HR Wallingford
Working with water

Indicators to assess the exposure of critical infrastructure in England to current and projected climate hazards

Final report

MCR5195-RT003-R05-00 May 2014

Document information

Document permissions	Confidential - client
Project number	MCR5195
Project name	Indicators to assess the exposure of critical infrastructure in England to current and projected climate hazards
Report title	Final report
Report number	RT003
Release number	R05-00
Report date	May 2014
Client	Committee on Climate Change
Client representative	Lola Vallejo
Project manager	Eleanor Hall
Project director	Mike Panzeri

Document authorisation

Prepared	Approved	Authorised
E M N Hall		

Document history

Date	Release	Prepared	Approved	Authorised	Notes
15 May 2014	05-00	EMN	MCP	MCP	
25 Apr 2014	04-00	EMN	MCP	MCP	
07 Apr 2014	03-00	EMN	MCP	MCP	Revised following final client review
24 Mar 2014	02-00	EMN	MCP	MCP	Revised version following peer review
03 Mar 2014	01-00	EMN	MCP	MCP	

Executive summary

The Adaptation Sub-Committee (ASC) of the Committee on Climate Change has a statutory duty to report to Parliament with an independent assessment of the UK Government's progress in implementing its National Adaptation Programme report (NAP)[1]. In order to make its assessment of progress, the ASC is producing a series of annual progress reports that assess preparedness for the main risks and opportunities facing the UK from climate change, as identified by the UK Climate Change Risk Assessment (CCRA)[2]. The latest annual report will include analysis of the preparedness of health, infrastructure and business to the projected impacts of climate change. Assessment of preparedness requires the development of spatial indicators.

HR Wallingford have been commissioned to provide a national level (England only), spatial assessment of the exposure of a number of infrastructure assets to weather related hazards including: coastal erosion, flooding from rivers, the sea, groundwater and surface water, natural landslides, shrink-swell subsidence and river scour. Whilst it was preferable to provide measures of vulnerability to hazards over simply exposure, the lack of underlying data to do this meant that this was not possible at a national scale.

Overview

High susceptibility to shrink-swell subsidence and groundwater flooding were the hazards that consistently returned the highest levels of exposure for England's infrastructure assets. The instances of high susceptibility to shrink-swell subsidence are highest in and around London, the East of England and the South East of England. These areas contain some of the most densely populated areas of England. It may be expected that with large populations will come larger number of and/or more densely distributed assets. Therefore, the degree of exposure to shrink-swell subsidence is logical. The highest levels of susceptibility to groundwater flooding, although not always in the same areas as shrink-swell subsidence, follow a similar pattern of being coincident with regions of large populations. Engineered resilience measures with regard to shrink-swell subsidence or groundwater flooding are not included in the assessment.

In general, the next highest level of exposure, of the hazards assessed, was to flooding from rivers or the sea or from surface water. With respect to flooding from rivers or the sea the analysis undertaken includes the presence and condition of raised publicly owned flood defences. What is not included, for any asset, is any local or privately owned defences or resilience measures against flooding. The results of the exposure analysis is therefore the current worst case scenario, excluding any action taken by asset owners.

For all assets, potential for exposure to coastal erosion and natural landslides was low. However, the coastal erosion hazard dataset used in this assessment is intended to identify the level of exposure at a national level only. At a local level, individual assets may be exposed to coastal erosion that are not identified at a national level. Only natural landslides were assessed, the following types of failure are not included:

[1] https://www.gov.uk/government/publications/adapting-to-climate-change-national-adaptation-programme

[2] http://ccra.hrwallingford.com/

- Failure of natural slopes due to interference e.g. undercutting the toe of the slope;
- Failure of man-made slopes or embankments.

Summary of results by sector

Education

The assessment investigated the exposure of primary, secondary and schools for all ages to weather related hazards. Results from flooding from rivers, the sea and surface water, coastal erosion and natural landslides indicated a very low level of exposure; the proportion of exposed assets never exceeding 1% for the present day. The results for the proportion of schools exposed to a high susceptibility of groundwater flooding and shrink-swell subsidence were a magnitude higher.

Energy

The assessment for the energy sector was made up of multiple assets including substations, power stations, towers, wind turbines, underground electricity cable and underground gas pipes. For the majority of asset types, exposure was greatest from flooding from groundwater and shrink-swell subsidence. These results need to be interpreted with caution as the influence of foundation types from engineered structures on instances of groundwater flooding and, engineered resilience measures of assets to shrink-swell subsidence were not incorporated into the analysis. By comparison, the assessment indicated low exposure across all assets from coastal erosion and natural landslides. The assessment indicates low to moderate exposure to flooding from rivers or the sea (taking into account publicly owned and maintained but not private asset level flood resilience and defence measures) for the present day, although this increases under projected future scenarios. In general, exposure to surface water flooding is low.

Health

Care homes, GPs surgeries, hospitals and emergency services were assessed against coastal erosion, flooding from rivers, the sea, groundwater and surface water, natural landslides and shrink-swell subsidence. As per the energy sector, the assets are most exposed to a high susceptibility of groundwater flooding and shrink-swell subsidence. Coastal erosion and landslides present the least exposure and flooding from rivers, the sea and surface water present low to moderate exposure in this sector for the present day.

ICT

The ICT sector was a challenging sector to assess since datasets of the location of the physical assets are generally unavailable for use in the public domain. Data centres and mobile telecommunication masts were assessed for their exposure to coastal erosion, flooding from rivers, the sea, groundwater and surface water, natural landslides and shrink-swell subsidence. As per previous sectors, exposure to landslides and coastal erosion was low or zero. Exposure to flooding from rivers, the sea and surface water was also quite low. The greatest levels of exposure was from flooding from groundwater and shrink-swell subsidence.

Transport

The transport sector assets assessed were roads, railway lines, railway stations and road and rail bridges that cross primary and secondary rivers. As per many of the other sectors the greatest level of exposure was to a high susceptibility of groundwater flooding and shrink-swell subsidence. Exposure to high susceptibility of natural landslides and coastal erosion was assessed to be very low and exposure to flooding from rivers or the sea slightly higher. Mid-depth and infrequent surface water flooding returned exposure

rates of around 9% for railway lines and roads. It should be noted, for railway lines in particular, that whilst the percentage of assets directly exposed to certain hazard may be low, the impact of such a hazard may be disproportionately higher. For example, damage from coastal flooding in one small stretch of railway line may prevent the entire line from being used. The direct physical damage may conceivably be small, when compared to the disruption costs.

Bridge Scour

Road and rail bridges over primary and secondary rivers were assessed for increase in scour risk due to climate change. The assessment has shown that the scour risk is low for all of the climate change scenarios assessed except for the high emissions, p90 2080s scenario under which approximately a quarter of all bridges have medium scour risk and 1 in 20 have high scour risk.

Water

Clean and waste water treatment sites were assessed against coastal erosion, flooding from rivers, the sea, groundwater and surface water and shrink-swell subsidence. Unsurprisingly, the exposure of both types of asset, but especially waste water treatment works, from flooding from rivers or the sea, was high. This is primarily a consequence of where such works have to be situated in order to function. Exposure to flooding from groundwater was of a similar magnitude for both asset types but exposure to flooding from surface water was a little lower. Coastal erosion exposure was negligible and exposure to shrink-swell subsidence was around 10%.

Acknowledgement

We wish to acknowledge the input and supply of datasets from numerous people and organisations in all of the sectors included in this assessment. Without this assistance, much of this work would not have been possible.

Contents

Figures

Tables

1. Introduction

The Adaptation Sub-Committee (ASC) of the Committee on Climate Change has a statutory duty to report to Parliament with an independent assessment of the UK Government's progress in implementing its National Adaptation Programme report (NAP). In order to make its assessment of progress, the ASC is producing a series of annual progress reports that assess preparedness for the main risks and opportunities facing the UK from climate change, as identified by the UK Climate Change Risk Assessment (CCRA). Three such reports have already been completed:

1. 2011 – Adapting to climate change in the UK: Measuring progress.
2. 2012 – Climate change – is the UK preparing for flooding and water scarcity?
3. 2013 – Managing the land in a changing climate.

The next report will include analysis of the preparedness of health, infrastructure and business to the projected impacts of climate change. Assessment of preparedness requires the development of spatial indicators that can monitor changes over time in preparedness. Such indicators fall into three broad categories:

- Indicators of risk - These measure changes in the **exposure** and **vulnerability** of the sector to the weather or other related hazard;
- Indicators of adaptation **action** - These aim to measure the extent of actions to reduce risks from climate change;
- Indicators of climate **impacts** - These track the realised impacts of weather on the economy, society and environment.

This report aims to provide spatial indicators of exposure to hazards for national infrastructure. This is not an assessment of risk; exposure to a hazard is only one component of risk. It forms one part of the catalogue of supporting evidence for the ASC's 2014 annual report which, will provide an assessment of realised climate impacts, the uptake and investment in action and resilience measures and an evaluation of relevant policy.

The infrastructure sectors of interest in this report are as follows:

- Education
- Energy
- Health
- ICT
- Transport
- Water.

In consultation with various stakeholders, including Government Departments, its Agencies and Regulators, industry representatives and private organisations, 259 separate spatial indicators were explored for the infrastructure sectors and the broad indicator categories described above. Very few of the vulnerability, action or impact indicators were possible to analyse quantitatively at a national scale. This is primarily due to the poor availability of underpinning data. In the majority of cases, data pertaining to vulnerability, action and impact indicators is not collected in a manner that enables national assessment. There are exceptions to this. For example, energy infrastructure providers do have centralised data on the flood prevention improvements that have been or are due to be made to their substations. Also, the Highways Agency does keep centralised information on the number of incidents and engineered structures that may help mitigate flooding of their network. A further challenge faced by these sectors with regard to data, is the sharing of

information that may either compromise national security or be commercially sensitive in nature. To a greater or lesser extent, national security and/or commercial sensitivity is an issue for all infrastructure sectors.

Of the 259 indicators explored, 91 indicators of exposure have been taken forward for spatial analysis[3]. To improve understanding of degree of risk associated with the indicators, estimates of **criticality** are made, where possible and, when interpreting the results, consideration should be given to whether local adaptation measures are known to exist; these are highlighted in the text. The criticality measures adopted are not synonymous with the criticality measures used by the Cabinet Office. Critical National Infrastructure (CNI) as defined by the Cabinet Office was not used in this assessment for national security reasons.

The general methodology used for the spatially analysis of each indicator is described in Section 2.

2. Methodology

A method for developing spatial indicators of risk, action and impact was devised by HR Wallingford to provide evidence that fed into the ASC's second report, on preparedness for flooding and water scarcity. The method is based upon the use of a Geographical Information System (GIS) to spatially pre-process data from the most robust and reliable sources of readily available, national scale, data. Pre-processing first involves converting the data into the required spatial format and then clipping the data to tiles and sub-dividing the data into a grid. For this assessment, multiple layers of gridded data on hazards (e.g. flooding) and assets are then built up into a high-resolution spatial database. Queries are subsequently run on the data to identify where the chosen assets and hazards intersect[4] and therefore exposure of the asset to the hazard is possible. Trends may also be identified between different hazards, assets and time periods. Typically, using traditional GIS methods, performing spatial comparison between a large number of mapping datasets can be very time consuming, particularly when processing very complex continuous (e.g. polygon) data. As additional layers are added, it can become impractical due to increasing complexity of the unique combinations through all datasets. The more efficient assessment approach adopted here, using gridded information held within a database, is reliable, unbiased, repeatable, easily validated and can be efficiently extended in the future for new indicators or new snapshots in time.

The 91 indicators of exposure taken forward for spatial analysis cover 6 infrastructure sectors (described in Section 1) and 7 weather related-hazards: flooding from rivers or the sea, flooding from surface water, flooding from groundwater, coastal erosion, shrink-swell subsidence, natural landslides and river scour. High winds and heat stress were also considered. There is currently no nationally available gridded dataset on extreme winds that could be used with our methodology described above. With regard to heat stress, overhead power cables and railway track were considered to be the assets most susceptible to this hazard and national data is available. However, the analysis work undertaken for the Climate Change Risk Assessment (CCRA) in 2012 (McColl *et al.*, 2012; Thornes *et al.*, 2012) provides a good assessment of risk from this hazard and so no further assessment has been undertaken. Relevant excerpts from the CCRA are shown in Appendix B.

The results from this assessment will form one part of the evidence that underpins the ASC's 2014 annual report which will also incorporate an assessment of realised climate impacts, the uptake and investment in action and resilience measures and an evaluation of relevant policy.

[3] The ASC made a pragmatic decision regarding which indicators were required for spatial analysis.

[4] Where assets and hazards do not intersect, exposure of the asset to the hazard is assumed to not occur.

3. Hazard datasets

The same set of hazard datasets has been used for each indicator. A brief description of the hazards datasets is shown below. Any limitations described apply similarly to each of the indicators in Section 4.

3.1. Coastal erosion

The National Coastal Erosion Risk Map (NCERM) data from the Environment Agency provides nationally consistent information on the predominant risk at the coast for the purpose of regional management planning activities. It is not intended to provide information for individual properties.

The data describes the upper and lower estimates of erosion risk at a particular location, within which the actual location of the coastline is expected to lie. It is intended as an up-to-date and reliable benchmark dataset showing erosion extents and rates for three periods and across different scenarios: No active intervention and Shoreline Management Plan (SMP) policies:

- Time periods:
  - Short Term (0 – 20yr)
  - Medium Term (20 – 50yr)
  - Long Term (50 – 100yr).
- Scenario types:
  - **No active intervention scenario:** It is assumed there is no investment in coastal defences or operations everywhere.
  - **SMP2 policies:**
    - **No active intervention policy:** Where the local policy is for no investment in coastal defences or operations.
    - **Managed realignment:** The shoreline is allowed to move backwards or forwards, with management to control or limit movement.
    - **Hold the line:** The existing defence is maintained by either maintaining or changing the standard of protection.
    - **Advance the line:** The existing defence line is advanced by building new defences on the seaward side of the original defences.

In addition to the time periods, the data for erodible coastlines provides recession rates for the fifth percentile (five per cent chance of the recession being greater than the given amount within the assessment term), fiftieth percentile (50%chance the recession being greater than the given amount) and ninety fifth percentile (95% chance of the recession being greater than the given amount), giving a measure of uncertainty.

For the purpose of the indicators related to this hazard, assets are counted if they are within the estimated erosion zone for each time period and at the 5 percentile predicted erosion rate to provide a cautious assessment for the indicator. Only scenarios and policies where assets are exposed either in the short, medium or long term are presented.

The process of projecting the erosion rates inland for an appraisal period has inherent weakness due to uncertainty about the predicted rates, the natural variation in the rate over time (due to numerous factors including changes in climatic conditions, nearshore bathymetry, sea level, geology of the exposed face) and change in policy over time. It follows that the greater the forecast period, the greater the uncertainty.

3.2. Flooding (groundwater)

The Groundwater Flood Risk Map of England and Wales from ESI combines BGS national datasets of geology, permeability of bedrock and superficial deposits, and modelled groundwater surfaces in bedrock with data on historic flood events. This provides a consistent, reliable and ground-truthed map of the susceptibility of groundwater flooding at different locations, categorised into 4 different bands:

> **CLASS1: High:** There is a high risk of groundwater flooding in this area with an estimated return period of 1 in 200 years or more frequent.
>
> **CLASS 2:Moderate:** There is a moderate risk of groundwater flooding in this area with a return period of estimated 1 in 200 years.
>
> **CLASS 3: Low risk:** There is a low risk of groundwater flooding in this area with an estimated return period of less than the estimated 1 in 200 years.
>
> **CLASS 4: Negligible risk**: There is a negligible risk of groundwater flooding in this area and any groundwater flooding incidence will be less frequent than the estimated 1 in 200 years return period.
>
> It is important to note that in order to provide a consistent national approach and in the light of data deficiencies, there are significant limitations in the assessment of flooding likelihood. For example, groundwater flooding events in one location may correspond to a 1 in 50 year flood with the same event representing a 1 in 500 year event elsewhere. The 1 in 200 year return period should therefore be regarded as 'indicative'.
>
> *ESI, 2014*[5]

Consistent with the underlying datasets, this map shows areas of potential groundwater emergence. Emergence of groundwater may not translate directly to flooding at that location as the magnitude of flow is not taken into account. In addition, in built up areas in particular, emergent groundwater may not lead to flooding at the location it emerges due to permeable formations such as sewers, granular fill around utilities and road sub-grade draining some high groundwater flows away. This process would tend to move the groundwater flooding problem down the catchment. Furthermore, based upon the descriptions of the risk bands used, only the high risk band is relevant in terms of potential damage or disruption to national infrastructure. The description of this risk band is provided as follow:

> It is likely that incidence of groundwater flooding will occur, which could lead to damage to property or harm to other sensitive receptors at, or near, this location. Flooding may result in damage to property, road or rail closures and, in exceptional cases, may pose a risk to life. Surface water flooding will be exacerbated when groundwater levels are high. Further consideration of the level of risk and mitigation, by a suitably qualified professional, is recommended.
>
> *ESI, 2014*

[5] A return period of 1 in 200 years or more frequent should be interpreted as a 1 in 200 chance of occurrence in any given year or more frequently.

Lower categories of risk indicate that groundwater flooding is possible, but that, for example, road or rail closures should not be required. For these reasons, only the high risk band has been used in this assessment.

Upgrades of this Groundwater Flood Risk map are released on a six monthly cycle, incorporating model improvements and updates to the underlying datasets. The map is intended to inform preliminary assessments and is not intended as a substitute to local risk assessments for individual buildings or sites.

3.3. Flooding (river and coastal)

The National Flood Risk Assessment (NaFRA) is EA's best available national data on flood risk. It defines the likelihood of the onset of flooding from rivers or the sea and enables a comparison of the relative risks and their distribution. It does not take any account of property level resilience, such as the raising of property thresholds or any property level flood proofing, nor does it consider the availability of flood warnings. It is therefore not possible to provide an indication of the specific vulnerability of individual assets. NaFRA does, however, take into account the presence and condition of publicly owned and maintained flood defences. This assessment assumes that the present system of publicly owned flood defences are maintained to the current standard with no new defences being built or existing defences being raised. NaFRA 2013, has been used for all snapshots, therefore any variations observed between the snapshots are as a consequence of changes in the assets. Variations between the results of this assessment and previous similar assessments are to be expected as this is a new version of NaFRA, with new categories of flood likelihood.

The data are reported in categories of flooding probability as defined by the National Flood Risk Assessment (2013)[6]:

- Very low; Less than 1 in 1000 (0.1%) chance in any given year
- Low; Less than 1 in 100 (1%) but great than or equal to 1 in 1000 (0.1%) chance in any given year
- Medium; Less than 1 in 30 (3.3%) but greater than or equal to 1 in 100 (1%) chance in any given year)
- High; Greater than or equal to 1 in 30 (3.3%) chance in any given year.

The probability of inundation provided by the NaFRA is uplifted for future scenarios, based upon the increases in peak flow estimated for the CCRA using the UK Climate Projections 2009.

3.4. Flooding (surface water)

The updated Flood Map for Surface Water (uFMfSW), from the EA, is the most reliable and consistent national surface water flood map available. The data are reported in categories of flooding probability:

- 1 in 30 year (3.3%)
- 1 in 100 (1%)
- 1 in 1000 (0.1%).

[6] NB – The probabilities defined by NaFRA 2013 are different to previous versions of NaFRA. The probabilities in NaFRA 2011 were as follows:

  - Low; 0.1% to 0.5% (1 in 1000 to 1 in 200 chance in any given year)
  - Moderate; 0.5% to 1.3% (1 in 200 to 1 in 75 chance in any given year)
  - Significant; more than 1.3% (more than 1 in 75 chance in any given year)

For each likelihood category a range of potentially depth threshold classes is provided:

- <0.15 m
- 0.15-0.30 m
- 0.3-0.6 m
- 0.6-0.9 m
- 0.9-1.2 m
- >1.2 m.

Three storm durations were examined for the development of the updated Flood Map for Surface Water flooding. At any given location, the most severe is taken. Whilst this may often be the 1 hour storm duration, in some, flatter areas, more prolonged events may be more critical.

The EA advise the following limitations to the mapping:

- A single drainage rate has been assumed for all urban areas within the national scale modelling. Large subsurface drainage elements such as flood relief culverts and flood storage are not included. These assumptions can affect the modelled extent and pattern of flooding.
- Limited recorded surface water flood data exists for Lead Local Flood Authorities (LLFA) to perform validation, so in many places no validation has yet been carried out.
- As with many other flood models:
  - The input information, model performance and modelling that were used to create the uFMfSW vary for different areas; these affect the reliability of the mapped flood extents and, in turn, the suitability for different applications.
  - uFMfSW does not take individual property threshold heights into account.
  - The flood extents show predicted patterns of flooding based on modelled rainfall. In reality, no two storms are the same, and so two floods of similar rarity may result in different patterns of flooding and consequently these maps cannot definitively show that an area of land or property is, or is not, at risk of flooding.

3.5. Natural landslides

> A landslide is a movement of a mass of rock, earth or debris down a slope. Landslides can happen as a result of natural processes (e.g. excessive rainfall, coastal or river erosion, lithological/structural failure) or manmade ones (e.g. detrimental alteration of drainage, loading of the slope, removing material from the toe of the slope).
>
> *BGS (2013) pers. comms.*

The Geosure Slope Instability (landslides) data is the most complete and consistent dataset on the susceptibility of locations in England to natural landslides available. The dataset defines the susceptibility of an area to undergo natural landslides, taking into account the local geology and slope of an area along with the geotechnical and structural characteristics of the geological formation. This dataset does not cover man-made landslides or other slope failures.

Risk is usually considered to equate to the probability of a hazardous event multiplied by the consequences if the hazard occurs. The Geosure datasets do not identify the cost (consequences in either monetary,

social or environmental terms) of a particular geological hazard being realised, and therefore cannot consider a measure of risk. Geosure only examines the conditions that leave an area exposed to a hazard.

The Geosure dataset categorises locations according to their level of susceptibility to a particular geological hazard. In the case of landslides, these categories are as follows:

- A: Slope instability problems are not thought to occur but consideration to potential problems of adjacent areas impacting on the site should always be considered.
- B: Slope instability problems are not likely to occur but consideration to potential problems of adjacent areas impacting on the site should always be considered.
- C: Slope instability problems may be present or anticipated. Site investigation should consider specifically the slope stability of the site.
- D: Slope instability problems are probably present or have occurred in the past. Land use should consider specifically the stability of the site.
- E: Slope instability problems almost certainly present and may be active. Significant constraint on land use.

Due to resource pressures, it was only possible to purchase the Geosure Slope instability data for those locations categorised as D or E susceptibility. This equates to a high susceptibility to natural landslides. The proportion of local authority land that is classified under these susceptibility categories is shown in Figure 3.1.

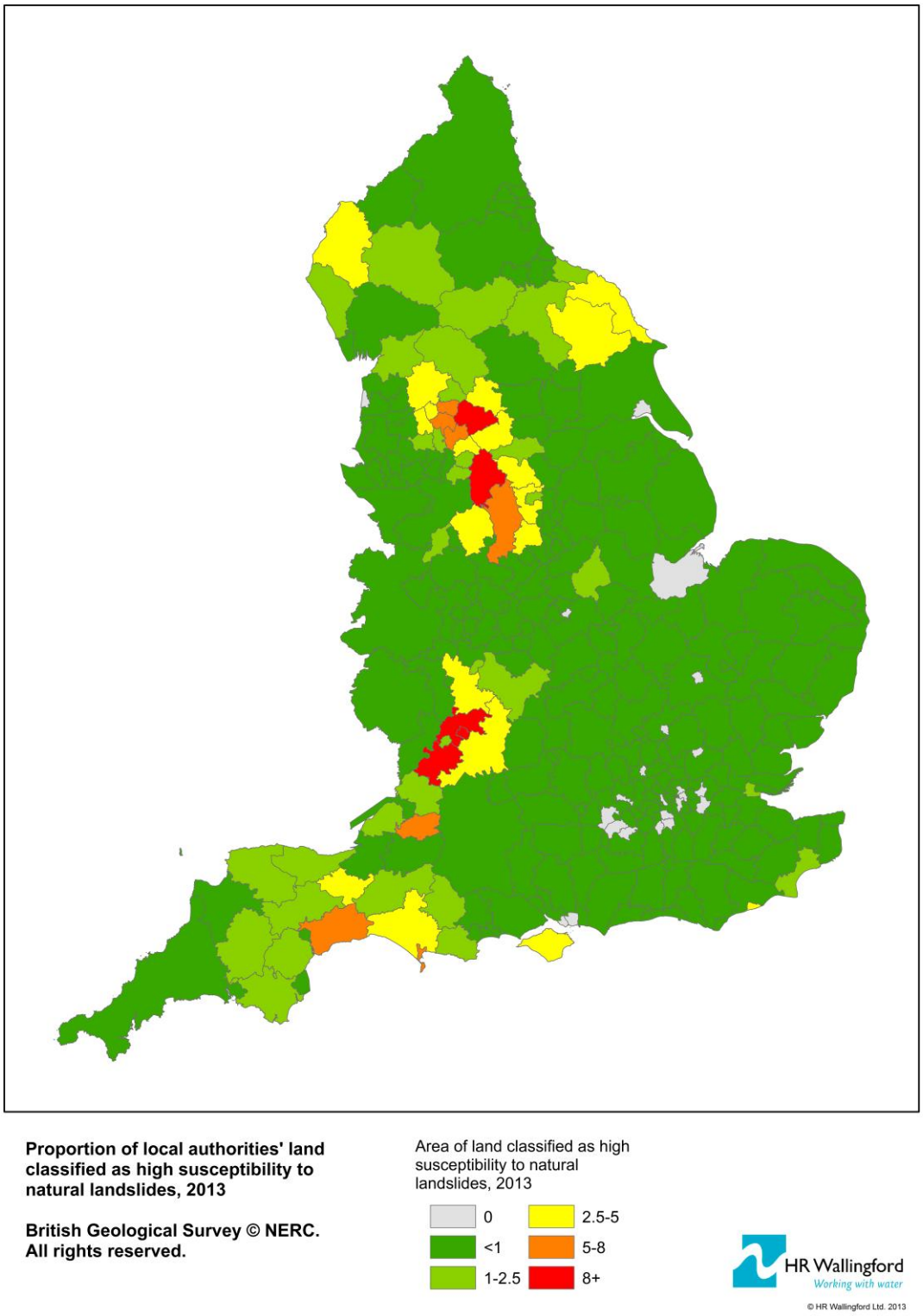

Figure 3.1: Natural landslides, local authority map

Source: n/a

3.6. Shrink-swell subsidence

> Subsidence is a lowering or collapse of the ground. It can be triggered by man-made disturbance or natural phenomena. Subsidence has the potential to cause engineering problems such as damage to foundations, buildings and infrastructure.
>
> *BGS (2013) pers. comms.*

There are a number of natural processes that may lead to subsidence. The Geosure Shrink-swell dataset defines the susceptibility to one type of subsidence only. The shrinking and swelling of clay occurs as a result of changes in the moisture content of clay-rich soils. This soil moisture content may be related to weather variations, vegetation effects (in particular, the growth and removal of trees) and man-made activities (including increasing the use of impermeable paving on previously open areas of land). Swelling pressures can cause heaving or lifting of structures whilst shrinkage can cause differential settlement. This shrink–swell behaviour is the most damaging geohazard in Britain today, costing the economy an estimated £3 billion over the past 10 years (BGS, 2014). It is anticipated that the results of the analysis for shrink-swell subsidence will show a strong regional pattern, with London and the East of England expected to be most susceptible to this type of hazard.

The Geosure dataset categorises locations according to their level of susceptibility to a particular geological hazard. These categories provide a relative and qualitative measure of likelihood but not an absolute measure of how likely shrink-swell subsidence is to occur. In the case of shrink-swell subsidence, these categories are as follows:

- A: Ground conditions predominantly non-plastic.
- B: Ground conditions predominantly low plasticity.
- C: Ground conditions predominantly medium plasticity.
- D: Ground conditions predominantly high plasticity.
- E: Ground conditions predominantly very high plasticity.

Due to resource pressures, it was only possible to purchase the Geosure Shrink-swell data for those locations categorised as D or E susceptibility. This equates to a high susceptibility to shrink-swell subsidence. The proportion of local authority land that is classified under theses susceptibility categories is shown in Figure 3.2. These levels indicate the hazard but this may not directly equate to a similar level of risk. For example, if the properties in a location with predominantly very high plasticity have been built with foundations suitable to withstand changes in ground stability, then the properties will be at a lower level of risk than the level of hazard might suggest.

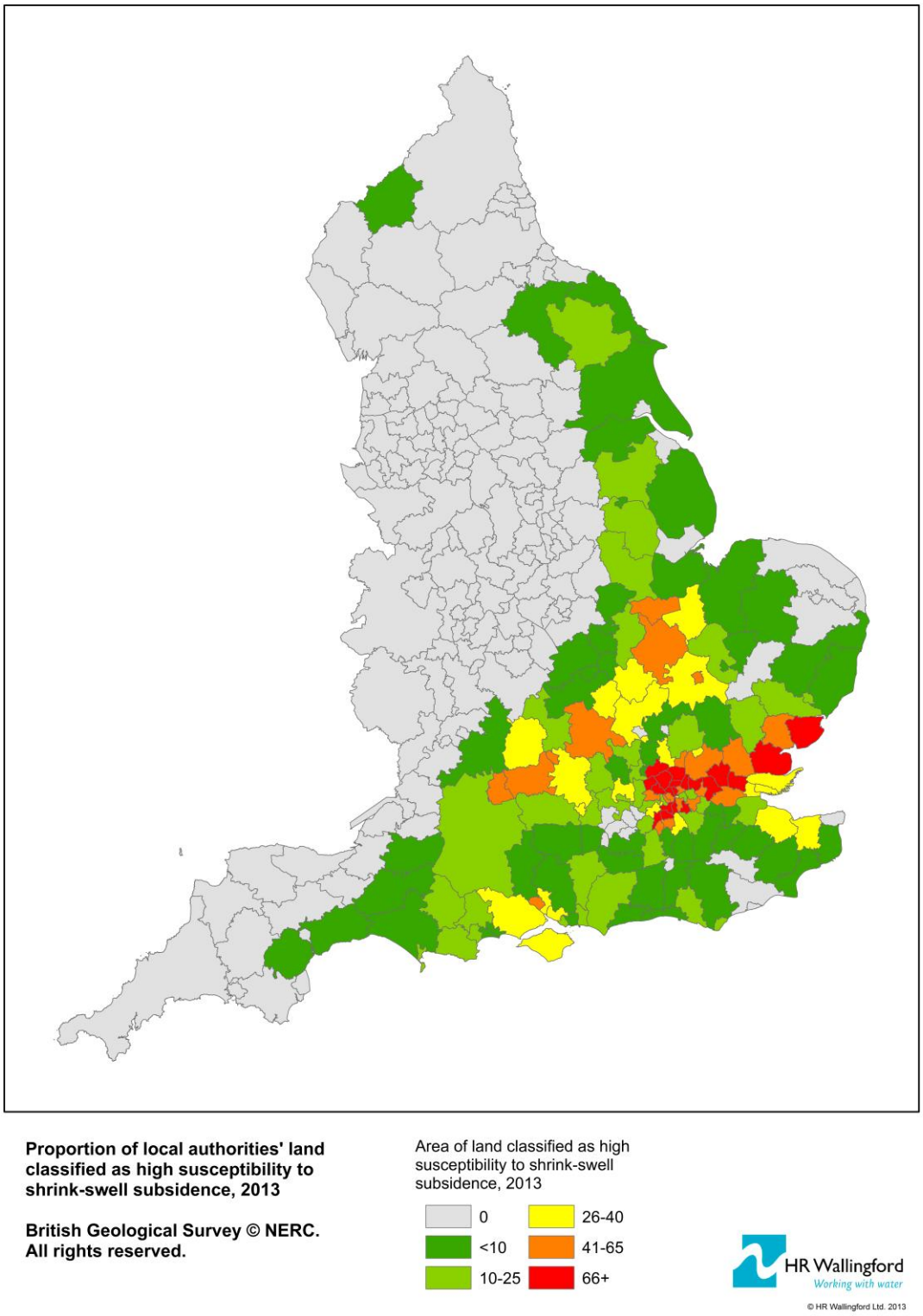

Figure 3.2: Shrink-swell subsidence, local authority map

Source: n/a

Research undertaken by BGS explored the relationship between shrink-swell subsidence and weather (rainfall and temperature) with reference to climate change. Their research indicates that the susceptibility to shrinkage of soil today is influenced by the rainfall of the preceding two-year period. Temperature was also found to be influential as increased temperatures lead to more evaporation and evapotranspiration which, in turn, leads to further drying and shrinking soils (Harrison *et al.*, 2012).

3.7. River scour

The risk of bridge failure, considering failure as the loss of structural integrity due to river processes related to scour, is defined as the probability of failure multiplied by the consequences if such failure happens.

$R = P * C$

The probability of failure has two main components: hazard and vulnerability.

$P = H * V$

The hazard describes the source of potential failure and the vulnerability, the susceptibility of the structure to such hazard. The hazard that undermines piers and abutments is the mobility of the river, both vertically and laterally, that may cause scour. The main hazard considered here is local scour developed around bridge piers (which is identified in the literature as one of the main potential causes of bridge failure, Lagasse *et al.*, 2007). The vulnerability depends mainly on bridge foundation. There are no available datasets at national level that compile this type of information, so it was not possible to assess the vulnerability.

A simple approach to estimate local scour is presented in Gao (2012) as follows:

$ys = (b\ h)^{1/2}$,

where ys is the local scour,

b the width of the bridge pier, and

h the water depth.

As the geometry of the pier, b, is not known, it is not possible to estimate an absolute value of scour. However, it is possible to estimate the increase of scour due to climate change. This is proportional to the square root of the increase in water depth:

$\%\ \text{increase of local scour} = (h_{\text{climatechange}} / h_{\text{current conditions}})^{0.5} - 1$

To estimate the change in velocity and depth that can be expected in the future, extreme river flows were uplifted according to increases in peak flow estimated for the CCRA using the UK Climate Projections 2009. The increased flows were used to estimate the future projections of velocity and depth at each bridge using depth and velocity versus discharge curves calculated using The Conveyance Estimation System for each river reach. The exposure to scour at each bridge was then classified according to the rules presented in Table 3.1.

Table 3.1: Classification of bridge scour risk

Scour exposure	Description of future flow velocity, depth and increase in local scour
High	Bridge cross-sections with flow velocities greater than 0.2 m/s and water depths greater than 1 m and with an increase of local scour greater than 10%. Bridge cross-sections with flow velocities greater than 0.2 m/s and water depths greater than 9 m and with an increase of local scour greater than 8%.
Medium	Bridge cross-sections with flow velocities greater than 0.2 m/s and water depths greater than 1 m and with an increase of local scour between 5 and 10%. Bridge cross-sections with flow velocities greater than 0.2 m/s and water depths greater than 9 m and with an increase of local scour between 3 and 8%.
Low	Bridge cross-sections that do not match the previous criteria.

Source: HR Wallingford.

The criteria above consider the impact of a significant change due to the flow changes, not the absolute risk of scour of the bridge. They are a first attempt to classify the exposure to bridge scour and could be further developed in the future.

The flow velocity equal to 0.2 m/s corresponds to the threshold of movement of a very fine sand. Lower values than this are unlikely to cause significant scour at the bridge locations.

In a scenario with relatively wide bridge piers (b=5 m), water depths lower than 1m are unlikely to develop scour depths greater than 2.5 m, which is considered a typical value of foundation depth and therefore are unlikely to cause significant damage to the bridge.

It has not been possible to determine, in detail, the risk of toe and foundation scour at each bridge due to both the complex engineering and geotechnical data requirements of such a task and the detailed modelling that is required. Furthermore, the assessment has not taken into consideration any changes to river substrate or vegetation.

4. The Indicators

Table 4.1: Indicators of exposure

		Flooding (River and Coastal)	Flooding (groundwater)	Flooding (surface water)	Coastal erosion	Shrink-swell subsidence	Natural landslides	Bridge scour
Education	Schools	✓	✓	✓	✓	✓	✓	
Energy	Substations	✓	✓	✓	✓	✓	✓	
	Power stations	✓	✓	✓	✓	✓		
	Towers				✓	✓	✓	
	Turbines	✓	✓		✓	✓	✓	
	Cable				✓	✓		
	Gas pipes				✓	✓		
Health	Care homes	✓	✓	✓	✓	✓	✓	
	Emergency services	✓	✓	✓	✓	✓	✓	
	GPs	✓	✓	✓	✓	✓		
	Hospitals	✓	✓	✓	✓	✓		
ICT	Data centres	✓	✓	✓	✓	✓	✓	
	Mobile telecommunication masts				✓	✓	✓	
Transport	Railway stations	✓	✓	✓	✓	✓	✓	
	Railway lines	✓	✓	✓	✓	✓	✓	
	Roads	✓	✓	✓	✓	✓	✓	
	Road and rail bridges					✓		✓
Water	Clean water treatment works	✓	✓	✓	✓	✓		
	Waste water treatment works	✓	✓	✓	✓	✓		

Source: ✓present day only was assessed. ✓present day and recent trends or future projections assessed. Not all assessed results are presented in the chapters. See relevant text for more information.

4.1. Education

Data

Department for Education (DfE): 2013 Performance Statistics Spine Data (school location).

DfE: 2013 School Census (number of pupils).

Environment Agency (EA): National Flood Risk Assessment (NaFRA) Spatial Internal Grid 2013 (flooding from rivers or the sea).

EA: National Coastal Erosion Risk Map (NCERM) 2011.

EA: updated Flood Map for Surface Water (2013).

British Geological Survey (BGS): Map of susceptibility to natural landslides. British Geological Survey © NERC. All rights reserved.

BGS: Map of susceptibility to shrink-swell subsidence. British Geological Survey © NERC. All rights reserved.

ESI: Groundwater flooding risk map. ESI Groundwater Flood Risk Map of England and Wales © http://esinternational.com/

4.1.1. Schools

Table 4.2: Total number of schools and pupils in England in this assessment

Totals	Primary	Secondary	All ages schools	Total
Schools	18,077	3,895	2,295	24,267
Pupils	4,455,355	3,249,770	521,635	8,226,760

In order to assess the level of criticality of the educational assets, these results may be grouped by the age and the number of pupils registered at each school. For the purposes of this analysis, schools are separated into three categories:

- Primary schools: For children aged 5-11 years old
- Secondary schools: For children aged 11-18 year olds
- All ages schools: Schools catering for children aged 5-18 years of age and those that were unclassified and did not contain data on age groups.

The asset data used in this assessment is from a reliable source; asset location (postcodes) and criticality information from DfE is collected annually as part of their Consistent Financial Reporting. Whilst the location information is considered accurate, postcodes must be digitised into co-ordinates for the spatial assessment and this introduces some error.

In this analysis, there were 24,267 schools (18,077 primary schools, 3,895 secondary schools and 2,295 all ages schools) educating more than 8,226,760 young people (4,455,355 in primary and 3,249,770 in secondary education and 521,635 attending all ages schools).

Table 4.3: Number (and proportion) of schools exposed to different hazards in England

	Coastal erosion[1]	Groundwater flooding[2]	River and coastal flooding[3]	Surface water flooding[4]	Natural landslides[5]	Shrink-swell subsidence[6]
Primary	7 (0%)	1576 (9%)	1095 (6%)	100 (1%)	11 (0%)	2413 (13%)
Secondary	1 (0%)	303 (8%)	235 (6%)	17 (0%)	1 (0%)	550 (14%)
Other schools*	2 (0%)	178 (8%)	111 (5%)	13 (1%)	0 (0%)	350 (15%)

Notes: **Includes schools for which there was no recorded information on the age of the children that attended the school as well as schools that cater for children aged 5-18 years old.*

Percentages are calculated as a proportion of the total number of assets per criticality category.

[1]No active intervention, long term, 5th percentile scenario

[2]High susceptibility of groundwater flooding, estimated as 1 in 200 years or more frequent.

[3]Present day flooding from rivers or the sea under any likelihood category.

[4]Mid-depth (0.3m<= depth <1.2m; 1 in 1000 year likelihood)

[5]High susceptibility category to natural landslides.

[6]High susceptibility category to shrink-swell subsidence.

Table 4.4: Number (and proportion) of school pupils exposed to different hazards in England

	Coastal erosion[1]	Groundwater flooding[2]	River and coastal flooding[3]	Surface water flooding[4]	Natural landslides[5]	Shrink-swell subsidence[6]
Primary	1,080 (0%)	405,760 (9%)	653,155 (15%)	33,765 (1%)	4,090 (0%)	720,975 (16%)
Secondary	45 (0%)	233,045 (7%)	389,290 (12%)	18,110 (1%)	1,650 (0%)	494,915 (15%)
Other schools*	380 (0%)	45,795 (9%)	44,460 (9%)	3,965 (1%)	930 (0%)	101,045 (19%)

Source: *Includes schools for which there was no recorded information on the age of the children that attended the school as well as schools that cater for children aged 5-18 years old.*

Percentages are calculated as a proportion of the total number of assets per criticality category.

[1]No active intervention, long term, 5th percentile scenario

[2]High susceptibility of groundwater flooding, estimated as 1 in 200 years or more frequent.

[3]Present day flooding from rivers or the sea under any likelihood category.

[4]Mid-depth (0.3m<= depth <1.2m; 1 in 1000 year likelihood)

[5]High susceptibility category to natural landslides.

[6]High susceptibility category to shrink-swell subsidence.

Coastal erosion

The indicator assesses the number and proportion of primary and secondary schools located within locations that are projected to be exposed to coastal erosion over the next 100 years and the number and proportion of assets at risk behind the Shoreline Management Plan policies.

Table 4.3 shows that only a very small proportion of schools are likely to be affected by coastal erosion. Regardless of the scenario, less than 1% of schools are considered to be at risk on a national scale.

Table 4.5: Number (and proportion) of primary, secondary and all ages schools and pupils located in areas that are susceptible to coastal erosion, by UKCP09[7] administrative region

	Primary	Secondary	All ages
East Midlands	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils
East of England	2 (0%) or ~155 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils
London	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils
North East	2 (0%) or ~465 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils
North West	0 (0%) or ~0 pupils	1 (0%) or ~45 pupils	1 (0%) or ~0 pupils
South East England	3 (0%) or ~315 pupils	0 (0%) or ~0 pupils	1 (0%) or ~380 pupils
South West England	1 (0%) or ~155 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils
West Midlands	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils
Yorkshire & Humberside	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils
Total	**8 (0%) or ~1090 pupils**	**1 (0%) or ~45 pupils**	**2 (0%) or ~380 pupils**

*Notes: * Only the No Active Intervention, long term, 5th percentile scenario yielded any results. In other words, all schools in regions that would be lost to erosion under the No Active Intervention policy are presently located in areas of land that benefit from a policy of 'Hold the Line'. Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.*

Flooding (groundwater)

This indicator assesses the number and proportion of primary and secondary schools located in areas that are of high susceptibility to groundwater flooding. A small number of schools are located in such areas. The level of susceptibility to this hazard does not change significantly with school type. Table 4.6 shows the distribution of high susceptibility to groundwater flooding across the regions in England.

Table 4.6: Number (and proportion) of primary, secondary and all ages schools and pupils located in areas that are of high susceptibility to groundwater flooding, by UKCP09 administrative region

Region	Primary	Secondary	Other schools
East Midlands	155 (9%) or ~33890 pupils	31 (9%) or ~21815 pupils	20 (10%) or ~2540 pupils
East of England	185 (9%) or ~39810 pupils	46 (10%) or ~31655 pupils	13 (6%) or ~4345 pupils
London	424 (20%) or ~151705 pupils	87 (16%) or ~73365 pupils	52 (14%) or ~18415 pupils
North East	20 (2%) or ~3735 pupils	6 (3%) or ~4085 pupils	1 (1%) or ~160 pupils
North West	112 (4%) or ~23445 pupils	22 (4%) or ~15070 pupils	10 (3%) or ~1620 pupils
South East	325 (12%) or ~79270 pupils	58 (10%) or ~55620 pupils	53 (11%) or ~14500 pupils
South West	142 (7%) or ~27865 pupils	23 (6%) or ~15895 pupils	12 (5%) or ~1420 pupils
West Midlands	128 (7%) or ~30120 pupils	19 (4%) or ~11960 pupils	9 (4%) or ~1735 pupils
Yorkshire & Humberside	85 (5%) or ~15920 pupils	11 (3%) or ~3580 pupils	8 (5%) or ~1060 pupils
Total	**1576 (9%) or ~405760 pupils**	**303 (8%) or ~233045 pupils**	**178 (8%) or ~45795 pupils**

Notes: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

[7] http://ukclimateprojections.metoffice.gov.uk/

Flooding (river and coastal)

This indicator quantifies the number and proportion of primary and secondary schools within the floodplain by flood likelihood category and takes into account the presence, performance and condition of raised flood defences. The results of the exposure assessment for schools and pupils exposed to any likelihood category of flooding from rivers or the sea are shown in Table 4.7.

Table 4.7: Number (and proportion) of primary, secondary and all ages schools and pupils located in areas that are currently at any likelihood category of flooding from rivers or the sea, by UKCP09 administrative region

Region	Primary Schools	Secondary schools	All ages Schools
East Midlands	141 (8%) or ~73055 pupils	34 (10%) or ~62720 pupils	13 (7%) or ~2800 pupils
East of England	100 (5%) or ~49480 pupils	25 (5%) or ~32140 pupils	8 (3%) or ~3935 pupils
London	241 (11%) or ~202490 pupils	50 (9%) or ~90420 pupils	35 (9%) or ~20170 pupils
North East	9 (1%) or ~3480 pupils	0 (0%) or ~0 pupils	1 (1%) or ~2145 pupils
North West	100 (4%) or ~44520 pupils	36 (7%) or ~48615 pupils	17 (6%) or ~3695 pupils
South East England	152 (5%) or ~86250 pupils	23 (4%) or ~40660 pupils	11 (2%) or ~3925 pupils
South West England	106 (5%) or ~49900 pupils	20 (5%) or ~44805 pupils	11 (5%) or ~2515 pupils
West Midlands	39 (2%) or ~17120 pupils	13 (3%) or ~12460 pupils	2 (1%) or ~250 pupils
Yorkshire & Humberside	207 (11%) or ~126860 pupils	34 (10%) or ~57470 pupils	13 (8%) or ~5025 pupils
Total	**1095 (6%) or ~653155 pupils**	**235 (6%) or ~389290 pupils**	**111 (5%) or ~44460 pupils**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

The national results for this indicator are presented in Table 4.8 for schools exposed to a high likelihood of flooding from rivers or the sea.

