Indicative Atlas of Radon in England and Wales

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ABSTRACT

This report presents an overview of the results of detailed mapping in England and Wales of radon potential, defined as the estimated percentage of homes in an area above the radon Action Level. The work was carried out jointly by the Health Protection Agency and the British Geological Survey and was based on the results of measurements of radon in 460,000 homes. The method allows variations in radon potential both between and within geological units to be mapped. The resulting map, which defines radon Affected Areas in England and Wales, includes much more detail than could be shown in an atlas. The full detail is instead published as a dataset which can be licensed for use in geographical information systems. The estimated radon potential for an individual home can be obtained through a website, www.UKradon.org. The atlas presents a simplified version of the map, so is indicative rather than definitive: that is, each 1-km grid square is coloured according to the highest radon potential found within it.

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This report reflects understanding and evaluation of the current scientific evidence as presented and referenced in this document.

EXECUTIVE SUMMARY

Radon has been recognised as a cause of lung cancer in humans for many years. Because of the risk from radon, the Health Protection Agency (HPA) and its radiation protection predecessor, the National Radiological Protection Board (NRPB), have advised that excessive exposures to radon should be reduced. It proposed a comprehensive control strategy based on the concept of a radon Action Level and the identification of radon Affected Areas. The Government accepted this advice.

To allow the UK radon programme to be implemented, it is essential to identify the areas most affected by radon problems. This report presents an overview of the results of detailed mapping in England and Wales of radon potential, defined as the estimated percentage of homes in an area above the radon Action Level. The radon potential therefore corresponds to the probability that a home that has not had a radon measurement will have a long-term average radon concentration above the radon Action Level. This work was carried out jointly by the Health Protection Agency and the British Geological Survey.

The new joint mapping method is based on the results of measurements of radon in 460,000 homes. The radon results are grouped first by geological boundaries and then by 1-km grid squares. The method allows variations in radon potential both between and within geological units to be mapped.

The resulting map, which defines radon Affected Areas in England and Wales, includes much more detail than could be shown in an atlas. The full detail is instead published as a dataset which can be licensed for use in geographical information systems. The estimated radon potential for an individual home can be obtained through a website, www.UKradon.org. The atlas presented here is a simplified version of the map, so is indicative rather than definitive: that is, each 1-km grid square is coloured according to the highest radon potential found within it.

The new atlas will assist in implementing the HPA radon policies that existing homes in Affected Areas should have radon measurements, radon concentrations at or above the Action Level of 200 Bq m^{-3} should be reduced to as low as reasonably practicable, and new homes built within localities delimited by the appropriate Government authorities should be constructed with precautions against radon.

CONTENTS

1 INTRODUCTION

Radon has been recognised as a cause of lung cancer in humans for many years. Recently a study pooling the results of 13 European case–control epidemiological studies of people exposed to radon at home (Darby et al, 2005) has confirmed the risk and refined the accuracy of the risk estimate. It also showed that the risk from radon is considerably higher for cigarette smokers than for non-smokers.

Because of the risk from radon, the Health Protection Agency (HPA) and its radiation protection predecessor, the National Radiological Protection Board (NRPB), have advised that excessive exposures to radon should be reduced. In 1990, the NRPB recommended to Government that the Action Level for radon in homes should be 200 Bq m^{-3} averaged over a year, ten times the average UK concentration. It proposed a comprehensive control strategy based on the concept of a radon Action Level and the identification of radon Affected Areas (NRPB, 1990). Radon Affected Areas were defined as those with 1% or more of homes above the radon Action Level. The Government accepted this advice (DOE, 1990).

Since 1990, programmes to identify and remediate homes with high radon concentrations and to prevent high concentrations occurring in new homes have been pursued (Kendall et al, 2005). The Building Research Establishment (BRE) has developed effective methods of reducing high radon concentrations in existing homes (BRE, 1993–2001), and preventing them in new homes (BRE, 1999, 2007).

To allow the UK radon programme to be implemented, it is essential to identify the areas most affected by radon problems. The NRPB has published maps showing the estimated radon potential, or proportion of homes above the Action Level, by grid square in different parts of the UK (NRPB, 1993; Green et al, 1999, 2002). The British Geological Survey (BGS) has also mapped radon potential using the same indoor radon data, but analysed by grouping the results by geological unit (Miles and Appleton, 2000).

Indoor radon concentrations depend on a number of factors, including the geological characteristics of the ground underneath buildings, details of construction, and the habits of the occupants. Maps of radon potential take account of the first of these factors, but other factors result in there being a very wide variation of indoor radon concentrations found in dwellings built on ground with the same radon potential.

The previous maps published separately by the NRPB and BGS grouped domestic radon results either by grid square or by geological unit, before applying lognormal modelling (Miles, 1998). Both of these mapping methods ignore some part of the geographical variation in radon potential: grid square mapping ignores variation between geological units within grid squares, and geological mapping ignores variation within areas sharing combinations of geological characteristics. It was realised by the HPA and BGS that combining the two methods could give more accurate mapping than either separately. The two organisations cooperated to develop a joint geological/grid square mapping method. This atlas is the outcome of applying this method to radon mapping in England and Wales, and supersedes the previous atlas of radon potential in England and Wales (Green et al, 2002). The data on which the mapping is based, summarised by administrative area and by divisions of the postcode system, are given elsewhere (Bradley et al, to be published; Green et al, to be published).

2 MEASUREMENTS

The domestic radon results used in mapping are collated from the many different radon survey programmes carried out by the NRPB and HPA. These surveys were seldom representative of the housing stock of large areas or regions. Indeed, many were intentionally targeted to areas where higher levels were expected. The initial national survey (Wrixon et al, 1988) was the only one in which care was taken to obtain a population-weighted sample of homes throughout the UK. The results of this survey continue to provide the best estimates of the average exposure at both national and county level.

Measurements in all surveys are made with two passive integrating detectors in each dwelling – one in the main living area and one in a regularly used bedroom (Hardcastle et al, 1996). The detectors were placed for three months and the results combined to reflect typical occupancy patterns. Since indoor radon levels are usually higher in cold weather, the results reported to householders are normalised for typical seasonal variations in radon levels to allow the estimated annual radon concentration to be reported (Wrixon et al, 1988; Pinel et al, 1995). It has been shown (Miles, 1998) that the seasonal variations correspond to average outdoor temperature variations. To allow for the fact that weather patterns vary from year to year, the annual average radon concentrations in dwellings used in the mapping reported here were calculated using temperature corrections based on temperature at the time of measurement, rather than seasonal corrections.

3 RADON MAPS

The integrated geological/grid square method used here for mapping radon potential is described in detail by Miles and Appleton (2005). In the integrated method, each combination of geological characteristics (bedrock, superficial and others) is taken in turn, and the spatial variation of radon potential within the combination is mapped, treating it as if the combination was continuous over the land area.

3.1 Location of each home

In order to determine which geological unit a dwelling lies on, it is necessary to know its location as accurately as possible. Ordnance Survey ADDRESS-POINT® locates dwellings on the national grid to an accuracy of 0.1 metre if the full address is known and it corresponds with an address in the ADDRESS-POINT® database. It was possible to obtain ADDRESS-POINT® coordinates for 81% of the dwellings in England and Wales with radon measurement results. For the other 19%, coordinates were obtained from Ordnance Survey Code-Point®, which allocates coordinates according to the postcode of a dwelling. In the UK each postcode covers 15 dwellings on average, but in densely populated areas the number is higher and in sparsely populated areas it is lower. In most cases the grid reference allocated to a dwelling using Code-Point® will be accurate to within a few hundred metres, but in sparsely populated areas the error may be greater.

3.2 Attribution of geological codes to measurement locations

Bedrock and superficial geological codes were attributed to the location of each dwelling using the BGS 1:50,000 scale DiGMapGB digital data. Each different combination of geological characteristics may appear at the land surface in many discontinuous locations across the country. Geological mapping of the UK has been carried out over many years during which time there have been changes in the nomenclature of mapped rock units. Consequently, the names of geological units sometimes change at map sheet boundaries. In order to facilitate the seamless 1-km interpolation of radon potential within major geological units, simplified bedrock and superficial geology classification systems were developed. These ensure continuity across map sheet boundaries and also group some geological units with similar characteristics. Grouping similar geological units ensured that there were sufficient indoor radon measurements for intra-geological unit grid square mapping to be carried out over a greater proportion of England and Wales. There are nearly 4500 named bedrock geological units in England and Wales and these were grouped using a simplified bedrock classification comprising 406 units (Appleton, 2005). The 892 individually named 1:50,000 scale superficial geological units were grouped into ten types according to a simplified system based on permeability and generic type.

3.3 Estimation of radon potential

Within each geological combination with more than 100 radon measurements, the variation of indoor radon concentrations was mapped using 1-km squares of the national grid. A radon potential was allocated to each 1-km grid square on the basis of the nearest 30 domestic radon measurement results to that square, or all of the results in the square if there were 30 or more. The geometric mean (GM) and geometric standard deviation (GSD) of the results allocated to each square were calculated, and a lognormal model was used to estimate the proportion of the distribution above the Action Level. This parameter, equivalent to the radon potential, is the parameter shown in the maps.

In order to improve the accuracy of the estimates of the radon potential, certain corrections were applied. It has been shown (Darby, 2003) that the measured GSD for any group of domestic radon measurement results, each made over three months, is higher than the GSD that would have been observed if the measurements had been made over several years in each dwelling. The difference is caused by uncertainties in estimates of long-term average radon concentrations, both from extrapolating from three months to a year, and from year-to-year variations in radon levels. It is possible to correct measured GSDs for this effect, using data from studies of the year-to-year variation in three-month domestic radon measurement results. Such corrections always reduce GSDs, and therefore always reduce percentages above a threshold, if the GM of the area is below the threshold. This correction was applied in the mapping exercise reported here. Earlier mapping exercises, in the UK and elsewhere, did not take account of this factor.

There is also some random variation in the calculated values of the GSD. It has been shown (Miles and Appleton, 2000) that the use of Bayesian estimates of the GSD gives less uncertain estimates of the proportion of homes above the Action Level, and does not bias the estimates in any way. The reduction of the uncertainty by the use of Bayesian statistics was significant but not very large. This correction was also applied in the mapping exercise reported here.

The resulting map is highly detailed, with an implied accuracy of less than 1 metre. In fact there is some uncertainty in the location of the boundaries on geological maps and in the location of dwellings. To reduce the possibility of advising householders that the risk of radon problems was small, when in fact it could be significant, a buffer was applied around each area. This buffer was applied in sequence from the highest to the lowest radon areas. The uncertainty in geological boundaries was assigned a value of 50 metres, and the uncertainty in building location was assigned a value of 25 metres, giving a combined buffer width of 75 metres. Because of the difficulty of processing the highly detailed data, it was necessary to simplify the map, converting it to 25-metre squares of the national grid, each attributed a uniform value of the highest radon potential within it.

3.4 Presentation of results

The resulting map includes much more detail than could be shown in an atlas. The full detail is instead published as a dataset which can be licensed for use in geographical information systems, on application to the BGS (see www.bgs.ac.uk/about/copyright/digital.html). The estimated radon potential for an individual home can be obtained through a website, www.UKradon.org. The atlas presented here is based on data that are further processed, to group the data by 1-km grid square. As a result, the atlas is indicative rather than definitive: that is, each 1-km grid square is coloured according to the highest radon potential found within it (see Figure 1). However, grid squares marked as 0–1% above the radon Action Level contain no radon Affected Areas as defined by the HPA, so in these cases the atlas is definitive.

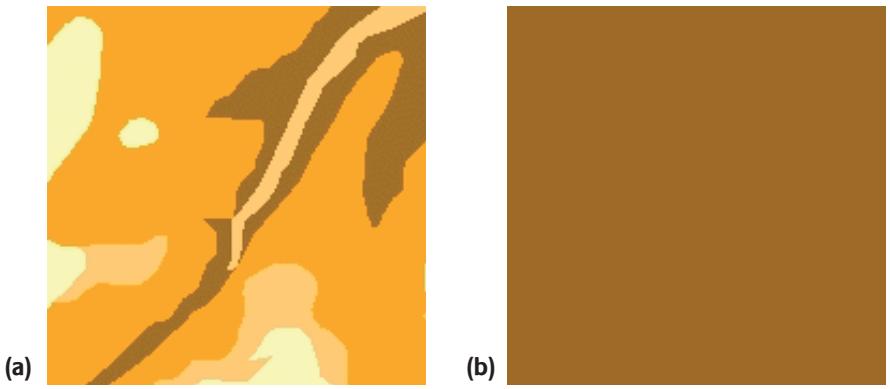

FIGURE 1 Derivation of indicative map from detailed map

If a 1-km grid square on the definitive radon map contains more than one percentage band (a), it is shown on the indicative map presented in this atlas entirely coloured as the highest percentage band within the square (b)

The map plates show the major road network as well as larger settlements chosen to give a reasonable geographical spread across the maps regardless of population density. Superimposed on the maps are the administrative boundaries at district council and unitary authority level. Council names are given wherever possible subject to the limitations of space, especially in urban areas. Electronic versions of this atlas are available with and without place names on the HPA website, www.hpa.org.uk. The latter version may be helpful to clarify the result where it is obscured by a place

name. The provision of the 100-km grid letters in the map title and the national grid coordinates on the X and Y axes allow easy cross-reference to other maps.

An overall map of England and Wales (Figure 2) precedes a map giving the key to the following 20 maps, each covering about 16,000 km^2 (Figure 3). The majority of these maps are centred on one 100-km grid square of the national grid; the exceptions are to accommodate the variations in the coast line.

4 CONCLUSIONS AND RECOMMENDATIONS

This atlas provides an overview of radon levels in dwellings throughout England and Wales. It updates previous reports and complements the formal advice of the HPA on the need to reduce long-term exposure to elevated radon levels. It will be of use and interest to individuals and organisations with a duty to reduce the radon exposure of the population, both in the home and in the workplace. It is expected that further updates, incorporating the latest available data, will be published at intervals.

