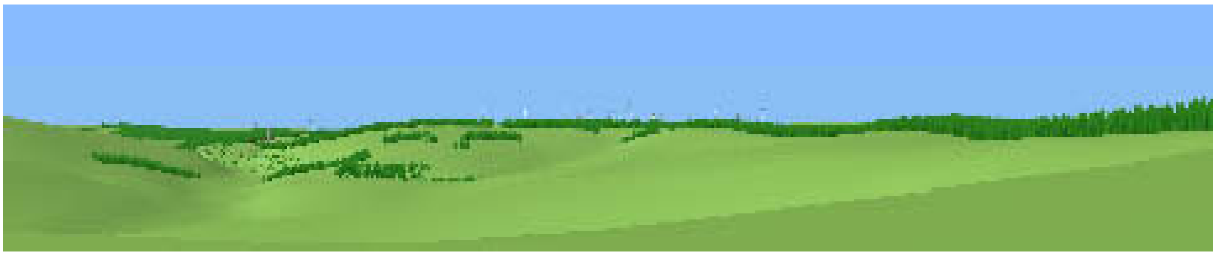


Figure31: Coloured rendering showing proposed forestry works associated with a windfarm

Hand drawn illustrations

223 Drawings and paintings have been used for centuries to illustrate proposed landscape or architectural change. However, it is the production of these using computers that has resulted in radical changes to the way images are conventionally presented, with an associated demand for these to be based on technical data for which accuracy can be measured.

224 There are instances, however, when hand drawn illustrations remain an invaluable tool to the process of visual analysis and the illustration of impacts within an ES. This is mainly because they can offer the following:

- a clarity of image, by omitting some of the distracting details that might be prominent within a photograph but which are actually overlooked on site;
- they can incorporate an element of interpretation by highlighting prominent focal features; and, finally,
- their limitations are obvious – they are clearly not trying to replicate an exact view as it would be seen by the human eye.

225 However, for these same reasons, hand drawn illustrations also have disadvantages, chiefly that their quality is closely linked to the nature and abilities of the illustrator and they may be distrusted for incorporating 'artistic licence'. Hand drawn sketches are commonly included within ESs in two different formats as discussed below.

Diagrammatic sketches and annotated visualisations

226 Diagrammatic sketches allow the key visual elements of the visual composition to be drawn out and highlighted. This may be in relation to the landscape or the windfarm development, highlighting the main visual characteristics and principles of design. The

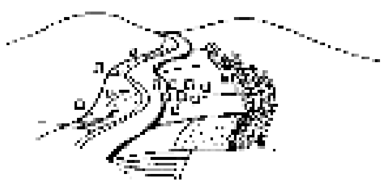


Figure32: Diagrammatic sketch of a landscape

advantage of using this medium is that important points can be stressed without these being clouded by insignificant details. In addition, these diagrams are clearly not attempting to replicate an actual view.

227 It is useful to include within an ES visualisations that are annotated to show the position of key elements of the windfarm proposal, such as access tracks and borrow pits, in addition to the turbines. It is also useful to include turbine numbering on some of the visualisations so that individual machines can be easily identified and cross referenced.

Free-hand sketches

Figure33: Free-hand sketch of a landscape

228 Free-hand sketches may be based on just observation, or made in combination with a computer generated image. They can highlight the key visual elements or components of a view, similar to other hand drawn illustrations but, even better, they can also convey some of the elements of landscape experience, such as exposure, landform shape and colour. These can be used in combination with photographs within an ES, but should not be used as a substitute for these.

Animation

229 Wind turbines are intrinsically dynamic objects, with large moving parts and variable orientation, so static images are in many ways an unsatisfying medium of illustration. Computer animation, videomontage and virtual reality techniques are being used to some extent to address this issue.

230 To date, most animation and videomontage has been used principally as a means of conveying a general impression of a development to the determining authority and the public, rather than as a tool for carrying out VIA or as part of an ES. However considerable scope exists for their use in the future as various techniques are developed and presented, and then tested against windfarms once these have been

built (similar to the scrutiny applied in the past to wirelines and photomontages). At present, the application of these techniques require specialist contractors.

231 Guidance on the various methods of animation is not within the scope of this study. However, it is hoped that supplementary information on this subject may be provided at a later date as the practice develops further.

Choice of visualisation

232 This section considers which, how, why and by whom photographs, wirelines and photomontages should be used.

233 To record the baseline conditions of a view, a photograph is required to be presented within the ES. In addition, a wireline diagram is required to indicate the position, scale and shape of proposed wind turbines. Photomontages can also be useful, to provide an impression of visual impacts and help people to interpret the judgements of the landscape architect or experienced specialist assessor, especially if they have less familiarity and/or experience of the particular landscape in question and how windfarms appear in different conditions. However photomontages can only illustrate how a windfarm would appear in a photograph of a development, not how it would appear in reality as discussed in paragraph 119.

234 The choice of viewpoints to be illustrated using photomontages in addition to wireline diagrams may be impossible to determine until after the initial stages of VIA, although many practitioners observe that it is predictably difficult to produce clear photographs, and thus photomontages, of windfarms from distances over 15km. It is recommended that the local planning authority and SNH are consulted regarding the final choice of visualisations for each viewpoint wherever possible.

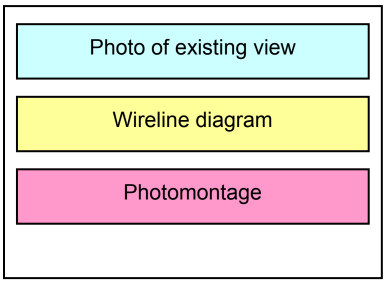


Figure34: The triple arrangement of visualisations

235 In the past, there was often some dissatisfaction with the convention of presenting visualisations from separate viewpoints as a triple arrangement comprising a photograph of the existing view and corresponding wireline diagram and photomontage as shown in figure 34 opposite. This was no fault of the visualisation arrangement *per se*, but because it is not possible to present the triple visualisation at A3 paper

size while satisfying recommended image height and viewing distance criteria (paragraphs 126 and 129). This resulted in three key problems:

- the image was not clear because it was too small to represent the required amount of detail (discussed further in Appendix D);
- the image was held at the correct viewing distance, but this was too close to be viewed comfortably; or
- more commonly, the image was naturally held by the viewer at a comfortable distance, but this was not at the defined viewing distance so that the geometry of the image was incorrect and thus the image scale (and the elements seen within it) was viewed incorrectly.

Nevertheless, the triple format is a useful arrangement and should still be considered as one method for visualisation presentation when using sheets over A3 size, as described within Table 15 and shown in figures 38 and 40.

236 It is important to highlight that the production of different visualisations involves varying levels of data interpretation. Wirelines are based purely on objective data and thus, if only these are used to carry out visual analysis on site, there is a very clear, simple and direct relationship between the data and judgements made. In contrast, the production of photomontages incorporates a much more complex process of judgements in order to construct and render these, similar to any artistic illustration. In this way, although the scale siting and geometry of photomontages can be technically measured, the other qualities of the image will vary in relation to the skill and experience of the illustrator.

237 The difference between photomontages and wirelines in terms of the nature of information they convey and how this informs judgements, was considered by the University of Newcastle (2002). They state "wireframes [wirelines] tended to cause less under (or

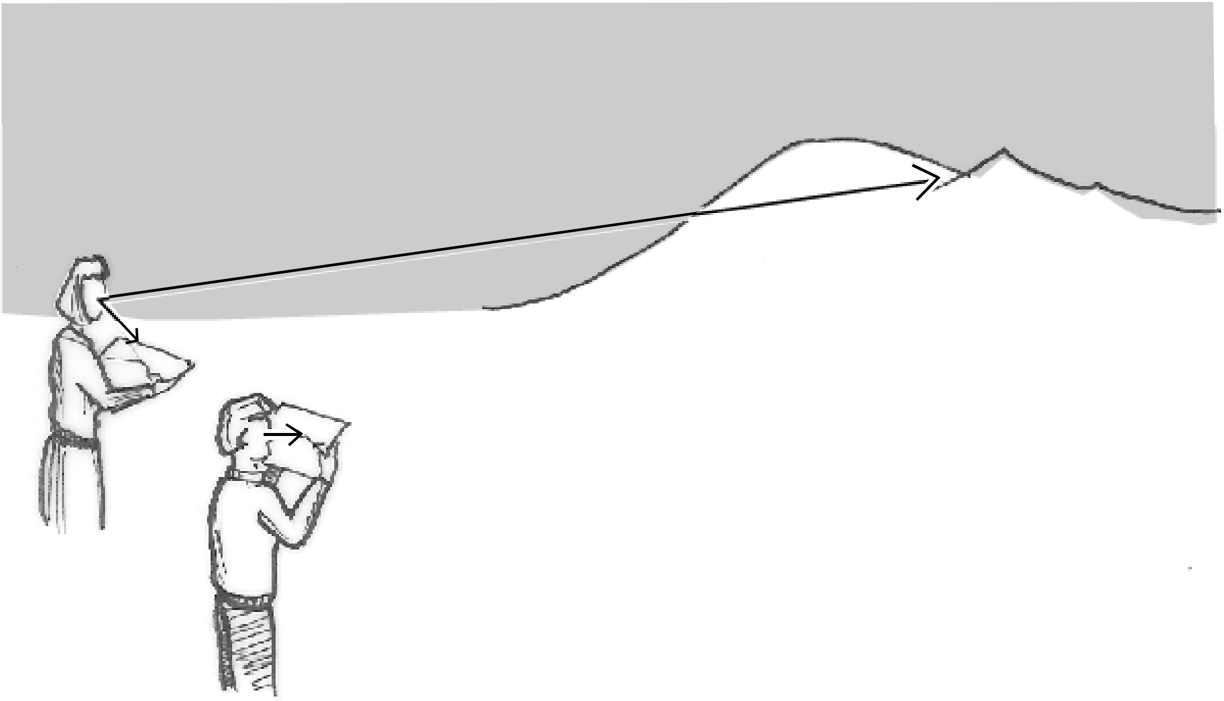
over) estimation of visibility and visual effect, compared to photomontages….".

238 Photomontages are discussed in more detail within the separate section on these within paragraphs 202-220. The proportion of viewpoints illustrated using photomontages within an ES will vary, depending on the specific characteristics of the proposed development and the landscape and visual resource; however ESs within Scotland commonly include photomontages for around one third of the viewpoints illustrated.

239 In certain circumstances, 'regular' photomontages (which are based upon a 50mm lens or equivalent) may be supplemented by a telephoto photomontage. This is where the photograph of the existing view is taken using a telephoto lens (as described in paragraph 155). Normally this would provide no benefit over a photo taken with a standard 50mm lens (or digital equivalent) and enlarged to a sufficient image size and comfortable viewing size, as shown by figure 21. However, in specific circumstances, the additional detail shown in a telephoto photograph can help compensate for the lack of shade differentiation able to be illustrated upon the printed page (refer to paragraph 134). These circumstances tend to occur where a windfarm would be seen in the very far distance against the sky. In these instances, the benefits may compensate for the disadvantage that this creates in terms of having to view an image at a very long viewing distance (figure 22c) and that this distance will vary from other visualisations produced for the same viewpoint.

240 It is important to stress that visualisations should never be used as a substitute to visiting a viewpoint. They remain only a tool for assessment - that is as an image that can be compared with an actual view of the landscape while other elements of the landscape experience can also be appreciated that are unable to

Figure 35: Use of a comfortable viewing distance



At a comfortable viewing distance (400 - 500mm) the viewer can alternate their view between the existing landscape and the visualisation, easing direct comparison and thus judgements on the proposed effect.

