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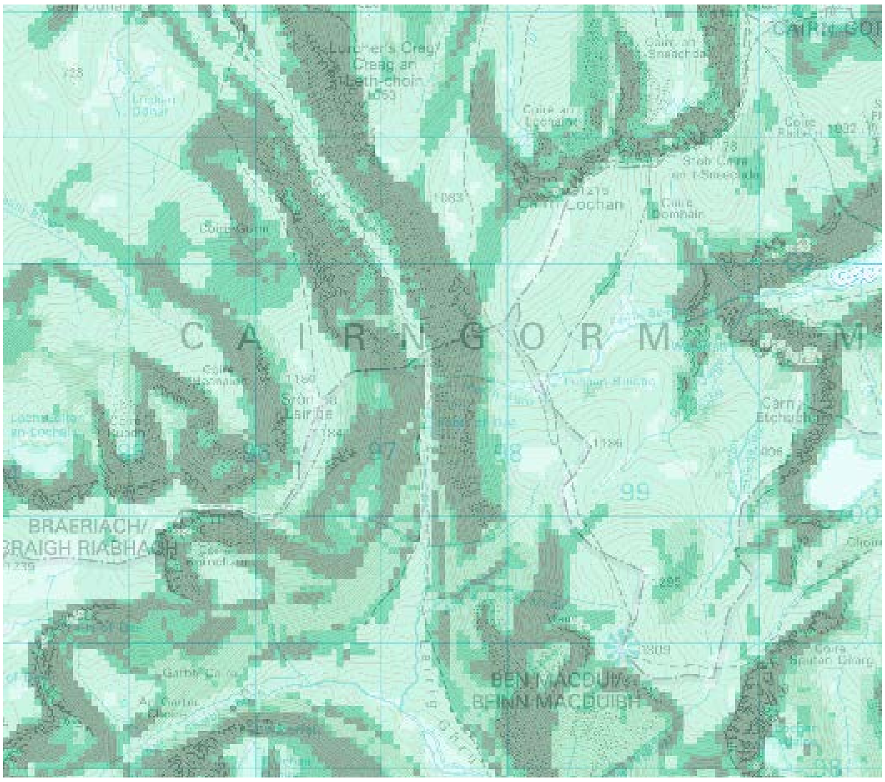
A User Guide for the GeoSure Extra: Debris Flow Susceptibility Model for Great Britain (version 6.0)

GeoAnalytics & Modelling and Engineering Geology Directorates

Open Report OR/17/031



BRITISH GEOLOGICAL SURVEY

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A user guide for the GeoSure Extra: Debris Flow Susceptibility Model for Great Britain (version 6.0)

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Debris Flow Susceptibility Model excerpt from the Cairngorms National Park, Scotland. Contains Ordnance Survey data © Crown Copyright and database rights 2017.

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Summary

This report is the published product of a study by the British Geological Survey (BGS) to produce a national scale Debris Flow Susceptibility Map for Great Britain. It builds on research BGS has conducted over the past decade investigating debris flows and extends the work conducted by Harrison *et al*., (2006) as part of the Transport Scotland Scottish Road Network Landslides Study (Winter *et al*., 2005, Winter *et al*., 2009).

The Debris Flow Susceptibility Model provides information on the potential of the ground, at a given location, to form a debris flow. It is based on a combination of digital geological, hydrogeological and topographic data. The methodology develops an additional dimension to the BGS GeoSure Landslides surface layer (Dashwood *et al*., 2014) and is designed for users interested specifically in debris flow susceptibility.

This document outlines the background to why the dataset was created, its potential uses and gives a brief description of the GIS raster file. Technical information regarding the GIS and how the data were created is described and advice is provided on using the dataset.

Acknowledgements

A number of individuals in the GeoAnalytics & Modelling, Engineering Geology and the Geology and Regional Geophysics Directorates have contributed to the project. This assistance has been received at all stages of the study. In addition to the collection and processing of data, many individuals have freely given their advice, and provided local knowledge.