The comprehensive control strategy, recommended by the NRPB and accepted by the Government (DOE, 1990; NRPB, 1990), includes recommendations which are still extant and relevant to the current document.

a Existing homes in Affected Areas should have radon measurements.

b Radon concentrations at or above the Action Level of 200 Bq m^{-3} should be reduced to as low as reasonably practicable.

c New homes built within localities delimited by the appropriate Government authorities should be constructed with precautions against radon.

Although the radon data used in the production of this alas come from measurements in homes, the maps indicate the likely extent of the local radon hazard in all buildings. The information in this atlas is therefore relevant to employers in assessing workplace risks. Under the Health and Safety at Work etc Act (Health and Safety Executive, HSE, 1974), employers must, so far as is reasonably practicable, ensure the health and safety of employees and others who have access to their work environments. The Management of Health and Safety at Work Regulations (HSE, 1999) require the assessment of health and safety risks, and guidance on how to apply the maps contained in this atlas in assessing workplace radon is available from the HSE website, www.hse.gov.uk.

In general, for underground workplaces in all parts of the UK this risk assessment will almost certainly require radon measurements to be carried out. For ground floor workplaces, measurements should be carried in all premises located in a radon Affected Area. Employers may therefore choose to consult the definitive dataset to determine this or take a conservative approach and undertake measurements in all premises located in a 1-km grid square that is shaded in this atlas.

The HSE and local authorities are responsible for enforcing the regulations in various workplaces.

5 ACKNOWLEDGEMENTS

The data used to construct the maps have been collated from many different radon surveys carried out by the NRPB and HPA. Many of the measurements were funded by central government (the Department of Health, the Department for Environment, Food and Rural Affairs and the National Assembly for Wales, and their predecessors), by local government at county and district level, by landlords and by individual householders.

6 GLOSSARY

Becquerel (symbol Bq) The unit of the amount or activity of a radionuclide. Describes the rate which transformations occur. 1 Bq = 1 transformation per second.

Becquerel per cubic metre of air (symbol Bq m^{-3}) The amount of a radionuclide in each cubic metre of air. Often referred to as the activity concentration.

Radon Action Level The recommended limit for the activity concentration of radon in UK homes. Its value, expressed as the annual average radon gas concentration in the home, is 200 Bq m^{-3}.

Radon Affected Areas Parts of the country with a 1% probability or more of present or future homes being above the Action Level.

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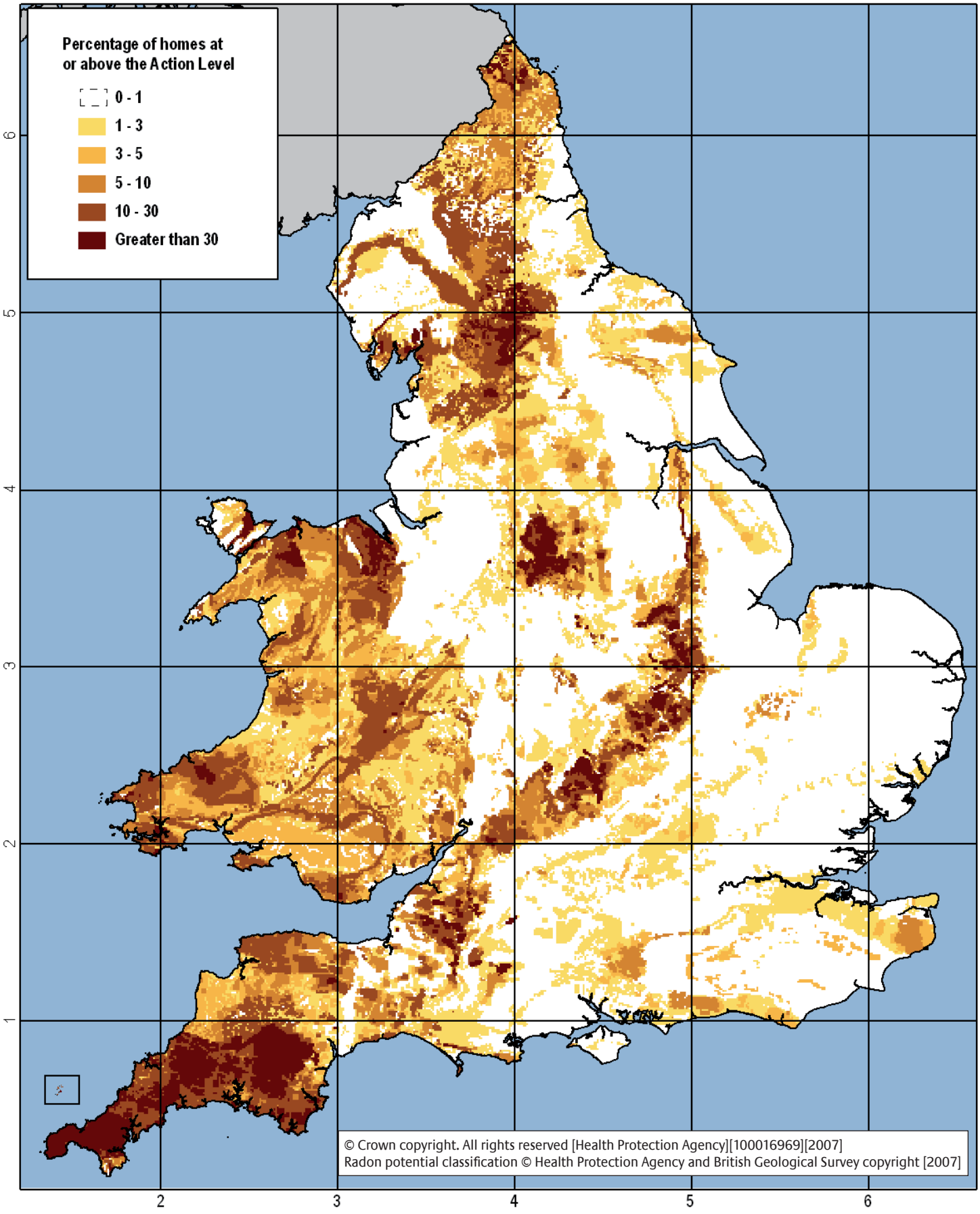


FIGURE 2 Overall map of radon Affected Areas in England and Wales (axis numbers are the 100-km coordinates of the national grid)

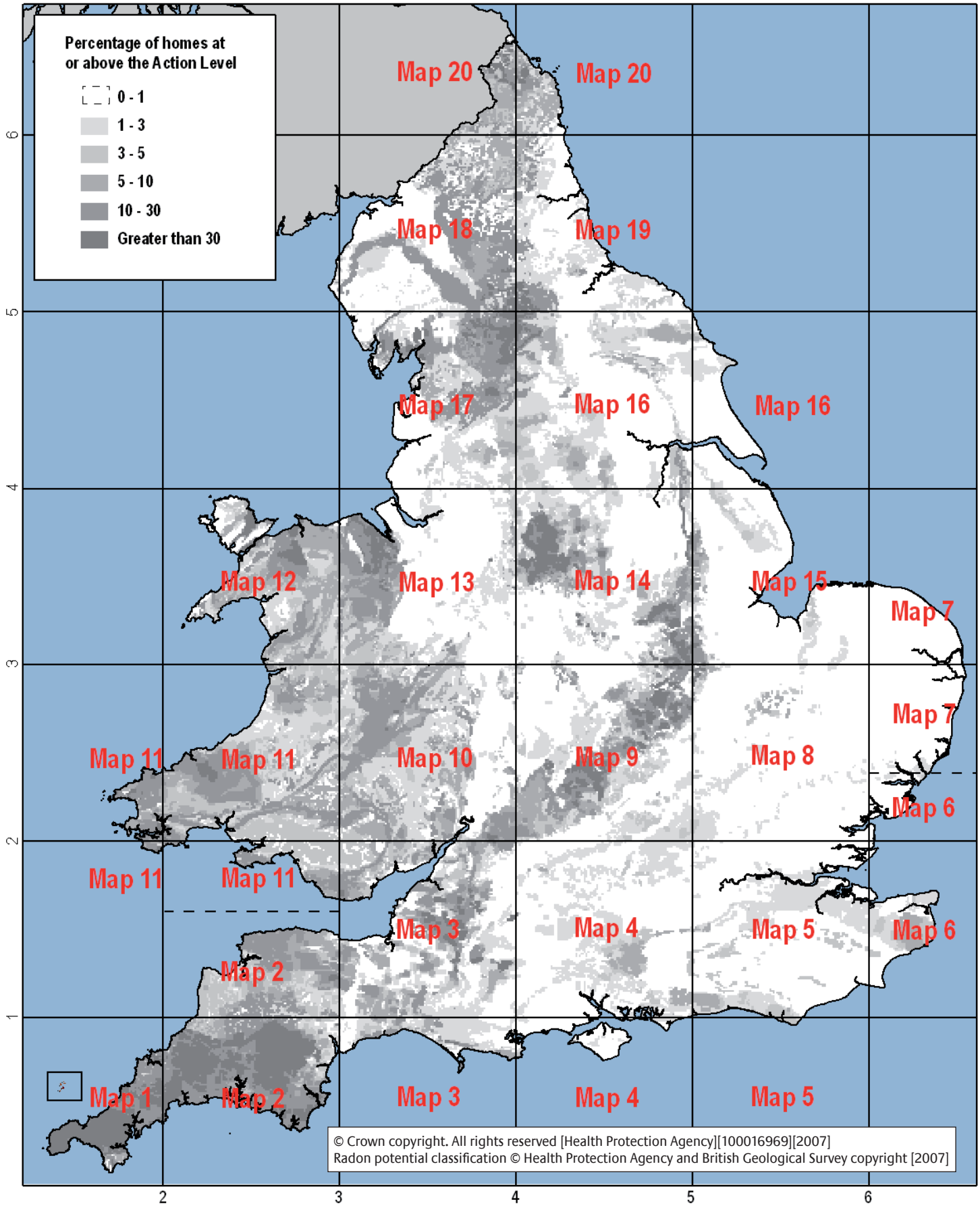
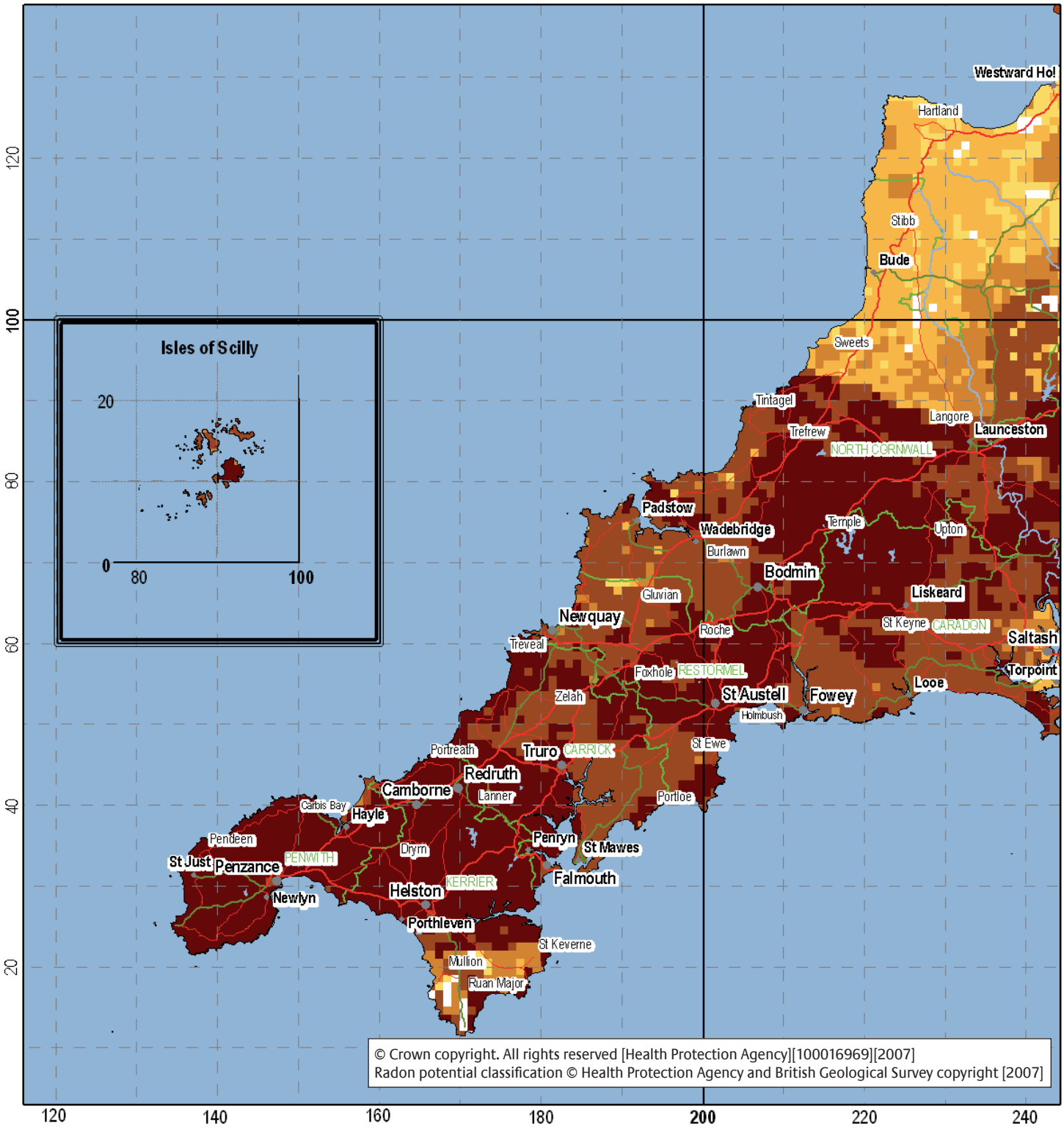


FIGURE 3 Key to larger scale maps (axis numbers are the 100-km coordinates of the national grid)



The colours show the maximum percentage band within each 1-km grid square of the national grid (see page 4). The best estimate for an individual property in a coloured square can be obtained for a small charge from www.ukradon.org. The white squares, the 0-1% band, contain no Affected Areas as defined by the HPA.