Table 4.8: Number (and proportion) of primary, secondary and all ages schools and pupils located in areas that are currently at high likelihood of flooding from rivers or the sea, by UKCP09 administrative region

	Current (2011-2012)		
East Midlands	11 (1%) or ~6950 pupils	1 (0%) or ~2130 pupils	1 (1%) or ~20 pupils
East of England	9 (0%) or ~2725 pupils	1 (0%) or ~2330 pupils	0 (0%) or ~0 pupils
London	8 (0%) or ~7620 pupils	0 (0%) or ~0 pupils	2 (1%) or ~365 pupils
North East	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils
North West	11 (0%) or ~3970 pupils	2 (0%) or ~6690 pupils	1 (0%) or ~70 pupils
South East	22 (1%) or ~13400 pupils	4 (1%) or ~3720 pupils	1 (0%) or ~365 pupils
South West	20 (1%) or ~8030 pupils	0 (0%) or ~0 pupils	2 (1%) or ~390 pupils
West Midlands	7 (0%) or ~2900 pupils	2 (0%) or ~1005 pupils	0 (0%) or ~0 pupils
Yorkshire & Humberside	17 (1%) or ~5435 pupils	2 (1%) or ~1870 pupils	0 (0%) or ~0 pupils
Total	**105 (1%) or ~51030 pupils**	**12 (0%) or ~17745 pupils**	**7 (0%) or ~1210 pupils**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.9: Number (and proportion) of primary, secondary and all ages schools and pupils located in areas that are projected to be at high likelihood of flooding from rivers or the sea, in the 2020s and 2050s, by UKCP09 administrative region

	2020s Medium p50			2050s Medium p50		
Region	**Pri**	**Sec**	**All**	**Pri**	**Sec**	**All**
East Midlands	18 (1%) or ~9380 pupils	1 (0%) or ~2130 pupils	1 (1%) or ~20 pupils	29 (2%) or ~17350 pupils	4 (1%) or ~11470 pupils	2 (1%) or ~620 pupils
East of England	12 (1%) or ~4455 pupils	1 (0%) or ~2330 pupils	0 (0%) or ~0 pupils	14 (1%) or ~4725 pupils	1 (0%) or ~2330 pupils	0 (0%) or ~0 pupils
London	8 (0%) or ~7620 pupils	0 (0%) or ~0 pupils	2 (1%) or ~365 pupils	8 (0%) or ~7620 pupils	0 (0%) or ~0 pupils	2 (1%) or ~365 pupils
North East	4 (0%) or ~1505 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	4 (0%) or ~1505 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils
North West	16 (1%) or ~6240 pupils	5 (1%) or ~9470 pupils	5 (2%) or ~90 pupils	18 (1%) or ~6670 pupils	5 (1%) or ~9470 pupils	5 (2%) or ~90 pupils
South East	24 (1%) or ~14420 pupils	4 (1%) or ~3720 pupils	1 (0%) or ~365 pupils	33 (1%) or ~18285 pupils	5 (1%) or ~8440 pupils	1 (0%) or ~365 pupils
South West	27 (1%) or ~11800 pupils	1 (0%) or ~525 pupils	3 (1%) or ~1130 pupils	37 (2%) or ~19415 pupils	5 (1%) or ~9175 pupils	5 (2%) or ~1150 pupils
West Midlands	9 (0%) or ~3475 pupils	3 (1%) or ~4225 pupils	0 (0%) or ~0 pupils	9 (0%) or ~3475 pupils	3 (1%) or ~4225 pupils	0 (0%) or ~0 pupils
Yorkshire & Humberside	29 (2%) or ~11890 pupils	3 (1%) or ~1875 pupils	0 (0%) or ~0 pupils	48 (3%) or ~24230 pupils	9 (3%) or ~15335 pupils	2 (1%) or ~895 pupils
Total	**147 (1%) or ~70785 pupils**	**18 (0%) or ~24275 pupils**	**12 (1%) or ~1970 pupils**	**200 (1%) or ~103275 pupils**	**32 (1%) or ~60445 pupils**	**17 (1%) or ~3485 pupils**

Source: Pri – Primary; Sec – Secondary; All – All ages schools. Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.10: Number (and proportion) of primary, secondary and all ages schools located in areas that are projected to be at high likelihood of flooding from rivers or the sea, in the 2080s, by UKCP09 administrative region

Region	2080s Low p10 - High p90		
	Primary	Secondary	All ages Schools
East Midlands	24 (1%) - 112 (7%)	2 (1%) - 26 (8%)	1 (1%) - 11 (6%)
East of England	12 (1%) - 81 (4%)	1 (0%) - 19 (4%)	0 (0%) - 7 (3%)
London	8 (0%) - 235 (11%)	0 (0%) - 49 (9%)	2 (1%) - 35 (9%)
North East	4 (0%) - 9 (1%)	0 (0%) - 0 (0%)	0 (0%) - 1 (1%)
North West	15 (1%) - 90 (3%)	4 (1%) - 29 (5%)	5 (2%) - 11 (4%)
South East	28 (1%) - 145 (5%)	4 (1%) - 21 (4%)	1 (0%) - 10 (2%)
South West	31 (2%) - 100 (5%)	3 (1%) - 16 (4%)	4 (2%) - 11 (5%)
West Midlands	7 (0%) - 23 (1%)	2 (0%) - 8 (2%)	0 (0%) - 0 (0%)
Yorkshire & Humberside	34 (2%) - 204 (11%)	3 (1%) - 33 (9%)	0 (0%) - 13 (8%)
Total	**163 (1%) - 999 (6%)**	**19 (0%) - 201 (5%)**	**13 (1%) - 99 (4%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.11: Number (and proportion) of primary, secondary and all ages pupils located in areas that are projected to be at high likelihood of flooding from rivers or the sea, in the 2080s, by UKCP09 administrative region

Region	2080s Low p10 - High p90		
	Primary pupils	Secondary pupils	All ages pupils
East Midlands	15115 (4%) - 55615 (15%)	4110 (1%) - 47400 (16%)	20 (0%) - 2590 (9%)
East of England	4585 (1%) - 34725 (7%)	2330 (1%) - 16615 (4%)	0 (0%) - 3930 (6%)
London	7620 (1%) - 195780 (26%)	0 (0%) - 89475 (19%)	365 (0%) - 20170 (19%)
North East	1505 (1%) - 3480 (2%)	0 (0%) - 0 (0%)	0 (0%) - 2145 (14%)
North West	5830 (1%) - 37275 (6%)	8640 (2%) - 42090 (10%)	90 (0%) - 405 (1%)
South East	15920 (2%) - 81590 (12%)	3720 (1%) - 37160 (7%)	365 (0%) - 3745 (3%)
South West	16245 (4%) - 47850 (12%)	8610 (3%) - 39845 (12%)	410 (1%) - 2515 (5%)
West Midlands	2900 (1%) - 10480 (2%)	1005 (0%) - 6820 (2%)	0 (0%) - 0 (0%)
Yorkshire & Humberside	15085 (3%) - 125435 (27%)	2385 (1%) - 57055 (18%)	0 (0%) - 5025 (15%)
Total	**84805 (2%) - 592230 (13%)**	**30800 (1%) - 336460 (10%)**	**1250 (0%) - 40525 (8%)**

As shown in Table 4.8, Table 4.9, Table 4.10 and Table 4.11 the number and proportion of schools and pupils, across the different types, that are located in areas susceptible to flooding is low. Even in the most extreme projections, this figure does not exceed 6% of schools in England. In the East Midlands and Yorkshire & Humberside, the project increase in exposure is above the national average.

Flooding (surface water)

This indicator quantifies the number and proportion of primary and secondary schools located in areas susceptible to surface water flooding in a 1:30 year, 1:100 year and 1:1000 year rainfall event for depths between 0.3m and 1.2m and for depths greater than 1.2m.

Table 4.13 shows the number of schools located in areas susceptible to surface water flooding in excess of 30 cm deep. The number of schools that may be affected by this hazard is very low. Other depths were investigated. All depths indicate minimal exposure to this hazard on a national scale, however at a local scale, the impacts from such a hazard may be more significant.

Table 4.12: Number (and proportion) of primary, secondary and all ages schools and pupils located in areas that are susceptible to mid-depth surface water flooding, by UKCP09 administrative region

	Mid-depth: 0.3m<= depth <1.2m 3.3% likelihood			Mid-depth: 0.3m<= depth <1.2m 0.1% likelihood		
Region	**Primary**	**Secondary**	**All ages Schools**	**Primary**	**Secondary**	**All ages Schools**
East Midlands	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	1 (1%) or ~190 pupils	14 (1%) or ~3415 pupils	1 (0%) or ~1020 pupils	0 (0%) or ~0 pupils
East of England	1 (0%) or ~75 pupils	1 (0%) or ~680 pupils	0 (0%) or ~0 pupils	21 (1%) or ~4020 pupils	4 (1%) or ~2295 pupils	2 (1%) or ~490 pupils
London	4 (0%) or ~1115 pupils	1 (0%) or ~720 pupils	0 (0%) or ~0 pupils	38 (2%) or ~12040 pupils	8 (1%) or ~5170 pupils	11 (3%) or ~2590 pupils
North East	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	1 (0%) or ~290 pupils	1 (0%) or ~1055 pupils	0 (0%) or ~0 pupils
North West	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	13 (0%) or ~2775 pupils	4 (1%) or ~4670 pupils	4 (1%) or ~190 pupils
South East England	1 (0%) or ~315 pupils	1 (0%) or ~20 pupils	0 (0%) or ~0 pupils	18 (1%) or ~3995 pupils	0 (0%) or ~0 pupils	2 (0%) or ~530 pupils
South West England	1 (0%) or ~190 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	6 (0%) or ~940 pupils	2 (1%) or ~1565 pupils	0 (0%) or ~0 pupils
West Midlands	1 (0%) or ~220 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	7 (0%) or ~2380 pupils	5 (1%) or ~1385 pupils	1 (0%) or ~165 pupils
Yorkshire & Humberside	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	13 (1%) or ~3910 pupils	1 (0%) or ~950 pupils	0 (0%) or ~0 pupils
Total	**8 (0%) or ~1915 pupils**	**3 (0%) or ~1420 pupils**	**1 (0%) or ~190 pupils**	**131 (1%) or ~33765 pupils**	**26 (1%) or ~18110 pupils**	**20 (1%) or ~3965 pupils**

Source: Percentages are calculated as a proportion of the total number of assets, per criticality category, per UKCP09 administrative region.

Table 4.13: Number (and proportion) of primary, secondary and all ages schools and pupils located in areas that are susceptible to very deep surface water flooding, by UKCP09 administrative region

Region	Very deep: Depth >1.20m 3.3% likelihood			Very deep: Depth >1.20m 0.1% likelihood		
	Primary	Secondary	All ages Schools	Primary	Secondary	All ages Schools
East Midlands	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	1 (0%) or ~185 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils
East of England	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils
London	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	7 (0%) or ~2070 pupils	2 (0%) or ~1520 pupils	2 (1%) or ~1035 pupils
North East	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils
North West	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	1 (0%) or ~320 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils
South East England	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	1 (0%) or ~315 pupils	1 (0%) or ~20 pupils	0 (0%) or ~0 pupils
South West England	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	1 (0%) or ~70 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils
West Midlands	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	1 (0%) or ~220 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils
Yorkshire & Humberside	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	1 (0%) or ~155 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils
Total	**0 (0%) or ~0 pupils**	**0 (0%) or ~0 pupils**	**0 (0%) or ~0 pupils**	**13 (0%) or ~3335 pupils**	**3 (0%) or ~1540 pupils**	**2 (0%) or ~1035 pupils**

Source: Percentages are calculated as a proportion of the total number of assets, per criticality category, per UKCP09 administrative region.

Natural landslides

This indicator quantifies the number and proportion of primary and secondary schools located in areas of high susceptibility to natural landslides where; slope instability problems are probably present or have occurred in the past or slope instability problems are almost certainly present and may be active. Such issues with slope stability may present a significant constraint on the use of land or any development would need to give specific consideration to the stability of the site.

Less than 0.5% of schools (fewer than 5000 pupils) in England are located in areas of high susceptibility to natural landslides. This hazard is therefore not likely to be a significant risk on a national scale.

Shrink-swell subsidence

This indicator quantifies the number and proportion of primary and secondary schools located in areas of high susceptibility to shrink-swell subsidence where ground conditions are of predominantly high or very high plasticity.

The results of the exposure analysis are shown in Table 4.14.

Table 4.14: Number (and proportion) of primary, secondary and all ages schools and pupils located in areas of high susceptibility to shrink-swell subsidence

Region	Primary Schools	Secondary schools	All ages Schools
East Midlands	27 (2%) or ~4235 pupils	5 (1%) or ~5515 pupils	3 (2%) or ~505 pupils
East of England	562 (26%) or ~138740 pupils	126 (27%) or ~108655 pupils	52 (22%) or ~15205 pupils
London	1230 (57%) or ~427610 pupils	297 (55%) or ~265655 pupils	209 (55%) or ~61350 pupils
North East	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils
North West	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils
South East England	460 (16%) or ~118325 pupils	96 (17%) or ~91760 pupils	74 (15%) or ~22870 pupils
South West England	121 (6%) or ~30405 pupils	24 (6%) or ~21865 pupils	11 (5%) or ~1060 pupils
West Midlands	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils	0 (0%) or ~0 pupils
Yorkshire & Humberside	13 (1%) or ~1660 pupils	2 (1%) or ~1465 pupils	1 (1%) or ~55 pupils
Total	**2413 (13%) or ~720975 pupils**	**550 (14%) or ~494915 pupils**	**350 (15%) or ~101045 pupils**

Source: All ages schools also includes those school for which there was no data on the age of the pupils in attendance. Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

The analysis indicates that up to 15% of schools in England are located in areas susceptible to shrink-swell subsidence. This type of hazard is of most significance for those located in London, the East of England and the South East of England, (presented in Figure 4.1) , which corresponds to those areas of the country with clay soil types.

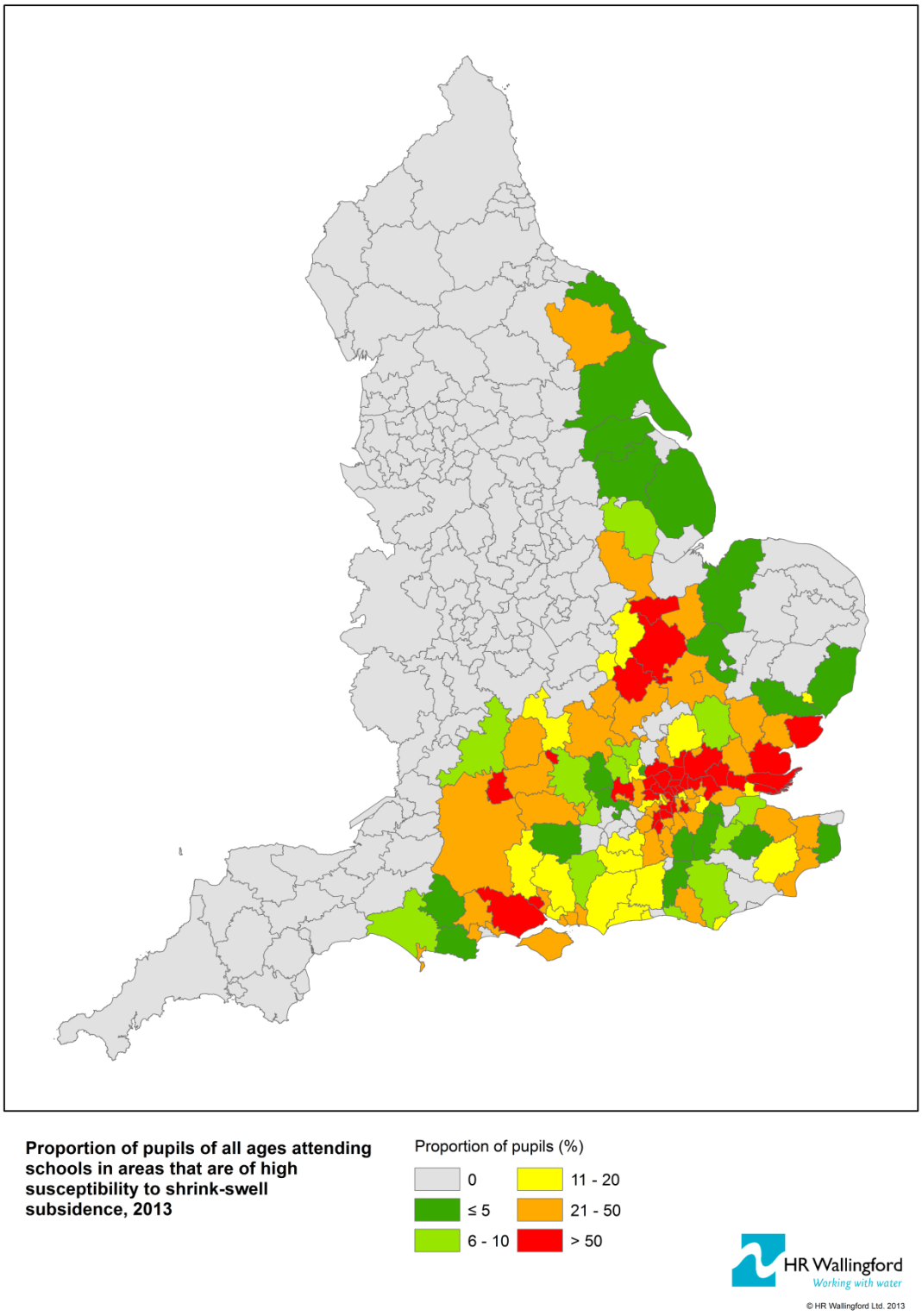

Figure 4.1: Proportion of pupils in schools located in areas of high susceptibility to shrink-swell subsidence

4.2. Energy

Data

National Grid: Electricity transmission substations, underground electricity cable, towers locations (2013).

Energy Networks Association: Substations in a floodplain.

National Grid Distribution, Wales and West Utilities, Southern Gas Networks and Northern Gas Networks: Underground gas pipe location, with the help of the Health and Safety Laboratory (2013).

Renewable UK: Wind farm location (2013).

Environment Agency (EA): Power stations locations (derived from IPCC licences) (2010).

EA: NaFRA Spatial Internal Grid 2013 (flooding from rivers or the sea).

EA: NCERM 2011 (coastal erosion).

EA: updated Flood Map for Surface Water (2013).

British Geological Survey (BGS): Map of susceptibility to natural landslides. British Geological Survey © NERC. All rights reserved.

BGS: Map of susceptibility to shrink-swell subsidence. British Geological Survey © NERC. All rights reserved.

ESI: Groundwater flooding risk map. ESI Groundwater Flood Risk Map of England and Wales © http://esinternational.com/

4.2.1. Electricity sub-stations

For exposure to flooding from rivers or the sea, a subset of Distribution Network Operators (DNO) substation locations data obtained from the ENA has been used in the exposure analysis.

In order to assess the level of criticality of the electricity sub-stations at risk, the substations have been categorised according to their voltage and therefore the approximate numbers of customers they serve. The categories adopted follow those specified in the Multi-Coloured Manual (2013), which are shown in Table 4.16. Data from ENA do not include distribution sub-stations. There are around 230,000 ground-mounted and 350,000 pole mounted (frequently 4.3m from ground level) distribution substations in the UK. Such substations serve their immediate surrounding and therefore the homes and businesses in their vicinity are likely to be exposed to the same hazards. For example, they may be exposed to flooding simultaneously with local residential and non-residential buildings.

Table 4.15: Total number of substations, from different sources, used in this analysis

Source	Number of substations
Energy Networks Association	671
National Grid	429

Source: Various.

Although there are limitations with the datasets as discussed above, the location information offered by all datasets is of high quality.

Table 4.16: Criticality categorisation of electricity substations from ENA data obtained

Sub-station type	Typical physical size	Typical voltage transformation levels	Approximate number in the ENA dataset obtained*	Typical number of customers supplied
Grid (super grid)	250m x 250m	400kV to 132kV	33	200,000 to 500,000
Grid (bulk supply point)	75m x 75m	132kV to 33kV	155	50,000 to 125,000
Primary	25m x 25m	66/33kV to 11/6.6kV	423	5,000 to 30,000
Unclassified	Unknown	Unknown	42	Unknown
Extra high voltage switch stations	Unknown	Unknown	17	Unknown
High voltage switch stations	Unknown	Unknown	1	Unknown

Notes: **Numbers based upon the sub-station information supplied by the Energy Networks Association for England only. The number of substations of different types in England, especially distribution substations is much greater than is available in the datasets used.*

Data includes high voltage and extra high voltage switch stations. There are also sub-stations where the voltage information is missing or incomplete. In these cases, the stations have been recorded as unclassified.

Table 4.17: Number (and proportion) of electricity sub-stations exposed to different hazards in England

Dataset	River and coastal flooding[1]	Surface water flooding[2]
ENA	303 (45%)	81 (12%)

Notes: [1]*Present day flooding from rivers or the sea under any likelihood category.*

[2]*Mid-depth (0.3m<= depth <1.2m; 1 in 1000 year likelihood)*

Flooding (river and coastal)

This indicator quantifies the number and proportion of electricity substations within the floodplain by flood likelihood category and takes into account the presence, performance and condition of raised flood defences.

The results of the exposure assessment to any likelihood category of flooding from rivers or the sea are shown in Table 4.18.

Table 4.18: Number (and proportion) of electricity substations located in areas that are at any likelihood category of flooding from rivers or the sea, by UKCP09 administrative region

Region	HV Sw Stn	EHV Sw Stn	Primary	Grid (bulk supply point)	Grid (super grid)	Unclassified
East Midlands	0 (0%)	1 (100%)	35 (100%)	11 (85%)	0 (0%)	0 (0%)
East of England	0 (0%)	1 (100%)	7 (32%)	0 (0%)	0 (0%)	7 (58%)
London	0 (0%)	0 (0%)	1 (17%)	0 (0%)	0 (0%)	11 (48%)
North East England	0 (0%)	0 (0%)	5 (23%)	2 (11%)	0 (0%)	0 (0%)
North West England	0 (0%)	2 (50%)	36 (24%)	8 (19%)	0 (0%)	0 (0%)
South East England	0 (0%)	0 (0%)	29 (54%)	3 (33%)	0 (0%)	5 (71%)

Region	HV Sw Stn	EHV Sw Stn	Primary	Grid (bulk supply point)	Grid (super grid)	Unclassified
South West England	0 (0%)	0 (0%)	36 (69%)	15 (94%)	0 (0%)	0 (0%)
West Midlands	0 (0%)	0 (0%)	8 (89%)	5 (71%)	0 (0%)	0 (0%)
Yorkshire & Humberside	0 (0%)	2 (33%)	43 (58%)	19 (38%)	11 (50%)	0 (0%)
Total	**0 (0%)**	**6 (35%)**	**200 (47%)**	**63 (41%)**	**11 (33%)**	**23 (55%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

The results of the exposure assessment to a high likelihood of flooding from rivers or the sea using are shown in Table 4.19 and Table 4.20.

Table 4.19: Number (and proportion) of electricity substations, by criticality type, located in areas that are at high current likelihood of flooding from rivers or the sea, by UKCP09 administrative region

Region	Current (2011-2012)						
	HV Sw Stn	EHV Sw Stn	Primary	Grid (bulk supply point)	Grid (super grid)	Unclassified	Total
East Midlands	0 (0%)	1 (100%)	4 (11%)	0 (0%)	0 (0%)	0 (0%)	5 (10%)
East of England	0 (0%)	0 (0%)	2 (9%)	0 (0%)	0 (0%)	0 (0%)	2 (6%)
London	0 (0%)	0 (0%)	1 (17%)	0 (0%)	0 (0%)	1 (4%)	2 (7%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	10 (7%)	2 (5%)	0 (0%)	0 (0%)	12 (6%)
South East	0 (0%)	0 (0%)	9 (17%)	1 (11%)	0 (0%)	1 (14%)	11 (16%)
South West	0 (0%)	0 (0%)	11 (21%)	5 (31%)	0 (0%)	0 (0%)	16 (24%)
West Midlands	0 (0%)	0 (0%)	2 (22%)	0 (0%)	0 (0%)	0 (0%)	2 (13%)
Yorkshire & Humberside	0 (0%)	0 (0%)	4 (5%)	2 (4%)	1 (5%)	0 (0%)	7 (5%)
Total	**0 (0%)**	**1 (6%)**	**43 (10%)**	**10 (6%)**	**1 (3%)**	**2 (5%)**	**57 (8%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.20: Number (and proportion) of electricity substations, of any criticality type, located in areas that are at high likelihood of flooding from rivers or the sea, by UKCP09 administrative region now and projected into the future.

Region	Current (2011-2012)	2020s	2050s	2080s	
		Medium p50	Medium p50	Low p10 - High p90	
East Midlands	5 (10%)	7 (14%)	11 (22%)	9 (18%)	40 (82%)
East of England	2 (6%)	3 (9%)	4 (11%)	4 (11%)	14 (40%)
London	2 (7%)	2 (7%)	4 (14%)	3 (10%)	12 (41%)
North East	0 (0%)	2 (4%)	3 (5%)	3 (5%)	7 (13%)
North West	12 (6%)	13 (7%)	13 (7%)	13 (7%)	40 (20%)

Region	Current	2020s	2050s	2080s	
South East England	11 (16%)	12 (17%)	15 (21%)	15 (21%)	37 (53%)
South West England	16 (24%)	22 (32%)	26 (38%)	21 (31%)	47 (69%)
West Midlands	2 (13%)	2 (13%)	2 (13%)	2 (13%)	8 (50%)
Yorkshire & Humberside	7 (5%)	21 (14%)	23 (15%)	15 (10%)	70 (46%)
Total	**57 (8%)**	**84 (13%)**	**101 (15%)**	**85 (13%)**	**275 (41%)**

Source: Percentages are calculated as a proportion of the total number of assets, per UKCP09 administrative region.

Licensed Electricity Transmission and Distribution Companies report to OFGEM regarding how the risk to these assets is being reduced e.g. by asset level measures. In their reporting, around three-quarters of this subset of assets have had some sort of protection put in place already. Therefore, this analysis should be interpreted with extreme caution as this indicator measures potential exposure and not vulnerability to flooding from rivers and the sea. The flood resilience activities undertaken by energy companies have not been included in this assessment.

Flooding (surface water)

This indicator quantifies the number and proportion of electricity substations located in areas susceptible to surface water flooding in a 1:30 year, 1:100 year and 1:1000 year rainfall event for depths of between 0.3m and 1.2m and for depths greater than 1.2m.

The results of the exposure assessment are shown in Table 4.21, Table 4.22, Table 4.23 and Table 4.24. A low proportion of substations are exposed to this hazard.

Table 4.21: Number (and proportion) of electricity substations located in areas that are susceptible to surface water flooding, by UKCP09 administrative region

Region	Mid-depth: 0.3m<= depth <1.2m 3.3% likelihood	Mid-depth: 0.3m<= depth <1.2m 0.1% likelihood	Very deep: Depth >1.20m 3.3% likelihood	Very deep: Depth >1.20m 0.1% likelihood
East Midlands	1 (2%)	7 (14%)	0 (0%)	1 (2%)
East of England	0 (0%)	2 (6%)	0 (0%)	0 (0%)
London	0 (0%)	2 (7%)	0 (0%)	1 (3%)
North East	0 (0%)	3 (5%)	0 (0%)	0 (0%)
North West	6 (3%)	23 (12%)	0 (0%)	5 (3%)
South East England	1 (1%)	15 (21%)	0 (0%)	1 (1%)
South West England	3 (4%)	8 (12%)	0 (0%)	3 (4%)
West Midlands	0 (0%)	3 (19%)	0 (0%)	0 (0%)
Yorkshire & Humberside	1 (1%)	18 (12%)	0 (0%)	3 (2%)
Total	**12 (2%)**	**81 (12%)**	**0 (0%)**	**14 (2%)**

Source: Percentages are calculated as a proportion of the total number of assets, per UKCP09 administrative region.

Table 4.22: Number (and proportion) of electricity substations, of different criticality categories, located in areas that are susceptible to mid-depth surface water flooding, with a likelihood of 3.3%, by UKCP09 administrative region

	Mid-depth: 0.3m<= depth <1.2m						
	3.3% likelihood						
Region	HV Sw Stn	EHV Sw Stn	Primary	Grid (bulk supply point)	Grid (super grid)	Unclassified	Total
East Midlands	0 (0%)	0 (0%)	0 (0%)	1 (8%)	0 (0%)	0 (0%)	1 (2%)
East of England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
London	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	4 (3%)	2 (5%)	0 (0%)	0 (0%)	6 (3%)
South East England	0 (0%)	0 (0%)	1 (2%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)
South West England	0 (0%)	0 (0%)	3 (6%)	0 (0%)	0 (0%)	0 (0%)	3 (4%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (5%)	0 (0%)	1 (1%)
Total	**0 (0%)**	**0 (0%)**	**8 (2%)**	**3 (2%)**	**1 (3%)**	**0 (0%)**	**12 (2%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.23: Number (and proportion) of electricity substations, of different criticality categories, located in areas that are susceptible to mid-depth surface water flooding, with a likelihood of 0.1%, by UKCP09 administrative region

	Mid-depth: 0.3m<= depth <1.2m						
	0.1% likelihood						
Region	HV Sw Stn	EHV Sw Stn	Primary	Grid (bulk supply point)	Grid (super grid)	Unclassified	Total
East Midlands	0 (0%)	0 (0%)	6 (17%)	1 (8%)	0 (0%)	0 (0%)	7 (14%)
East of England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (17%)	2 (6%)
London	0 (0%)	0 (0%)	1 (17%)	0 (0%)	0 (0%)	1 (4%)	2 (7%)
North East	0 (0%)	0 (0%)	2 (9%)	1 (6%)	0 (0%)	0 (0%)	3 (5%)
North West	1 (100%)	1 (25%)	15 (10%)	6 (14%)	0 (0%)	0 (0%)	23 (12%)
South East England	0 (0%)	0 (0%)	13 (24%)	2 (22%)	0 (0%)	0 (0%)	15 (21%)
South West England	0 (0%)	0 (0%)	8 (15%)	0 (0%)	0 (0%)	0 (0%)	8 (12%)
West Midlands	0 (0%)	0 (0%)	1 (11%)	2 (29%)	0 (0%)	0 (0%)	3 (19%)
Yorkshire & Humberside	0 (0%)	0 (0%)	12 (16%)	6 (12%)	0 (0%)	0 (0%)	18 (12%)
Total	**1 (100%)**	**1 (6%)**	**58 (14%)**	**18 (12%)**	**0 (0%)**	**3 (7%)**	**81 (12%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.24: Number (and proportion) of electricity substations, of different criticality categories, located in areas that are susceptible to very deep surface water flooding, with a likelihood of 3.3%, by UKCP09 administrative region

Region	Very deep: Depth >1.20m						
	0.1% likelihood						
	HV Sw Stn	EHV Sw Stn	Primary	Grid (bulk supply point)	Grid (super grid)	Unclassified	Total
East Midlands	0 (0%)	0 (0%)	1 (3%)	0 (0%)	0 (0%)	0 (0%)	1 (2%)
East of England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
London	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (4%)	1 (3%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	4 (3%)	1 (2%)	0 (0%)	0 (0%)	5 (3%)
South East England	0 (0%)	0 (0%)	1 (2%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)
South West England	0 (0%)	0 (0%)	3 (6%)	0 (0%)	0 (0%)	0 (0%)	3 (4%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	0 (0%)	0 (0%)	2 (3%)	0 (0%)	1 (5%)	0 (0%)	3 (2%)
Total	**0 (0%)**	**0 (0%)**	**11 (3%)**	**1 (1%)**	**1 (3%)**	**1 (2%)**	**14 (2%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

4.2.2. Power stations

In order to assess the level of criticality of power stations, they are categorised by installed capacity (MW). The categories of installed capacity of power stations varies in the literature, therefore the categories used here are based upon making the number of power stations of different sizes broadly similar:

- Large: >1000MW
- Medium: 100 – 999MW
- Small: <99MW.

Table 4.25: Total number of power stations in this assessment

MW category	Small	Medium	Large	Total
Power stations	35	34	26	95

In this analysis, there were 95 power stations in England, 35 fall into the small, 34 in the medium and 26 in the large category. The power stations included are all those that are over 1MW capacity that were operational at the end of May 2010. This includes all types of power station including, but not limited to, nuclear, coal, oil, biomass and renewables. The results present the *potential* exposure of power stations to the assessed hazards and not their *actual* vulnerability once mitigating measures have been taken into account.

The location information for power stations is digitised from postcodes. There is inherent error in this translation. Furthermore, power stations often cover large sites, however, data on the area covered by each

power station was not represented by the data used and therefore, each power station has been digitised to a single point. It is conceivable that different parts of a power station site could be exposed to different hazards in different ways.

Table 4.26: Number (and proportion) of power stations exposed to different hazards in England

MW category	Coastal erosion[1]	Groundwater flooding[2]	River and coastal flooding[3]	Surface water flooding[4]	Shrink-swell subsidence[5]
Large	0 (0%)	6 (23%)	10 (38%)	2 (8%)	0 (0%)
Medium	0 (0%)	6 (18%)	16 (47%)	1 (3%)	7 (21%)
Small	0 (0%)	5 (14%)	13 (37%)	3 (9%)	5 (14%)

Notes: Percentages are calculated as a proportion of the total number of assets per criticality category.

[1]Range of exposure dependent upon time period, scenario and policy

[2]High susceptibility of groundwater flooding, estimated as 1 in 200 years or more frequent.

[3]Present day flooding from rivers or the sea under any likelihood category.

[4]Mid-depth (0.3m<= depth <1.2m; 1 in 1000 year likelihood)

[5]High susceptibility category to natural landslides.

Coastal erosion

The indicator assesses the number and proportion of power stations located within locations that are projected to be exposed to coastal erosion over the next 100 years and the number and proportion of assets at risk behind the Shoreline Management Plan policies.

There are no power stations that fall within the boundaries of the National Coastal Erosion Risk Map. This is a national assessment and unsuitable for asset level analysis which means that at a local level, there may be some power stations that may be affected by coastal erosion.

Flooding (groundwater)

This indicator assesses the number and proportion of power stations located in areas that are potentially of high susceptibility to groundwater flooding. Nationally there are 17 (18%) power stations located in susceptible areas. The distribution between power stations of different size categories is relatively even. Regionally the East Midlands has the highest proportion and number of power stations exposed to this hazard.

The results of the exposure analysis are shown in Table 4.27 and Figure 4.2.

Table 4.27: Number (and proportion) of power stations, categorised by size, located in areas of high susceptibility to groundwater flooding, by UKCP09 administrative region.

	Small	Medium	Large	Grand Total
East Midlands	2 (67%)	1 (20%)	4 (100%)	7 (58%)
East of England	1 (17%)	1 (17%)	0 (0%)	2 (14%)
London	0 (0%)	1 (50%)	0 (0%)	1 (17%)
North East England	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West England	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South East England	0 (0%)	1 (14%)	2 (33%)	3 (17%)
South West England	0 (0%)	0 (0%)	0 (0%)	0 (0%)
West Midlands	0 (0%)	1 (50%)	0 (0%)	1 (25%)
Yorkshire and Humberside	2 (29%)	1 (25%)	0 (0%)	3 (18%)
Total	**5 (14%)**	**6 (18%)**	**6 (23%)**	**17 (18%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

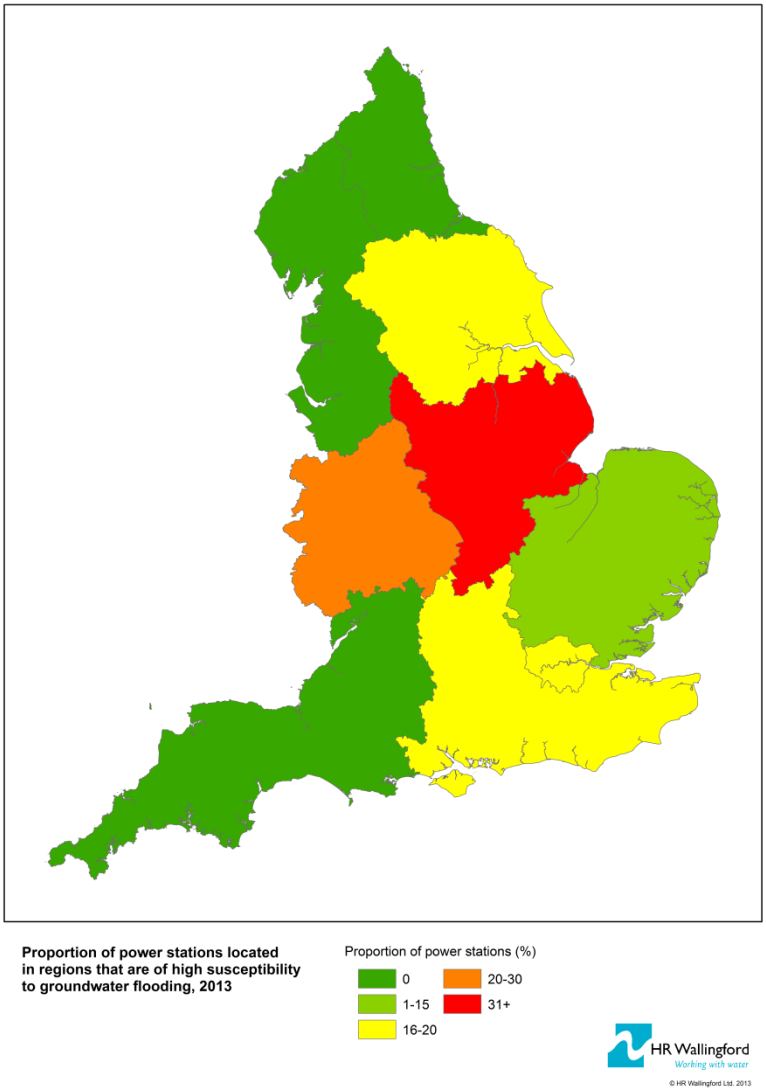

Figure 4.2: Proportion of power stations located in regions that are of high susceptibility from groundwater flooding, 2013

Flooding (river and coastal)

This indicator quantifies the number and proportion of power stations within the floodplain by flood likelihood category and takes into account the presence, performance and condition of raised flood defences. The results of the exposure analysis to any likelihood category of flooding from rivers or the sea are shown in Table 4.28.

Table 4.28: Number (and proportion) of power stations, categorised by size, located in areas that are currently at any likelihood category of flooding from rivers or the sea, by UKCP09 administrative region

Region	Small	Medium	Large	All
East Midlands	2 (67%)	3 (60%)	2 (50%)	7 (58%)
East of England	1 (17%)	5 (83%)	1 (50%)	7 (50%)
London	2 (67%)	1 (50%)	1 (100%)	4 (67%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South East England	3 (60%)	2 (29%)	3 (50%)	8 (44%)
South West England	1 (25%)	2 (40%)	0 (0%)	3 (30%)
West Midlands	0 (0%)	1 (50%)	0 (0%)	1 (25%)
Yorkshire & Humberside	4 (57%)	2 (50%)	3 (50%)	9 (53%)
Total	**13 (37%)**	**16 (47%)**	**10 (38%)**	**39 (41%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

The results of the exposure analysis to a high likelihood of flooding from rivers or the sea are shown in Table 4.29 and Table 4.30.

The results indicate that relatively few power stations are currently located in areas that are susceptible to flooding from rivers or the sea. Whilst this figure does increase in the projected figures, it should be borne in mind that this indicator refers to the exposure to such a hazard and not the vulnerability to it. Power stations that may be in service in the 2080s should be built with changing flood risk in mind if the current appropriate National Policy Statements are followed correctly. Therefore the level of risk to power stations in the future should be low, even if the exposure to such hazards increases.

Table 4.29: Number (and proportion) of power stations, categorised by size, located in areas that are currently at high likelihood of flooding from rivers or the sea, by UKCP09 administrative region

	Current (2010)		
Region	Small	Medium	Large
East Midlands	0 (0%)	0 (0%)	1 (25%)
East of England	1 (17%)	0 (0%)	1 (50%)
London	0 (0%)	0 (0%)	0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)
South East	1 (20%)	0 (0%)	0 (0%)
South West	0 (0%)	0 (0%)	0 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	0 (0%)	1 (25%)	0 (0%)
Total	**2 (6%)**	**1 (3%)**	**2 (8%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.30: Number (and proportion) of power stations, categorised by size, located in areas that are projected to be at high likelihood of flooding from rivers or the sea, by UKCP09 administrative region

	2020s			2050s			2080s		
	Medium p50			Medium p50			Low p10 - High p90		
Region	**S**	**M**	**L**	**S**	**M**	**L**	**S**	**M**	**L**
East Midlands	0 (0%)	1 (20%)	2 (50%)	0 (0%)	1 (20%)	2 (50%)	0 (0%) - 2 (67%)	1 (20%) - 3 (60%)	2 (50%) - 2 (50%)
East of England	1 (17%)	0 (0%)	1 (50%)	1 (17%)	0 (0%)	1 (50%)	1 (17%) - 1 (17%)	0 (0%) - 5 (83%)	1 (50%) - 1 (50%)
London	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%) - 2 (67%)	0 (0%) - 0 (0%)	0 (0%) - 1 (100%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%) - 0 (0%)	0 (0%) - 0 (0%)	0 (0%) - 0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%) - 0 (0%)	0 (0%) - 0 (0%)	0 (0%) - 0 (0%)
South East	1 (20%)	0 (0%)	0 (0%)	1 (20%)	0 (0%)	0 (0%)	1 (20%) - 3 (60%)	0 (0%) - 2 (29%)	0 (0%) - 3 (50%)
South West	1 (25%)	0 (0%)	0 (0%)	1 (25%)	2 (40%)	0 (0%)	0 (0%) - 1 (25%)	2 (40%) - 2 (40%)	0 (0%) - 0 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%) - 0 (0%)	0 (0%) - 0 (0%)	0 (0%) - 0 (0%)
Yorkshire & Humberside	0 (0%)	1 (25%)	0 (0%)	0 (0%)	2 (50%)	0 (0%)	0 (0%) - 4 (57%)	1 (25%) - 2 (50%)	0 (0%) - 2 (33%)
Total	**3 (9%)**	**2 (6%)**	**3 (12%)**	**3 (9%)**	**5 (15%)**	**3 (12%)**	**2 (6%) - 13 (37%)**	**4 (12%) - 14 (41%)**	**3 (12%) - 9 (35%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Flooding (surface water)

This indicator quantifies the number and proportion of power stations located in areas susceptible to surface water flooding in a 1:30 year, 1:100 year and 1:1000 year rainfall event for depths between 0.3m and 1.2m and for depths greater than 1.2m.

The results of the exposure analysis are shown in Table 4.31 and Table 4.32.

Table 4.31: Number (and proportion) of power stations, categorised by size, located in areas susceptible to mid-depth surface water flooding, by UKCP09 administrative region

	Mid-depth: 0.3m<= depth <1.2m 3.3% likelihood			Mid-depth: 0.3m<= depth <1.2m 0.1% likelihood		
Region	**Small**	**Medium**	**Large**	**Small**	**Medium**	**Large**
East Midlands	0 (0%)	0 (0%)	0 (0%)	1 (33%)	0 (0%)	1 (25%)
East of England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
London	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)	1 (25%)	0 (0%)	1 (33%)
South East England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South West England	0 (0%)	0 (0%)	0 (0%)	1 (25%)	0 (0%)	0 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (50%)	0 (0%)
Yorkshire & Humberside	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Total	**0 (0%)**	**0 (0%)**	**0 (0%)**	**3 (9%)**	**1 (3%)**	**2 (8%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.32: Number (and proportion) of power stations, categorised by size, located in areas susceptible to very deep surface water flooding, by UKCP09 administrative region

	Deep: Depth >1.2m 3.3% likelihood			Deep: Depth >1.2m 0.1% likelihood		
Region	**Small**	**Medium**	**Large**	**Small**	**Medium**	**Large**
East Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
East of England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
London	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South East England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South West England	0 (0%)	0 (0%)	0 (0%)	1 (25%)	1 (20%)	0 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Total	**0 (0%)**	**0 (0%)**	**0 (0%)**	**1 (3%)**	**1 (3%)**	**0 (0%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Up to around 6% of power stations in England are located in areas that may be susceptible to surface water flooding between 30cm and 1.2m with a likelihood of 1 in 1000 or more frequent. The most susceptible areas are in the East and West Midlands and the North West. In the South West of England, there may be a local risk of very deep surface water flooding (over 1.2 meters).

Shrink-swell subsidence

This indicator quantifies the number and proportion of power stations located in areas of high susceptibility to shrink-swell subsidence where ground conditions are of predominantly high or very high plasticity.

The results of the analysis of exposure to potential shrink-swell subsidence is presented in Table 4.33 and Figure 4.3.

Table 4.33: Number (and proportion) of power stations, categorised by size, located in areas of high susceptibility to shrink-swell subsidence, by UKCP09 administrative region

Region	Small	Medium
East Midlands	0 (0%)	0 (0%)
East of England	2 (33%)	2 (33%)
London	1 (33%)	2 (100%)
North East	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)
South East England	1 (20%)	3 (43%)
South West England	1 (25%)	0 (0%)
West Midlands	0 (0%)	0 (0%)
Yorkshire & Humberside	0 (0%)	0 (0%)
Total	**5 (14%)**	**7 (21%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

There are no power stations over 1000MW co-located in areas that are of high susceptibility to shrink-swell subsidence; 21% of medium-sized power stations and 14% of small power stations are located in areas that are also susceptible to shrink-swell subsidence. Power station sites may be many hundreds of square metres if not several square kilometres. This analysis focussed on the point location of the power stations borne by the address. At a local scale, the magnitude of the threat that subsidence may pose may not be uniform across the whole site. The true significance of this hazard therefore lies in the vulnerability of the individual buildings and assets at a site level and local soil types.