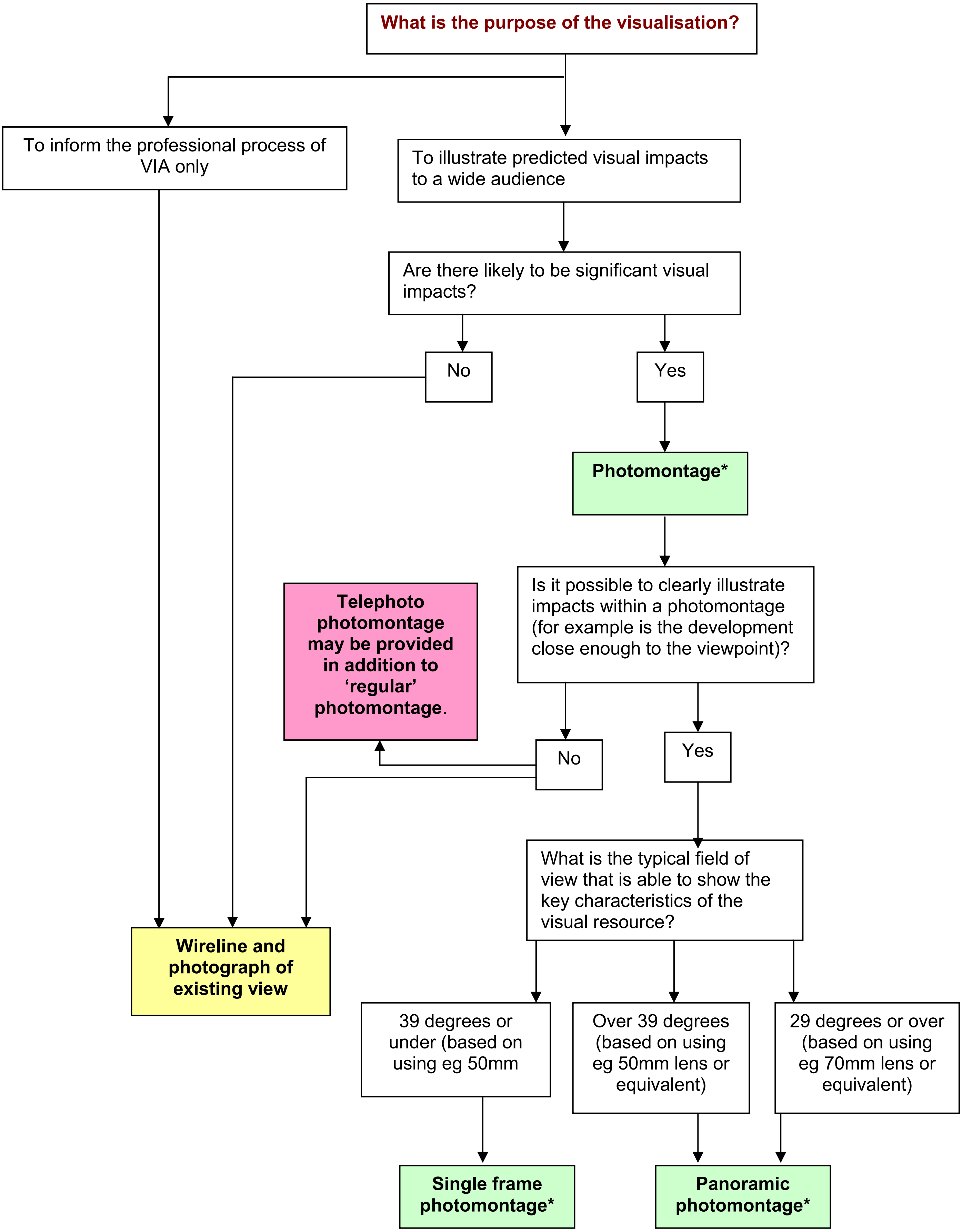
At a short viewing distance (300mm or less) the viewer can only either see the visualisation in front of them, or the existing view - not both. Thus direct comparison is less easy.

be incorporated within a two dimensional picture. To allow this use, it is recommended that visualisations should either be available to be taken out on site by the individual or, alternatively, are mounted upon boards out on site, as illustrated in figure 36. Because of a risk of vandalism or theft, the latter arrangement may be possible during organised visits only.

Figure 36: Visualisation mounted on a board on site in order to provide a direct comparison with present conditions.
(Image courtesy Stuart Young Consulting)

241 Table 13 sets out the various applications of visualisations by different users, while figure 37 indicates the process by which different visualisations may be chosen.

Figure 37: Process of choosing visualisations for each individual viewpoint
(subject also to consultation and agreement with the Planning Authority and SNH).



*plus photograph of existing view and wireline

Table 13: Use of visualisations within VIA

User	*Process*	*Visualisation**	*Use*	*Basis of judgement*	*Judgement*
Landscape Architect or Experienced Specialist Assessor	LVIA as part of EIA	Wireline	On site comparison with visual resource	Professional knowledge and experience of Visual Impact Assessment (VIA), windfarms, and how wireline visualisations compare with built windfarms	Judgements of visual impact magnitude and significance of effect to be reported in ES
		Photomontage	On site comparison with visual resource	Professional knowledge and experience of VIA, windfarms, and how photomontage visualisations compare with built windfarms	For general information only, not usually basis of professional judgement
Officer from Planning Authority or Consultee	Assessment of ES	Wireline	On site comparison with visual resource	Knowledge and experience of the landscape, windfarms, and how wireline visualisations compare with built windfarms	Confirmation of judgements made in LVIA part of ES
		Photomontage	On site comparison with visual resource	Knowledge and experience of the landscape, windfarms, and how photomontage visualisations compare with built windfarms	Supplementary information to help illustrate the likely visual impacts of the windfarm in its landscape setting in addition to associated developments and/ or land use change
Determining authority	Assessment of ES	Wireline	On site comparison with visual resource or, of lesser value, in comparison with photo of existing visual resource	Advice from planning officers. Variable experience of the landscape and windfarms.	Assess planning officers' report regarding confirmation of judgements made in LVIA part of ES
		Photomontage	On site comparison with visual resource or, of lesser value, in comparison with photo of existing visual resource	Advice from planning officers. Variable knowledge and experience of the landscape and windfarms.	Supplementary general information to help illustrate the likely visual impacts of the windfarm in its landscape setting in addition to associated developments and/ or land use change

Member of the public	Understanding of ES and general visual effect of proposed development	Wireline	Access to ES only likely to occur in public building, thus comparison with photo of existing visual resource	Variable background knowledge on the landscape and visual impacts of windfarms.	General indication of the likely visibility, scale and form of the wind turbines.
		Photomontage	Access to ES only likely in public building, thus in comparison with photo of existing visual resource.	Variable background knowledge on the landscape and visual impacts of windfarms.	Supplementary information to help illustrate the likely appearance of the windfarm.

** Telephoto photomontages may also be produced and used in specific circumstances as supplementary information as described in paragraph 239.*

Presentation of visualisations

Presentation for different audiences and uses

242 There are numerous different ways to present visualisations within windfarm ESs. The most appropriate format will depend on a number of factors as follows:

- How and by whom the information will be used;
- Where the information will be used;
- What is required to be illustrated by the visualisation; and
- How the information will be distributed.

243 The landscape architect or experienced specialist assessor will use visualisations as a tool for VIA, both interpreting the images and basing their assessment on a high level of experience and knowledge of VIA and windfarms, as well as a clear understanding of how visualisations differ from views seen with the naked eye. Planners will use visualisations similarly, although they tend to use photomontages (rather than wirelines) more than the assessor. They may also study the visualisations to verify the landscape architect or experienced specialist assessors' findings. The general public will more commonly use photomontages as an illustration of the predicted image of a windfarm and expect minimal interpretation to be required.

244 If the visualisations are to be used in the field, there is generally less need to explain and stress the differences between these images and real life views, although the importance of minimising page size and page 'fold-outs' will be greater. If the visualisations are to be viewed only in an office, home or other building, it will be more important to emphasise how the visualisations should be used and their limitations in relation to real life views, whilst the size of images may be more flexible. For public meetings or displays, visualisations will usually need to be larger; but the

limitations of viewing remote from the real view also apply.

245 The specification of the visualisation will affect how it can be presented, particularly what size of paper is required to illustrate the required horizontal field of view, viewing distance and desired image height. Figures on the size of paper required to accommodate these variables are included in Table 14. There is no perfect solution, as the choice of paper size inevitably involves trade-offs between clarity, ease and cost of reproduction, and practicality of use. All formats have advantages and disadvantages, some of which are described in Table 15.

246 The developer is required to send paper copies of the ES to the determining authority and consultees. However they may charge for some or all parts of the ES if requested by other parties or individuals. As a consequence, for the sake of maximising accessibility, it is in everyone's interests to minimise the potential costs of reproduction. To enable greater numbers of people to study visualisations on site, it may be possible to produce a select number of these within the ES Non Technical Summary (NTS) or as a separate appendix (either free or for a small cost). The disadvantage of producing an extract of this sort, however, is that the visualisations may be misused or misunderstood due to the lack of accompanying information that is found within the main ES.

247 Options may exist for purchasing an ES digitally on CD or for the report to be available via the developer's website, which would incur minimal financial cost. However some domestic or office PCs may struggle to handle the volume of data involved in the photographic images used. In addition, as many of the visualisations represent a wide field of view that would ordinarily be printed at a size larger than most computer screens, the viewer will either need to view these images at a shorter distance than specified or,

alternatively, zoom in on only one part of the image at a time – both of which are unsatisfactory practices.

248 The size of paper required to illustrate visualisations will depend on 4 key factors: the field of view represented by the photograph (paragraph 127); the viewing distance of the paper (see paragraphs 125-126 and 255-256 and Appendix A); the required image size to be clear (showing sufficient detail) (paragraph 129); and how many images are required to fit on each sheet. As mentioned in paragraph 129, an image height over 130mm is acceptable, while an image height of approximately 200mm high is recommended. The following table shows some examples of how these factors influence paper size.

Table 14: Size of paper required to accommodate specific field of view, image size and viewing distance (using 50mm camera lens).

Viewing distance of 500mm, with image height of 200mm			Viewing distance of 400mm, with image height of 200mm		
Field of view (deg)	Width of paper required (mm)	Standard paper size	Field of view (deg)	Width of paper required (mm)	Standard paper size
30	262	A4	30	209	A4
40	349	A3	40	279	A3
50	436	A2	50	349	A3
60	524	A2	60	419	A2
70	611	A1	70	489	A2
80	698	A1	80	559	A2
90	785	A1	90	628	A1
100	873	A0	100	698	A1
110	960	A0	110	768	A1
120	1047	A0	120	838	A0
130	1134	A0	130	908	A0
140	1222	> A0	140	977	A0
150	1309	> A0	150	1047	A0
160	1396	> A0	160	1117	A0
170	1484	> A0	170	1187	> A0
180	1571	> A0	180	1257	> A0

Combinations of visualisations

249 When presenting visualisations in an ES or at an exhibition, it is usual to present combinations of visualisations together, most commonly photograph and wireline, or photograph, wireline and photomontage. This allows the user of the ES to refer to a photograph of the existing conditions and then make a direct comparison between this and the wireline and photomontage.

250 In the past, it has been common practice to present all three of these images together, one above the other on a single A3 sheet. However, as discussed previously in paragraph 235, this layout is only possible if the fields of view shown, the viewing distances, or both, are severely limited beyond recommended standards.

251 A number of alternative options exist for producing combinations of visualisations within an ES. Some of these are described below, illustrated diagrammatically within figure 38, and shown as examples of presentations in figures 39-44. However it is important to stress that these options represent just a few of the many possible scenarios available and each of these has advantages and disadvantages. There is no perfect solution, as implied within Table 15. Rather, the relative pros and cons of all options need to be weighed up for each VIA while considering the following guidance.

- For every viewpoint
  A photo of the existing view and corresponding wireline diagram is required. The viewing distance should be over 300mm, with a recommendation of between 400-500mm. The field of view of the photograph should be determined by the landscape architect or experienced specialist assessor based on the key characteristics of the visual resource and the extent of view required to illustrate this in relation to the windfarm (see paragraphs 135-138).

If the recommended image height of 200mm is used (University of Newcastle, 2002) for the photograph of the existing view (taken with a 50mm focal length lens or equivalent and printed with the minimum acceptable viewing distance of 300mm), this combination can only be accommodated upon an A3 height sheet if the wireline is severely cropped both top and bottom (figure 39). This may be acceptable, where there is only little variation of landform represented within the lower and upper parts of the image, and thus little wireline information is required to be able to directly compare this to the photograph. However, for viewpoints where this is not the case, either the height of the image size needs to be less, the page larger, or the photograph and wireline need to be shown on separate pages. Neither of these options is ideal, as detailed in table 15. Consequently, a decision needs to be made that is based on balancing the relative advantages and disadvantages for each viewpoint.

- For viewpoints where there is likely to be significant visual impacts and where illustration is possible using photomontage
  A photomontage, if required, may either be presented together with the photograph and wireline, as a triple arrangement, as discussed in paragraph 235 and shown in figure 40, or upon a separate page from the photograph and/or wireline. The advantages of the former is that direct comparison between all the visualisations are possible; the advantages of the latter is that presentation on a separate page emphasises the different quality of information that the photomontage presents while maximising its legibility. Whichever format used, the image height, horizontal field of view and viewing distance should match the photograph of the existing view and meet the minimum standards stated.

- For viewpoints where there is likely to be significant visual impacts, but where it is not possible to adequately illustrate the windfarm due to its far distance and because it is seen against the sky.
  In these circumstances, the viewpoint should usually be illustrated using a photograph of the baseline conditions in addition to a wireline diagram. However, in exceptional circumstances, as discussed in paragraph 239, for example a designated site of international importance, a photomontage based on a photograph taken with a telephoto lens may be useful. However it is important to highlight that this photomontage should only be produced in addition to the 'regular' photomontage (based on a 50mm lens) and upon a separate sheet. It should never be produced in isolation as it will not show the full context of the view in relation to the windfarm and key characteristics of the visual resource. Additionally, the use of these photomontages should only be provided with caution, as they will usually require a very long viewing distance that means that the montage needs to be wall mounted or held by another person, and this viewing distance will obviously differ from the other photomontages within the ES, which is not recommended.

- For viewpoints where there are very wide or panoramic views
  As previously discussed, the width of view of the photograph, and thus the standard photomontage, should be based on a judgement of what is necessary to illustrate the key characteristics of the visual resource comprising the 'essential' setting to the proposed development (paragraph 127). However, in certain circumstances, for example where a viewpoint enjoys a panoramic view up to 360°, such as from a mountain top, it may be useful to also include an additional 'context' photograph of the wider panorama. Not because this is required to illustrate the essential setting of

the proposed windfarm, but just for background information. This context photograph should be presented together with the standard photograph, with an outline showing which part of it corresponds to the extent of the standard photograph. Given that the context photograph is for background information only, it does not need to meet recommendations for image size or viewing distance (this should be noted on the visualisation).

