MEDIA, SINKHOLES, AND THE UK NATIONAL KARST DATABASE

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Abstract

The British Geological Survey (BGS) maintains a number of databases that feed into hazard susceptibility assessments, including karst, landslide, and mining susceptibility. The winter period from December 2013 to January 2014 was one of, if not the most, exceptional periods of winter rainfall in the last 248 years for England and Wales. During this period the Jet Stream diverted easterly tracking cyclones along a more southerly route than is usual across the United Kingdom (UK). This resulted in south-east and central-southern England experiencing total rainfall values of 372.2mm for this period, which was the wettest two-month period since 1910. This period was associated with extensive flooding and increased numbers of slope failures, landslides, and sinkholes, which affected transport routes into and out of London, thereby generating considerable media attention. In addition to government and stakeholder requirements, the BGS experienced an unusually high level of enquiries from the public and the media pertaining to sinkholes, which put an additional strain on

resources, but is an acknowledged component of the BGS remit. During February alone, the BGS received reports of 19 sinkholes. The majority of these occurred in the Cretaceous Chalk of southern England. Approximately half were not naturally occurring sinkholes, but were due to the collapse of anthropogenic features. Typically, the anthropogenic subsidence collapse features included: the collapse of chalk shafts associated with historic extraction of chalk for brickworks; the collapse of deneholes (medieval chalk workings for chalk for ground improvement), and chalk mine shaft collapses. This paper describes the National Karst Database, stakeholder requirements, and how the BGS has responded with new and improved mechanisms for data collection, storage and dissemination.

Introduction

Shallow geohazard and risk research at the British Geological Survey (BGS) is focused at a range of scales, from site-specific process understanding to national scale hazard susceptibility assessments. Results of these

assessments are delivered through the product GeoSure. This product was driven by stakeholders (primarily the home insurance-sector) and comprises a series of national datasets providing geological information about potential ground movement or subsidence. More specifically, GeoSure comprises national scale (1:50,000) GIS-derived susceptibility maps for collapsible deposits, compressible ground, landslides, running sand, shrink-swell sediments, and soluble rocks (Figure 1). These maps are aimed at the non-scientific community and incorporate a simple hazard rating (A=low to E=high susceptibility). The main soluble rock types that are encountered in the UK comprise (in order of decreasing solubility and dissolution rate): Triassic salt, Permian gypsum and dolomite, Triassic gypsiferous rocks, Cretaceous chalk, Jurassic limestone, and Palaeozoic limestone. The susceptibility map was built by scoring each of these rock types based on differential weighting of lithology, topography, geomorphology, superficial cover type and superficial cover thickness (Farrant and Cooper, 2008). The knowledge behind the scoring methodology is partly derived from the understanding that comes from maintaining the National Karst Database. It was also enhanced by local knowledge and manual subdivisions. In particular, the evaporites have a slightly different set of determinative parameters that are calculated separately (Farrant and Cooper, 2008).

The National Karst Database, which is being populated and maintained by the BGS, aims to provide data pertaining to the distribution of dolines, stream sinks, caves, springs and incidences of building damage. This data is being retrieved from field slips and paper maps (with additional fine-scale data and ground-truthing derived from fieldwork), from remote sensing techniques such as Light Detection and Ranging (LiDAR) and from existing documentary data sources such as historical and modern Ordnance Survey maps, cave surveys, academic papers and historical documents. Other data such as a legacy “Applied Geology” database (more recently held by Peter Brett Associates) that was originally funded by the Department of the Environment during the 1990s, and the Mendip Cave Registry data are also being used to identify relevant features. This is a time-intensive data gathering exercise, which has been driven by the karst research interests of the scientists involved. Consequently, the data gathering has been very detailed; for example, there are seventeen attribute fields associated with springs.

Both GeoSure and the National Karst Database were designed to capture information on the distribution of naturally occurring karst features. However, during the winter of 2013-2014 an exceptional number of sinkholes were reported in the UK. A significant number of these were found to be anthropogenically derived. They had a significant impact on infrastructure and property, which captured the attention of the media, and consequently, the imagination of the public. This resulted in demands for data delivery comparable with that of the BGS National Landslide Database (Pennington et al., 2015), which was also adapted to incorporate anthropogenic slope failures as well as the core of natural landslides. Here we describe the triggering factors for the unusually high number of sinkhole events, the nature of the events, the demand on resources and how BGS has responded by developing new collaborations and a new portal for data delivery.

Figure 1. Soluble rock susceptibility map with February 2014 “sinkholes” superimposed. BGS©NERC. Contains OS Open data©Crown Copyright and database rights, 2014.