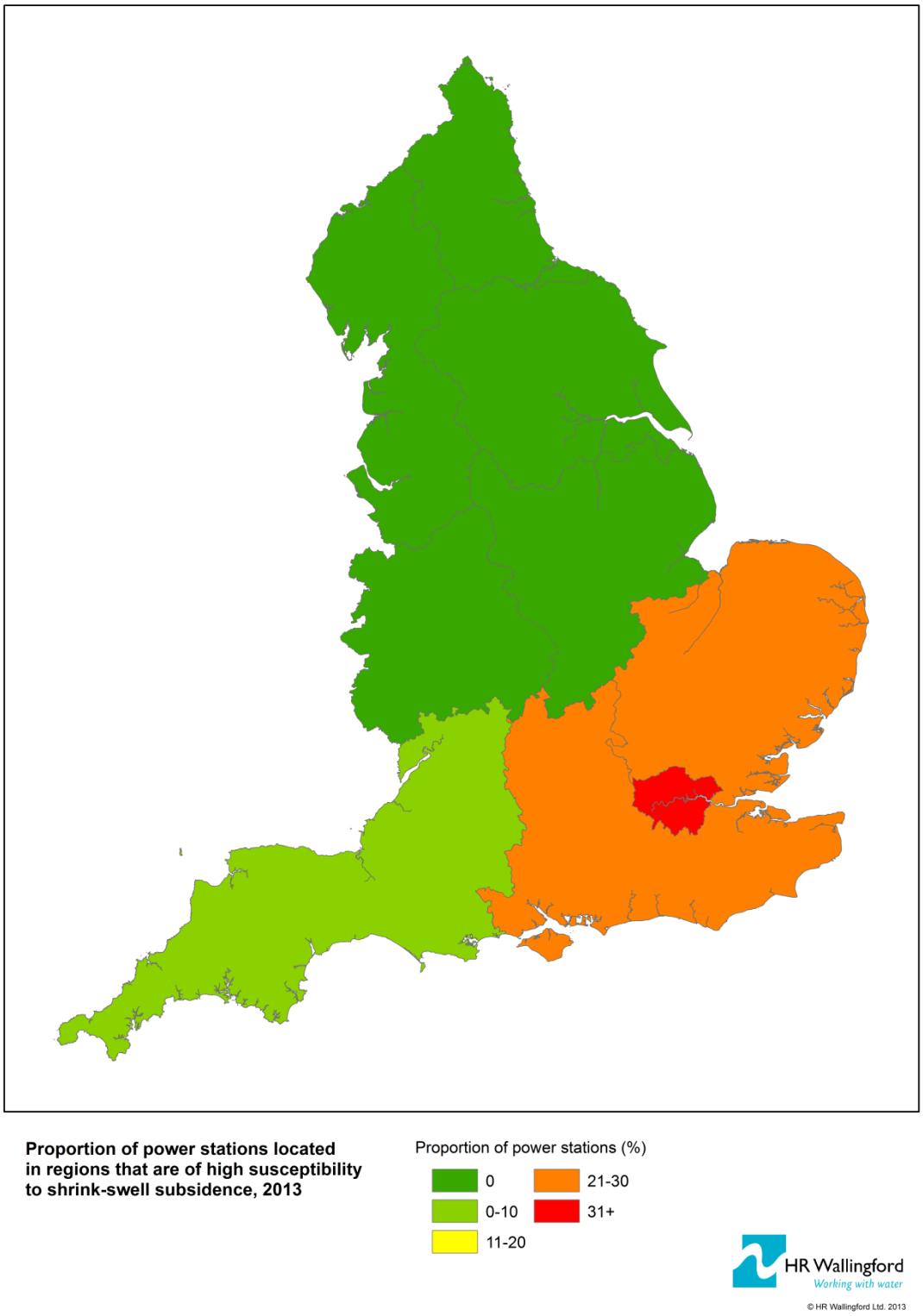

Figure 4.3: Proportion of power stations located in regions that are of high susceptibility to shrink-swell subsidence, 2013

4.2.3. Towers

In order to assess the level of criticality of towers (electricity pylons for transmission), they are split by the capacity of the lines they carry (kV). The categories of capacity used here are:

- High: >400kV
- Medium: 132-400kV
- Low: <132kV.

Table 4.34: Total number of towers, categorized by size, in this assessment

Voltage category	High	Medium	Low	Total
Towers	15,215	3,956	71	19,242

In this analysis, there were 19,242 towers, the majority of which (15,215) fall into the high capacity category (71 are low and 3,956 are medium capacity). The location data used was in a high quality spatial data format.

Table 4.35: Number (and proportion) of electricity towers exposed to different hazards in England

Voltage category	Coastal erosion[1]	Natural landslides[2]	Shrink-swell subsidence[3]
High	3 (0%) – 5 (0%)	88 (1%)	1193 (8%)
Medium	0 (0%)	29 (1%)	515 (13%)
Low	0 (0%)	0 (0%)	0 (0%)

Notes: *Percentages are calculated as a proportion of the total number of assets per criticality category.*

[1]Range of exposure dependent upon time period, scenario and policy

[2]High susceptibility category to natural landslides.

[3]High susceptibility category to shrink-swell subsidence.

Coastal erosion

The indicator assesses the number and proportion of towers located within areas that are projected to be exposed to coastal erosion over the next 100 years and the number and proportion of assets at risk behind the 'hold the line', 'no active intervention' or 'managed realignment' Shoreline Management Plan policies. Table 4.35 shows that only towers in the criticality category ‘high’ are affected by coastal erosion. On a national scale a very small proportion of towers are shown to be exposed to coastal erosion. Table 4.36 and Table 4.37 indicate that there is a small risk to towers from both the no active intervention (NAI) and shoreline management plan (SMP) scenarios but that this represents a very small proportion of towers in the South East and South West of England only.

Table 4.36: Number (and proportion) of towers, categorised by capacity, located in areas at risk from coastal erosion, per UKCP09 administrative region under the 'No Active Intervention' scenario

	Medium term			Long term		
	Low	Medium	High	Low	Medium	High
East Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
East of England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
London	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South East	0 (0%)	0 (0%)	2 (0%)	0 (0%)	0 (0%)	4 (0%)
South West	0 (0%)	0 (0%)	1 (0%)	0 (0%)	0 (0%)	1 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Grand Total	**0 (0%)**	**0 (0%)**	**3 (0%)**	**0 (0%)**	**0 (0%)**	**5 (0%)**

Source: No active intervention, 5th percentile for the short (no results), medium and long term scenarios were analysed.

Table 4.37: Number (and proportion) of towers, categorised by capacity, located in areas at risk from coastal erosion, per UKCP09 administrative region under the shoreline management plan scenario, where the policy is no active intervention

	Medium term			Long term		
	Low	Medium	High	Low	Medium	High
East Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
East of England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
London	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South West	0 (0%)	0 (0%)	1 (0%)	0 (0%)	0 (0%)	1 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Grand Total	**0 (0%)**	**0 (0%)**	**1 (0%)**	**0 (0%)**	**0 (0%)**	**1 (0%)**

Source: Shoreline management plan, 5th percentile for the short (no results), medium and long term scenarios were analysed.

Natural landslides

This indicator quantifies the number and proportion of towers located in areas of high susceptibility to natural landslides where; slope instability problems are probably present or have occurred in the past or slope instability problems are almost certainly present and may be active.

The number and proportion of towers located in areas of high susceptibility to natural landslides is shown in Table 4.38.

Table 4.38: Number (and proportion) of towers, categorised by capacity, located in areas of high susceptibility to natural landslides, per UKCP09 administrative region

Region	Medium	High	Total
East Midlands	0 (0%)	9 (0%)	9 (0%)
East of England	1 (0%)	0 (0%)	1 (0%)
North East England	0 (0%)	0 (0%)	0 (0%)
North West England	1 (0%)	0 (0%)	1 (0%)
South East England	2 (0%)	14 (1%)	16 (1%)
South West England	0 (0%)	5 (0%)	5 (0%)
West Midlands	1 (0%)	30 (1%)	31 (1%)
Yorkshire and Humberside	0 (0%)	5 (0%)	5 (0%)
Total	**24 (3%)**	**25 (1%)**	**49 (2%)**

Notes: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

The proportion of towers located in areas of high susceptibility to natural landslides at a national scale is very low at less than 2%. This is not currently a significant national level hazard, although at a local level natural land stability issues may still present engineering challenges. It is unsurprising that more towers carrying high voltage lines are located in areas that are highly susceptible than medium voltage lines as there are many more high voltage lines in England, as previously described. It is to be noted that man-made land stability issues are not included in this analysis and may be a hazard for such infrastructure. This is not currently quantifiable at a national level.

Shrink-swell subsidence

This indicator quantifies the number and proportion of towers located in areas of high susceptibility to shrink-swell subsidence where ground conditions are of predominantly high or very high plasticity.

The number and proportion of towers located in areas of high susceptibility to shrink-swell subsidence is shown in Table 4.39.

Table 4.39: Number (and proportion) of towers, categorised by capacity, located in areas of high susceptibility to shrink-swell subsidence, per UKCP09 administrative region

Region	Low	Medium	High
East Midlands	0 (0%)	0 (0%)	30 (1%)
East of England	0 (0%)	313 (72%)	346 (16%)
London	0 (0%)	183 (56%)	2 (1%)
North East	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)
South East England	0 (0%)	15 (9%)	551 (22%)
South West England	0 (0%)	4 (1%)	258 (10%)
West Midlands	0 (0%)	0 (0%)	0 (0%)
Yorkshire and Humberside	0 (0%)	0 (0%)	6 (0%)
Total	**0 (0%)**	**515 (13%)**	**1193 (8%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

There are no lower capacity towers located in areas highly susceptible to shrink-swell subsidence. The majority of those assets that are co-located with high plasticity soils are of high voltage. As highlighted above, there are many more high voltage towers than medium of low voltage towers. Overall, the national level of susceptibility to this geological hazard is low and confined to those regions with clay soil types.

4.2.4. Turbines

The dataset used to understand the exposure of onshore wind turbines to weather-related hazards provided the location of wind farms and their total capacity (MW). The number, but not the specific locations of wind turbines at each wind farm is also provided. Wind farms with higher capacity have more turbines. In order to assess the level of criticality of onshore wind power, the locations are categorised by their installed capacity (MW). The categories of capacity used here are:

- High: >100MW (average of ~70 turbines per wind farm)
- Medium: 20-99MW (average of ~20 turbines per wind farm)
- Low: <20MW (average of 4 turbines per wind farm).

Table 4.40: Total number of turbines, categorized by capacity, used in this assessment

Capacity	Low	Medium	High	Total
Turbines	180	21	N/A	201

There were 201 wind farms analysed; 180 were of low capacity and 21 were medium capacity. This analysis does not include wind farms from the High category. This is due to the fact that the largest wind farms are located offshore and in Scotland and are therefore not included in this assessment.

Table 4.41: Number (and proportion) of onshore wind turbines exposed to different hazards in England

Capacity	Coastal erosion[1]	Groundwater flooding[2]	River and coastal flooding[3]	Natural landslides[4]	Shrink-swell subsidence[5]
High	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Medium	0 (0%)	1 (5%)	9 (43%)	1 (5%)	1 (5%)
Low	2 (1%)	6 (3%)	33 (18%)	0 (0%)	11 (6%)

Notes: Percentages are calculated as a proportion of the total number of assets per criticality category.

[1]No active intervention, long term 5th percentile scenario.

[2]High susceptibility of groundwater flooding, estimated as 1 in 200 years or more frequent.

[3]Present day flooding from rivers or the sea under any likelihood category.

[4]High susceptibility category to natural landslides.

[5]High susceptibility category to shrink-swell subsidence.

Coastal erosion

The indicator assesses the number and proportion of wind farms located within locations that are projected to be exposed to coastal erosion over the next 100 years and the number and proportion of assets at risk behind the Shoreline Management Plan policies. This national assessment shows a very low proportion of on-shore wind farms are at risk from coastal erosion. This is not considered to be a national risk.

Flooding (groundwater)

This indicator assesses the number and proportion of wind farms located in areas that are considered to be of high susceptibility to groundwater flooding. There are a total of 7 wind farms that may be exposed to this hazard, which is around 4% of total number of wind farms in England. Only one of the wind farms is included in the medium category of capacity, all others are from the low category.

Flooding (river and coastal)

This indicator quantifies the number and proportion of wind farms within the floodplain by flood likelihood category and takes into account the presence, performance and condition of raised flood defences. The results of the exposure analysis for any likelihood category of flooding from rivers or the sea is shown in Table 4.42.

Table 4.42: Number (and proportion) of wind farms, categorised by capacity, located in areas currently at any likelihood category of flooding from rivers or the sea, per UKCP09 administrative region

Region	Low capacity	Medium capacity	High capacity
East Midlands	8 (27%)	1 (33%)	0 (0%)
East of England	12 (38%)	3 (75%)	0 (0%)
London	4 (80%)	0 (0%)	0 (0%)
North East	1 (3%)	0 (0%)	0 (0%)
North West	1 (3%)	0 (0%)	0 (0%)
South East England	1 (25%)	1 (100%)	0 (0%)
South West England	1 (5%)	0 (0%)	0 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	5 (20%)	4 (67%)	0 (0%)
Total	**33 (18%)**	**9 (43%)**	**0 (0%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

The results of the exposure analysis for high likelihood of flooding from rivers or the sea are shown in Table 4.43 and Table 4.44.

Table 4.43: Number (and proportion) of wind farms, categorised by capacity, located in areas currently at high likelihood of flooding from rivers or the sea, per UKCP09 administrative region

Region	Current (2013)	
	Low capacity	Medium capacity
East Midlands	1 (3%)	0 (0%)
East of England	1 (3%)	1 (25%)
London	1 (20%)	0 (0%)
North East	0 (0%)	0 (0%)
North West	1 (3%)	0 (0%)
South East	0 (0%)	0 (0%)
South West	0 (0%)	0 (0%)
West Midlands	0 (0%)	0 (0%)
Yorkshire & Humberside	0 (0%)	0 (0%)
Total	**4 (2%)**	**1 (5%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.44: Number (and proportion) of wind farms, categorised by capacity, located in areas projected to be at high likelihood of flooding from rivers or the sea, per UKCP09 administrative region

	2020s		2050s		2080s	
	Medium p50		Medium p50		Low p10 - High p90	
Region	**Low**	**Medium**	**Low**	**Medium**	**Low**	**Medium**
East Midlands	1 (3%)	0 (0%)	1 (3%)	0 (0%)	1 (3%) - 8 (27%)	0 (0%) - 1 (33%)
East of England	1 (3%)	1 (25%)	1 (3%)	1 (25%)	1 (3%) - 11 (34%)	1 (25%) - 3 (75%)
London	1 (20%)	0 (0%)	1 (20%)	0 (0%)	1 (20%) - 4 (80%)	0 (0%) - 0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%) - 0 (0%)	0 (0%) - 0 (0%)
North West	1 (3%)	0 (0%)	1 (3%)	0 (0%)	1 (3%) - 1 (3%)	0 (0%) - 0 (0%)
South East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%) - 1 (25%)	0 (0%) - 1 (100%)
South West	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%) - 1 (5%)	0 (0%) - 0 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%) - 0 (0%)	0 (0%) - 0 (0%)
Yorkshire & Humberside	0 (0%)	2 (33%)	1 (4%)	2 (33%)	1 (4%) - 5 (20%)	2 (33%) - 4 (67%)
Total	**4 (2%)**	**3 (14%)**	**5 (3%)**	**3 (14%)**	**5 (3%) - 31 (17%)**	**3 (14%) - 9 (43%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

The current level of exposure of this asset type to flooding from rivers or the sea is low at up to 5% depending upon the capacity of the wind farm. However, the projected future exposure is much higher, between 3 and 43% of wind farms depending upon capacity of the wind farm and scenario.

Natural landslides

This indicator quantifies the number and proportion of wind farms located in areas of high susceptibility to natural landslides where; slope instability problems are probably present or have occurred in the past or slope instability problems are almost certainly present and may be active.

Only one wind farm was located in an area of high susceptibility to natural landslides. This is not currently a significant residual hazard at a national scale for this type of infrastructure.

Shrink-swell subsidence

This indicator quantifies the number and proportion of wind farms located in areas of high susceptibility to shrink-swell subsidence where ground conditions are of predominantly high or very high plasticity.

The results of the exposure analysis for this hazard and asset combination are shown in Table 4.45.

Table 4.45: Number (and proportion) of turbines, categorised by capacity, located in areas of high susceptibility to shrink-swell subsidence, per UKCP09 administrative region

Region	Low	Medium	High
East Midlands	0 (0%)	0 (0%)	0 (0%)
East of England	8 (25%)	1 (25%)	0 (0%)
London	2 (40%)	0 (0%)	0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)
South East England	1 (25%)	0 (0%)	0 (0%)
South West England	0 (0%)	0 (0%)	0 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	0 (0%)	0 (0%)	0 (0%)
Total	**11 (6%)**	**1 (5%)**	**0 (0%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Onshore wind farms that fall into the 'high' category are only found in Scotland. Wind farms with relatively few turbines are more common in England and 5% of these are situated in locations that are also categorised as high susceptibility to shrink-swell subsidence. The East of England has the greatest concentration of wind farms that are co-located with this hazard type.

4.2.5. Underground electricity transmission cable

In order to assess the variation of criticality of underground electricity transmission cable, the carrying capacity (kV) is used. The categories used are:

- High: 132-400kV
- Medium: 33 to <132kV
- Low: <33kV.
- No data: Primarily non-voltage carrying cables.

In total, this analysis reviewed the exposure of more than 2,000 km of electricity transmission cable (i.e. only the highest voltage transmission cable, not distribution cabling). In excess of 750 km of cable falls into the highest capacity group; 16 km in the medium capacity group and over 1,000 km into the lowest capacity group. The location data used was in a high quality spatial data format.

Table 4.46: Length of electricity cable in each criticality category, used in this assessment

Carrying capacity	Length (km)
High	756
Medium	16
Low	59
No data	1178

Table 4.47: Length (and proportion) of electricity transmission cable exposed to different hazards in England

Carrying capacity	Coastal erosion[1]	Shrink-swell subsidence[2]
High	49m (0%) – 474m (0%)	264km (35%)
Medium	0m (0%)	2km (13%)
Low	0m (0%)	9km (15%)
No data	0 – 5080m (0%)	347km (29%)

Notes: Percentages are calculated as a proportion of the total number of assets per criticality category.

[1]Range of exposure dependent upon time period, scenario and policy

[2]High susceptibility category to shrink-swell subsidence.

Coastal erosion

The indicator assesses the length and proportion of electricity transmission cable located within areas that are projected to be exposed to coastal erosion over the next 100 years and the number and proportion of assets at risk behind the Shoreline Management Plan policies.

Table 4.48 and Table 4.49 show the length and proportion of electricity transmission cable that may be exposed to this hazard.

Table 4.48: Length (and proportion) of electricity transmission cable, categorised by capacity, potentially exposed to coastal erosion under the 'No Active Intervention' scenario

	Short term				Medium term				Long term			
Region	L	M	H	ND	L	M	H	ND	L	M	H	ND
East Midlands	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)
East of England	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)
London	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)
North East	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)
North West	0m (0%)	0m (0%)	3m (0%)	11m (0%)	0m (0%)	0m (0%)	7m (0%)	30m (0%)	0m (0%)	0m (0%)	14m (0%)	659m (1%)
South East England	0m (0%)	0m (0%)	41m (0%)	94m (0%)	0m (0%)	0m (0%)	130m (0%)	2048m (1%)	0m (0%)	0m (0%)	419m (1%)	4421m (1%)
South West England	0m (0%)	0m (0%)	8m (0%)	0m (0%)	0m (0%)	0m (0%)	20m (0%)	0m (0%)	0m (0%)	0m (0%)	41m (0%)	0m (0%)
West Midlands	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)
Yorkshire & Humberside	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)
Total	**0m (0%)**	**0m (0%)**	**52m (0%)**	**105m (0%)**	**0m (0%)**	**0m (0%)**	**157m (0%)**	**2078m (0%)**	**0m (0%)**	**0m (0%)**	**474m (0%)**	**5080m (0%)**

Source: 'L' – Low capacity; 'M' – Medium capacity; 'H' – High capacity; 'ND' – No data. No active intervention, 5th percentile for the short (no results), medium and long term scenarios were assessed. Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.49: Length (and proportion) of electricity transmission cable, categorised by capacity, potentially exposed to coastal erosion under the shoreline management plan, where the policy is no active intervention policy.

	Short term				Medium term				Long term			
Region	**L**	**M**	**H**	**ND**	**L**	**M**	**H**	**ND**	**L**	**M**	**H**	**ND**
East Midlands	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)
East of England	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)
London	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)
North East	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)
North West	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	2m (0%)	0m (0%)	0m (0%)	0m (0%)	162m (0%)
South East England	0m (0%)	0m (0%)	41m (0%)	0m (0%)	0m (0%)	0m (0%)	130m (0%)	1469 m (0%)	0m (0%)	0m (0%)	419m (1%)	3816 m (1%)
South West England	0m (0%)	0m (0%)	8m (0%)	0m (0%)	0m (0%)	0m (0%)	20m (0%)	0m (0%)	0m (0%)	0m (0%)	41m (0%)	0m (0%)
West Midlands	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)
Yorkshire & Humberside	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)	0m (0%)
Total	**0m (0%)**	**0m (0%)**	**49m (0%)**	**0m (0%)**	**0m (0%)**	**0m (0%)**	**150m (0%)**	**1471 m (0%)**	**0m (0%)**	**0m (0%)**	**460m (0%)**	**3978 m (0%)**

Source: 'L' – Low capacity; 'M' – Medium capacity; 'H' – High capacity; 'ND' – No data. Shoreline Management Plan, 5th percentile for the short, medium and long term scenarios were analysed. Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Despite there being some cable susceptible to coastal erosion in the assessment for all terms and most importantly under the SMP policy option scenario, these cables are often of the lower voltage rating and represent less than 1% of the total length of cable in their voltage category. There may be instances at a local level where coastal erosion is an issue.

Shrink-swell subsidence

This indicator quantifies the length and proportion of electricity transmission cables located in areas of high susceptibility to shrink-swell subsidence where ground conditions are of predominantly high or very high plasticity.

Table 4.50 shows the length and proportion of electricity transmission cable that are located in areas of high susceptibility of shrink-swell subsidence.

Table 4.50: Length (and proportion) of electricity transmission cable, categorised by capacity, located in areas with high susceptibility to shrink-swell subsidence

Region	Low	Medium	High	No data
East Midlands	0km (0%)	0km (0%)	0km (0%)	0km (0%)
East of England	8km (62%)	0km (0%)	10km (37%)	16km (45%)
London	2km (18%)	2km (21%)	244km (58%)	277km (49%)
North East	0km (0%)	0km (0%)	0km (0%)	0km (0%)
North West	0km (0%)	0km (0%)	0km (0%)	0km (0%)
South East England	0km (0%)	0km (0%)	8km (13%)	54km (17%)
South West England	0km (0%)	0km (0%)	1km (8%)	0km (0%)
West Midlands	0km (0%)	0km (0%)	0km (0%)	0km (0%)
Yorkshire & Humberside	0km (0%)	0km (0%)	0km (0%)	0km (0%)
Total	**9km (15%)**	**2km (13%)**	**264km (35%)**	**347km (29%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

In some regions, there is a high proportion of cable assets that are located in areas of high susceptibility to shrink-swell subsidence, see Figure 4.4. This regions are co-incident with the location of clay soil types.

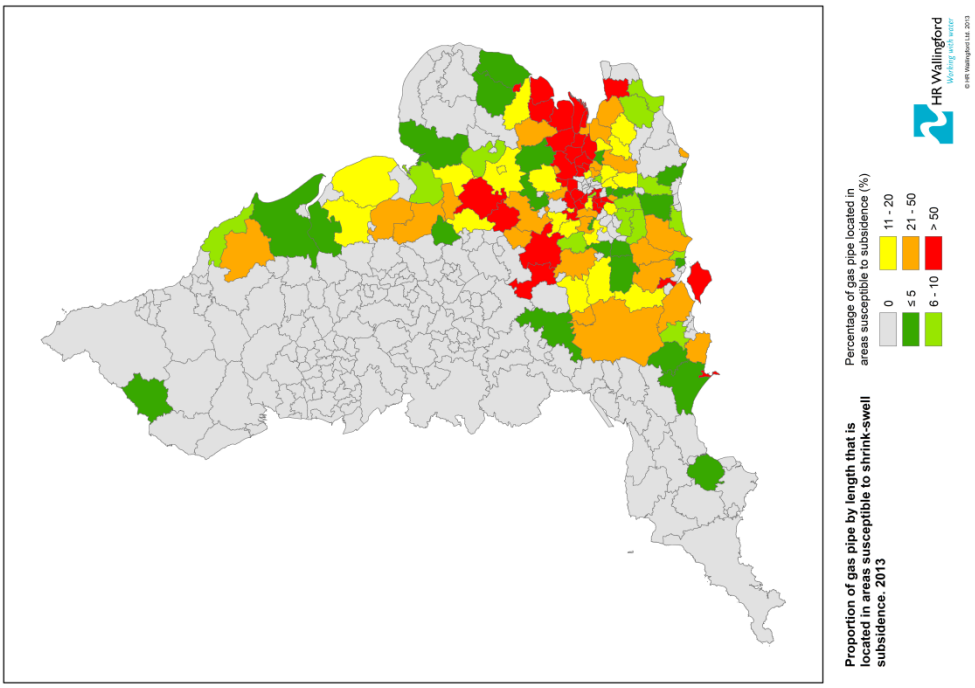

Figure 4.5: Proportion of high pressure, natural gas pipelines located in areas of high susceptibility to shrink-swell subsidence

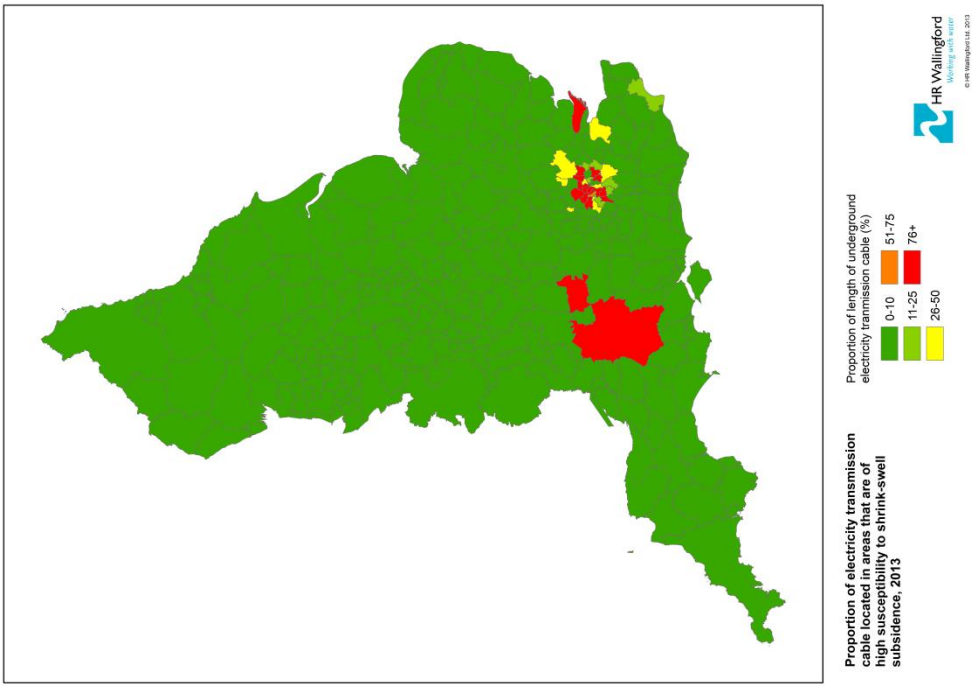

Figure 4.4: Proportion of electricity transmission cable (including non-voltage carrying cable) located in areas of high susceptibility to shrink-swell subsidence

4.2.6. Underground gas pipes

In order to assess the criticality of Major Accident Hazard Pipeline (MAHP), underground gas pipes, the Safe Operating Limit (SOL) is used. The pressure in these piped systems must not, under any circumstances, be allowed to rise above the SOL. This measure therefore reflects the most extreme pressure that should be found in any piped system and not the average or 'normal' operating conditions. The categories used are:

- High: >66 barg
- Medium: 33-66 barg
- Low: <33 barg.

Table 4.51: Total length of gas pipe, categorised by SOL, used in this assessment

SOL	High	Medium	Low	Total
Gas pipes	6,076km	4,087km	4,183km	14,345km

In this assessment a total of 14,345 km of high pressure natural gas pipes were reviewed[8]. In the highest pressure category there was approximately 6,075 km of pipeline; 4,086 km in the medium category and 4,183 km in the lowest pressure category. The location data used was in a high quality spatial data format.

Table 4.52: Length (and proportion) of MAHP underground gas pipes exposed to different hazards in England

SOL	Coastal erosion[1]	Shrink-swell subsidence[2]
High	0-175m (0%)	608km (10%)
Medium	0-594m (0%)	566km (14%)
Low	0 – 0-7,577m (0%)	503km (12%)

Notes: Percentages are calculated as a proportion of the total number of assets per criticality category.

[1]Range of exposure dependent upon time period, scenario and policy

[2]High susceptibility category to shrink-swell subsidence.

Coastal erosion

The indicator assesses the length and proportion of MAHP underground gas pipes located within locations that are projected to be exposed to coastal erosion over the next 100 years and the length and proportion of assets at risk behind the Shoreline Management Plan policies.

In all of the no active intervention and shoreline management plan policies less than 1% of underground gas pipeline is located in areas that may be at risk either now or in the long-term. At a local scale, there may be lengths of such pipeline in England that is affected by coastal erosion, but on a national scale, this hazard does not appear to present a serious issue.

[8] Pipeline spatial data was obtained from the Health and Safety Laboratory who are collating data on all pipelines classed as Major Accident Hazard Pipelines (MAHP). A subset of this data was used in this analysis, including only natural gas pipelines from operators with national coverage: National Grid Distribution, Wales and West Utilities, Southern Gas Networks and Northern Gas Networks.

Shrink-swell subsidence

This indicator quantifies the number and proportion of MAHP underground gas pipes located in areas of high susceptibility to shrink-swell subsidence where ground conditions are of predominantly high or very high plasticity. The results of the exposure assessment are shown in Figure 4.5 and Table 4.53.

Table 4.53: Length (and proportion) of MAHP underground gas pipes, categorised by SOL pressure, located in areas with high susceptibility to shrink-swell subsidence

#	Low	Medium	High
East Midlands	1km (1%)	11km (2%)	133km (19%)
East of England	219km (28%)	255km (33%)	338km (25%)
London	65km (54%)	107km (62%)	1km (28%)
North East	0km (0%)	0km (0%)	0km (0%)
North West	0km (0%)	0km (0%)	0km (0%)
South East England	149km (30%)	168km (16%)	112km (27%)
South West England	48km (6%)	17km (13%)	5km (1%)
West Midlands	0km (0%)	0km (0%)	0km (0%)
Yorkshire & Humberside	21km (3%)	6km (2%)	20km (3%)
Total	**503km (12%)**	**566km (14%)**	**608km (10%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

On average, 12% of high pressure, natural gas pipelines in England are located in areas that are considered to be of high susceptibility to shrink-swell subsidence. The highest levels of exposure to this hazard are found in London, the East of England and the South East of England, which is co-incident with the location of susceptible soils. Whilst the exposure to this type of hazard is quite high, the vulnerability to its affects may not be. The specific vulnerability of gas pipelines in England has not been assessed.

4.3. Health

Data

Care Quality Commission: Registered care homes (March 2008, January 2012 and November 2013).

Ordnance Survey MasterMap, October 2013: Emergency services locations.

Health and Social Care Information Centre: GP practices Q4 2013 and Hospital Estates and Facilities Statistics, 2012/2013.

Environment Agency (EA): NaFRA Spatial Internal Grid 2013 (flooding from rivers or the sea).

EA: NCERM 2011 (coastal erosion).

EA: updated Flood Map for Surface Water (2013).

British Geological Survey (BGS): Map of susceptibility to natural landslides. British Geological Survey © NERC. All rights reserved.

BGS: Map of susceptibility to shrink-swell subsidence. British Geological Survey © NERC. All rights reserved.

ESI: Groundwater flooding risk map. ESI Groundwater Flood Risk Map of England and Wales © http://esinternational.com/

4.3.1. Care homes

In 2013, there were 17,398 registered care homes in England. This figure has fallen slightly since 2008 by around 1% per year. In 2013, there were 452,914 beds within registered care homes in England. In order to assess the criticality of care homes in 2013, the number of beds is used. The categories used are:

- Large: >140 beds
- Medium: 71 – 139 beds
- Small: <70 beds.

Table 4.54: Number of care homes, categorized by number of beds, used in this assessment

	Large	Medium	Small	No data	Total
Care homes	45	726	16,598	29	17398

Of the care homes (from 2013) in this analysis, 45 can be considered large, 726 medium and 16,598 small in size. There were 29 care homes that did not provide information on the number of beds. Whilst the location information is considered accurate, postcodes provide the location information. Postcodes must be digitised into co-ordinates for the spatial assessment and this introduces some error.

Table 4.55: Number (and proportion) of care homes exposed to different hazards in England

No. of beds category	Coastal erosion[1]	Groundwater flooding[2]	River and coastal flooding[3]	Surface water flooding[4]	Natural landslides[5]	Shrink-swell subsidence[6]
Large	0 (0%)	5 (11%)	5 (11%)	0 (0%)	0 (0%)	5 (11%)
Medium	0 (0%)	59 (8%)	47 (6%)	1 (1%)	1 (0%)	116 (16%)
Small	0 (0%)	1355 (8%)	1024 (6%)	11 (1%)	39 (0%)	2108 (13%)
No data	0 (0%)	4 (14%)	2 (7%)	0 (0%)	0 (0%)	11 (38%)

Notes: Percentages are calculated as a proportion of the total number of assets per criticality category.

[1]Range of exposure dependent upon time period, scenario and policy

[2]High susceptibility of groundwater flooding, estimated as 1 in 200 years or more frequent.

[3]Present day flooding from rivers or the sea under any likelihood category.

[4]Mid-depth (0.3m<= depth <1.2m; 1 in 1000 year likelihood)

[5]High susceptibility category to natural landslides.

[6]High susceptibility category to shrink-swell subsidence.

Coastal erosion

The indicator assesses the number and proportion of care homes located within locations that are projected to be exposed to coastal erosion over the next 100 years and the number and proportion of assets at risk behind the Shoreline Management Plan policies.

There are no care homes that fall within the boundaries of the National Coastal Erosion Risk Map. However, this is a national assessment and unsuitable for asset level analysis. There might be local exposure to coastal erosion to care homes which have not been picked up by this assessment.

Flooding (groundwater)

This indicator assesses the number and proportion of care homes located within areas that are of high susceptibility to groundwater flooding. Nationally 8% of all care homes are located in areas prone groundwater flooding. This proportion has not changed between 2008 and 2013. The absolute values have reduced slightly, in line with the general reduction in the number of care homes in England. Table 4.56

shows that, proportionally, there is an even distribution of care homes potentially exposed to this hazard across the different criticality categories. However, the small category contains 95% of all care homes. Therefore, the majority of homes exposed are the small care homes. Table 4.56 shows the regional distribution of care homes that are potentially exposed to groundwater flooding. London has the largest number of care homes and the highest proportion of care homes exposed. Both Yorkshire and Humberside and the North East have very low proportion of care homes exposed.

Table 4.56: Number (and proportion) of care homes, classified by size, located in areas currently of high susceptibility to groundwater flooding, by UKCP09 administrative region

Region	Small	Medium	Large	No Data	All
East Midlands	135 (9%)	5 (11%)	0 (0%)	1 (100%)	141 (9%)
East of England	161 (9%)	9 (9%)	0 (0%)	0 (0%)	170 (9%)
London	286 (18%)	15 (16%)	2 (40%)	1 (9%)	304 (17%)
North East	33 (4%)	0 (0%)	0 (0%)	0 (0%)	33 (4%)
North West	108 (5%)	4 (5%)	0 (0%)	0 (0%)	112 (5%)
South East England	330 (10%)	18 (12%)	1 (25%)	2 (20%)	351 (10%)
South West England	140 (6%)	5 (8%)	1 (50%)	0 (0%)	146 (6%)
West Midlands	104 (6%)	3 (4%)	0 (0%)	0 (0%)	107 (6%)
Yorkshire & Humberside	58 (4%)	0 (0%)	1 (20%)	0 (0%)	59 (4%)
Total	**1355 (8%)**	**59 (8%)**	**5 (11%)**	**4 (14%)**	**1423 (8%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region. Data is from 2013.

Flooding (river and coastal)

This indicator quantifies the number and proportion of care homes within the floodplain by flood likelihood category and takes into account the presence, performance and condition of raised flood defences. The overall results, a sum of all likelihoods, are presented in Table 4.57.

Table 4.57: Number (and proportion) of care homes, classified by size, located in areas currently at any likelihood of flooding from rivers or the sea, by UKCP09 administrative region

	2013					2011	2008
Region	Small	Medium	Large	No Data	All	No Data	No Data
East Midlands	155 (10%)	4 (9%)	0 (0%)	0 (0%)	159 (10%)	170 (10%)	170 (11%)
East of England	104 (6%)	4 (4%)	0 (0%)	0 (0%)	108 (6%)	109 (6%)	103 (6%)
London	116 (7%)	11 (12%)	2 (40%)	1 (9%)	130 (7%)	142 (8%)	157 (8%)
North East	15 (2%)	0 (0%)	0 (0%)	0 (0%)	15 (2%)	16 (2%)	15 (2%)
North West	89 (4%)	3 (4%)	1 (7%)	0 (0%)	93 (4%)	95 (4%)	96 (4%)
South East England	175 (5%)	7 (5%)	0 (0%)	1 (10%)	183 (5%)	198 (6%)	210 (6%)
South West England	116 (5%)	5 (8%)	0 (0%)	0 (0%)	121 (5%)	123 (5%)	122 (5%)
West Midlands	59 (3%)	3 (4%)	1 (14%)	0 (0%)	63 (3%)	69 (4%)	71 (4%)
Yorkshire & Humberside	195 (13%)	10 (13%)	1 (20%)	0 (0%)	206 (13%)	202 (12%)	199 (12%)
Total	**1024 (6%)**	**47 (6%)**	**5 (11%)**	**2 (7%)**	**1078 (6%)**	**1124 (6%)**	**1143 (6%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

The results of the exposure analysis for only high likelihood, are shown in Table 4.58.

Table 4.58: Number (and proportion) of care homes, classified by size, located in areas currently at high likelihood of flooding from rivers or the sea, by UKCP09 administrative region

	Current (2013)				
Region	**Small**	**Medium**	**Large**	**No data**	**All**
East Midlands	12 (1%)	0 (0%)	0 (0%)	0 (0%)	12 (1%)
East of England	14 (1%)	0 (0%)	0 (0%)	0 (0%)	14 (1%)
London	3 (0%)	0 (0%)	0 (0%)	0 (0%)	3 (0%)
North East	2 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (0%)
North West	5 (0%)	0 (0%)	0 (0%)	0 (0%)	5 (0%)
South East	24 (1%)	1 (1%)	0 (0%)	0 (0%)	25 (1%)
South West	25 (1%)	0 (0%)	0 (0%)	0 (0%)	25 (1%)
West Midlands	11 (1%)	0 (0%)	0 (0%)	0 (0%)	11 (1%)
Yorkshire & Humberside	6 (0%)	0 (0%)	0 (0%)	0 (0%)	6 (0%)
Total	**102 (1%)**	**1 (0%)**	**0 (0%)**	**0 (0%)**	**103 (1%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

The current level of exposure of care homes in England to a high likelihood of flooding from rivers or the sea is low; around 1%. Small care homes are the most common types and are correspondingly the most frequently exposed. Regionally, it would appear that the number of care homes located in areas of high likelihood of flooding from rivers or the sea are lowest in the North of England and increase in a southerly direction with the exception being London which is also low. The projected level of exposure to this hazard is presented in Table 4.63, Table 4.59 and Table 4.60.

Table 4.59: Number (and proportion) of care homes, classified by size, located in areas projected to be at high likelihood of flooding from rivers or the sea, in the 2020s and 2050s, by UKCP09 administrative region

	2020s			2050s		
	Medium p50			Medium p50		
Region	**Small**	**Medium**	**Large**	**Small**	**Medium**	**Large**
East Midlands	27 (2%)	0 (0%)	0 (0%)	31 (2%)	0 (0%)	0 (0%)
East of England	17 (1%)	0 (0%)	0 (0%)	20 (1%)	0 (0%)	0 (0%)
London	4 (0%)	0 (0%)	0 (0%)	4 (0%)	0 (0%)	0 (0%)
North East	5 (1%)	0 (0%)	0 (0%)	5 (1%)	0 (0%)	0 (0%)
North West	5 (0%)	0 (0%)	0 (0%)	5 (0%)	0 (0%)	0 (0%)
South East	27 (1%)	1 (1%)	0 (0%)	29 (1%)	1 (1%)	0 (0%)
South West	34 (1%)	0 (0%)	0 (0%)	43 (2%)	1 (2%)	0 (0%)
West Midlands	14 (1%)	0 (0%)	0 (0%)	14 (1%)	0 (0%)	0 (0%)
Yorkshire & Humberside	17 (0%)	0 (0%)	0 (0%)	27 (0%)	1 (0%)	0 (0%)
Total	**150 (1%)**	**1 (0%)**	**0 (0%)**	**178 (1%)**	**3 (0%)**	**0 (0%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.60: Number (and proportion) of care homes, classified by size, located in areas project to be at high likelihood of flooding from rivers or the sea, in the 2080s, by UKCP09 administrative region

	2080s Low p10 - High p90				
Region	**Small**	**Medium**	**Large**	**No data**	**All**
East Midlands	27 (2%) - 127 (0%)	0 (0%) - 4 (0%)	0 (0%) - 0 (0%)	0 (0%) - 0 (0%)	27 (2%) - 131 (8%)
East of England	18 (1%) - 89 (0%)	0 (0%) - 2 (0%)	0 (0%) - 0 (0%)	0 (0%) - 0 (0%)	18 (1%) - 91 (5%)
London	4 (0%) - 105 (0%)	0 (0%) - 10 (0%)	0 (0%) - 2 (0%)	0 (0%) - 1 (0%)	4 (0%) - 118 (7%)
North East	5 (1%) - 13 (0%)	0 (0%) - 0 (0%)	0 (0%) - 0 (0%)	0 (0%) - 0 (0%)	5 (1%) - 13 (1%)
North West	5 (0%) - 70 (0%)	0 (0%) - 2 (0%)	0 (0%) - 1 (0%)	0 (0%) - 0 (0%)	5 (0%) - 73 (3%)
South East	27 (1%) - 168 (0%)	1 (1%) - 6 (0%)	0 (0%) - 0 (0%)	0 (0%) - 1 (0%)	28 (1%) - 175 (5%)
South West	33 (1%) - 109 (0%)	1 (2%) - 5 (0%)	0 (0%) - 0 (0%)	0 (0%) - 0 (0%)	34 (1%) - 114 (5%)
West Midlands	11 (1%) - 39 (0%)	0 (0%) - 1 (0%)	0 (0%) - 1 (0%)	0 (0%) - 0 (0%)	11 (1%) - 41 (2%)
Yorkshire & Humberside	20 (0%) - 182 (0%)	0 (0%) - 9 (0%)	0 (0%) - 1 (0%)	0 (0%) - 0 (0%)	20 (0%) - 192 (0%)
Total	**150 (1%) - 902 (0%)**	**2 (0%) - 39 (0%)**	**0 (0%) - 5 (0%)**	**0 (0%) - 2 (0%)**	**152 (1%) - 948 (5%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

The projected exposure to a high likelihood of flooding from rivers or the sea indicates only a small increase in the number and proportion of current care homes exposed to the hazard. However it is important to recognise that those living in care homes are among the most vulnerable to flooding hazards and are generally unable to self-evacuate.

Flooding (surface water)

This indicator quantifies the number and proportion of care homes located in areas susceptible to surface water flooding in a 1:30 year, 1:100 year and 1:1000 year rainfall event for depths between 0.3m and 1.2m and for depths greater than 1.2m.

Table 4.61: Number (and proportion) of care homes, classified by size, located in areas that are susceptible to mid-depth surface water flooding, by UKCP09 administrative region

	Mid-depth: 0.3m<= depth <1.2m 3.3% likelihood			Mid-depth: 0.3m<= depth <1.2m 0.1% likelihood		
Region	**Small**	**Medium**	**Large**	**Small**	**Medium**	**Large**
East Midlands	0 (0%)	0 (0%)	0 (0%)	12 (1%)	0 (0%)	0 (0%)
East of England	1 (0%)	1 (1%)	0 (0%)	15 (1%)	1 (1%)	0 (0%)
London	3 (0%)	0 (0%)	0 (0%)	30 (2%)	3 (3%)	0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	1 (0%)	0 (0%)	0 (0%)	18 (1%)	1 (1%)	0 (0%)

	Mid-depth: 0.3m<= depth <1.2m			Mid-depth: 0.3m<= depth <1.2m		
South East England	1 (0%)	0 (0%)	0 (0%)	24 (1%)	1 (1%)	0 (0%)
South West England	1 (0%)	0 (0%)	0 (0%)	16 (1%)	0 (0%)	0 (0%)
West Midlands	1 (0%)	0 (0%)	0 (0%)	6 (0%)	2 (3%)	0 (0%)
Yorkshire & Humberside	3 (0%)	0 (0%)	0 (0%)	11 (1%)	0 (0%)	0 (0%)
Total	**11 (0%)**	**1 (0%)**	**0 (0%)**	**132 (1%)**	**8 (1%)**	**0 (0%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.62: Number (and proportion) of care homes, classified by size, located in areas that are susceptible to very deep surface water flooding, by UKCP09 administrative region

	Very deep: Depth >1.20m			Very deep: Depth >1.20m		
	3.3% likelihood			0.1% likelihood		
Region	**Small**	**Medium**	**Large**	**Small**	**Medium**	**Large**
East Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
East of England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
London	0 (0%)	0 (0%)	0 (0%)	8 (0%)	0 (0%)	0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)	1 (0%)	0 (0%)	0 (0%)
South East England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South West England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	3 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	0 (0%)	0 (0%)	0 (0%)	3 (0%)	0 (0%)	0 (0%)
Total	**0 (0%)**	**0 (0%)**	**0 (0%)**	**15 (0%)**	**0 (0%)**	**0 (0%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

As can be seen in Table 4.61 and Table 4.62 only a very small proportion of care homes are located in areas that are susceptible to surface water flooding. Regionally, there is an even distribution of exposure to this hazard. As the majority of care homes are small in size, it is these homes that are exposed most.

Natural landslides

This indicator quantifies the number and proportion of care homes in England located in areas of high susceptibility to natural landslides where; slope instability problems are probably present or have occurred in the past or slope instability problems are almost certainly present and may be active. Table 4.63 shows the number and proportion of care homes, since 2008, which are located in areas that are at high susceptibility to natural landslides.

Table 4.63: Number (and proportion) of care homes, classified by size, located in areas that are of high susceptibility to natural landslides, by UKCP09 administrative region

	2013			2011	2008
Region	**Small**	**Medium**	**No Data**	**No Data**	**No Data**
East Midlands	2 (0.1%)	0 (0%)	0 (0%)	2 (0%)	2 (0%)
East of England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
London	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (0%)
North West	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South East England	13 (0.4%)	0 (0%)	0 (0%)	14 (0%)	14 (0%)
South West England	18 (0.8%)	0 (0%)	0 (0%)	19 (0%)	20 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	6 (0.4%)	1 (1.3%)	0 (0%)	7 (0%)	7 (0%)
Total	**39 (0%)**	**1 (0%)**	**0 (0%)**	**42 (0%)**	**45 (0%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

The greatest susceptibility in terms of absolute figures is in the south of England in both the East and West of the country. However, these still represent a very small proportion of the number of care homes and care home beds that are found in England as a whole. The greatest number of care homes and care homes beds is found in the South East and South West of England. The number of care homes potentially susceptible to landslides has changed little since 2008.

Shrink-swell subsidence

This indicator quantifies the number and proportion of care homes located in areas of high susceptibility to shrink-swell subsidence where ground conditions are of predominantly high or very high plasticity. The number of care homes and care home beds located in areas of high susceptibility to shrink-swell subsidence is shown in Table 4.64 and Figure 4.6.

