Nottingham Caves Technical Guide

August 2025

LOCUS OSE consulting

Nottingham City Council

Funded by Historic England

Cover Photo: Mortimer's Hole, Nottingham Castle. Courtesy of Tracey Whitefoot.

Acknowledgements

The assistance of the following is gratefully acknowledged: David Grant of Deckchair Hairdressers; Graham Armitage at Wollaton Hall; Michael Goodchild and Lee Stevenson at Survey Hub; Scott Lomax at Nottingham City Council; Alice Ullathorne, Tom Street, Faye Sadler and Cal Warren, all formerly of Nottingham City Council; Tim Allen and Clive Fletcher at Historic England; the staff at Paul Smith headquarters Willoughby House; Dave Stretton and Allan Mather from Parks and Open Spaces at Nottingham City Council; Angelo Trivigno at Gigi Bottega; Lamar Francois photography; and Dan Brown at The Curious Venues.

Special thanks to Dr. Tony Waltham for his expertise and review of the document, as well as the reproduction of imagery.

Foreword: Cllr Hayes, Executive Member for Planning and Housing

Nottingham's caves are a defining feature of the city's historic environment, forming an extraordinary legacy carved into sandstone over the course of more than 1000 years. Nottingham City Council is committed to safeguarding this irreplaceable subterranean heritage, recognising the importance of the caves not only as archaeological assets but as a distinctive part of the city's cultural and economic identity. The preservation and sustainable use of the city's caves are a responsibility for owners, but also an opportunity.

This *Nottingham Caves Technical Guide* complements Policy HE2 (Caves) of the *Land and Planning Policies Local Plan (Part 2)* and sits alongside the *Management of the Caves of Nottingham Supplementary Planning Document*. Together, these documents form a robust framework for ensuring that caves are identified, protected, maintained, and, where appropriate, brought into new uses that respect their significance.

Through practical advice and clear guidance, this document supports those who own engage with Nottingham's caves—as owners or developers—in making informed, responsible decisions that help conserve and celebrate these remarkable heritage assets.

Disclaimer:

Caves may not be stable structures and should always be accessed with caution. The guidance in this document is given on the basis that cave owners have made their own investigations into the stability of the cave situated on their property and that the appropriate risk assessments are in place. Cave owners should seek appropriate advice, including professional advice where necessary. Nottingham City Council, Locus Consulting and OSE Consulting take no responsibility for any damage, incident, accident or injury that occurs to any object or person as a result of cave access instigated by this guidance.

CONTENTS

Introduction

Introduction

Nottingham has a unique collection of approximately 930 known sandstone cave systems. Whether a simple cellar or an ornately carved chamber, every cave in the city is significant in some way. As a collection they are internationally important, with some individual examples offered the highest levels of protection.

This guidance document provides a technical introduction to the key issues and opportunities associated with the use and conservation of Nottingham's caves. A growing number of owners and businesses are re-using their caves in creative ways and this guidance aims to facilitate the process of securing new sustainable uses for them.

A City of Caves

Ensuring caves are maintained and put to a use is important in ensuring they are conserved and enjoyed in the future. Those without a use are more likely to become redundant, neglected and potentially damaged or even destroyed.

Finding uses for caves can be a challenge, but beneath the city's streets and buildings there is untapped potential. Re-purposed in city life for use as gin bars, micro-event spaces, tourist attractions and wine cellars, the unique collection of underground spaces are experiencing a renaissance. There is need for both creative and practical thinking in how more caves can be accessed, used and integrated into city life with purpose. Caves require looking after too, and their sustainable reuse is actively encouraged.

The city's caves form an important part of its identity and tourist offer, and their appeal to the city's domestic and international visitors is forecast to grow. Increased access to caves, both physically and virtually, is a priority. Their conservation and enhancement now carry increasing weight in planning strategy and decision-making. New development above, over or adjacent to caves must account for the impact upon them, and that their sustainable re-use will be supported.

Some uses, particularly intensive ones, can present challenges to a cave's conservation, and this guidance highlights some of the key issues that need to be considered.

The suitability of potential uses should be evaluated by understanding what a cave can achieve in partnership with other caves, as well as in isolation. The approach is fundamental to enjoying the city's caves to their full potential and works well with how caves lend themselves to being experienced, often occasionally and for relatively short periods of time. The principle applies to many potential uses of caves, such as performance art, tours, and tastings. With around 930 known caves in the city, the options are endless.

CASE STUDY 1: Nottingham Caves Festival

The Nottingham Caves Festival aims to 'raise awareness of the city's unique heritage and provide opportunities to access caves that are usually closed to the public.' First established in 2016 by Nottingham City Museums and Galleries, the festival was adopted as part of the Nottingham Castle Project.

The project initially worked with established heritage partners, with subsequent festivals broadening their approach to include participation from city retailers and landowners with caves on their premises. In 2018 it was decided to adopt a headline event format, revealing a normally inaccessible cave to the public each year.

The festival programme features a wide range of events at various locations across the city, designed to showcase the diversity of Nottingham's underground resource. Previous years have included cave tours (including caves not usually open to the public), history talks and ghost tours, as well as more unusual events such as cave petanque, cave film screenings, art installations and yoga classes in the Park Tunnel.

Organisations involved varied from established museums and tour operators, to the council and small businesses. Individual owners and organisations were encouraged to produce and manage their own risk assessments and health and safety challenges, although in some cases an example risk assessment was provided by the project team. For some of the more extensive cave systems, such as Peel Street and the Catacombs, the Nottinghamshire Fire and Rescue Service assisted in undertaking risk assessments and rescue plans.

Volunteers played a key role during the festival, acting as cave stewards at entrances and exits, tour guides, as well as assisting with the planning and delivery of events.

Both free to enter and fee-paying ticketed events saw extremely high levels of popularity, with all but one event selling out leading to several events extended their programmes. The Yoga in the Park Tunnel event sold out before the event was promoted. The oversubscribed levels of interest in the Peel Street caves headline event in 2018, which had not been publicly accessible since the 1990s, prompted Nottingham City Museums and Galleries opening the caves on a regular basis for public tours.

It is hoped that the Festival will return to full swing, with more businesses, owners and organisations involved than ever before, building on the success of previous years and capturing the clear appetite for experiencing caves in Nottingham.

Peel Street Caves - Credit Lamar Francois

Using this Guide

This guide is divided into five-parts aimed at securing the long-term use and conservation of caves. Each part sets out helpful advice about the key considerations for using caves, with advice on where to find further information.

Depending on the circumstances, each part can be consulted individually or in succession as part of a process of bringing a new use to a cave. Once you've located a cave (Part A), understanding its characteristics (Part B), both in terms of its architectural qualities as well as its condition (Part C), is an essential step. The character of a cave will have a strong influence on the type and intensity of use that it can accommodate. Some caves are more capable of securing a use than others and enabling works can be undertaken, with some common examples discussed in Parts D and E.

In some circumstances planning permission for the development of a cave, including a change of Use Class, may be required. Other consents may also apply for works undertaken to protected caves. In the vast majority of instances, a permission is not required and works should be undertaken in accordance with good practice and guidance, examples of which are highlighted throughout this report.

This guide should also be read in conjunction with the Nottingham City Council's *Supplementary Planning Document - Management of the Caves of Nottingham* (2019) which provides further detail regarding the management of caves in the planning process.

A	**Locating Caves**
B	**Understanding & Recording your Cave**
C	**Condition**
D	**Using your Cave**
E	**Alterations and Maintenance**

A Brief History of Nottingham's Caves

The earliest reference of caves in Nottingham was from 9th century AD with King Alfred's chronicler Bishop Asser describing Nottingham as *Tiggua Cobauc* in the archaic Brittonic language and *Speluncarum Domus* in Latin. Both translate as 'House of Caves'. However, the extent of the city's caves and types of uses they were put to during this early period remains a mystery. Consequently, any evidence that might shed light on the early use of caves is highly valuable.

Few caves appear to have been cut for the purposes of quarrying, with Nottingham's stone too friable to be used in construction. Softer areas of geology were occasionally dug for building sand, such as along Mansfield Road. More often than not, caves were dug with a specific purpose in mind for the space created.

The earliest surviving material evidence for the construction and use of caves is Medieval. Fragments of 13th century pottery were recovered from a cave along Castle Gate and at Drury Hill. Early caves were frequently cut into the sides of exposed sandstone cliffs and sometime accessed via a building attached to the cliff face. Today, the arrangement can still be experienced at the Trip to Jerusalem and the Hand and Heart public houses.

Ye Olde Trip to Jerusalem, Nottingham

During the Medieval period caves were likely used either as domestic cellars or for industrial and commercial purposes. In houses they most likely were used for storing food and produce. Their relatively low temperatures and constant climatic conditions promoted them as the city's early fridges and larders, including as cellars by Nottingham's many pubs. There is an early record from 1244 AD of a cave being used for accommodation by two monks at Lenton Hermitage, but little further evidence until much later in the medieval period.

Caves were also put to industrial uses during the Medieval period, with their climatic conditions once again lending themselves to specific uses. Some of the most common uses were tanning and malting.

Industrial uses were often complex and required certain shapes and sizes of caves, occasionally leading to complexes of interlinked chambers. Malt kiln caves, such as those on Castle Gate, Bridlesmith Gate and Drury Hill, typically consist of a large circular kiln chamber (around 3-4m across) with adjacent caves used for the germination process and for storage in pits and on ledges. Descending deep beneath the surface, caves often contained well shafts to access water.

Nottingham's caves had a central and valued role in medieval life and influenced the city's industrial and economic development. A limited number of individual caves fulfilled more strategic roles as tunnels, providing important points of access and escape. Perhaps the most famous example in the city is Mortimer's Hole, which led between the base of Castle Rock to the castle's upper bailey. Some other tunnels and links still exist beneath the city, although most stories of connecting tunnels between cave systems are myths.

The majority of caves appear to have been excavated in the period between 1600-1900 AD. The city was expanding rapidly at this time, particularly from the mid-19th century onwards. Caves continued to be used for industrial and commercial purposes: many appear to have been increasingly cut beneath private houses for both practical reasons and for entertainment, but also for simple extra space within the very crowded city centre that Nottingham then was. Although many are utilitarian in character, some are highly architectural in form and layout, often including columns, buttresses, arches, pillars, and staircases. The features demonstrate that the cutting of caves had become an artform and had matured to support an industry of skilled craftsmen. A fine example are the three interlinked circular chambers beneath Willoughby House on Low Pavement, cut in the 18th century (See Case Study 2 below).