The Unusual Weather Conditions During Winter 2013-2014

On 21 February 2014, the UK Met Office reported on the winter storms of December 2013 to January 2014. They advised that this was one of, if not the most, exceptional periods of winter rainfall in the last 248 years for England and Wales. The rainfall total for December and January was 287.6mm (119.9 and 167.7mm respectively) for the south-east and central-southern England region, which was the wettest two-month period in their records from 1910. During February, there was a further 126.1mm for the south and south-east. Between late January and mid-February, twelve storms hit the south and south-east making it the stormiest period of weather that the UK has experienced for at least twenty years (<http://www.metoffice.gov.uk/research/news/2015/uk-winter-storms-one-year-on>).

The four storms from early to mid-February were particularly severe giving rise to strong winds and huge waves as well as significant rainfall. The sequence of storms was attributed to the position and strength of the Jet Stream, driving a succession of low pressure systems across the Atlantic in a marginally more southerly route than usual. The impact of the rapid succession of events was significant coastal erosion and extensive flooding, particularly of the Somerset Levels. Inevitably this resulted in self-questioning with respect to UK resilience. It is this sustained period of wet weather that is suspected to be the trigger for the spate of sinkholes and collapse subsidence features that were reported, primarily occurring in the south and south-east (Table 1; Figure 1).

Table 1. Sinkhole occurrences in February 2014.

Date in 2014	Location	National Grid Reference	Description
28 Jan	Walkern Croft, Benington Road, Walkern, Hertfordshire	5285 2250	Collapse of karst flow path
2 Feb	Walter's Ash, High Wycombe	4839 1978	Suspected chalk mine shaft associated with former brickworks. Car collapse into subsidence feature
6 Feb	Duddleswell, East Sussex	5467 1285	Collapse associated with disused soakaway
11 Feb	M2 between junctions 5 and 6	5942 1590	Suspected denehole. Considerable disruption to motorway traffic.
12 Feb	Rainham Mark Grammar School, Gillingham, Kent	5806 1668	Collapse of brick capped denehole.
	Upper Basildon	4586 1763	Associated with former brickworks and chalk mine.
13 Feb	Gillingham Anchorian Rugby Club	5786 1664	Doline associated with feather edge of Thanet Beds over Chalk
	Oakridge Gardens, Wood Lane End, Hemel Hempstead	5075 2078	Associated with former brickworks
	Turner's Hill	5353 1360	Sand piping
	Warren Farm, Finmere, Buckinghamshire	4624 2332	Collapse of karst flow path
	Holmesdale Grove, Barnehurst, Bexley	5513 1760	Doline associated with feather edge of Thanet Beds over Chalk
16 Feb	Croxley Green, Hertfordshire	5071 1963	Doline associated with Glacial sand and gravel over Chalk
	Nettlebed, Oxfordshire	4703 1863	Chalk mines associated with former brickworks
	Windermere Road, St Albans	5169 2065	Doline in chalk
17 Feb	Magdalen's Road, Ripon	4316 4719	Doline formation due to gypsum dissolution below ground
20 Feb	Devizes Road, Salisbury	4134 1307	Doline in Chalk
21 Feb	Wilmington, Dartford, Kent	5509 1707	Doline
21 Feb	Wilmington, Dartford, Kent	5510 1703	Doline
22 Feb	Victoria Avenue, Broadstairs, Kent	6380 1696	Associated with brickworks
22 Feb	Percy Avenue, Broadstairs, Kent	6389 1707	Associated with brickworks
26 Feb	Bridge House, High Street, Dartford, Kent	5543 1739	3 voids in garden area; suggested possibility of this being related to former leats. Otherwise suspected natural dolines.
1 March	Chilcompton, Somerset	5160 2065	Collapse of karst flow path

“Sinkhole” Occurrences

Whilst the true definition of a sinkhole describes a naturally occurring closed depression, the media uses this term primarily to describe any sudden opening of a cavity in the ground. It soon became clear that there was a demand for statistics regarding the extent of media interpreted “sinkhole” occurrences. A new Access database was initiated to serve this need. Twenty-four “sinkholes” were captured in this database for February 2014. The events were divided into eight categories (Figure 2), which can be grouped as 1) naturally occurring pipes in the chalk; 2) natural gypsum-related collapse; 3) shaft or mine collapses associated with former chalk workings (medieval deneholes or more recent workings associated with brick making), and 4) piping-related events on non-soluble bedrock. The naturally occurring dolines in chalk commonly occur close to the feather edge of the overlying Palaeogene strata or where the chalk is overlain by glacial or glacio-fluvial sands and gravel (suffosion dolines). It is suspected that water migrating through the capping materials reacts with pyrite (iron sulfide) in the granular strata, which causes a reduction in pH and therefore greater potential for dissolution of the chalk bedrock (Edmonds, 1983). The high percentage of collapse features associated with former brickworks is attributed to the historic practice of using locally-won wash mill ground chalk as an additive (up to 15%) in brick making. The addition of chalk improved the brick firing process and gave a yellow hue to the bricks.