Table 4.64: Number (and proportion) of care homes, classified by size, located in areas that are of high susceptibility to shrink-swell subsidence, by UKCP09 administrative region

Summary statistics	2013				2011	2008
Region	**Small**	**Medium**	**Large**	**No Data**	**No Data**	**No Data**
East Midlands	21 (1%)	1 (2%)	0 (0%)	0 (0%)	22 (1%)	22 (1%)
East of England	495 (28%)	34 (34%)	2 (25%)	1 (100%)	532 (29%)	539 (28%)
London	986 (60%)	48 (52%)	2 (40%)	8 (73%)	1044 (60%)	1110 (60%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South East England	516 (16%)	30 (20%)	1 (25%)	2 (20%)	549 (16%)	547 (16%)
South West England	84 (4%)	3 (5%)	0 (0%)	0 (0%)	87 (4%)	93 (4%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	6 (0%)	0 (0%)	0 (0%)	0 (0%)	6 (0%)	7 (0%)
Total	**2108 (13%)**	**116 (16%)**	**5 (11%)**	**11 (37%)**	**2240 (13%)**	**2318 (13%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

The greatest number of care homes highly susceptible to shrink-swell subsidence is coincident with the location of the majority of clay soil types and so are to be expected. The overall number of care homes located in areas high susceptibility shrink-swell subsidence has reduced slightly between 2008 and 2013 in absolute terms however, the proportion that are located in areas of high susceptibility to this hazard has remained the same. The average proportion of small, medium and large-sized care homes on susceptible soils is 13%, however, where care homes have not disclosed the number of beds, this proportion rises to nearly 40%.

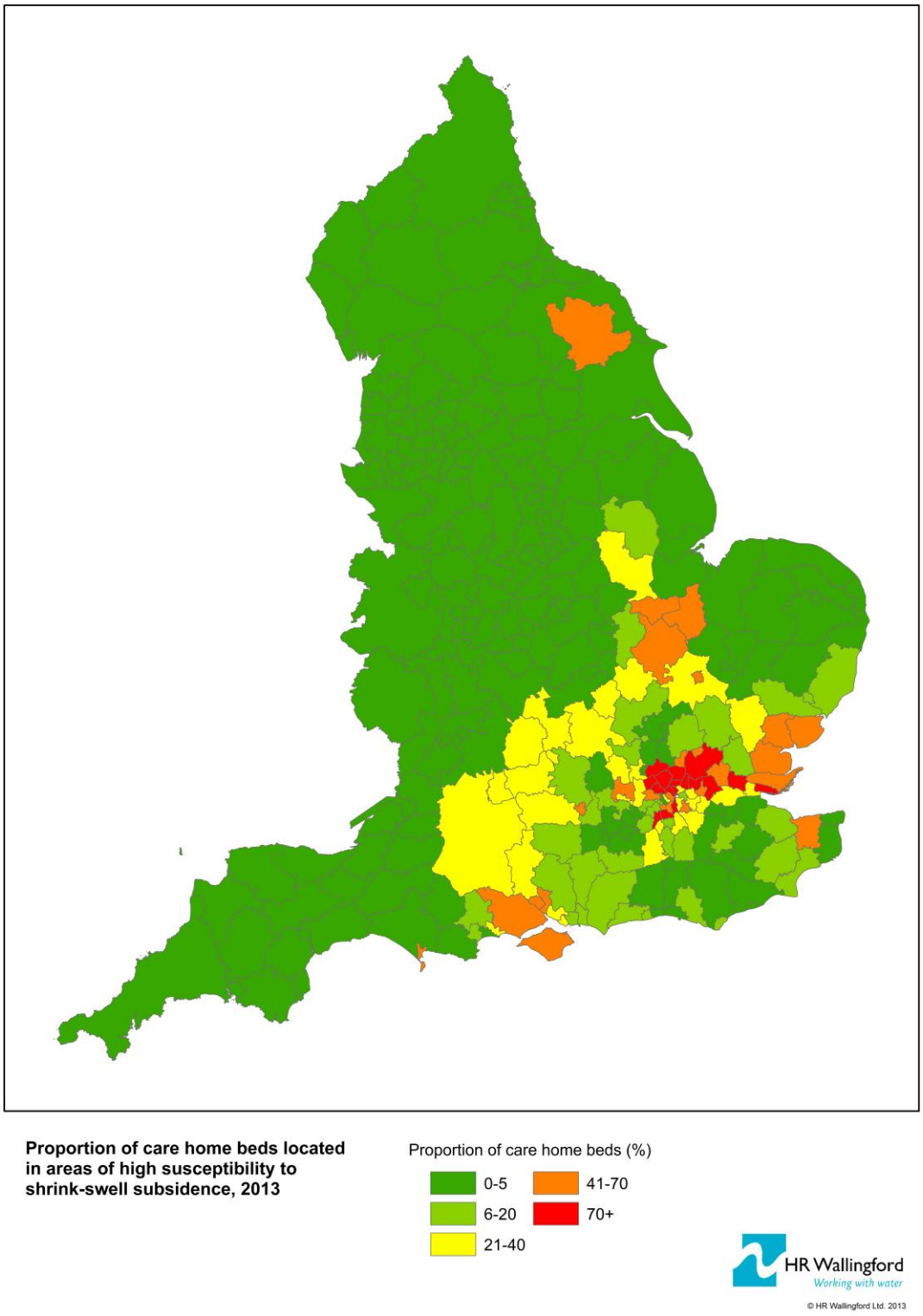

Figure 4.6: Proportion of care home beds located in areas that are also of high susceptibility to shrink-swell subsidence

4.3.2. Emergency Services

In this exposure analysis there were 2,551 emergency services stations in England. Of these, 795 were for the ambulance services, 1,330 for fire and rescue services and 426 for the police. Location information was taken from the OS Master Map using the BaseFunction categorisation.

Table 4.65: Number of emergency services stations used in this assessment

	Ambulance	Fire and rescue services	Police	Total
Stations	795	1330	426	2551

Table 4.66: Number (and proportion) of emergency services exposed to different hazards in England

	Coastal erosion[1]	Groundwater flooding[2]	River and coastal flooding[3]	Surface water flooding[4]	Shrink-swell subsidence[5]
Ambulance	3 (0%)	97 (12%)	106 (13%)	14 (2%)	65 (8%)
Fire	2 (0%)	183 (14%)	154 (12%)	28 (2%)	157 (12%)
Police	1 (0%)	55 (13%)	43 (10%)	9 (2%)	32 (8%)

Notes: Percentages are calculated as a proportion of the total number of assets, per service type.

[1]No active intervention, long term, 5th percentile scenario.

[2]High susceptibility of groundwater flooding, estimated as 1 in 200 years or more frequent.

[3]Present day flooding from rivers or the sea under any likelihood category.

[4]Mid-depth (0.3m<= depth <1.2m; 1 in 1000 year likelihood)

[5]High susceptibility category to shrink-swell subsidence.

Coastal erosion

The indicator assesses the number and proportion of emergency services located within areas that are projected to be exposed to coastal erosion over the next 100 years and the number and proportion of assets at risk behind the Shoreline Management Plan policies. Table 4.66 shows that a very low proportion of emergency services are at risk from coastal erosion. This data used for this assessment are not appropriate to analyse coastal erosion risk at an asset level.

Flooding (groundwater)

This indicator assesses the number and proportion of emergency services located in areas that are of high susceptibility to groundwater flooding. Table 4.67 shows that the proportional exposure to groundwater flooding is distributed evenly among the different services; the fire service has the most assets at exposed, but they also have the most assets. There are large differences between the regions. London and South East England both have more than 20% of their emergency services exposed, whilst the West Midlands has less than 1% of emergency services exposed. There is a relatively equal distribution of exposure to groundwater flooding between the different services on a regional level.

Table 4.67: Number (and proportion) of emergency services stations located in areas of high susceptibility to groundwater flooding, by UKCP09 administrative region

Region	Ambulance	Fire	Police	Total
East Midlands	17 (19%)	15 (13%)	9 (18%)	24 (9%)
East of England	14 (14%)	30 (15%)	5 (12%)	35 (10%)
London	14 (24%)	32 (25%)	9 (26%)	41 (19%)
North East England	3 (10%)	7 (9%)	1 (8%)	8 (7%)
North West England	12 (10%)	10 (7%)	4 (6%)	14 (4%)
South East England	27 (19%)	51 (22%)	13 (20%)	64 (15%)
South West England	7 (5%)	20 (14%)	5 (14%)	25 (8%)
Yorkshire and Humberside	0 (0%)	0 (0%)	2 (3%)	2 (1%)
West Midlands	3 (4%)	18 (13%)	7 (15%)	25 (10%)
Total	**97 (12%)**	**183 (14%)**	**55 (13%)**	**238 (9%)**

Notes: Percentages are calculated as a proportion of the total number of assets, per UKCP09 administrative region.

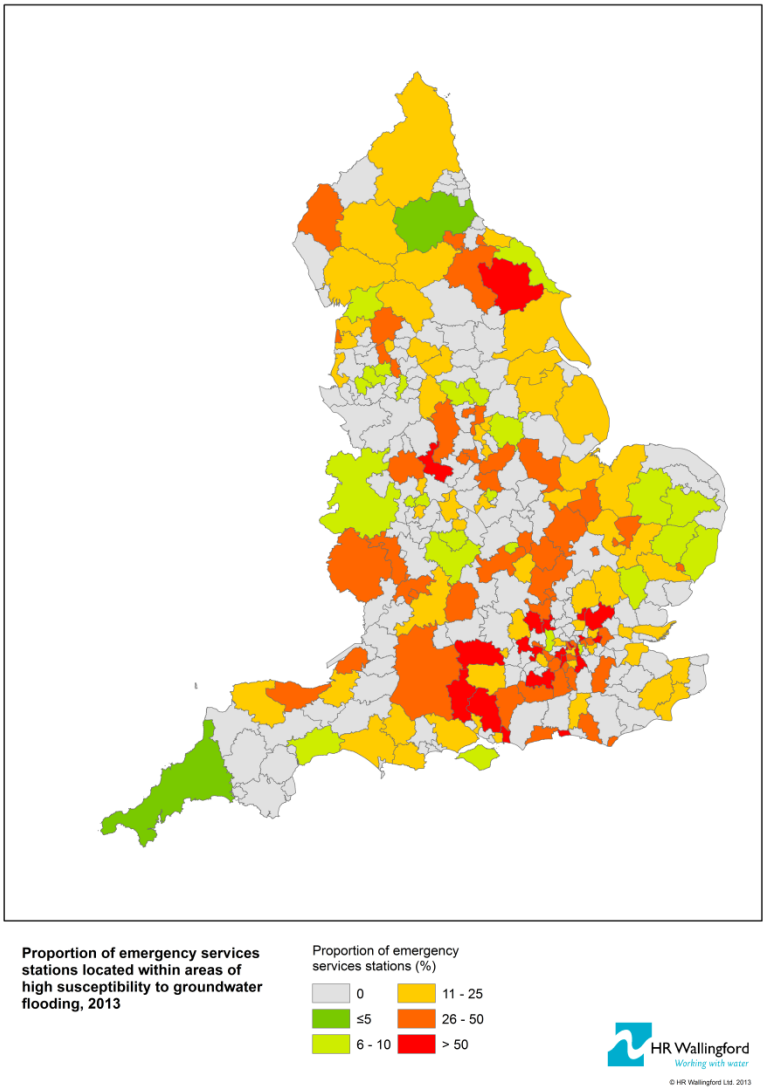

Figure 4.7: Proportion of emergency services stations located within areas of high susceptibility to groundwater flooding, 2013

Flooding (river and coastal)

This indicator quantifies the number and proportion of emergency services stations within the floodplain by flood likelihood category and takes into account the presence, performance and condition of raised flood defences. The results of the assessment of exposure to any likelihood category of flooding from rivers or the sea is shown in Table 4.68.

Table 4.68: Number (and proportion) of emergency services stations located in areas currently at any likelihood category of flooding from rivers or the sea, by UKCP09 administrative region

Region	Ambulance	Fire	Police
East Midlands	21 (23%)	11 (10%)	6 (12%)
East of England	12 (12%)	27 (13%)	5 (12%)
London	9 (15%)	15 (12%)	6 (17%)
North East	1 (3%)	5 (6%)	1 (8%)
North West	13 (11%)	13 (9%)	4 (6%)
South East	16 (11%)	32 (14%)	4 (6%)
South West	19 (15%)	16 (11%)	1 (3%)
West Midlands	5 (6%)	12 (9%)	1 (2%)
Yorkshire & Humberside	10 (23%)	23 (14%)	15 (20%)
Total	**106 (13%)**	**154 (12%)**	**43 (10%)**

Source: Percentages are calculated as a proportion of the total number of assets, per UKCP09 administrative region.

The current and projected results of the exposure analysis to a high likelihood of flooding are shown in Table 4.69, Table 4.70 and Table 4.71. The current level and future exposure up to the 2050s is low. In the 2080s, the level of exposure may rise to up to ~10% under the most extreme scenario assessed. The emergency services in Yorkshire & Humberside, East Midlands and London are projected to be more exposed than the average in the 2080s.

Table 4.69: Number (and proportion) of emergency services stations located in areas currently at high likelihood of flooding from rivers or the sea, by UKCP09 administrative region

	Current (2013)		
Region	Ambulance	Fire	Police
East Midlands	3 (3%)	2 (2%)	1 (2%)
East of England	1 (1%)	7 (3%)	0 (0%)
London	1 (2%)	0 (0%)	0 (0%)
North East	0 (0%)	1 (1%)	0 (0%)
North West	4 (3%)	2 (1%)	1 (2%)
South East England	2 (1%)	9 (4%)	0 (0%)
South West England	2 (2%)	2 (1%)	0 (0%)
West Midlands	1 (1%)	5 (4%)	1 (2%)
Yorkshire & Humberside	0 (0%)	2 (1%)	1 (1%)
Total	**14 (2%)**	**30 (2%)**	**4 (1%)**

Source: Percentages are calculated as a proportion of the total number of assets, per UKCP09 administrative region.

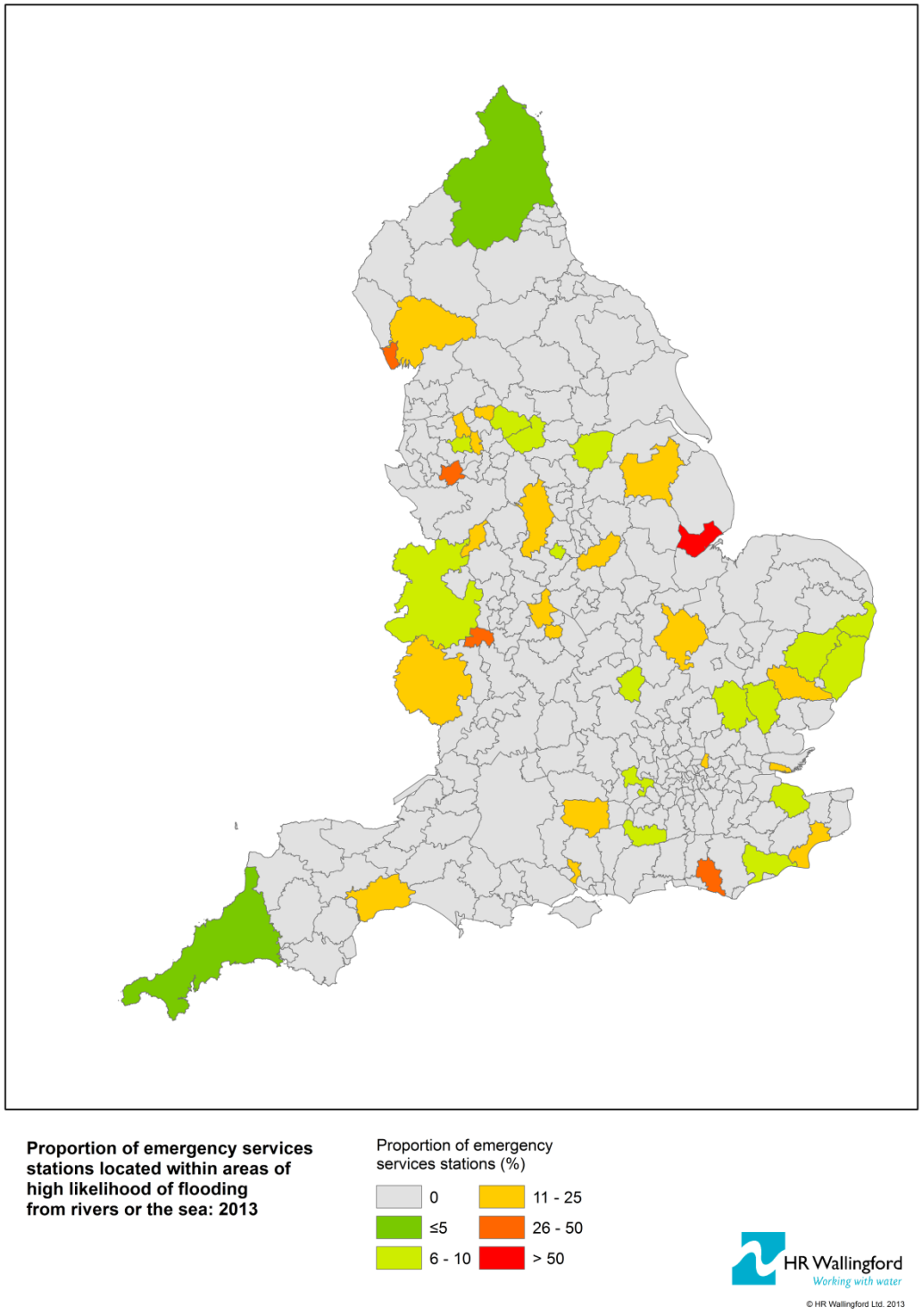

Figure 4.8: Proportion of emergency services stations located within areas of high likelihood of flooding from rivers or the sea, 2013

Table 4.70: Number (and proportion) of emergency services stations located in areas projected to be at high likelihood of flooding from rivers or the sea, by UKCP09 administrative region

	2020s Medium p50			2050s Medium p50			2080s Low p10 - High p90		
Region	**A**	**F**	**P**	**A**	**F**	**P**	**A**	**F**	**P**
East Midlands	4 (4%)	3 (3%)	2 (4%)	6 (7%)	4 (4%)	2 (4%)	4 (4%) - 15 (16%)	2 (2%) - 9 (8%)	2 (4%) - 5 (10%)
East of England	1 (1%)	7 (3%)	0 (0%)	1 (1%)	7 (3%)	0 (0%)	1 (1%) - 9 (9%)	7 (3%) - 23 (11%)	0 (0%) - 4 (9%)
London	1 (2%)	0 (0%)	0 (0%)	1 (2%)	0 (0%)	0 (0%)	1 (2%) - 8 (14%)	0 (0%) - 15 (12%)	0 (0%) - 6 (17%)
North East	0 (0%)	1 (1%)	0 (0%)	0 (0%)	2 (3%)	0 (0%)	0 (0%) - 1 (3%)	2 (3%) - 4 (5%)	0 (0%) - 1 (8%)
North West	5 (4%)	3 (2%)	1 (2%)	5 (4%)	3 (2%)	1 (2%)	5 (4%) - 12 (10%)	2 (1%) - 11 (8%)	1 (2%) - 4 (6%)
South East	5 (3%)	10 (4%)	0 (0%)	6 (4%)	12 (5%)	0 (0%)	5 (3%) - 15 (10%)	10 (4%) - 31 (13%)	0 (0%) - 4 (6%)
South West	5 (4%)	3 (2%)	0 (0%)	8 (6%)	6 (4%)	0 (0%)	5 (4%) - 17 (13%)	4 (3%) - 14 (10%)	0 (0%) - 1 (3%)
West Midlands	2 (3%)	5 (4%)	1 (2%)	2 (3%)	5 (4%)	1 (2%)	1 (1%) - 3 (4%)	5 (4%) - 8 (6%)	1 (2%) - 1 (2%)
Yorkshire & Humberside	1 (2%)	4 (2%)	3 (4%)	1 (2%)	9 (6%)	4 (5%)	0 (0%) - 9 (21%)	6 (4%) - 22 (14%)	2 (3%) - 14 (18%)
Total	**24 (3%)**	**36 (3%)**	**7 (2%)**	**30 (4%)**	**48 (4%)**	**8 (2%)**	**22 (3%) - 89 (11%)**	**38 (3%) - 137 (10%)**	**6 (1%) - 40 (9%)**

Source: A – Ambulance; F – Fire service; P – Police. Percentages are calculated as a proportion of the total number of assets, per UKCP09 administrative region.

Table 4.71: Number (and proportion) of emergency services stations located in areas susceptible to surface water flooding, by UKCP09 administrative region

	Mid-depth: 0.3m<= depth <1.2m 3.3% likelihood			Mid-depth: 0.3m<= depth <1.2m 0.1% likelihood			Very deep: Depth >1.20m 3.3% likelihood			Very deep: Depth >1.20m 0.1% likelihood		
Region	**A**	**F**	**P**	**A**	**F**	**P**	**A**	**F**	**P**	**A**	**F**	**P**
East Midlands	0 (0%)	0 (0%)	0 (0%)	2 (2%)	4 (4%)	1 (2%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
East of England	1 (1%)	0 (0%)	1 (2%)	2 (2%)	11 (5%)	2 (5%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)	1 (0%)	0 (0%)
London	1 (2%)	0 (0%)	1 (3%)	4 (7%)	1 (1%)	2 (6%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)	2 (2%)	1 (1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South East England	1 (1%)	1 (0%)	2 (3%)	3 (2%)	3 (1%)	1 (2%)	0 (0%)	0 (0%)	0 (0%)	2 (1%)	0 (0%)	0 (0%)
South West England	0 (0%)	0 (0%)	0 (0%)	1 (1%)	5 (4%)	1 (3%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (1%)	2 (3%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)
Total	**3 (0%)**	**1 (0%)**	**4 (1%)**	**14 (2%)**	**28 (2%)**	**9 (2%)**	**0 (0%)**	**0 (0%)**	**0 (0%)**	**3 (0%)**	**1 (0%)**	**1 (0%)**

Source: 'A' – Ambulance Service; 'F' Fire Service; 'P' – Police. Percentages are calculated as a proportion of the total number of assets, per UKCP09 administrative region.

Flooding (surface water)

This indicator quantifies the number and proportion of emergency services located in areas susceptible to surface water flooding in a 1:30 year, 1:100 year and 1:1000 year rainfall for depths between 0.3m and 1.2m and for depths greater than 1.2m.

Table 4.71 shows the exposure analysis of emergency services in England to areas susceptible to surface water flooding.

Only a very small proportion of emergency services are located in areas that are susceptible to surface water flooding. There is no strong regional of service type signal in these results.

Shrink-swell subsidence

This indicator quantifies the number and proportion of emergency service stations located in areas of high susceptibility to shrink-swell subsidence where ground conditions are of predominantly high or very high plasticity.

The results of the analysis at a regional level are shown in Table 4.72.

Table 4.72: Number (and proportion) of emergency service stations located in areas of high susceptibility of shrink-swell subsidence, by UKCP09 administrative region

Region	Ambulance	Fire	Police
East Midlands	1 (1%)	0 (0%)	0 (0%)
East of England	24 (25%)	53 (26%)	8 (19%)
London	20 (34%)	58 (46%)	16 (46%)
North East England	0 (0%)	0 (0%)	0 (0%)
North West England	0 (0%)	0 (0%)	0 (0%)
South East England	16 (11%)	37 (16%)	6 (9%)
South West England	4 (3%)	7 (5%)	2 (6%)
West Midlands	0 (0%)	0 (0%)	0 (0%)
Yorkshire and Humberside	0 (0%)	2 (1%)	0 (0%)
Total	**65 (8%)**	**157 (12%)**	**32 (8%)**

Notes: Percentages are calculated as a proportion of the total number of assets, per UKCP09 administrative region.

As would be expected, the greatest exposure to shrink-swell susceptible locations is coincident with areas of predominantly clay soils in England. Assets in London and the East of England are at greatest susceptibility and 1.5 times the proportion of fire services are susceptible compared to either ambulance or police.

4.3.3. GP surgeries

In order to assess the criticality of GP surgeries, the number of people signed up to the surgery is used. The categories used are:

- High: >10,000 people
- Medium: >5000 to 10,000 people
- Low: <5,000 people
- No data.

Table 4.73: Number of GP surgeries, categorized by the number of people registered, used in this assessment

	High	Medium	Low	Total
GP surgeries	1,783	3,115	3,046	7,997

Where the number of people signed up to the surgery was 0, no data has been assumed. Of the 7,997 GP surgeries included in the analysis, 3,046 had a low level subscription to their services, 3,115 had a medium level of subscription, 1,783 had a high level of subscription and 53 did not provide any information on the number of people subscribed to their services. Whilst the location information is considered accurate, postcodes provide the location information. Postcodes must be digitised into co-ordinates for the spatial assessment and this introduces some error.

Table 4.74: Number (and proportion) of GP surgeries exposed to different hazards in England

No. of patients category	Coastal erosion[1]	Groundwater flooding[2]	River and coastal flooding[3]	Shrink-swell subsidence[4]
High	0 -3 (0%)	251 (14%)	176 (10%)	278 (16%)
Medium	2 - 5 (0%)	358 (11%)	262 (8%)	475 (15%)
Low	0 (0%)	320 (11%)	257 (8%)	517 (17%)
No data	0 (0%)	7 (13%)	6 (11%)	9 (17%)

Notes: Percentages are calculated as a proportion of the total number of assets per criticality category.

[1]Range of exposure dependent upon time period, scenario and policy

[2]High susceptibility of groundwater flooding, estimated as 1 in 200 years or more frequent.

[3]Present day flooding from rivers or the sea under any likelihood category.

[4]High susceptibility category to shrink-swell subsidence.

Coastal erosion

The indicator assesses the number and proportion of GP surgeries located within locations that are projected to be exposed to coastal erosion over the next 100 years and the number and proportion of assets at risk behind the Shoreline Management Plan policies. Table 4.75 shows the regional distribution of GP surgeries potentially at risk from coastal erosion.

Table 4.75: Number (and proportion) of GP surgeries, categorised by patient numbers, located in areas susceptible to coastal erosion, by UKCP09 administrative region

Region	Medium term				Long term			
	L	M	H	Total	L	M	H	Total
East Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
East of England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0%)	0 (0%)	1 (0%)
London	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South East	0 (0%)	2 (0%)	0 (0%)	2 (0%)	0 (0%)	4 (1%)	1 (0%)	5 (0%)
South West	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)	1 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)	1 (0%)
Total	**0 (0%)**	**2 (0%)**	**0 (0%)**	**2 (0%)**	**0 (0%)**	**5 (0%)**	**3 (0%)**	**8 (0%)**

Notes: 'L' – Low level subscription; 'M' – Medium level subscription; 'H' – High level subscription. Shoreline Management Plan scenarios, 5th percentile for the short (no results), medium and long term were analysed. Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

A very low proportion of GP surgeries were found to be located in areas that may be at risk from coastal erosion. At a local level there may be assets that are at risk, although site level assessments should be made to identify such hazards at a local scale.

Flooding (groundwater)

This indicator assesses the number and proportion of GP surgeries located in areas that are considered to be of high susceptibility to groundwater flooding. There is a relatively even distribution of exposure among the criticality categories. The regional break down of the GP surgeries exposed to a high susceptibility to groundwater flooding is presented in Table 4.76 and Figure 4.9. London has the highest absolute number and the largest proportion of surgeries that may be exposed to groundwater flooding.

Table 4.76: Number (and proportion) of GP surgeries, categorised by patient numbers, located in areas of high susceptibility to groundwater flooding, by UKCP09 administrative region

Region	Low	Medium	High	No data	Total
East Midlands	27 (13%)	29 (12%)	18 (12%)	0 (0%)	74 (12%)
East of England	23 (10%)	32 (11%)	34 (14%)	0 (0%)	89 (11%)
London	135 (21%)	116 (21%)	47 (20%)	2 (14%)	300 (21%)
North East England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South East England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South West England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
West Midlands	21 (5%)	22 (7%)	24 (14%)	0 (0%)	67 (7%)
Yorkshire and Humberside	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Total	**320 (11%)**	**358 (11%)**	**251 (14%)**	**7 (13%)**	**936 (12%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Flooding (river and coastal)

This indicator quantifies the number and proportion of GP surgeries within the floodplain by flood likelihood category and takes into account the presence, performance and condition of raised flood defences.

The results of the exposure analysis for all flood likelihoods is shown in Table 4.77.

Table 4.77: Number (and proportion) of GP surgeries, categorised by patient numbers, located in areas currently at any likelihood category of flooding from rivers or the sea, by UKCP09 administrative region

Region	Low	Medium	High	No Data
East Midlands	16 (7%)	25 (10%)	16 (11%)	1 (33%)
East of England	28 (12%)	23 (8%)	16 (7%)	0 (0%)
London	53 (8%)	63 (11%)	31 (13%)	2 (14%)
North East	2 (1%)	0 (0%)	0 (0%)	0 (0%)
North West	33 (6%)	29 (6%)	15 (8%)	2 (20%)
South East	37 (13%)	30 (7%)	33 (9%)	1 (20%)
South West	17 (9%)	41 (13%)	25 (13%)	0 (0%)
West Midlands	10 (2%)	9 (3%)	13 (8%)	0 (0%)
Yorkshire & Humberside	61 (21%)	42 (14%)	27 (16%)	0 (0%)
Total	**257 (8%)**	**262 (8%)**	**176 (10%)**	**6 (11%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

The results of the exposure and the projections analysis are shown in Table 4.78, Table 4.79, Table 4.80, Table 4.81 and Figure 4.10. Around 1% of GP surgeries are currently located in areas that are susceptible to flooding from rivers or the sea. In the 2080s the this figure may change to between 1-8% (low emissions p10 to high emissions p90) of all GP surgeries in England, depending upon the scenario.

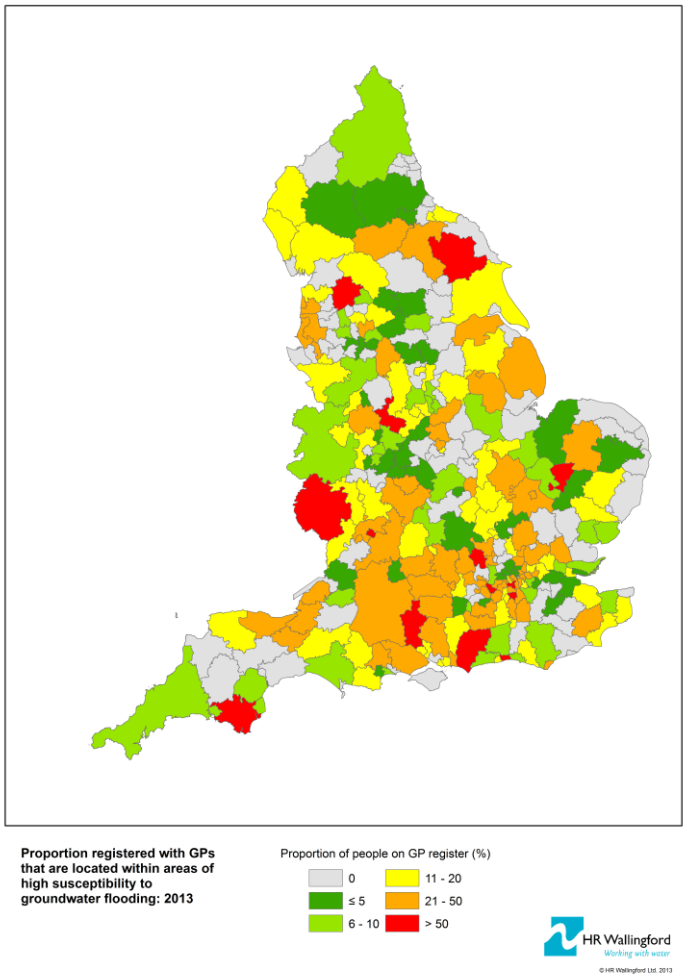

Figure 4.9: Distribution of GP surgeries located in areas of high susceptibility to groundwater flooding

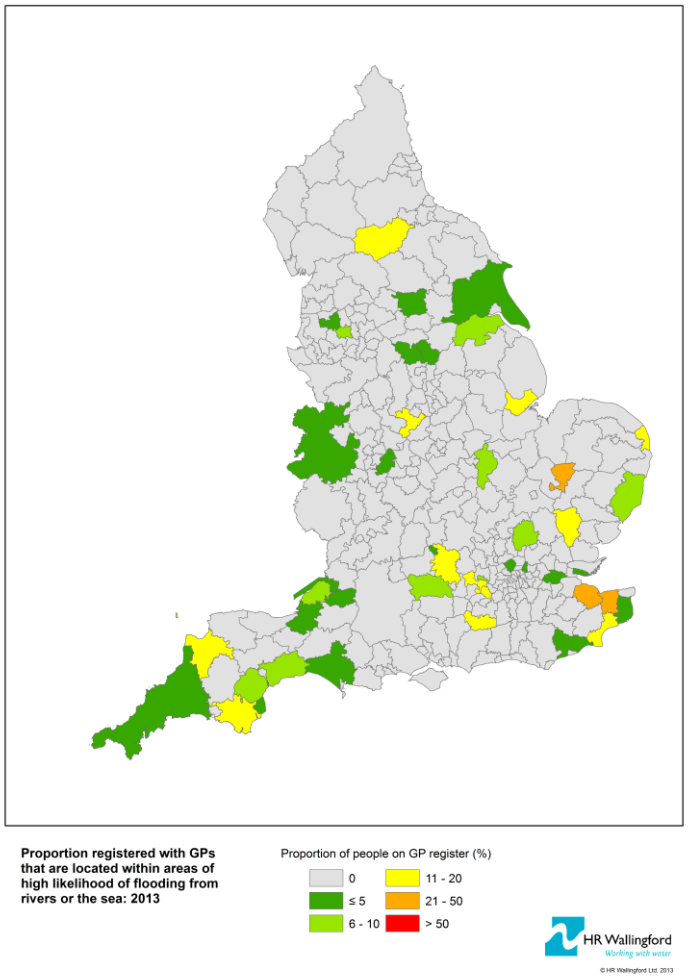

Figure 4.10: Proportion registered with GPs that are located within areas of high likelihood of flooding from rivers or the sea, 2013

Table 4.78: Number (and proportion) of GP surgeries, categorised by patient numbers, located in areas currently at high likelihood of flooding from rivers or the sea, by UKCP09 administrative region

	Current (2011-2012)				
Region	**Low**	**Medium**	**High**	**No data**	**All**
East Midlands	0 (0%)	2 (1%)	1 (1%)	0 (0%)	3 (0%)
East of England	2 (1%)	3 (1%)	3 (1%)	0 (0%)	8 (1%)
London	0 (0%)	2 (0%)	1 (0%)	0 (0%)	3 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	2 (0%)	1 (0%)	1 (1%)	1 (10%)	5 (0%)
South East	13 (4%)	2 (0%)	8 (2%)	0 (0%)	23 (2%)
South West	4 (2%)	9 (3%)	1 (1%)	0 (0%)	14 (2%)
West Midlands	1 (0%)	0 (0%)	1 (1%)	0 (0%)	2 (0%)
Yorkshire & Humberside	1 (0%)	4 (1%)	1 (1%)	0 (0%)	6 (1%)
Total	**23 (1%)**	**23 (1%)**	**17 (1%)**	**1 (2%)**	**64 (1%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.79: Number (and proportion) of GP surgeries, categorised by patient numbers, located in areas projected to be at high likelihood of flooding from rivers or the sea, in the 2020s, by UKCP09 administrative region

	2020s				
	Medium p50				
Region	**Low**	**Medium**	**High**	**No data**	**All**
East Midlands	1 (0%)	4 (2%)	4 (3%)	0 (0%)	9 (1%)
East of England	3 (1%)	5 (2%)	4 (2%)	0 (0%)	12 (2%)
London	0 (0%)	2 (0%)	1 (0%)	0 (0%)	3 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	3 (1%)	1 (0%)	3 (2%)	1 (10%)	8 (1%)
South East	13 (4%)	2 (0%)	9 (3%)	0 (0%)	24 (2%)
South West	5 (3%)	12 (4%)	3 (2%)	0 (0%)	20 (3%)
West Midlands	2 (0%)	1 (0%)	2 (1%)	0 (0%)	5 (1%)
Yorkshire & Humberside	5 (2%)	7 (2%)	4 (2%)	0 (0%)	16 (2%)
Total	**32 (1%)**	**34 (1%)**	**30 (2%)**	**1 (2%)**	**97 (1%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.80: Number (and proportion) of GP surgeries, categorised by patient numbers, located in areas projected to be at high likelihood of flooding from rivers or the sea, in the 2050s, by UKCP09 administrative region

	2050s Medium p50				
Region	**Low**	**Medium**	**High**	**No data**	**All**
East Midlands	3 (1%)	6 (2%)	6 (4%)	0 (0%)	15 (2%)
East of England	3 (1%)	6 (2%)	4 (2%)	0 (0%)	13 (2%)
London	0 (0%)	3 (1%)	1 (0%)	0 (0%)	4 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	3 (1%)	1 (0%)	3 (2%)	1 (10%)	8 (1%)
South East	16 (5%)	3 (1%)	11 (3%)	0 (0%)	30 (3%)
South West	7 (4%)	16 (5%)	8 (4%)	0 (0%)	31 (4%)
West Midlands	2 (0%)	2 (1%)	2 (1%)	0 (0%)	6 (1%)
Yorkshire & Humberside	13 (4%)	10 (3%)	8 (5%)	0 (0%)	31 (4%)
Total	**47 (2%)**	**47 (2%)**	**43 (2%)**	**1 (2%)**	**138 (2%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.81: Number (and proportion) of GP surgeries, categorised by patient numbers, located in areas projected to be at high likelihood of flooding from rivers or the sea, in the 2080s, by UKCP09 administrative region

	2080s Low p10 - High p90				
Region	**Low**	**Medium**	**High**	**No data**	**All**
East Midlands	1 (0%) - 9 (4%)	5 (2%) - 20 (8%)	2 (1%) - 14 (9%)	0 (0%) - 1 (33%)	8 (1%) - 44 (7%)
East of England	3 (1%) - 20 (8%)	5 (2%) - 17 (6%)	3 (1%) - 13 (5%)	0 (0%) - 0 (0%)	11 (1%) - 50 (6%)
London	0 (0%) - 52 (8%)	3 (1%) - 60 (11%)	1 (0%) - 31 (13%)	0 (0%) - 2 (14%)	4 (0%) - 145 (10%)
North East	0 (0%) - 2 (1%)	0 (0%) - 0 (0%)	0 (0%) - 0 (0%)	0 (0%) - 0 (0%)	0 (0%) - 2 (1%)
North West	3 (1%) - 25 (4%)	1 (0%) - 28 (6%)	2 (1%) - 13 (7%)	1 (10%) - 2 (20%)	7 (1%) - 68 (6%)
South East	14 (5%) - 36 (12%)	2 (0%) - 26 (6%)	9 (3%) - 30 (8%)	0 (0%) - 1 (20%)	25 (2%) - 93 (8%)
South West	7 (4%) - 16 (8%)	15 (5%) - 38 (12%)	7 (4%) - 22 (11%)	0 (0%) - 0 (0%)	29 (4%) - 76 (11%)
West Midlands	1 (0%) - 5 (1%)	0 (0%) - 4 (1%)	2 (1%) - 9 (5%)	0 (0%) - 0 (0%)	3 (0%) - 18 (2%)
Yorkshire & Humberside	8 (3%) - 53 (18%)	7 (2%) - 41 (13%)	5 (3%) - 26 (15%)	0 (0%) - 0 (0%)	20 (3%) - 120 (15%)
Total	**37 (1%) - 218 (7%)**	**38 (1%) - 234 (8%)**	**31 (2%) - 158 (9%)**	**1 (2%) - 6 (11%)**	**107 (1%) - 616 (8%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Flooding (surface water)

This indicator quantifies the number and proportion of GP surgeries located in areas susceptible to surface water flooding in a 1:30 year, 1:100 year and 1:1000 year rainfall event for depths between 0.3m and 1.2m and for depths greater than 1.2m.

Table 4.82 and Table 4.83 presents the results for the exposure analysis. Few GP surgeries are located in areas that are susceptible to surface water flooding to these depths. There is no clear regional signal from these results.

Table 4.82: Number (and proportion) of GP surgeries, categorised by patient numbers, located in areas susceptible to mid-depth surface water flooding, by UKCP09 administrative region

	Mid-depth: 0.3m<= depth <1.2m 3.3% likelihood				Mid-depth: 0.3m<= depth <1.2m 0.1% likelihood			
Region	**Low**	**Medium**	**High**	**No data**	**Low**	**Medium**	**High**	**No data**
East Midlands	1 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0%)	3 (1%)	1 (1%)	0 (0%)
East of England	0 (0%)	1 (0%)	0 (0%)	0 (0%)	4 (2%)	7 (2%)	2 (1%)	0 (0%)
London	3 (0%)	1 (0%)	0 (0%)	0 (0%)	15 (2%)	9 (2%)	4 (2%)	0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (1%)	2 (2%)	1 (100%)
North West	0 (0%)	1 (0%)	0 (0%)	0 (0%)	5 (1%)	11 (2%)	3 (2%)	1 (10%)
South East England	0 (0%)	0 (0%)	1 (0%)	0 (0%)	9 (3%)	4 (1%)	8 (2%)	0 (0%)
South West England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	3 (2%)	4 (1%)	0 (0%)	0 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	3 (1%)	0 (0%)	1 (1%)	0 (0%)
Yorkshire & Humberside	0 (0%)	0 (0%)	0 (0%)	0 (0%)	4 (1%)	2 (1%)	1 (1%)	0 (0%)
Total	**4 (0%)**	**3 (0%)**	**1 (0%)**	**0 (0%)**	**44 (1%)**	**42 (1%)**	**22 (1%)**	**2 (4%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.83: Number (and proportion) of GP surgeries, categorised by patient numbers, located in areas susceptible to very deep surface water flooding, by UKCP09 administrative region

	Very deep: Depth >1.20m 3.3% likelihood				Very deep: Depth >1.20m 0.1% likelihood			
Region	**Low**	**Medium**	**High**	**No data**	**Low**	**Medium**	**High**	**No data**
East Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
East of England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0%)	0 (0%)	0 (0%)
London	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0%)	0 (0%)	0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (0%)	1 (0%)	0 (0%)	0 (0%)
South East England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (0%)	1 (0%)	0 (0%)
South West England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0%)	0 (0%)	0 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0%)	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)	0 (0%)
Total	**0 (0%)**	**0 (0%)**	**0 (0%)**	**0 (0%)**	**3 (0%)**	**6 (0%)**	**2 (0%)**	**0 (0%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Shrink-swell subsidence

This indicator quantifies the number and proportion of GP surgeries located in areas of high susceptibility to shrink-swell subsidence where ground conditions are of predominantly high or very high plasticity.

The results of the exposure analysis are shown in Table 4.84.

Table 4.84: Number (and proportion) of GPs surgeries, categorised by patient numbers, that are located in areas of high susceptibility to shrink-swell subsidence, by UKCP09 administrative region

Region	Low	Medium	High
East Midlands	1 (0%)	1 (0%)	3 (2%)
East of England	89 (37%)	71 (24%)	56 (23%)
London	377 (59%)	320 (57%)	132 (56%)
North East	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)
South East	41 (14%)	68 (15%)	71 (20%)
South West	7 (4%)	14 (4%)	15 (8%)
West Midlands	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	2 (1%)	1 (0%)	1 (1%)
Total	**517 (17%)**	**475 (15%)**	**278 (16%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

In some regions, the proportion of GPs surgeries located in areas that are highly susceptible to shrink-swell subsidence is nearly as high as 60%. This is likely to be reflective of both the location of suitable clay soils and areas of dense population i.e. London and the South East.

4.3.4. Hospitals

In order to assess the criticality of hospitals, the total number of beds is used. The categories used are:

- Large: >400 beds
- Medium: > 200 to 400 beds
- Small: <200 beds
- No data.

Table 4.85: Number of hospitals, categorized by the number of beds, used in this assessment

	Large	Medium	Small	No data	Total
Hospitals	130	73	803	380	1,386

Of the 1,386 hospitals in this analysis, 803 are considered to be small hospitals, 73 medium sized and 130 are large. Around 27% (380) of hospitals fall into the 'no data' category. The number of hospitals in each size category may therefore not appropriately represent the size distribution of English hospitals. Whilst the location information is considered accurate, postcodes provide the location information. Postcodes must be digitised into co-ordinates for the spatial assessment and this introduces some error. Furthermore, hospitals often cover large sites. Data on the area covered by each hospital was not represented by the postcode data used and therefore, each hospital has been digitised to a single point. It is conceivable that different parts of a hospital site could be exposed to different hazards in different ways.

Table 4.86: Number (and proportion) of hospitals exposed to different hazards in England

No. of beds category	Coastal erosion[1]	Groundwater flooding[2]	River and coastal flooding[3]	Surface water flooding[4]	Shrink-swell subsidence[5]
Large	0 (0%)	11 (8%)	47 (6%)	1 (1%)	103 (13%)
Medium	0 (0%)	8 (11%)	2 (3%)	0 (0%)	3 (4%)
Small	4 (0%)	50 (6%)	6 (5%)	9 (1%)	17 (13%)
No data	1 (0%)	37 (10%)	26 (7%)	5 (1%)	62 (16%)

Notes: Percentages are calculated as a proportion of the total number of assets per criticality category.

[1]No Active Intervention, long-term, 5th percentile scenario

[2]High susceptibility of groundwater flooding, estimated as 1 in 200 years or more frequent.

[3]Present day flooding from rivers or the sea under any likelihood category.

[4]Mid-depth (0.3m<= depth <1.2m; 1 in 1000 year likelihood)

[5]High susceptibility category to shrink-swell subsidence.

Coastal erosion

The indicator assesses the number and proportion of hospitals located within areas that are projected to be exposed to coastal erosion over the next 100 years and the number and proportion of assets at risk behind the Shoreline Management Plan policies. Table 4.86 shows that a very small proportion hospitals are potentially exposed to coastal erosion. Only hospitals in the low criticality category are located in areas that may be at risk.

Flooding (groundwater)

This indicator assesses the number and proportion of hospitals located in areas that are of high susceptibility to groundwater flooding. At a national level ~8% of all hospitals are located in these areas. The distribution among the criticality categories is relatively even. The regional distribution of the results is presented in Table 4.87. London and the South East of England have the highest number and proportion of hospitals in areas of high susceptibility to groundwater flooding.