The most ornate of caves come from the 18th and 19th centuries, showing they were used to express status and perhaps even had ritual uses. Most, if not all, sit beneath high-status houses, forming garden features, and can include elaborate carvings worked into the sandstone. The most renowned was commissioned by lace-maker Thomas Herbert and features a huge carving depicting Daniel in the Lion's Den.

Daniel in the Lions' Den sculpture in a cave beneath The Park (Credit: Nottingham Post)

Few caves were cut beyond the second half of the 19th century except in exceptional circumstances. During World War II more than 80 were used as air raid shelters, including some that were purposely dug, with new passageways to connect them. In the years since, caves have found occasional uses, but only for few people. Over the course of the 20th century the trend was regrettably one of abandonment and loss, but the tide is now turning with caves finding new uses in city life.

CASE STUDY 2: The Caves of Nottingham Survey

The Caves of Nottingham survey improved understanding of the city's caves and is enabling greater virtual access into some of the city's caves. Laser scanning and photography of 66 of the city's caves and their associated buildings generated 3D imagery and video flythroughs that provide a remarkable insight into the unique underground resource.

Analysis of the results have raised understanding about the relationship between caves and their overlying buildings and surrounding infrastructure. The 3D images also allow for comparison of the morphology of caves, identifying variances and communalities in their design and construction so that their value as a group can be better understood and promoted.

The outcomes of the report are now an engaging educational tool enabling residents and visitors to the city to explore the city's caves via a dedicated app and desktop website (see Case Study 11).

Willoughby House Caves beneath Paul Smith on Low Pavement (Courtesy of York Archaeology)

Part A – Locating Caves

Identifying if you have a cave associated with your property is important step for many building owners and tenants in historic areas of the city.

Locating caves is useful as:

- Caves can influence the structural integrity of overlying and adjacent buildings and infrastructure
- The impact of development upon the significance of caves is a consideration in the planning process
- Caves are unique assets that can bring significant benefits for owners and businesses.

The guidance below provides some useful ways to understand whether a cave is, or is likely to be, associated with a property. The locations of many caves are known; however, many lie undiscovered. If you think there is potential for a cave to exist, there are some simple steps that can be taken to evaluate whether one is present.

OPTION 1: **LOCATION**	**OPTION 2:** **DESK-BASED RESEARCH**	**OPTION 3:** **SITE-BASED RESEARCH**

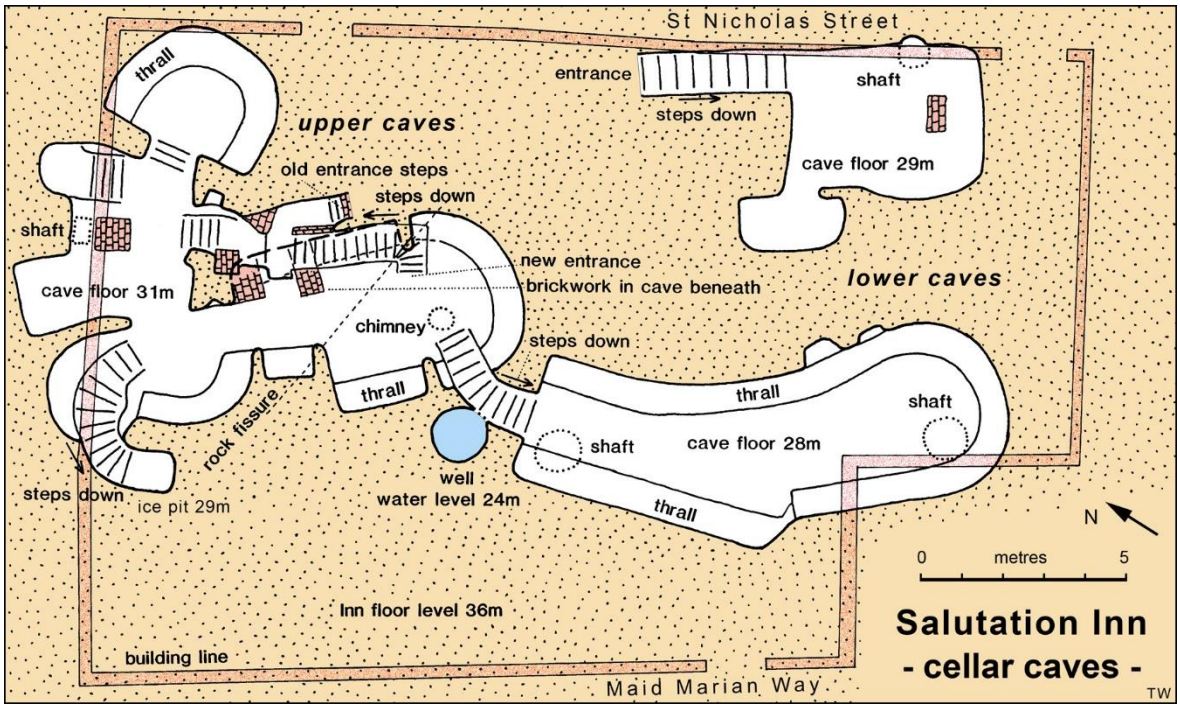
When is a cave a cave?

Passageway at Wollaton Hall cave

It's important to know what you are looking for. When is a cave a cave, and not just a cellar? Caves in the city come in many different shapes and sizes, and commonly are overlooked as cellars.

Whilst some may be simple rock-cut cellars, others are extensive complexes of chambers linked by passageways. For a space to be considered as a cave it must be cut from the bedrock and have, or once had, a rock ceiling supported by rock walls. There is no specific definition in terms of size, but the space should be large enough to comfortably accommodate at least one person.

The interrelationship between caves and buildings varies considerably, with most cut directly beneath a building's footprint, and others extending far beyond its foundations and plot. Typically, caves will be accessed from their attendant building via stairs from the ground floor or the basement. Additional points of access may also be from surrounding garden plots, rear yards and, in some instances, neighbouring buildings and caves.

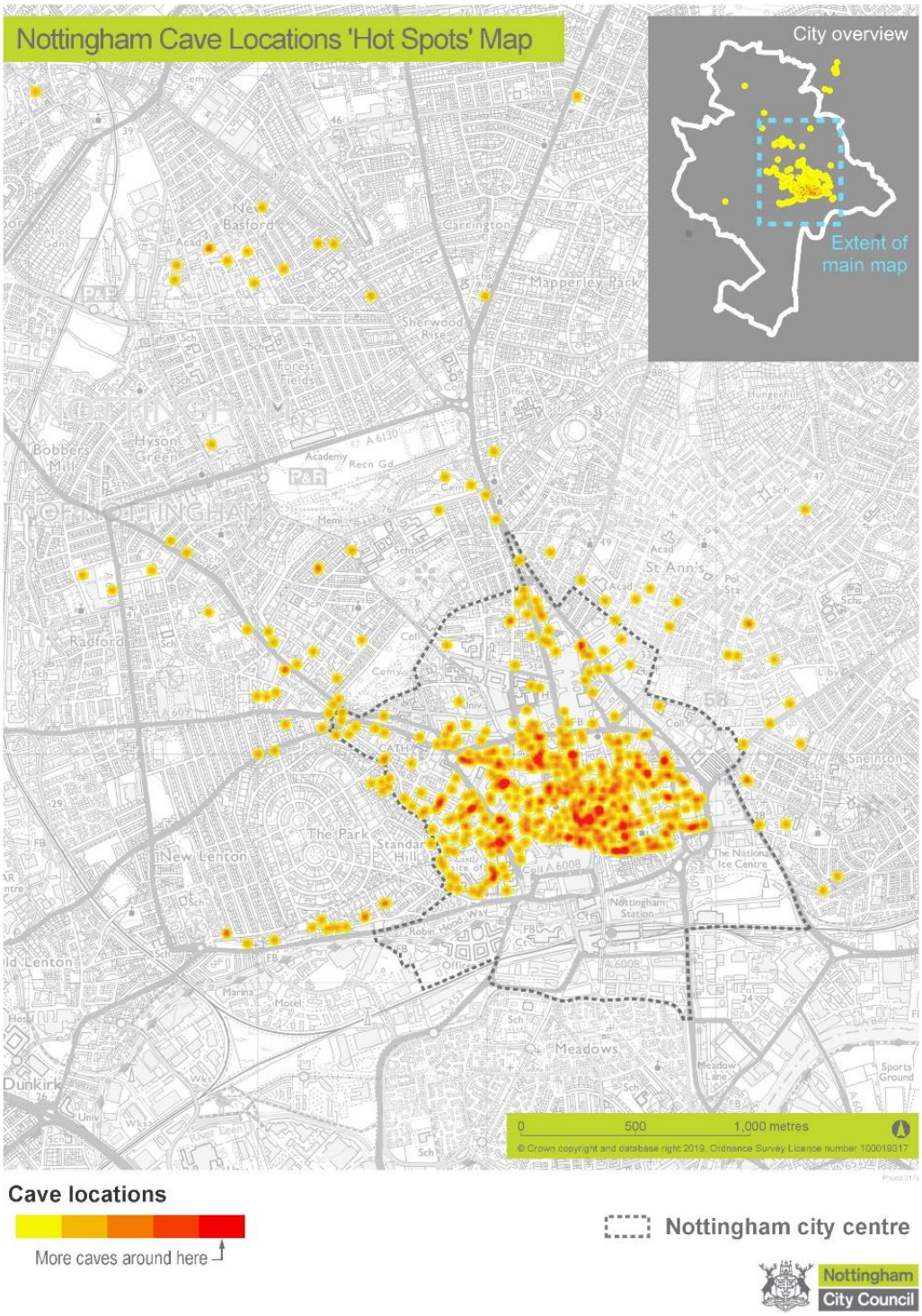


Plan of the caves under the Salutation Inn on Maid Marian Way. The different levels are indicated by the approximate floors' altitudes. There is another cave, currently inaccessible, beneath the frontage on St. Nicholas Street between the two mapped caves. Survey by Tony Waltham and Richard Storm. **(Credit: Tony Waltham)**