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1 Introduction

Founded in 1835, the British Geological Survey (BGS) is the world's oldest national geological survey and the United Kingdom's premier centre for earth science information and expertise. The BGS provides expert services and impartial advice in all areas of geoscience. Our client base is drawn from the public and private sectors both in the UK and internationally.

Our innovative digital data products aim to help describe the ground surface and what's beneath across the whole of Great Britain. These digital products are based on the outputs of the BGS survey and research programmes and our substantial national data holdings. This data coupled with our in-house geoscientific knowledge are combined to provide products relevant to a wide range of users in central and local government, insurance and housing industry, engineering and environmental business, and the British public.

The Debris Flow Susceptibility Model (DFSM) provides information on the potential for a debris flows to occur at a given location based on a combination of digital geological, hydrogeological and topographic data. These data are represented in a Geographical Information System (GIS).

Further information on all the digital data provided by the BGS can be found on our website at http://www.bgs.ac.uk/data/digitaldata/digitaldata.cfm or by contacting:

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2 The Debris Flow Susceptibility Dataset

2.1 BACKGROUND

The public’s understanding of the effect of ground conditions on the safety of their property and the implication for the value of their property is growing. Local councils are under increasing pressure from central government to provide environmental information. Information about geological hazards is needed, in particular, the identification of areas with a potential for ground movement.

In response to this, the BGS initiated a development programme to produce datasets that identified and assessed potential geohazards threatening the human environment in Great Britain: GeoSure. GeoSure ground stability data consist of six data layers in GIS format that identify areas of potential hazard in Great Britain. One of these six layers is concerned with landslides and best simulates shallow translational and rotational landslide types. In order to improve and widen this capability to include debris flows, the debris flow susceptibility dataset has been created.

After a series of debris flows in 2004 that affected main roads in Scotland, the Scottish Road Network Landslides Study was commissioned by the Scottish Executive (Winter *et al*., 2005). This review assessed the slopes adjacent to the trunk road network and identified areas that had the greatest potential for similar events in the future. The Debris Flow Susceptibility Model described here builds on the earlier work carried out, updates the data sources and extends the coverage to the whole of Great Britain.

2.1.1 What are debris flows?

The term debris flow refers to the rapid downslope flow of poorly-sorted debris mixed with water (Ballantyne, 2004). Debris flows are described by Hungr *et al*. (2014) as: "v*ery rapid to extremely rapid surging flow of saturated debris in a steep channel. Strong entrainment of material and water from the flow path*". They are a widespread phenomenon in mountainous terrain and are distinct from other types of landslides as they can occur periodically on established paths, usually gullies and first- or second-order drainage channels. Debris flows in Great Britain are most commonly found in upland Scotland but also in parts of Wales and the Lake District (e.g. Figure 1).

Figure 1 Examples of debris flows in Lairig Ghru, Cairngorms, Scotland. Photograph courtesy GoogleEarth: Getmapping plc 2016

In Great Britain, there are two types of debris flow (Figure 2; Cruden and Varnes, 1996; Ballantyne, 2004; Nettleton *et al*., 2005):

Hill Slope or *Open-Slope Debris Flows* form their own path down valley slopes as tracks or sheets and deposit material on the lower slopes where the gradient shallows.

Valley-confined or *Channelised Debris Flows* originate in bedrock gullies and are channelled for at least part of their length along the gully floor. The flows have the consistence equivalent to that of wet concrete and can be fronted by a boulder concentration or 'head'.

The two categories are transitional; many valley-confined flows debouch on to open ground in their lower reaches, and hillslope flows often follow shallow gullies cut in valley-side drift, talus or regolith.