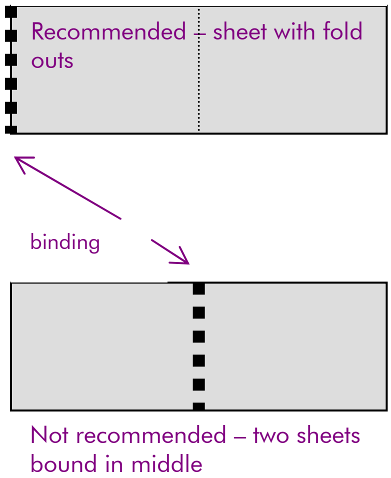
Table 15: Comparison of advantages and disadvantages for different visualisation combinations						
Option no fig no	Paper size	horizontal field of view based on 50mm lens/ viewing distance	Approximate height of image (mm)	No of sheets required to show photograph, wireline and photomontage	**Advantages**	**Disadvantages**
1	A1	117° VD = 400mm	Photo = 200 Wireline = 140 Photomontage = 200	1	Triple arrangement allows direct comparison between existing photograph, wireline and photomontage. Clarity of recommended image size and viewing distance. Large paper size may be simpler to present at exhibition.	Large paper size is unwieldy. Requires vertical and horizontal fold-out within A4/ A3 ES document.
1a 40	A2	82° VD = 400mm	Photo = 140 Wireline = 100 Photomontage = 140	1	Triple arrangement allows direct comparison between existing photograph, wireline and photomontage. Large paper size may be simpler to present at exhibition.	Large paper size is unwieldy. Requires vertical and horizontal fold-out within A4/ A3 ES document. Image height shorter than recommended size for best representation.
2 42a, b, c	A3	57° VD =400mm	Photo = 200 Wireline = 200	3	Clarity of recommended image size and viewing distance.	Can only accommodate narrow horizontal field of view that will only be acceptable from a limited number of viewpoints. Comparison of existing photograph and wireline more difficult on separate sheets
3 41a, b	A3	76° VD =300mm	Photo=150 Wireline =100	2	Size of sheet easy to accommodate within ES report.	Image height shorter than recommended size for best representation. Viewing distance shorter than recommended. Need to crop wireline.

Option no fig no	Paper size	horizontal field of view based on 50mm lens/ viewing distance	Approximate height of image (mm)	No of sheets required to show photograph, wireline and photomontage	Advantages	Disadvantages
4 43a, b	A3 height A2 width	110° VD =300mm	Photo = 150 Wireline = 100	2	Allows wider horizontal field of view than on A3.	Image height acceptable, but shorter than recommended size for best representation. Viewing distance shorter than recommended. Fold-outs are more difficult to manage within ES document.
5 44a, b	A3 height A2 width	94° VD =500mm	Photo = 200 Wireline = 200	3/4	Image height meets recommendations and allows wider horizontal field of view. If supplementary telephoto photomontage shown, may improve visibility of very distant windfarm seen against the sky	Comparison of existing photograph and wireline more difficult on separate sheets. Fold-outs are more difficult to manage within ES document. If supplementary telephoto photomontage included, this will need to be viewed at viewing distance that varies from other visualisations and is usually longer than can be hand held.
6	A3 height A3 and A2 width	57° VD =400mm	Photo = 200 Wireline = 200 Context photo = 70mm	3	Image height meets recommendations. Limited horizontal field of view. Supplementary panorama photograph can show wider context of site.	Supplementary 'context' panorama photograph will be limited in height if included upon same page as standard photomontage. If A3 width, narrow horizontal field of view.

Option no fig no	Paper size	horizontal field of view based on 50mm lens/ viewing distance	Approximate height of image (mm)	No of sheets required to show photograph, wireline and photomontage	Advantages	Disadvantages
7	A2 portrait	57° VD =400mm	Photo = 200 Wireline = 200	2	Photo and wireline can be shown on a single page and thus directly compared easily.	A2 size page difficult to include within ES and use on site. Either as loose map within bound wallet, or bound sheet that has to be folded up and out. Photomontage sheet either on different sized paper or inefficiently occupying small proportion of A2 sheet.

252 To allow easy comparison between visualisations on separate pages, it is recommended that these are included within a loose leaf format so they can be taken out and observed side-by-side as necessary. This arrangement also facilitates the temporary removal of certain graphics for use in the field. However, with this flexibility comes the risk that parts of the ES, and particularly the visualisations, may be extracted, and either not returned or, alternatively, inserted back incorrectly. This is a difficult issue to resolve although, as discussed in paragraph 246, it may be ameliorated if some key visualisations for each scheme are available (either free or at a small cost) within a separate document or within the ES Non Technical Summary.

Figure 45 – Binding of oversize sheets within report'



253 Where visualisations are not required to represent a very narrow horizontal field of view, a sheet wider than A3 will be required. These can either be bound within the document with fold-outs to the side, or alternatively, included as loose folded sheets within a bound wallet. Double-sized A3 sheets or an extended A3 sheet (A3 height +A2 or A1 width) are sometimes bound into a document so that the image extends over both facing pages; however these face the problem of the binder obstructing or distracting attention to/from part of the image, even if using a minimal sized velo binder, and are thus not recommended. Nevertheless, if binding is carried out in this way, it is advised that the visualisation is positioned so that the proposed development does not lie within the spine area.

254 Usually, it will be appropriate to present the photograph, wireline and photomontage such that the proposed wind turbines are centralised in the horizontal field of view. However, at certain viewpoints, it may be appropriate to centre the view on an alternative feature, or part way between two or more foci. These additional foci may or may not be windfarms. In these circumstances, it is important that the proposed windfarm does not appear at the far

edge of the image. This is because sufficient context/ horizontal field of view needs to be provided for each of the foci.

255 As previously highlighted, it is important that visualisations are viewed at the correct 'viewing distance' – that is the distance between the eye and the image that directly relates to the visualisation calculations and image size. This is discussed further within paragraphs 125-126 and 255-256 and Appendices A and C. This distance should always be stated next to a visualisation. In addition, the visualisation should be large enough to show sufficient field of view and detail as described further in paragraphs 129 and 248.

256 To accommodate the horizontal and vertical field of view required at the recommended viewing distance, there will usually be a requirement to use pages larger than A3, either as pull-outs or folded within a wallet. It is important that the viewing distance should be the same for all visualisations in an ES (unless there is a very good reason for doing otherwise, which should be stated and clearly justified). This avoids the need to search out the specification for viewing distance on every image and to repeatedly adjust the position of the document. Experience has shown that, where different viewing distances are used, rather than the viewer altering the distance at which they view each visualisation, there is a tendency to either just adopt the first viewing distance marked and assume this to be standard or, alternatively, adopt a single 'average' viewing distance for convenience. Either action is unsatisfactory as it results in some of the visualisations being viewed incorrectly.

Information to provide

257 Information provided on the specification of a visualisation should be sufficient for the reader of either an ES or a display board to understand the basis of the visualisation, but not so much as to be

overwhelming. Some of this information should be shown upon the visualisation sheet itself, while the remainder can be put within the VIA or appendices. The information provided should include that within the following Table 16.

Table 16: Information to accompany visualisations	
1	Overall 'health warning' summarising how the photomontage should be used and its limitations, and referring to further detail on this issue elsewhere in the ES
2	Information on viewpoint location, altitude and horizontal field of view, as listed within Table 8.
3	Direction of centre of photograph as a bearing
4	Correct viewing distance
5	Whether the image is panoramic or planar perspective and/ or cylindrically projected.
6	Distance to nearest visible turbine in kilometres
7	Cross reference to assessment of viewpoint within VIA and relevant technical appendices. Cross reference to information on photography, listed within Table 12, within VIA and/ or relevant technical appendices.
8	Position of view horizon where there has been unequal cropping between the top and bottom of the image (for example because the key view from a mountain top is downwards)

258 Additional information on the production of the visualisations is important (for example the camera specification and date and time of photograph). However this is not required to interpret the visualisation, and thus can be provided elsewhere within the VIA text or in a clearly referenced appendix.

Paper and printing

259 There is an extremely wide variety of different printers and paper types available with which to print visualisations. To obtain the best results in relation to the size and type of visualisation, it is recommended that advice is sought from specialist providers.

However a number of very general guidelines can be provided within this Good Practice Guidance.

260 If using an inkjet printer, in order to produce a higher contrast finish (where ink sits on the surface rather than soaking in), a high gloss paper is recommended as shown within figure 46a. Very glossy paper, similar in appearance to photographic paper will tend to provide the best image resolution. However this is very expensive and tends to be heavy and thick; so, while it is useful for exhibitions, it can add undesirable weight and bulk to an ES document. As a compromise, coated paper is an acceptable alternative (figure 46b), having lower absorption rates than standard copy paper (figure 46c), while possessing some of the shine and impenetrable surface of high gloss paper, and while being less expensive and heavy.

261 If using a colour laser printer, a smooth white copier paper is usually recommended. This should be of at least 90gm weight.

262 The quality of a printed visualisation will depend significantly on the printing process and set-up. Colour inkjet printers tend to show more detail than other machines because of their higher colour range and resolution. However, it is generally difficult to produce large numbers of pages in this way; so, for mass printing, either colour laser printing or professional printing may be advisable.

263 Printing multiple copies of sheets larger than A3 can be expensive and, if folding is required, may result in a bulky ES report. However, these difficulties must usually be accepted if recommendations for viewing distance, field of view and presentation are to be met; indeed, they are already commonplace for most windfarm ES submissions in Scotland.

Exhibition display

264 Exhibitions provide an opportunity to present larger visualisations. There is a definite advantage in printing at large sizes to include as much detail as possible, particularly photographs and photomontages. The viewing distances should always be stated, as for ES visualisations and as noted within Table 16. These may be larger than the 500mm maximum appropriate for hand-held material. The use of a footplate or cordon in front of exhibition boards can direct viewers to the correct viewing distance.

265 Cylindrical panoramas should either be presented on a curved surface, or presented in a way that allows sideways movement from one side of the image to the other at a constant viewing distance (see Appendix B).

Table 17: GOOD PRACTICE GUIDANCE SUMMARY

VISUALISATION			
	Paragraph in report	Minimum requirements_	Preferred requirements
General	119 134	The limitations of visualisations should be understood before making any assessment based upon them. Assessment of visualisations off site should include consideration of the description of viewpoint characteristics within the ES that cannot be represented by a 2-dimensional image.	Assessment of visualisations should be carried out on site where direct comparison can be made to the real life view.
Key issues affecting visualisations	124	The size of visualisation should be determined by the most appropriate vertical and horizontal field of view and the recommended viewing distance (while being large enough to show sufficient detail).	
	126	A viewing distance of 300mm – 500mm.	A viewing distance of 400 – 500mm.
	127 143	The horizontal and vertical field of view for each visualisation should be determined by the landscape architect or experienced specialist assessor.	
	129 142	An image height of over 130mm for hand-held material.	An image height of approximately 200mm for hand-held material.
	130	Viewpoint visualisations should be assessed together with other aspects of VIA, including visibility as shown by ZTVs.	
Photography	146	SLR camera for 35mm film or digital SLR	
	135-138	Field of view, vertically and horizontally, should be determined by the landscape architect or experienced specialist assessor, in addition to the central point of the photo.	A panorama should be taken to extend the entire width of open view (excluding towards the sun if this is at a low angle)
	147	Levelled photographs, using tripod and spirit level	Panoramic tripod head
	149	Fine-grained 35mm film (ISO 200 or less)	Film ISO 100 or less

	Paragraph in report	Minimum requirements_	Preferred requirements
Photography (continued)	152-153 157-158	50mm fixed focal length lens for 35mm film. Lens giving similar field of view for digital. Do not use zoom lens. Take vertical (portrait) format panorama where a tall vertical field of view is to be represented.	Telephoto lens in very specific circumstances in addition to 50mm.
	159-161 Table 11 164	Ensure good contrast within photograph. Direction and intensity of light should be sufficient to capture existing/ proposed wind turbines on photographs. Not directly into sun. Reveal site and surrounding key characteristics of landscape and visual resource.	Take photographs in strong side light conditions to emphasise topography.
	165-167	Record information on specification and conditions of photographs as listed in Table 12.	
	163	For panorama, manually set exposure setting to ensure good lighting over the entire panorama, but particularly the site and key characteristics of the area.	
Post photographic processing	168-169	Scan negatives to a minimum of 2400ppi, taking care to achieve clean image	Use a bureau service offering Photo CD scans
	174-175	Splice frames manually to build up panorama for photomontages	Use software to re-map frames to cylindrical perspective and correct for lens defects
	173	Use automatic splicing software only for photos to be used as background information and never for photomontages	
	175	Provide overlap of frames by between ¼ and ½ frame width.	
	176	Illustration of turbines should be based upon correct hub height, rotor diameter and general shape	It is recommended that Illustration of turbines should be based on detailed 'engineering' drawing.
	177-179	Wind turbines should be shown all facing a specific compass bearing, not all towards the viewpoint.	Wind turbines shown facing the direction of the prevailing wind

	Paragraph in report	Minimum requirements_	Preferred requirements
Post photographic processing (continued)	180-184	Image enhancement, such as sharpening and colour balance should be avoided if possible. However, if required to improve clarity, this should only be carried by experienced practitioner and with care. Only methods that could be done in a conventional darkroom should be adopted. These should be applied over the whole image, rather than selectively to emphasise only some features that will change the image content.	
Wirelines	189-191	Use OS Panorama DTM as basis for wirelines	Use OS Profile DTM as basis for wirelines
	190	Ensure sufficient data is included to extend to the distant horizon (which may be outwith the study area)	
	194	Include earth curvature correction in wirelines	
	192-193	True panoramas or planar perspectives with a panel width of less than 20°	Ensure that wirelines are true panoramas
	176 197-200	Ensure that all proposed turbines are revealed in wirelines	Include associated elements such as proposed tracks, buildings and overhead electricity lines.
	197 196	Use contrasting colour and/or shade for turbines and DTM mesh	Use DTM landform lines, possibly with lighter coloured broad DTM mesh too, to avoid colour/shading mass seen at far distances.
	188 200	Wirelines with labelled turbine numbers should be included within the ES.	
Photomontage	205	Produce photomontages where significant impacts can clearly be illustrated	
	206	Do not excessively exaggerate the visibility of the windfarm, limiting rendering to that which looks realistic and could be done in a conventional darkroom.	