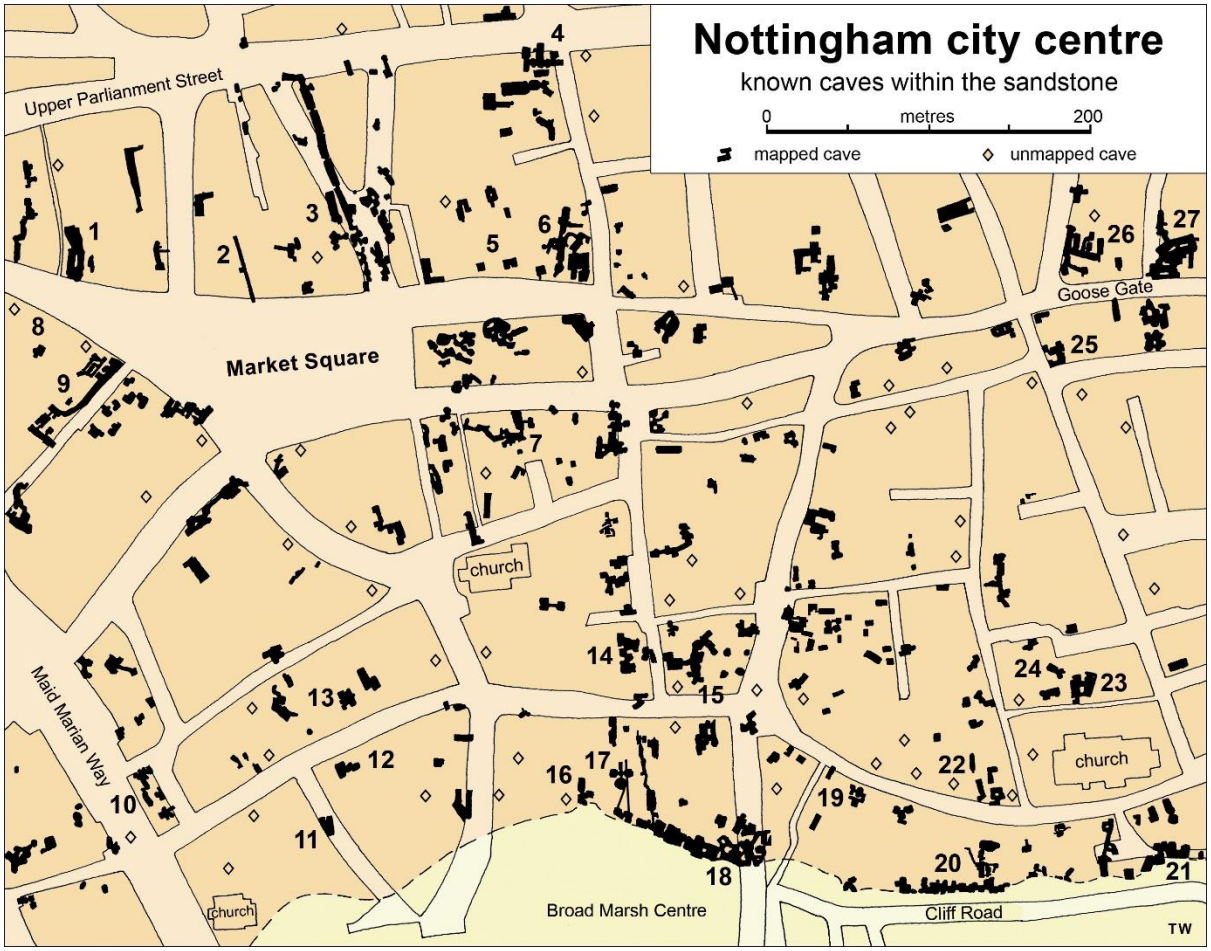
The older a cave, the more likely it will have two or more phases, having been re-cut, repaired or extended. Many caves have also been reduced in size or sealed off, most commonly with brickwork. Phasing can be easy to detect, where new man-made materials have been introduced, or much harder, where previous surfaces have been reworked or concealed. As such, exposed areas of rock within buildings that appear to have been worked may be traces of a former cave or an indication of a concealed cave.

Option 1: Location

Understanding where you are located in Nottingham, specifically in respect of the city centre and the underlying geology, is a useful starting point for understanding the location of caves. There are now easy to use resources available online that can be quickly consulted.



Heat Map of Caves in Nottingham city centre



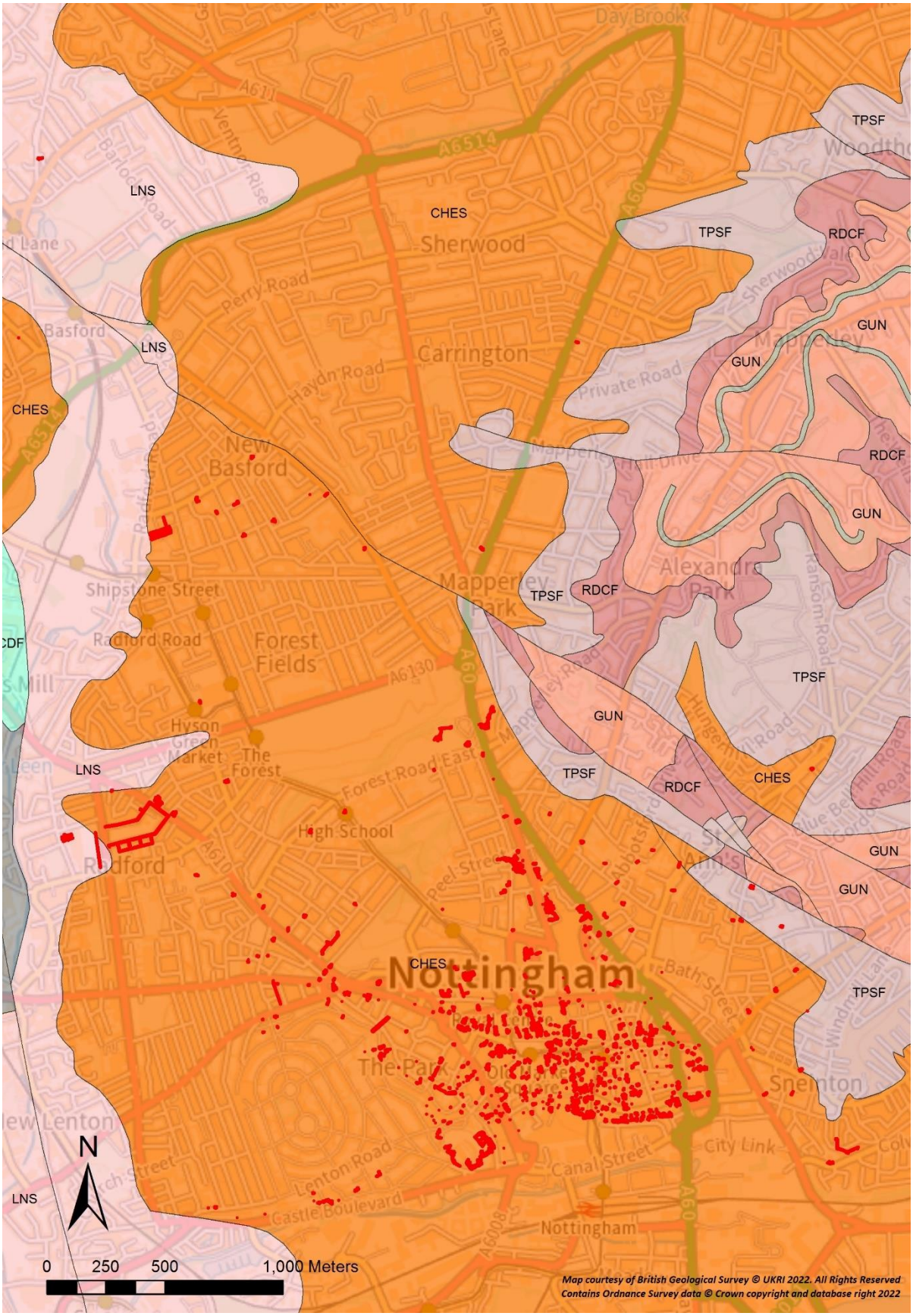
Some of the sandstone caves beneath Nottingham city centre (Credit: Tony Waltham)

Geology: Almost all the city's known caves are located in areas of Chester Formation sandstone, (formerly known as Nottingham Castle Sandstone Foundation). This rock unit occurs at outcrop, thereby forming the ground immediately beneath its thin soil cover. The extents of the sandstone in around the city centre lies between Lenton Boulevard and Radford Boulevard in the west, the Forest Road East cemetery and St Ann's in the north-east, and Sneinton in the east, as shown in Nottingham Bedrock Geology figure below.

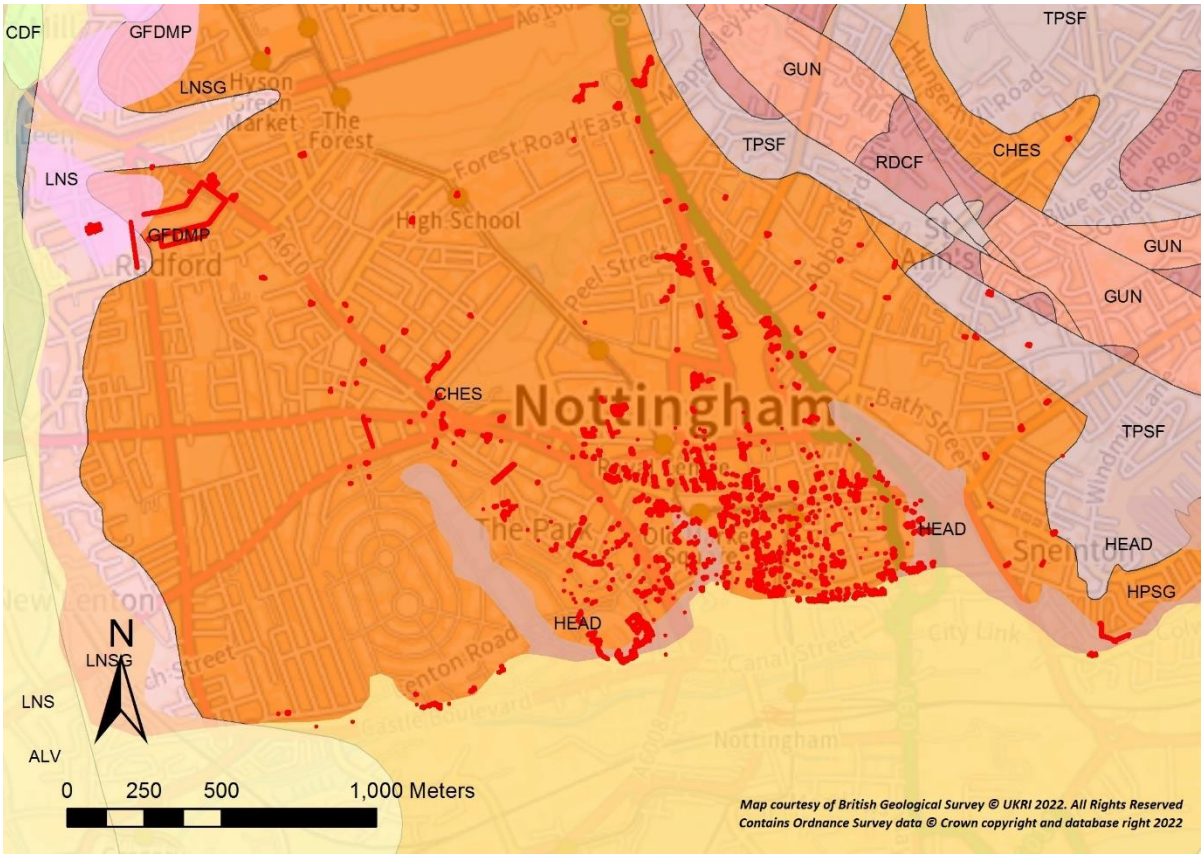
Caves do extend outside of this area, and beyond the city boundary, but they are relatively few in number. The potential for caves to the south of the city centre is constrained by geological conditions coinciding with superficial alluvial deposits, and likely corresponding higher water tables and softer rock. The extent of the alluvium can be seen on the Nottingham Bedrock and Superficial Geology figure below, which shows that caves only extend into the very fringes of this geological horizon. .