Percentage of homes at or above the Action Level

- 0 - 1
- 1 - 3
- 3 - 5
- 5 - 10
- 10 - 30
- Greater than 30

Settlements

- Helston
- Padstow
- Portloe
- Carbis Bay

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

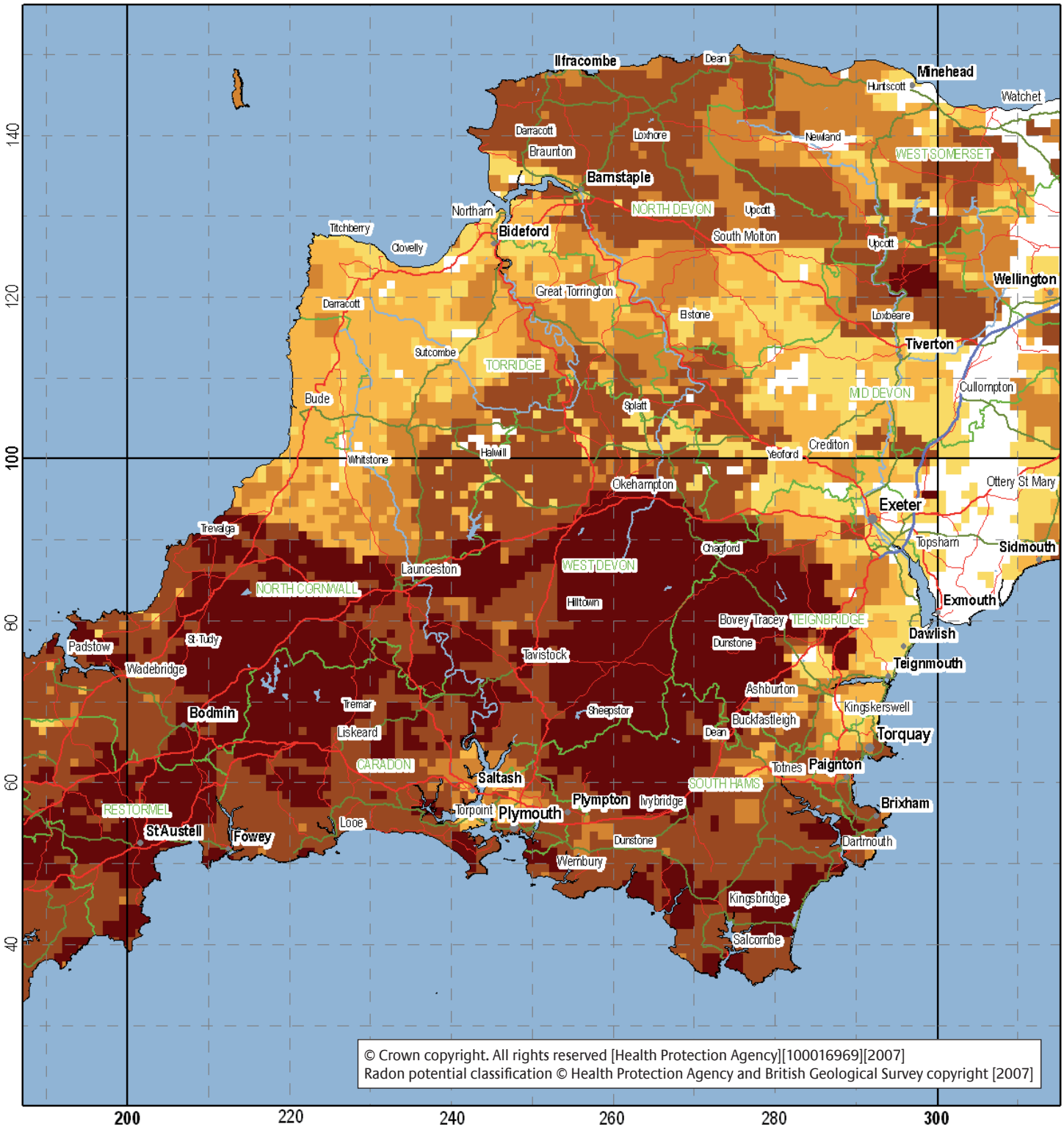
National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

MAP 1 West Cornwall, 100-km grid square SW (axis numbers are the coordinates of the national grid)



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Percentage of homes at or above the Action Level

- 0 - 1
- 1 - 3
- 3 - 5
- 5 - 10
- 10 - 30
- Greater than 30

Settlements

- Torquay
- Bodmin
- Bude
- Huntscott

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

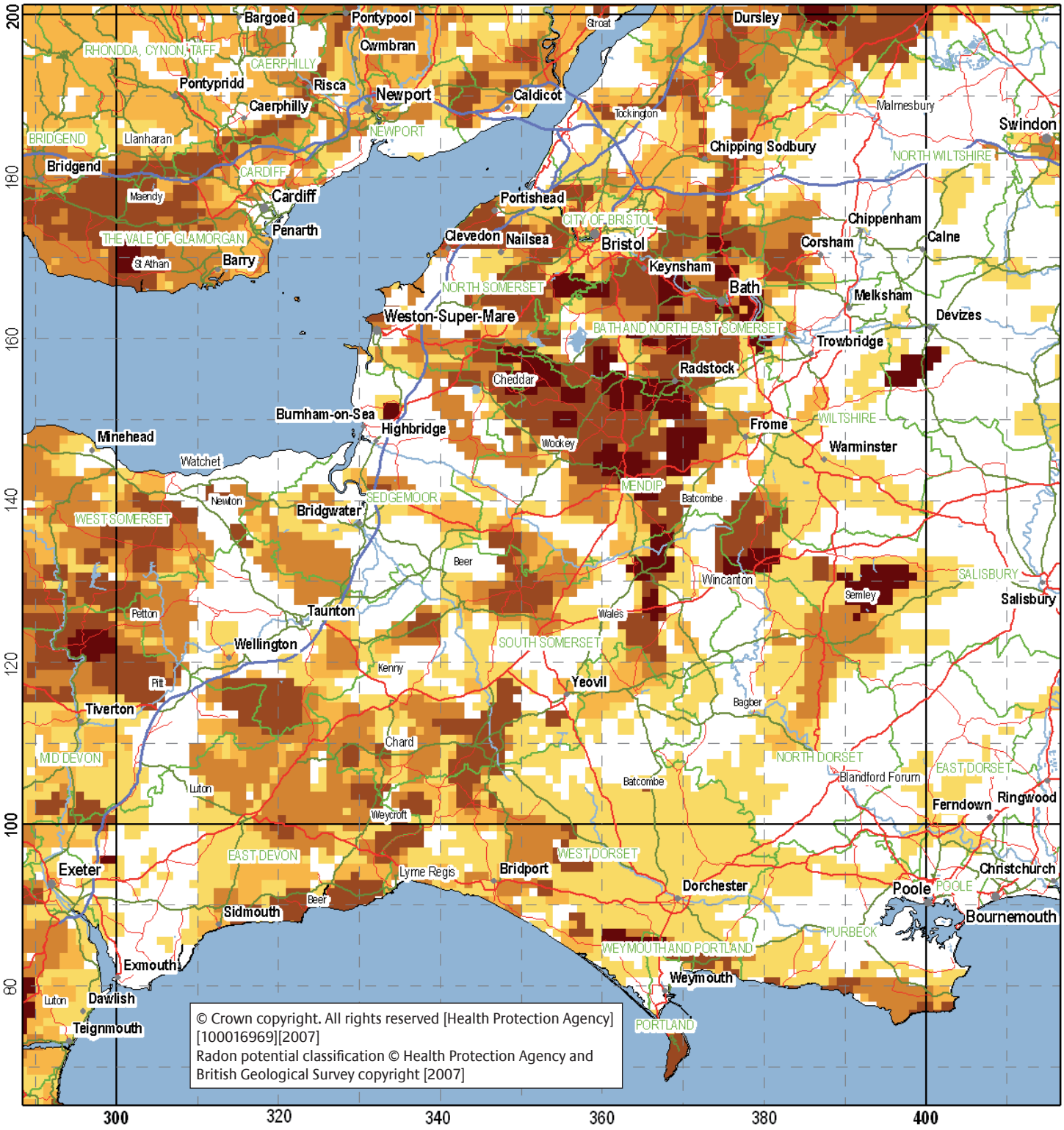
National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

MAP 2 East Cornwall and west Devon, 100-km grid squares SS and SX (axis numbers are the coordinates of the national grid)



The colours show the maximum percentage band within each 1-km grid square of the national grid (see page 4). The best estimate for an individual property in a coloured square can be obtained for a small charge from www.ukradon.org. The white squares, the 0-1% band, contain no Affected Areas as defined by the HPA.

Percentage of homes at or above the Action Level

- 0 - 1
- 1 - 3
- 3 - 5
- 5 - 10
- 10 - 30
- Greater than 30

Settlements

- Bath
- Weymouth
- Watchet
- Semley

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

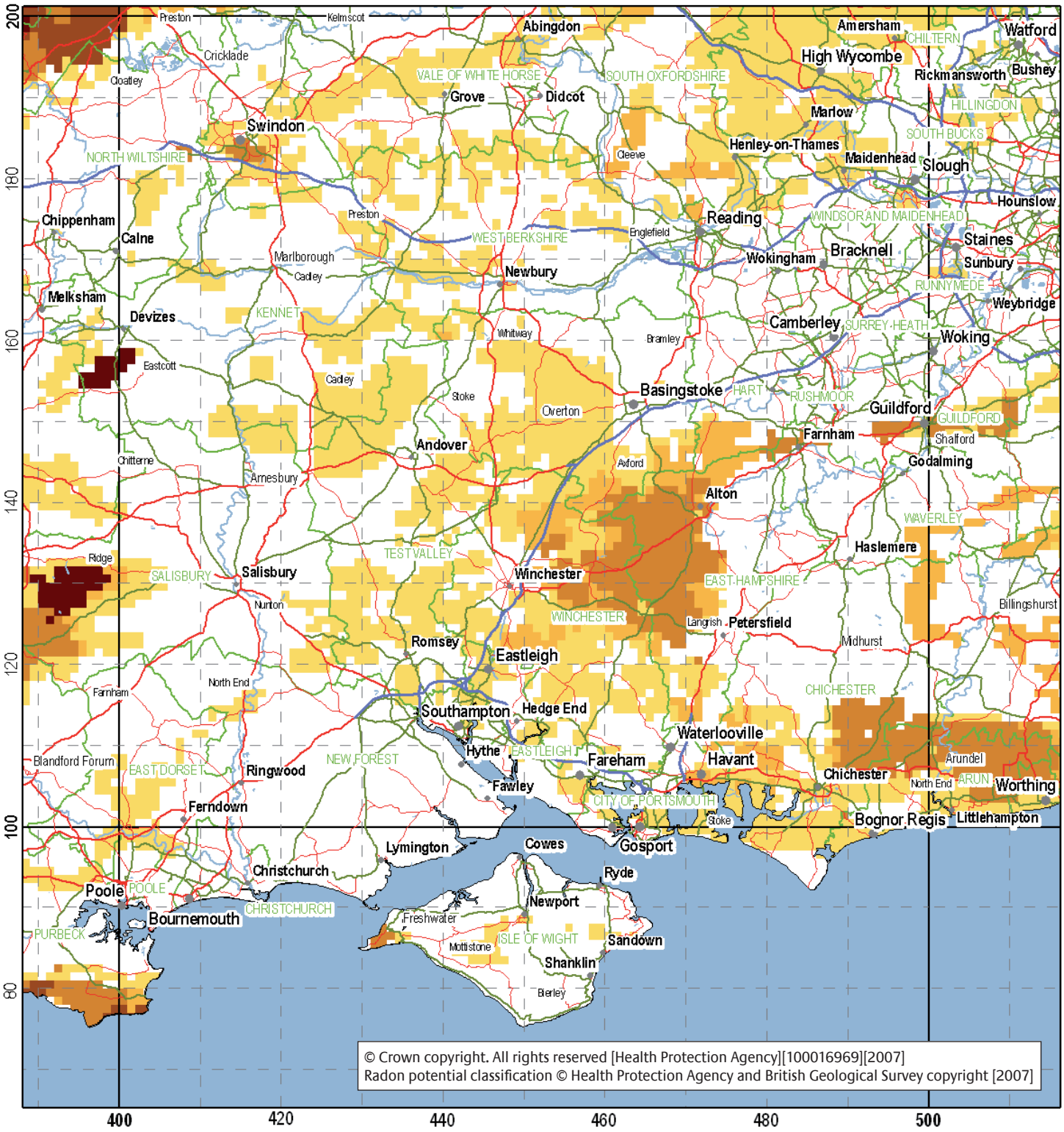
National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

MAP 3 Dorset, Somerset, Wiltshire and the Bristol Channel, 100-km grid squares ST and SY (axis numbers are the coordinates of the national grid)



