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# Standards and methods of hazard assessment for mass-movements in Great Britain

**Summary**

With less extreme topography and limited tectonic activity Great Britain experiences a different landslide regime than countries in many other parts of the world e.g. Italy and France. Glacial modification of the landscape during the Pleistocene, followed by severe periglacial conditions have led to the presence of high numbers of ancient or relict landslides. Debris flows and rock falls common to higher relief areas of Europe occur but are less likely to interfere with development and population centres. Despite the often subdued nature of landslides in Great Britain, numerous high profile events in recent years have highlighted the continued need to produce useable, applied landslide information. The British Geological Survey has developed a national landslide susceptibility map which can be used to highlight potential areas of instability. It has been possible to create the national susceptibility map (GeoSure) because of the existence of vast data archives collected by the survey such as the National Landslide Database, National Geotechnical Database and digital geological maps. This susceptibility map has been extensively used by the insurance industry and has also been adopted for a number of externally funded projects targeting specific problems.

**Keywords**

British Geological Survey, Landslides, GeoSure, National Landslide Database

## Background to landslide research and planning in Great Britain.

Prior to the 1966 Aberfan disaster, which led to the deaths of 144 people, landsliding was not widely considered to be particularly extensive or problematic in Great Britain (GB). In the years following the disaster a limited amount of research into landslide distribution and mechanisms was undertaken but failed to lead to a structured regulatory framework for managing landslide risk. The Aberfan landslide and costly disruptions to infrastructure projects in the 1960/70's (Skempton & Weeks 1976 and Early & Skempton 1972) strengthened the view that the extent of ground instability was neither well understood nor managed by developers or planners. This view led to national assessments of landslides being carried out in the 1980's and 1990's on which the current national policy is largely based. These assessments provided the basis for planning policies and guidance that to some degree continue to control development on or around unstable ground. However, limited resources since this initial push to understand the problem meant that these initiatives have failed to develop into an effective, integrated, national response to deal with landslides in GB. The current systems, which are neither centralized nor legally binding, comprises a system of planning regulations (Town and Country Panning Act 1990), guidance notes, operational regulations and building codes (Building Regulations, 2006). With the exception of the Building Regulations, none of these legal statutes specifically mention landslides. The majority of the legislation can be interpreted as placing responsibility with the developer, utility operator or landowner to ensure landslides are not an issue.

The main source of regulatory information regarding slope instability issues is contained within Planning Policy Guidance Note 14 (PPG14) and its associated Annex (Anon 1990, 1994). The Annex sets out the procedure for landslide recognition and hazard assessment and emphasises the need to consider ground instability throughout the whole development process from land-use planning, through design to construction. These documents provide recommendations that slope instability is considered in any planning decision. If landsliding is a known issue 'a developer' must provide evidence that any development activity will not exacerbate landslide activity and that any building will be safe. However, PPG14 is not legally compulsory and only recommends that the local planning authorities should endeavour to make use of any relevant expertise when assessing whether a planning application may be affected by ground instability. The guidance notes do not specifically refer to geological or geotechnical expertise but details of some information sources of are provided, including BGS data. Despite this, there is no legal compulsion for a planning authority to understand the extent or nature of landslide hazards within their area of concern and, thus, include them in planning decisions. Building regulations put further emphasis on the role of the developer to control the impact of instability requiring that *"The building shall be constructed so that ground movement caused by…. land-slip or subsidence (other than subsidence arising from shrinkage), in so far as the risk can be reasonably foreseen, will not impair the stability of any part of the building."* (Anon. 2004).

The current PPG14 predates the era of GIS and advises that citizens consult geological maps and the now defunct Department of the Environment Landslide Database. These sources of information have been superseded by the BGS's 'GeoSure' and continually updated National Landslide Database. Despite the availability of these resources national guidance has never been updated to take this into account. Despite the advances in landslide mapping and hazard mapping there is still no legal compulsion to use or consider it within a planning application in GB.

**Development of landslide susceptibility maps and databases in GB**

BGS began to map geological hazards digitally in the mid 1990's, these early steps have paved the way for the development of much more detailed hazard maps that cover the whole of Great Britain and are complimented by detailed landslide mapping and an extensive National Landslide Database (NLD).