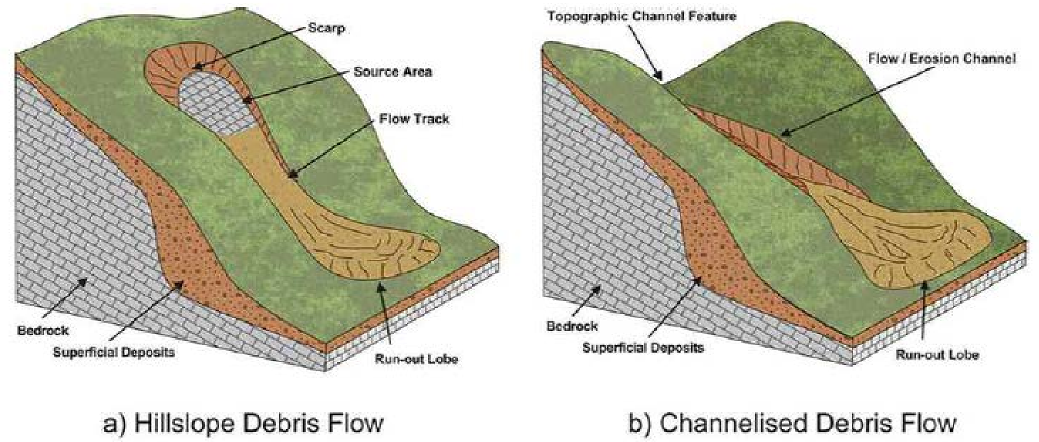

Figure 2 Hillslope (a) and channelised debris flow (b) Taken from Nettleton *et al*. (2005) © Crown Copyright 2005

Figure 3 Debris flows in Lairig Grhu, Cairngorms, Scotland showing levée features. Photograph courtesy GoogleEarth: Getmapping plc 2016

Debris flows consist of three main parts: a source area, track and depositional area.

Source areas may be initiated by a slide, debris avalanche or rock fall from a steep bank, or by spontaneous instability of the steep stream bed (Hungr *et al*., 2014). Irrespective of the mode of flow initiation, debris flows are generated when a build-up of pore water pressures in unconsolidated sediments causes a reduction in the shear resistance, leading to failure and sediment flow (Ballantyne, 2004). Most debris flows in Great Britain occur following a period of high magnitude precipitation events.

Debris flows tend to follow long, narrow tracks. The upper, erosional section of the flow consists of a gully that is continued downslope by parallel levées (e.g. Figure 3) of dominantly coarse debris that enclose the track of the flow and often terminate downslope in one or more lobes of bouldery debris (Ballantyne, 2004).

Finally, the debris flow event is deposited on a debris flow fan. Characteristic features used to distinguish debris flow material from other sediment on a fan include high slope angle of the fan, very large individual particles, coarse levées and boulder trains, signs of impact loading on obstacles, U-shaped eroded channels and steep, debris-loaded channels upstream (Hungr *et al*., 2014).

2.1.2 Debris flow impacts

Debris flows are potentially very destructive as they can cause significant erosion of the substrates over which they flow, thereby increasing their sediment charge and further increasing their erosive capabilities (Nettleton *et al*., 2005). The Scottish road and rail networks in particular have been affected by debris flows. Recent disruptive events include:

- the A85 road at Glen Ogle where 57 people were stranded on the roadway between two debris flows (Figure 4; British Geological Survey, 2006);
- the western slopes of Stob Coire Sgriodain by Loch Treig, in the Scottish Highlands where a train was derailed (Figure 5; British Geological Survey, 2012); and
- the A83 Rest and Be Thankful Pass, the most widely reported locality for debris flows, much more than any other part of the trunk road network in Scotland (Figure 6 and Figure 7; Winter *et al*., 2013). The Rest and Be Thankful is the main route between Arrochar and Inverary through mountainous terrain. When this road is closed, a 55-mile detour and associated high economic consequences are regularly reported in the media. Wig-wag warning systems (Winter *et al*., 2013) were installed in 2011 and ten bespoke debris flow barriers in 2014 (Maccaferi, 2014).