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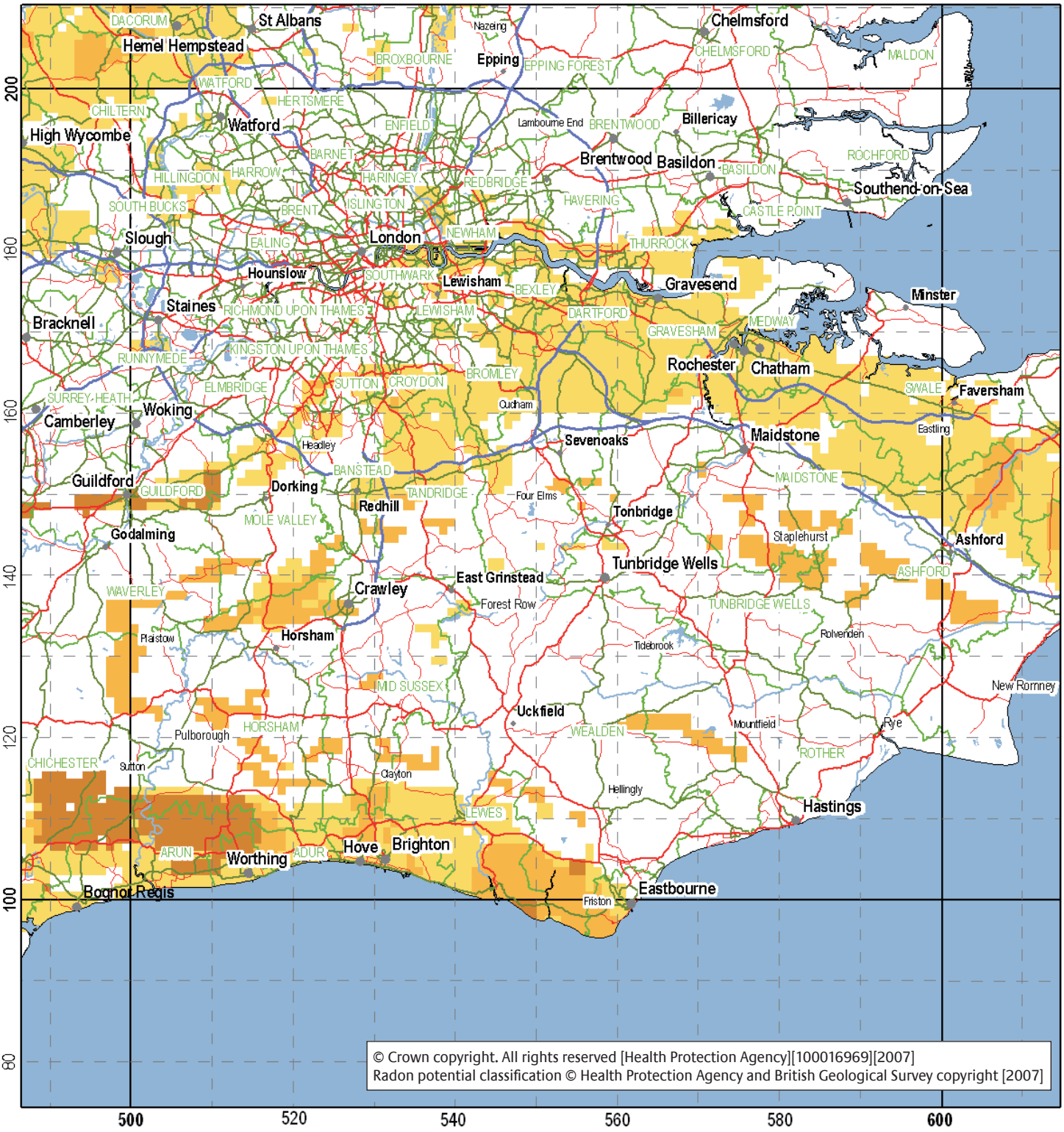
MAP 4 Hampshire, Berkshire and south Oxfordshire, 100-km grid squares SU and SZ (axis numbers are the coordinates of the national grid)



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Percentage of homes at or above the Action Level

- 0 - 1
- 1 - 3
- 3 - 5
- 5 - 10
- 10 - 30
- Greater than 30

Settlements

- London
- Horsham
- Rye
- Sutton

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

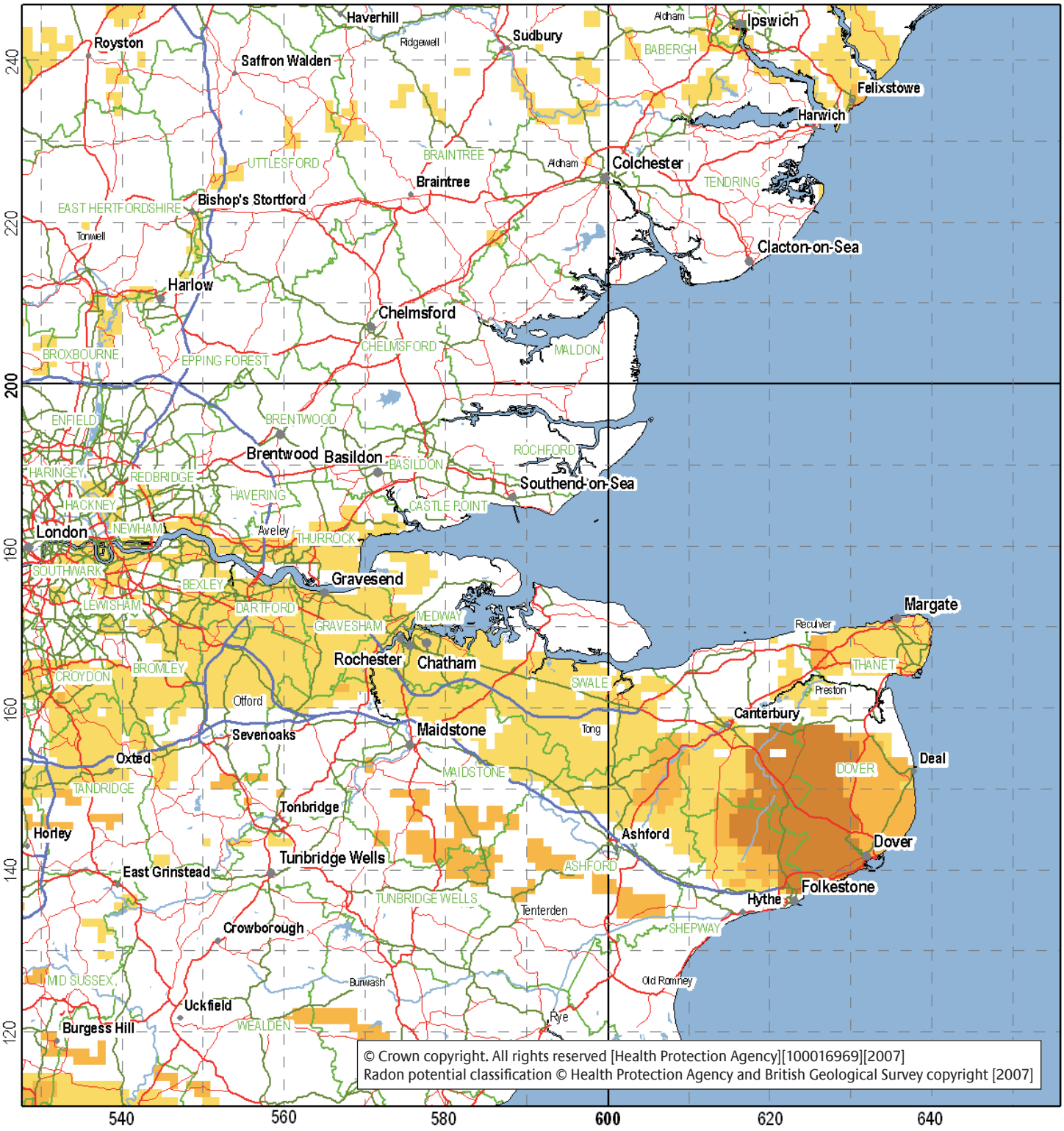
National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

MAP 5 London, Sussex and west Kent, 100-km grid squares TQ and TV (axis numbers are the coordinates of the national grid)



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Percentage of homes at or above the Action Level

- 0 - 1
- 1 - 3
- 3 - 5
- 5 - 10
- 10 - 30
- Greater than 30

Settlements

- Chelmsford
- Hythe
- Aveley
- Aldham

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

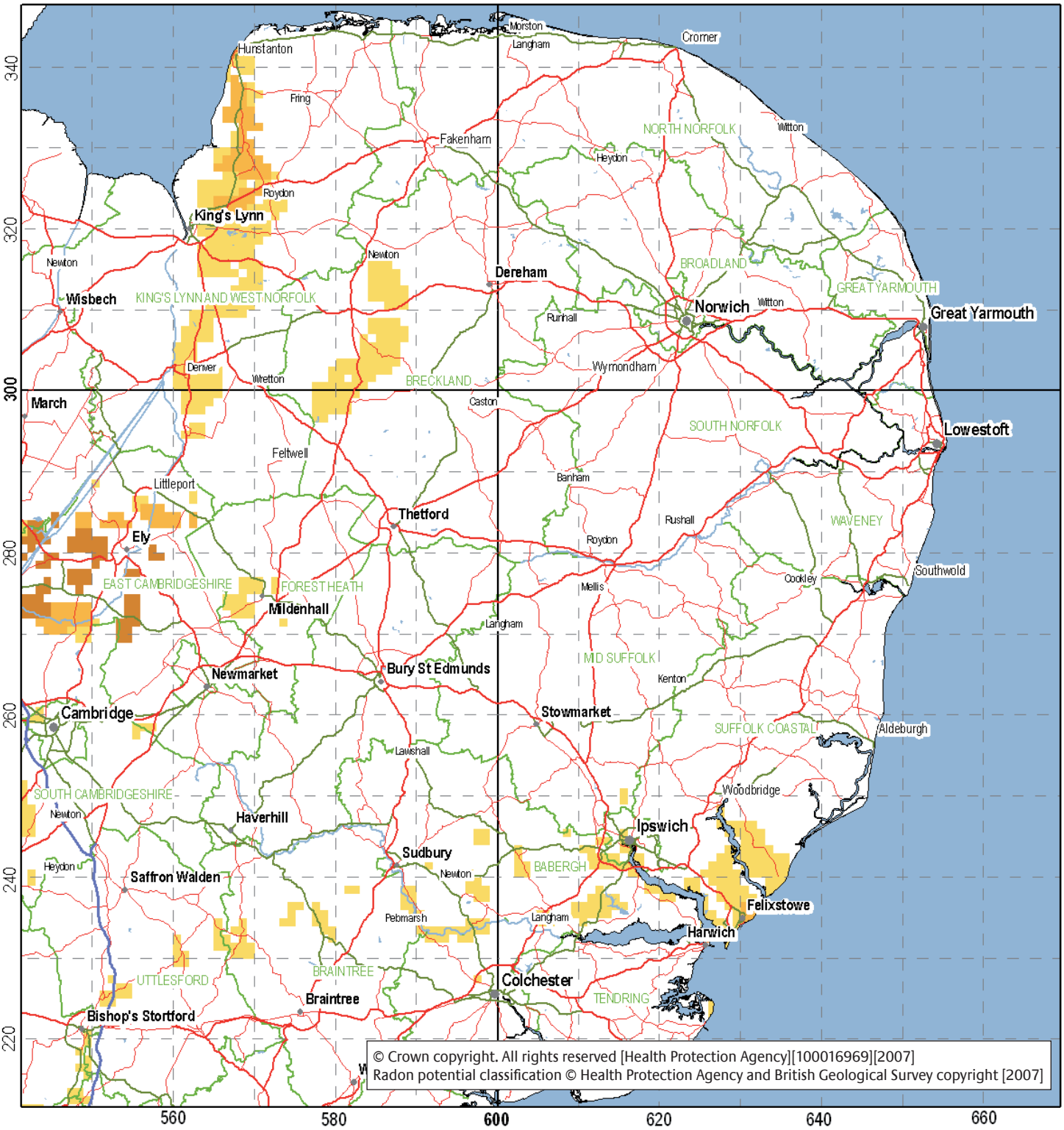
National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

MAP 6 Essex, Thames estuary and east Kent, 100-km grid squares TM and TR (axis numbers are the coordinates of the national grid)



The colours show the maximum percentage band within each 1-km grid square of the national grid (see page 4). The best estimate for an individual property in a coloured square can be obtained for a small charge from www.ukradon.org. The white squares, the 0-1% band, contain no Affected Areas as defined by the HPA.