Media Interest

For BGS the media created a storm of a different kind. The “sinkholes” started to appear in early February and

the resultant newspaper headlines captured in Table 2 are typical. Interest seemed relentless, evolving from sensationalism to concerns about the cost implications for individuals. Requests for radio and television interviews of BGS staff were equally numerous. Whilst there was some benefit for BGS from the publicity, the requests placed a huge demand on already stretched resources.

Enquiries and the Public

Sensational headlines triggered the imagination of the British public, the consequence of which was a “flood” of enquiries (Figure 3), each one requiring an individual response. Many enquiries related directly to the reported incidents, requesting information on how to manage and remediate sinkholes, a number related to hazard susceptibility in specific areas underlain by soluble bedrock, some related to other types of foundation problem or subsidence and others were requests for further descriptions of how and where sinkholes occur. Unsurprisingly, there was increased interest from researchers, particularly undergraduate students undertaking independent research projects.

The increased number of enquiries to BGS appears to have stemmed from the amount of media coverage that the BGS was exposed to during this time and also from other public sector organisations providing BGS contact details. As with the media, public enquiries presented an extra strain on resources.

State of Emergency

The UK Civil Contingencies Act dictates what happens during emergencies with a requirement to ensure that relevant organisations collaborate. A state of emergency was declared and meetings of COBR (Cabinet Office Briefing Rooms), the emergencies committee, which includes the key people that are able to make things happen (ministers, senior officials and people from outside government, in this case including representatives from the Environment Agency, Ministry of Defence and Met Office), took place. Between Christmas and 5 February 2014, twenty-one COBR meetings had taken place, primarily to respond to the threat of floods. During February 2014 COBR was being informed by the Scientific Advisory Group for Emergencies (SAGE), which is responsible for coordinating and peer reviewing, as far as possible, scientific and technical advice to inform decision-making. A number of senior BGS staff were called upon to advise SAGE.

Figure 2. Pie chart to show break down of the types of “sinkhole”. BGS©NERC.

Table 2. “Sinkhole” related newspaper headlines February 2014.

Date	Newspaper	Headline
2 February 2014	Bucks Free Press	Family evacuated from home after sinkhole swallows car
3 February 2014	Guardian	Sinkhole swallows car in High Wycombe
	Mail	The Home Counties sinkhole that swallowed a CAR! Family flee village home after their VW disappears into 30ft-deep crater which appeared overnight.
12 February 2014	News Shopper	Giant sinkhole opens in Barnehurst back garden.
14 February 2014	Your Maidstone	Two more “sink holes” open in Medway
16 February 2014	Daily Mail	Terrifying sinkholes that are opening up all over Britain
17 February 2014	Huffington Post	UK Weather: Homes evacuated as yet another giant sinkhole appears, this time in Hemel Hempstead
17 February 2014	International Business Times	Sinkholes in the UK: Why is the ground collapsing?
18 February 2014	The Telegraph	Why sinkholes are swallowing Britain
	The Guardian	North Yorkshire home wrecked by ninth sinkhole in a month
	Express	Sinking Britain! Now sinkholes even threaten the dead as they appear in a cemetery
	Independent	What are sinkholes, how do they form and why are we seeing so many?
19 February 2014	Metro	Sinkholes: Why are they here and how do they happen?
20 February 2014	Mirror	Why are so many sinkholes appearing in the UK? All you need to know about the phenomenon
21 February 2014	The Guardian	Sinkholes on the increase after UK’s wet weather
24 February 2014	Live Science	Sinkholes swallow more after UK’s big storms
26 February 2014	Construction News	Sinkholes: can they be stopped?
4 March 2014	Guardian	Sinkholes: there’s good and bad news

The Government Chief Scientific Adviser particularly required information on hazard susceptibility, the numbers and distribution of “sinkholes” and landslides, and the processes associated with their occurrence to be made available to infrastructure managers.