The first systematic assessment of hazards was triggered by the insurance industry after it identified a need to better understand geological hazards. Insurance losses caused by ground movements (including subsidence) between 1989 and 1991 reached around £1-2bn following a particularly dry period and as a result, a digital geohazard information system (GHASP – GeoHAzard Susceptibility Package) was developed by the BGS. This first decision support system (DSS) gave a weighted averaged result for each of the 10000 postcode sectors in GB and came to be used by around 35% of the Industry (Culshaw & Kelk, 1994). Since the development of GHASP, improvements in GIS technology and the availability of digital topographical and geological mapping for 98% of GB have led to advances in the methods used to map geohazard potential.

The BGS has since developed a Geographical Information System (GIS)-based system (GeoSure) to assess the principal geological hazards across the country (Foster *et al*. 2008, Walsby 2007, 2008). One output is a GIS layer that provides ratings of the susceptibility of the country to landsliding on a rating scale of A (low or nil) to E (significant), which has been simplified for Figure 1. Importantly, a high susceptibility score does not necessarily mean that a landslide has happened in the past or will do so in the future, but where a landslide hazard is most likely to occur if the slope conditions are adversely altered by a change in one or more of the factors controlling slope instability (Figure 1). GeoSure is produced at 1:50 000 scale and can be integrated to show the spatial distribution of landslide susceptibility in relation to buildings and infrastructure. According to the dataset, 350 000 households in the UK, representing 1% of all housing stock, are in areas considered to have a 'significant' landslide susceptibility (Rated E).

GeoSure works by modelling the causative factors of landsliding: lithology, slope angle and discontinuities being of prime importance. This has been made possible through the use of GIS due to its ability to spatially display and manipulate data (Soeters & Van Westen, 1996). The GeoSure methodology uses a heuristic approach to assess and classify the propensity of a geological formation to fail as well as to score the relevant causative factors. The BGS holds large amounts of information about the lithological nature of the rocks and soils within Great Britain. The National Geotechnical Physical Properties database contains information on the geographical distribution of physical properties (such as strength) of a wide range of rocks and soils present in GB. This information is vitally important in determining the propensity of a material to fail. The scores assigned to each lithology are based on material strength, permeability and known susceptibility to instability. Discontinuities were assessed as an important causative factor as they reflect the mass strength of a material, its susceptibility to failure and its ability to allow water to penetrate a rock mass. Scores were defined in line with those used in the British Standard 5930: Field Description of Rocks and Soils (British Standards Institute 1990) and by Bieniawski (1989). Analysis of known landslides showed that slope angle is one of the major controlling factors and this was derived from the NEXTMap digital terrain model of Britain at a 5m resolution. The scores for all the causative factors at each grid cell are combined in an algorithm to give an overall score based on the relative susceptibility to landsliding. The method is flexible enough to allow alteration (nationally or locally) of the algorithm in the future and include other factors such as the presence and nature of superficial deposits.