Table 4.87: Number (and proportion) hospitals, categorised by size, located in areas of high susceptibility to groundwater flooding, by UKCP09 administrative region

	Small	Medium	Large	No data	Total
East Midlands	3 (4%)	0 (0%)	1 (9%)	3 (10%)	7 (5%)
East of England	4 (5%)	0 (0%)	2 (17%)	2 (5%)	8 (6%)
London	13 (12%)	3 (38%)	2 (12%)	17 (27%)	35 (18%)
North East	4 (7%)	0 (0%)	0 (0%)	1 (3%)	5 (4%)
North West	3 (3%)	0 (0%)	0 (0%)	2 (6%)	5 (3%)
South East	13 (10%)	3 (27%)	4 (18%)	5 (9%)	25 (11%)
South West	4 (5%)	0 (0%)	1 (4%)	2 (4%)	7 (4%)
West Midlands	4 (5%)	1 (10%)	1 (11%)	5 (12%)	11 (7%)
Yorkshire & Humberside	2 (3%)	1 (14%)	0 (0%)	0 (0%)	3 (3%)
Total	**50 (6%)**	**8 (11%)**	**11 (8%)**	**37 (10%)**	**106 (8%)**

Notes: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Flooding (river and coastal)

This indicator quantifies the number and proportion of hospitals located within the floodplain by flood likelihood category and takes into account the presence, performance and condition of raised flood defences. The results of the exposure analysis to any likelihood category of flooding from rivers or the sea is shown in Table 4.88.

Table 4.88: Number (and proportion) of hospitals, categorised by size, located in areas currently of any likelihood category of flooding from rivers or the sea, by UKCP09 administrative region

Region	Small	Medium	Large	No Data
East Midlands	7 (8%)	0 (0%)	2 (18%)	4 (14%)
East of England	2 (2%)	0 (0%)	0 (0%)	0 (0%)
London	11 (10%)	1 (13%)	1 (6%)	6 (10%)
North East	0 (0%)	0 (0%)	0 (0%)	1 (3%)
North West	5 (5%)	0 (0%)	2 (13%)	0 (0%)
South East	1 (1%)	1 (9%)	0 (0%)	3 (5%)
South West	10 (12%)	0 (0%)	1 (4%)	5 (10%)
West Midlands	1 (1%)	0 (0%)	0 (0%)	2 (5%)
Yorkshire & Humberside	10 (14%)	0 (0%)	0 (0%)	5 (19%)
Total	**47 (6%)**	**2 (3%)**	**6 (5%)**	**26 (7%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

The results of the exposure analysis to high likelihood of flooding from rivers or the sea is shown in Table 4.89, Table 4.90, Table 4.91 and Table 4.92.

Table 4.89: Number (and proportion) of hospitals, categorised by size, located in areas currently of high likelihood of flooding from rivers or the sea, by UKCP09 administrative region

	Current (2011-2012)				
Region	Small	Medium	Large	No Data	All
East Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
East of England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
London	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	1 (1%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)
South East	0 (0%)	0 (0%)	0 (0%)	1 (2%)	1 (0%)
South West	0 (0%)	0 (0%)	0 (0%)	2 (4%)	2 (1%)
West Midlands	1 (1%)	0 (0%)	0 (0%)	1 (2%)	2 (1%)
Yorkshire & Humberside	1 (1%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)
Total	**3 (0%)**	**0 (0%)**	**0 (0%)**	**4 (1%)**	**7 (1%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.90: Number (and proportion) of hospitals, categorised by size, located in areas projected to be of high likelihood of flooding from rivers or the sea, in the 2020s, by UKCP09 administrative region

	2020s				
	Medium p50				
Region	**Small**	**Medium**	**Large**	**No Data**	**All**
East Midlands	0 (0%)	0 (0%)	0 (0%)	1 (3%)	1 (1%)
East of England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
London	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	1 (1%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)
South East	0 (0%)	1 (9%)	0 (0%)	1 (2%)	2 (1%)
South West	0 (0%)	0 (0%)	0 (0%)	2 (4%)	2 (1%)
West Midlands	1 (1%)	0 (0%)	0 (0%)	1 (2%)	2 (1%)
Yorkshire & Humberside	1 (1%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)
Total	**3 (0%)**	**1 (1%)**	**0 (0%)**	**5 (1%)**	**9 (1%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.91: Number (and proportion) of hospitals, categorised by size, located in areas projected to be of high likelihood of flooding from rivers or the sea, in the 2050s, by UKCP09 administrative region

	2050s				
	Medium p50				
Region	**Small**	**Medium**	**Large**	**No Data**	**All**
East Midlands	0 (0%)	0 (0%)	1 (9%)	1 (3%)	2 (1%)
East of England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
London	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	1 (1%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)
South East	0 (0%)	1 (9%)	0 (0%)	1 (2%)	2 (1%)
South West	0 (0%)	0 (0%)	0 (0%)	2 (4%)	2 (1%)
West Midlands	1 (1%)	0 (0%)	0 (0%)	1 (2%)	2 (1%)
Yorkshire & Humberside	3 (4%)	0 (0%)	0 (0%)	0 (0%)	3 (3%)
Total	**5 (1%)**	**1 (1%)**	**1 (1%)**	**5 (1%)**	**12 (1%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.92: Number (and proportion) of hospitals, categorised by size, located in areas projected to be of high likelihood of flooding from rivers or the sea, in the 2080s, by UKCP09 administrative region

	2080s			
	Low p10 to High p90			
Region	**Small**	**Large**	**No Data**	**All**
East Midlands	0 (0%) - 6 (7%)	0 (0%) - 0 (0%)	0 (0%) - 2 (18%)	1 (3%) - 4 (14%)
East of England	0 (0%) - 2 (2%)	0 (0%) - 0 (0%)	0 (0%) - 0 (0%)	0 (0%) - 0 (0%)
London	0 (0%) - 11 (10%)	0 (0%) - 1 (13%)	0 (0%) - 1 (6%)	0 (0%) - 6 (10%)
North East	0 (0%) - 0 (0%)	0 (0%) - 0 (0%)	0 (0%) - 0 (0%)	0 (0%) - 1 (3%)
North West	1 (1%) - 5 (5%)	0 (0%) - 0 (0%)	0 (0%) - 2 (13%)	0 (0%) - 0 (0%)
South East	0 (0%) - 0 (0%)	0 (0%) - 1 (9%)	0 (0%) - 0 (0%)	1 (2%) - 3 (5%)
South West	0 (0%) - 10 (12%)	0 (0%) - 0 (0%)	0 (0%) - 1 (4%)	2 (4%) - 5 (10%)
West Midlands	1 (1%) - 1 (1%)	0 (0%) - 0 (0%)	0 (0%) - 0 (0%)	1 (2%) - 2 (5%)
Yorkshire & Humberside	2 (3%) - 10 (14%)	0 (0%) - 0 (0%)	0 (0%) - 0 (0%)	0 (0%) - 5 (19%)
Total	**4 (0%) - 45 (6%)**	**0 (0%) - 2 (3%)**	**0 (0%) - 6 (5%)**	**5 (1%) - 26 (7%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

In the present day, the level of exposure in England of hospitals to flooding from rivers or the sea is ~1%. In some scenarios, this increases to up to 6% (high emissions p90). In Yorkshire & Humberside, London and the East Midlands, the change in exposure is greatest. There is little difference between the exposure of different sizes of hospitals.

Flooding (surface water)

This indicator quantifies the number and proportion of hospitals located in areas susceptible to surface water flooding in a 1:30 year, 1:100 year and 1:1000 year rainfall event for depths between 0.3m and 1.2m and for depths greater than 1.2m. The results of the exposure analysis are presented in Table 4.93 and Table 4.94. Very few hospitals are located in areas that are susceptible to surface water flooding to these depths.

Table 4.93: Number (and proportion) of hospitals, categorised by size, located in areas susceptible to mid-depth surface water flooding, by UKCP09 administrative region

	Mid-depth: 0.3m<= depth <1.2m 3.3% likelihood				Mid-depth: 0.3m<= depth <1.2m 0.1% likelihood			
Region	**Small**	**Medium**	**Large**	**No data**	**Small**	**Medium**	**Large**	**No data**
East Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
East of England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (2%)	0 (0%)	0 (0%)	0 (0%)
London	0 (0%)	0 (0%)	0 (0%)	0 (0%)	5 (5%)	0 (0%)	1 (6%)	3 (5%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (3%)
North West	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South East England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South West England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)	0 (0%)	0 (0%)	0 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (2%)
Yorkshire & Humberside	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)	0 (0%)	0 (0%)	0 (0%)
Total	**0 (0%)**	**0 (0%)**	**0 (0%)**	**0 (0%)**	**9 (1%)**	**0 (0%)**	**1 (1%)**	**5 (1%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.94: Number (and proportion) of hospitals, categorised by size, located in areas susceptible to very deep surface water flooding, by UKCP09 administrative region

	Very deep: Depth >1.20m 3.3% likelihood				Very deep: Depth >1.20m 0.1% likelihood			
Region	**Small**	**Medium**	**Large**	**No data**	**Small**	**Medium**	**Large**	**No data**
East Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
East of England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
London	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)	0 (0%)	0 (0%)	0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South East England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South West England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Total	**0 (0%)**	**0 (0%)**	**0 (0%)**	**0 (0%)**	**1 (0%)**	**0 (0%)**	**0 (0%)**	**0 (0%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Shrink-swell subsidence

This indicator quantifies the number and proportion of hospitals located in areas of high susceptibility to shrink-swell subsidence where ground conditions are of predominantly high or very high plasticity.

Analysis of the exposure of hospitals to this hazard, shown in Table 4.95, indicates that around 12% of all hospitals may be exposed to shrink-swell subsidence due to their location on high plasticity soils. Unsurprisingly, the majority of these hospitals are located in London, the East and South East of England, co-incident with the location of clay soil types. There are fewer medium-sized hospitals at risk, compared to large or small hospitals. The local authority distribution of this exposure indicator is shown in Table 4.95.

Table 4.95: Number (and proportion) of hospitals, categorised by size, located in areas of high susceptibility of shrink-swell subsidence, by UKCP09 administrative region

Region	Small	Medium	Large	No Data
East Midlands	0 (0%)	0 (0%)	0 (0%)	1 (3%)
East of England	11 (14%)	1 (17%)	4 (33%)	8 (21%)
London	60 (56%)	1 (13%)	10 (59%)	34 (55%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South East	26 (20%)	1 (9%)	2 (9%)	14 (24%)
South West	6 (7%)	0 (0%)	1 (4%)	5 (10%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Total	**103 (13%)**	**3 (4%)**	**17 (13%)**	**62 (16%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

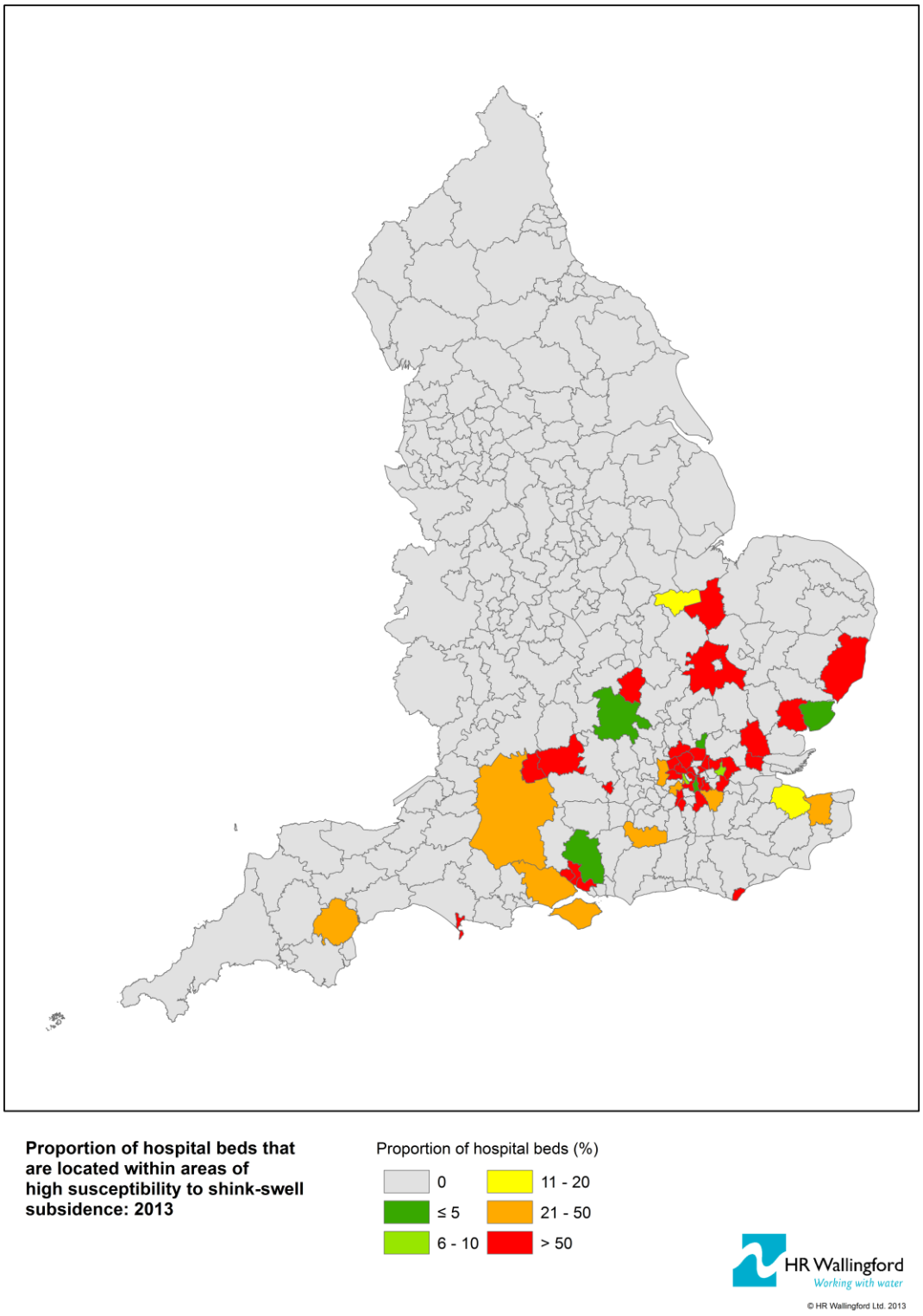

Figure 4.11: Proportion of hospitals beds located in areas of high susceptibility of shrink-swell subsidence

4.4. ICT

Data

Data Centre Map © Data Centre Map.

OFCOM: Mobile telecommunications masts (May, 2013).

Environment Agency (EA): NaFRA Spatial Internal Grid 2013 (flooding from rivers or the sea).

EA: updated Flood Map for Surface Water.

EA: NCERM 2011 (coastal erosion).

British Geological Survey (BGS): Map of susceptibility to natural landslides. British Geological Survey © NERC. All rights reserved.

BGS: Map of susceptibility to shrink-swell subsidence. British Geological Survey © NERC. All rights reserved.

ESI: Groundwater flooding risk map. ESI Groundwater Flood Risk Map of England and Wales © http://esinternational.com/

4.4.1. Data centres

There are two main types of data centre in England. The first are run by independent organisations that sell their digital capabilities to other businesses. The second type are data centres run specifically for the use of particular organisations such as for large financial organisations and other large multi-national companies. The location of this second type is extremely commercially and security sensitive and is not available publicly. The dataset that was obtained for this research contains only those organisations that fall into the first type. The postcode is provide for each centre and this has been digitised into the required spatial format for the assessment.

Table 4.96: Number of data centres in England used in this assessment

	Count
Data centres	116
Number of local authorities that are known to have data centres located within their boundaries	74

The dataset used in this assessment is therefore missing a large proportion of the data centres that actually exist in England. Following consultation with an industry representative, this may be as much as half the number of data centres in England. Consultation indicated that whilst the absolute number of data centres used in the analysis is incorrect, the general distribution of data centres, at a regional scale, in the dataset used was reasonably accurate. Therefore, the results from the analysis are not presented in absolute terms, instead, where a known data centre and hazard occur in the same location, the exposure of data centres to that hazard are considered to be present. Where known data centres and hazard do not overlap spatially, the exposure is considered to be absent. The results of the analysis will therefore indicate where there are pockets of data centres and certain hazard types overlapping, but not the number of data centres that may be exposed. This exposure analysis can therefore only be used to gain an understanding of the relative geographical distribution of data centre exposure to certain hazards.

Around 23% of the local authorities in England are home to organisations running data centres. These local authorities are generally those that are located in and around England's largest cities.

Table 4.97: Number (and proportion) of local authorities where data centres are located and are *potentially* exposed to different hazards, in England

	Coastal erosion	Groundwater flooding[2]	River and coastal flooding[3]	Surface water flooding[4]	Natural landslides[5]	Shrink-swell subsidence[6]
Number	0	18	9	4	0	10
Proportion	0%	24%	12%	5%	0%	14%

Notes: Proportion equates to the number of local authorities where data centres are known to exist.

[1]Range of exposure dependent upon time period, scenario and policy

[2]High susceptibility of groundwater flooding, estimated as 1 in 200 years or more frequent.

[3]Present day flooding from rivers or the sea under any likelihood category.

[4]Mid-depth (0.3m<= depth <1.2m; 1 in 1000 year likelihood)

[5]High susceptibility category to natural landslides.

[6]High susceptibility category to shrink-swell subsidence.

Coastal erosion

The indicator assesses the number and proportion of data centres located within locations that are projected to be exposed to coastal erosion over the next 100 years and the number and proportion of assets at risk behind the Shoreline Management Plan policies. Results are presented in terms of the presence or absence of such exposure.

There are no known data centres that fall within the boundaries of the National Coastal Erosion Risk Map.

Flooding (groundwater)

This indicator assesses the number and proportion datacentres located in areas that are of high susceptibility to groundwater flooding. Results are presented in terms of the presence or absence of such exposure.

There are 18 local authority areas that have datacentres that are located in areas of high susceptibility to groundwater flooding, see Figure 4.12. This represents around 24% of known data centres.

The greatest concentration of data centres is found inside the Greater London area. Around, 30% of the local authorities affected in this portion of the analysis were based in the London region. Therefore it is anticipated that a higher proportion of data centres than is indicated here would potentially be located in London.

Figure 4.12: Presence of data centres in local authorities that are located in areas of high susceptibility to groundwater flooding

Flooding (river and coastal)

This indicator quantifies the number and proportion of data centres within the floodplain by flood likelihood category and takes into account the presence, performance and condition of raised flood defences.

There are 9 (12%) local authorities where there are known data centres that are susceptible to any likelihood category of flooding from rivers or the sea. There is only one local authority, where there are known datacentres located in areas that are susceptible to a high likelihood of flooding from rivers or the sea. Under the most extreme scenario (high emissions, p90) this rises to 11% of local authorities.

Surface water flooding

This indicator quantifies the number and proportion of data centres located in areas that are susceptible to surface water flooding in a 1:30 year, 1:100 year and 1:1000 year rainfall event for depths between 0.3m and 1.2m and for depths greater than 1.2m.

There are three local authorities where data centres are located in areas that are susceptible to mid-depth and very deep surface water flooding of either 1 in 30 year or 1 in 1000 year likelihood. There is no regional

pattern to the distribution of potentially affected assets, they are found in the East of England, the South East, West Midlands and the Yorkshire & Humberside region.

Natural Landslides

This indicator quantifies the number and proportion of data centres in England located in areas of high susceptibility to natural landslides where; slope instability problems are probably present or have occurred in the past or slope instability problems are almost certainly present and may be active. There are no known data centres exposed to this hazard.

Shrink-swell subsidence

This indicator quantifies the number and proportion of data centres located in areas of high susceptibility to shrink-swell subsidence where ground conditions are of predominantly high or very high plasticity.

There are 10 local authority areas that have data centres where there is a high susceptibility of shrink-swell subsidence. This represents around 14% of known data centres. The greatest concentration of data centres is found inside the Greater London area. Around 40% of the local authorities affected in this portion of the analysis were based in the London region. Therefore it is anticipated that a higher proportion of data centres than is indicated here would potentially be exposed to high susceptibility of shrink-swell subsidence.

4.4.2. Telecommunications masts

In order to assess the criticality of mobile telecommunication masts, the height of the mast is used as a proxy for the type and criticality of the mast to the wider network. The categories used are:

- Large: >100m
- Medium: 50-100m
- Small: <50m
- No data.

Table 4.98: Number of telecommunications masts, categorized according to height, used in this assessment

	Large	Medium	Small	No height	Total
Masts	43	1,613	117,755	106	119,517

There were 119,517 mobile telecommunication masts used in the analysis. Of these, 117,755 were small, 1,613 medium, 43 large and 106 did not specify a height. The location information was provided using British National Grid reference which were translated to co-ordinates suitable for the spatial analysis.

Table 4.99: Number (and proportion) of mobile telecommunications masts exposed to different hazards in England

Height of mast	Coastal erosion[1]	Natural landslides[2]	Shrink-swell subsidence[3]
Small	3 – 237 (0%)	310 (0%)	17,297 (15%)
Medium	0 - 4 (0%)	1 (0%)	324 (20%)
Large	0 (0%)	0 (0%)	5 (12%)
No data	0 (0%)	0 (0%)	18 (17%)

Notes: Percentages are calculated as a proportion of the total number of assets per criticality category.

[1]Range of exposure dependent upon time period, scenario and policy

[2]High susceptibility category to natural landslides.

[3]High susceptibility category to shrink-swell subsidence.

Coastal erosion

The indicator assesses the number and proportion of telecommunication masts located within locations that are projected to be exposed to coastal erosion over the next 100 years behind the 'hold the line', 'no active intervention' or 'managed realignment' Shoreline Management Plan policies.

Table 4.99 shows a small proportions of telecommunications masts are at risk. Most of the mast are in the small category. Table 4.100 shows the risk from coastal erosion categorised by the regions and scenarios used in this analysis.

Table 4.100: Number (and proportion) of mobile telecommunication masts located in areas at risk from coastal erosion per UKCP09 administrative region (no active intervention scenarios)

	Short-term			Medium term			Long term		
	S	M	L	S	M	L	S	M	L
East Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
East of England	0 (0%)	0 (0%)	0 (0%)	19 (0%)	0 (0%)	0 (0%)	34 (0%)	2 (2%)	0 (0%)
London	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	5 (0%)	0 (0%)	0 (0%)	11 (0%)	0 (0%)	0 (0%)
North West	1 (0%)	0 (0%)	0 (0%)	2 (0%)	0 (0%)	0 (0%)	30 (0%)	0 (0%)	0 (0%)
South East	17 (0%)	0 (0%)	0 (0%)	40 (0%)	0 (0%)	0 (0%)	94 (0%)	0 (0%)	0 (0%)
South West	0 (0%)	0 (0%)	0 (0%)	16 (0%)	0 (0%)	0 (0%)	45 (0%)	2 (2%)	0 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Total	**18 (0%)**	**0 (0%)**	**0 (0%)**	**89 (0%)**	**0 (0%)**	**0 (0%)**	**237 (0%)**	**4 (0%)**	**0 (0%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region. No active intervention, 5th percentile for the short, medium and long term scenarios were analysed.

Table 4.101: Number (and proportion) of mobile telecommunication masts, categorised by size, located in areas at risk from coastal erosion per UKCP09 administrative region (Shoreline Management Plan scenarios)

	Short-term			Medium term			Long term		
	S	M	L	S	M	L	S	M	L
East Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
East of England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0%)	0 (0%)	0 (0%)
London	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0%)	0 (0%)	0 (0%)
South East	3 (0%)	0 (0%)	0 (0%)	5 (0%)	0 (0%)	0 (0%)	11 (0%)	0 (0%)	0 (0%)
South West	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Total	**3 (0%)**	**0 (0%)**	**0 (0%)**	**5 (0%)**	**0 (0%)**	**0 (0%)**	**13** (0%)**	**0 (0%)**	**0 (0%)**

*Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region. Shoreline management plans, 5th percentile for the short, medium and long term scenarios were analysed. **All results reference the Shoreline Management Plan scenario where the policy is no active intervention (NAI) except for this result: 12 masts are exposed under the NAI policy and 1 is exposed under the managed realignment policy.*

Natural landslides

This indicator quantifies the number and proportion of mobile telecommunication masts located in areas of high susceptibility to natural landslides where; slope instability problems are probably present or have occurred in the past or slope instability problems are almost certainly present and may be active.

Whilst there are 310 mobile telecommunication masts located in areas of high susceptibility to landslides, this equates to less than 0.3% of the total number of such masts in England. This is not considered to currently be a significant hazard for this type of asset.

Shrink-swell subsidence

This indicator quantifies the number and proportion of mobile telecommunication masts located in areas of high susceptibility to shrink-swell subsidence where ground conditions are of predominantly high or very high plasticity.

The results of the exposure analysis, shown in Table 4.102 and Figure 4.13, indicate that around 16% of mobile telecommunications masts are located in areas with high plasticity soils. The vulnerability of specific assets will greatly depend upon the type of asset in question. Some masts are fixed to the ground, others may be located on top of, or even inside, large buildings. The vulnerability is therefore potentially linked to surrounding built assets. The regional distribution of exposed assets is co-incident with the location of clay soils and large population centres i.e. London.

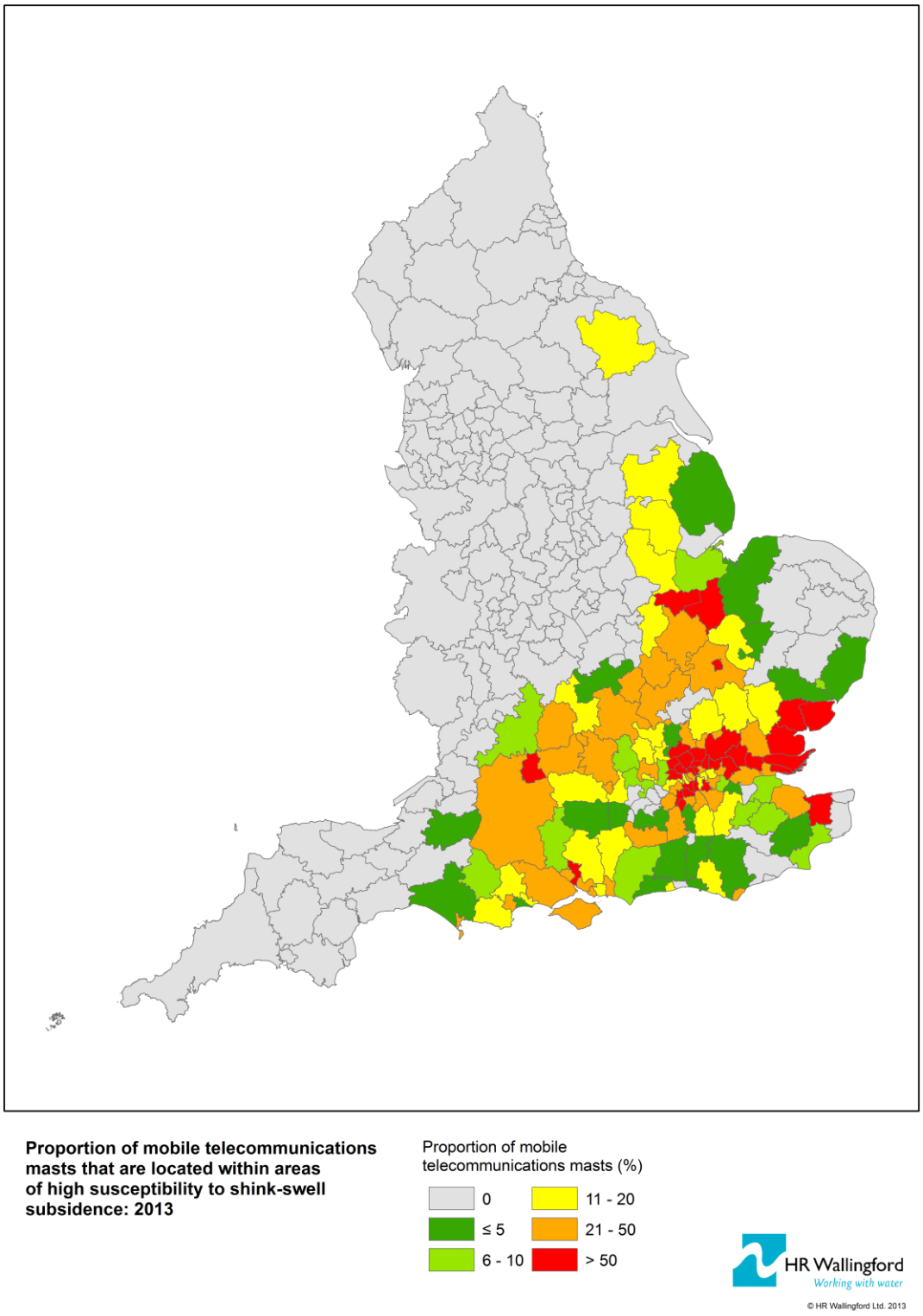

Figure 4.13: Proportion of mobile telecommunications masts that are located within areas of high susceptibility to shrink-swell subsidence, 2013

Table 4.102: Number (and proportion) of mobile telecommunication masts, categorised by size, located in areas of high susceptibility to shrink-swell subsidence

Region	Small	Medium	Large	No data
East Midlands	138 (1%)	0 (0%)	0 (0%)	0 (0%)
East of England	3562 (27%)	27 (24%)	0 (0%)	2 (15%)
London	9454 (48%)	261 (53%)	5 (71%)	11 (58%)
North East England	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West England	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South East England	3425 (15%)	34 (19%)	0 (0%)	4 (14%)
South West England	697 (6%)	2 (2%)	0 (0%)	1 (25%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Yorkshire and Humberside	21 (0%)	0 (0%)	0 (0%)	0 (0%)
Total	**17297 (15%)**	**324 (20%)**	**5 (12%)**	**18 (17%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

4.5. Transport

Data

Network Rail: Railway line criticality 2013.

Ordnance Survey data © Crown copyright and database right 2013: Railway stations.

OpenStreetMap: Road network © OpenStreetMap contributors http://www.openstreetmap.org/copyright

Department for Transport (DfT): Annual Average Daily Flow 2001, 2008 and 2012.

DfT: Major Road link network, 2013.

Environment Agency (EA): NaFRA Spatial Internal Grid 2013 (flooding from rivers or the sea).

EA: updated Flood Map for Surface Water.

EA: NCERM 2011 (coastal erosion).

British Geological Survey (BGS): Map of susceptibility to natural landslides. British Geological Survey © NERC. All rights reserved.

BGS: Map of susceptibility to shrink-swell subsidence. British Geological Survey © NERC. All rights reserved.

ESI: Groundwater flooding risk map. ESI Groundwater Flood Risk Map of England and Wales © http://esinternational.com/

4.5.1. Railway line

In order to assess the criticality of railway lines (only Network Rail assets), the criticality score as assigned by Network Rail has been used. Railway lines are scored from 1-5, 1 being the most critical and 5 being the

least critical. Nearly 119,000km of track was included in this analysis, of that, around 1,600 km is criticality category 1; 2,600km is category 2; 3,900km is category 3; 1,900km is category 4 and 1,900km is category 5, see Figure 4.14.

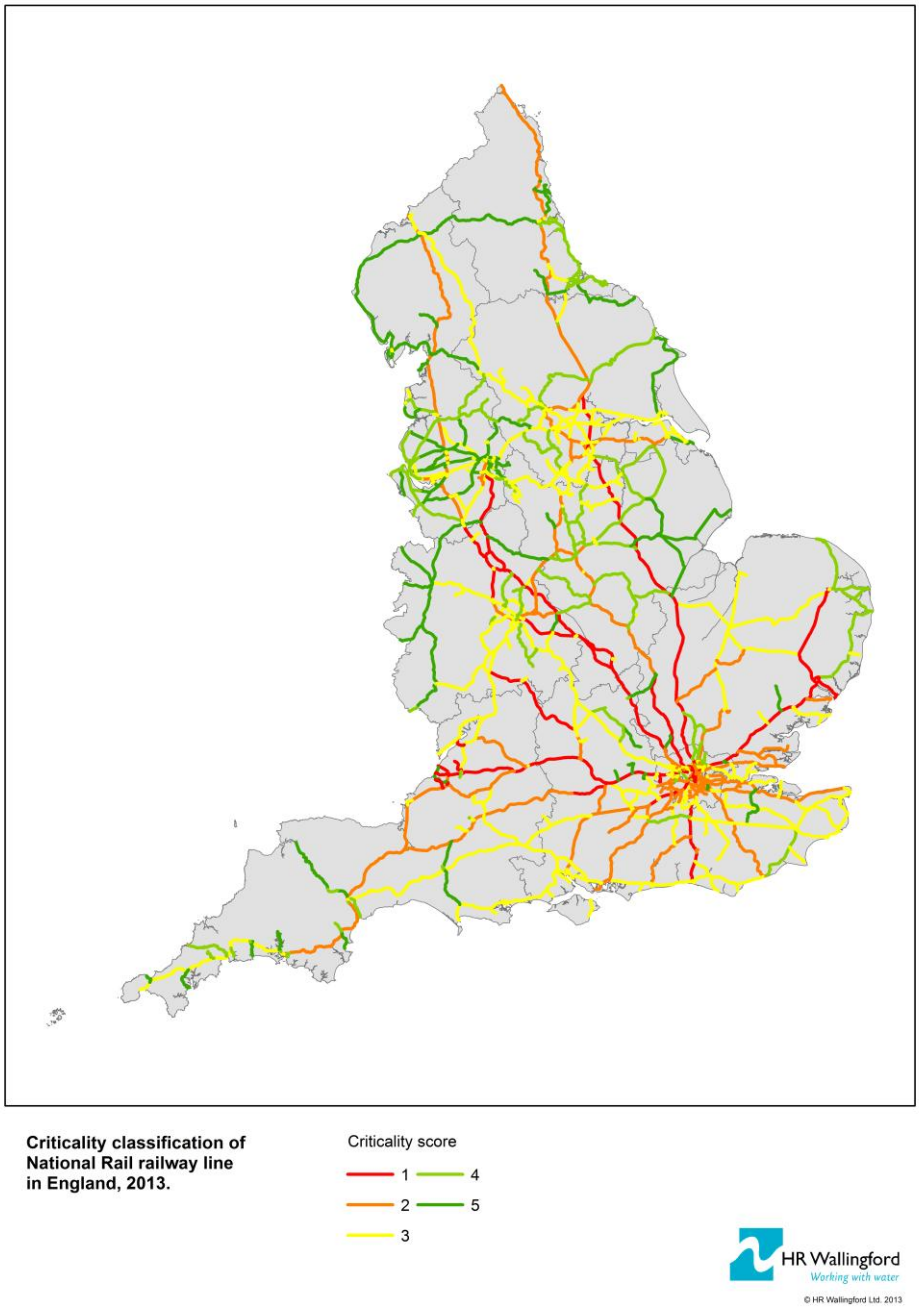

Figure 4.14: Criticality scores of National Rails' track network.

Source: © National Rail.

Criticality is based upon the average cost per delay incident. It should be noted that this assessment identifies direct exposure to hazards. For railway lines, direct exposure of 1% of any particular line may lead

to disruption across the whole line and knock-on effects to other services. Therefore, the consequences of exposure to a hazard might be larger than direct physical impacts to the asset(s).

Table 4.103: Total length of Network Rail railway line, categorised by criticality, used in this assessment

	Category 1	Category 2	Category 3	Category 4	Category 5	Total
Railway line	1,600km	2,600km	3,900km	1,900km	1,900km	11,900km

Table 4.104: Length (and proportion) of railway lines exposed to different hazards in England

Criticality category	Coastal erosion[1]	Groundwater flooding[2]	River and coastal flooding[3]	Surface water flooding[4]	Natural landslides[5]	Shrink-swell subsidence[6]
1	0-0km (0%)	285km (18%)	163km (10%)	184km (12%)	1km (0%)	347km (22%)
2	2-12km (0%)	494km (19%)	417km (16%)	253km (10%)	12km (0%)	455km (17%)
3	4-20km (0-1%)	635km (16%)	698km (18%)	338km (9%)	30km (1%)	397km (10%)
4	1-9km (0%)	323km (17%)	321km (17%)	201km (10%)	21km (1%)	150km (8%)
5	4-21km (0-1%)	319km (17%)	368km (20%)	154km (8%)	27km (1%)	82km (4%)

Notes: Percentages are calculated as a proportion of the total number of assets per criticality category.

[1]Range of exposure dependent upon time period, scenario and policy

[2]High susceptibility of groundwater flooding, estimated as 1 in 200 years or more frequent.

[3]Present day flooding from rivers or the sea under any likelihood category.

[4]Mid-depth (0.3m<= depth <1.2m; 1 in 1000 year likelihood)

[5]High susceptibility category to natural landslides.

[6]High susceptibility category to shrink-swell subsidence.

The location of railway lines was obtained from Network Rail.

Coastal erosion

The indicator assesses the length and proportion of railway line located within locations that are projected to be exposed to coastal erosion over the next 100 years behind the 'hold the line', 'no active intervention' or 'managed realignment' Shoreline Management Plan policies.

Table 4.105: Total length of railway line located in areas that are exposed to coastal erosion under the no active intervention scenario and categorised by line criticality score.

Criticality	Short term	Medium term	Long term
1	0km (0%)	0km (0%)	0km (0%)
2	2km (0%)	8km (0%)	12km (0%)
3	4km (0%)	14km (0%)	20km (1%)
4	1km (0%)	4km (0%)	9km (0%)
5	4km (0%)	12km (1%)	21km (1%)

Source: Percentages are calculated as a proportion of the total number of assets per criticality category.

As shown in Table 4.105, very little railway line is located in areas that are also susceptible to coastal erosion. Exposure is greatest in the South West of England, followed by the North West, South East, North East and then the East of England.

A few kilometres of track (between 0-5km total), nationally, may be exposed to coastal erosion under the SMP scenario no active intervention policy and managed realignment policy.

Flooding (groundwater)

This indicator assesses the length and proportion of railway line located in areas that are of high susceptibility to groundwater flooding.

Table 4.106: Length (and proportion) of railway line, categorised by criticality score (1-5), located in areas of high susceptibility to groundwater flooding per UKCP09 administrative region

Region	1	2	3	4	5	Total
East Midlands	27km (15%)	57km (33%)	26km (14%)	157km (32%)	29km (14%)	295km (24%)
East of England	68km (17%)	40km (16%)	78km (20%)	24km (10%)	16km (29%)	226km (17%)
London	41km (23%)	99km (26%)	33km (24%)	15km (16%)	1km (8%)	189km (23%)
North East	0km (0%)	25km (14%)	1km (4%)	10km (6%)	32km (21%)	68km (13%)
North West	2km (4%)	14km (5%)	15km (4%)	19km (6%)	57km (8%)	108km (6%)
South East England	80km (29%)	90km (16%)	214km (20%)	17km (14%)	28km (33%)	430km (20%)
South West England	17km (12%)	81km (18%)	117km (20%)	22km (24%)	40km (20%)	277km (19%)
West Midlands	50km (19%)	45km (46%)	49km (12%)	17km (13%)	81km (31%)	242km (20%)
Yorkshire & Humberside	0km (0%)	43km (17%)	101km (14%)	44km (16%)	34km (17%)	222km (15%)
Total	**285km (18%)**	**494km (19%)**	**635km (16%)**	**323km (17%)**	**319km (17%)**	**2056km (17%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.106, Figure 4.15 and Figure 4.16 show the length and proportion of the railway line in England, managed by Network Rail, that are located in areas of high susceptibility to groundwater flooding. Overall, nearly 20% of railway line may be susceptible to this hazard. There is little difference in the level of exposure between the different criticality categories or with most of the regions, except the North East and North West of England, which has a lower proportion than the rest of the country.

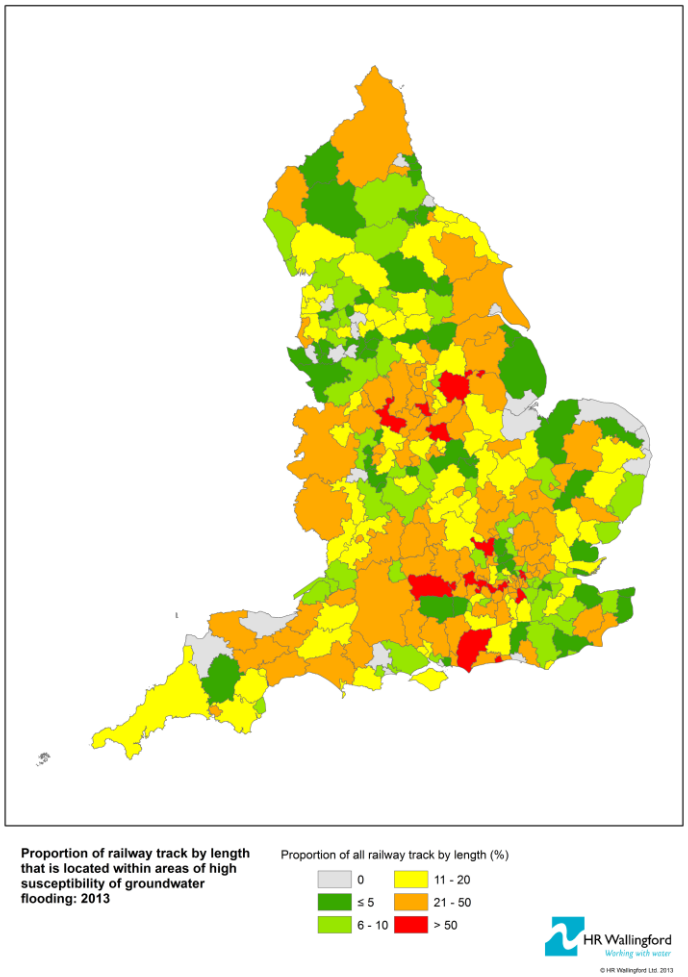

Figure 4.15: Proportion of railway line, all criticality categories, located in areas of high susceptibility to groundwater flooding

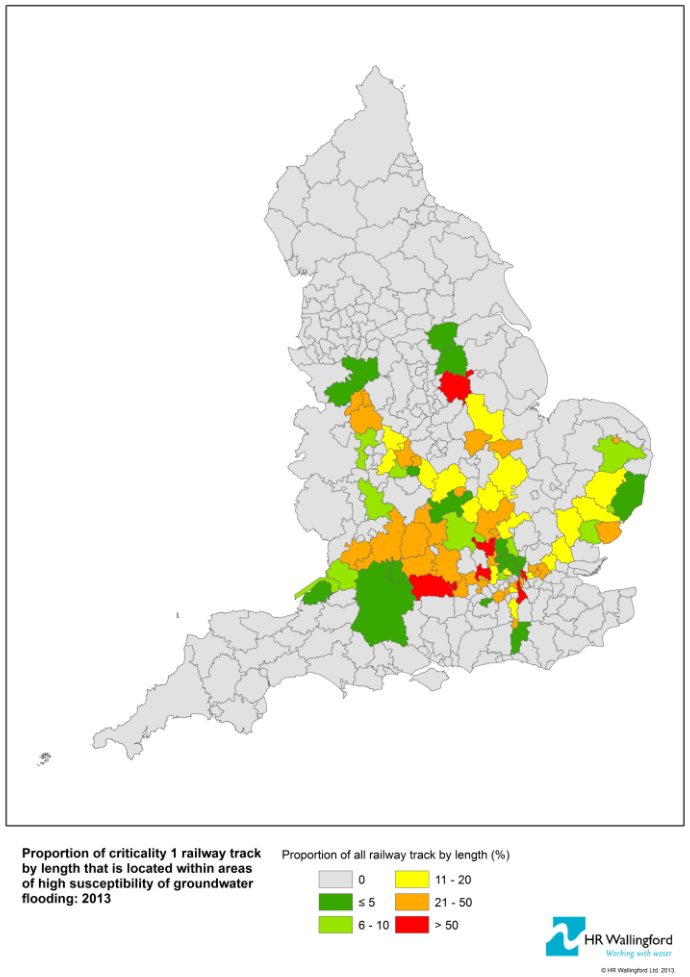

Figure 4.16: Proportion of railway line, criticality category 1, located in areas of high susceptibility to groundwater flooding

Flooding (river and coastal)

This indicator quantifies the length and proportion of railway line within the floodplain by flood likelihood category and takes into account the presence, performance and condition of raised flood defences. The results of the exposure analysis to any likelihood category of flooding from rivers or the sea are shown in Table 4.107.

Table 4.107: Length (and proportion) of railway line, categorised by criticality score (1-5), located in areas that are currently at any likelihood category of flooding from rivers or the sea, per UKCP09 administrative region

Region	1	2	3	4	5	Total
East Midlands	15km (9%)	49km (28%)	25km (13%)	114km (23%)	85km (41%)	288km (23%)
East of England	26km (6%)	30km (12%)	144km (36%)	73km (31%)	5km (9%)	278km (21%)
London	20km (11%)	60km (16%)	18km (13%)	11km (12%)	0km (1%)	109km (14%)
North East	0km (0%)	15km (9%)	2km (6%)	9km (6%)	24km (15%)	50km (10%)
North West	2km (4%)	17km (6%)	34km (9%)	18km (5%)	77km (11%)	147km (9%)
South East England	22km (8%)	52km (9%)	184km (17%)	24km (20%)	31km (36%)	314km (15%)
South West England	20km (14%)	99km (22%)	54km (9%)	20km (21%)	70km (35%)	262km (18%)
West Midlands	35km (13%)	27km (27%)	31km (7%)	16km (12%)	37km (14%)	146km (12%)
Yorkshire & Humberside	23km (36%)	68km (27%)	207km (30%)	35km (13%)	39km (19%)	372km (25%)
Total	**163km (10%)**	**417km (16%)**	**698km (18%)**	**321km (17%)**	**368km (20%)**	**1966km (17%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

The results of the exposure analysis to a high likelihood of flooding from rivers or the sea are shown in Table 4.108, Table 4.109, Table 4.110, Table 4.111, Figure 4.17 and Figure 4.18. Exposure to this type of hazard increases with decreasing criticality of track, a pattern which is reflected in the subsequent projections of exposure levels. There notable differences between different regions. The highest levels of exposure are to be found in the South West and the East of England. This remains the case in the projected results, but, in addition, the potential projected levels of exposure are also high (up to around 20% for the high emissions scenario p90) for the East Midlands and Yorkshire & Humberside.