Percentage of homes at or above the Action Level

- 0 - 1
- 1 - 3
- 3 - 5
- 5 - 10
- 10 - 30
- Greater than 30

Settlements

- Norwich
- Harwich
- Cromer
- Pebmarsh

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

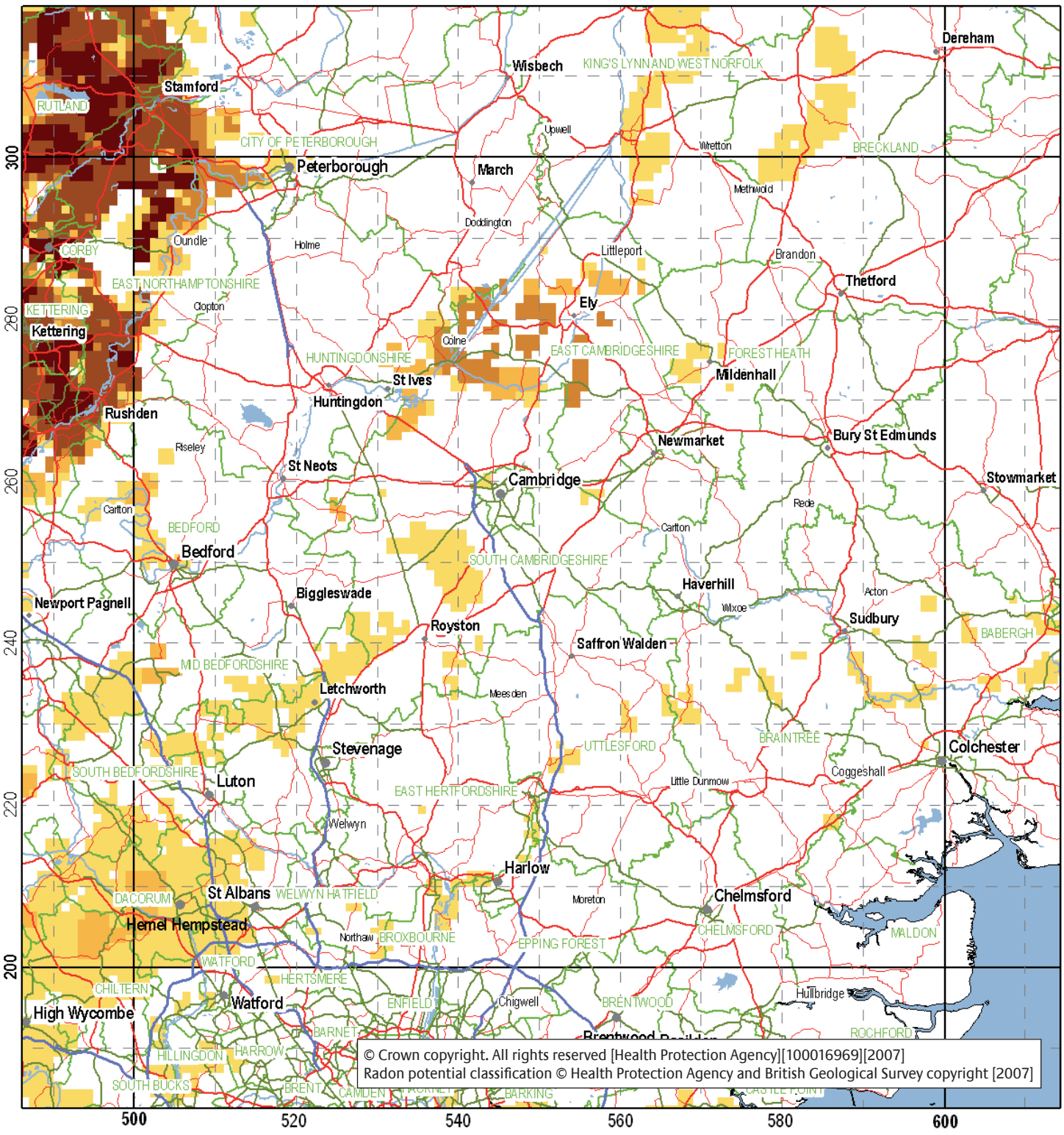
National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

MAP 7 Suffolk and Norfolk, 100-km grid squares TG and TM (axis numbers are the coordinates of the national grid)



The colours show the maximum percentage band within each 1-km grid square of the national grid (see page 4). The best estimate for an individual property in a coloured square can be obtained for a small charge from www.ukradon.org. The white squares, the 0-1% band, contain no Affected Areas as defined by the HPA.

Percentage of homes at or above the Action Level

- 0 - 1
- 1 - 3
- 3 - 5
- 5 - 10
- 10 - 30
- Greater than 30

Settlements

- St Albans
- Sudbury
- Brandon
- Holme

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

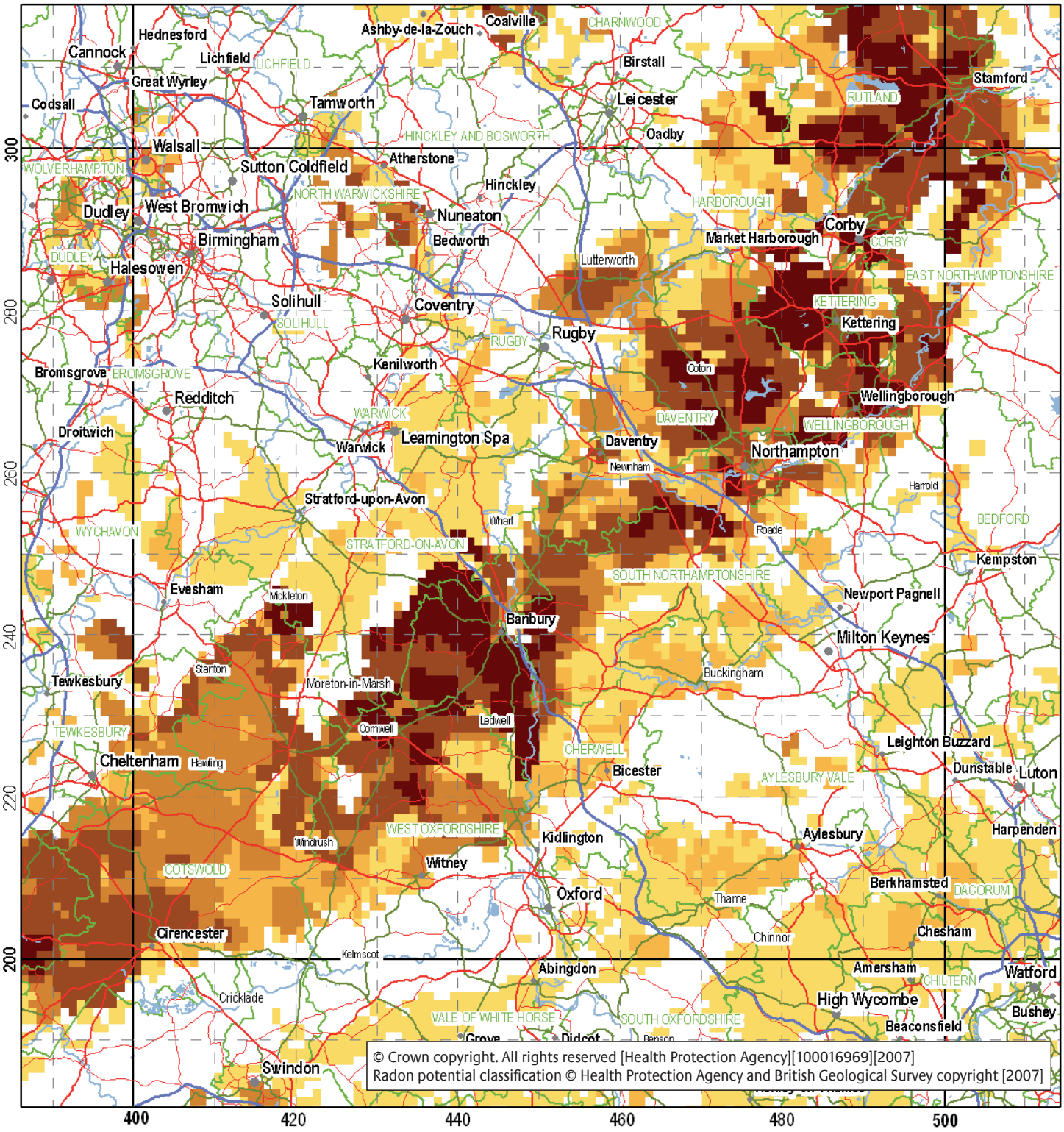
National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

MAP 8 Cambridgeshire and Hertfordshire, 100-km grid square TL (axis numbers are the coordinates of the national grid)



The colours show the maximum percentage band within each 1-km grid square of the national grid (see page 4). The best estimate for an individual property in a coloured square can be obtained for a small charge from www.ukradon.org. The white squares, the 0-1% band, contain no Affected Areas as defined by the HPA.

Percentage of homes at or above the Action Level

- 0 - 1
- 1 - 3
- 3 - 5
- 5 - 10
- 10 - 30
- Greater than 30

Settlements

- Solihull
- Aylesbury
- Lutterworth
- Stanton

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

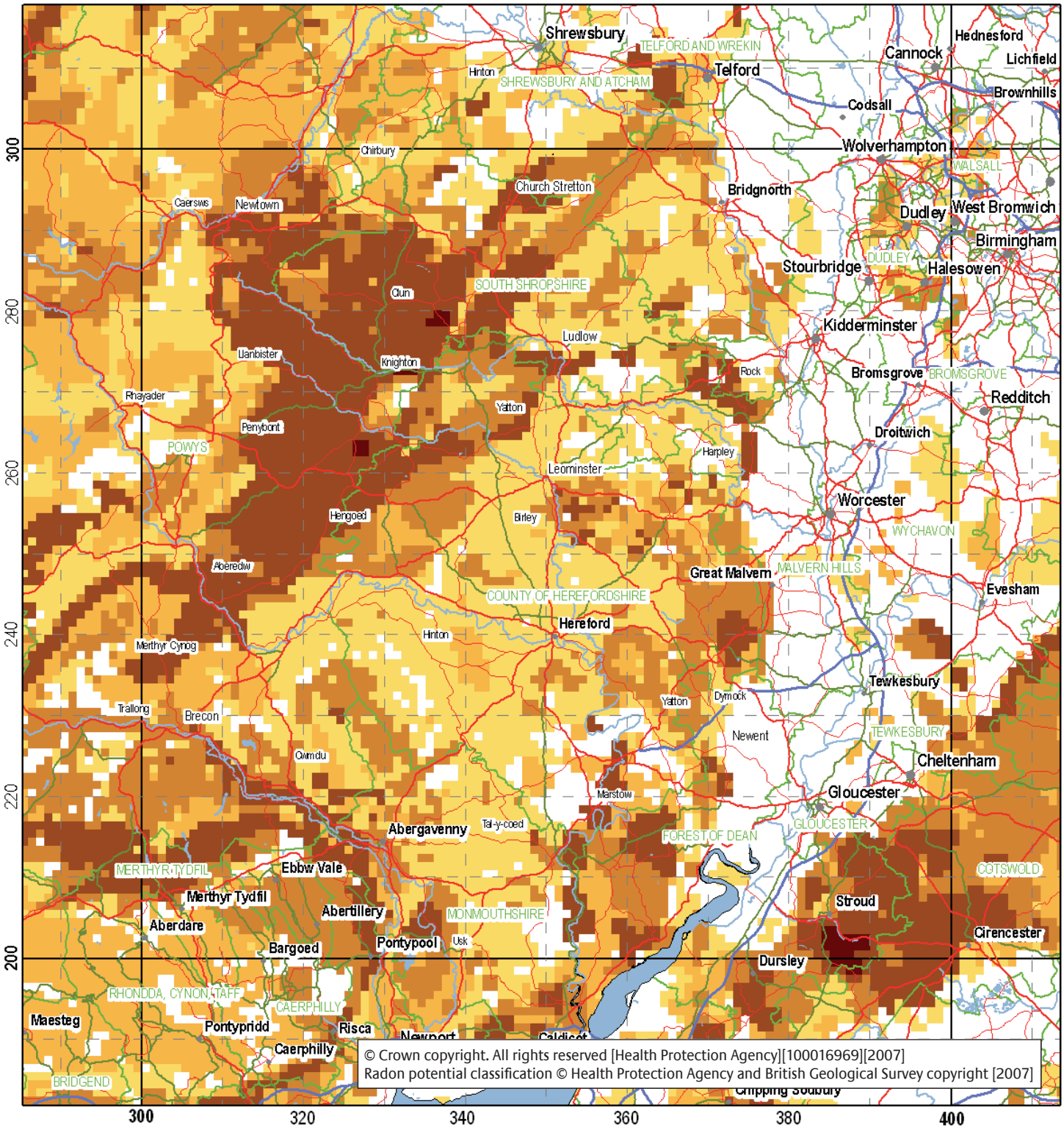
National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

MAP 9 Oxfordshire, Northamptonshire and Warwickshire, 100-km grid square SP (axis numbers are the coordinates of the national grid)



The colours show the maximum percentage band within each 1-km grid square of the national grid (see page 4). The best estimate for an individual property in a coloured square can be obtained for a small charge from www.ukradon.org. The white squares, the 0-1% band, contain no Affected Areas as defined by the HPA

Percentage of homes at or above the Action Level

- 0 - 1
- 1 - 3
- 3 - 5
- 5 - 10
- 10 - 30
- Greater than 30

Settlements

- Gloucester
- Ebbw Vale
- Ludlow
- Caersws

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

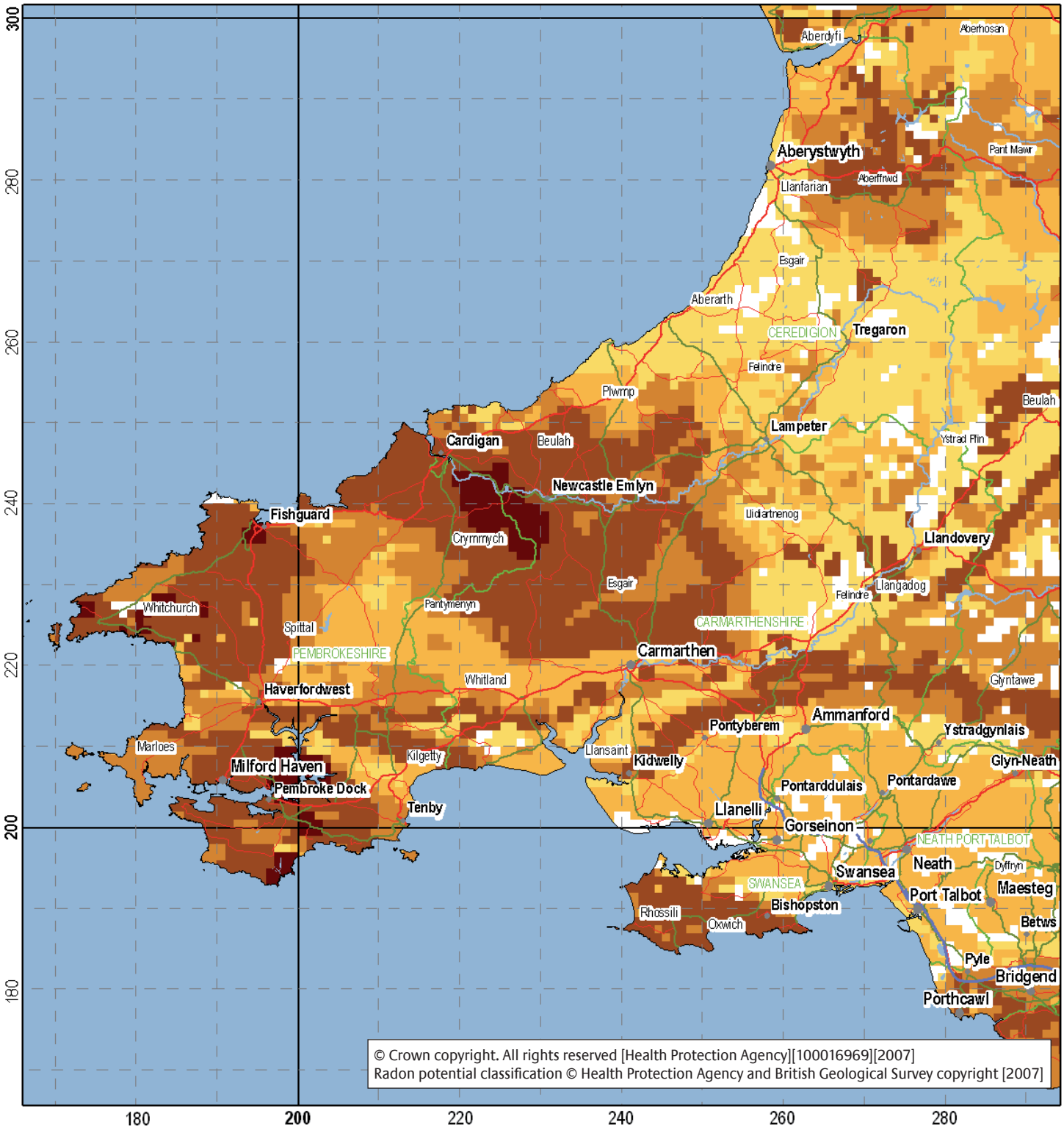
National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

MAP 10 Southern Welsh Marches and Gloucestershire, 100-km grid square SO (axis numbers are the coordinates of the national grid)



The colours show the maximum percentage band within each 1-km grid square of the national grid (see page 4). The best estimate for an individual property in a coloured square can be obtained for a small charge from www.ukradon.org. The white squares, the 0-1% band, contain no Affected Areas as defined by the HPA.