A lexicon of the underlying bedrock units marked on the bedrock map can be found on the British Geological Survey webpage at https://webapps.bgs.ac.uk/lexicon/.

You can check with the British Geological Survey to see if a building lies within an area of Chester Formation sandstone at https://geologyviewer.bgs.ac.uk/?_ga=2.176399653.1283934900.1663152590-446594215.1663152590.



Nottingham Bedrock Geology. Caves are shown in red.



Nottingham Bedrock and Superficial Geology. Caves are shown in red.

Historic Maps: Understanding the historical development of Nottingham and looking at its extents during the late 19th century provides a useful insight into the potential for a cave to exist. Caves are typically associated with parts of the city developed prior to the 20th century (1900 AD). As such, many caves are likely to have been associated with a Victorian or earlier building, although some early, and many later, caves were independent structures.

The easiest way to check if a site was developed prior to 1900 AD is to consult historic mapping, and the First (c.1882) and Second Edition (c.1899) Ordnance Survey mapping available online is a great place to start. There are several useful resources, including the City's mapping application https://maps.nottinghamcity.gov.uk/insightmapping/ as well as https://maps.nls.uk/geo/find/ and https://www.oldmapsonline.org/ which are amongst the easiest to use.

Early maps of the city, including Bankes (1609), Badder & Peat (1744), Dearden (1844) and Salmon (1861) can give further insight into when a site was developed, assisting with ascertaining the date of any underlying caves.

Looking at the date of a building currently on a site gives a useful clue too and may often be suggestive of an earlier date to some of the city's older caves. It is important to remember that a modern building may have replaced earlier buildings, and caves often still survive beneath them.

For any building within the area of the old town of Nottingham (between Upper Parliament Street and the flat land south of the cliff line through Broad Marsh then along Cliff Road (see the map on the previous page), there is a significant probability that there was once a cave. It may be open and accessible, or sealed off and inaccessible, or filled with concrete from subsequent development, or

totally removed by excavations prior to redevelopment. Within the old town, property owners should assume there is a cave until it is proven that there is not.

Option 2: Desk-based research

Desk based research can be a rapid or lengthy process, depending on the amount of information available and the appetite to examine it. The resources below are easily accessible and offer a quick and highly useful insight into the history of localised areas of the city, often on a building-by-building basis.

Historic Environment Record

The Nottingham City Historic Environment Record is the most complete mapped database of the city's known archaeology, including caves and cave systems, with approximately 930 currently recorded. Information recorded for each cave can vary from a few lines of text to significant amounts of information with links to detailed reports.

New caves are frequently being found in the city and their location mapped within the Historic Environment Record.

> ***Useful Tip:*** *Even if a cave is not recorded for a specific address or location, information about surrounding areas may provide valuable insight into the potential for caves to exist. For this reason, it is often helpful to broaden your search into neighbouring areas.*

The record can be checked for a small fee for commercial enquiries. To consult the Historic Environment Record, please contact the City Archaeologist at uad@nottinghamcity.gov.uk.

British Geological Survey

The British Geological Survey also holds a register of caves in Nottingham, but their data was mainly collected in 1989, and last updated in 2010. Their data, held within a Geographical Information System with associated data layers and a database, including maps and detailed indexes, has been incorporated into, and superseded by, the Nottingham City Historic Environment Record.

Local Archives

Documentary or archival research is key to identifying the location of caves and understanding their development and use. A considerable amount of work has already been undertaken through the Nottingham Caves Database and later research, however many resources remain untapped. The Nottinghamshire Archives has a huge collection of archived materials including historic building plans, deeds, conveyancing and ownership documents, census records, historic photographs and newspapers.

As discussed later, the way people have used a cave over time is part of its interest. Some uses of buildings may also increase the likelihood of a cave being present. For example, many public houses stored their beer in cave cellars.

The Nottinghamshire Archives can be accessed in person, or remote searches can be undertaken for a small fee. See https://www.inspireculture.org.uk/heritage/archives/ for more information.

CASE STUDY 3: Desk Based Assessment and Statements of Significance

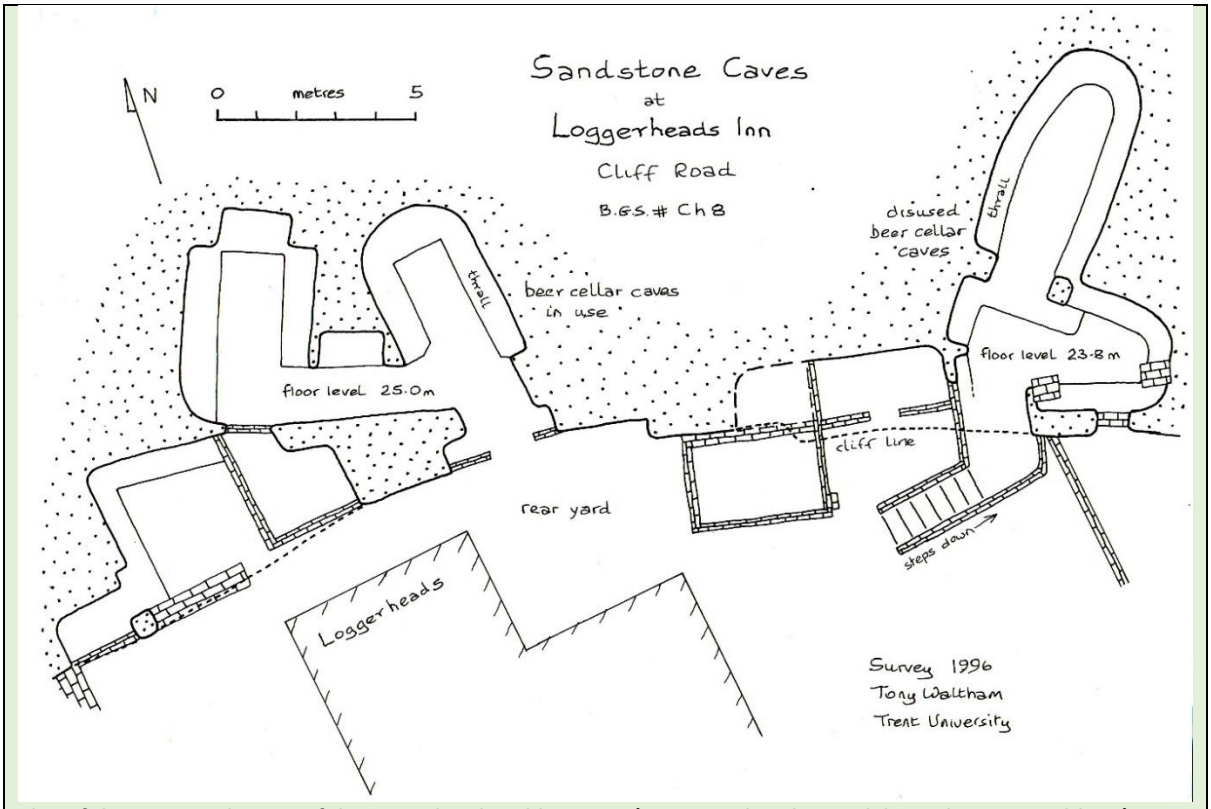
Gathering information through archival research is a proven way of evaluating the potential for caves, often providing positive results and/or enabling targeted on-site investigation. Where caves are found or know their heritage significance is evaluated to understand their architectural, historic, artistic and archaeological interest. So-called 'Desk-Based Assessments' are routinely undertaken as part of the planning process where there is potential for development to interact with caves on a site.

Under the Nottingham City Council's *Supplementary Planning Document - Management of the Caves of Nottingham* (2019) applicants are required to submit a Desk-Based Assessment for development on sites where caves exist or potentially exist and might be affected by the proposals.

In February 2020 York Archaeology was commissioned to compile a Statement of Significance (a type of Desk-Based Assessment), for a series of known caves associated with the former Loggerheads Public House at 59 Cliff Road, Nottingham, to inform a proposed development consisting of the refurbishment and extension of the former public house with the intention of creating 13 residential units.

The assessment consulted both the National Heritage List for England (NHLE) and the Historic Environment Record (HER), which revealed that there were 89 other cave complexes within the vicinity of the site, and that although associated with standing 18th and 19th century buildings, many had much earlier origins.

A variety of cartographic sources were also consulted, including the 1831 Staveley & Wood map, 1882 First Edition Ordnance Survey and the 1886 Goad Insurance Plan, to track the historical development of buildings on the site. The assessment consulted a series of documentary sources, both historical and contemporary, which revealed that a portion of the cliff collapsed in 1829, warranting site clearance the construction of the present building. Documentary sources also confirmed that the caves were historically used for the storage of beer, as was common for 19th century public houses in the city.