Table 4.108: Length (and proportion) of railway line, categorised by criticality score (1-5), located in areas that are currently at high likelihood of flooding from rivers or the sea, per UKCP09 administrative region

	Current (2011-2012)				
Region	**1**	**2**	**3**	**4**	**5**
East Midlands	3km (2%)	12km (7%)	4km (2%)	17km (3%)	8km (4%)
East of England	3km (1%)	8km (3%)	8km (2%)	45km (19%)	0km (1%)
London	1km (0%)	3km (1%)	1km (1%)	0km (0%)	0km (0%)
North East	0km (0%)	2km (1%)	0km (0%)	1km (0%)	9km (6%)
North West	0km (1%)	5km (2%)	8km (2%)	4km (1%)	15km (2%)
South East	5km (2%)	12km (2%)	42km (4%)	6km (5%)	12km (14%)
South West	3km (2%)	30km (7%)	15km (3%)	5km (6%)	34km (16%)
West Midlands	5km (2%)	8km (8%)	5km (1%)	1km (1%)	9km (4%)
Yorkshire & Humberside	2km (3%)	18km (7%)	21km (3%)	6km (2%)	9km (4%)
Total	**22km (1%)**	**98km (4%)**	**104km (3%)**	**86km (4%)**	**97km (5%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.109: Length (and proportion) of railway line, categorised by criticality score (1-5), located in areas that are projected to be at high likelihood of flooding from rivers or the sea, in the 2020s, per UKCP09 administrative region

	2020s Medium p50				
Region	**1**	**2**	**3**	**4**	**5**
East Midlands	3km (2%)	12km (7%)	7km (4%)	21km (4%)	9km (4%)
East of England	3km (1%)	9km (4%)	9km (2%)	48km (21%)	0km (1%)
London	1km (0%)	3km (1%)	3km (2%)	0km (0%)	0km (0%)
North East	0km (0%)	3km (2%)	0km (1%)	3km (2%)	10km (7%)
North West	0km (1%)	6km (2%)	9km (2%)	6km (2%)	25km (4%)
South East	6km (2%)	13km (2%)	48km (4%)	7km (6%)	12km (14%)
South West	4km (3%)	38km (9%)	16km (3%)	7km (7%)	36km (18%)
West Midlands	7km (2%)	10km (10%)	8km (2%)	3km (2%)	13km (5%)
Yorkshire & Humberside	3km (4%)	25km (10%)	41km (6%)	9km (3%)	13km (6%)
Total	**26km (2%)**	**119km (5%)**	**141km (4%)**	**104km (5%)**	**119km (6%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.110: Length (and proportion) of railway line, categorised by criticality score (1-5), located in areas that are projected to be at high likelihood of flooding from rivers or the sea, in the 2050s, per UKCP09 administrative region

	2050s Medium p50				
Region	**1**	**2**	**3**	**4**	**5**
East Midlands	4km (2%)	15km (8%)	9km (5%)	26km (5%)	11km (5%)
East of England	4km (1%)	9km (4%)	11km (3%)	52km (22%)	0km (1%)
London	1km (0%)	4km (1%)	4km (3%)	0km (0%)	0km (0%)
North East	0km (0%)	3km (2%)	0km (1%)	5km (3%)	10km (7%)
North West	0km (1%)	6km (2%)	9km (2%)	6km (2%)	29km (4%)
South East	6km (2%)	14km (3%)	56km (5%)	8km (7%)	13km (15%)
South West	9km (7%)	47km (10%)	24km (4%)	10km (10%)	42km (20%)
West Midlands	7km (3%)	10km (10%)	8km (2%)	3km (2%)	14km (5%)
Yorkshire & Humberside	4km (6%)	32km (13%)	58km (8%)	11km (4%)	15km (8%)
Total	**34km (2%)**	**139km (5%)**	**179km (5%)**	**121km (6%)**	**135km (7%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.111: Length (and proportion) of railway line, categorised by criticality score (1-5), located in areas that are projected to be at high likelihood of flooding from rivers or the sea, in the 2080s, per UKCP09 administrative region

	2080s Low p10 - High p90				
Region	**1**	**2**	**3**	**4**	**5**
East Midlands	3km (2%) - 12km (7%)	12km (7%) - 36km (21%)	7km (4%) - 22km (12%)	21km (4%) - 95km (19%)	10km (5%) - 83km (40%)
East of England	3km (1%) - 24km (6%)	9km (4%) - 29km (11%)	10km (3%) - 130km (33%)	51km (22%) - 70km (30%)	0km (1%) - 4km (8%)
London	1km (0%) - 19km (11%)	4km (1%) - 57km (15%)	3km (2%) - 17km (12%)	0km (0%) - 11km (12%)	0km (0%) - 0km (1%)
North East	0km (0%) - 0km (0%)	3km (1%) - 15km (8%)	0km (0%) - 2km (6%)	5km (3%) - 8km (5%)	10km (6%) - 24km (15%)
North West	0km (1%) - 2km (4%)	6km (2%) - 16km (6%)	9km (2%) - 30km (8%)	6km (2%) - 17km (5%)	26km (4%) - 74km (11%)
South East	5km (2%) - 22km (8%)	13km (2%) - 50km (9%)	53km (5%) - 176km (16%)	8km (6%) - 24km (20%)	13km (15%) - 29km (34%)
South West	9km (6%) - 20km (14%)	42km (9%) - 96km (21%)	23km (4%) - 51km (9%)	9km (10%) - 19km (20%)	41km (20%) - 70km (34%)
West Midlands	5km (2%) - 29km (11%)	8km (8%) - 17km (17%)	5km (1%) - 17km (4%)	2km (1%) - 10km (7%)	10km (4%) - 24km (9%)
Yorkshire & Humberside	2km (3%) - 23km (36%)	25km (10%) - 68km (27%)	36km (5%) - 192km (27%)	9km (3%) - 35km (13%)	14km (7%) - 33km (16%)
Total	**29km (2%) - 149km (10%)**	**120km (5%) - 383km (15%)**	**146km (4%) - 638km (16%)**	**111km (6%) - 289km (15%)**	**123km (7%) - 340km (18%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

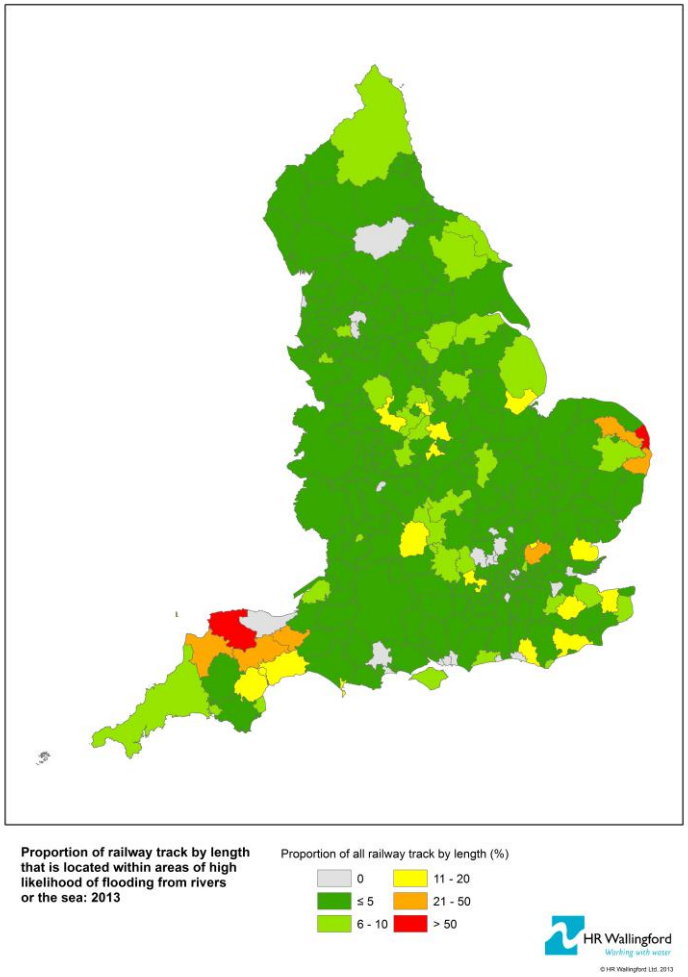

Figure 4.17: Proportion of railway track by length that is located within areas of high likelihood of flooding from rivers or the sea, 2013

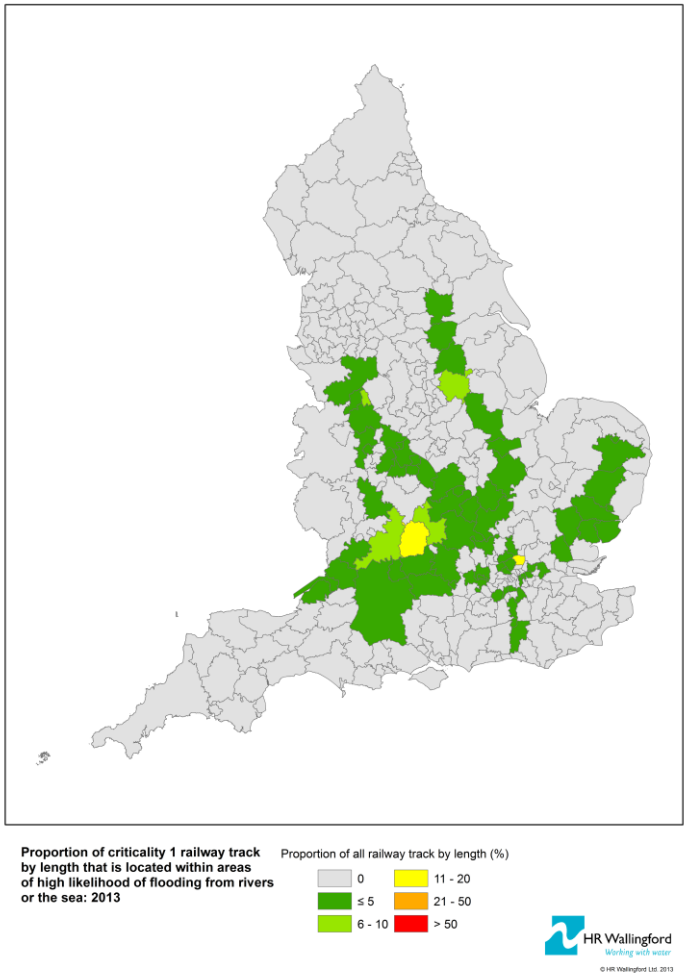

Figure 4.18: Proportion of railway track by length that is located within areas of high likelihood of flooding from rivers or the sea, 2013. Criticality class 1 only

Flooding (surface water)

This indicator quantifies the length and proportion of railway line located in areas susceptible to surface water flooding in a 1:30 year, 1:100 year and 1:1000 year rainfall event for depths between 0.3m and 1.2m and for depths greater than 1.2m.

Table 4.112: Length (and proportion) of railway line, categorised by criticality score (1-5), located in areas susceptible to mid-depth (0.30-1.2m) surface water flooding, per UKCP09 administrative region

	Mid-depth: 0.3m<= depth <1.2m 3.3% likelihood						Mid-depth: 0.3m<= depth <1.2m 0.1% likelihood					
Region	**1**	**2**	**3**	**4**	**5**	**Total**	**1**	**2**	**3**	**4**	**5**	**Total**
East Midlands	6km (3%)	5km (3%)	3km (1%)	5km (1%)	2km (1%)	20km (2%)	21km (12%)	18km (10%)	15km (8%)	44km (9%)	9km (4%)	108km (9%)
East of England	5km (1%)	7km (3%)	3km (1%)	2km (1%)	0km (0%)	17km (1%)	49km (12%)	29km (12%)	17km (4%)	10km (5%)	4km (8%)	109km (8%)
London	4km (2%)	13km (3%)	3km (2%)	5km (6%)	0km (3%)	25km (3%)	27km (15%)	69km (18%)	21km (15%)	16km (18%)	2km (16%)	135km (17%)
North East	0km (0%)	1km (0%)	1km (3%)	2km (1%)	3km (2%)	7km (1%)	0km (0%)	6km (3%)	4km (14%)	13km (8%)	10km (6%)	33km (6%)
North West	1km (1%)	2km (1%)	7km (2%)	7km (2%)	10km (1%)	27km (2%)	4km (9%)	25km (9%)	45km (12%)	59km (18%)	84km (12%)	217km (13%)
South East England	6km (2%)	7km (1%)	16km (2%)	1km (1%)	1km (1%)	31km (1%)	32km (12%)	49km (9%)	98km (9%)	6km (5%)	8km (9%)	192km (9%)
South West England	8km (5%)	10km (2%)	6km (1%)	1km (1%)	5km (2%)	29km (2%)	20km (14%)	36km (8%)	39km (7%)	6km (6%)	15km (7%)	116km (8%)
West Midlands	3km (1%)	1km (1%)	8km (2%)	2km (1%)	2km (1%)	15km (1%)	29km (11%)	8km (8%)	54km (13%)	20km (14%)	12km (5%)	122km (10%)
Yorkshire & Humberside	0km (0%)	4km (2%)	6km (1%)	5km (2%)	3km (2%)	18km (1%)	1km (2%)	14km (6%)	45km (6%)	26km (9%)	9km (5%)	97km (6%)
Total	**32km (2%)**	**50km (2%)**	**53km (1%)**	**29km (1%)**	**26km (1%)**	**189km (2%)**	**184km (12%)**	**253km (10%)**	**338km (9%)**	**201km (10%)**	**154km (8%)**	**1130km (9%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.113: Length (and proportion) of railway line, categorised by criticality score (1-5), located in areas susceptible to very deep (>1.2m) surface water flooding, per UKCP09 administrative region

	Very deep: Depth >1.2m 3.3% likelihood						Very deep: Depth >1.2m 0.1% likelihood					
Region	**1**	**2**	**3**	**4**	**5**	**Total**	**1**	**2**	**3**	**4**	**5**	**Total**
East Midlands	1km (0%)	0km (0%)	0km (0%)	1km (0%)	0km (0%)	2km (0%)	3km (0%)	4km (0%)	2km (0%)	5km (0%)	0km (0%)	14km (1%)
East of England	0km (0%)	1km (0%)	0km (0%)	0km (0%)	0km (0%)	1km (0%)	5km (0%)	4km (0%)	1km (0%)	1km (0%)	0km (0%)	11km (1%)
London	1km (0%)	1km (0%)	0km (0%)	1km (0%)	0km (0%)	3km (0%)	9km (1%)	21km (3%)	5km (1%)	8km (1%)	0km (0%)	42km (5%)
North East	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	3km (0%)	1km (0%)	4km (1%)
North West	0km (0%)	0km (0%)	1km (0%)	0km (0%)	1km (0%)	2km (0%)	1km (0%)	2km (0%)	8km (0%)	8km (0%)	8km (0%)	27km (2%)
South East England	0km (0%)	2km (0%)	1km (0%)	0km (0%)	0km (0%)	3km (0%)	5km (0%)	7km (0%)	12km (1%)	1km (0%)	0km (0%)	24km (1%)
South West England	1km (0%)	0km (0%)	1km (0%)	0km (0%)	0km (0%)	3km (0%)	5km (0%)	6km (0%)	4km (0%)	0km (0%)	2km (0%)	17km (1%)
West Midlands	0km (0%)	0km (0%)	1km (0%)	0km (0%)	0km (0%)	2km (0%)	1km (0%)	1km (0%)	9km (1%)	2km (0%)	1km (0%)	14km (1%)
Yorkshire & Humberside	0km (0%)	0km (0%)	1km (0%)	1km (0%)	1km (0%)	2km (0%)	0km (0%)	2km (0%)	7km (0%)	4km (0%)	3km (0%)	16km (1%)
Total	**3km (0%)**	**4km (0%)**	**5km (0%)**	**3km (0%)**	**2km (0%)**	**18km (0%)**	**28km (0%)**	**45km (0%)**	**46km (0%)**	**32km (0%)**	**17km (0%)**	**170km (1%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

As shown in Table 4.112 and Table 4.113 only a very small proportion of railway line is located in areas that are susceptible to surface water flooding. This does include lengths line with the highest criticality category, although the assessment does not take into consideration any local flood prevention measure that are in place.

Natural landslides

This indicator quantifies the length and proportion of railway line located in areas of high susceptibility to natural landslides where; slope instability problems are probably present or have occurred in the past or slope instability problems are almost certainly present and may be active. The results of the exposure analysis are shown in Table 4.114; only a very small proportion of railways line may be directly exposed. It is important to note that this analysis refers to natural landslides and not to landslides that are the product of human intervention and/or in engineered structures. These may be more significant issues for the railway network. Also, as per the other hazards assessed, disruption to a relatively small stretch of line may have far reaching consequences to the rest of the line and potentially, to other lines and services in the network.

Table 4.114: Length (and proportion) of railway line, categorised by criticality score (1-5), located in areas that are of high susceptibility to natural landslides, per UKCP09 administrative region

Region	1	2	3	4	5	Total
East Midlands	0km (0%)	1km (1%)	5km (3%)	4km (1%)	3km (1%)	13km (1%)
East of England	0km (0%)	1km (0%)	0km (0%)	0km (0%)	0km (0%)	1km (0%)
London	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (1%)	1km (0%)
North East	0km (0%)	0km (0%)	0km (0%)	0km (0%)	2km (1%)	2km (0%)
North West	0km (0%)	1km (0%)	1km (0%)	3km (1%)	4km (1%)	10km (1%)
South East England	0km (0%)	0km (0%)	4km (0%)	0km (0%)	0km (0%)	5km (0%)
South West England	0km (0%)	8km (2%)	8km (1%)	4km (4%)	3km (2%)	24km (2%)
West Midlands	0km (0%)	0km (0%)	1km (0%)	0km (0%)	2km (1%)	4km (0%)
Yorkshire & Humberside	0km (0%)	1km (0%)	10km (1%)	9km (3%)	12km (6%)	31km (2%)
Total	**1km (0%)**	**12km (0%)**	**30km (1%)**	**21km (1%)**	**27km (1%)**	**91km (1%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Shrink-swell subsidence

This indicator quantifies the length and proportion of railway line located in areas of high susceptibility to shrink-swell subsidence where ground conditions are of predominantly high or very high plasticity.

Table 4.115 shows the results of the exposure analysis. On average, country-wide, around 12% of railway lines are located in areas that are of high susceptibility to shrink-swell subsidence. However, there is a strong regional and criticality category pattern displayed. In London, the proportion of exposed assets is nearly 60%. Exposure is also high in the East of England. This is due to the local soil types. Correspondingly, ~20% the most significant criticality categories, 1 and 2 are exposed compared to ~7% for the least critical categories, see Figure 4.19 and Figure 4.20.

Table 4.115: Length (and proportion) of railway line, categorised by criticality score (1-5), located in areas that are of high susceptibility to shrink-swell subsidence, per UKCP09 administrative region

Region	1	2	3	4	5	Total
East Midlands	4km (2%)	0km (0%)	0km (0%)	11km (2%)	25km (12%)	39km (3%)
East of England	126km (31%)	114km (46%)	101km (25%)	18km (8%)	32km (58%)	390km (29%)
London	114km (64%)	205km (53%)	73km (52%)	65km (71%)	10km (80%)	467km (58%)
North East	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)
North West	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)
South East England	72km (26%)	82km (15%)	181km (17%)	47km (38%)	14km (16%)	396km (19%)
South West England	32km (23%)	51km (11%)	41km (7%)	0km (0%)	2km (1%)	126km (9%)
West Midlands	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)
Yorkshire & Humberside	0km (0%)	3km (1%)	0km (0%)	9km (3%)	0km (0%)	12km (1%)
Total	**347km (22%)**	**455km (17%)**	**397km (10%)**	**150km (8%)**	**82km (4%)**	**1431km (12%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

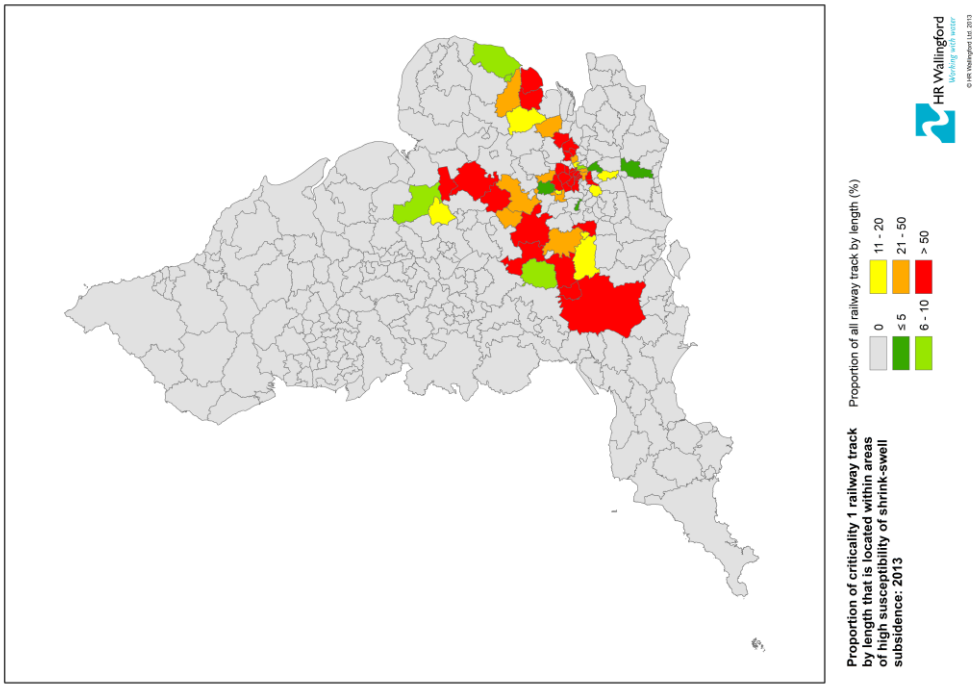

Figure 4.19: Proportion of railway line by length located in areas of high susceptibility to shrink-swell subsidence

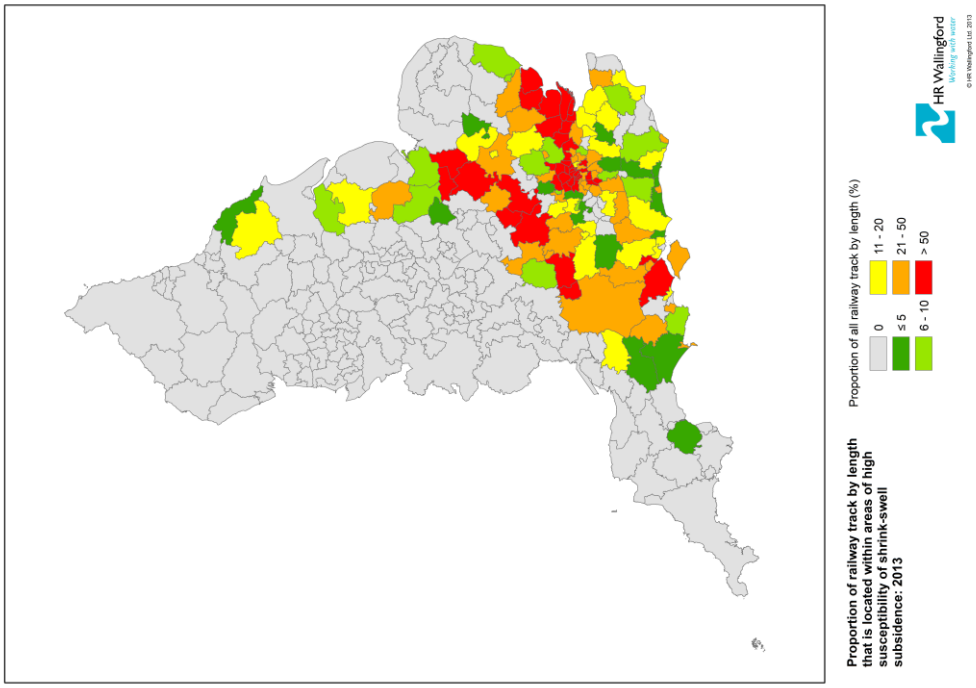

Figure 4.20: Proportion of railway line, criticality category 1, located in areas of high susceptibility to shrink-swell subsidence

4.5.2. Railway stations

In order to assess the criticality of railway stations, they have been categorised by station usage figures. These figures are derived from ticket sales. Where stations are grouped, estimates of station usage are made. A few specific operators are not included in the recording system, including Eurostar and Heathrow Express. The categories used are:

- Large: > 1,000,000 entries and exits per year
- Medium: >10,000 to < 999,999 entries and exits per year
- Small: < 10,000 entries and exits per year.

Table 4.116: Total railways stations, categorised by station usage, used in this assessment

	Large	Medium	Small	Total
Railway stations	461	1,367	136	1,964

In 2011/12 there were 136 stations in the small category, 1,367 in the medium category and 461 in the large category. The vast majority of the largest stations are in London and the South East of England. Medium sized stations and small stations are more evenly distributed across the country. Station location information was provided by the Office for Rail Regulation in the form of postcodes. Whilst the location information is considered accurate, postcodes must be digitised into co-ordinates for the spatial assessment and this introduces some error.

Table 4.117: Number (and proportion) of railway stations exposed to different hazards in England

No. of customers category	Coastal erosion[1]	Groundwater flooding[2]	River and coastal flooding[3]	Surface water flooding[4]	Natural landslides[5]	Shrink-swell subsidence[6]
Large	0-1 (0%)	93 (20%)	41 (30%)	15 (3%)	0 (0%)	135 (29%)
Medium	1-5 (0%)	200 (15%)	172 (13%)	35 (3%)	1 (1%)	179 (13%)
Small	0 (0%)	27 (20%)	56 (12%)	4 (3%)	3 (0%)	4 (3%)

Notes: Percentages are calculated as a proportion of the total number of assets per criticality category.

[1]Range of exposure dependent upon time period, scenario and policy

[2]High susceptibility of groundwater flooding, estimated as 1 in 200 years or more frequent.

[3]Present day flooding from rivers or the sea under any likelihood category.

[4]Mid-depth (0.3m<= depth <1.2m; 1 in 1000 year likelihood)

[5]High susceptibility category to natural landslides.

[6]High susceptibility category to shrink-swell subsidence.

Groundwater flooding

This indicator assesses the number and proportion of railway stations located in areas that are considered to be of high susceptibility to groundwater flooding.

At national level around 16% of stations may be exposed to groundwater flooding. Table 4.117 shows that a large proportion of stations in the high and low categories are at risk. Table 4.118 shows the regional distribution of groundwater flooding exposure on railway stations. The largest proportion of stations located in areas prone to groundwater flooding are in the South East of England and London. These two regions also have the largest number of stations exposed.

Table 4.118: Number (and proportion) of railway stations located in areas that are of high susceptibility to groundwater flooding, categorised by the number of passengers entering and exiting the stations

Region	Small	Medium	Large	All
East Midlands	5 (31%)	21 (26%)	3 (33%)	29 (27%)
East of England	4 (33%)	21 (14%)	9 (18%)	34 (16%)
London	0 (0%)	32 (23%)	41 (21%)	73 (22%)
North East	2 (17%)	4 (11%)	0 (0%)	6 (11%)
North West	4 (20%)	19 (7%)	1 (2%)	24 (7%)
South East	1 (8%)	63 (20%)	28 (27%)	92 (22%)
South West	2 (7%)	10 (8%)	5 (29%)	17 (10%)
West Midlands	2 (22%)	18 (15%)	4 (17%)	24 (16%)
Yorkshire & Humberside	7 (25%)	12 (9%)	2 (11%)	21 (11%)
Total	**27 (20%)**	**200 (15%)**	**93 (20%)**	**320 (16%)**

Notes: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Coastal erosion

The indicator assesses the number and proportion of railway stations located within locations that are projected to be exposed to coastal erosion over the next 100 years and the number and proportion of assets at risk behind the Shoreline Management Plan policies.

Table 4.118 shows the distribution of coastal erosion risk across the different regions for the short, medium and long term time horizons.

Table 4.119: Number (and proportion) of railway stations located in areas that may be at risk from coastal erosion, categorised by the number of passengers entering and exiting the stations

	Short term			Medium term			Long term		
	S	M	L	S	M	L	S	M	L
East Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
East of England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
London	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South East	0 (0%)	1 (0%)	0 (0%)	0 (0%)	3 (1%)	0 (0%)	0 (0%)	3 (1%)	1 (1%)
South West	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (2%)	0 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Total	**0 (0%)**	**1 (0%)**	**0 (0%)**	**0 (0%)**	**3 (0%)**	**0 (0%)**	**0 (0%)**	**5 (0%)**	**1 (0%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

The level of potential exposure of railway stations to coastal erosion is very low and distributed in the south of England.

Flooding (river and coastal)

This indicator quantifies the number and proportion of railway stations within the floodplain by flood likelihood category and takes into account the presence, performance and condition of raised flood defences. The results of the exposure analysis for all likelihood categories or flooding from rivers or the sea is shown in Table 4.120.

Table 4.120: Number (and proportion) of railway stations located in areas that may be exposed to any likelihood category of flooding from rivers or the sea, categorised by the number of passengers entering and exiting the stations

	2008			2011		
Region	**Small**	**Medium**	**Large**	**Small**	**Medium**	**Large**
East Midlands	27 (29%)	3 (23%)	0 (0%)	8 (50%)	19 (23%)	3 (33%)
East of England	29 (15%)	3 (21%)	1 (50%)	6 (50%)	21 (14%)	6 (12%)
London	28 (10%)	1 (7%)	5 (31%)	0 (0%)	14 (10%)	26 (13%)
North East	2 (4%)	0 (0%)	0 (0%)	0 (0%)	2 (5%)	0 (0%)
North West	21 (7%)	0 (0%)	0 (0%)	3 (15%)	17 (6%)	0 (0%)
South East England	58 (14%)	4 (20%)	0 (0%)	4 (33%)	44 (14%)	14 (14%)
South West England	30 (19%)	1 (25%)	0 (0%)	5 (19%)	25 (21%)	1 (6%)
West Midlands	17 (12%)	0 (0%)	0 (0%)	2 (22%)	13 (11%)	2 (9%)
Yorkshire & Humberside	31 (19%)	3 (15%)	0 (0%)	13 (46%)	17 (12%)	4 (22%)
Total	**243 (13%)**	**15 (12%)**	**6 (25%)**	**41 (30%)**	**172 (13%)**	**56 (12%)**

The results of the exposure analysis for the present day and projections for future periods for a high likelihood of flooding from rivers or the sea are shown in Table 4.121 and Table 4.122.

Table 4.121: Number (and proportion) of railway stations located in areas that are exposed to a high likelihood of flooding from rivers or the sea, categorised by the number of passengers entering and exiting the stations

	Current (2011-2012)			
Region	**Small**	**Medium**	**Large**	**All**
East Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)
East of England	2 (17%)	2 (1%)	1 (2%)	5 (2%)
London	0 (0%)	1 (1%)	0 (0%)	1 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	1 (5%)	0 (0%)	0 (0%)	1 (0%)
South East	0 (0%)	9 (3%)	1 (1%)	10 (2%)
South West	1 (4%)	3 (2%)	0 (0%)	4 (2%)
West Midlands	0 (0%)	2 (2%)	0 (0%)	2 (1%)
Yorkshire & Humberside	1 (4%)	5 (4%)	0 (0%)	6 (3%)
Total	**5 (4%)**	**22 (2%)**	**2 (0%)**	**29 (1%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.122: Number (and proportion) of railway stations located in areas that are projected to be exposed to a high likelihood of flooding from rivers or the sea, categorised by the number of passengers entering and exiting the stations

	2020s			2050s			2080s	
	Medium p50			Medium p50			Low p10 - High p90	
Region	**Small**	**Medium**	**Large**	**Small**	**Medium**	**Large**	**Small**	**Large**
East Midlands	1 (6%)	1 (1%)	0 (0%)	2 (13%)	1 (1%)	0 (0%)	1 (6%) - 6 (38%)	0 (0%) - 1 (11%)
East of England	2 (17%)	3 (2%)	1 (2%)	2 (17%)	3 (2%)	1 (2%)	2 (17%) - 6 (50%)	1 (2%) - 6 (12%)
London	0 (0%)	1 (1%)	0 (0%)	0 (0%)	1 (1%)	0 (0%)	0 (0%) - 0 (0%)	0 (0%) - 26 (13%)
North East	0 (0%)	1 (3%)	0 (0%)	0 (0%)	1 (3%)	0 (0%)	0 (0%) - 0 (0%)	0 (0%) - 0 (0%)
North West	1 (5%)	0 (0%)	0 (0%)	1 (5%)	1 (0%)	0 (0%)	1 (5%) - 3 (15%)	0 (0%) - 0 (0%)
South East	0 (0%)	10 (3%)	1 (1%)	1 (8%)	11 (4%)	2 (2%)	1 (8%) - 4 (33%)	1 (1%) - 11 (11%)
South West	1 (4%)	6 (5%)	0 (0%)	2 (7%)	9 (7%)	0 (0%)	2 (7%) - 5 (19%)	0 (0%) - 1 (6%)
West Midlands	0 (0%)	3 (3%)	0 (0%)	0 (0%)	3 (3%)	0 (0%)	0 (0%) - 1 (11%)	0 (0%) - 2 (9%)
Yorkshire & Humberside	1 (4%)	7 (5%)	1 (6%)	2 (7%)	8 (6%)	1 (6%)	1 (4%) - 9 (32%)	0 (0%) - 4 (22%)
Total	**6 (4%)**	**32 (2%)**	**3 (1%)**	**10 (7%)**	**38 (3%)**	**4 (1%)**	**8 (6%) - 34 (25%)**	**2 (0%) - 51 (11%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

The current level of exposure to flooding from rivers or the sea is quite low. However, the proportion of stations that may be exposed in the future to this type of flooding increases from 11% currently to up to 74% of small stations in the most extreme scenario in the 2080s. The range of the proportion of small stations that may be exposed to flooding from rivers or the sea in the 2080s is very wide, from 21-74%. Medium and large stations are not currently exposed, nor projected to be exposed, to the same extent as small stations.

In terms of regional distribution, currently, the East of England, followed by the South West, Yorkshire & Humberside and North West are the most exposed regions. This pattern of exposure continues in the projections but also increases in the South East and East Midlands.

Flooding (surface water)

This indicator quantifies the number and proportion of railway stations located in areas susceptible to surface water flooding in a 1:30 year, 1:100 year and 1:1000 year rainfall event for depths between 0.3m and 1.2m and for depths greater than 1.2m. The results of the exposure analysis are shown in Table 4.123 for mid-depth flooding and Table 4.124 for very deep flooding.

Table 4.123: Number (and proportion) of railway stations located in areas susceptible to mid-depth (0.30-1.2m) surface water flooding, categorised by the number of passengers entering and exiting the stations

Region	Mid-depth: 0.3m<= depth <1.2m 3.3% likelihood			Mid-depth: 0.3m<= depth <1.2m 0.1% likelihood		
	Small	Medium	Large	Small	Medium	Large
East Midlands	0 (0%)	0 (0%)	0 (0%)	1 (6%)	1 (1%)	0 (0%)
East of England	0 (0%)	1 (1%)	0 (0%)	0 (0%)	6 (4%)	1 (2%)
London	0 (0%)	1 (1%)	1 (1%)	0 (0%)	4 (3%)	2 (1%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)	1 (5%)	5 (2%)	2 (5%)
South East England	0 (0%)	0 (0%)	1 (1%)	1 (8%)	2 (1%)	2 (2%)
South West England	0 (0%)	0 (0%)	0 (0%)	1 (4%)	1 (1%)	0 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)	0 (0%)
Yorkshire & Humberside	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (1%)	1 (6%)
Total	**0 (0%)**	**2 (0%)**	**2 (0%)**	**4 (3%)**	**22 (2%)**	**8 (2%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.124: Number (and proportion) of railway stations located in areas susceptible to very deep (>1.2m) surface water flooding, categorised by the number of passengers entering and exiting the stations

Region	Very deep: Depth >1.2m 3.3% likelihood			Very deep: Depth >1.2m 0.1% likelihood		
	Small	Medium	Large	Small	Medium	Large
East Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
East of England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
London	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)	2 (1%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (1%)	0 (0%)
South East England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)
South West England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (4%)
Yorkshire & Humberside	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)	0 (0%)
Total	**0 (0%)**	**0 (0%)**	**0 (0%)**	**0 (0%)**	**4 (0%)**	**4 (1%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Only a very small proportion of railway stations are located in areas that are susceptible to surface water flooding. There is little variation in the size or location of the station(s) exposed. Underlying data for 2008/09 were also analysed. There is very little variation between the results for 2008/09 and 2011/12 and so these are not presented.

Natural landslides

This indicator quantifies the number and proportion of railway stations located in areas of high susceptibility to natural landslides where; slope instability problems are probably present or have occurred in the past or slope instability problems are almost certainly present and may be active. The results of the exposure analysis, shown in Table 4.125, indicate that only a very low proportion of stations are exposed to this hazard.

Table 4.125: Number (and proportion) of railway stations located in areas of high susceptibility to natural landslides, categorised by the number of passengers entering and exiting the stations

Region	2008	
	Small	Medium
East Midlands	0 (0%)	2 (2%)
East of England	0 (0%)	0 (0%)
London	0 (0%)	0 (0%)
North East	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)
South East England	0 (0%)	0 (0%)
South West England	1 (4%)	0 (0%)
West Midlands	0 (0%)	0 (0%)
Yorkshire & Humberside	0 (0%)	1 (1%)
Total	**1 (1%)**	**3 (0%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Shrink-swell subsidence

This indicator quantifies the number and proportion of railway stations located in areas of high susceptibility to shrink-swell subsidence where ground conditions are of predominantly high or very high plasticity. The results of the exposure analysis are shown in Table 4.126.

Table 4.126: Number (and proportion) of railway stations located in areas of high susceptibility to shrink-swell subsidence, categorised by the number of passengers entering and exiting the stations

Region	2008			2011		
	Small	Medium	Large	Small	Medium	Large
East Midlands	2 (2%)	0 (0%)	0 (0%)	0 (0%)	2 (2%)	0 (0%)
East of England	60 (31%)	5 (36%)	0 (0%)	3 (25%)	46 (31%)	16 (31%)
London	167 (58%)	10 (67%)	11 (69%)	0 (0%)	84 (61%)	104 (54%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South East England	54 (13%)	3 (15%)	0 (0%)	1 (8%)	44 (14%)	13 (13%)
South West England	4 (3%)	0 (0%)	0 (0%)	0 (0%)	2 (2%)	2 (12%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	1 (1%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)	0 (0%)
Total	**288 (16%)**	**18 (15%)**	**11 (46%)**	**4 (3%)**	**179 (13%)**	**135 (29%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

The results show that around 16% of railway stations are located in areas that are of high susceptibility to this type of hazard. The exposure to this hazard has reduced between 2008/09 and 2011/12 from ~26%. It is thought that this is due to one of two reasons:

1. More passengers using the railway network.
2. Variation in the way in which the number of passengers is recorded.

This changes the number of stations that are exposed per category and therefore appears to alter the proportion that may be exposed. There were 317 stations included in the analysis for 2008/2009 and 318 in the analysis for 2011/2012, so the number of assets in the analysis hardly changed.

4.5.3. Roads

In order to assess the criticality of roads, annual average daily flow (AADF) of traffic has been used as an alternative measure to length. These figures are derived from traffic surveys. AADF figures are produced for each junction to junction link on the major road network for every year and measure the average, over a full year, of the number of vehicles passing a point in the road network each day. Major roads are considered to be: motorways and all class 'A' roads. A sampling methodology is used to estimate AADF for some minor roads. The AADF data for minor roads is incomplete. AADF data was combined with the road network data taken from Ordnance Survey and Open Street Map.

Table 4.127: Total road length, categorised by type, used in this assessment

Road type	Major	Minor	Other	Total
Roads	35,131km	267,803km	3,343km	306,277km

The results for road exposure, by length, to the hazards assessed are summarised in Table 4.128.

Table 4.128: Length (and proportion) of roads exposed to different hazards in England

Road type	Coastal erosion[1]	Groundwater flooding[2]	River and coastal flooding[3]	Surface water flooding[4]	Natural landslides[5]	Shrink-swell subsidence[6]
Major	5 – 66km (0%)	3919km (11%)	3613km (10%)	1656km (5%)	230km (1%)	3162km (9%)
Minor	44 – 512km (0%)	22232km (8%)	22688km (8%)	17947km (7%)	1399km (1%)	25024km (9%)
Other	4 – 15km (0%)	322km (10%)	285km (9%)	196km (6%)	22km (1%)	380km (11%)
All	53 – 593km (0%)	26472km (9%)	26586km (9%)	19799km (6%)	1651km (1%)	28566km (9%)

Notes: Percentages are calculated as a proportion of the total number of assets per criticality category.

[1]Range of exposure dependent upon time period, scenario and policy

[2]High susceptibility of groundwater flooding, estimated as 1 in 200 years or more frequent.

[3]Present day flooding from rivers or the sea under any likelihood category.

[4]Mid-depth (0.3m<= depth <1.2m; 1 in 1000 year likelihood)

[5]High susceptibility category to natural landslides.

[6]High susceptibility category to shrink-swell subsidence.

Coastal erosion

The indicator assesses the length, proportion and AADF of roads located within locations that are projected to be exposed to coastal erosion over the next 100 years and the number and proportion of assets at risk behind the Shoreline Management Plan policies.

Table 4.129: Length (and proportion) of roads, categorised by type, located in areas that are susceptible to coastal erosion, by UKCP09 administrative region, under the No Active Intervention scenario

	Length								
	Short-term			Medium-term			Long-term		
Region	Major	Minor	Other	Major	Minor	Other	Major	Minor	Other
East Midlands	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)
East of England	0km (0%)	6km (0%)	0km (0%)	1km (0%)	43km (0%)	1km (0%)	3km (0%)	95km (0%)	2km (0%)
London	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)
North East	0km (0%)	5km (0%)	1km (1%)	3km (0%)	20km (0%)	1km (1%)	10km (1%)	44km (0%)	1km (1%)
North West	0km (0%)	3km (0%)	1km (0%)	8km (0%)	21km (0%)	1km (0%)	12km (0%)	55km (0%)	2km (0%)
South East England	3km (0%)	22km (0%)	1km (0%)	14km (0%)	86km (0%)	3km (0%)	32km (1%)	198km (0%)	8km (1%)
South West England	0km (0%)	5km (0%)	0km (0%)	2km (0%)	39km (0%)	0km (0%)	6km (0%)	83km (0%)	1km (0%)
West Midlands	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)
Yorkshire & Humberside	1km (0%)	2km (0%)	0km (0%)	2km (0%)	16km (0%)	1km (0%)	3km (0%)	36km (0%)	1km (0%)
Total	**5km (0%)**	**44km (0%)**	**4km (0%)**	**30km (0%)**	**224km (0%)**	**8km (0%)**	**66km (0%)**	**512km (0%)**	**15km (0%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.130: Total AADF of major and minor roads, located in areas that are susceptible to coastal erosion, by UKCP09 administrative region (thousands) , under the No Active Intervention scenario

Region	AADF								
	Short-term			Medium-term			Long-term		
	2001	2008	2012	2001	2008	2012	2001	2008	2012
East Midlands	0	0	0	0	0	0	0	0	0
East of England	60	60	60	80	80	80	130	130	130
London	0	0	0	0	0	0	0	0	0
North East	10	10	20	50	50	60	100	100	100
North West	180	180	180	390	380	380	430	420	420
South East England	460	500	490	1220	1240	1240	2030	2000	2040
South West England	360	390	390	470	510	500	600	630	630
West Midlands	0	0	0	0	0	0	0	0	0
Yorkshire & Humberside	0	0	0	0	0	0	20	20	20
Total	**1080**	**1150**	**1140**	**2210**	**2270**	**2260**	**3290**	**3300**	**3340**

Source: Proportions are not calculated; the manner in which AADF values are measured means that aggregation at the regional or local level can lead to double-counting.

The results of the exposure analysis under the No Active Intervention scenario are shown in Table 4.129and Table 4.130. Under the Shoreline Management Plan scenario policies, fewer roads are exposed, see Table 4.131 and Table 4.132.

Table 4.131: Length (and proportion) of roads, categorised by type, located in areas that are susceptible to coastal erosion, by UKCP09 administrative region, under the Shoreline Management Plan scenario and no active intervention policy

Region	Length								
	Short-term			Medium-term			Long-term		
	Major	Minor	Other	Major	Minor	Other	Major	Minor	Other
East Midlands	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)
East of England	0km (0%)	0km (0%)	0km (0%)	0km (0%)	3km (0%)	1km (0%)	0km (0%)	9km (0%)	1km (0%)
London	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)
North East	0km (0%)	1km (0%)	0km (0%)	1km (0%)	4km (0%)	0km (0%)	3km (0%)	7km (0%)	0km (0%)
North West	0km (0%)	0km (0%)	0km (0%)	0km (0%)	1km (0%)	0km (0%)	1km (0%)	3km (0%)	0km (0%)
South East	0km (0%)	0km (0%)	0km (0%)	2km (0%)	3km (0%)	0km (0%)	6km (0%)	9km (0%)	0km (0%)
South West	0km (0%)	1km (0%)	0km (0%)	1km (0%)	6km (0%)	0km (0%)	2km (0%)	18km (0%)	0km (0%)
West Midlands	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)	0km (0%)
Yorkshire & Humberside	0km (0%)	2km (0%)	0km (0%)	0km (0%)	7km (0%)	0km (0%)	0km (0%)	14km (0%)	0km (0%)
Total	**1km (0%)**	**5km (0%)**	**0km (0%)**	**4km (0%)**	**24km (0%)**	**1km (0%)**	**12km (0%)**	**61km (0%)**	**2km (0%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.132: Total AADF of major and minor roads, located in areas that are susceptible to coastal erosion, by UKCP09 administrative region (thousands) , under the Shoreline Management Plan scenario where the policy is No Active Intervention

	AADF								
	Short-term			Medium-term			Long-term		
Region	2001	2008	2012	2001	2008	2012	2001	2008	2012
East Midlands	0	0	0	0	0	0	0	0	0
East of England	50	50	50	50	50	50	60	60	60
London	0	0	0	0	0	0	0	0	0
North East	10	10	20	10	10	20	20	20	20
North West	0	0	0	0	0	0	0	0	0
South East	240	270	270	280	310	300	370	400	390
South West	130	130	130	150	160	150	170	180	180
West Midlands	0	0	0	0	0	0	0	0	0
Yorkshire & Humberside	0	0	0	0	0	0	20	20	20
Total	**430**	**470**	**470**	**490**	**530**	**540**	**630**	**680**	**680**

Source: Proportions are not calculated; the manner in which AADF values are measured means that aggregation at the regional or local level can lead to double-counting.

Under the SMP scenario where the policy is managed realignment or hold the line, the length of road, in total, in England that may be exposed to coastal erosion does not exceed 15km (around 20,000 AADF).

Flooding (groundwater)

This indicator assesses the length, proportion and AADF of roads located in areas that are considered to be of high susceptibility to groundwater flooding.

The results of the exposure analysis are shown in Table 4.133, Table 4.134 and Table 4.135.

Table 4.133: Length (and proportion) of roads, categorised by type, located in areas that are of high susceptibility to groundwater flooding, by UKCP09 administrative region

Region	Major	Minor	Other	All
East Midlands	504km (12%)	2757km (10%)	22km (10%)	3284km (10%)
East of England	531km (13%)	3111km (9%)	39km (11%)	3681km (9%)
London	387km (21%)	2486km (19%)	36km (17%)	2909km (19%)
North East	105km (6%)	614km (4%)	5km (3%)	723km (4%)
North West	285km (6%)	1699km (5%)	20km (5%)	2004km (5%)
South East England	842km (14%)	5025km (12%)	120km (12%)	5987km (12%)
South West England	500km (10%)	2718km (6%)	28km (7%)	3245km (6%)
West Midlands	430km (11%)	2061km (7%)	31km (10%)	2523km (8%)
Yorkshire & Humberside	335km (9%)	1762km (6%)	20km (6%)	2117km (7%)
Total	**3919km (11%)**	**22232km (8%)**	**322km (10%)**	**26472km (9%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.134: Total AADF of major and minor roads, located in areas that are of high susceptibility to groundwater flooding, by UKCP09 administrative region (thousands)

Region	Major	Minor	All
East Midlands	16350	230	16580
East of England	18870	260	19130
London	29480	200	29680
North East	4420	40	4460
North West	14240	50	14300
South East England	35730	370	36100
South West England	13840	170	14010
West Midlands	16750	320	17070
Yorkshire & Humberside	11920	130	12050
Total	**161590**	**1770**	**163370**

Source: Proportions are not calculated; the manner in which AADF values are measured means that aggregation at the regional or local level can lead to double-counting.