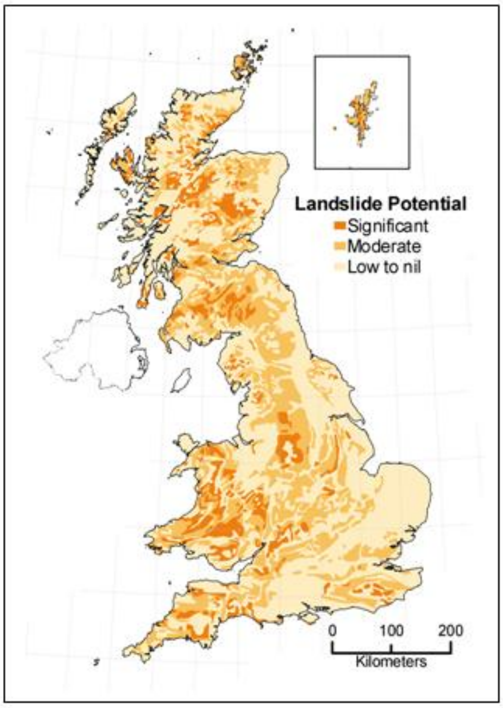


**Figure 1 GeoSure layer showing the potential for landslide hazard.**

Another important tool to both inform and assess landslide susceptibility in GB is the National Landslide Database (NLD). Landslide databases are commonplace in Europe but there is variability in their complexity and amount of further work carried out to further enhance or update the datasets. Assessing an area's susceptibility to landsliding requires knowledge of the distribution of existing failures and also an understanding of the causative factors and their spatial distribution. This type of information is only available from a detailed database of past events from which one can draw out relevant information which may inform the user of where landslides may occur in the future. The National Landslide Database is the most comprehensive source of information on recorded landslides in GB and currently holds records of over 15 000 landslide events (Figure 2). Each of the 15 000+ landslide records can hold information on over 35 attributes including location, dimensions, landslide type, trigger mechanism, damage caused, slope angle, slope aspect, material, movement date, vegetation, hydrogeology, age, development and a full bibliographic reference. A fully digital workflow has been developed at BGS to enable capture of landslide information. The first stage of the process involves using digital aerial photograph interpretation software (SocetSet) to capture digital landslide polygons which can then be altered through field checking using BGS·SIGMA mobile technology (Jordan 2009; Jordan *et al*. 2005). BGS·SIGMAmobile is the BGS digital field data capture system running on rugged tablet PCs with integrated GPS units, and is used extensively for all geological mapping activities within the British Geological Survey (Jordan *et al.*, 2008).


**Figure 2. Distribution of landslide database points from the National Landslide GIS database. OS topography © Crown Copyright. All rights reserved.**

When collecting landslide information, either for the NLD or for digital maps, internationally recognised standards have been followed where appropriate. The database dictionaries have been produced using internationally recognised terminology. For landslide type, the dictionary definitions follow the conventions set out by Varnes (1978), the EPOCH project (Flageollet, J.C., 1993) and the WP/WLI (1990). Age and activity of a landslide are important factors to record within a landslide inventory. Temporal landslide data is as important to understanding the geomorphic evolution of an area as the spatial distribution of slides. However, it is extremely difficult to date ancient landslide events with any degree of accuracy and, as such, the ages assigned to landslides only provide an arbitrary indication of age. The WP/WLI (1990) regrouped the Varnes (1978) definitions on age and activity under the following headings: 'state of activity,' 'distribution of activity' and 'style of activity.' Whilst the NLD follows the style of activity definitions, it has simplified the state of activity terms defined by Varnes (1978) into active, inactive and stabilised whilst also adding descriptions on the state of development (Advanced, degraded, incipient). Whilst activity state and style have been described in the WP/WLI definitions (WP/WLI, 1993), age has been somewhat neglected. Data for modern landslides observed either at the time of the event or through comparison of aerial photographs and geological mapping, is included in the NLD. To record cause, the NLD has incorporated both triggering and preparatory factors, limited to those most likely to be identifiable and relevant in GB. The definitions are based upon the WP/WLI (1990).

**Further adaptations of landslide susceptibility maps in Great Britain**

Following the creation of the Geosure methodology BGS has worked within a consortium including the Transport Research Laboratory (TRL) and the Scottish Executive to create a digital hazard layer specifically for debris flows. This work was triggered in August 2004 following a period of intense rainfall which led to two debris flows trapping 57 motorists on the A85 trunk road in Scotland. As a consequence of this event, and others, during the same period, the Scottish Executive commissioned a study to assess the potential impact of further debris flows on the transport network of Scotland (Winter *et al*., 2005). BGS was involved in the provision of a GIS layer highlighting slopes susceptible to debris flows. Debris flows, one of the five main types of landslide, have a specific set of preparatory criteria which differs from translational and rotational slides. This modified assessment sought to digitally capture this set of criteria and create a layer showing areas where debris flows are most likely to occur in the future. An initial study determined five main components which should be considered when determining the hazard potential of debris flows affecting the road network:

1. Availability of debris material
2. Hydrogeological conditions
3. Land Use
4. Proximity of Stream Channels
5. Slope Angle

It was considered that information regarding each of these could be extracted from existing digital datasets. The resulting interpreted data were combined to produce a working model of debris flow hazard that could be validated by comparing with known events (Figure 2). The 2004 A85 debris flow event is shown alongside the modelled susceptibility layer, existing drainage channels are shown as particularly susceptible to failure through debris flows. Whilst the assessment of debris flows highlights areas where they may occur in the future it does not attempt to model the run-out of such failures.