Percentage of homes at or above the Action Level

- 0 - 1
- 1 - 3
- 3 - 5
- 5 - 10
- 10 - 30
- Greater than 30

Settlements

- Swansea
- Lampeter
- Whitchurch
- Dyffryn

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

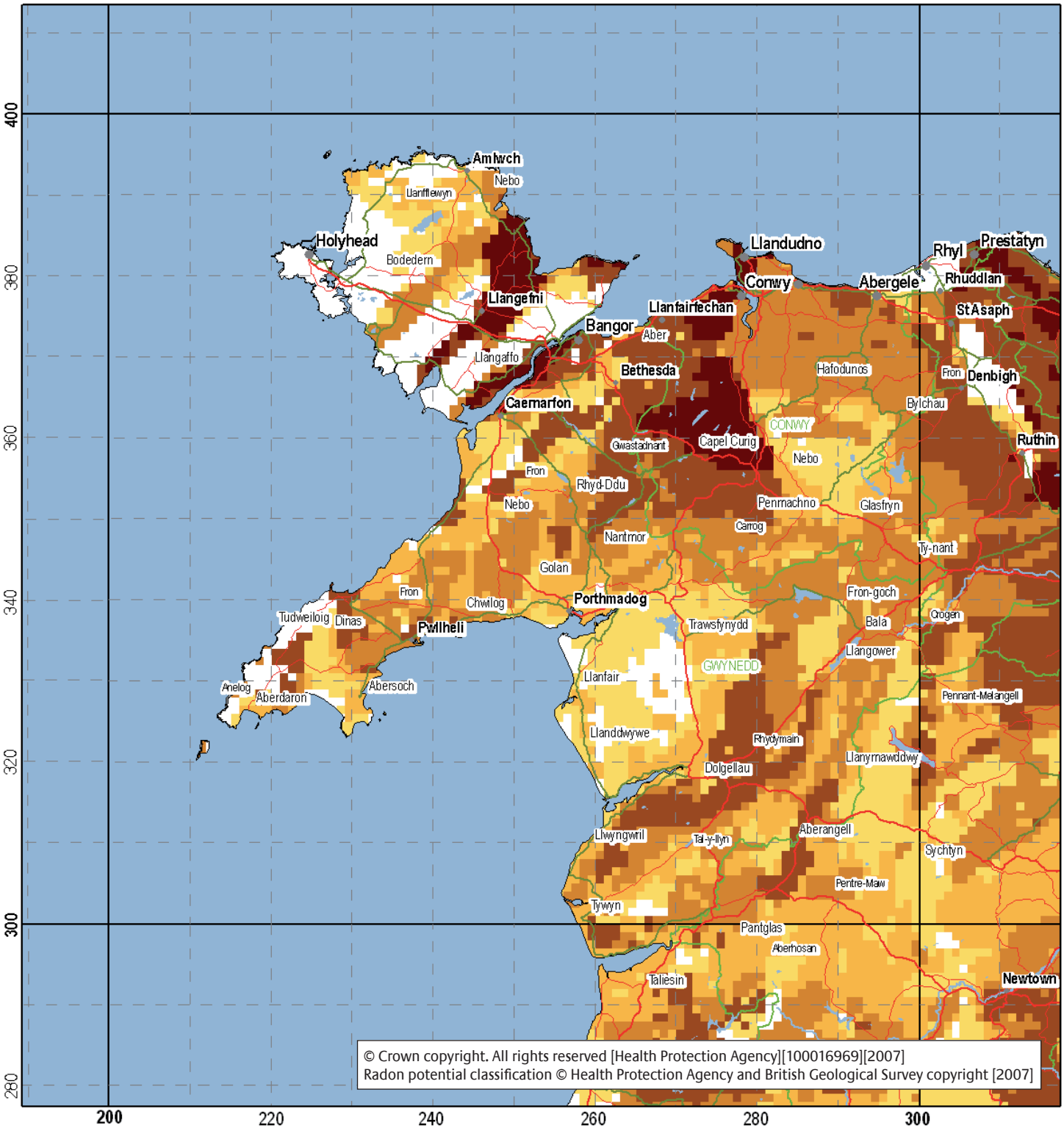
National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

MAP 11 Southwest Wales, 100-km grid squares SM, SN, SR and SS (axis numbers are the coordinates of the national grid)



The colours show the maximum percentage band within each 1-km grid square of the national grid (see page 4). The best estimate for an individual property in a coloured square can be obtained for a small charge from www.ukradon.org. The white squares, the 0-1% band, contain no Affected Areas as defined by the HPA.

Percentage of homes at or above the Action Level

- 0 - 1
- 1 - 3
- 3 - 5
- 5 - 10
- 10 - 30
- Greater than 30

Settlements

- Bangor
- Porthmadog
- Dolgellau
- Carrog

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

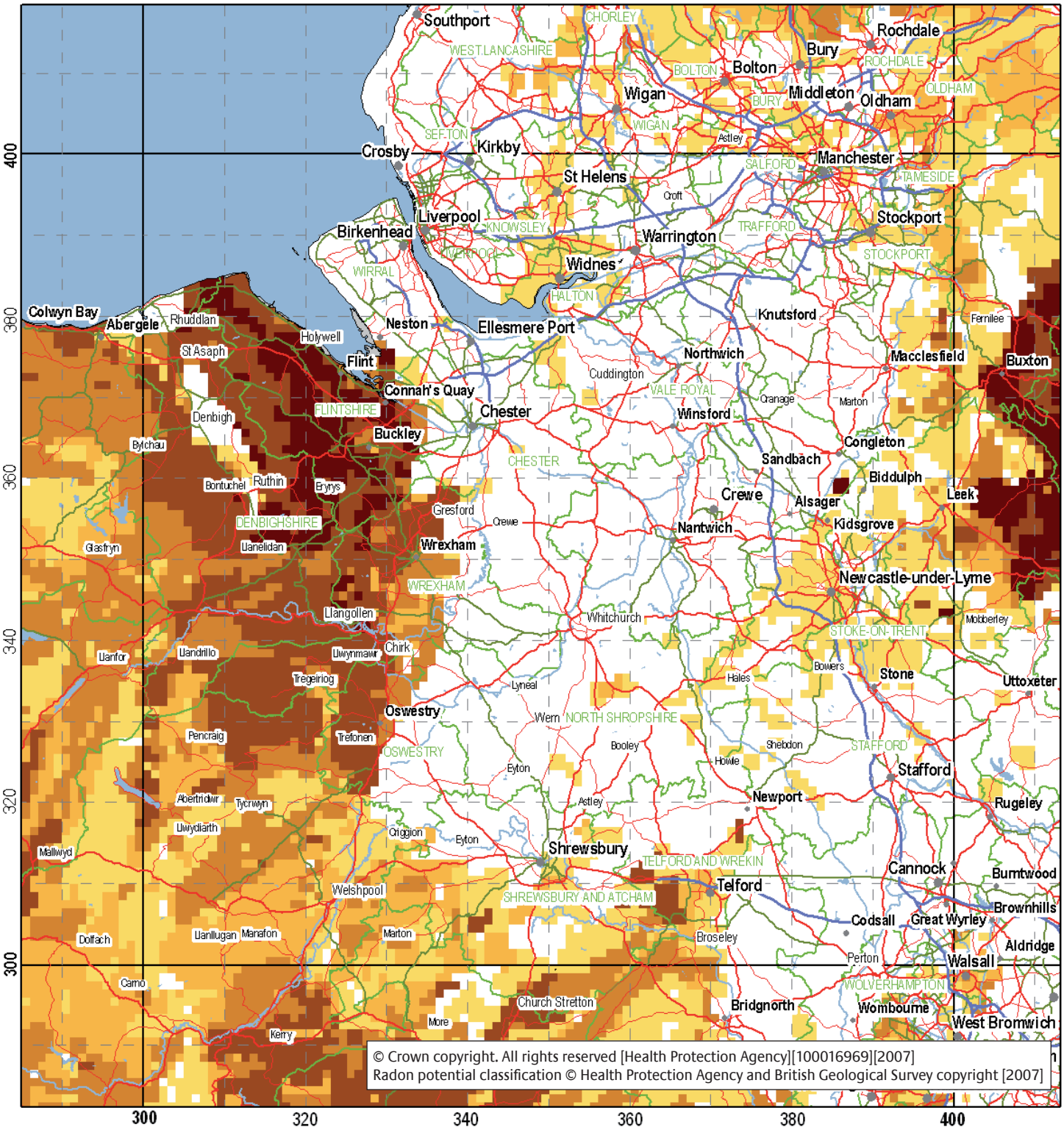
National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

MAP 12 Northwest Wales, 100-km grid square SH (axis numbers are the coordinates of the national grid)



The colours show the maximum percentage band within each 1-km grid square of the national grid (see page 4). The best estimate for an individual property in a coloured square can be obtained for a small charge from www.ukradon.org. The white squares, the 0-1% band, contain no Affected Areas as defined by the HPA.