	Paragraph in report	Minimum requirements_	Preferred requirements
Photomontage (continued)	210	Use a wireline to ensure accurate perspective match with photographs	
	212	Provide 12 figure grid reference to ensure good match of photo and photomontage.	Provide compass bearings to prominent features in the view.
	217	Ensure that lighting of montage matches lighting of photograph. This should be based upon date and time photo was taken.	
	176 219	Illustrate all wind turbines within photomontage.	Show variable rotor position within photomontage. Include additional elements in photomontage, such as forestry works, roads and borrow pits
Other visualisation techniques	221-231	Consider use of techniques other than simple photos, wirelines and photomontages where appropriate.	
Choice of visualisation type	233	Wirelines are required for each viewpoint in addition to a matching photograph of the existing view.	Provide photomontages where impacts are likely to be significant and a windfarm could be clearly seen within a photograph
	236-237	Wirelines should be used where visualisations require to be based on objective data only	
Presentation	246-247	Provide paper copies of all visualisations within the ES	Provide digital copies of visibility maps and visualisations in addition to paper copies, or provide extracts that can be obtained/ purchased separately (free of charge or at minimal cost).
	129	Images should be at least 130mm high.	Images approx 200mm high are recommended.
		If more than one image is shown upon a page, this should be separated by an area or strip of blank space to maximise legibility.	
	249 250 251	A photograph of the existing view should be followed directly by the wireline. The wireline should then be followed by the corresponding photomontage(s) if being produced.	Wirelines should ideally be presented next to the corresponding photograph upon a single page whilst also meeting the recommended image height and viewing distance.

	Paragraph in report	Minimum requirements_	Preferred requirements
Presentation (continued)	249 250 251	A photograph of the existing view should be followed directly by the wireline. The wireline should then be followed by the corresponding photomontage(s) if being produced.	Wirelines should ideally be presented next to the corresponding photograph upon a single page whilst also meeting the recommended image height and viewing distance.
	124 255 256	The page size should be determined by the most appropriate field of view together with the required viewing distance.	
	252	Allow visualisations to be obtained separate from the main ES for direct comparison side-by-side and to be viewed in the field.	Include visualisations within ES in loose leaf format so that visualisations can be extracted and compared side-by-side.
	125-126, 255-256	Always note correct viewing distance on a visualisation. Use a viewing distance of 300-500mm for material intended to be hand held.	A viewing distance of 400-500mm is strongly recommended. The viewing distance should be the same for each visualisation within an ES.
	257	Include all information in Table 16, including location, direction of view, viewing distance and distance to nearest visible turbine on page	
	241 251 Table 13	Consider carefully the different options for presenting visualisations for different viewpoints.	Consult with the Planning Authority and SNH regarding options
	260	Use coated paper for printing.	Use high gloss paper for specific presentations where weight and mass are not a limiting factor.
	240 264-265	Use large display boards for exhibitions. The correct viewing distance should be very obviously marked upon the ground.	Consider use of curved display boards for visualisations at exhibitions. Consider mounting some visualisations on display boards on site at the viewpoint locations for direct comparison with the 'real life' view.

5 Conclusions

266 Visual analysis of windfarms is just one part of the wider study of Visual Impact Assessment. In turn, VIA forms just one part of the wider Landscape and Visual Impact Assessment within an Environmental Impact Assessment. Yet within the visual analysis process itself, there is a wide range of different tools and techniques that can be used.

267 While this Good Practice Guidance can advise on the different purposes, uses and limitations of these processes and set down some minimum technical requirements, it cannot prescribe a single recommended method as there is no 'one size fits all' solution.

268 When selecting the most appropriate type of ZTV mapping and visualisations, it is important to remember why they are being produced, how they can be used and what they can offer. Essentially ZTVs and visualisations are only tools. Behind all their planning, specification and production is the desire for them to aid the assessment of significant visual effects; however they can never reflect the whole story nor, indeed, provide the whole answer.

269 ZTVs and visualisations will be read in different ways by different people, based on their experience and understanding of visual impacts, windfarms, and how these are typically represented by visualisations. As a consequence, there is no single format nor method of production that will satisfy every person's requirements. The Environmental Statement should instead focus on including information used by the landscape architect or experienced specialist assessor in carrying out the VIA, and providing sufficient information to aid other people's understanding of the likely impacts of a windfarm in the landscape and how the judgements within the VIA were made.

270 It is imperative that the selection and use of ZTVs and visualisations as part of a VIA process is carried out in an informed, methodical manner and for this process and its findings to be documented in a transparent way. The integrity and credibility of VIA and EIA depends on a detailed and explicit declaration of the basis upon which all aspects of the assessment have been made. For VIA, this includes the technical specification of visibility maps and visualisations.

271 General guidance on assessing significance of impacts is contained within the Guidelines for Landscape and Visual Impact Assessment (Landscape Institute & Institute of Environmental Management & Assessment, 2002).

272 This Good Practice Guidance provides a starting point for understanding the various methods of visual representation of windfarms, while appreciating that these methods will continue to change and evolve, as people find new and better methods and tools. Thus this report reflects a current understanding of some of the key issues relevant to the visual representation of windfarms, but it is envisaged that this will require future updating.

273 A particular issue that calls for further guidance in terms of visual analysis is the cumulative landscape and visual impacts of windfarms. Whilst the basic principles of VIA for multiple developments are similar to those for individual developments, accumulation makes prediction and assessment during VIA even more complex, and presents new challenges in terms of illustration and presentation. Additional information usually required for cumulative VIA (CVIA) includes cumulative ZTVs and cumulative visualisations.

274 Offshore wind energy development also requires separate guidance in relation to visual representations. While the basic principles of VIA, and the tools used to carry out this process, are the same as for onshore

developments, there are some distinct differences, particularly in relation to visibility over the sea, the horizontal emphasis of views, turbine lighting, and the provision of distinct visual references.

275 Animation and video montage are other methods of visualisation, outwith the scope of this study, for which guidance would be beneficial.

Appendix i

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List of Environmental Statements assessed

These ESs were chosen by the Steering Group to represent a wide range of visualisation methodologies and quality and should not be taken as representing either best or worst practice.

Airtricity. 2002. Ardrossan Windfarm Environmental Statement.

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Appendix ii

Glossary

Definitions are provided below for terms as used in this document (these may differ within other publications).

Reference should be made to the glossary contained within the Guidelines for Landscape and Visual Impact Assessment (2002). Some of the terms are repeated here however (marked by an asterisk), due to their particular relevance to the visual representation of windfarms.

Assessment (landscape). An umbrella term for description, classification and analysis of landscape.*

Cumulative effects. The summation of effects that result from changes caused by a development in conjunction with other past, present or reasonably foreseeable actions.*

Element. A component part of the landscape or visual composition.

Environmental Impact Assessment. The evaluation of significant effects on the environment of particular development proposals.

Horizontal array angle. This term is used to describe the horizontal field of view occupied by the visible part of a windfarm.

Landscape. Human perception of the land conditioned by knowledge and identity with a place.*

Landscape character. The distinct and recognisable pattern of elements that occurs consistently in a particular type of landscape, and how this is perceived by people. It reflects particular combinations of geology, landform, soils, vegetation, land use and human settlement. It creates the particular sense of place of different areas of the landscape.*

Landscape effect. This derives from changes in the physical landscape, which may give rise to changes in its character and how this is experienced. *

Landscape feature. A prominent eye-catching element, for example, wooded hilltop or church spire.*

Landscape resource. The combination of elements that contribute to landscape context, character and value.*

Magnitude. A combination of the scale, extent and duration of any impact.*

Mitigation. Measures, including any process, activity or design to avoid, reduce, remedy or compensate for adverse landscape and visual impacts of a development project.*

Panorama. An image, covering a horizontal field of view wider than a single frame. Panoramic photographs may be produced using a special panoramic camera or put together from several photographic frames. Wirelines and photomontages may also be panoramas. See Appendix B.

Photomontage. A visualisation based on the superimposition of an image onto a photograph for the purpose of creating a realistic representation of proposed or potential changes to a view. These are now mainly generated using computer software.

Receptor. This term is used in landscape and visual impact assessments to mean an element or assemblage of elements that will be directly or indirectly affected by the proposed development*.

Sensitivity (landscape or visual). The extent to which a landscape or visual composition can accommodate of a particular type and scale without adverse effects on its character or value.

Scoping. The process of identifying the likely significant effects of a development on the environment which are then to be the subject of assessment.

Telephoto Photomontage. A type of photomontage (see above) based on a photograph taken using a telephoto lens (over 50mm).

35mm camera. This is a Single Lens Reflex (SLR) camera that uses a 35mm film gauge with a negative size of 36 x 24mm.

Visual Amenity. The value of a particular area or view in terms of what is seen.*

Visual effect. This results from changes in the composition of available views as a result of changes to the landscape, to people's responses to the changes, and to the overall effects with respect to visual amenity. *

Visualisation. Computer simulation, photomontage or other technique to illustrate the appearance of a development. *

Windfarm. Also known as a 'wind farm'. A development of wind turbines for the purposes of generating energy.

Wirelines. Also know as 'wireframes' or 'computer generated line drawings'. These are computer generated line drawings, based on digital terrain models (DTM), that illustrate the three-dimensional shape of the landscape in combination with additional elements.

Zone of Theoretical Visibility (ZTV). Also known as a Zone of Visual Influence (ZVI), Visual Envelope Map (VEM) and Viewshed. This represents the area over which a development can theoretically be seen, based on digital terrain data. This information is usually presented on a map base.

** As defined by the Landscape Institute and Institute of Environmental Management and Assessment (2002)*

Zone of Visual Influence (ZVI). See Zone of Theoretical Visibility (ZTV) above.

Appendix iii

Acronyms and abbreviations

APS	Advanced Photographic System
CAD	Computer Aided Design
CD	Compact disc
CIA	Cumulative Impact Assessment
CLVIA	Cumulative Landscape and Visual Impact Assessment
cm	Centimetre
DSM	Digital Surface Model
DTM	Digital Terrain Model
DPI	Dots per inch
EIA	Environmental Impact Assessment
ES	Environmental Statement
EXIF	Exchangeable image file
GIS	Geographical Information System
GPS	Global Positioning System
GLVIA	Guidelines for Landscape and Visual Impact Assessment
ISO	International Standards Organisation (set film speed ratings)
LIA	Landscape Impact Assessment
LVIA	Landscape and Visual Impact Assessment
m	Metre
mm	Millimetre
NGR	National Grid Reference
NTS	Non Technical Summary
OS	Ordnance Survey
PC	Personal Computer
PPI	Pixels per inch

RMS	Root mean square
SLR	Single lens reflex
SNH	Scottish Natural Heritage
SRF	Scottish Renewables Forum
SSDP	Scottish Society of Directors of Planning
TIN	Triangulated Irregular Network
VEM	Visual Envelope Map
VIA	Visual Impact Assessment
ZTV	Zone of Theoretical Visibility
ZVI	Zone of Visual Influence
2D	Two dimensional
3D	Three dimensional

Technical Appendices

A Camera Perspective

Linear Perspective
The pinhole camera
Practical cameras
Wide angle geometry
Image distortion
Correct viewing distance

B Panoramic Photography

Types of panoramic camera
Pseudo-panoramic systems
Fixed lens panoramic cameras
Rotating lens panoramic cameras
Spliced panoramas
Geometrical implications

C Human Vision

Acuity
Detail and contrast
Field of view
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D Choice of Focal Length

Size of image
Resolution
Field of view and detail

E Taking Good Photographs

Camera
Film
Tripod
Levelling
Focus
Aperture and exposure
Recording photographic details

F Earth Curvature and Refraction of Light

Technical Appendix A

Camera Perspective

Linear Perspective

A1 Leonardo da Vinci wrote, "Perspective is nothing else than seeing a place or objects behind a pane of glass, quite transparent, on which on which the objects which lie behind the glass are to be drawn. These can be traced in pyramids to the point in the eye, and these pyramids are intersected by the glass plane" (Richter and Richter 1939). This description is known as 'Leonardo's window' and is illustrated neatly (if quaintly) by a plate from *New Principles of Linear Perspective* by the English mathematician Brook Taylor (Taylor 1719).