How BGS Has Responded

In order to try and address the multiple needs of stakeholders BGS responded with updated web pages to provide information on what to do in the event of a sinkhole, case study reports on “sinkholes”, and an updated map showing the distribution of sinkholes during February 2014. This enabled the provision of relevant information for the public and media enquiries. Case studies comprised reports on site visits to exemplify the different types of feature. For example, deneholes are medieval chalk extraction pits; characteristically they comprise a narrow shaft with a number of chambers radiating from the base. Chalk was extracted for soil

improvement and was usually applied directly to the field, although sometimes it was first burnt in lime kilns to produce quicklime (calcium oxide). The addition of water to quicklime forms slaked lime (calcium hydroxide) a white powder, which can also be used in the preparation of mortar. Once they had reached their limits, the deneholes were commonly capped. A variety of capping techniques were used. Rainham Mark Grammar School, Gillingham, Kent provided an example of a denehole shaft collapse (Figure 4). Interestingly, this shaft was situated on relatively high ground, possibly reflecting the location of a former field boundary in an area with a relatively thin cover over the chalk. Figure 4 also shows the development of small dissolution pipes close to ground surface. Bricks in the base of the hole suggest that this feature may once have been capped with a brick arch. At one of the two northerly occurrences of sinkholes in February 2014, in Ripon, Yorkshire, a naturally occurring sinkhole, which

Figure 3. Increased number of “sinkhole” related enquiries during February 2014.

was roughly oval and approximately 11 x 15m and 0.7m deep, resulted in large cracks within and evacuation of a detached property. This feature formed the focus of a second case study, characteristic of sinkholes in the Ripon area, which have been attributed to sub-surface, joint-guided dissolution of gypsum (Cooper et al., 2013).

In addition to the responsive work, the BGS has been addressing the requirements of a specific request from the London Fire Brigade; collaborating with the Chief Fire Officers Association Urban Search and Rescue (USAR) group to help develop standard operating procedures and training with respect to

Figure 4a. Denehole collapse, Rainham Mark Grammar School, Gillingham, Kent. Photographs P Witney @BGS/NERC.

karst geohazards. The demands of the media, public and SAGE for “sinkhole statistics” has led to a more proactive and systematic approach to the collection of “sinkhole data” through media searches.

There is a greater urgency to complete the population of the karst database. Further, there has been a focus on developing and adapting a chalk cavity database as an Oracle delivery portal for information on sinkholes and also the karst features captured in the karst database. This will ensure consistent delivery of quality-assured data to all stakeholders, including infrastructure managers, researchers and commercial organisations, or other landowners with geohazard interests. The Oracle database has been adapted to incorporate a greater number of feature types, such as shafts, boreholes, dolines and springs, with a rapid search facility for data extraction purposes.

Lessons Learned

Some key lessons have been learned from February 2014:

1. The increasing storminess and reduced predictability of weather patterns has the potential to impact the occurrence of geohazards, including collapse subsidence features.
2. The 24-hour media underpinned by modern technologies further increases the demands on resources at times of increased incidences of geohazards.
3. The data requirements of our stakeholders extended beyond susceptibility mapping to database creation of actual events in order to

Figure 4b. Denehole collapse, Rainham Mark Grammar School, Gillingham, Kent. Photographs P Witney @BGS/NERC.

provide temporal information. This required the development of new data capture and delivery mechanisms.

4. Public awareness of BGS services has been heightened, as is evident in the ongoing number of “sinkhole” related enquiries. It is suspected that this is partly due to the reduction in local government funding, resulting in the public seeking new ways of addressing planning and building enquiries.
5. Increased interest from research students has continued, but is tending towards a focus on impact rather than process understanding, which will require further development of our datasets.

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References

- Cooper AH, Odling NE, Murphy PJ, Miller C, Greenwood CJ, Brown DS. 2013. The role of sulfate-rich springs and groundwater in the formation of sinkholes over gypsum in Eastern England. In: Land L, Doctor DH, Stephenson JB (editors.) Sinkholes and the Engineering and Environmental Impacts of Karst: Proceedings of the Thirteenth Multidisciplinary Conference, May 6–10. National Cave and Karst Research Institute, Carlsbad, New Mexico, 141–150.
- Edmonds CN. 1983. Towards the prediction of subsidence risk upon the Chalk outcrop. *Quarterly Journal of Engineering Geology and Hydrogeology* 16: 261–266. <http://dx.doi.org/10.1144/GSL.QJEG.1983.016.04.03>.
- Farrant AR, Cooper AH. 2014. A hole lot of trouble. *Geoscientist* 24 (6): 12–17.
- Farrant AR, Cooper AH. 2008. Karst geohazards in the UK: the use of digital data for hazard management. *Quarterly Journal of Engineering Geology and Hydrogeology* 41: 339–356.
- Pennington C, Freeborough K, Dashwood C, Dijkstra T, Lawrie K. 2015. The National Landslide Database of Great Britain: acquisition, communication and the role of social media. *Geomorphology* [In press, corrected proof] <http://dx.doi.org/10.1016/j.geomorph.2015.03.013>.
- Reviewing the 2013–2014 UK winter storms [Internet]. 2015. [Place of publication unknown]: <http://www.metoffice.gov.uk/>; [updated 2015 February 6; cited 2015 March 1]. Available from: <http://www.metoffice.gov.uk/research/news/2015/uk-winter-storms-one-year-on>.