Plan of the caves to the rear of the Loggerheads Public House (survey undertaken and drawn by Tony Waltham)

The assessment deepened understanding of existing caves on site and the evaluation considered them to be of local interest with '*greater significance is derived from considering the complex as part of the wider network of caves, particularly those associated with 19th century public houses'* (Lobb, 2020).

Identification and analysis of the cave resources at an early stage enabled an informed approach to the design process, avoiding impact where possible. The assessment emphasises the value of consulting with the Nottingham City Archaeologist at the earliest opportunity, so that appropriate mitigation strategies for caves can be put in place.

A full copy of the report is freely available through the City Council's planning portal.

The National Heritage List for England

The National Heritage List for England is the official register of all nationally protected buildings and sites in England. It includes entries for listed buildings and scheduled monuments, and other designated heritage assets including world heritage sites, registered parks and gardens, protected wrecks and battlefields.

Information is easily accessible via an online map at https://historicengland.org.uk/listing/the-list. The results of a search will identity the existence of designated heritage assets on or within the vicinity of a building/site. Associated information such as building descriptions may divulge the presence of a cave.

Option 3: Site Investigation

A site investigation is most useful when undertaken in conjunction with desk-based research as it can help target your efforts and prepare for an inspection. Health and Safety is the primary concern for all site visits, so it is essential that you take time to complete a risk assessment and ensure that it is safe to proceed. If the structural stability of the cave is not known or could impact on any development in or above it, a geotechnical engineer should be consulted to ensure a cave can be entered safely.

Caves may be encountered when undertaking building or associated works or simply through performing a search of a property. Sometimes there is no evidence to suggest the existence of a cave, but very often there are tell-tale signs.

Site Investigation

If a cave does not immediately present itself site investigation may reveal some signs that one has previously existed or still exists.

If a building located within the area of Chester Formation outcrop (see Option 1 above) has a basement, there is an increased likelihood that an associated cave may exist, as lower lying rooms were often carved into the underlying sandstone. Accessing the lower floors of a property, as well as low-lying parts of any garden plots, may reveal evidence for caves.

Any exposed areas of sandstone incorporated within walls or floors are a strong indicator of an existing or previous cave. If sandstone is apparent in the ceiling, you are likely standing in one! Equally if sandstone is exposed in the garden plot of a property, there is an elevated chance of finding a cave.

Many caves and basements have been filled in with rubbish or dumped materials and subsequently blocked off by walls or floors. The roofs of caves may also have been purposefully removed or have fallen in, with floors reconstructed over the top of them. Comparing materials (e.g. the size of bricks) within the walls, floors and ceilings of a basement may show different phases of construction and can help identify the location of caves. Features such as doors, floor hatches, steps and bricked-up openings within cellars or ground floors may indicate the existence of a cave.

Word of mouth is also important, and the owners/occupiers of neighbouring properties may possess relevant information about a property or those within the vicinity.

If no physical signs exist, or potential caves are completely obscured by later finishes, other options for locating caves set out above will be of greatest assistance.

Caves Found During Ground Works

Caves are commonly found in the process of undertaking development works as well as minor works to ground floors and basements. Very often internal works to the lower floors of buildings and external groundworks within the city centre will expose sandstone bedrock as overlying materials are removed. If evidence exists (see Option 2 above) to suggest caves are common in the area, including within the site itself, works should temporarily pause to allow for a short phase of further investigation likely in the form of probing (see below). Exposed sandstone often forms part of a cave's crown (see Part C) and disturbing it or reducing its thickness can quickly have significant structural ramifications for both the cave and any overlying structures or land. If sandstone is exposed alongside dumped materials, then a cave may have collapsed and been infilled, or a blocked entrance has been uncovered. In all

scenarios, external advice (see Case Studies 4 & 10) should be sought before proceeding further, beginning with the City Archaeologist.

If uncovered in the process of undertaking development (i.e. works that are subject to planning permission) or works to a listed building, the City Archaeologist must be informed. Guidance within the Nottingham City Council's *Supplementary Planning Document - Management of the Caves of Nottingham* (2019) must be followed in conjunction with any associated planning conditions.

In some cases, caves beneath the property may extend under the highway (i.e., road and pavements abutting the property). In this instance the local highway authority should be informed and consulted.

Advanced Techniques

Where evidence suggests there is a good potential for an unknown cave to exist their presence can be confirmed with some more advanced techniques. However, there is no guarantee that a cave will be located during the process.

The only guaranteed means of determining if there is or is not a cave below a building or property is to probe into the rock with a sufficient number of probes This requires a hand-held pneumatic drill with extension steels that can reach depths between 3 and 5 metres at minimal cost, depending on the loadings of any structure above the cave. Such probing will be required by the Building Control Department within Nottingham's planning system, where any structural development is intended with foundations bearing on the rock within the cave-rich area of the old town. Probing is a standard and rapid procedure for locating voids beneath buildings, and local Geo-Environmental Consultants have developed equipment specifically for this process and can often be called out onto site quickly in order to verify whether a cave exists.

CASE STUDY 4: The Confetti Campus HQ, Nottingham Trent University

Built in 2018, Nottingham Trent's Confetti Campus HQ is now home to more than 2,000 creative technology students.

An Archaeological Desk Based Assessment undertaken by York Archaeology identified the potential for caves to exist on the basis of the site's location and historical activity upon it. Geotechnical and Environmental Associates (GEA) undertook initial ground investigation prior to demolition of buildings on the site however no caves were encountered. Due to its location within the city probing of the site on a tight grid pattern was recommended when access became available.

Following demolition, archaeological investigation of the site revealed layers of history, mostly believed to be Victorian and Georgian structures, alongside a hand-carved stone spiral stair capped with Victorian brickwork. Further investigation revealed the entrance to two connected caves and a programme of archaeological fieldwork was agreed with the City Archaeologist.

"Lying immediately outside Nottingham's medieval defences, the excavation has provided important new information about what was happening immediately outside the town up to 700 years ago. This site is the most significant to be excavated in the city centre in more than a decade." (Scott Lomax, City Archaeologist)

Once the archaeological survey was complete GEA returned to carry out probing works within and around the caves to check for additional caves. Probing was undertaken using a handheld compressed air rock drill in the caves and in areas that were not accessible to large machinery. The remainder of the site was investigated using a Comacchio Geo 305 rotary rig.

The discovery required a rapid rethink of the proposed piling methods for the building's foundations to ensure the cave was protected and that piles were embedded into solid sandstone. The piles supported a suspended ground floor slab that spanned over the caves. The caves were backfilled with Type 1 crushed concrete and excavated sandstone in preparation for the construction phase. The impact on the cave was minimised to the partial loss of a section of its roof and a supporting pillar.

Early engagement with the City Archaeologist and contractors, including York Archaeology, ensured a hard deadline for the completion of enabling works on site was met and the building programme for the £9.12m scheme was uninterrupted. Members of the public were engaged through information boards facing Lower Parliament Street, and the project offered a remarkable opportunity to raise the client's public profile, including through considerable positive press coverage.

Image Courtesy of York Archaeology

For more information see: https://www.gea-ltd.co.uk/the-confetti-campus-hq.html

However, it is important to stress that not only is probing expensive, but it can be a destructive process in itself, can lead to risk of collapse, and can lead to future issues, such as water ingress, . As such it should only be used where necessary and in accordance with the *Nottingham City Council's Supplementary Planning Document - Management of the Caves of Nottingham (2019).* Recent trials by the British Geological Survey show that geophysical techniques, such as ground penetrating radar, electro-magnetic surveying, and gravity surveying, may be viable non-destructive alternatives for cave prospecting that could reduce both risk and cost.

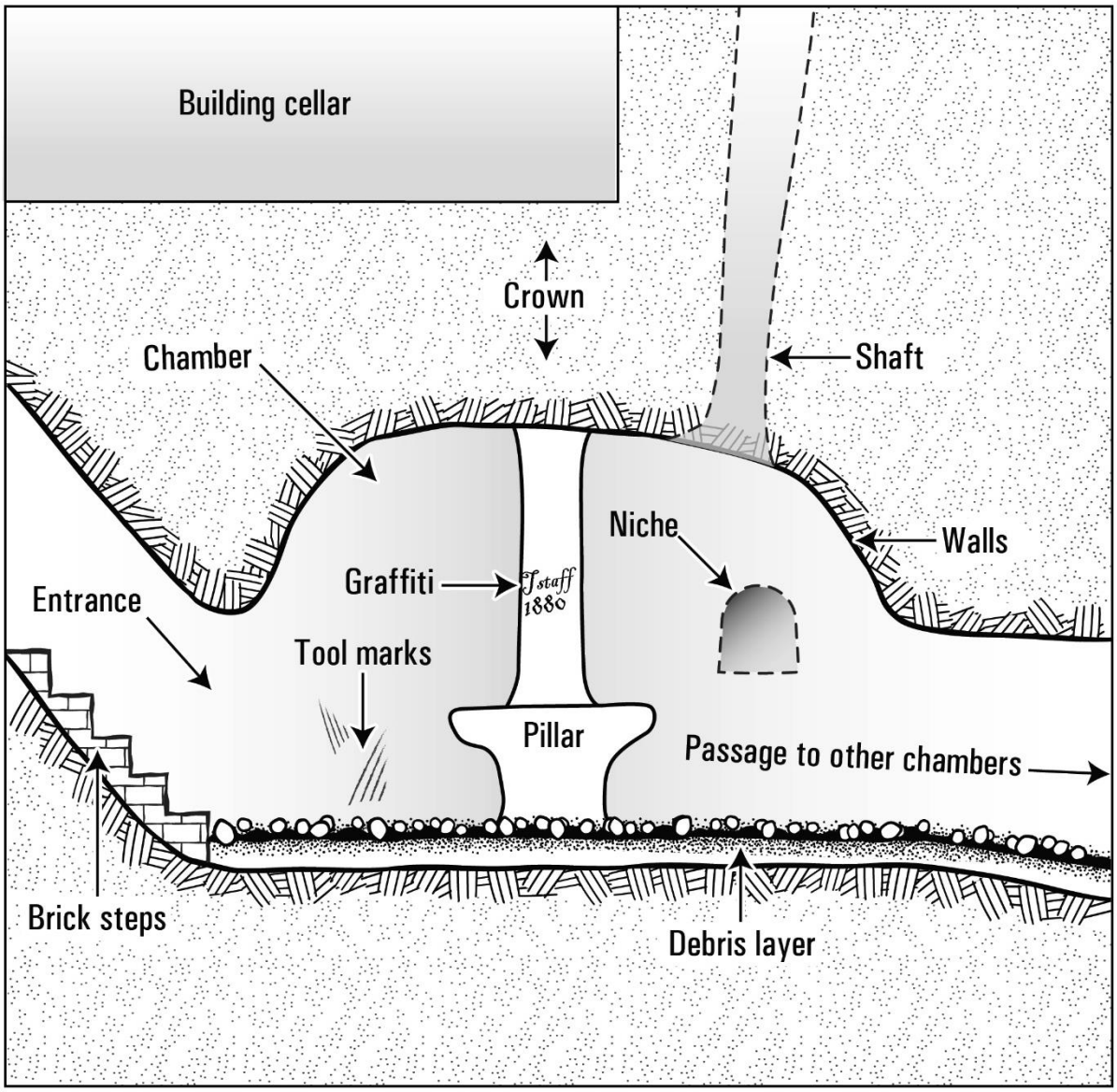
Impact of Cave Probing including localised area of spalling and later water ingress (Credit: Tim Allen)

Part B – Understanding & Recording your Cave

Caves provide a fascinating insight into the underlying geology of the city, but their value primarily lies in their heritage significance. Making a record of your cave can be an exciting undertaking and will almost certainly reveal something new and intriguing.