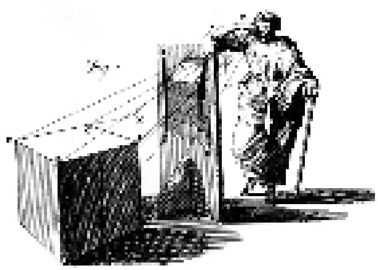


Figure A1: Leonardo's window as illustrated in Taylor's 'New Principles of Linear Perspective'.

A2 In Taylor's diagram, the top corners of a cube, **ABCD**, are shown projected onto the picture plane as points **abcd**. Each point on the object is projected onto a corresponding point on the image by a straight line passing through the observer's eye (we have to assume that the other eye is closed for this purpose).

A3 Straight lines in the object are necessarily represented by straight lines in the image. Consider, for example, the line **AB**. It forms a plane triangle with the observer's eye point **O**. The intersection of a plane triangle with a plane (in this case the picture plane **FGHI**) can only be a straight line, so it follows that the projected line **ab** must also be straight. This property is a characteristic of perspective with a single eye point and a planar picture surface.

A4 The geometry described by Taylor is that found in any textbook on 'measured perspective', the construction of accurate perspective views using drawing instruments (Walters and Bromham 1970). It is also the geometry found in the perspective projections provided by computer graphics software.

The Pinhole Camera

A5 The principle of the pinhole camera was known to Leonardo (in the form of the 'camera obscura') and described by him (Richter and Richter 1939). Instead of the rays of light passing through a transparent picture plane to a single eye point, they pass through a single point, the pinhole, to project an image onto the picture plane. As in the case of Leonardo's window, the straight lines followed by the rays of light ensure that straight lines in the object project as straight lines in the image.

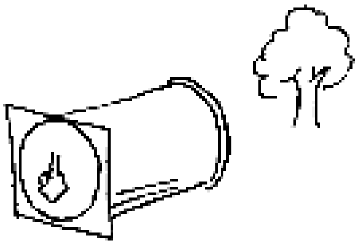


Figure A2: A simple pinhole camera made from an old tin can.

A6 A pinhole camera may be constructed quite simply from an empty tin can with a small hole punched in one end and a piece of tracing paper used as a screen. This is in essence the camera obscura used by some artists in the 17th and 18th centuries as a means of quickly establishing the perspective of a scene, drawing directly onto paper stretched over the back of the device. The longer the distance between the pinhole and the screen, the larger will be the projected image.

Figure A3: A pinhole camera improvised by replacing the lens of a digital SLR with a modified body cap.

A7 A working photographic pinhole camera may be constructed by replacing the lens of a single-lens reflex camera with a pinhole in the form of a small hole drilled in thin sheet metal and supported on an adapted camera body cap. The disadvantage of a pinhole over a lens becomes immediately obvious

Figure A4: Photograph taken with the pinhole 'lens' on a digital SLR as shown in Figure A3.

Figure A5: Photograph taken with 50mm lens on the same digital SLR.

when it is put to use; the pinhole admits very little light, resulting in very long exposure times (up to a 10 seconds) to form an image. The pinhole size determines the sharpness of the image: too large and the image is blurred because each point on the image is illuminated by light from more than a single point in the scene; too small and the diffraction of the light as it passes through the pinhole blurs the image. Even the optimum pinhole diameter of about 0.2mm produces results far inferior to a lens.

Practical Cameras

A8 As mentioned above, the camera obscura was used as a perspective aid by some artists. With just a pinhole, the image would be too faint to use comfortably, particularly if working out of doors, so a lens was used. A good lens behaves in the same way as the pinhole in that the light appears to travel in a straight line from object to image, passing through a point at the centre of the lens. In reality, the light passes through all parts of the lens but is bent by the glass in such a way that light from any given point on the object viewed arrives at a corresponding single point on the image, no matter which part of the lens it passes through on the way. As the light can pass through the whole area of the lens, the resulting image is much brighter than with a pinhole.

Figure A6: Digital SLR fitted with 50mm focal length lens.

A9 The earliest photographic cameras constructed by William Fox Talbot in the 1830s were direct adaptations of the camera obscura with chemically sensitised paper in place of the screen for drawing (Arnold 1977).

A10 All modern cameras follow Fox Talbot's basic model of a lightproof box with light passing through a lens and being focussed onto a sensitised surface, either film or an electronic sensor in modern cameras. The quality of the resulting image is largely dependent on the quality and precision of the lens used.

Wide angle geometry

A11 Although Leonardo's window must necessarily produce a true perspective as the image exactly overlaps the object, very wide fields of view can nevertheless produce results which are surprising at first glance.

Figure A7: Photograph taken with equivalent of a 20mm lens on a 35mm camera, showing perspective and scale effects of extreme wide angle

A12 This example was taken with a very wide-angle lens, giving a horizontal field of view of 84° Elements in the scene towards the corners of the frame seem to be elongated and stretched away from the centre of the photograph. However, referring to Brook Taylor's illustration of Leonardo's window, these elements would be seen by the statuesque viewer at a very oblique angle and the foreshortening introduced by this oblique angle exactly compensates for the elongation in the image. (See the section below on viewing distance.)

A13 This elongation of elements in very wide angle images is often referred to as 'distortion'. However it is incorrect to do so as it is simply a consequence of the geometry of linear perspective.

Image Distortion

Figure A8: Barrel distortion

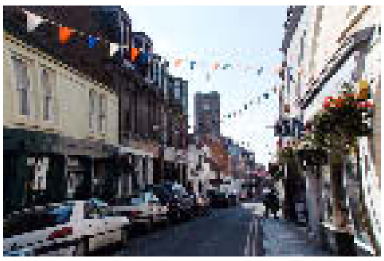


Figure A9: Pincushion distortion

A14 'Distortion' has a very specific meaning with reference to the properties of camera lenses. There are five classes of monochromatic lens defects (that is, ones that do not affect the colour in an image). Of those, the only one that affects the geometry of the resulting image is 'distortion'. (The others, spherical aberration, astigmatism, coma and field curvature only affect image sharpness.) Distortion is the phenomenon of straight lines on the objects in a scene being represented by curved lines in the image. If these curves bend outwards from the centre of the image, the lens (and the image) is said to exhibit 'barrel distortion'. If the curves bend inwards, the condition is termed 'pincushion distortion'.

A15 The best quality fixed focal length lenses are substantially free of distortion. However, wide angle lenses are difficult to make distortion-free and even very good quality examples sometimes have a small amount of barrel distortion.

A16 Zoom lenses are well known to suffer from quite substantial distortion. This is a consequence of the compromises involved in designing a lens which will offer a range of focal lengths and still have a reasonably wide maximum aperture. Typically, a zoom lens will exhibit barrel distortion at the shortest focal length it provides and pincushion distortion at the longest focal length. There may be a point in between where there is effectively no distortion or there may be a combination of pincushion (in the centre of the image field) and barrel (at the edges). Generally, the distortion effects are more pronounced the greater the range of focal lengths provided and are more pronounced on lenses with greater maximum apertures.

A17 With a fixed focal length lens on a digital camera it is possible to calibrate any distortion and remove it by using suitable software.

Correct Viewing Distance

A18 Given a photograph printed on a transparent plastic sheet, it would be possible to go to the location where the camera was set up, to hold the photograph up and to look through it at the actual scene. Clearly, if the photograph is held too close to the eye, the elements in the image will appear too big. If it is held too far away, the elements will appear too small. There will be only one distance at which the photograph will exactly match the real scene. This is usually termed the 'correct viewing distance'. Books on geometrical perspective casting tend to use the term 'perspective distance' for the same physical dimension. Brook Taylor used the term 'principal distance' (Taylor 1719) and that term is still used in camera optics.

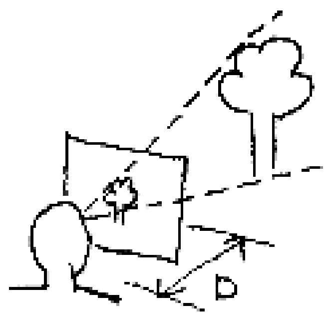


Figure A10: Image and scene coincide only when viewed from the correct viewing distance.

A19 In a pinhole camera, all the light passing through the pinhole really does pass through a single point (or very nearly so, given that the pinhole has a finite size). In a simple (single thickness of glass) thin lens (like a magnifying glass) this is also true. Although the light passes through the whole of the lens, the image formation may be understood as if it converged from the object to the centre of the lens, termed the 'nodal point', and radiated from that point to form an image.

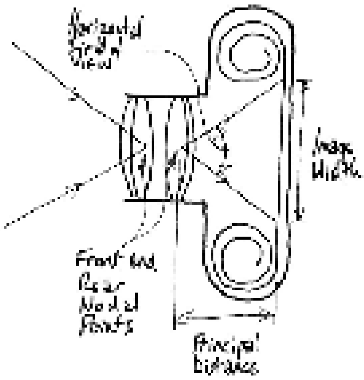


Figure A11: Optical properties of a camera and lens.

A20 In a camera lens, there are generally four or more separate lens elements, typically bonded together in two groups, with the iris of the lens between them. Generally the point at which light from the image appears to converge, the 'front nodal point', is distinct from the point from which it appears to diverge, the 'rear nodal point'. These points are usually almost coincident in a 50mm focal length standard lens for a 35mm camera.

A21 The principal distance is defined as the distance from the film plane to the rear nodal point of the lens. Also by definition, when the lens is focussed on infinity, this is also the focal length of the lens. A pinhole camera does not have a focal length as it has no lens, but it does have a principal distance.

A22 Because most landscape photography is done with the lens focussed on infinity, the distinction between focal length and principal distance is sometimes not expressed precisely.

A23 Although a camera projects its image rather than looking through it as Leonardo's window illustration does, the geometry is exactly the same, except that the image is inverted by the light rays crossing over in the lens's nodal points. Leonardo conceptualised the object as being contained by a pyramid with its apex at the observer's eye. Similarly the whole field of view of the camera will be described by a pyramid whose apex is the lens's rear nodal point and whose base is the area of exposed film.

A24 As the principal distance is the focal length of the lens (assuming it is focussed at infinity), this is therefore also the correct viewing distance for the image if no enlargement is applied to it. Given a 50mm focal length lens and 35mm film, this would give a 36 x 24mm image to be viewed only 50mm from the eye. Some enlargement is therefore necessary. A simple scaling of all the dimensions involved will preserve all the angles of the pyramid which contains the field of view, so for example, the whole image area scaled up to 350 x 240mm would have a correct viewing distance of 500mm.

A25 In other words, if a photograph is taken with a 50mm lens on a 35mm camera and the whole image is printed on a transparent medium to a size of 360 x 240mm, then standing at the point from which the photograph was taken, it will be possible to hold that print at a distance of 500mm from the eye and see the photographic image exactly line up with the real scene, Similarly, a 180 x 120mm print will line up with the scene at 250mm, but will be too close to focus comfortably for most people, and a 720 x 480mm print will line up at 1000mm, but will be further away than the length of one's arms.

Horizontal Field of View

A26 The horizontal field of view for any camera lens is defined by the focal length of the lens and the width of the image formed (the width of the negative for film cameras or the width of the sensor for digital cameras).

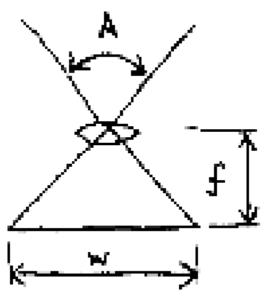


Figure A12: Calculating the horizontal field of view.

A27 The formula for horizontal field of view is as follows:

$$A = 2\arctan\left(\frac{w}{2f}\right)$$

where

A is the horizontal field of view in degrees

W is the width of the image in millimetres (36mm for 35mm film)

f is the lens focal length in millimetres

$\arctan$ is a standard mathematical function (the inverse of the tangent function) and must return degrees in this case.

A28 Examples of horizontal fields of view for a variety of focal lengths in conjunction with 35mm film (with a negative size of 36 x 24mm) are shown in Table 14. Both 'round number' focal lengths and commonly-available focal lengths are shown in Table 18. (Diagonal fields of view are included for completeness as some lens manufacturers quote this as the field of view of their lenses, but the figure is of little practical use.)

Table A1: Focal lengths and fields of view			
Focal length (mm)	Horizontal field of view (degrees)	Vertical field of view (degrees)	Diagonal field of view (degrees)
20	84.0	61.9	94.5
30	61.9	43.6	71.6
40	48.5	33.4	56.8
50	39.6	27.0	46.8
60	33.4	22.6	39.7
70	28.8	19.5	34.3
80	25.4	17.1	30.3
90	22.6	15.2	27.0
100	20.4	13.7	24.4
150	13.7	9.1	16.4
200	10.3	6.9	12.3
250	8.2	5.5	9.9
300	6.9	4.6	8.2
14	104.3	81.2	114.2
18	90.0	67.4	100.5
20	84.0	61.9	94.5
24	73.7	53.1	84.1
28	65.5	46.4	75.4
35	54.4	37.8	63.4
50	39.6	27.0	46.8
85	23.9	16.1	28.6
100	20.4	13.7	24.4
135	15.2	10.2	18.2

Technical Appendix B

Panoramic Photography

Types of Panoramic Camera

B1 A panoramic camera is one designed to take photographs with a very wide horizontal field of view and an image very wide in relation to its height in comparison with conventional photography. There are two main types of panoramic camera: fixed lens and rotating lens. In addition there are several other photographic systems which are styled in one way or another as 'panoramic' but which can be at best only described as 'pseudo-panoramic'.