Percentage of homes at or above the Action Level

- 0 - 1
- 1 - 3
- 3 - 5
- 5 - 10
- 10 - 30
- Greater than 30

Settlements

- Chester
- Oswestry
- Rhuddlan
- Bowers

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

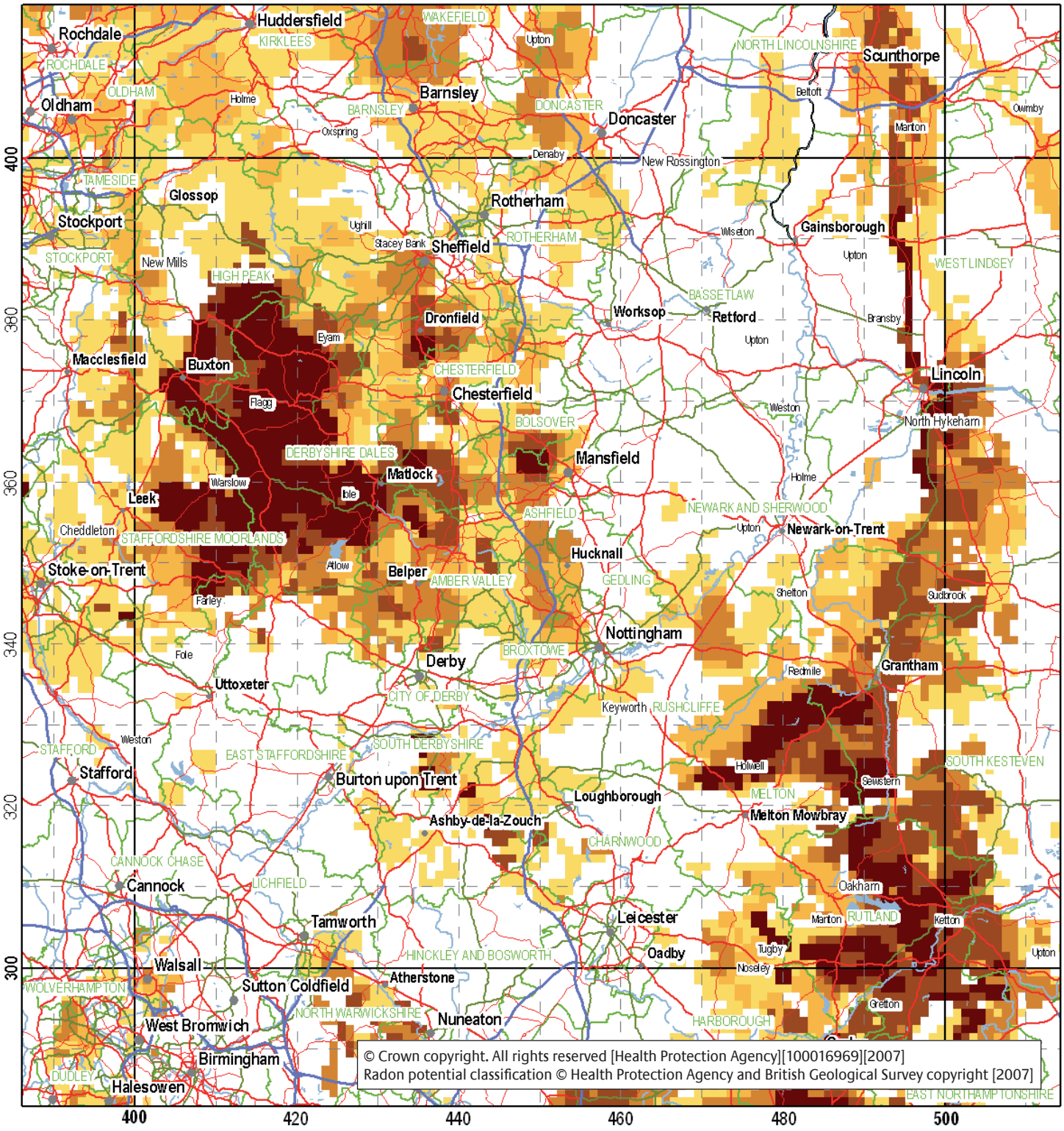
National Grid

- 100-km
- 10-km

Other Features

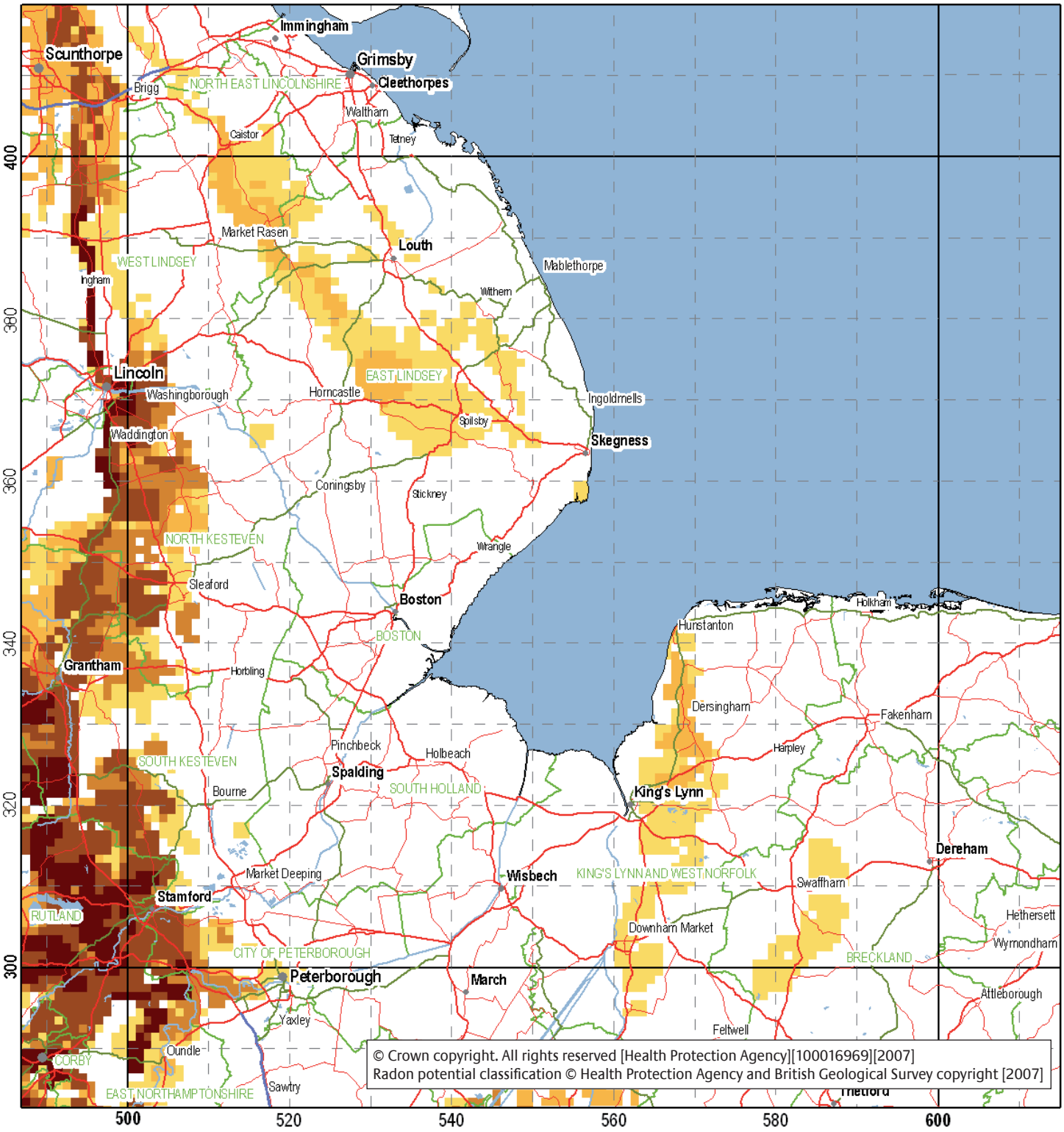
- LOCAL ADMINISTRATIVE DISTRICT
- Water features

MAP 13 Northern Welsh Marches and Liverpool, 100-km grid square SJ (axis numbers are the coordinates of the national grid)



The colours show the maximum percentage band within each 1-km grid square of the national grid (see page 4). The best estimate for an individual property in a coloured square can be obtained for a small charge from www.ukradon.org. The white squares, the 0-1% band, contain no Affected Areas as defined by the HPA.

MAP 14 Derbyshire, Leicestershire and Nottinghamshire, 100-km grid square SK (axis numbers are the coordinates of the national grid)



The colours show the maximum percentage band within each 1-km grid square of the national grid (see page 4). The best estimate for an individual property in a coloured square can be obtained for a small charge from www.ukradon.org. The white squares, the 0-1% band, contain no Affected Areas as defined by the HPA.

Percentage of homes at or above the Action Level

- 0 - 1
- 1 - 3
- 3 - 5
- 5 - 10
- 10 - 30
- Greater than 30

Settlements

- Lincoln
- Spalding
- Holbeach
- Spilsby

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

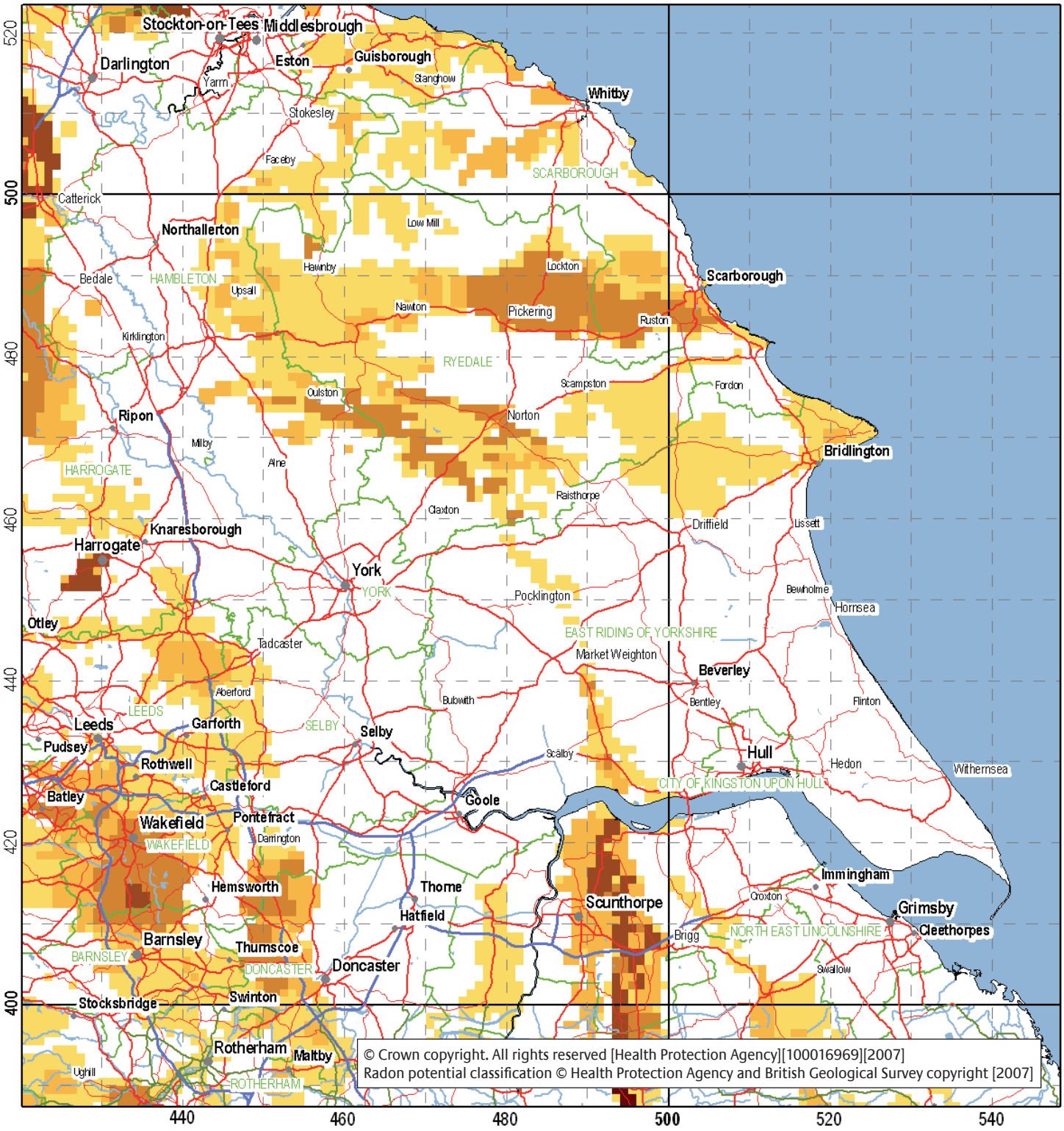
National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

MAP 15 Lincolnshire and the Wash, 100-km grid square TF (axis numbers are the coordinates of the national grid)



The colours show the maximum percentage band within each 1-km grid square of the national grid (see page 4). The best estimate for an individual property in a coloured square can be obtained for a small charge from www.ukradon.org. The white squares, the 0-1% band, contain no Affected Areas as defined by the HPA.

Percentage of homes at or above the Action Level

- 0 - 1
- 1 - 3
- 3 - 5
- 5 - 10
- 10 - 30
- Greater than 30

Settlements

- York
- Batley
- Brigg
- Lissett

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

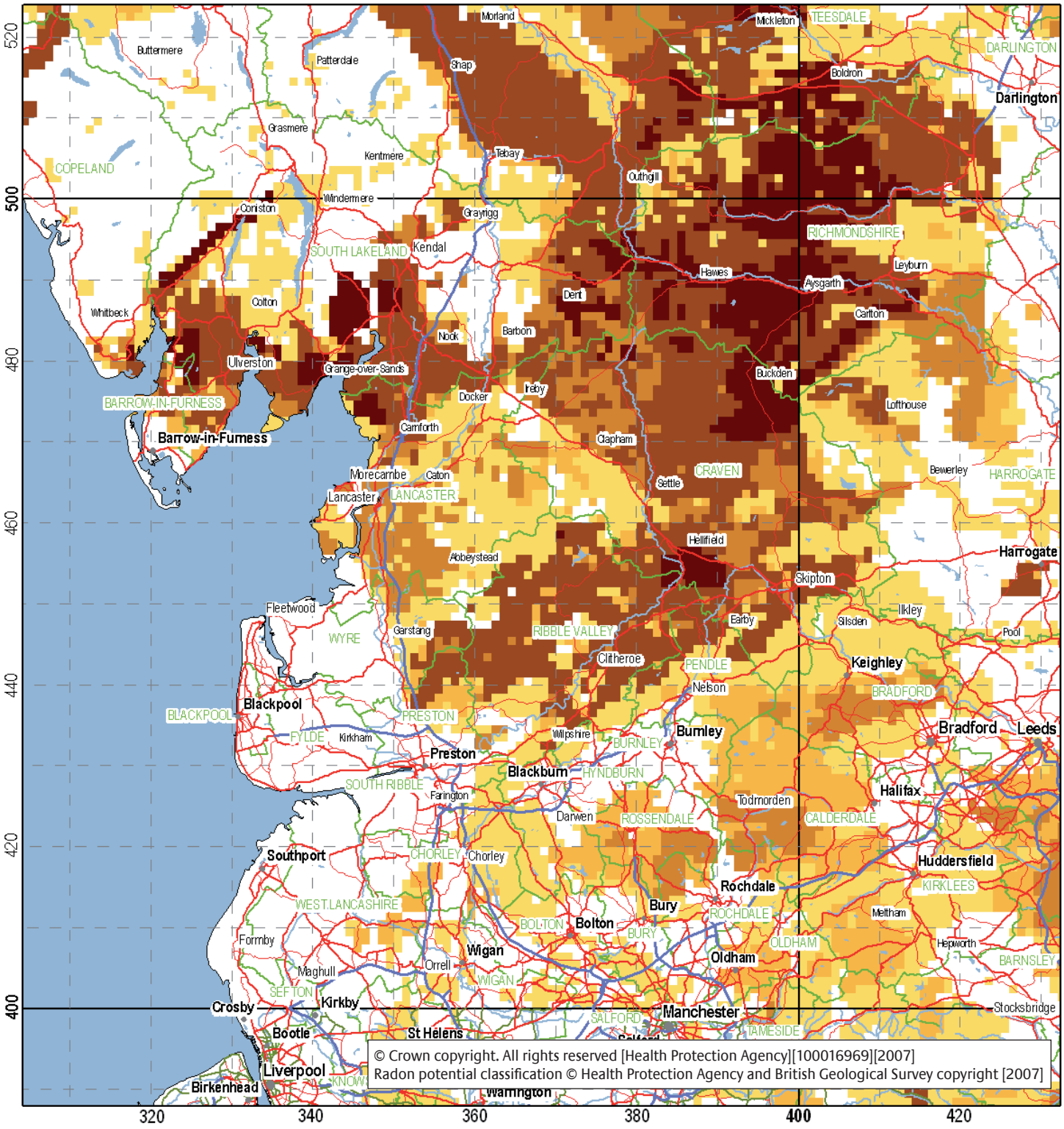
National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

MAP 16 Humberside and eastern North Yorkshire, 100-km grid squares SE and TA (axis numbers are the coordinates of the national grid)



The colours show the maximum percentage band within each 1-km grid square of the national grid (see page 4). The best estimate for an individual property in a coloured square can be obtained for a small charge from www.ukradon.org. The white squares, the 0-1% band, contain no Affected Areas as defined by the HPA.

