The new National Landslide Database and Landslide Hazard Assessment of Great Britain

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Abstract: The British Geological Survey (BGS) is the national geological agency for Great Britain. Part of the organisations remit is to provide government and citizens with information on the spatio-temporal occurrence of natural hazards. Since 2000 BGS has developed a series of National Geohazard Assessments, central to which is the new National Landslide Database (NLDB), which contains data on landslides across England, Scotland and Wales. The NLDB began with a series of inherited databases, which between them held around 9000 entries. Even though many of these entries have been removed (through a validation process), the NLDB now holds over 14,000 entries and expands every year. Importantly, BGS is moving towards digital data collection methods which will feed automatically into the National landslide database, providing the most up to date information and images to the users at minimal cost to the tax payer. A project has also been started to map all coastal landslides as well as producing a coastal slope stability assessment using remote sensing. It is hoped this will provide useful information on the nature and extent of coastal landslides and the hazards that these pose to infrastructure.

The database is used, alongside other information, to inform a series of National Geohazard Assessments. These GIS based assessments provide information on the susceptibility of the UK landmass to landslide activity. The information is used by government planners, insurance companies and utility operators. The dataset is also made available to citizens through a number of internet based 'resellers'. In 2006/07 1.4 million citizens accessed the information and used the results to support decisions about the purchase or modification to residential or commercial property.

Keywords: Landslide, Database, National Hazard Assessment

1. Starting Point: The first National Assessment of Landslides

Britain, as a whole, does not experience extreme climatic or tectonic events nor have the mountainous regions associated with large scale, destructive landslides. Despite this, landslides are common in Britain and several major landslides have occurred, usually with little warning. Examples of these have caused structural damage (Holbeck Hall Landslide, Scarborough; Lee 1999), interrupting transportation routes (Glen Ogle, Scotland; Winter et al. 2006) and resulting in fatalities (Whitehaven, Cumbria; Jenkins and Hobbs 2007).

Prior to a national assessment of landslides being undertaken, the subdued topography and degraded nature of many ancient failures meant that landsliding was not considered to be widespread or problematic in Great Britain. However, costly disruptions to projects in the 1960's such as the Sevenoaks Road By-pass (Skempton and Weeks 1976) and the Waltons Wood motor way embankment (Early and Skempton 1974) by reactivations of previously unknown landslides led to the realisation that research needed to be done to determine the significance and extent of the problem. The first national focussed assessment of landsliding was undertaken for the Government Department of the Environment (DoE) in the mid 1980s. It produced a database of landslides and a review by Jones and Lee (1994). This initial assessment was undertaken as a desk study, collating information from maps, journals, technical reports and books as well as university research and theses. The final number of landslides recorded was 8835, a figure far greater than the initial estimate of 1000 landslides (Jones and Lee 1994). . However, this initial study had several problems similar to those associated with other databases produced through a desk study approach (Jones 1998). These included a bias of information toward areas of concentrated and conspicuous landslide activity, which reflect detailed studies such as those covering the South Wales Coalfield (Conway et al. 1980), Southeast England (Hutchinson 1969), and the Jurassic escarpment (Chandler 1970). Other problems related to gaps in the available data, for instance information on the type and cause of landsliding was very limited, and many database fields remained unpopulated. During the study no distinction was made between small landslides and more extensive areas of landsliding; this lead to a lack of comparability and an overestimation of the overall landslide hazard. This lack of attribution and basic characterization (as opposed to the detailed classification that was adopted) severely limited the analytical potential of the database. A further fundamental flaw of the database (but not of the data itself) was that it used a non-proprietary software system (as might be expected of the time) that quickly became incompatible with newer computer systems.

This National Database, which contains information on over 35 landslide attributes, has been incorporated into the British Geological Survey National Landslide Database (NLDB). However, in building a new database, BGS is attempting to deal with a number of the issues encountered by the previous system.