Pseudo-Panoramic Systems:

B2 APS (Advanced Photographic System) cameras mostly offer 'panoramic' as one of three settings. All this does is to tag the image to be cropped to a 'letterbox' format. The horizontal field of view is not increased; rather the vertical field of view is restricted. There is no good reason ever to use this setting.

B3 Anamorphic adapters are available to fit to the front of ordinary lenses for 35mm single lens reflex cameras. These work in the same way as the lenses used in some types of widescreen cinematography, squeezing a wide letterbox format into an ordinary 35mm frame. Most squeeze the image by a factor of 1.5 or 2, converting the 3:2 aspect ratio of 35mm to 4.5:2 or 6:2 with a correspondingly increased horizontal field of view (Ray 2002). There is inevitably some image degradation and distortion with these adapters and better results are probably achieved with a very high quality extreme wide-angle lens or by splicing several frames together.

Fixed Lens Panoramic Cameras

B4 There are several makes of fixed-lens panoramic camera. Most are medium format (120 or 220 roll

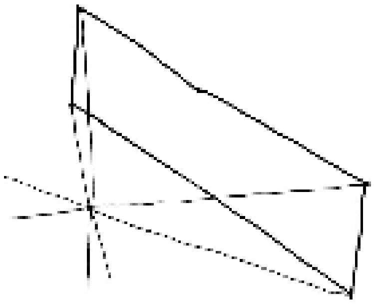


Figure B1: Geometry of fixed lens panoramic camera. This is no different from the geometry of a conventional camera, except for extreme field of view and aspect ratio.

Figure B2: Fuji fixed lens panoramic camera.

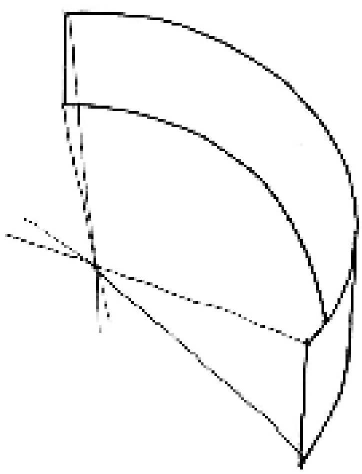


Figure B3: Geometry of rotating lens panoramic camera showing effective cylindrical image surface.

film) but a few are 35mm format. These cameras are really just ordinary cameras with very wide-angle lenses and letterbox aspect ratios. The maximum horizontal field of view offered is about 80° and the perspective is the conventional linear perspective discussed in Appendix A. Consequently, the scale of the image is not constant, with the extreme sides of the image being significantly enlarged compared to the centre and with a noticeable stretching of shapes towards the edges. (There is a corresponding increase in scale towards the top and bottom of the image but this is far less noticeable as the vertical field of view is so much less than the horizontal.) Unless the image content is explained carefully, photography made using this type of camera can be misleading.

B5 As was explained in the case of wide-angle single-frame images, as described in Appendix A, if a panorama of this type is viewed from the correct distance, the oblique line of sight to the edges of the image exactly counterbalance the stretching towards the edges of the image so that the image looks correct. However, viewed at other distances, the scale variation is very much apparent.

Rotating Lens Panoramic Cameras

B6 Rotating (or swing) lens panoramic cameras are also available. As the name suggests, during exposure, the lens rotates horizontally to pan across the width of the image, which can be up to 150 degrees in some makes. While this is happening, the film is wound past a narrow slit which acts as the shutter. (These cameras are commonly encountered when they are used to take school photographs.)

B7 The result is a very wide photograph with a cylindrical rather than planar projection. That is, the perspective will only be theoretically correct if the photograph is displayed on the inside of a cylinder and viewed from its centre. The correct viewing distance will be the radius of the cylinder and will also be the principal distance (or focal length) multiplied by the enlargement ratio of print size to negative size.

B8 The medium format versions of these cameras can produce excellent results. However, owing to the non-standard aspect ratio, it can be difficult to get the resulting negatives printed or scanned.

Figure B4: Widelux medium format rotating lens panoramic camera.

B9 35mm format rotating lens panoramic cameras are lighter and more portable than their medium format counterparts but can produce disappointing results. The focal length of lens is generally quite short (26mm is common) so the size of image detail is slightly smaller than that captured by a 28mm wide-angle lens on a conventional camera. Also, the finite width of the shutter slit results in a slightly less sharp image than would be obtained with the same focal length lens on a conventional camera. The non-standard aspect ratio makes scanning and printing difficult, as in the case of the medium format cameras. Rotating lens panoramic cameras do not in general offer the option to use lenses of different focal lengths as the speed of rotation and speed of film transport are intimately related to focal length.

Figure B5: Noblex 35mm rotating lens panoramic camera.

Spliced Panoramas

B10 Given that panoramic cameras are expensive and cumbersome as well as introducing the technical difficulties in handling the finished photographs which were described above, most practitioners choose to use conventional photography and to assemble panoramas by splicing together sequences of individual frames.

B11 Before the advent of inexpensive scanners and PCs capable of handling large images efficiently, the usual way to assemble a panorama was manually, by physically joining together prints of the individual frames. Anyone undertaking this would rapidly become familiar with the fact that image scale increases towards the edges of the print. There was a considerable knack to finding the point in two adjacent frames where the scale matched and then to make a neat, clean (and irreversible) cut in the print. While it was possible to match the geometry of the images quite accurately this way, differences in brightness and contrast would often show up and repairs to moving clouds or changing lighting conditions were out of the question.

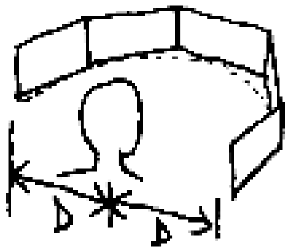


Figure B6: Panorama spliced together out of separate frames without transformation to cylindrical projection

B12 A panorama spliced together out of conventional planar photographs is not strictly a true panorama as it does not form a smooth cylinder. Instead, if each frame were to be set up at the correct viewing distance and orientation to the observer, it would form a polygon on plan. With sufficient frames, this is not a

Figure B7: Two adjacent frames overlapped in image editing software ready to splice them together

Figure B8: The splice point has been found and the frames joined together problem in practice and differs only slightly from a true panorama.

B13 With suitable computer image editing software, it is possible to assemble panoramas out of individual frames (either scanned or from a digital camera). The greatest control is obtained by applying a method analogous to the manual method, that is to find corresponding points on adjacent frames where the scale matches and then to crop them at that point. Contrast, brightness and colour balance can be matched quite accurately by eye.

B14 Unless a geometrical transformation is applied to each frame, a panorama assembled digitally will still be a succession of planar panels. Linear elements running across the image, such as overhead wires or kerb lines will kink slightly across each panel boundary. Straight lines in the scene will, however, still project as straight lines.

B15 It is possible to use specialised computer software to transform the geometry of each frame so that it acquires a cylindrical rather than planar perspective. The lens properties need to be known accurately in order to do this. Once transformed, the need to find a point on adjacent frames where the scale matches is obviated; the scale will match correctly everywhere in the region of overlap.

Figure B9: Photograph taken with 50mm lens

Figure B10: Photograph transformed to cylindrical projection using software

Figure B11: Two adjacent frames transformed and overlapped in image editing software ready to splice them

Figure B12: The splice point can be anywhere in the overlap as the horizontal image scale is constant across both images

B16 A wide variety of low-cost panorama-splicing software is available, often bundled free with digital cameras. Most produce superficially convincing panoramas with minimal effort. Left to themselves, they apply a planar-to-cylindrical transformation to each frame, find matching image detail in adjacent frames, colour balance them and then splice them together. The results are not always perfect or even usable. Automatic detection of matching detail is technically difficult to achieve in landscape photographs, where all detail is small and often confusingly similar. If software allows the user to override its choice of splice points, then reasonable control may be applied to the creation of the panorama, if not, then the results will probably not be usable. Most automated panorama software cannot achieve a perfect match across the whole of the area of overlap between frames and disguises this by applying a blurry transition between them. In many cases, this can be obtrusive and visually distracting and may well obscure important areas of detail. The results of an automated splice should be checked carefully and critically. While judicious use of this type of software can produce visually acceptable results, it generally cannot produce the degree of geometrical accuracy needed for the base image for a photomontage.

Geometrical Implications

B17 Planar photographs (conventional single-frame photographs) have a correct viewing distance defined in terms of 'Leonardo's Window' as described in Appendix A. A panorama, on the other hand, is a cylindrical projection rather than a planar one. The equivalent of Leonardo's Window would be a glass cylinder with the eye-point in the centre. A panorama could be constructed in the manner that Leonardo imagined by drawing directly on the cylinder so that the lines exactly coincided with the lines scene in the outside scene. Similarly a panoramic photograph can be superimposed upon the scene by wrapping it around this cylinder. The superimposition will clearly only work correctly if the cylinder is of the correct diameter. The geometry is similar to planar perspectives in that the correct viewing distance is the principal distance of the lens (often the same as focal length) multiplied by the enlargement factor applied to the print. The correct viewing distance is always the same as the radius of the cylinder.

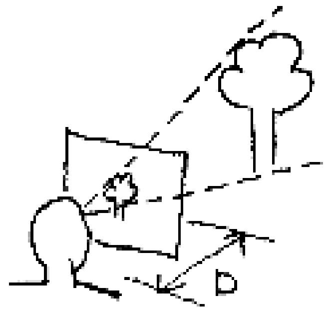


Figure B13: A planar image can be superimposed on the scene it represents when viewed from the correct viewing distance.

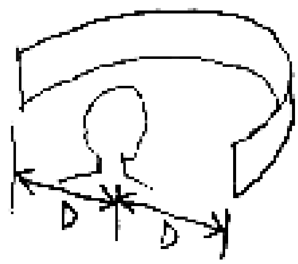


Figure B14: A cylindrical panorama can be superimposed on the scene when viewed from the centre of curvature of a curved surface whose radius is the correct viewing distance.

B18 As in the case of a planar perspective, any straight line segment in the scene will form a plane triangle with the viewer's eye position forming the third vertex. The projection of that line segment on the perspective surface will be defined by the intersection of the triangle with the cylinder described above. With the exception of perfectly vertical or horizontal triangles, the resulting intersection line will always be a curve. A vertical triangle corresponds to a vertical line in the scene and a horizontal triangle to a horizontal line at the same level as the viewer's eye.

Viewing a Panorama

B19 The ideal method of viewing a panorama would be with the image presented as part of a cylinder of the correct radius and then viewed from the centre of that cylinder. Also, ideally, the image should be large enough that viewing comfortably with both eyes is a possibility. This is practical in an exhibition situation, where it would be possible to erect a curved display board several metres wide and to mark a point on the floor for a viewer to stand. Straight lines in the scene, which become curves if the image is laid out flat, look correctly straight when viewed in this way.

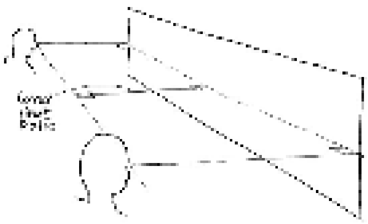


Figure B15: A panorama can be viewed from the correct viewing distance even if displayed flat. The view must always be perpendicular to the plane of th image and never oblique.

B20 Clearly there are many situations where it will be impractical to present a panorama on a curved surface, particularly when a number of panoramas are bound into a document. With care, it is possible to obtain a near-correct view of a cylindrical panorama laid out flat. In the case of a panorama laid flat, the eye point (which would be a single point if the panorama was presented as part of a cylinder), becomes spread out along an imaginary line parallel to the surface of the image and separated from it by the correct viewing distance for the panorama. So long as the gaze is kept perpendicular to the surface of the image, a view from any point along that line will be a good approximation to a correct view. Moving from one end of this line to the other is geometrically equivalent to standing at the middle of the cylinder and turning one's head to left or right. The reason that this approach works is that the eye is capable of seeing only a small part of a scene in detail (generally taken to be about 6-10° - see Appendix C) and there is not a great deal of difference between a flat and a curved image over that angle.

B21 With a flat panorama, there is always the temptation to stand back so that the whole width of the image may be seen easily. This misrepresents the image in two distinct ways: firstly, viewing from a distance greater than the correct viewing distance will make the image appear too small; secondly, the view obtained will compress the panorama into a narrower field of view than that obtained in reality at the viewpoint location, thus presenting a view that cannot in reality be experienced.

Figure B16: Planar panorama with a horizontal field of view of 106°. This is the type of image produced by a fixed-lens panoramic camera and is equivalent to an extreme wide-angle single frame. The increase in image scale towards the sides of the image are very apparent.

Figure B17: Cylindrical panorama with a horizontal field of view of 106°. This is the type of image produced by a rotating lens panoramic camera or by splicing together single frames from a conventional panorama. The horizontal scale is the same across the whole width of the image. The viewing distances for both panoramas are the same, so the scales are equal in the centre of the planar panorama.