Figure 4 A85 Debris Flow at Glen Ogle. 57 people were trapped in their cars

Figure 5 Stob Coire Sgriodain by Loch Treig, in the Scottish Highlands where a train was derailed. Right photograph used with permission of Route Asset Manager, Geotechnics Scotland

Figure 6 Debris flow deposit blocking the A83 Rest and Be Thankful, August 2012

Figure 7 Recent debris flows on the A83 Rest and Be Thankful Pass

2.2 WHO MIGHT REQUIRE THIS DATASET

Debris flows may lead to financial loss for anyone involved in the ownership or management of property, including developers, householders, loss adjusters, surveyors or local government. These costs could include increased insurance premiums, depressed house prices and, in some cases, engineering works to stabilise land or property. These hazards may also impact on anyone involved in the construction or maintenance of infrastructure networks (road or rail) or utility companies. Armed with knowledge about potential debris flows, preventative steps can be put in place to alleviate the impact of the hazard to people and assets (such as property). The cost of such prevention may be low, and is often many times lower than the repair bill following ground movement.

2.3 WHAT THE DATASET SHOWS

This addition to the GeoSure ground stability data consists of a single data layer in GIS format that identifies areas of potential debris flow hazard. It is essentially a national hazard susceptibility map. These data have been produced by engineering geologists and geospatial data analysts at the British Geological Survey and is presented as a digital spatial data layer. It is important to remember that the focus in this dataset was the identification of source areas and so not all of the track and area where material may be deposited will be covered for long run-out failures.

Debris flows occur when particular slope characteristics (such as regolith, gradient, drainage, sources of water, or the actions of people) combine to make the slope unstable. Debris flows are potentially very destructive and, due to the speed at which they take place, can for example rapidly block infrastructure routes and damage assets.

3 Technical Information

3.1 DEFINITIONS

- Hazard: A potentially damaging event or phenomenon.
- Risk: The impact of the hazard on people, property or capital.

For example, a debris flow could be perceived as a hazard, but the likelihood of it causing structural damage would be the risk.

A high hazard does not necessarily translate to a high risk. For example, if a particular location has a relatively high ground stability hazard, but the infrastructure routes that are built there have taken this into account, and are designed to withstand the hazard, they will not have a comparable level of risk. This is because the likelihood of the hazard causing any loss has been reduced due to the design of the property.

The Debris Flow Susceptibility Model does not identify the cost of a hazard being realised or the exposure of assets or people, and therefore does not consider risk. The Debris Flow Susceptibility Model only examines the conditions that leave an area predisposed to a debris flow occurring.

3.2 BGS IMPERATIVE

BGS GeoSure is a set of six national ground-stability layers developed in vector GIS format at 1:50 000 scale. The six layers include Compressible Ground, Collapsible Ground, Landslides, Running Sands, Soluble Rocks and Shrink–Swell. GeoSure aids decision makers, responds to the legislation and provides income to BGS via data licensing and GeoReport sales. The Debris Flow Susceptibility Model V6.0* is an additional dimension to the GeoSure

Landslides surface layer and is designed for users specifically interested in debris flow potential.

[*NB: Version 6 refers to the version of BGS DiGMap used to create the bedrock and superficial permeability datasets used in its creation. This is to be consistent with the way that version numbers have been allocated to other BGS data products derived from DiGMap].

3.3 SCALE

The Debris Flow Susceptibility Model Great Britain (Version 6.0) dataset is produced for use at 1:50 000 scale providing 50 m ground resolution.

3.4 ATTRIBUTE TABLE FIELD DESCRIPTORS

Table 1 Attribute table field descriptions

Field name	Field description
VALUE	An automatically generated number (1-5) to represent each discrete category in the dataset.
COUNT	The number of cells within the associated [Value] field.
LEGEND	Classification of hazard on a scale of A - E
SHORT_DESC	Description of the hazard
VERSION	Dataset name and version number (DFSM_GB_V6.0)

3.5 CREATION OF THE DATASET

The Debris Flow Susceptibility Model GIS layer is rated on an A-E classification, representing increasing hazard (Table 2).