Reading a Cave

Caves are typically made up of a limited number of core elements, including one or more **entrances** providing access and/or egress to a cave **chamber** with rock cut **walls**, a rock **ceiling,** and a **floor.**



Illustrative Cave Diagram

The manner by which caves are accessed varies and, to some degree, dictates whether the cave fits into two loose types: those accessed from above and those accessed from the side. Access typically comprises a flight of cut stone **steps,** sometime replaced with brick, although some caves cut into exposed rock cliffs can be entered at ground floor level.

Floors are sometimes made of packed earth or brick above the rock surface to protect the soft, exposed, sandstone although bare sandstone floors are also well known.

Other entrances or exits might have specific functions, such as **barrel drops** for public houses, **shafts** and **chimneys**. **Windows** and **light wells** are less common, with the former only seen in caves cut into rock cliffs, such as at Castle Rock.

Many caves are made up of a single chamber with single point of access from ground floor or basement level. However, there are some highly complex **cave systems,** made up of two or more chambers linked via **passages** that extend laterally and **stairwells** that descend vertically. The most complicated systems known to date comprise up to 20 chambers on multiple levels and connecting passageways extending for around 150m. Vertical arrangements of multiple chambers can be linked by stairwells, and **tunnels** are often used to establish a secondary access, sometimes extending a considerable distance to establish an alternative route or connection. Tunnels may have been a means of escape or as a means of bringing bulky materials into a cave when access from above is restricted.

Smaller chambers are often entirely supported by their walls, but a few with broader spans incorporate supporting **columns** or **pillars**. Where carved from natural stone, these often-decorative pillars form part of a cave's original design, such as those beneath Willoughby House. Brick built columns are likely to have been added later, to provide additional support due to structural concerns or because a smaller chamber has been enlarged. A key element of a cave is its **crown**, comprising the thickness of rock between the cave's ceiling and the nearest overlying surface above.

Decorative **carvings** are rare and of high value, typically including sculptures, tables and embellished pillars. Many caves have functional features that are illustrative of a specific domestic, commercial or industrial use. Features include **wells, cisterns, coal chutes candle shelfs**, **wine bins, alcoves**, **niches**, and **ledges** cut in the rock. **Thralls** are a common feature and comprise a broad low-level shelf around the perimeter of the cave wall. More specialist features are of high value and include **tanning pits or vats**, **cess pits**, and **barrel drops**. Rarely, caves are entirely formed to fulfil single specialist functions such as the malt kilns under Castle Gate.

Kiln chamber within a malting complex beneath a building on Castle Gate (Credit: Tony Waltham)

Caves often have features associated with their construction, such as **carved or scratched initials**, **tool markings**, and **bore holes**. These latter features were used to ascertain the location or one cave in relation to another cave or the surface.

More information about the features of caves can be found in the book "Sandstone Caves of Nottingham" by Tony Waltham.

Evaluating a Cave

Identifying what is significant about a cave is a key step in making plans for its future. Understanding its construction, architecture, history and condition will be a source of understanding and assist in securing it a sustainable use.

Technical surveys can be commissioned but expert advice is not always needed. The value of basic approaches to recording significance should not be underestimated. Undertaking your own research into the significance of a cave is a useful process in identifying the preferred use of a cave.

Research does not have to be exhaustive and should focus on setting out some of the key aspects of the cave's architecture, as well as the history of the cave's creation and use. Specific surveys can also consider condition, structural integrity, maintenance needs, accessibility and environmental characteristics, some of which are discussed in Part D.

Articulating Heritage Significance

A cave's 'heritage significance' is best described according to a its architectural, artistic, historic and/or archaeological interest. The four terms are a useful starting point for setting out what is special about a cave, and a 'Statement of Significance' is a requirement of applications for planning permission and listed building consent when a cave is a material consideration in the planning process.

Architectural Interest

Architectural interest concerns the design and aesthetic of structures. As relatively rare man-made features, hewn out of the bedrock by hand, the shape and plan form of caves has architectural interest.

Many caves were created with a design in mind, for reasons of art and/or function. The layout and shape of caves provides insight into both the processes of construction and the rationale behind them. Varying degrees of craftsmanship can be detected in the way the cave has been sculpted out from the rock, with bespoke decorative and/or functional features of highest interest.

What to look for:

- Chamber form
- Staircases
- Tool marks
- Storage shelves
- Features which tell us about use or history (e.g. tanning pits, malt kilns)

Other caves, especially older caves, may embrace successive phases and can be weathered through use and natural processes. A limited number have a naturalised character. The phasing and age of caves can create a pleasing aesthetic, a patina that can only develop over an extended period of time.

Historical Interest

Caves are not only a material legacy. They encapsulate many centuries of Nottingham's history. Some are illustrative of the city's industries, such as malting and tanning, or form part of residential accommodation, showing the role they played in domestic life. Others are associated with particular individuals, including their owners and architects. A small number of caves commemorate legends, luminaries or specific events in the city's history, taking on a high communal value.

What to look for:

- Associations with important individuals (e.g. owners, architects, victors)
- Associations with events (e.g. Blitz, Civil War)
- Features or information which afford an insight into a cave's use

Historical interest is typically unearthed through desk-based and site-based research (See Options 2 and 3 above). What we understand about caves' historical interest animates them, bringing them to life and adding value to their architectural fabric.

Importantly, an understanding of the historical interest of caves affords them a collective meaning as a group, stimulating a sense of cultural identity amongst owners, visitors and the wider community alike, which is unique to Nottingham.

Artistic Interest

Elements of a cave may also have artistic interest, especially decorative features with expressive characteristics. Artistic interest manifests in human creative skills, with deliberately conceived elements of decoration or ornamentation, such as sculpture. Several caves in the city display remarkable artistic interest from small scale graffiti to artistic scenes, such as Daniel in the Lions' Den. Artistic interest is also evident in the design and craftsmanship of a cave's excavation, with round-arched roofs and doorways bestowing the caves an enchanting character.

What to look for:

- Sculpture (e.g. Daniel in the Lions' Den)
- Relief carvings
- Ornamentation with tufa
- Carved column/pilasters (table at Willoughby House)

Archaeological Interest

Archaeology is the interpretation of the material remains of past human activity, offering a unique understanding of how and when a cave was used. The most common and easily accessible remains with archaeological interest are objects simply left in the caves, abandoned when they fell out of use. These are usually quite recent in date, such as 19th and 20th century glass bottles and pottery, which, are the most common artefacts found. In rarer cases, air raid posters and signs can be found. Many caves are also used as dumping grounds, often for materials removed from the host building. Residual material may be of interest in understanding the relationship between the cave and building (or buildings) it was associated with. Dumped materials may also be mixed in with earlier archaeology relating to the cave itself. Older archaeology, including remains of medieval date, can also be found within the floors of caves. When adapted for new uses cave floors were often made up with mud, aggregate, sand and more recently cementitious materials,

What to look for:

- Tool marks
- Floor surfaces capable of concealing buried deposits
- Phasing
- Surviving artefacts

such as concrete. Materials introduced can conceal and preserve traces of earlier human activity. As such care should be taken when excavating floors and expert advice taken wherever possible.

Group Value

Once the heritage significance of a cave has been defined, think about how it relates to the wider landscape of the city and identify any connections that afford it a group value. Where relationships exist with designated heritage assets, such as conservation areas and listed buildings, group value is likely to be amplified.

The value of Nottingham's caves as an assemblage is of growing importance to the city. How one cave compares to another in terms of its architectural, artistic, historical and archaeological value is broadening our understanding of a resource that is unique to the city.

Caves share group value with other caves, buildings and structures in the city for many reasons. Many retain active relationships with their 'host' building, some of which are protected as designed heritage assets (e.g. listed buildings), offering the cave the same level of protection. Group value may also be through a shared location, such as the many caves in built into Castle Rock. Caves with common uses (e.g. industrial) and the same period of construction also combine to generate group value.

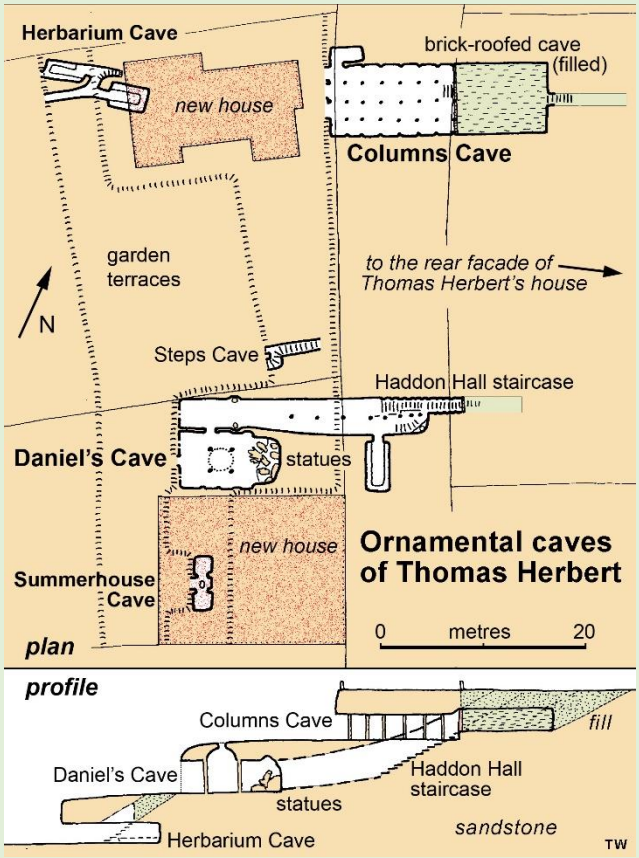
What to look for:

- Historic buildings within the immediate vicinity of the cave
- Heritage designations (listed buildings, conservation areas, scheduled monuments)
- Known caves with similar historical uses and/or construction properties, built around the same period in the immediate area and in the wider city.