Calculating the correct viewing distance

B22 The correct viewing distance is the distance at which the perspective in a photograph (or photomontage) correctly reconstructs the perspective seen from the location from which the photograph was taken. It also follows that, as seen from the correct viewing distance, the photographic image will occupy the same horizontal angle as the horizontal field of view it represents. This is true of both single-frame and panoramic photographs.

B23 The single-frame case is simpler geometrically. Seen from above, the photograph is merely a straight line of length *w*. We can construct an isosceles triangle with the apex representing the viewpoint and the height of the triangle, *d*, representing the viewing distance. At the correct viewing distance the apex angle, *A*, of the triangle must correspond to the horizontal field of view of the photograph. The correct viewing distance is then given by:

$$d = \frac{w}{2\tan\left(\frac{A}{2}\right)}$$

(single frame only)

where:

d is the correct viewing distance in mm
w is the image width in mm
A is the horizontal field of view in degrees
tan is the trigonometric tangent function

B24` If the horizontal field of view and the required viewing distance is known, then the formula rearranges thus to give the image width:

$$w = 2d\tan\left(\frac{A}{2}\right)$$

(single frame only)

B25 Finally, if the image width and viewing distance are known, the formula can also be arranged to give the horizontal field of view. (This version of the formula is useful to determine the horizontal field of view that can be accommodated on a fixed page size.):

$$A = 2\arctan\left(\frac{w}{2d}\right)$$ (single frame only)

B26 In the case of a panorama, the image is assumed to be wrapped around the inside surface of a cylinder whose radius is the correct viewing distance. The horizontal field of view must by definition therefore correspond to the arc of the cylinder subtended by the image.

B27 Given the width of the image and the horizontal field of view, the correct viewing distance is given by:

$$d = \frac{180w}{\pi A}$$ (panorama only)

where:

d is the correct viewing distance in mm
w is the image width in mm
A is the horizontal field of view in degrees
π has its usual geometrical meaning

B28 Given the viewing distance and the horizontal field of view, the image width is given by:

$$w = \frac{\pi A d}{180}$$ (panorama only)

B29 Lastly, if the image width and viewing distance are known, this formula can also be arranged to give the horizontal field of view:

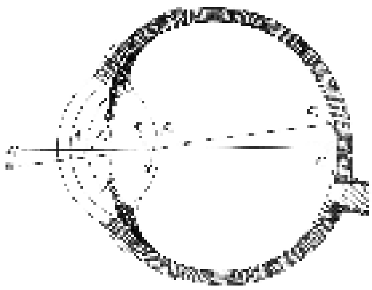
$$A = \frac{180w}{\pi d}$$ (panorama only)

Technical Appendix C

Human Vision

Acuity

C1 Acuity is the ability of the eye to resolve detail. Acuity varies greatly with the brightness of a scene (which corresponds with our everyday experience that fine print is hard to read in dim light). Under bright conditions, the human eye is just able to resolve a pattern of black and white stripes with each stripe covering an angle of 1 minute of arc (1/60 of a degree) (Gregory 1990). The primary reason for this is the spacing of the light sensors at the centre of the eye's retina rather than limitations of the lens system or diffraction at the pupil, both of which would in principle allow finer detail to be resolved. (Pirenne 1967).



Structure of the human eye showing the form of the lens system and the position of its nodal points (from Helmholtz *Handbuch der Physiologishen Optik 1896*).

C2 This figure for acuity does not mean that it is impossible to see objects which are narrower than 1 minute. On the contrary, narrow objects such as overhead wires seen against the sky often subtend narrower angles. The issue is that it is impossible to resolve detail finer than that. Consider, for example, a black-and-white photograph rendered as a halftone for reproduction in a book. The different shades of grey are represented by a pattern of different sizes of black dots on white. At normal viewing distances, the individual dots are not individually resolvable. However, they are not invisible. Each receptor in the eye will receive an image made up of a mixture of several dots and the intervening white paper. The resulting sensation will be indistinguishable from the equivalent shade of grey obtained by mixing the black and white together. The result is that the eye sees shades of grey.

Detail and Contrast

C3 Although we speak of seeing an object, our eyes do not see objects directly. Instead, we detect variations in colour and brightness in a scene and from those infer the boundaries of objects which we then recognise as such. In order for this to take place, there must be sufficient contrast to make those edges, and therefore the objects they define, visible. Contrast may be in colour or in brightness, with contrast in brightness being the more important of the two for vision.

C4 There is a trade-off between detail and contrast. Low contrast limits our ability to resolve detail (Pirenne 1967).

Field of View

C5 The human field of view is hard to define meaningfully. The extremes to left and right are controlled by the optical properties of the lens system of the eyes, which together give a horizontal field of view of about 100° either side of centre. The limits upwards and downwards are defined by an individual's skull configuration, but 60° upwards (limited by eyebrows) and 75° downwards (limited by cheeks) are a good average (Pirenne 1967).

C6 Within that very large overall visual field, only a very small central area will be seen in detail. This is the part of the image which falls on the fovea of the eye and is about 6-10° across (Pirenne 1967).

C7 These figures are based on the naïve assumption that a viewer keeps the head motionless and the eyes fixed on a point. In practice, the eyes automatically turn to place the image of any object we look at on the fovea (the 'fixation reflex') (Pirenne 1970). The horizontal field of view naturally turns as the eyes turn. Turning the eyes far from their central position is uncomfortable, so we tend to turn our heads and if necessary our whole bodies to take in a wide view.

C8 Various figures in to 45-60° range are often quoted as being representative of the human field of view with regard to illustration or photography. It is certainly true that the majority of photographs, paintings and drawing fall into this range, but there is no physiological justification for that figure.

C9 While it is true that we can only see part of the full 360° around us at any one time and only a small fraction of that clearly at any one time, we move our eyes, heads and bodies as necessary and the overall field of view of which we are aware largely depends on what there is to see.

Comfortable Viewing Distance

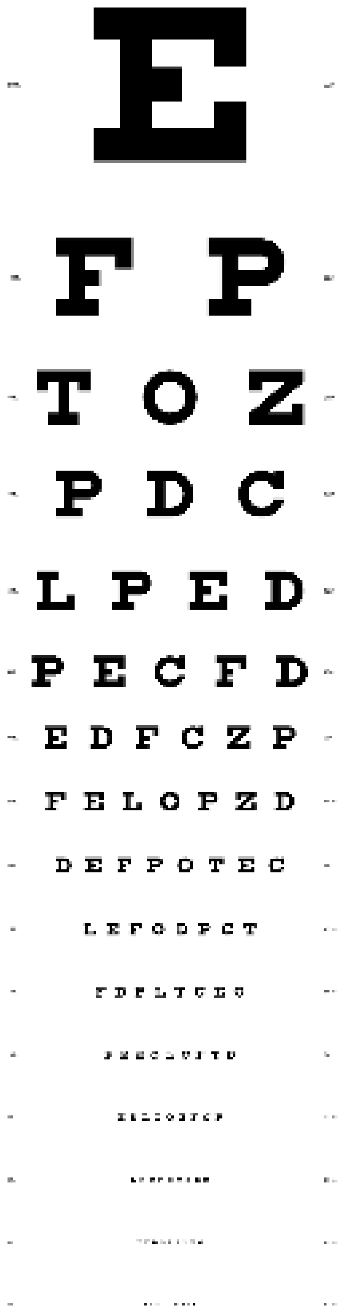
C10 The distance at which we can comfortably focus our eyes is largely determined by age. The ability to change focus is known as 'accommodation' and diminishes with time as the lens in the eye stiffens with age. Very young children can focus as close as 70mm, by age 25 the median is about 100mm and over age 50 it is about 500mm (Gregory 1990). Although the loss of accommodation is a lifelong phenomenon, most people have no need to think about using reading spectacles to compensate until middle age.

C11 John Benson's recommendation of a viewing distance of 300-500mm (Benson 2002) therefore represents a compromise. Some older people will probably need to wear reading spectacles to achieve this.

Reproducing the Visual Experience

C12 There are two issues to be considered in reproducing the visual experience either on a screen or on a printed page. One is the resolution of the image to ensure that sufficient detail is captured. The other is the contrast in the image as presented, to ensure that the detail is visible.

C13 Given the known resolution of the average human eye (1 minute of arc) it is in principle possible to specify a



A Snellen chart for assessing visual acuity (one of several test objects designed by Hermann Snellen). Printed at the correct size and viewed from a distance of 6m, the bars and gaps in the letters in the line DEFPOTEC all subtend 1 min of arc. Being able to read that line at that distance is the definition of 20/20 vision (6/6 in metres) and is regarded as average. Many people can read the next line but few the one below that.

specification for image capture and reproduction which would match that.

C14 The calculations are fairly complicated and involve knowing the resolving power of the lens used, the resolving power of the film, resolution (and other parameters) of the scanner and finally the resolution of the printer used (more complicated than a simple dots-per-inch value).

C15 With a film camera, it is theoretically just possible to capture sufficient detail on 35mm film, provided that the lens and film used are of very good quality, the film processing is to the best professional standards and the scanning is carefully carried out at high resolution. However, even the best film can capture only a limited range of contrast, so that the contrast seen in even a good photograph is necessarily very compressed. This naturally limits the detail that can actually be seen in the image.

C16 The resolving power of a digital camera's sensor is determined by the size of the sensor and the number of pixels it contains. Most digital SLRs have a sensor resolving power which exceeds the resolving power of the camera lens, so provided that a high enough resolution is selected, it should be possible to capture sufficient image data. Just as with film, digital camera sensors are limited in the range of contrast they can capture, therefore similarly imposing limits on the detail that can be seen.

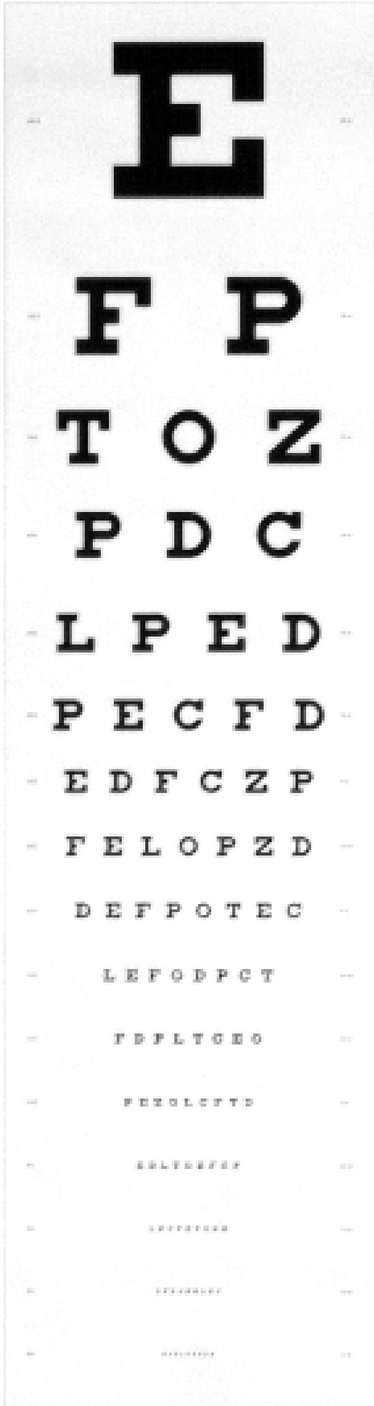
C17 (Note that the subsequent operations applied to an image, including transforming to a cylindrical projection and colour correction or balancing will all have a small detrimental effect on the detail in the image.)

C18 The required resolution in a finished print is easily obtained by current photo quality inkjet printers.

C19 Reproducing the full contrast range visible in a scene is, in general, impossible. On a bright day outdoors, we may experience a brightness ratio of 1,000:1 between the brightest highlights and the darkest shadows. A very good quality computer monitor has a far more limited range available. The lightest colour displayable is the monitor's maximum white and the darkest is the colour seen when the monitor is switched off, usually a dark grey. The brightness ratio is about 100:1 at best. On a printed image, the range is far less, rarely better than 10:1. Acceptable images can only be produced in these media by making compromises: in order to achieve a good tonal range in the middle of the scale, detail in shadows is lost to black and detail in bright areas may bleach out to white. In practice the eye is extraordinarily tolerant of the degree of contrast compression it will accept as 'realistic' in images of outdoor scenes.

C20 It is possible to trade detail and resolution off against one another, so that if the print resolution is higher than strictly necessary then the contrast between adjacent pixels is likely also to be slightly higher and this will allow the eye to pick out more detail. (Consider the image of a wind turbine at a long distance from the viewpoint. A lower resolution image will have pixels which contain parts of both turbine and background and which are therefore of an intermediate colour and possibly hard to pick out. A higher resolution will allow more pixels to be all turbine or all background and therefore easier to distinguish. Even though the eye may well average very fine detail together, the fact that the detail is there makes a difference to the legibility of the image.) Figures 18a, 18b and 18c illustrate this point.

C21 It is just possible to capture the spatial resolution seen by the eye using 35mm photography (or equivalent digital photography) provided great care is taken with the choice of equipment and the procedures used. However, the detail we see in a scene is a function not



Snellen chart photographed from 6m with a 50mm lens on a Fuji Finepix S2 digital SLR. The camera has resolved more detail than the photographer could see (he could read LEFODPCT). The camera would still not capture the fine detail visible in a typical outdoor scene, owing to inability to reproduce the required contrast range. (This is a huge enlargement of a small part of an image, but this does add detail not captured by the camera.)

only of the resolution of our eyes but also the very high contrast present in an outdoor scene. No printing or display technology can come close to these levels of contrast, therefore, it is not generally possible to reproduce the levels of detail that would be easily perceptible in a scene.