Table 2 Debris Flow Susceptibility Model legend

Legend	SHORT_DESC	Longer description/ Interpretation (not included in spatial layer)
A	Debris flows are not though to occur.	Debris flows are not thought to occur. This is due to a lack of available slope materials, high drainage rates or low slope angle.
B	Debris flows are not likely to occur.	Debris flows are not likely to occur. This is either due to a limited availability slope materials, sufficient drainage rates or low slope angles.
C	Debris flows may be present or anticipated.	Debris flows may be present or anticipated. The combinations of increasing slope angle, poor drainage condition and the presence of

		available material may increase the potential for failures to occur.
D	Debris flows are probably present or have occurred in the past.	Debris flows are probably present or have occurred in the past. The combinations of steep slopes, poor drainage conditions and an increased presence of available material suggest that debris flows are likely to be present at these sites.
E	Debris flows are highly likely to be present.	Debris flows are highly likely to be present. The heightened combinations of steep slopes, poor drainage conditions and the presence of available material suggest that debris flows are highly likely to be present at these sites.

To produce the Debris Flow Susceptibility Model layer, an assessment of hazard is made by:

- identifying the factors that are involved in creating the hazard
- assessing which are thought to be present at each location
- assessing how significant they are thought to be at each location

The factors are then combined to estimate the level of hazard. The level of potential hazard does not mean that a damaging debris flow event is going to happen but is an indication of how many causative factors may be present and how severe they are thought to be. The Debris Flow Susceptibility Model is created from a stack of grids that represent the following factors:

- the type of material (regolith) available to flow
- the gradient of the slope
- how free-draining the slope is
- influence of stream channels
- Quaternary history

3.6 COVERAGE

The Debris Flow Susceptibility Model covers Great Britain (Figure 8). This does not include the Isle of Man, the Channel Islands or Northern Ireland.