2. New BGS Database

The new BGS National Landslide Database, running since 2002, currently documents over 14,000 landslides across Great Britain (Fig. 1). The primary source of information is the National Digital Geological Map (DiGMap) at 1:10 000 (DigMap10) and 1:50 000 scale (DiGMap50). Other data is collected through media reports, site investigations, journal articles and new direct mapping in the field. Data is stored within fully relational ORACLE database which can be accessed through a typographical (Microsoft Access) or geographical (ArcGIS) interface. The database stores up to 70 different types of spatial, temporal, physical and environmental data plus details of socio-economic impacts. Information is stored in 30 fully-relational data tables. To ensure compliance with the regulations that govern national archive databases in the UK, each data table is linked to a history table that records details of every change made to the database. Thus, all information within the database can be fully audited and details, including time, date, personnel, and landslide information of every change can be recorded and traced. This also means that in the event of a catastrophic information error, the database can be recreated to any point in the past. In common with other digital national datasets, the system is also backed up every 24 hours in three separate geographical locations to guard against physical damage to the system.

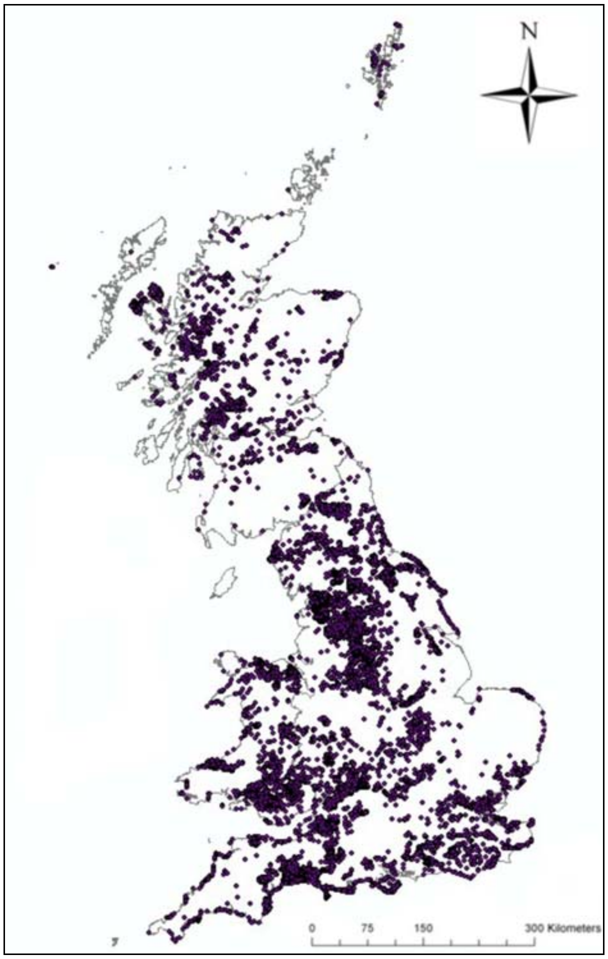

Fig. 1 Distribution of recorded landslides held by BGS. OS topography © Crown Copyright. All rights reserved. 100017897 / 2008

The landslide database forms part of the BGS Geodatabase, and as such is compatible with other data dictionaries used in the BGS. For instance, the database uses BGS standard dictionaries for lithological and stratigraphical nomenclature. Similarly, nationally and internationally recognised dictionaries are used for other data tables, such as location, damage type and land use. Wherever possible, details of each landslide are recorded using terminology from the World Landslide Inventory (IAEG Commission on Landslides 1990). An example of this is given in Table 1.

3. Data Collection.

The database undergoes continual revision and update. New data collection is ongoing and is carried out by a wide number of geological survey staff. Geologists are provided with a pro–forma which is taken into the field to collect data regarding any landslides mapped. Each landslide characteristic is entered as a shortened attribute code, related to dictionaries definitions. In reality these pro-formas are shortened versions as geologists may be unable to collect information on all of the attributes due to time constraints. With the advent of the new digital geological field mapping equipment, MIDAS (Mobile Integrated Data Acquisition System), landslide database pro-formas are being loaded onto ruggedized pc's to be used in the field.

Table 1 Sample Dictionary for 'Landslide Style' from the BGS National Landslide Database.