Technical Appendix D

Choice of Focal Length

Size of Image

D1 The main difference that different focal lengths of lens make is to change the size of the image on the film (or sensor). Changing from a 50mm focal length lens to a 100mm lens will exactly double the linear scale of the image. (Other changes in focal length will change the scale proportional to the ratio of focal lengths.) Good lenses should be substantially free of distortions and other defects, so there will not be any other differences in the images: the image taken with the 100mm lens will be the same as the centre portion of that taken with the 50mm lens but enlarged to fill the whole frame. Perspective is uniquely determined by the viewpoint position, and direction of view, so is not influenced by focal length (Ray 2002).

D2 Note that the printed size of an image is independent of the focal length. If an image is defined in terms of its horizontal field of view and its correct viewing distance, then those parameters uniquely define the printed size. The only difference between using the 50mm lens and the 100mm lens from the previous paragraph is that the base image taken with the 50mm lens will have to be enlarged more than would be the case with the 100mm lens.

Resolution

D3 The resolving power of most good-quality fixed focal length lenses is about the same (about 80-100 lines/mm at optimum aperture. The resolving power of the film or sensor is naturally unchanged irrespective of the lens used (Ray 2002).

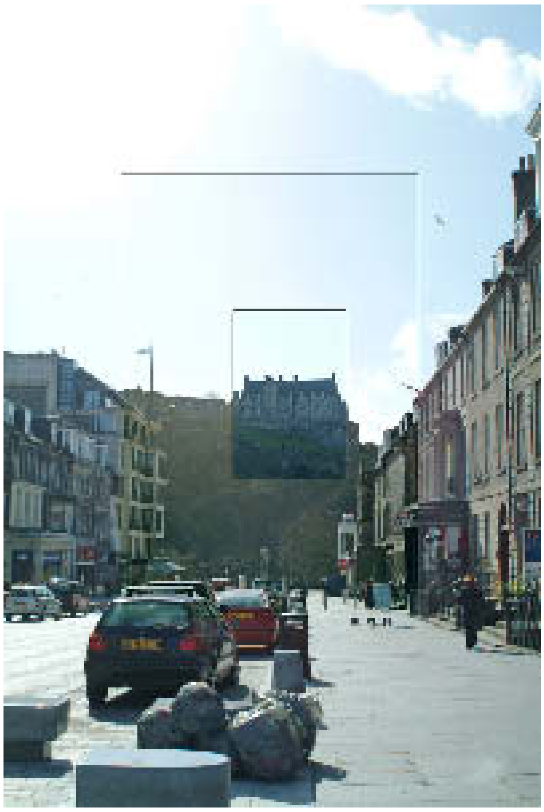
D4 However, as the image on the film is larger with a longer focal length, it follows that the level of detail captured is also greater. (Same lines/mm, but each

Figure D1: Focal length does not alter perspective

Photograph taken with 28mm lens on digital SLR

Photograph taken with 50mm lens on digital SLR

Photograph taken with 135mm lens on digital SLR



All three images can be superimposed accurately and differ only in scale, not in perspective.

millimetre represents a smaller part of the scene in more detail.) Particularly if very large prints are required, a longer focal length lens might be advantageous in order to improve the level of detail.

Field of View and Detail

D5 The larger image scale of a longer focal length lens is accompanied by a correspondingly smaller field of view. For the overall horizontal field of view in a panorama, this is not a problem; it simply means that for a given field of view there will be more individual frames to be processed and spliced together.

D6 For vertical field of view, it is more problematic as that dimension is inherited from the vertical field of view of a single frame. The consequence can be an undesirable loss of foreground and tops of tall objects in the scene. By setting the camera up in portrait orientation, the vertical field of view can be increased somewhat, at the expense of a slightly more fiddly procedure to do so.

D7 In many cases, however, there will be a choice between detail in the photographs and the field of view obtained and both may be undesirable compromises.

Technical Appendix E

Taking Good Photographs

E1 This appendix is not intended to be a general manual of photography; there are plenty of good books available on that subject. Rather, it sets out briefly the main issues relating to photography aimed at constructing panoramas suitable for photomontages and ES work.

Camera

E2 A good quality camera is essential. For photography onto film, a 35mm (or medium format) SLR should be used. For digital photography, a digital SLR should be used, ideally one that is based on a 35mm SLR design.

Figure E1: Good quality digital SLR camera

E3 Lenses should be good quality as well; cheap lenses are likely to produce less sharp images. Very fast lenses (f/1.4 or faster) are useful for taking photographs in poor light, but often have poorer optical characteristics than slower lenses (f/2 or slower). In particular they sometimes have noticeable barrel distortion.

Film

E4 Very fast film should be avoided as it generally has a coarser grain structure and lower resolving power than slower films. ISO100 colour print film is generally the best choice. Kodak, Fuji and Agfa all produce reliable film at this speed. Avoid budget film or 'own-brand' film, which is generally less satisfactory in image quality and less consistent in performance.

E5 Digital cameras will produce a lot of data when operating at the required resolution, so memory cards of at least 512MB and probably 1GB are likely to be required.

Figure E2: Setting up the tripod. The photographer's height tends to dictate the camra's height above ground level under most circumstances.

Figure E3:Camera on a panoramic tripod head. This particular design of head can accept the camera in either landscape or portrait mode. The camera is positioned so that the front nodal point of the lens (the camera's 'eye position') is directly above the axis of rotation of the panoramic head.

Figure E4: Placing a spirit level against the filter-ring of the camera lens allows the camera to be levelled accurately. This works both for landscape and portrait orientations of the camera.

Tripod

E6 A stable tripod is essential. As a minimum, a head with independent tilt adjustments for both pitch and roll should be used. (Ball-head tripods cannot be levelled satisfactorily.) Ideally a panoramic head should be used, allowing a single adjustment to be made for an entire panorama.

Levelling

E7 In order to obtain photographs which will splice together satisfactorily to make a panorama, it is essential that they be levelled accurately. A simple, cheap spirit level will do this quite satisfactorily and, with care, can produce images levelled to an accuracy of about 0.2°. A tripod head with a built-in sprit level and adjusting screws is better. Panorama heads always have spirit levels built in.

Focus

E8 The camera lens should always be focussed on infinity both for consistency and to ensure that the focal length and principal distance are equal.

E9 On auto-focus lenses, the focussing should be set to manual or locked on infinity.

Aperture and Exposure

E10 If at all possible, exposure should be metered once for a complete panorama and then used for all frames either by using a manual setting or by locking the exposure.

E11 For greatest depth of field in the images, aperture should be set to the minimum available on the lens (typically f/16 or f/22). If it is necessary to obtain slightly more resolution, it may help to use a slightly wider aperture: f/5.6 or f/8 are often the optimum settings.

E12 Shutter speed should be selected to obtain the correct exposure consistent with the aperture selected. If there are existing wind turbines in the view, the shutter speed will affect the degree of blurring seen in the photograph due to the movement of the blades.

Recording Photographic Details

E13 As a minimum, the following details should be recorded at each viewpoint used as a photo location:

- Position as an OS National Grid Reference. A hand-held GPS receiver is generally sufficient for this purpose. However, take note of the EPE (Estimated Position Error) figure, which is a measure of accuracy, when taking the reading. An EPE of 8m or more may indicate that there was a poor configuration of satellites, possibly because part of the sky is hidden by buildings or landform. If this happens, the EPE may improve by waiting a few minutes or alternatively it may be necessary to change the location. EGNOS and other supplementary technologies may usefully improve the accuracy of GPS.

- Camera lens focal length. This is obvious but important if more than one lens is being used. (On a digital camera, the EXIF data may record this for you.)

- Frame numbers. With film cameras, frame numbers are useful to identify which frames belong to which locations when the film comes back from processing and scanning.

- Camera altitude above OS datum. The GPS altitude should be noted as a check, but in general a more accurate altitude will be obtained by reference to the OS 1:10,000 or 1:25,000 map and estimating from the contours with reference to the features actually visible on site. This will also generally be more accurate than relying on a height interpolated from the DTM. The height of the camera above ground level should also be recorded, but will often be a constant determined by the photographer's height and the need to be able to see through the camera viewfinder.

- Approximate direction of the centre of the panorama as a bearing in degrees. Also, in some situations, particularly on flat or otherwise featureless terrain, it is useful to take accurate bearings to identifiable objects in the scene using a suitable sighting compass. It is sometimes worthwhile also noting the approximate angular separation of frames in a panorama, although it is often convenient to do this by eye, judging the overlap through the viewfinder, or to rely on the indexing on a panoramic tripod.

- Date and time of photography. In conjunction with the position, this will allow the direction of the light to be calculated for photomontage. Also, on a digital camera, there are no frame numbers to note down, so the date and time may well be invaluable in identifying which photographs belong to which locations by referring to the creation time of each image file. (Of course, this will only work if you have set the date and time correctly on the camera.)

- Wind direction is sometimes also useful if there are existing wind turbines in the photograph and it is desired to match their orientation in a photomontage.

E14 Note that other details to do with observation conditions should also be noted, as listed in Tables 8 and 12.

Technical Appendix F

Earth Curvature and Refraction of Light

F1 OS co-ordinates are not fully 3-dimensional. The northing and easting define a point on a plane corresponding to the OS transverse Mercator map projection and the altitude above OS datum is measured above an equipotential surface passing through the OS datum point at Newlyn. In reality, the earth is of course round, so a correction has to be made in order to position geographical features correctly in three dimensions for ZTV calculation and for visualisation.

F2 If it wasn't for the presence of the Earth's atmosphere, a simple allowance for curvature would be sufficient. The formula for this can be worked out quite easily from Pythagoras' theorem.

F3 Consider an observer at a point *A* looking towards point *B* at a distance *c*. The difference *h* between the vertical position of *B* measured along a true horizontal and along the surface of the earth is the height correction required. Points *A* and *B* and the centre of the earth (or radius *r*) form a right-angled triangle. Applying Pythagoras:

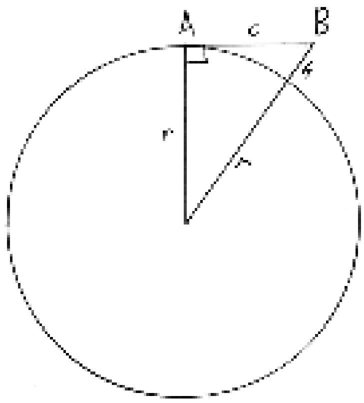


Figure F1: Calculating the height correction due to earth curvature

$$
\begin{aligned}
c^2 + r^2 &= (r+h)^2 \\
c^2 + r^2 &= r^2 + 2rh + h^2 \\
c^2 &= 2rh + h^2 \\
&= 2(r+h)h \\
c &= \sqrt{2(r+h)h}
\end{aligned}
$$

h is very small in comparison with *r*, so the formula can be approximated with:

$$c = \sqrt{2rh}$$

Rearranging for *h*, we get:

$$\sqrt{2rh} = c$$
$$2rh = c^2$$
$$h = \frac{c^2}{2r}$$

r, c and *h* must all be in the same units, either metres or kilometres.

F4 Note that although the local vertical at ***B*** is very different from the local vertical at ***A*** in the diagram, in reality these points are very close together compared to the size of the earth and assuming that the height ***h*** correction is vertical does not introduce significant errors. (The horizontal correction increases with the square of distance, as in the same way that the vertical correction does, but at 45km from the viewpoint, it is still only about 1m.).

F5 In practice, rays of light representing sightlines over long distances are also curved downwards as a result of refraction of light through the atmosphere, allowing one to see slightly beyond the expected horizon. (The atmosphere reduces the vertical correction due to curvature alone by about 15%.) The standard formula used in surveying work is modified from the one derived above as follows:

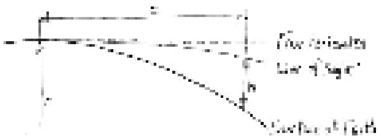


Figure F2: Calculating the height correction due to earth curvature and refraction through the atmosphere

$$h = \frac{c^2(1-2k)}{2r}$$

Where:

h is the height correction in metres
c is the distance to the object in metres
k is the refraction coefficient
r is the radius of the Earth in metres

F6 The parameter ***k*** is not constant but varies with temperature and barometric pressure (and therefore also with altitude). For precise geodetic surveying work both these quantities would have to be measured at both ends of a line of sight. Visualisation and visibility analysis do not require such precision, therefore a representative value may be used. 0.075 is a reasonable average for inland upland observations, but very slightly different values may be found quoted in surveying or navigation textbooks. (***k*** is a numerical coefficient and therefore has no units.)

F7 Taking $\boldsymbol{k}$ = 0.075 and $\boldsymbol{r}$ = 6,367,000m, the following example values are obtained:

Table 19: Height corrections for earth curvature and refraction

Distance c	Vertical correction for Earth curvature and atmospheric refraction h
5 km	1.7m
10 km	6.7m
15 km	15.0m
20 km	26.7m
25 km	41.7m
30 km	60.1m
35 km	81.8 m
40 km	106.8 m
45 km	135.2 m
50 km	166.9 m
55 km	201.9 m
60 km	240.3 m