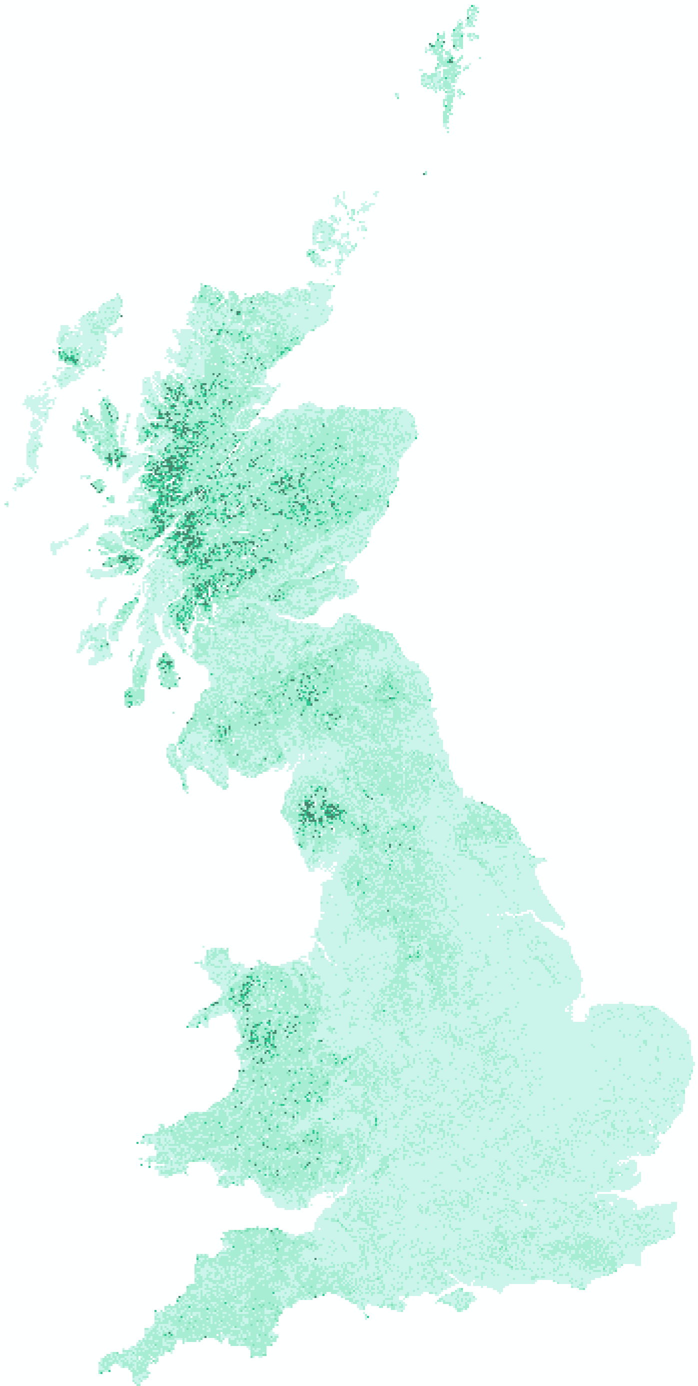

Figure 8 Extent of coverage of the Debris Flow Susceptibility Model. Contains Ordnance Survey data © Crown Copyright and database rights 2017

3.7 DATA FORMAT

The Debris Flow Susceptibility Model dataset has been created as an ESRI GRID raster file. The data can also be made available in ASCII or other formats on request, subject to the limitations and availability of translational software.

3.8 LIMITATIONS

- The Debris Flow Susceptibility Model has been developed at 1:50 000 scale and must not be used at larger scales.
- All spatial searches against the data should be done with a minimum 50 m buffer.
- The Debris Flow Susceptibility Model is concerned with potential ground stability related to NATURAL geological conditions only. This does not, therefore, include man made slopes such as embankments or cuttings.
- The Debris Flow Susceptibility Model is based on, and limited to, an interpretation of the records in the possession of the British Geological Survey at the time the dataset was created.
- An indication of natural ground instability does not necessarily mean that a slope will be affected by ground movement or subsidence. Such an assessment can only be made by inspection of the area by a qualified professional.
- The level of potential hazard does not mean that a damaging debris flow event is going to happen but is an indication of how many causative factors may be present and how severe they are thought to be.
- The words provided in the Table 5 are designed to provide a general indication of the meaning of the various Debris Flow Susceptibility Model hazards levels. If the data are to be used for advising specific sectors of end users in detail, e.g. home-buying, property insurance, site development and construction, then the BGS can provide additional end user guides and attribution details for the data. To find more about this, please contact our Business Solutions department through the Central Enquiries Desk using the contact details at the start of this document.
- A slope model was derived directly from the NEXTMap™ digital terrain model of Britain. The NEXTMap™ dataset was generated from an airborne survey at 5 m resolution. It is recognised that the NEXTMap™ elevation model does not always accurately represent the ground surface and produces erroneous elevation and slope data in some locations. This occurs because of the oblique way in which NEXTMap™ data are collected. Examples of this include the coast, verges of dense stands of trees and large structures such as warehouses or extensive stretches of seawall. There are artefacts of this problem found in this version of the debris flow model and values are therefore likely to be over-exaggerated in these areas.
- There are several areas within mainland GB which have values of ‘No Data’. These generally occur where there are inland bodies of water such as lakes. Where the underlying geological mapping within the Soil-Parent Material V6 data shows these areas to be ‘NA’, it was not possible to assign a lithology score and the cell is therefore recorded as ‘no data’. In some areas, which are coincident with water bodies, the geological map has attributed the underlying surface geology with a lithology. In such cases, a score was possible and as such, the cell was not assigned with a score rather than a ‘no data’ value.
- This model is limited to areas where debris flows are initiated, as well as parts of the debris flow track. It does not indicate where the material involved in the failure will flow.
- The model does not include any influence of land cover on the stability of a slope. The stabilising influence of certain types of vegetation is well documented in the literature, however the data available at the national-scale does not reflect vegetation-type updated on a regular basis. Therefore, any changes to vegetation (e.g. a felled forest would have a destabilising effect on the slope) would not be captured until the next release of data enabling incorrect assumptions to be made about debris flow potential.
- The Debris Flow Susceptibility Model is limited to the latest version of the Soil Parent Material Dataset. Version 6.0 will therefore be subject to future updates within the BGS data products delivery schedule.

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British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: https://envirolib.apps.nerc.ac.uk/olibcgi.

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