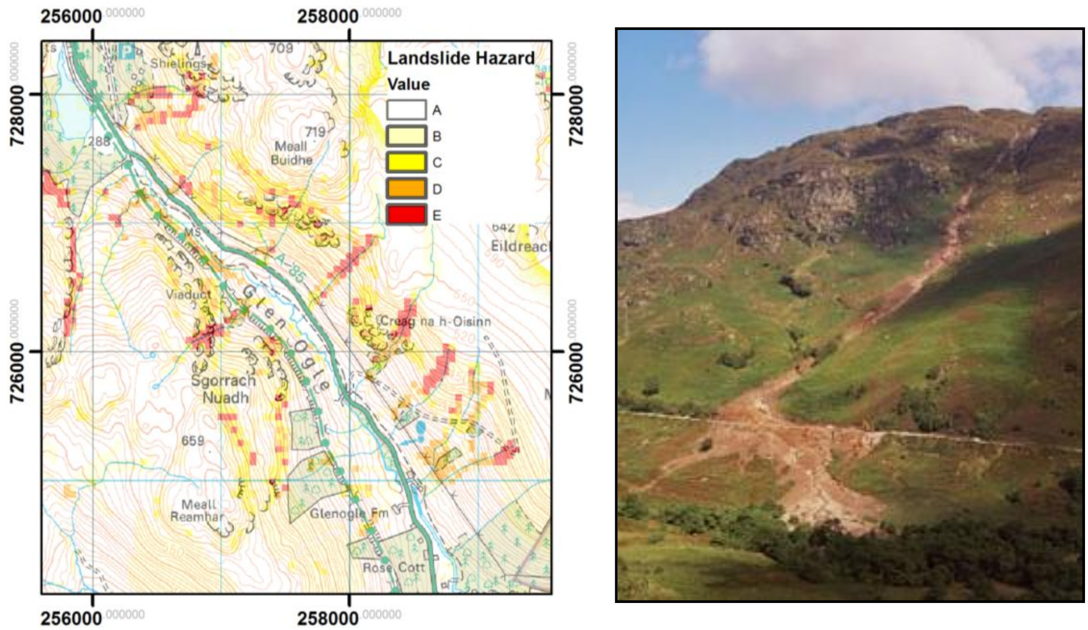


**Figure 2 a) Extract from the Debris Flow Susceptibility Layer along with b) the Glen Ogle debris flow of 2004.**

## Future Developments

Currently work is ongoing to validate the current methodology against statistical methods such as bivariate statistical analysis and probabilistic methods. The GeoSure method is based upon expert knowledge and a heuristic approach which is being tested against more statistically based approaches to assess its validity. Naranjo *et al.*, (1994) consider statistical methods to be the most appropriate method for mapping regional landslide susceptibility because the technique is objective, reproducible and easily updateable. Bivariate analysis for instance relies upon the availability of landslide occurrence and causal parameter maps, which are compared against each other to create a weighted value for each parameter determined by calculating the landslide density (Aleotti and Chowdhury, 1999 and Süzen and Doyuran, 2004). Results from an initial pilot study suggest that, in small areas, where detailed landslide mapping exists bivariate (conditional probability) and probabilistic approaches are able to more accurately predict landslide susceptibility than GeoSure. However, this approach only works where landslides have been mapped. This technique cannot be used where no landslide mapping has been undertaken. Another issue with the conditional probability technique is that it relies on the assumption that all the parameters are mutually exclusive. The value of the heuristic approach is its ability to highlight areas where there are no known landslides but where there is existing knowledge on the underlying causative factors. The heuristic approach is able to produce national scale assessments which could be refined in the future by numerical methods for smaller, regional studies.

Further adaptations to the GeoSure methodology, similar to those used to assess debris flows, are planned for the future. Rock fall hazard could be another type of mass movement that is investigated using the heuristic GeoSure approach applying different causal factors and scoring algorithms.

## Conclusion

In Great Britain landsliding does not have a structured regulatory framework, but historical events, such as the Aberfan disaster and Scottish debris flow events (Winter et al, 2005), have highlighted the importance of understanding the distribution and mechanisms that cause landslide mass movement events in Great Britain. The BGS GeoSure methodology, using spatially distributed data and causal factor information contained in the National Landslide Database of Great Britain, and assesses the landslide susceptibility in Great Britain. It uses a heuristic approach to model the causative factors that cause these events. It assesses and classifies the propensity of a geological formation to fail as well as to score the relevant causative factors (e.g. slope angle). By using these methodologies and datasets a national assessment of the potential hazard to landsliding mass movement events in Great Britain can therefore be undertaken.

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