The resources set out in Part B – Option 2: Desk-Based Research can help identify Group Value.

CASE STUDY 5: A Remarkable Group of Caves in The Park Estate

Considered by some to be the most spectacular caves in Nottingham are those excavated for Alderman Thomas Herbert, a wealthy lace manufacturer, and his cousin, William Herbert on the north side of the Park Estate in the mid-19th century. The series of individual caves were located within gardens and were accessed by a tunnel from his property on The Ropewalk.



Plan and profile section of Thomas Herbert's garden caves (Waltham A. C., The Sandstone Caves of Nottingham, 1992) **(Credit: Tony Waltham)**

Columns Cave is a rectangular rock cut chamber approximately 13m by 7m in plan and 3m high, open to its western end. The roof of the cave is carried on 3 rows of 6 square rock columns, one of which is replaced in brick, with relief panels and capitals. The walls are divided by similar half-columns, and between them figures and crucifixes carved into the stone.

Herbarium Cave comprises two rock cut chambers at different levels, each approximately 3m by 2m in size. Linked by a tunnel which is accessed from the garden by a gate, the western chamber has an open veranda looking out over The Park Estate. Perimeter ledges with pronounced raised and rounded edges may have been used for potted plants and the chambers were heated by a hypocaust.

Summerhouse Cave is a small grotto like cave with carved date of 1872. The chamber has a central font with animals carved in full and bas relief on walls and columns. Recessed walls are adorned with blocks of tufa believed to be imported from the Peak District.

Daniel's Cave (See also Case Study 6) is perhaps one of Nottingham's most renowned ornamental caves. The cave is 10m by 6m and is open to the daylight at its western end and via a rooflight set in a carved and ribbed dome roof supported by 4 columns. Within the rear wall, a near life-size scene carved directly from the bedrock depicts Daniel and the Lions' Den. Although the cave is

older, dating from about 1840, the carving is believed to date from around 1856. Attached, immediately north, is a passageway and flight of rock cut steps with pillars and balustrades carved in the sandstone adorned with niches and statues. The stairs are a copy from those at the stately home, Haddon Hall in Derbyshire.

All of the caves, as well as the Haddon Stairs, are Grade II listed buildings in their own right. Together they have incredible Group Value as an assemblage of ornamental caves associated with a prominent individual in Nottingham's history, Alderman Herbert. They now sit beneath the gardens of privately-owned houses and not accessible to visitors.

Rendered 3D Scan of Columns Cave (Credit: York Archaeology)

Making a Record

Our knowledge of caves to date is contingent upon records of their existence and character. Making and sharing even a simple record of a cave raises our understanding of the resource considerably. A record, including a plan, is an essential part of maintaining a cave and succeeding in finding it a viable use.

Measured Plan

A simple measured survey of your cave is a very useful task to undertake. A 'baseline offset survey' of your cave will enable you to accurately plot the outline of your cave and any features. The technique requires some basic equipment such as graph paper, two tape measures, a couple of tent pegs, and two pairs of hands. You can also measure and draw sections of you caves by taking height measurements. Taking a compass with you will help you orientate the cave too. The process is great fun and there are many videos online that explain the technique.

Plans can then be annotated with information about architectural features of interest (such as candle holders, columns, barrel drops etc), condition and services. Usefully, a measured plan will also assist in understanding the capacity for items to be introduced into a cave, such as furniture or even people.

Where possible, orientating the plan of your cave to the building above is a very useful thing to do. It can explain how a building and cave interrelate, and show the extents of the cave from above ground.

If you're able to measure height, then it can also help to understand the depth of the cave's crown. The process will also help identify if surface activity is impacting upon a cave and how this can be mitigated (e.g. drainage).

3D Laser scan image of Deckchair (Credit: SurveyHub)

Due to advances in technology, the general accepted best practice for creating a permanent record of a cave is to obtain a **3D Laser Scan** and resulting **point cloud**, as shown in the above image. This 'point cloud' effectively reproduces the extents of what is surveyed into a digital format, viewable on computers and applications once pieced together. The specialist process is now much more financially accessible and produces precise results that can be used for a variety of uses. These include dissemination online and producing sectional or plan views from the surveyed area. The process can also demonstrate the relationship between a cave and any overlying structures.

A previously carried out point cloud 'fly-through' of caves below Derby Road can be seen by visiting this link: https://youtu.be/tA0eNlfyi5E.

Photographic survey

A photographic survey of a cave is a useful exercise that anyone with a basic camera can undertake. Caves can be a bit tricky to photograph well and some simple equipment will make a big difference. Ensuring you have plenty of light is key, and multiple lights will help avoid shadows. Using a tripod will also significantly improve the quality of imagery in low light conditions. Placing a scale such as a ranging pole or, for smaller features, a ruler scale or similar, will assist in interpreting the content of photographs. If you can, an arrow indicating the orientation of the photograph should also be used.

Photogrammetry can also be used to produce 3D models. Free software and guides are available online. Although it is not as accurate as LiDAR, it is a cheaper alternative and can produce scale 3D model from a conventional camera or mobile phone

Photograph of tool markings at Wollaton Hall cave with 30cm scale and north arrow

Archival and Documentary Research

Discovering your cave's past uses will provide an invaluable insight into its historical interest. The first port of call will be any private collections of documents about the host building, and there's no substitute for speaking to people who have lived in or nearby the building for long period of time. See Part B – Option 2 for more guidance.

Documenting the Results

Creating a short and concise report is an important part of making a record and sets a benchmark for more information to be added. There is no strict format, but details might include:

• Property address • Location of cave and details of access • Scaled plans or otherwise • Photographs • Construction and phasing • Description of heritage significance	• Observations about condition • Services installed • Previous uses • Associations with other structures • Any designations that apply • References consulted

Don't forget to identify the author(s) too as you are likely to know the most information about your cave!

When a cave is a consideration in the planning process (see Part E for more information), the information gathered can be used to inform a formal 'Statement of Significance' that is required for applications for planning permission and listed building consent.

Historic England have produced guidance which can assist in creating Statement of Significance, which is available at https://historicengland.org.uk/images-books/publications/statements-heritage-significance-advice-note-12/heag279-statements-heritage-significance/.

Shared Understanding

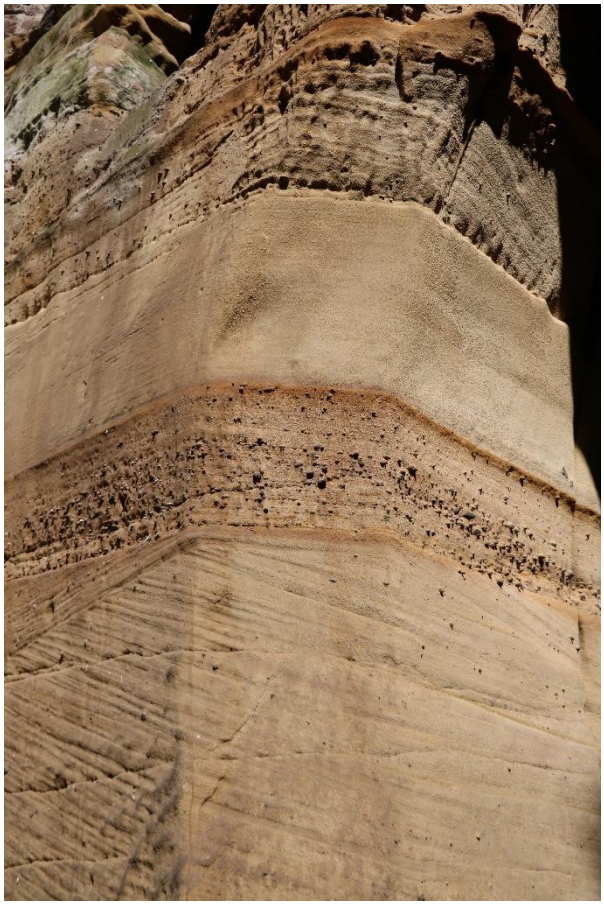
Current understanding of the city's numerous caves is very fragmented and sharing information about individual caves is essential to understanding the nature of the resource. The results of surveys can be shared directly with the Nottingham City Historic Environment Record and, if the cave is attached to a listed building, you can submit information to be included on the National Heritage List for England via https://historicengland.org.uk/listing/the-list/ .

Part C – Condition

Beyond the characteristics of your cave, establishing its baseline condition, be it environmental or structural, is vital in establishing its future use. A range of techniques are available, and some have been tested and pioneered in Nottingham. Technical surveys range from intrusive techniques such as probing to un-intrusive surveys (See Part B).

Geological Properties

The sandstone beneath the city possesses the ideal properties for cutting caves, and the bedrock geology was almost certainly a factor in the founding of the modern city today.



Sandstone geology of the Park Tunnel opening

Chester Formation

Nottingham's caves are predominantly associated with a Triassic sandstone created some 252 million years ago. Known as the Chester Formation, although previously called Nottingham Castle Sandstone, it lies within the Sherwood Sandstone Group. Nearly all the caves in the city are cut into this formation.