Style	Description
Composite	A composite landslide exhibits at least two movements simultaneously in different parts of the displacing mass.
Complex	A complex slide involves one of the five main types of movement followed by two or more of the other main types of movement.
Successive	Repeated shallow rotational slips each of limited extent down slope but considerable extent across it, forming cross slope steps or terraces.
Cluster	Cluster or group of small landslides on a section of slope with similar characteristics.
Single	A single event failure with no additional movements of the same type.
Multiple	A series of movements of the same type e.g. a series of slices failing in multiple rotational style.

4. National Hazard Assessment using the Database

In addition to its value as a scientific tool, the development of a landslide inventory, in the form of the National Landslide Database, was an important first step in the production of a national landslide hazard assessment. To assess the hazard posed by landslides it is necessary not only to be aware of their distribution, but to also understand the causative factors and their spatial distribution. The spatial modelling of landslide causative factors has been made possible through the use of Geographic Information Systems (GIS). The increase in processing and storage capabilities of GIS has made it possible to manipulate, analyse and model the causative factors of landsliding to create a landslide susceptibility model for the whole of Great Britain. The current GIS assessment of landslide hazard for the British Mainland, developed by the BGS, is called GeoSure. The GeoSure methodology was developed using elements of both a deterministic and heuristic approach. The heuristic approach uses expert judgement to assess and classify the hazard, and determine the likely causative factors of landsliding (Soeters and Van Weston, 1996). The deterministic approach within GeoSure assesses the presence of the causative factors, giving each one a rating according to their relative importance in causing slope instability.

Research into the causative factors of landsliding in GB identified lithology, slope angle, hydrogeology, climate and the presence of discontinuities to be the most important. After several iterations, three key factors were used - slope, geology and bedrock discontinuities. It was possible to digitally capture most of these causative factors, although some were already available as corporate datasets. Digital geological polygons were assigned a score defining the potential of that material to fail. The score was based upon an additive algorithm that took into account the material strength, permeability and known susceptibility to instability of different lithologies, together with slope angle. The geological data was based upon geotechnical data, literature reviews and experience of geologists.

Discontinuities were assessed as an important causative factor, often reflecting the strength of a material, its susceptibility to failure and its ability to allow water to penetrate a rock mass. Detailed information about rock discontinuities was not consistently available for the majority of rock types in Britain. Therefore categories 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). Slope angle is one of the major controlling factors in landslides, and for this methodology, the slope was derived directly from the NEXTMap digital terrain model of Britain. The NEXTMap dataset was generated from an airborne survey and has a 5m resolution. This resolution was considered too detailed and too memory intensive for nationwide use, so it was resampled to 25 m for use in GeoSure. 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.

Once all the contributing factors were identified they were easily combined using a multi-criterion technique. The multi-criterion approach applied a series of rules against the available data to provide a hazard 'score' for each location in Britain. A high score does not necessarily mean that the hazard has happened in the past or will do so in the future but that the conditions mean there is a potential for future landsliding. A simplified GeoSure layer for landslide hazards in Great Britain is shown in Fig. 2.

Inevitably when dealing with large datasets on a national scale there are issues. Although computing power is increasing rapidly, there are still limits to what can be achieved. Further problems arose from the introduction of fuzzy error, which is magnified as processing continues. By using grids to do the multi-criterion analysis, fuzzy errors were reduced and the processing speed increased. The grids were converted to a polygon file for distribution and use. These polygons maintained the pixilated form inherited from the grid which may appear unattractive, but does act to enforce the resolution of the data. The blocky appearance ensures that the user is made aware of the accuracy of the data as soon as they zoom beyond the 1:50,000 working scale of the model (Wildman and Forster 2005).

Validation of the dataset revealed problems in the slope model associated with false slopes created by tree stands and man made embankments. The tree issue was solved using data derived from Landsat data which were used to identify vegetation cover at a national scale using 2D scatter plot analysis to create training classes. These training classes were then used for GIS Parallelepiped classification to detect trees. Parallelpiped classification uses a standard deviation threshold taken from the mean pixel value of each training class. Once all of the trees were identified it was possible to remove them from the NEXTMap model.