Slightly less than 10% of roads may be exposed to groundwater flooding. There is little variation between road types but there is variation between regions. London has the highest proportion of roads exposed and the second largest number of vehicles. In absolute terms, the South East of England has the largest length with potential to be affected and the largest number of vehicles. The North East of England has the least exposure both in absolute and proportional terms (length and AADF).

AADF from three time periods has been used in this analysis. There is very little variation in the figures between 2001 and 2012 (less than 1% change nationwide).

Table 4.135: Total AADF of major and minor roads, located in areas that are of high susceptibility to groundwater flooding, over time (2001, 2008 and 2012)

	2001	2008	2012
Major	162390	164280	161590
Minor	1900	1960	1770
All	164290	166250	163370

Flooding (river and coastal)

This indicator quantifies the length, proportion and AADF of roads within the floodplain by flood likelihood category and takes into account the presence, performance and condition of raised flood defences. The results of the exposure analysis to any likelihood category of flooding from rivers or the sea is shown in Table 4.136 and Table 4.137.

Table 4.136: Length (and proportion) of roads, categorised by type, located in areas that are currently susceptible to any likelihood category of flooding from rivers or the sea, by UKCP09 administrative region

Region	Major	Minor	Other	All
East Midlands	589km (15%)	4484km (16%)	29km (12%)	5102km (16%)
East of England	494km (12%)	3445km (10%)	33km (9%)	3972km (10%)
London	308km (17%)	1585km (12%)	22km (11%)	1915km (13%)
North East	90km (5%)	410km (3%)	8km (5%)	507km (3%)
North West	345km (7%)	1906km (6%)	31km (8%)	2282km (6%)
South East England	540km (9%)	3265km (8%)	83km (8%)	3888km (8%)

Region	Major	Minor	Other	All
South West England	453km (9%)	2864km (6%)	26km (7%)	3343km (7%)
West Midlands	265km (7%)	1260km (4%)	23km (8%)	1548km (5%)
Yorkshire & Humberside	529km (14%)	3469km (12%)	30km (10%)	4028km (12%)
Total	**3613km (10%)**	**22688km (8%)**	**285km (9%)**	**26586km (9%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.137: Total AADF of major roads*, located in areas that are projected to be susceptible to any likelihood category of flooding from rivers or the sea, by UKCP09 administrative region (thousands)

Region	AADF (1000s)
East Midlands	132740
East of England	122000
London	68080
North East	34270
North West	123790
South East England	189180
South West England	155310
West Midlands	109410
Yorkshire & Humberside	131850
Total	**1066630**

*Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region. *minor roads were included in the assessment but did not have any CP values.*

The results of the exposure analysis to a high likelihood of flooding from rivers or the sea are shown in Table 4.138, Table 4.139, Table 4.140, Table 4.141 and Table 4.142. Around 1% of roads are currently exposed to this hazard. There is little variation by type of road or by region, however, major roads are more likely to have engineered resilience measures installed and therefore their vulnerability may be lower than the results suggest. By the 2080s, the projection indicate that between around 2% and 8% of roads will be exposed. This equates to around 171,560,000 to 479,520,000 vehicles (AADF).

Table 4.138: Length (and proportion) of roads, categorised by type, located in areas that are currently susceptible to a high likelihood of flooding from rivers or the sea, by UKCP09 administrative region

	Current (2011-2012)			
Region	Major	Minor	Other	All
East Midlands	74km (2%)	569km (2%)	7km (3%)	651km (2%)
East of England	97km (2%)	515km (1%)	4km (1%)	616km (2%)
London	19km (1%)	66km (0%)	1km (1%)	86km (1%)
North East	21km (1%)	115km (1%)	1km (1%)	137km (1%)
North West	72km (2%)	341km (1%)	5km (1%)	418km (1%)
South East	112km (2%)	656km (2%)	22km (2%)	789km (2%)
South West	119km (2%)	799km (2%)	6km (2%)	924km (2%)
West Midlands	72km (2%)	334km (1%)	6km (2%)	412km (1%)
Yorkshire & Humberside	74km (2%)	328km (1%)	5km (2%)	407km (1%)
Total	**660km (2%)**	**3723km (1%)**	**58km (2%)**	**4441km (1%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.139: Length (and proportion) of roads, categorised by type, located in areas that are projected to be susceptible to a high likelihood of flooding from rivers or the sea, in the 2020s, by UKCP09 administrative region

Region	2020s			
	Medium p50			
	Major	Minor	Other	All
East Midlands	111km (3%)	867km (3%)	9km (4%)	987km (3%)
East of England	106km (3%)	565km (2%)	5km (1%)	676km (2%)
London	22km (1%)	73km (1%)	1km (1%)	96km (1%)
North East	32km (2%)	164km (1%)	3km (2%)	200km (1%)
North West	89km (2%)	430km (1%)	6km (2%)	525km (1%)
South East	122km (2%)	721km (2%)	25km (2%)	867km (2%)
South West	157km (3%)	998km (2%)	8km (2%)	1162km (2%)
West Midlands	95km (2%)	439km (2%)	7km (2%)	541km (2%)
Yorkshire & Humberside	113km (3%)	645km (2%)	9km (3%)	767km (2%)
Total	**847km (2%)**	**4902km (2%)**	**73km (2%)**	**5822km (2%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.140: Length (and proportion) of roads, categorised by type, located in areas that are projected to be susceptible to a high likelihood of flooding from rivers or the sea, in the 2050s, by UKCP09 administrative region

Region	2050s			
	Medium p50			
	Major	Minor	Other	All
East Midlands	141km (3%)	1068km (4%)	10km (4%)	1219km (4%)
East of England	115km (3%)	618km (2%)	5km (1%)	738km (2%)
London	26km (1%)	80km (1%)	2km (1%)	108km (1%)
North East	39km (2%)	177km (1%)	3km (2%)	219km (1%)
North West	92km (2%)	453km (1%)	6km (2%)	551km (1%)
South East	137km (2%)	825km (2%)	27km (3%)	989km (2%)
South West	206km (4%)	1294km (3%)	9km (2%)	1510km (3%)
West Midlands	97km (3%)	450km (2%)	8km (3%)	555km (2%)
Yorkshire & Humberside	156km (4%)	979km (3%)	12km (4%)	1146km (4%)
Total	**1009km (3%)**	**5945km (2%)**	**82km (2%)**	**7036km (2%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.141: Length (and proportion) of roads, categorised by type, located in areas that are projected to be susceptible to a high likelihood of flooding from rivers or the sea, in the 2080s, by UKCP09 administrative region

	2080s			
	Low p10 - High p90			
Region	Major	Minor	Other	All
East Midlands	118km (3%) - 522km (13%)	926km (3%) - 4092km (15%)	9km (4%) - 25km (11%)	1052km (3%) - 4638km (15%)
East of England	107km (3%) - 454km (11%)	574km (2%) - 3153km (9%)	5km (1%) - 31km (9%)	685km (2%) - 3638km (9%)
London	23km (1%) - 295km (16%)	73km (1%) - 1498km (11%)	2km (1%) - 21km (10%)	98km (1%) - 1814km (12%)
North East	36km (2%) - 84km (5%)	158km (1%) - 391km (3%)	3km (2%) - 8km (5%)	197km (1%) - 483km (3%)
North West	85km (2%) - 314km (7%)	426km (1%) - 1649km (5%)	6km (2%) - 27km (7%)	517km (1%) - 1989km (5%)
South East	125km (2%) - 516km (9%)	746km (2%) - 3111km (7%)	27km (3%) - 79km (8%)	898km (2%) - 3707km (8%)
South West	185km (4%) - 425km (8%)	1157km (3%) - 2735km (6%)	8km (2%) - 24km (6%)	1350km (3%) - 3185km (6%)
West Midlands	74km (2%) - 192km (5%)	341km (1%) - 870km (3%)	6km (2%) - 15km (5%)	421km (1%) - 1077km (3%)
Yorkshire & Humberside	102km (3%) - 506km (14%)	666km (2%) - 3279km (12%)	8km (3%) - 30km (10%)	776km (2%) - 3815km (12%)
Total	**856km (2%) - 3308km (9%)**	**5066km (2%) - 20779km (8%)**	**73km (2%) - 259km (8%)**	**5995km (2%) - 24346km (8%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.142: Total AADF of major and minor roads, located in areas that are projected to be susceptible to a high likelihood of flooding from rivers or the sea, by UKCP09 administrative region (thousands)

	AADF 2012				
	Current (2011-2012)	2020s	2050s	2080s	2080s
		Medium p50	Medium p50	Low p10	High p90
Region	All	All	All	All	All
East Midlands	15300	17030	20810	16640	45630
East of England	18120	19870	21720	18730	53240
London	12410	13090	14520	13160	50580
North East	4450	6160	6810	5990	13730
North West	18160	21250	22560	20890	53820
South East England	32600	35320	39060	35250	102450
South West England	18640	24060	29010	25280	60400
West Midlands	18360	23390	24290	19360	48560
Yorkshire & Humberside	12620	17720	21630	16260	51120
Total	**150670**	**177880**	**200420**	**171560**	**479520**

Source: Proportions are not calculated; the manner in which AADF values are measured means that aggregation at the regional or local level can lead to double-counting.

Flooding (surface water)

This indicator quantifies the length, proportion and AADF of roads located in areas susceptible to surface water flooding in a 1:30 year, 1:100 year and 1:1000 year rainfall event for depths of between 0.3 and 1.2m and for depths greater than 1.2m.

The results of the exposure analysis are shown in Table 4.143, Table 4.144, Table 4.145 and Table 4.146. Relatively small lengths of roads are exposed to very deep or mid-depth and frequent surface water flooding. A slightly higher proportion may be exposed to mid-depth infrequent flooding. There is little variation across the different road types and only small differences in the proportion of length of road exposed across regions. In absolute terms, the East of England, South East of England and South West of England have the highest length of roads that may be exposed to mid-depth infrequent surface water flooding. This equates to around 225,140,000 vehicles (AADF).

Table 4.143: Length (and proportion) of roads, categorised by type, located in areas that are susceptible to mid-depth surface water flooding, by UKCP09 administrative region

	Mid-depth: 0.3m<= depth <1.2m				Mid-depth: 0.3m<= depth <1.2m			
	3.3% likelihood				0.1% likelihood			
Region	Major	Minor	Other	All	Major	Minor	Other	All
East Midlands	35km (1%)	272km (1%)	2km (1%)	309km (1%)	172km (4%)	1616km (6%)	13km (5%)	1800km (6%)
East of England	47km (1%)	563km (2%)	4km (1%)	615km (2%)	242km (6%)	3041km (9%)	27km (8%)	3310km (8%)
London	23km (1%)	191km (1%)	2km (1%)	216km (1%)	204km (11%)	1870km (14%)	20km (10%)	2094km (14%)
North East	17km (1%)	126km (1%)	1km (1%)	144km (1%)	61km (3%)	637km (4%)	8km (5%)	706km (4%)
North West	38km (1%)	312km (1%)	4km (1%)	354km (1%)	192km (4%)	2204km (7%)	23km (6%)	2419km (6%)
South East England	55km (1%)	558km (1%)	8km (1%)	621km (1%)	308km (5%)	3394km (8%)	54km (5%)	3756km (8%)
South West England	39km (1%)	455km (1%)	3km (1%)	497km (1%)	172km (3%)	2062km (5%)	15km (4%)	2250km (4%)
West Midlands	38km (1%)	364km (1%)	2km (1%)	403km (1%)	178km (5%)	1858km (6%)	20km (6%)	2056km (6%)
Yorkshire & Humberside	26km (1%)	186km (1%)	3km (1%)	215km (1%)	126km (3%)	1266km (4%)	16km (5%)	1409km (4%)
Total	317km (1%)	3027km (1%)	30km (1%)	3374km (1%)	1656km (5%)	17947km (7%)	196km (6%)	19799km (6%)

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.144: Length (and proportion) of roads, categorised by type, located in areas that are susceptible to very deep surface water flooding, by UKCP09 administrative region

Region	Very deep: Depth >1.20m				Very deep: Depth >1.20m			
	3.3% likelihood				0.1% likelihood			
	Major	Minor	Other	All	Major	Minor	Other	All
East Midlands	3km (0%)	9km (0%)	0km (0%)	12km (0%)	18km (0%)	91km (0%)	1km (1%)	110km (0%)
East of England	4km (0%)	17km (0%)	0km (0%)	21km (0%)	33km (1%)	192km (1%)	1km (0%)	227km (1%)
London	2km (0%)	3km (0%)	0km (0%)	6km (0%)	23km (1%)	87km (1%)	1km (0%)	111km (1%)
North East	1km (0%)	3km (0%)	0km (0%)	4km (0%)	9km (1%)	32km (0%)	0km (0%)	41km (0%)
North West	3km (0%)	9km (0%)	0km (0%)	13km (0%)	30km (1%)	109km (0%)	2km (0%)	140km (0%)
South East England	4km (0%)	14km (0%)	0km (0%)	18km (0%)	36km (1%)	165km (0%)	4km (0%)	205km (0%)
South West England	3km (0%)	18km (0%)	0km (0%)	22km (0%)	17km (0%)	128km (0%)	1km (0%)	146km (0%)
West Midlands	2km (0%)	8km (0%)	0km (0%)	10km (0%)	24km (1%)	102km (0%)	1km (0%)	127km (0%)
Yorkshire & Humberside	3km (0%)	8km (0%)	0km (0%)	11km (0%)	19km (1%)	76km (0%)	2km (1%)	97km (0%)
Total	**27km (0%)**	**90km (0%)**	**1km (0%)**	**117km (0%)**	**210km (1%)**	**979km (0%)**	**14km (0%)**	**1203km (0%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.145: Total AADF, categorised by road type, located in areas that are susceptible to mid-depth surface water flooding, by UKCP09 administrative region (thousands)

Region	Mid-depth: 0.3m<= depth <1.2m			Mid-depth: 0.3m<= depth <1.2m		
	3.3% likelihood			0.1% likelihood		
	Major	Minor	All	Major	Minor	All
East Midlands	26830	360	27200	49210	570	49770
East of England	37300	630	37930	69600	970	70570
London	32880	250	33130	77510	600	78120
North East	11420	150	11570	22320	200	22510
North West	41820	220	42040	84930	370	85300
South East England	55010	760	55770	107350	1070	108420
South West England	27920	470	28390	46950	660	47620
West Midlands	32350	820	33170	62380	1140	63520
Yorkshire & Humberside	21980	360	22340	44070	550	44630
Total	**287520**	**4020**	**291540**	**564330**	**6130**	**570460**

Source: Proportions are not calculated; the manner in which AADF values are measured means that aggregation at the regional or local level can lead to double-counting.

Table 4.146: Total AADF, categorised by road type, located in areas that are susceptible to very deep surface water flooding, by UKCP09 administrative region (thousands)

Region	Very deep: Depth >1.20m			Very deep: Depth >1.20m		
	3.3% likelihood			0.1% likelihood		
	Major	Minor	All	Major	Minor	All
East Midlands	66770	880	67650	113190	1310	114500
East of England	91790	1380	93170	155970	1950	157920
London	92310	800	93110	186880	1300	188180
North East	28380	330	28710	54520	390	54920
North West	104820	550	105370	201400	770	202170
South East England	139970	1740	141710	247030	2240	249270
South West England	64950	1000	65950	105840	1380	107220
West Midlands	78540	1780	80320	145260	2410	147670
Yorkshire & Humberside	57040	820	57860	106670	1130	107800
Total	**724560**	**9290**	**733850**	**1316770**	**12890**	**1329660**

Source: Proportions are not calculated; the manner in which AADF values are measured means that aggregation at the regional or local level can lead to double-counting.

Natural landslides

This indicator quantifies the length, proportion and AADF of roads located in areas of high susceptibility to natural landslides where; slope instability problems are probably present or have occurred in the past or slope instability problems are almost certainly present and may be active. Such issues with slope stability may present a significant constraint on the use of land or any development would need to give specific consideration to the stability of the site. Many roads may also be subject to land instability on man-made slopes which is not included in this analysis.

The results of the exposure analysis are shown in Table 4.147, Table 4.148 and Table 4.149.

Table 4.147: Length (and proportion) of roads, categorised by type, located in areas that are susceptible to natural landslides, by UKCP09 administrative region

Region	Major	Minor	Other	All
East Midlands	43km (1%)	168km (1%)	2km (1%)	213km (1%)
East of England	1km (0%)	9km (0%)	0km (0%)	9km (0%)
London	0km (0%)	0km (0%)	0km (0%)	1km (0%)
North East	3km (0%)	17km (0%)	0km (0%)	21km (0%)
North West	24km (1%)	81km (0%)	2km (0%)	106km (0%)
South East England	13km (0%)	77km (0%)	7km (1%)	96km (0%)
South West England	80km (2%)	627km (1%)	6km (2%)	712km (1%)
West Midlands	23km (1%)	115km (0%)	2km (1%)	140km (0%)
Yorkshire & Humberside	44km (1%)	305km (1%)	4km (1%)	353km (1%)
Total	**230km (1%)**	**1399km (1%)**	**22km (1%)**	**1651km (1%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.148: Total AADF, categorised by road type, located in areas that are susceptible to natural landslides, by UKCP09 administrative region (thousands)

Region	Major	Minor	All
East Midlands	2070	30	2100
East of England	380	10	380
London	70	0	70
North East	480	0	490
North West	2940	0	2940
South East England	1990	20	2010
South West England	3050	60	3110
West Midlands	1370	50	1430
Yorkshire & Humberside	3600	50	3660
Total	**15960**	**230**	**16190**

Source: Proportions are not calculated; the manner in which AADF values are measured means that aggregation at the regional or local level can lead to double-counting.

Table 4.149: Total AADF of major and minor roads, located in areas that are susceptible to natural landslides, over time (2001, 2008 and 2012, thousands)

	2001	2008	2012
Major	15310	15870	15960
Minor	230	230	230
All	15530	16100	16190

Source: Proportions are not calculated; the manner in which AADF values are measured means that aggregation at the regional or local level can lead to double-counting.

Currently, only a very small proportion of roads are located in areas that are also susceptible to natural landslides. There is strong regionalisation; South West England, Yorkshire & Humberside and the East Midlands have the largest length of roads that may be exposed. The East of England and London have the least, a product of the location of steeper gradients of slope in England. There has been a slight increase in the AADF over time that may be exposed to this hazard; about 5% over the 11 year period.

Shrink-swell subsidence

This indicator quantifies the length, proportion and AADF of roads located in areas of high susceptibility to shrink-swell subsidence where ground conditions are of predominantly high or very high plasticity.

The results of the exposure analysis are shown in Table 4.150 and Table 4.151. Around 9 % of all roads are located in areas that are also of high susceptibility to shrink-swell subsidence. As with other indicators, there are marked differences between the regions, according to the location of clay soil types. Since 2001, the AADF of vehicles that are potentially exposed to this hazard has reduced slightly, by around 5%. This is due to the reduction in flow in areas that are of high susceptibility of this hazard, such as London.

Table 4.150: Length (and proportion) of roads, categorised by type, located in areas that are susceptible to shrink-swell subsidence, by UKCP09 administrative region

Region	Major	Minor	Other	All
East Midlands	101km (3%)	740km (3%)	4km (2%)	846km (3%)
East of England	975km (23%)	7953km (22%)	81km (23%)	9009km (22%)
London	892km (50%)	7400km (56%)	113km (55%)	8406km (55%)
North East	0km (0%)	0km (0%)	0km (0%)	0km (0%)
North West	0km (0%)	0km (0%)	0km (0%)	0km (0%)
South East England	920km (16%)	6474km (15%)	155km (15%)	7549km (15%)
South West England	233km (4%)	2140km (5%)	23km (6%)	2396km (5%)
West Midlands	0km (0%)	0km (0%)	0km (0%)	0km (0%)
Yorkshire & Humberside	41km (1%)	316km (1%)	3km (1%)	360km (1%)
Total	**3162km (9%)**	**25024km (9%)**	**380km (11%)**	**28566km (9%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.151: Total AADF, for all major and minor roads, located in areas that are susceptible to shrink-swell subsidence by UKCP09 administrative region (thousands)

	All		
Region	2001	2008	2012
East Midlands	610	670	640
East of England	18420	18840	18810
London	40990	38390	36290
North East	0	0	0
North West	0	0	0
South East England	21480	21290	21390
South West England	3370	3520	3440
West Midlands	0	0	0
Yorkshire & Humberside	220	230	230
Total	**85080**	**82940**	**80800**

Source: Proportions are not calculated; the manner in which AADF values are measured means that aggregation at the regional or local level can lead to double-counting.

4.5.4. Rail/Road bridges

The analysis assesses the future increase in exposure to scour, above the present day baseline, due to climate change using UKCP09 projections of changes in peak flow. The absolute risk to each bridge, including the present day baseline, has not been assessed due to the lack of availability of bridge specific data (e.g. materials, dimensions, foundation depth and geotechnical data).

Table 4.152: Total number of bridges, categorised by river type, used in this assessment

Bridges	Primary River	Secondary River	Total
Road (Major)	4919	3745	8664
Rail	2403	1836	4239

River scour to road bridges

The results for exposure to road bridges are shown in Table 4.153, Table 4.154 and Table 4.155. It can be seen that there is very little increased scour exposure across the country for all future scenarios except for the 2080s, high emissions, p90 scenario where 26% of road bridges have a medium category of increased scour exposure and 5% have a high category. In that future scenario the increase in exposure is greatest in the North East and North West of England.

Table 4.153: Proportion of major road bridges over rivers per scour exposure class

	Proportion of bridges per river scour exposure class.		
Scenario	**Low**	**Medium**	**High**
2020s Medium p50	100%	0%	0%
2050s Medium p50	100%	0%	0%
2080s Low p10	100%	0%	0%
2080s High p90	69%	26%	5%

Source: n/a

Table 4.154: Proportion of major road bridges over rivers per scour exposure class and per UKCP09 administrative region: 2020s and 2050s

	2020s Medium p50			2050s Medium p50		
Region	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**
East Midlands	100%	0%	0%	100%	0%	0%
East of England	100%	0%	0%	100%	0%	0%
London	100%	0%	0%	99%	1%	0%
North East	100%	0%	0%	99%	1%	0%
North West	100%	0%	0%	98%	2%	0%
South East	100%	0%	0%	100%	0%	0%
South West	100%	0%	0%	99%	1%	0%
West Midlands	100%	0%	0%	100%	0%	0%
Yorkshire & Humberside	100%	0%	0%	99%	1%	0%
Total	**100%**	**0%**	**0%**	**100%**	**0%**	**0%**

Source: n/a

Table 4.155: Proportion of major road bridges over rivers per scour exposure class and per UKCP09 administrative region: 2080s

	2080s Low p10			2080s High p90		
Region	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**
East Midlands	100%	0%	0%	72%	25%	3%
East of England	100%	0%	0%	74%	22%	4%
London	100%	0%	0%	68%	27%	5%
North East	100%	0%	0%	42%	49%	9%
North West	100%	0%	0%	49%	39%	12%
South East	100%	0%	0%	77%	19%	4%
South West	100%	0%	0%	75%	19%	6%
West Midlands	100%	0%	0%	75%	21%	4%
Yorkshire & Humberside	100%	0%	0%	64%	34%	2%
Total	**100%**	**0%**	**0%**	**69%**	**26%**	**5%**

Source: n/a

River scour to rail bridges

The results of the assessment for rail bridges are shown in Table 4.156, Table 4.157 and Table 4.158. Similar to road bridges, there is little change to scour exposure except for the high emissions p90 scenario for the 2080s and the increase is greatest in the north of England.

Table 4.156: Proportion of major rail bridges over rivers per scour exposure class

	Proportion of bridges per river scour exposure class.		
Summary	**Low**	**Medium**	**High**
2020s Medium p50	100%	0%	0%
2050s Medium p50	99%	1%	0%
2080s Low p10	100%	0%	0%
2080s High p90	69%	26%	5%

Source: n/a

Table 4.157: Proportion of rail bridges over rivers per scour exposure class and per UKCP09 administrative region: 2020s and 2050s

	2020s Medium p50			2050s Medium p50		
Region	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**
East Midlands	100%	0%	0%	99%	1%	0%
East of England	100%	0%	0%	100%	0%	0%
London	100%	0%	0%	100%	0%	0%
North East	100%	0%	0%	100%	0%	0%
North West	99%	1%	0%	98%	2%	0%
South East	100%	0%	0%	100%	0%	0%
South West	100%	0%	0%	100%	0%	0%
West Midlands	100%	0%	0%	100%	0%	0%
Yorkshire & Humberside	100%	0%	0%	99%	1%	0%
Total	**100%**	**0%**	**0%**	**99%**	**1%**	**0%**

Source: n/a

Table 4.158: Proportion of rail bridges over rivers per scour exposure class and per UKCP09 administrative region: 2080s

Region	2080s Low p10			2080s High p90		
	Low	Medium	High	Low	Medium	High
East Midlands	100%	0%	0%	63%	33%	4%
East of England	100%	0%	0%	74%	19%	7%
London	100%	0%	0%	73%	17%	10%
North East	100%	0%	0%	55%	40%	5%
North West	100%	0%	0%	54%	36%	10%
South East	100%	0%	0%	78%	17%	5%
South West	100%	0%	0%	75%	21%	5%
West Midlands	100%	0%	0%	71%	25%	3%
Yorkshire & Humberside	100%	0%	0%	60%	37%	4%
Total	**100%**	**0%**	**0%**	**69%**	**26%**	**5%**

Source: n/a

Shrink-swell subsidence

Table 4.159: Number (and proportion) of rail and road river bridges exposed to shrink-swell subsidence England

Bridge type	River type	Shrink-swell subsidence (2012)
Road	Primary	498 (10%)
	Secondary	173 (5%)
	All	671 (8%)
Rail	Primary	274 (11%)
	Secondary	169 (9%)
	All	443 (10%)

Source: n/a

The results of the assessment of exposure of major road river bridges to shrink-swell subsidence are shown in Table 4.160 and Table 4.161. Around 8% of major road river bridges may be exposed to this hazard with the most significant proportions to be found, as might be expected, in London, the East of England and the South East of England. This equates to around 12,340,000 vehicles (AADF). Among the busiest stretches of road in England are on the M25 and M4.

Table 4.160: Number (and proportion) of major road bridges that cross rivers, that are located in areas of high susceptibility to shrink-swell subsidence

Region	Primary river	Secondary river	All
East Midlands	29 (5%)	12 (2%)	41 (4%)
East of England	173 (28%)	59 (13%)	232 (22%)
London	88 (46%)	9 (16%)	97 (39%)
North East	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)
South East England	161 (19%)	64 (11%)	225 (16%)
South West England	40 (5%)	26 (4%)	66 (5%)
West Midlands	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	7 (2%)	3 (1%)	10 (1%)
Total	**498 (10%)**	**173 (5%)**	**671 (8%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.161: Total AADF of major roads on road bridges that cross rivers and are located in areas of high susceptibility to shrink-swell subsidence (thousands)

Region	Primary river	Secondary river	All
East Midlands	110	110	220
East of England	3360	990	4360
London	2700	300	3000
North East	0	0	0
North West	0	0	0
South East England	2800	1110	3900
South West England	490	280	780
West Midlands	0	0	0
Yorkshire & Humberside	50	40	90
Total	**9510**	**2840**	**12340**

Source: Proportions are not calculated; the manner in which AADF values are measured means that aggregation at the regional or local level can lead to double-counting.

The results of the assessment of exposure of rail river bridges to areas of high susceptibility for shrink-swell subsidence is shown in Table 4.162. Around 10% of rail bridges that cross rivers, may be exposed to this hazard. Whilst the highest proportion of these is in London, the largest overall number are in the South East and East of England.

Table 4.162: Number (and proportion) of rail bridges that cross rivers, that are located in areas of high susceptibility to shrink-swell subsidence

Region	Primary river	Secondary river	All
East Midlands	7 (3%)	10 (4%)	17 (3%)
East of England	87 (33%)	51 (28%)	138 (31%)
London	55 (53%)	14 (61%)	69 (54%)
North East	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)
South East England	95 (21%)	69 (19%)	164 (20%)
South West England	27 (6%)	20 (7%)	47 (7%)
West Midlands	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	3 (1%)	5 (2%)	8 (1%)
Total	274 (11%)	169 (9%)	443 (10%)

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

4.6. Water

Data

Ordnance Survey MasterMap, October 2013, Yorkshire Water 2013, Severn Trent Water 2013: Clean water treatment locations.

Environment Agency (EA): Consented Discharges to Controlled Waters, 2013.

EA : NaFRA Spatial Internal Grid 2013 (flooding from rivers or the sea).

EA : NCERM 2011 (coastal erosion).

British Geological Survey (BGS): Map of susceptibility to natural landslides. British Geological Survey © NERC. All rights reserved.

BGS: Map of susceptibility to shrink-swell subsidence. British Geological Survey © NERC. All rights reserved.

ESI: Groundwater flooding risk map. ESI Groundwater Flood Risk Map of England and Wales © http://esinternational.com/

4.6.1. Clean water treatment sites

There were a total of 1,718 water treatment works (WTW) in this analysis. The majority of these locations were acquired from OS MasterMap Property layer, but two water companies were able to disclose the locations of their WTW and in a few cases (17), the number of customers those WTW serve, ranges from 56,000 to 1,218,000 each.

Table 4.163: Total number of clean water treatment sites, used in this assessment

	Count
Clean water treatment sites	1,718

Table 4.164: Number (and proportion) of clean water treatment sites exposed to different hazards in England

Annual average daily flow category	Coastal erosion[1]	Groundwater flooding[2]	River and coastal flooding[3]	Surface water flooding[4]	Shrink-swell subsidence[5]
Number	0	262	586	57	174
Proportion	0%	15%	34%	3%	10%

Notes: Percentages are calculated as a proportion of the total number of assets per criticality category.
[1]Range of exposure dependent upon time period, scenario and policy
[2]High susceptibility of groundwater flooding, estimated as 1 in 200 years or more frequent.
[3]Present day flooding from rivers or the sea under any likelihood category.
[4]Mid-depth (0.3m<= depth <1.2m; 1 in 1000 year likelihood)
[5]High susceptibility category to shrink-swell subsidence.

Coastal erosion

The indicator assesses the number and proportion of WTW located within locations that are projected to be exposed to coastal erosion over the next 100 years, behind the Shoreline Management Plan policies.

There are no clean water treatment sites that fall within the boundaries of the National Coastal Erosion Risk Map. However, this is a national assessment and unsuitable for asset level analysis. At a local level, there may be clean water treatment sites which have not been identified.

Flooding (groundwater)

This indicator assesses the number and proportion of clean water treatment sites located in areas that are at of high susceptibility to groundwater flooding. The regional distribution assets exposed to this hazard is presented in Table 4.165. The highest proportion of exposure is located in London, the East of England and the South East of England. Overall, ~15% of WTW may be exposed to this hazard. Of the WTW data provided by the water companies, there are three WTW sites, serving 681,000 people, that are included in these national figures.

Table 4.165: Number (and proportion) of water treatment works located in areas that are susceptible to groundwater flooding, by UKCP09 administrative regions

Region	WTW
East Midlands	24 (23%)
East of England	27 (11%)
London	20 (30%)
North East England	6 (13%)
North West England	16 (11%)
South East England	81 (19%)
South West England	31 (12%)
West Midlands	37 (15%)
Yorkshire and Humberside	20 (11%)
Total	**262 (15%)**

Notes: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Flooding (river and coastal)

This indicator quantifies the number and proportion of WTW within the floodplain by flood likelihood category and takes into account the presence, performance and condition of publicly owned and maintained raised flood defences but not private local flood defence or resilience measures. The overall results, a sum of all likelihoods, are presented in Table 4.166.

Table 4.166: Number (and proportion) of WTW located in areas currently at any likelihood of flooding from rivers or the sea, by UKCP09 administrative region

Region	WTW
East Midlands	30 (29%)
East of England	63 (25%)
London	66 (100%)
North East	15 (31%)
North West	55 (37%)
South East England	153 (36%)
South West England	47 (19%)
West Midlands	68 (28%)
Yorkshire & Humberside	89 (49%)
Total	**586 (34%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

The results of the exposure analysis are shown in Table 4.167.

Table 4.167: Number (and proportion) of WTW located in areas that at high likelihood of flooding from rivers or the sea, by UKCP09 administrative region

Region	Current (2011-2012)	2020s	2050s	2080s	
		Medium p50	Medium p50	Low p10 - High p90	
East Midlands	8 (8%)	8 (8%)	30 (29%)	10 (10%)	27 (26%)
East of England	15 (6%)	16 (6%)	63 (25%)	16 (6%)	62 (25%)
London	1 (2%)	1 (2%)	66 (100%)	1 (2%)	63 (95%)
North East	1 (2%)	1 (2%)	15 (31%)	1 (2%)	13 (27%)
North West	27 (18%)	27 (18%)	55 (37%)	28 (19%)	55 (37%)
South East England	30 (7%)	38 (9%)	153 (36%)	36 (9%)	147 (35%)
South West England	11 (4%)	20 (8%)	47 (19%)	17 (7%)	41 (16%)
West Midlands	14 (6%)	18 (7%)	68 (28%)	16 (6%)	44 (18%)
Yorkshire & Humberside	13 (7%)	36 (20%)	89 (49%)	27 (15%)	88 (48%)
Total	**120 (7%)**	**165 (10%)**	**586 (34%)**	**152 (9%)**	**540 (31%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

The current level of exposure to flooding from rivers or the sea for WTW is moderate at around 7% of the national total. The situation is worst in the North West where 18% of WTW are exposed to this hazard and the South East where there are 30 exposed. Of the WTW data provided by the water companies, four WTW serving 839,000 people are included in this figure. This figure may rise in the future. In the 2080s, between

9 and 31% of WTW may be exposed to flooding from rivers or the sea (low emissions, p10 to high emissions p90 scenarios). Similar to the other indicators assessed, this does not take into consideration any asset scale flood prevention measures that exist.

Flooding (surface water)

This indicator quantifies the number and proportion of WTW located in areas also susceptible to surface water flooding in a 1:30 year, 1:100 year and 1:1000 year rainfall event for depths between 0.3m and 1.2m and for depths greater than 1.2m. The results are presented in Table 4.168.

Table 4.168: Number (and proportion) of WTW located in areas that are also susceptible to surface water flooding, by UKCP09 administrative region

Region	Mid-depth: 0.3m<= depth <1.2m 3.3% likelihood	Mid-depth: 0.3m<= depth <1.2m 0.1% likelihood	Very deep: Depth >1.20m 3.3% likelihood	Very deep: Depth >1.20m 0.1% likelihood
East Midlands	3 (3%)	8 (8%)	0 (0%)	3 (3%)
East of England	1 (0%)	7 (3%)	1 (0%)	2 (1%)
London	0 (0%)	2 (3%)	2 (3%)	4 (6%)
North East	0 (0%)	2 (4%)	0 (0%)	0 (0%)
North West	1 (1%)	4 (3%)	0 (0%)	2 (1%)
South East England	2 (0%)	15 (4%)	2 (0%)	2 (0%)
South West England	1 (0%)	10 (4%)	1 (0%)	3 (1%)
West Midlands	1 (0%)	4 (2%)	2 (1%)	6 (2%)
Yorkshire & Humberside	2 (1%)	5 (3%)	2 (1%)	6 (3%)
Total	**11 (1%)**	**57 (3%)**	**10 (1%)**	**28 (2%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

A small proportion of WTW are located in areas that are susceptible to surface water flooding. Of the WTW data provided by the water companies, there is one WTW serving 104,000 people that has been highlighted as being exposed to surface water flooding of 0.30-1.2m for all likelihoods. At a local level, there may be individual assets that are exposed to very deep surface water flooding in London, the West Midlands and Yorkshire & Humberside in particular. Whilst this doesn't represent a high level of national exposure, it has the potential to present a high local level of risk to the water companies in question and their customers.

Shrink-swell subsidence

This indicator quantifies the number and proportion of WTW located in areas of high susceptibility to shrink-swell subsidence where ground conditions are of predominantly high or very high plasticity. The results of the exposure analysis are shown in Table 4.169. The results are highly regionalised. The most significant levels of exposure to this hazard are in London, the East of England and the East Midlands. None of the WTW for which there is information on the numbers of customers are exposed to this hazard.

Table 4.169: Number (and proportion) of WTW located in areas of high susceptibility to shrink-swell subsidence, by UKCP09 administrative region

Region	WTW
East Midlands	3 (3%)
East of England	62 (25%)
London	29 (44%)
North East	0 (0%)
North West	0 (0%)
South East	0 (0%)
South West	0 (0%)
West Midlands	0 (0%)
Yorkshire & Humberside	0 (0%)
Total	**174 (10%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

4.6.2. Wastewater treatment sites

In order to assess the level of criticality of the wastewater treatment works (WWTW) exposed to different hazards, they have been categorised according to their effluent dry weather flow. The categories used follow the Multi-Coloured Manual (2013):

- Significant: >30,000 cumecs effluent dry weather flow
- Moderate: 5,000 to 30,000 cumecs effluent dry weather flow
- Low: <5,000 cumecs effluent dry weather flow.

Table 4.170: Total number of wastewater treatment sites, categorized by effluent dry weather flow, used in this assessment

	Significant	Moderate	Low	No data	Total
Wastewater treatment sites	62	253	3,254	6,567	10,136

There were 10,136 sites in the analysis: 3,254 fall into the low category, 253 into the moderate category and 62 into the significant category; 6,567 sites has no information on dry weather flow. A summary of the results is presented in Table 4.171. The data was obtained from postcodes provided by the Environment Agency dataset. Whilst the location information is considered accurate, postcodes must be digitised into co-ordinates for the spatial assessment and this introduces some error.

Table 4.171: Number (and proportion) of wastewater treatment sites exposed to different hazards in England

Dry weather flow (cumecs)	Coastal erosion[1]	Groundwater flooding[2]	River and coastal flooding[3]	Surface water flooding[4]	Shrink-swell subsidence[5]
Significant	0 (0%)	18 (29%)	36 (58%)	9 (15%)	10 (16%)
Moderate	0 (0%) - 1 (0%)	102 (40%)	149 (59%)	46 (18%)	26 (10%)
Low	2 (0%) - 7 (0%)	961 (30%)	1290 (40%)	634 (19%)	265 (8%)
No data	4 (0%) - 8 (0%)	1506 (23%)	1859 (28%)	642 (10%)	540 (8%)

Notes: Percentages are calculated as a proportion of the total number of assets per criticality category. Less than half of the data that the EA has provided includes dry weather flow rates. If zero has been entered as the dry weather flow rate, 'no data' has been assumed.

[1]Range of exposure dependent upon time period, scenario and policy

[2]High susceptibility of groundwater flooding, estimated as 1 in 200 years or more frequent.

[3]Present day flooding from rivers or the sea under any likelihood category.

[4]Mid-depth (0.3m<= depth <1.2m; 1 in 1000 year likelihood)

[5]High susceptibility category to shrink-swell subsidence.

Coastal erosion

The indicator assesses the number and proportion of WWTW located within locations that are projected to be exposed to coastal erosion over the next 100 years and the number and proportion of assets at risk behind Shoreline Management Plan policies.

Table 4.172 shows the results of the exposure analysis. There are hardly any WWTW that are likely to be affected by coastal erosion, from a national perspective. The National Coastal Erosion Risk Map (NCERM) is unsuitable for analysis at the local scale as it was designed for national planning purposes in mind. There may be a small number of individual assets that are at risk from coastal erosion either now or in the future.

Table 4.172: Number (and proportion) of WWTW located in areas that are at risk from coastal erosion in the short, medium and long-term, by UKCP09 administrative region

	Short term				Medium term				Long term			
Region	L	M	S	ND	L	M	S	ND	L	M	S	ND
East Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
East of England	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
London	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North East	0 (0%)	0 (0%)	0 (0%)	2 (0%)	2 (1%)	0 (0%)	1 (33%)	2 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (0%)
North West	0 (0%)	0 (0%)	0 (0%)	1 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0%)
South East	0 (0%)	1 (2%)	0 (0%)	2 (0%)	1 (0%)	1 (2%)	0 (0%)	3 (0%)	0 (0%)	1 (2%)	0 (0%)	2 (0%)
South West	2 (0%)	0 (0%)	0 (0%)	0 (0%)	3 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (0%)	0 (0%)	0 (0%)	0 (0%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	0 (0%)	0 (0%)	0 (0%)	1 (0%)	1 (0%)	0 (0%)	0 (0%)	3 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0%)
Total	**2 (0%)**	**1 (0%)**	**0 (0%)**	**6 (0%)**	**7 (0%)**	**1 (0%)**	**1 (2%)**	**9 (0%)**	**2 (0%)**	**1 (0%)**	**0 (0%)**	**6 (0%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Up to 5 WWTW in England may be located in areas that are exposed to coastal erosion under the Shoreline Management Plan scenario where the policy is no active intervention or managed realignment.

Flooding (groundwater)

This indicator assesses the number and proportion of WWTW located in areas that are also of high susceptibility to groundwater flooding. This assessment shows that ~26% of all WWTW are located in areas susceptible to this hazard. Groundwater treatment sites need to be located in the lowest place in their catchment area and close to an outlet location. These areas are likely to have higher groundwater levels, so these results are to be expected.

The results of the exposure analysis are shown in Table 4.173.

Table 4.173: Number (and proportion) of WWTW located in areas that are of high susceptibility to groundwater flooding, by UKCP09 administrative region

Region	Low	Moderate	Significant	No data	Total
East Midlands	193 (36%)	25 (56%)	2 (33%)	175 (24%)	395 (30%)
East of England	140 (28%)	8 (28%)	3 (43%)	194 (21%)	345 (23%)
London	0 (0%)	0 (0%)	0 (0%)	8 (42%)	8 (22%)
North East	63 (30%)	5 (21%)	0 (0%)	83 (20%)	151 (23%)
North West	20 (38%)	0 (0%)	1 (20%)	236 (26%)	257 (27%)
South East	119 (34%)	18 (37%)	5 (50%)	236 (26%)	378 (29%)
South West	205 (27%)	17 (44%)	3 (38%)	252 (21%)	477 (24%)
West Midlands	142 (29%)	17 (59%)	3 (30%)	133 (25%)	295 (28%)
Yorkshire & Humberside	79 (22%)	12 (48%)	1 (17%)	189 (21%)	281 (22%)
Total	**961 (30%)**	**102 (40%)**	**18 (29%)**	**1506 (23%)**	**2587 (26%)**

Notes: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Flooding (river and coastal)

This indicator quantifies the number and proportion of WWTW within the floodplain by flood likelihood category and takes into account the presence, performance and condition of publicly owned and maintained raised flood defences but not of private local flood defence or resilience measures. The results of the exposure analysis for any likelihood category of flooding from rivers or the sea are shown in Table 4.174.

Table 4.174: Number (and proportion) of WWTW located in areas that are currently at any likelihood category of flooding from rivers or the sea, by UKCP09 administrative region

Region	Low	Moderate	Significant	No Data
East Midlands	231 (43%)	28 (62%)	5 (83%)	237 (32%)
East of England	196 (39%)	14 (48%)	4 (57%)	217 (23%)
London	0 (0%)	9 (82%)	2 (29%)	7 (37%)
North East	89 (43%)	9 (38%)	2 (67%)	110 (27%)
North West	24 (45%)	1 (50%)	4 (80%)	373 (41%)
South East England	143 (41%)	39 (80%)	7 (70%)	211 (23%)
South West England	268 (35%)	14 (36%)	4 (50%)	275 (23%)
West Midlands	168 (34%)	19 (66%)	2 (20%)	103 (19%)
Yorkshire & Humberside	171 (48%)	16 (64%)	6 (100%)	326 (37%)
Total	**1290 (40%)**	**149 (59%)**	**36 (58%)**	**1859 (28%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

The results of the exposure analysis for high likelihood of flooding from rivers or the sea are shown in Table 4.175.

Table 4.175: Number (and proportion) of WWTW located in areas that are currently at high likelihood of flooding from rivers or the sea, by UKCP09 administrative region

	Current (2011-2012)				
Region	Low	Moderate	Significant	No Data	All
East Midlands	106 (20%)	11 (24%)	3 (50%)	60 (8%)	180 (14%)
East of England	106 (21%)	4 (14%)	2 (29%)	76 (8%)	188 (13%)
London	0 (0%)	0 (0%)	1 (14%)	4 (21%)	5 (14%)
North East	40 (19%)	1 (4%)	2 (67%)	34 (8%)	77 (12%)
North West	18 (34%)	0 (0%)	1 (20%)	201 (22%)	220 (23%)
South East	80 (23%)	18 (37%)	3 (30%)	68 (7%)	169 (13%)
South West	145 (19%)	8 (21%)	1 (13%)	117 (10%)	271 (13%)
West Midlands	67 (14%)	10 (34%)	1 (10%)	33 (6%)	111 (10%)
Yorkshire & Humberside	74 (21%)	5 (20%)	4 (67%)	104 (12%)	187 (15%)
Total	**636 (20%)**	**57 (23%)**	**18 (29%)**	**697 (11%)**	**1408 (14%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

As per the results of the analysis for exposure to groundwater flooding, a high proportion of WWTW are exposed to flooding from rivers or the sea due to the necessity that they are positioned in lower lying areas of catchments, near to suitable outlet locations. Exposure to this hazard is relatively evenly spread across regions. A higher proportion of significant (large) WWTW are located in areas with this hazard. The projected change in the number and proportion of WWTW potentially exposed to flooding from rivers or the sea is shown in Table 4.176 and Table 4.177. The potential increases in exposure are high, particularly in London, the East Midlands, North East and Yorkshire & Humberside.

Flooding (surface water)

This indicator quantifies the number and proportion of WWTW located in areas susceptible to surface water flooding in a 1:30 year, 1:100 year and 1:1000 year rainfall event for depths of between 0.3m and 1.2m and for depths greater than 1.2m. The results of the exposure analysis are shown in Table 4.178 and Table 4.179. The number of assets exposed to this hazard is generally fairly low except for a couple of cases, particularly in the south and east of England for mid-depth flooding.