Percentage of homes at or above the Action Level

- 0 - 1
- 1 - 3
- 3 - 5
- 5 - 10
- 10 - 30
- Greater than 30

Settlements

- Blackburn
- Keighley
- Hawes
- Coniston

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

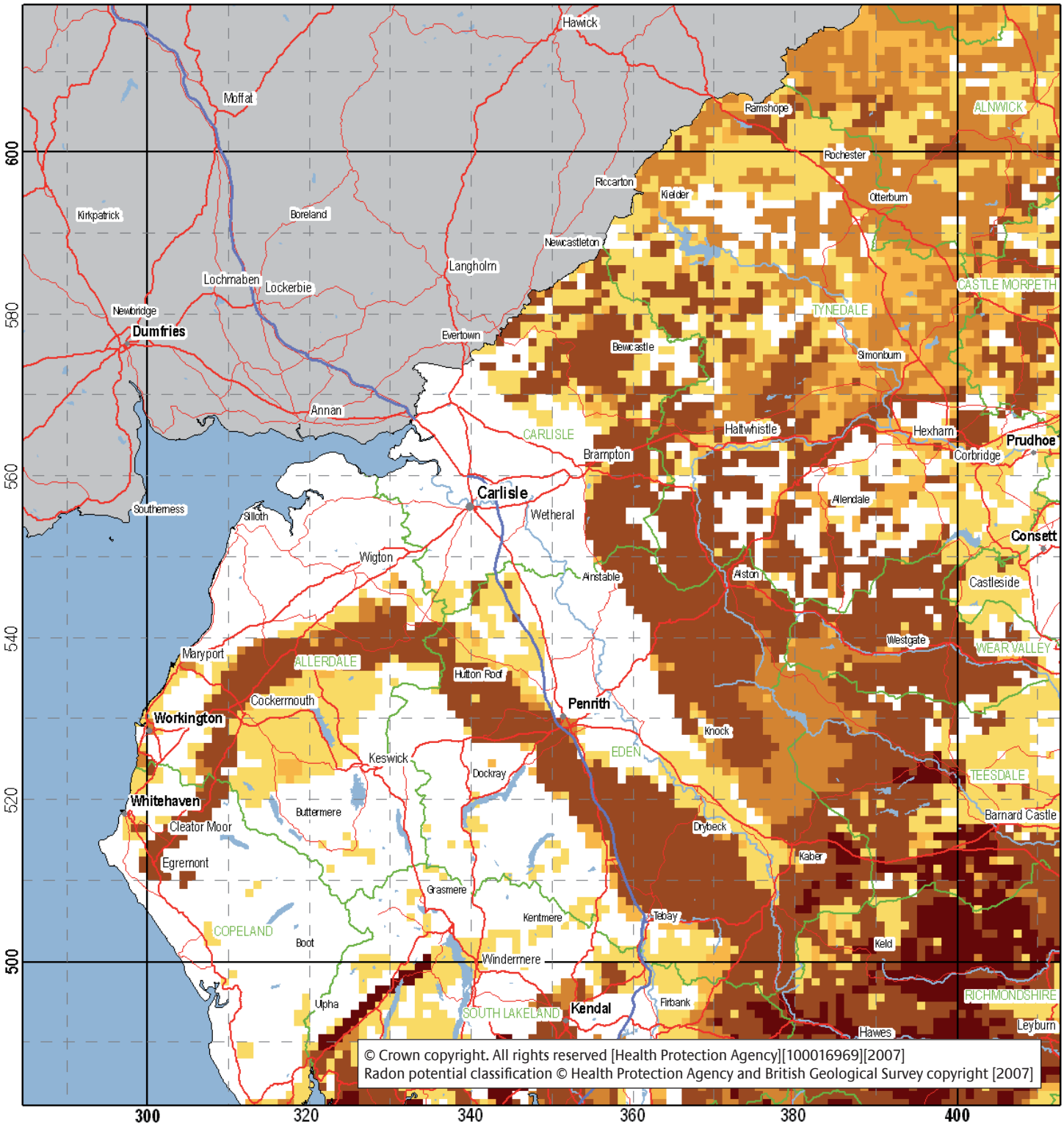
National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

MAP 17 Lancashire, south Cumbria and western North Yorkshire, 100-km grid squares SD and SE (axis numbers are the coordinates of the national grid)



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Percentage of homes at or above the Action Level

- 0 - 1
- 1 - 3
- 3 - 5
- 5 - 10
- 10 - 30
- Greater than 30

Settlements

- Carlisle
- Penrith
- Wigton
- Grasmere

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

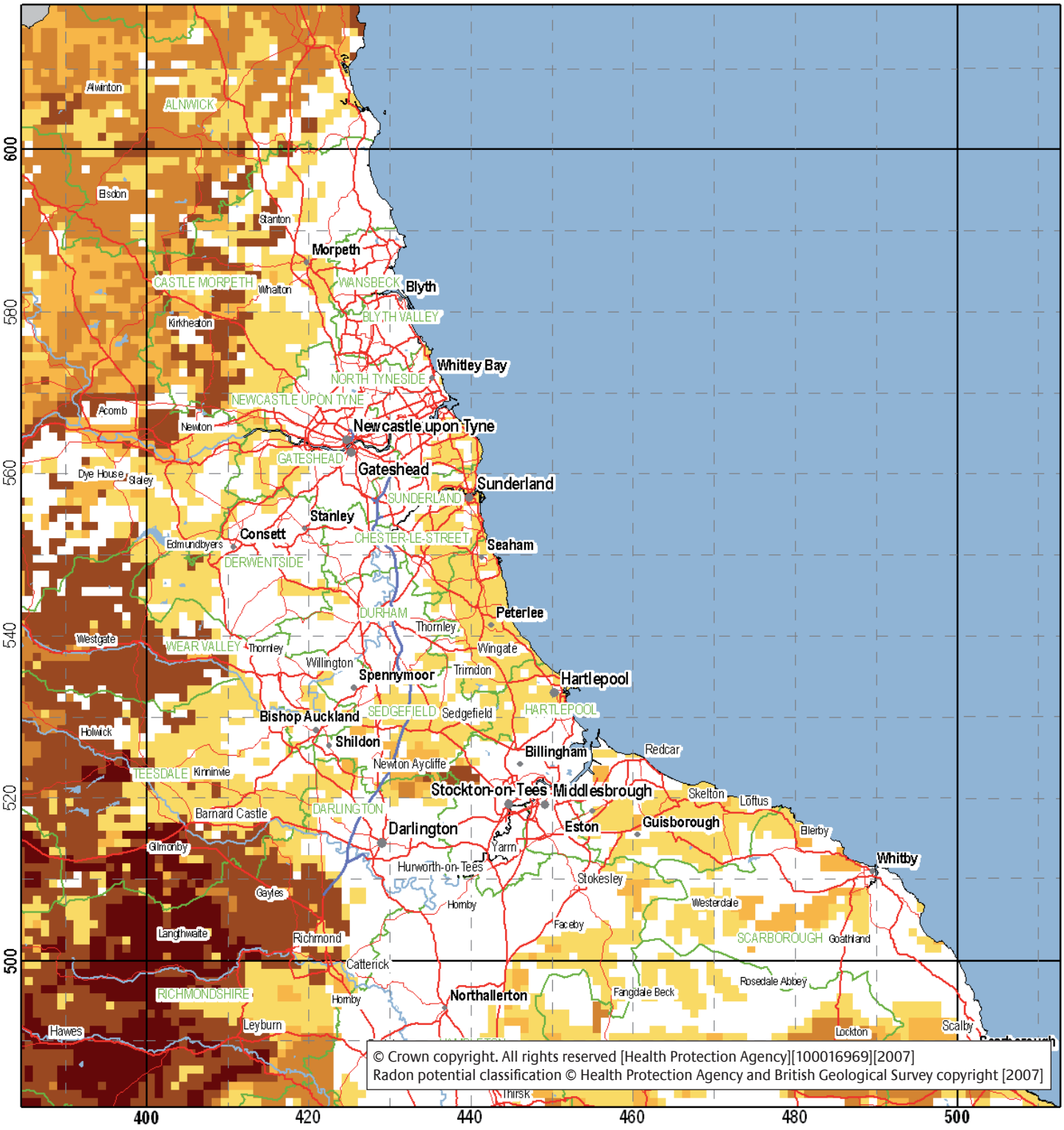
National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

MAP 18 North Cumbria, 100-km grid square NY (axis numbers are the coordinates of the national grid)



The colours show the maximum percentage band within each 1-km grid square of the national grid (see page 4). The best estimate for an individual property in a coloured square can be obtained for a small charge from www.ukradon.org. The white squares, the 0-1% band, contain no Affected Areas as defined by the HPA.

Percentage of homes at or above the Action Level

- 0 - 1
- 1 - 3
- 3 - 5
- 5 - 10
- 10 - 30
- Greater than 30

Settlements

- Sunderland
- Peterlee
- Yarm
- Slaley

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

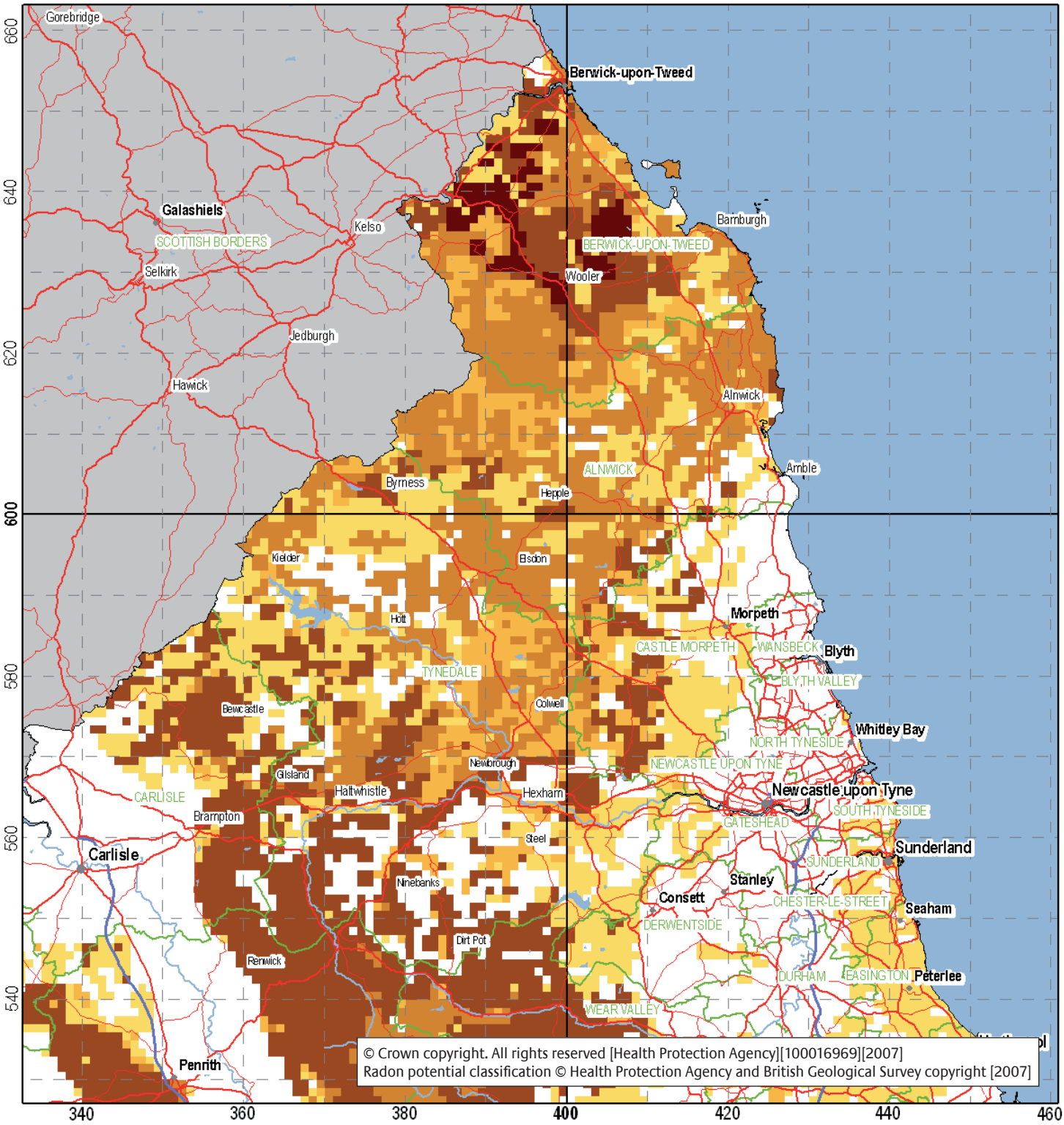
National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

MAP 19 Teeside, Tyneside and Wearside, 100-km grid square NZ (axis numbers are the coordinates of the national grid)



The colours show the maximum percentage band within each 1-km grid square of the national grid (see page 4). The best estimate for an individual property in a coloured square can be obtained for a small charge from www.ukradon.org. The white squares, the 0-1% band, contain no Affected Areas as defined by the HPA.

Percentage of homes at or above the Action Level

- 0 - 1
- 1 - 3
- 3 - 5
- 5 - 10
- 10 - 30
- Greater than 30

Settlements

- Newcastle upon Tyne
- Berwick-upon-Tweed
- Alnwick
- Hepple

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

MAP 20 Northumberland, 100-km grid squares NT and NU (axis numbers are the coordinates of the national grid)