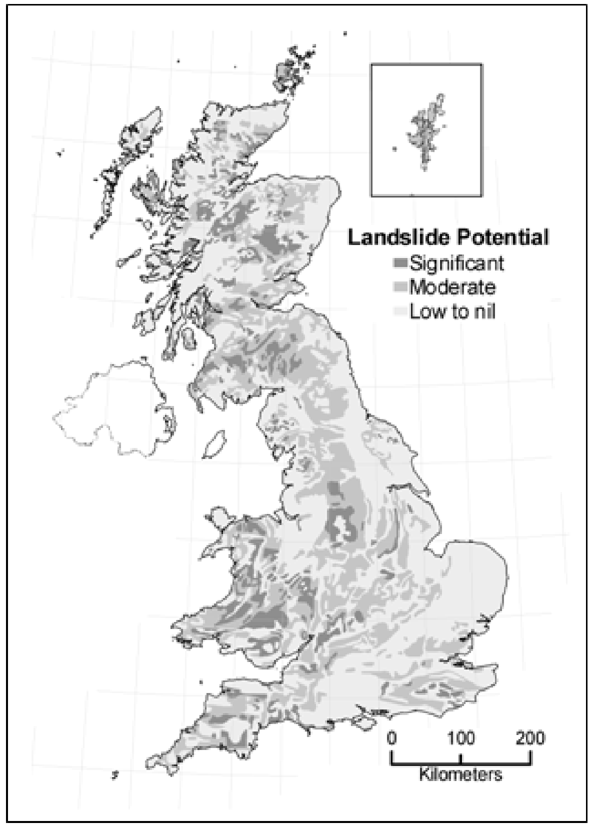

Fig. 2 Generalised GeoSure layer for Landslide hazard assessment. OS topography © Crown Copyright. All rights reserved. 100017897 / 2008

5. Discussion

The new national landslide database has been developed in light of a lack of knowledge of the distribution and nature of landslides Great Britain. The new database incorporates information from several sources including a previous national assessment, and has been designed to be 'future-proof' to new technological developments. The database contains far more information than previous national assessments and is used as the basis for detailed assessments of landslide risk in limited geographical regions.

The database represents a number of achievements including:

- Collation and validation of landslide records from the 1994 Department of the Environment Database
- Collation and validation of landslide records from other BGS databases including the South Wales Coalfield

Database, Calderdale Database, Leeds Database, Bradford Database, London Database.

- Cataloguing and characterization of BGS landslides mapped post 1994 (6000 records).
- Migration of landslide records to a fully relational database, compliant with international standards for national archive and compatible with all other BGS National Geoscience Datasets.
- Development of Database and GIS interfaces for input and interpretation.

The database is currently being used to develop regional models of landslide behaviour for the UK and has proven to be invaluable in designing a targeted data collection programme of landslide mapping and characterization. There is a long term commitment to survey more landslides, collect information from third party sources and increase the level of detail held in each database record. For instance, detailed work is underway to produce a National Landslide Hazard Assessment of the Coast. Here problems associated with the sample spacing of the DTM plus the influence of geological structures and multiple lithologies can lead to inaccuracies in GeoSure at the coast. Results will be used to define Coastal Stability Units which may better characterise the potential for, and location of, instability around the coast of Great Britain.

The database also underpins the development of a national hazard assessment of the entire country, with information on the spatial distribution of different types of landslide used as an important input to the GIS algorithm. However, this assessment is based primarily upon the spatial distribution of lithologies and slope gradient. Thus the assessment does not rely upon evaluating the significance of a history of past occurrences. The method does not require a complete, uniform dataset to carry out the assessment. The resulting GIS model provides a reasonable assessment of landslide susceptibility across the country that is 'informed' by the landslide database rather than controlled by it. The Landslide Database is an important resource because it can display the location of thousands of known landslides. However, due to the very nature of inventories the information available is limited to where data has been recorded. Most end-users wish to access a model that shows the potential for landsliding at a specific location, not necessarily in an area where information is contained within the Landslide Database. It was therefore essential to produce a nationwide model of landslide potential (GeoSure). This model is typically accessed through automatically generated reports and in 2007/08 over 1 000 000 UK citizens accessed the dataset.

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