Table 4.176: Number (and proportion) of WWTW located in areas that are projected to be at high likelihood of flooding from rivers or the sea, in the 2020s and 2050s, by UKCP09 administrative region

	2020s					2050s				
	Medium p50					Medium p50				
Region	**L**	**M**	**S**	**ND**		**L**	**M**	**S**	**ND**	
East Midlands	126 (24%)	13 (29%)	3 (50%)	74 (10%)	216 (16%)	136 (25%)	17 (38%)	3 (50%)	92 (12%)	248 (19%)
East of England	109 (21%)	4 (14%)	2 (29%)	79 (8%)	194 (13%)	112 (22%)	4 (14%)	2 (29%)	81 (9%)	199 (13%)
London	0 (0%)	0 (0%)	1 (14%)	4 (21%)	5 (14%)	0 (0%)	0 (0%)	1 (14%)	4 (21%)	5 (14%)
North East	50 (24%)	3 (13%)	2 (67%)	50 (12%)	105 (16%)	52 (25%)	3 (13%)	2 (67%)	51 (12%)	108 (17%)
North West	19 (36%)	0 (0%)	3 (60%)	214 (24%)	236 (25%)	19 (36%)	0 (0%)	3 (60%)	215 (24%)	237 (25%)
South East	82 (23%)	19 (39%)	3 (30%)	74 (8%)	178 (13%)	86 (25%)	19 (39%)	3 (30%)	77 (8%)	185 (14%)
South West	163 (22%)	10 (26%)	2 (25%)	137 (11%)	312 (15%)	167 (22%)	10 (26%)	2 (25%)	146 (12%)	325 (16%)
West Midlands	87 (18%)	12 (41%)	1 (10%)	40 (7%)	140 (13%)	87 (18%)	12 (41%)	2 (20%)	40 (7%)	141 (13%)
Yorkshire & Humberside	88 (25%)	11 (44%)	4 (67%)	155 (18%)	258 (20%)	96 (27%)	12 (48%)	4 (67%)	165 (19%)	277 (22%)
Total	**724 (22%)**	**72 (28%)**	**21 (34%)**	**827 (13%)**	**1644 (16%)**	**755 (23%)**	**77 (30%)**	**22 (35%)**	**871 (13%)**	**1725 (17%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.177: Number (and proportion) of WWTW located in areas that are projected to be at high likelihood of flooding from rivers or the sea, in the 2080s, by UKCP09 administrative region

	2080s				
	Low p10 - High p90				
Region	**Low**	**Moderate**	**Significant**	**No Data**	**All**
East Midlands	125 (23%) - 222 (42%)	13 (29%) - 27 (60%)	3 (50%) - 5 (83%)	79 (11%) - 228 (31%)	220 (17%) - 482 (36%)
East of England	108 (21%) - 189 (37%)	4 (14%) - 14 (48%)	2 (29%) - 4 (57%)	78 (8%) - 205 (22%)	192 (13%) - 412 (28%)
London	0 (0%) - 0 (0%)	0 (0%) - 9 (82%)	1 (14%) - 2 (29%)	4 (21%) - 7 (37%)	5 (14%) - 18 (49%)
North East	49 (24%) - 89 (43%)	3 (13%) - 9 (38%)	2 (67%) - 2 (67%)	47 (11%) - 109 (26%)	101 (16%) - 209 (32%)
North West	19 (36%) - 23 (43%)	0 (0%) - 1 (50%)	3 (60%) - 3 (60%)	213 (24%) - 360 (40%)	235 (24%) - 387 (40%)
South East	83 (24%) - 140 (40%)	19 (39%) - 39 (80%)	3 (30%) - 7 (70%)	73 (8%) - 205 (22%)	178 (13%) - 391 (30%)
South West	162 (21%) - 265 (35%)	9 (23%) - 14 (36%)	2 (25%) - 3 (38%)	133 (11%) - 270 (22%)	306 (15%) - 552 (27%)
West Midlands	69 (14%) - 129 (26%)	10 (34%) - 17 (59%)	1 (10%) - 2 (20%)	33 (6%) - 77 (14%)	113 (11%) - 225 (21%)
Yorkshire & Humberside	87 (25%) - 167 (47%)	8 (32%) - 16 (64%)	4 (67%) - 6 (100%)	140 (16%) - 324 (37%)	239 (19%) - 513 (40%)
Total	**702 (22%) - 1224 (38%)**	**66 (26%) - 146 (58%)**	**21 (34%) - 34 (55%)**	**800 (12%) - 1785 (27%)**	**1589 (16%) - 3189 (31%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.178: Number (and proportion) of WWTW located in areas susceptible to mid-depth surface water flooding, by UKCP09 administrative region and categorised by level of dry weather flow

	Mid-depth: 0.3m<= depth <1.2m 3.3% likelihood					Mid-depth: 0.3m<= depth <1.2m 0.1% likelihood				
Region	**L**	**M**	**S**	**ND**	**All**	**L**	**M**	**S**	**ND**	**All**
East Midlands	51 (10%)	6 (13%)	0 (0%)	31 (4%)	88 (7%)	141 (26%)	10 (22%)	1 (17%)	95 (13%)	247 (19%)
East of England	64 (13%)	1 (3%)	0 (0%)	27 (3%)	92 (6%)	120 (24%)	4 (14%)	0 (0%)	95 (10%)	219 (15%)
London	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (11%)	2 (5%)
North East	16 (8%)	0 (0%)	0 (0%)	12 (3%)	28 (4%)	37 (18%)	3 (13%)	0 (0%)	30 (7%)	70 (11%)
North West	5 (9%)	0 (0%)	0 (0%)	71 (8%)	76 (8%)	5 (9%)	0 (0%)	1 (20%)	130 (14%)	136 (14%)
South East England	37 (11%)	6 (12%)	0 (0%)	27 (3%)	70 (5%)	79 (23%)	14 (29%)	3 (30%)	89 (10%)	185 (14%)
South West England	65 (9%)	1 (3%)	0 (0%)	29 (2%)	95 (5%)	124 (16%)	6 (15%)	2 (25%)	90 (7%)	222 (11%)
West Midlands	39 (8%)	5 (17%)	0 (0%)	15 (3%)	59 (6%)	88 (18%)	6 (21%)	2 (20%)	37 (7%)	133 (12%)
Yorkshire & Humberside	20 (6%)	1 (4%)	0 (0%)	30 (3%)	51 (4%)	40 (11%)	3 (12%)	0 (0%)	74 (8%)	117 (9%)
Total	**297 (9%)**	**20 (8%)**	**0 (0%)**	**242 (4%)**	**559 (6%)**	**634 (19%)**	**46 (18%)**	**9 (15%)**	**642 (10%)**	**1331 (13%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.179: Number (and proportion) of WWTW located in areas susceptible to very deep surface water flooding, by UKCP09 administrative region and categorised by level of dry weather flow

	Very deep: Depth >1.2m 3.3% likelihood					Very deep: Depth >1.2m 0.1% likelihood				
Region	**L**	**M**	**S**	**ND**	**All**	**L**	**M**	**S**	**ND**	**All**
East Midlands	9 (2%)	0 (0%)	0 (0%)	1 (0%)	10 (1%)	29 (5%)	2 (4%)	0 (0%)	15 (2%)	46 (3%)
East of England	2 (0%)	1 (3%)	0 (0%)	3 (0%)	6 (0%)	28 (6%)	3 (10%)	1 (14%)	22 (2%)	53 (4%)
London	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (29%)	0 (0%)	0 (0%)
North East	1 (0%)	0 (0%)	0 (0%)	1 (0%)	2 (0%)	7 (3%)	1 (4%)	3 (100%)	10 (2%)	18 (3%)
North West	0 (0%)	0 (0%)	0 (0%)	4 (0%)	4 (0%)	5 (9%)	0 (0%)	4 (80%)	44 (5%)	49 (5%)
South East England	8 (2%)	0 (0%)	0 (0%)	4 (0%)	12 (1%)	25 (7%)	2 (4%)	5 (50%)	16 (2%)	43 (3%)
South West England	6 (1%)	0 (0%)	0 (0%)	6 (0%)	12 (1%)	42 (6%)	1 (3%)	6 (75%)	35 (3%)	78 (4%)
West Midlands	5 (1%)	0 (0%)	0 (0%)	2 (0%)	7 (1%)	21 (4%)	4 (14%)	7 (70%)	9 (2%)	34 (3%)
Yorkshire & Humberside	0 (0%)	0 (0%)	0 (0%)	2 (0%)	2 (0%)	15 (4%)	0 (0%)	8 (133%)	19 (2%)	34 (3%)
Total	**31 (1%)**	**1 (0%)**	**0 (0%)**	**23 (0%)**	**55 (1%)**	**172 (5%)**	**13 (5%)**	**9 (15%)**	**170 (3%)**	**355 (4%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Shrink-swell subsidence

This indicator quantifies the number and proportion of WWTW located in areas of high susceptibility to shrink-swell subsidence where ground conditions are of predominantly high or very high plasticity.

Table 4.180: Number (and proportion) of WWTW located in area of high susceptibility to shrink-swell subsidence, by UKCP09 administrative region

Region	Low	Moderate	Significant	No Data
East Midlands	27 (5%)	0 (0%)	0 (0%)	29 (4%)
East of England	118 (23%)	14 (48%)	4 (57%)	239 (25%)
London	0 (0%)	1 (9%)	1 (14%)	11 (58%)
North East	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North West	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South East England	72 (21%)	7 (14%)	3 (30%)	173 (19%)
South West England	33 (4%)	3 (8%)	2 (25%)	56 (5%)
West Midlands	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Yorkshire & Humberside	15 (4%)	1 (4%)	0 (0%)	32 (4%)
Total	**265 (8%)**	**26 (10%)**	**10 (16%)**	**540 (8%)**

Source: Percentages are calculated as a proportion of the total number of assets per criticality category, per UKCP09 administrative region.

Table 4.180 shows the strong regional signal in the results of the exposure analysis that is expected. The highest proportion of WWTW located in areas of high susceptibility to shrink-swell subsidence are located in those regions with clay soil types. There is a larger proportion of significant WWTW exposed which appears to be driven by the exposure found in the East of England.

5. Glossary

Adaptation

Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploit beneficial opportunities (IPCC, 2007).

Climate

The climate can be described simply as the 'average weather', typically taken over a period of 30 years. More rigorously, it is the statistical description of variables such as temperature, rainfall, snow cover, or any other property of the climate system (ASC, 2011).

Exposure

Subjection to a hazard which has the potential to cause harm (although exposure may not necessarily lead to harm). One facet of vulnerability, see below.

Indicator

A measurable parameter that shows state or condition.

- Indicators of risk - These measure changes in the exposure and vulnerability of the sector to the weather or other related hazard;
- Indicators of adaptation action - These aim to measure the extent of actions to reduce risks from climate change;
- Indicators of climate impacts - These track the realised impacts of weather on the economy, society and environment.

Hazard

A situation or event with the potential to cause harm. A hazard does not necessarily cause harm. (Willows and Connell, 2003).

Impact

An effect of climate change or a weather-event on the socio-bio-physical system (e.g. flooding, rails buckling etc.).

Likelihood

The chance of an event or outcome occurring, usually expressed as a probability (CCRA, 2012).

Risk

Combines the likelihood an event will occur with the magnitude of its outcome. The magnitude of risk is often evaluated in social, economic or environmental terms, e.g. the costs of damage, number of people affected or areas of land affected by a specific climate effect. (CCRA, 2012.)

Scenario

A coherent, internally consistent and plausible description of a possible future state of the world, usually based on specific assumptions. (Willows and Connell, 2003.)

UKCP09

The UK Climate Projections (UKCP09) provide probabilistic projections of climate change for the Low, Medium and High emissions scenarios and for seven overlapping time periods. Rather than being used as an indicator of the likelihood of particular outcomes, these projections should be interpreted as plausible scenarios illustrating a range of possible changes. (CCRA, 2012.)

Vulnerability

The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. (IPCC, 2007.)

Weather

Refers to the state of the atmosphere, across space and time, with regard to temperature, cloudiness, rainfall, wind, and other meteorological conditions (ASC, 2011).

6. References

ASC (2011) Adapting to climate change in the UK: Measuring progress. Adaptation Sub-Committee, Progress Report 2011.

BGS (2014) Shrink-swell. Online: http://www.bgs.ac.uk/products/geosure/shrink_swell.html [Accessed: 21/01/2014].

CCRA (2012) *CCRA Evidence Report*. UK 2012 Climate Change Risk Assessment, Defra, London.

ESI (2014) User Guide ESI Groundwater Flood Risk Map 1.0. ESI International. ESI Groundwater Flood Risk Map of England and Wales © http://esinternational.com/

Gao, J. (2012) Pier scour in clear water for sediment mixtures. Journal of Hydraulic Research, Vol 51,No 1, 18-27.

Harrison, A M, Plim, J F M, Harrison, M, Jones, L D, and Culshaw, M G. (2012) The relationship between shrink–swell occurrence and climate in south-east England. *Proceedings of the Geologists' Association*, Vol. 123, 556–575.

IPCC (2007) Climate change 2007: Impacts, adaptation and vulnerability Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (ed by Parry, M., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E., Cambridge University Press, Cambridge. pp976.

Lagasse, P.F., Clopper, P.E., Zevenbergen, L.W., Girard, L.G. (2007) Countermeasures to protect bridge piers from scour. National Cooperative Highway Research program. Report 593.

McColl, L., Betts, R. and Angelini, T. (2012) *CCRA Risk Assessment for the Energy Sector*. UK 2012 Climate Change Risk Assessment, Defra, London.

Reeves, H. (2013) *Personal communication*, email. “CCC Infrastructure Resilience Data record summary”. 16 December 2013.

Thornes, J., Rennie, M., Marsden, H. and Chapman, L. (2012) *CCRA Risk Assessment for the Transport Sector.* UK 2012 Climate Change Risk Assessment, Defra, London.

Willows, R.I. and Connell, R.K. (Eds.). (2003). Climate adaptation: Risk, uncertainty and decision-making. UKCIP Technical Report. UKCIP, Oxford.

Appendices

A. Results summary

Table A.1: Results of our analysis are summarised. Where the results did not produce a result greater than zero, this is stated, but these results are not provided in the main sections of this report

ID	Sub-sector	Asset/infrastructure type	Hazard	Results
256	Education	Schools	Coastal erosion	See main text
259			Flooding (groundwater)	See main text
254			Flooding (river and coastal)	See main text
255			Flooding (surface water)	See main text
258			Natural landslides	Few coincident asset/hazard locations.
257			Shrink-swell subsidence	See main text
85	Energy	Electricity sub-stations	Coastal erosion	See main text
230			Flooding (groundwater)	See main text
1			Flooding (river and coastal)	See main text
49			Flooding (surface water)	See main text
229			Natural landslides	See main text
154			Shrink-swell subsidence	See main text
88		Power stations	Coastal erosion	No coincident asset/hazard locations
233			Flooding (groundwater)	See main text
3			Flooding (river and coastal)	See main text
50			Flooding (surface water)	See main text
156			Shrink-swell subsidence	See main text
89		Towers	Coastal erosion	See main text
232			Natural landslides	See main text
231			Shrink-swell subsidence	See main text
236		Turbines	Coastal erosion	Few coincident asset/hazard locations.
235			Flooding (groundwater)	Few coincident asset/hazard locations.
234			Flooding (river and coastal)	See main text
238			Natural landslides	Few coincident asset/hazard locations.
237			Shrink-swell subsidence	See main text
90		Underground electricity transmission cable	Coastal erosion	See main text
157			Shrink-swell subsidence	See main text
86		Underground gas pipes	Coastal erosion	Few coincident asset/hazard locations.

ID	Sub-sector	Asset/infrastructure type	Hazard	Results
158			Shrink-swell subsidence	See main text
91	Health	Care homes	Coastal erosion	No coincident asset/hazard locations
253			Flooding (groundwater)	See main text
4			Flooding (river and coastal)	See main text
52			Flooding (surface water)	See main text
252			Natural landslides	See main text
159			Shrink-swell subsidence	See main text
92		Emergency Services	Coastal erosion	Few coincident asset/hazard locations.
246			Flooding (groundwater)	See main text
5			Flooding (river and coastal)	See main text
53			Flooding (surface water)	See main text
160			Shrink-swell subsidence	See main text
249		GP surgeries	Coastal erosion	See main text
251			Flooding (groundwater)	See main text
247			Flooding (river and coastal)	See main text
248			Flooding (surface water)	See main text
250			Shrink-swell subsidence	See main text
93		Hospitals	Coastal erosion	Few coincident asset/hazard locations.
245			Flooding (groundwater)	See main text
6			Flooding (river and coastal)	See main text
54			Flooding (surface water)	See main text
161			Shrink-swell subsidence	See main text
94	ICT	Data centres	Coastal erosion	No coincident asset/hazard locations
243			Flooding (groundwater)	See main text
7			Flooding (river and coastal)	See main text
55			Flooding (surface water)	See main text
267			Natural landslides	No coincident asset/hazard locations
162			Shrink-swell subsidence	See main text
96		Telecommunications masts	Coastal erosion	See main text
244			Natural landslides	Few coincident asset/hazard locations.
164			Shrink-swell subsidence	See main text
99	Transport	Railway line	Coastal erosion	Few coincident asset/hazard locations.
261			Flooding (groundwater)	See main text

ID	Sub-sector	Asset/infrastructure type	Hazard	Results
12			Flooding (river and coastal)	See main text
60			Flooding (surface water)	See main text
260			Natural landslides	See main text
167			Shrink-swell subsidence	See main text
100		Railway stations	Coastal erosion	See main text
263			Flooding (groundwater)	See main text
13			Flooding (river and coastal)	See main text
61			Flooding (surface water)	See main text
262			Natural landslides	See main text
168			Shrink-swell subsidence	See main text
101		Road	Coastal erosion	See main text
265			Flooding (groundwater)	See main text
14			Flooding (river and coastal)	See main text
62			Flooding (surface water)	See main text
264			Natural landslides	See main text
169			Shrink-swell subsidence	See main text
146/147		Rail/Road bridges	River bridge scour	See main text
268/269			Shrink-swell subsidence	See main text
102	Water	Clean water treatment sites	Coastal erosion	See main text
242			Flooding (groundwater)	See main text
15			Flooding (river and coastal)	See main text
63			Flooding (surface water)	See main text
170			Shrink-swell subsidence	See main text
103		Wastewater treatment sites	Coastal erosion	See main text
266			Flooding (groundwater)	See main text
16			Flooding (river and coastal)	See main text
64			Flooding (surface water)	See main text
171			Shrink-swell subsidence	See main text

Notes: The ID numbers are for ASC internal use only and reference the indicators that were brought forward for assessment from the original list of indicators developed for this assessment.

B. Relevant results from the CCRA

During the development of the indicators for this work, two indicators, related to heat stress on railway lines and overhead power cables were not taken forward for analysis. This decision was taken because it was deemed that the CCRA provided as much information as was currently possible using publicly available data and information.

An abridged version of the text presented in the CCRA by McColl *et al.* (2012) and Thornes *et al.* (2012) is shown below. More information is available, including details on the assumptions made, uncertainties, economic impacts and adaptive capacity, in the relevant sector reports, by McColl *et al.* (2012) and Thornes *et al.* (2012) and the main Evidence Report for the CCRA (HR Wallingford, 2012), see: http://ccra.hrwallingford.com/

B.1. Transmission capacity losses - McColl *et al.* (2012)

The capacity of the electricity networks (both transmission and distribution) refers to the amount of electricity that is transferred through the networks. This depends on a number of factors including demand. Network design takes account of normal load growth, which has historically been around 1.5 to 2% per annum. Increases in temperature are expected to reduce the capacity of the electricity networks since in high temperatures certain types of equipment must be "de-rated" (i.e. the amount of current carried must be reduced).

Although this historical level may reduce due to economic and energy efficiency pressures, load on the network is expected to double over the next forty years due to the electrification of the transport and heating systems (ENA, 2011).

The capacity is also affected by climate factors; specifically the effects of temperature. Equipment is heated by the electrical current which passes through it. The total amount of current that can be passed through (or the total current rating) is defined by the equipment's maximum permissible operating temperature (which varies depending on the materials used in the equipment's conductor/insulation material). The three types of equipment considered in this impact are:

1. Overhead line conductors: as temperature increases, thermal expansion results in increasing sag of overhead line conductors (there is a statutory ground clearance for sag).
2. Underground cables: soil temperature and air temperature are directly related; any increases in soil temperature reduce the soil's ability to conduct heat away from the cables.
3. Power transformers: the load capability of a transformer depends on a maximum temperature above which there is the potential for damage and an electrical fault. If temperature increases then the amount of current passed through the transformer must be reduced.

The transmission capacity metric is the capacity losses (%) that occur due to temperature increases and relates to overhead line conductors, underground cables and power transformers. In all these cases, the amount of current passing through the equipment must be reduced ("de-rated") as air temperature increases to ensure it does not exceed its maximum permissible operating temperature. This maximum temperature varies depending on the piece of equipment and the impact of increased temperatures also varies (for overhead lines it increase their sag, but for power transformers it can cause electrical faults).

The functions have been derived in work by Met Office (2008) and ENA (2011) and are listed in Table B.1

Table B.1: Response function for overhead line conductors, underground cables and power transformers relating the reduced current capacity with an increase of 1°C in temperature

Equipment	Type	Season	Existing Current Rating	Maximum Temperature (°C)	Current Reduction (per 1°C)
Overhead line conductors	Distribution: 25mm2 Cu 100mm2 Cu 175mm2 Lynx	Summer	126 Amps 316 Amps 342 Amps	50 50 50	1.6%
	Transmission: 400mm2 Zebra	Winter	1,230 Amps	75	0.81%
	Transmission: 500mm2 Zebra	Winter	1,600 Amps	90	0.63%
Underground cables	LV	Summer	335 Amps	80	0.60%
	11kV	Summer	270 Amps	65	0.79%
	33kV	Summer	355 Amps	65	0.78%
	132kV	Summer	755 Amps	85	0.56%
	400kV	Summer	1,052 Amps	85	0.99%
Power transformers	11kV	Summer	-	-	1%
	33 – 132kV	Summer	-	-	0.7%

Source: McColl et al. (2012)

UKCP09 future projections of daily maximum temperature for both summer and winter are used to scale the response functions to produce future projections of capacity losses. The projections are obtained for all 16 administrative regions and the minimum and maximum capacity losses reported. To explore the uncertainty associated with the results, UKCP09 projections with different emissions scenarios, time periods and probability levels are applied.

The baseline period for the projections is 1961-1990 (which is the UKCP09 baseline). In this analysis it is assumed that the baseline standard of the equipment examined is maintained to EU and international design standards.

Results for projections of future capacity losses relative to the existing current rating of each type of equipment are provided in Table B.1; the key conclusions from this table are summarised in the bullet points below:

- Overhead line conductors on the distribution network are the most susceptible to de-rating. The highest projections indicate capacity losses of 6.4% in the 2020s, 12% in the 2050s and 19% in the 2080s. However, there is large uncertainty associated with these projections; capacity losses in the 2080s could be as low as 1.4% (for the 10% probability level and the low emissions scenario). Considering the existing current rating, this relates to a reduction of between 2 and 25 Amps in the 2080s per 25mm^2 copper conductor, 4 and 60 Amps per 100mm^2 copper conductor and 5 and 65 Amps per 175mm^2 lynx conductor.
- Projections for the overhead line conductors on the transmission network are similar for both types (400 and 500 Zebra). In both cases the capacity losses are unlikely to be greater than 2% in the 2020s and

2050s and are unlikely to be greater than 5% in the 2080s. This relates to a reduction of no more than 62 Amps and 80 Amps in the 2080s per 400mm^2 and 500mm^2 zebra conductor respectively.

- The projected capacity losses for underground cables do not vary substantially for the different voltages. The central estimates for the medium emissions scenario in the 2020s is between approximately 1.5% and 2% capacity losses in for the 2050s between approximately 1.5% and 3.5%. In the 2080s capacity losses are unlikely to be greater than 12% and have a central estimate of between 2% and 5.5% for the medium emissions scenario and between 2.5% and 8% for the high emissions scenario. The existing current rating for underground cables varies from 335 Amps (low voltage) to 1,052 Amps (400kV).
- Power transformers at 11kV are at greater risk of de-rating than those at higher voltage. The UK central estimate for the medium emissions scenario for the 2050s ranges between 2.5% and 3.8% for 11kV and between 1.8% and 2.5% for 33kV or more. The highest capacity losses throughout the UK are unlikely to be greater than 12% (11kV) or 8% (33kV or more) based on a high emissions scenario.

The projections have been calculated for all administrative regions and the UK minimum and maximum value provided here. They are relative to the existing current rating of each type of equipment given in Table B.2.

Table B.2: Projected percentage capacity losses for different UKCP09 climate scenarios and electricity infrastructure (rounded to 1 significant figure)

Projection		Overhead Line Conductors						Underground Cables										Power Transformers			
		Distribution		Trans 400		Trans 500		LV		11kV		33kV		132kV		400kV		11kV		33-132kV	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
2020s	Med p10	0.5	1.0	0.2	0.4	0.2	0.3	0.3	0.5	0.2	0.5	0.2	0.5	0.2	0.3	0.3	0.6	0.3	0.6	0.2	0.4
	Med p50	2.4	3.5	1.0	1.1	0.8	0.9	1.4	2.1	1.2	1.7	1.2	1.7	0.8	1.2	1.5	2.2	1.5	2.2	1.1	1.5
	Med p90	4.5	6.4	1.6	2.0	1.3	1.6	2.7	3.8	2.2	3.2	2.2	3.2	1.6	2.2	2.8	4.0	2.8	4.0	2.0	2.8
2050s	Low p10	1.3	1.9	0.5	0.6	0.4	0.5	0.8	1.2	0.6	0.9	0.6	0.9	0.4	0.7	0.8	1.2	0.8	1.2	0.6	0.9
	Low p50	3.7	5.6	1.3	1.6	1.0	1.3	2.2	3.4	1.8	2.8	1.8	2.7	1.3	2.0	2.3	3.5	2.3	3.5	1.6	2.5
	Med p50	4.0	6.1	1.5	1.8	1.1	1.4	2.4	3.6	2.0	3.0	2.0	3.0	1.4	2.1	2.5	3.5	2.5	3.8	1.8	2.7
	High p50	5.3	6.9	1.6	2.0	1.3	1.6	3.2	4.1	2.6	3.4	2.6	3.4	1.8	2.4	3.3	1.3	3.3	4.3	2.3	3.0
	High p90	8.5	12.0	2.9	3.6	2.3	2.8	5.1	7.2	4.2	5.9	4.1	5.9	3.0	4.2	5.2	7.4	5.3	4.5	3.7	5.3
2080s	Low p10	1.4	2.1	0.8	0.9	0.6	0.7	0.9	1.2	0.7	1.0	0.7	1.0	0.5	0.7	0.9	1.3	0.9	1.3	0.6	0.9
	Low p50	4.5	6.6	1.7	2.1	1.3	1.6	2.7	3.9	2.2	3.2	2.2	3.2	1.6	2.3	2.8	4.1	2.8	4.1	2.0	2.9
	Med p50	5.9	8.6	1.9	2.4	1.4	1.9	3.6	5.2	2.9	4.3	2.9	4.2	2.1	3.0	3.7	5.3	3.7	5.4	2.6	3.8
	High p50	7.5	11.0	2.3	2.9	1.8	2.3	4.5	6.6	3.7	5.5	3.7	5.4	2.6	3.9	4.7	6.8	4.7	3.9	3.3	4.8
	High p90	13.3	19.0	4.3	5.3	3.3	4.2	8.0	11.4	6.6	9.4	6.5	9.3	4.6	6.7	8.2	11.8	8.3	11.9	5.8	8.3

Source: McColl et al. (2012)

The ENA (2011) report has also considered the risks of de-rating and included them in their risk matrix. The results for the 16 UKCP09 administrative regions for overhead line conductors on the distribution network are provided in Table B.3 for three climate scenarios in the 2050s. These projections are given to highlight the spatial variability in the results. There is little variation between the regions for the 10% probability level and low emissions scenario (the changes for all the regions range between 1% and 2%). There is greater variability for the 50% probability level, medium emissions and most for the 90% probability level, high emissions. The greatest percentage change is estimated for the South West, South East England and London and the smallest in Northern Ireland and Northern Scotland.

Table B.3: Projected percentage capacity losses for different UKCP09 climate scenarios and each administration region for overhead line conductors on the distribution network

Administration Region	2050s Low p10	2050s Med p50	2050s High p90
Channel Islands	1.64	5.45	10.86
East Midlands	1.72	5.31	10.56
East of England	1.83	5.44	10.80
Eastern Scotland	1.80	4.81	10.09
Isle of Man	1.39	4.55	9.03
London	1.89	5.91	11.81
North East England	1.58	5.15	10.17
North West England	1.61	5.23	10.37
Northern Ireland	1.27	4.30	8.56
Northern Scotland	1.41	3.98	8.47
South East England	2.00	5.95	11.8
South West England	1.92	6.10	12.05
Wales	1.69	5.37	10.65
West Midlands	1.75	5.78	11.47
Western Scotland	1.42	4.72	9.34
Yorkshire and Humberside	1.62	4.89	9.71

Source: McColl et al (2012)

It is not possible to calculate projections of future absolute current losses over the entire network, since its composition in terms of the different types of equipment is not known. However, the above results of projected capacity losses per equipment type can be considered in context of historical load growth to provide an indication of their magnitude. The networks have been subject to a load growth of approximately 1.5% to 2% per annum, therefore dealing with changes in capacity on the transmission and distribution network is not a new problem. This means that the impact of de-rating is not dissimilar to recent demand growth, which has been taken into account within the current design standards.

The ENA (2011) report states that the impact of rating reductions will vary from one circuit to another depending on how close the maximum demand on a particular circuit is to the circuit rating. For circuits of 33kV or more, when that limit is reached, the entire length of the circuit would have to be assessed, whereas for 11kV and LV circuits action on a proportion of the circuit would need to be considered. Possible actions would be to increase line height, re-conduct circuits to a higher operating temperature conductor, replace underground cables with larger cables or install additional circuits or substations to increase the capacity of the network.

This analysis is a reflection of the direct effect of temperature increases on the energy system as it is currently. However, due to current policy to move towards a low carbon economy, it is likely that the load on the network will double over the next forty years introducing new stresses on the electricity networks (for example due to the electrification of the transport system). Work undertaken by ENA and the Imperial College has found that 70% of this increase in demand could be incorporated into the existing network through the use of smart network technology, which would also respond to the impact of climate change on de-rating. This means that the use of smart network technology, although its primary function is mitigation through the transition to a low carbon economy, also provides an adaptation measure (ENA, 2011).

Adaptive capacity

Engagement with industry representatives and the regulator, and the existence of several industry-sponsored analyses of climate change risks, suggests that the energy sector has a relatively high awareness of the risks posed to the sector by climate change. However it is recognised that this varies within individual stakeholders (e.g. different energy companies, and even different sub-sections of the sector).

Adaptive capacity exists to the extent that weather sensitivities and influences are already routinely taken into account in planning in the energy sector. However, since there are often long lead times in implementing decisions (as they often require major changes such as in infrastructure), the response time of the sector may be slow in many cases, simply for practical reasons relating to the nature of the sector. Also, adaptive capacity may be constrained by other factors affecting decisions.

B.1.1. References

CCRA (2012) *CCRA Evidence Report*. UK 2012 Climate Change Risk Assessment, Defra, London.

ENA (2011) *Electricity Networks Climate Change Adaptation Report.* Adaptation Reporting Power report prepared for Defra.

McColl, L., Angelini, T. and Betts, R. (2012) *CCRA Risk Assessment for the Energy Sector.* UK 2012 Climate Change Risk Assessment, Defra, London.

Met Office (2008) *Energy Phase II project.* Details available at: http://www.metoffice.gov.uk/climatechange/businesses/casestudies/energy.html.

B.2. Rail buckling - Thornes *et al.* (2012)

Monthly frequency of rail buckling data for Great Britain has been calculated from a database of 575 rail buckling incidents for the years 1997-2009. Monthly data for 1995-1996 for 200 rail buckling incidents has also been obtained (Thornes, 1997) to give a total of 755 rail buckling incidents. Table B.4 shows the monthly rail buckling data together with the mean summer Central England air Temperature (CETsummer).

Table B.4: Rail buckling frequency and Central England air temperature

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	CETsummer
1995			1	14	60	23	37		135	17.4
1996			2	1	24	14	4		45	15.8
1997				6	2	10	19		37	16.6
1998				9	1	3	5		18	15.2
1999				5	9	38	5	2	59	15.9
2000				1	22	3	3		29	15.7
2001			1	15	12	19	1		48	16.1
2002	1		3	1	6	7	4		22	15.8
2003			4	10	15	56	51	1	137	17.3
2004			2	6	7	4	13		32	16.2
2005			1	2	29	22	1		55	16.2
2006			1	6	18	66			91	17.2
2007					3				3	15.2
2008				4	7	4	1		16	15.4
2009		1	1	4	15	7			28	15.8
Mean									50.3	16.1
Total									755	

Source: Thornes et al. (2012).

For the initial analysis, the annual totals have been plotted against the mean summer Central England Temperature (CET) as shown in Figure B.1. As can be seen there is an excellent agreement with a high degree of correlation, suggesting that up to 82% of the variations in annual rail buckling in Great Britain are due to variations in summer temperature.

Obviously, the actual track temperature that causes a rail to buckle will be much higher (40 to 50+ degrees Celsius) but there is no data available on rail track temperatures. For a discussion of the relationship between air and rail temperatures see Chapman *et al.*, 2008.

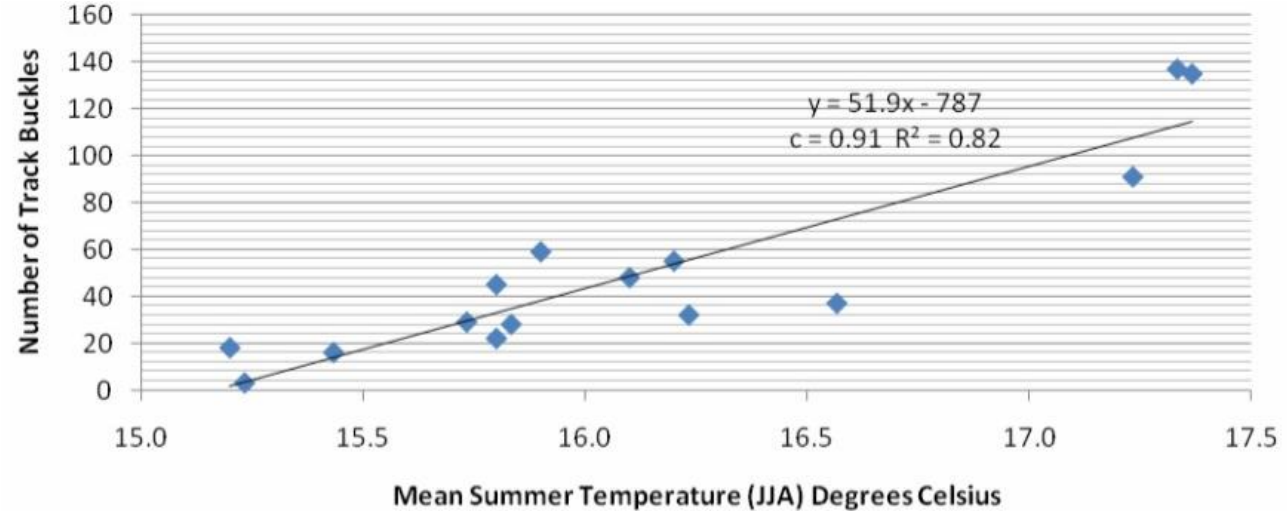

Figure B.1: Correlation between rail buckling and temperature

Source: Thornes et al. (2012)

The database supplied by Network Rail also provides the location for each of the rail buckling incidents for 1997-2009 (although location data is not available for 1995 and 1996 data). Where possible, incidents since 1997 have been classified as by UKCP09 administrative region. Table B.5 shows the distribution of rail buckles for 11 regions for which data was available. From this short period of data the impact of heat wave is clear with more rail buckling events recorded in 2003 than in any other year. From this data alone it is not possible to infer any regional bias (although one would be presumed based on regional variation in UK temperature). To understand this, further data would be required on the kilometres of track in each region so that a measure of exposure to risk can be developed.

Table B.5: Regional variation in observed rail buckling frequency

	EM	EE	SC	LO	NE	NW	SE	SW	WA	WM	YH	Total
1997	5	5	0	5	2	5	3	2	0	4	6	37
1998	1	1	0	4	1	2	2	1	1	3	2	18
1999	2	3	2	9	0	10	11	3	5	6	8	59
2000	2	3	1	6	1	1	3	3	0	4	5	29
2001	2	3	3	8	0	5	7	1	1	6	12	48
2002	1	1	0	7	0	2	1	1	0	7	2	22
2003	6	8	8	31	5	15	19	12	2	21	10	137
2004	3	3	0	8	1	4	4	1	0	4	4	32
2005	5	6	2	5	3	3	7	8	2	5	9	55
2006	4	11	0	13	5	18	6	8	6	10	10	91
2007	0	0	0	0	0	3	0	0	0	0	0	3
2008	0	0	2	0	1	1	3	1	1	1	6	16
2009	1	2	2	1	7	4	1	1	1	0	8	28
Total	32	46	20	97	26	73	67	42	19	71	82	575

Source: Thornes et al. (2012). Regions – EM: East Midlands; EE: East of England; SC: Scotland; LO: London; NE: North East; NW: North West; SE: South East; SW: South West; WA: Wales; WM: West Midlands; YH: Yorkshire & Humber.

Given the identified correlation between summer temperatures and rail buckling events it is possible to project the number of rail buckles that might take place in the future using the UKCP09 scenarios. The mean summer temperatures for each region have also been calculated for 1997-2009 to provide base line temperatures and best fit equations for each region as shown in Table B.5.

The relationships are not as strong as for the CET summer temperatures discussed previously but the correlation is still high for most regions (see Thornes *et al*. 2012 for more information). As might be expected, correlations are lowest in Scotland where fewer events occur. Using these response functions projected numbers of rail buckling events for Great Britain as a whole and by region have been estimated for UKCP09 scenarios, see Figure B.2, Figure B.3 and Figure B.4.

Figure B.2: Regional projections of rail buckling – low (10% probability level climate change projections, or 'p10')

Source: Thornes et al. (2012). The numbers in the legend are the numbers of individual buckles per country/region.

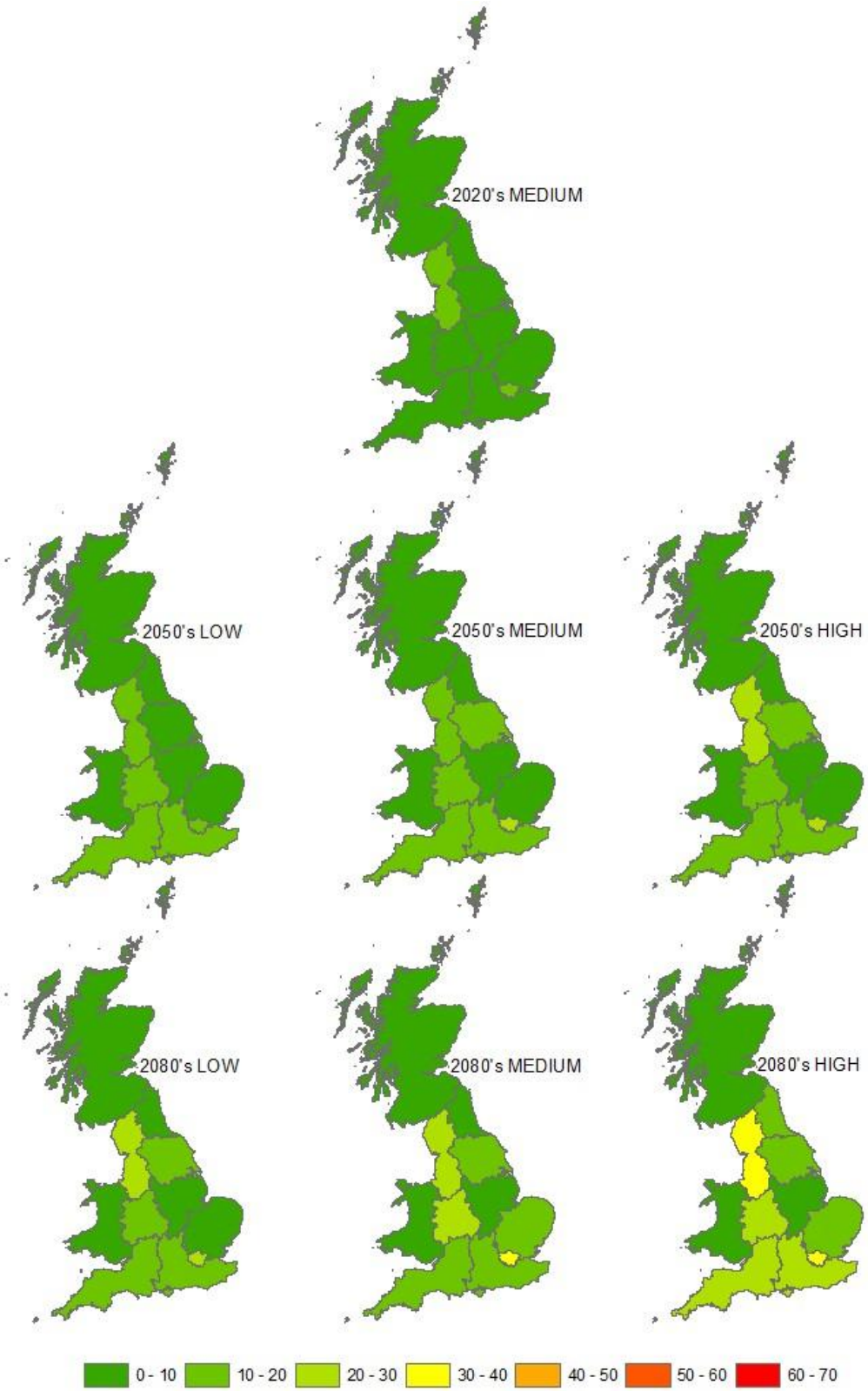

Figure B.3: Regional projections of rail buckling – medium (50% probability level climate change projections, or 'p50')

Source: Thornes et al. (2012). The numbers in the legend are the numbers of individual buckles per country/region.

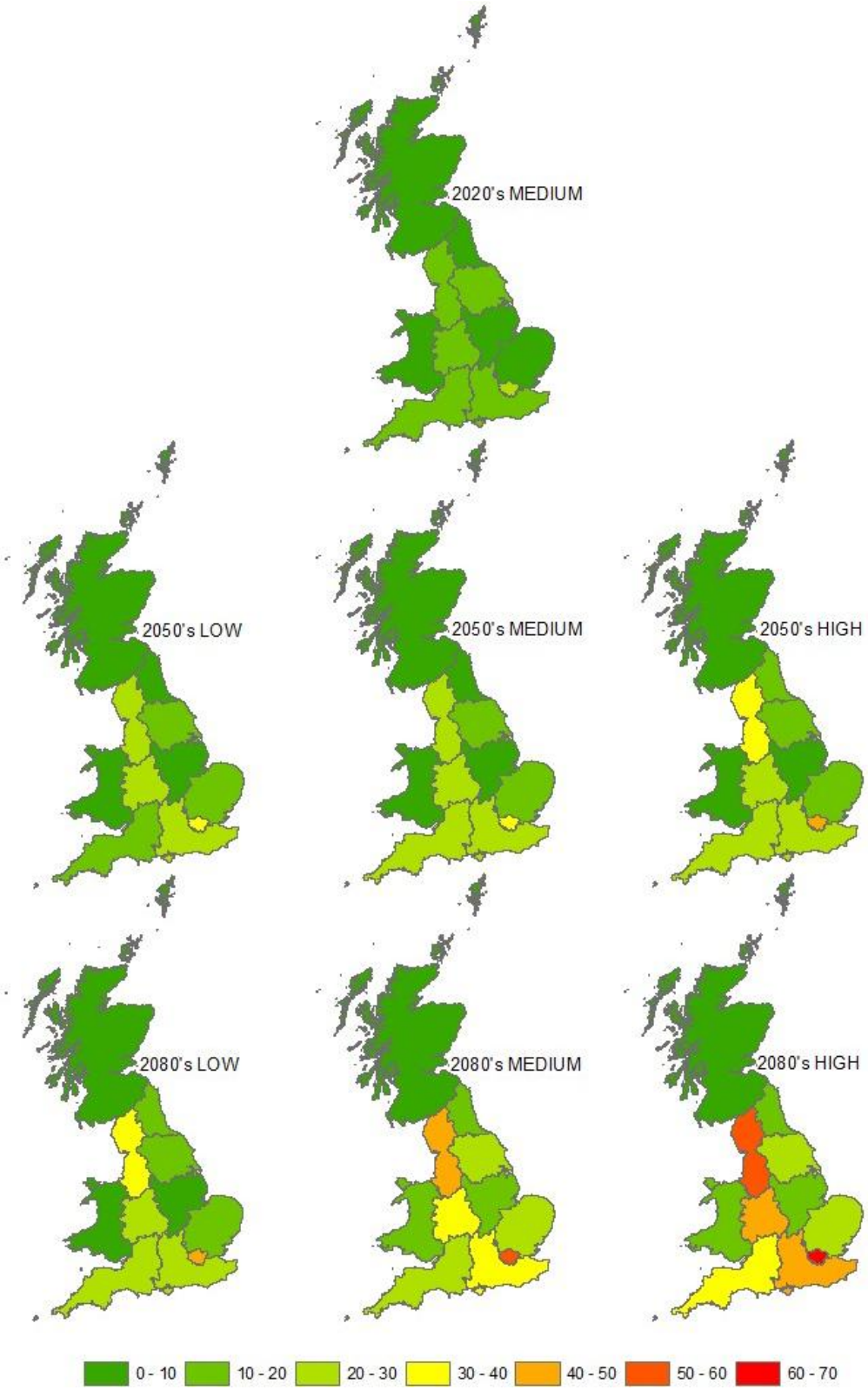

Figure B.4: Regional projections of rail buckling – high (90% probability level climate change projections, or 'p90')

Source: Thornes et al. (2012). The numbers in the legend are the numbers of individual buckles per country/region.

B.2.1. References

CCRA (2012) *CCRA Evidence Report*. UK 2012 Climate Change Risk Assessment, Defra, London.

Chapman, L., Thornes, J.E., Huang, Y., Cai, X., Sanderson, V.L. and White, S.P. (2008) Modelling of rail surface temperatures: a preliminary study, *Theor. Appl. Climatol*. 92, 121–131.

Thornes, J.E. (1997) Chapter 11. IN UEA, 1997. *Economic Impacts of the Hot Summer and Unusually Warm Year of 1995.* Report prepared at the request of the Department of Environment. Editors Palutikof, J. P., Subak, S., and Agnew, M.D. Published by the University of East Anglia, Norwich, UK. 1997. ISBN 0-902170-05-8.

Thornes, J., Rennie, M., Marsden, H. and Chapman, L. (2012) *CCRA Risk Assessment for the Transport Sector.* UK 2012 Climate Change Risk Assessment, Defra, London.

HR Wallingford
Working with water

HR Wallingford is an independent engineering and environmental hydraulics organisation. We deliver practical solutions to the complex water-related challenges faced by our international clients. A dynamic research programme underpins all that we do and keeps us at the leading edge. Our unique mix of know-how, assets and facilities includes state of the art physical modelling laboratories, a full range of numerical modelling tools and, above all, enthusiastic people with world-renowned skills and expertise.

HR Wallingford, Howbery Park, Wallingford, Oxfordshire OX10 8BA, United Kingdom
tel +44 (0)1491 835381 fax +44 (0)1491 832233 email info@hrwallingford.com
www.hrwallingford.com

Certificate No. FS 516431

Certificate No. EMS 558310