Key Properties

Nottingham's main sandstone, specifically the Chester Formation, is medium-to-coarse grained and is typically buff-grey in colour, with some pinkish red bands in a limited number of areas. The sandstone beneath the city has few joints, producing a consistent dependable rock mass. However, the rock sequence is broken by beds of more pebbly sandstone, mostly under 300 mm thick. These contain numerous rounded quartz pebbles measuring up to 50 mm across, as well as many flakes and lumps of mudstone ripup clasts that can become weathered to clay that range from 1 mm to 200 mm across. The clay-rich bases of these pebble beds form significant sub-horizontal weaknesses within the sandstone. Some cave roofs have broken or collapsed up to the pebble beds, creating profiles that are stepped away from the desirable stable arch, but the remaining pebble beds are generally stable. Most caves are cut into uniform sandstone with none of these troublesome beds.

The rock is characterised by its moderate intact rock mass strength and widely spaced fractures, which both enables it to be readily excavated or carved by hand tools as well as allowing it to support spans of around 5m. For this reason, the roofs of broad caves are often supported by pillars.

Due to its the low degree of cementing between the sandstone grains, it is friable and prone to erosion when exposed to the elements or even lightweight force. It is particularly susceptible to water, as even small increases in the moisture content of the sandstone can lead to significant reductions in strength. Undisturbed it will remain intact, and weathers slowly, as testified by the many caves around the city.

Most crowns of Nottingham caves have a thickness of between 1 and 3m, crowns less than 1m thick would likely have failed during the disturbance of a cave's excavation. Current building regulations

require at least 3 metres of solid, unweathered rock beneath any column bases or load-bearing walls. However, much thinner cave roofs are generally stable where they lie beneath lightly loaded floor slabs. While small scale roof failure is quite common in Nottingham caves, it has been noted that wholesale failure, leading to building damage or road collapse is very rare and almost invariably related to water ingress that weakens the sandstone.

Structural Condition

As with any building or structure, ensuring the cave is safe to enter and occupy is paramount. With most caves in Nottingham between 150 and 800 years old, it is important to have a structural and/or geotechnical survey undertaken before establishing a use and as part of an ongoing programme of maintenance. A geotechnical survey would establish the stability of the cave itself, and a structural survey may also be required for existing structures, such as supporting walls or pillars. Surveys may already exist, especially as part of conveyancing procedures.

Peel Street Caves (Credit: Lamar Francois)

An initial assessment is likely to come in the form of a simple visual inspection and, as with any property, caves should be inspected on a regular basis, using good lighting.

Initial considerations are signs of instability, failure and intensive erosion or weathering. The surface of caves will naturally exfoliate, as those parts in direct contact with the air dry out. However, the presence of fallen sand from the ceiling in concentrated areas may indicate disturbance of the cave face by water penetration or the beginnings of localised failure. Where there are small variations in geology, the intensity of weathering can vary accordingly, notably where flakes or slabs of red mudstone/clay within the pebble beds are wetted, softened and weakened. Although unsightly, the associated issues are unlikely to lead to structural failure.

Estimating the thickness of undisturbed natural rock above your cave, known as the crown, provides a good indication of its basic structural stability. In general terms, the depth of solid sandstone forming a crown should exceed 1m.

Technical Information
The unaxial compressive strength of Chester Formation sandstone typically lies within the 3.8 - 27.9 MPa range (5^{th} to 95^{th} percentiles), with a median average value (50^{th} percentile) of 12.5MPa, which is indicative of a low strength sandstone. The reason for this is the low degree of cementation between grains, which results in relatively high porosity (typically around 14% to 32%) and relatively low bulk densities (typically 1.97 to 2.46 g/cm^3) (British Geological Survey, 2020).

As is typical with weak sandstone, its strength declines between 20% and 60% when saturated. Typically, the sandstone recovers its strength in full when dried after a period of saturation (Waltham, T. The Sandstone Caves of Nottingham, 1992).

Strengthening

Caves that show signs of structural instability should not be accessed without taking professional advice from a geotechnical engineer, and structural engineer if appropriate. Weathering and signs of failure in the ceiling of the cave should be carefully monitored and treated with caution.

Timber, brick and cast iron/steel posts and pillars, as well as rock bolts have sometimes been incorporated into caves to provide additional structural support to the crown, walls, or openings. Due to the damp atmosphere of caves timber and metal are prone to rot and corrosion, and such features should be inspected with care. Rotten timbers at floor level covering openings and wells are a real risk factor when entering cave systems.

Methods that have been previously employed to address localised issues can have an adverse impact upon the fabric of a cave. For example, injecting strengthening fluid into stone can result in the superficially strengthened surface stone cleaving away from the unexposed substrate, resulting in the loss of significant areas of sandstone fabric. Cramp repairs introduce metals that can corrode in pre-existing damp conditions, and if these cramps expand sandstone fabric can be damaged.

Environmental Conditions

The majority of caves are well insulated from variations in weather, enabling them to maintain a relatively constant climate throughout the year. Exceptions include those caves that are directly integrated into living accommodation or exposed to external elements.

A basic assessment of a few aspects of a cave's environmental conditions is useful, and regular or even occasional monitoring will show how changeable or static the conditions are. This is important as it will show how responsive your cave is to external factors and will also assist in identifying the cause of any unusual activity.

Understanding the environmental conditions and regime of a cave will enable you to plan effectively for its use. Many caves provide ideal conditions for specific uses, such as the storage of wine and beer, with many pubs still choosing to store their barrels in caves.

Environmental Monitoring Devices
There are an increasing number of monitoring devices available on the open market that enable monitoring of a cave's environmental conditions including CO_2, temperature, and humidity levels. Many connect to WiFi networks enabling you to track changes in your cave's environment remotely and compare results with other cave owners. Together results would be of great value in understanding caves' environmental conditions across the city.

One of the principal reasons for understanding the environmental conditions of a cave is monitoring their health. Chester Formation Sandstone is bonded by cements which includes clay, and changes in the moisture content or rock are linked to surface decay and at times structural instability. The weakening of sandstone from moisture also occurs within quartz due to stress corrosion phenomena. Importantly, alternating conditions (e.g. phases of hot/cold, dry/wet) are understood to be detrimental to a cave, accelerating natural process of weathering.

Most of Nottingham's caves offer a very stable environment, with temperature and humidity that is almost constant year-round. However, this does depend largely on the caves being closed off behind doors. Any new doorway created into a cave has the potential of allowing the cave atmosphere to change with the weather, and the changes of humidity greatly increase wall decay (see Case Study #6 below). This is due the clay cement within the sandstone changing in volume and strength as it absorbs or expels water in response to the atmospheric changes. Any change of access to the cave therefore needs careful consideration of any implications. As Chester Formation sandstone is highly permeable, water/moisture ingress can also occur from above. As such, surface draining needs to be managed and water/sewage pipes, need to be maintained to prevent moisture ingress.

Monitoring

Environmental conditions that are useful to keep a record of include:

Humidity: Sandstone is a permeable rock, enabling water to percolate through at a slow and steady rate, forming as humidity in the air. Caves typically have high levels of humidity may influence items that can be used to furnish or be stored in a cave.

Surface Moisture: Percolating water, moisture in the air, and other sources of water will form on the surface of caves. This can be measured at certain points within the cave, both vertically and laterally, to understand localised conditions and issues.

Temperature: Caves maintain a relatively constant temperatures throughout the year but can fluctuate with the seasons or the heating of connecting living spaces. Knowing the ambient temperature of a cave will help understand its capacity for use, for instance how long people can be comfortably accommodated for.

Air Quality: There are often concerns about the quality of air in caves. Although pollution is not likely to be a problem, monitoring air quality for oxygen levels can be re-assuring and worthwhile. A relatively small reduction in the oxygen percentage can lead to impaired mental ability and can adversely affect others with pre-existing medical conditions. If in doubt further advice can be found through the Health and Safety Executive. Caves may be used for services, such as gas, so its good practice to ensure monitors are installed where necessary.

Air Flow: The flow of fresh air through a cave is harder to monitor, but research has shown that it has a strong influence on other environmental factors such as humidity, temperature and surface moisture. Detrimental levels of erosion to decorative features and cave walls have been reduced by regulating airflow.

Natural Growths: Many caves have natural growths on their walls such as algae, fungi and moulds. Growths can occur on any fixtures and objects in caves, especially wooden doors. The growths normally require some form of food source within their air, cave surfaces or deposited material (e.g. wood). Most are of no concern, but inspection by a qualified technician can be undertaken where necessary. A distinct lack of airflow in a cave may also

encourage some natural growths. The most common form of natural growth is around cave lights.

Natural growths within a cave ceiling close to its main entrance

Contamination

Historic uses of a cave may also impact upon its environmental conditions, and materials have the potential to be contaminated and/or hazardous to some degree. In many instances the materials in caves are inert and harmless.

Historical uses of caves include industrial or commercial processes such as malting and tanning, and residual deposits have the potential to be contaminated, although many are likely to be ancient and inert. Dumped materials are commonly encountered within caves and comprise a variety of waste materials some of which may be hazardous, such as broken glass and asbestos.

There is also some potential for surface contamination to leach into caves below. Historical land use records could give an indication if this is likely to be an issue.

Flooding

Flooding is unusual in caves, although caves that are close to the water table, such as those at Brewhouse Yard, are increasingly subject to ephemeral flooding during wetter periods and may only be seasonally accessible. In this instance water is likely to develop on the floor of your cave, with walls and the ceiling remaining relatively dry. Standing water in a cave will most likely relate to a burst pipe or damaged drain within close proximity to a cave, although natural springs can also occur underground such as at Wollaton Hall. The height of the water table can also contribute to standing water, such as at 8 Castle Gate, the Water Cave and the City of Caves. Water ingress will likely derive from a specific section or point of a cave's wall or ceiling rather occurring than uniformly across the cave. Understanding where domestic and mains water supplies as well as drains and sewers run in relation to a cave can be highly useful in determining the source of the issue. The impact from flooding, especially over a prolonged period of time can be catastrophic so it is important to act quickly.

Partial collapse of the ceiling of a cave at Wollaton Hall due to water ingress

Inadvertent water ingress

The vast majority of cave roof failures, either large or small, recorded over the years in Nottingham, appear to have been due to water input. Any significant saturation of the sandstone greatly reduces its strength. Most commonly it will then peel away from cave roofs, breaking away along closely spaced bedding planes that might be undetectable when the rock is dry. And the most common cause of water ingress is a broken pipeline, water main or drain. Any sign of failure therefore requires a rapid response that eliminates the source of water inflow. As the rock dries out, it will then recover most of its initial strength and stability. The water factor also accounts for the more frequent problems in caves that extend beneath gardens. The best way of ensuring a cave's stability is to have a building directly above it to act as an 'umbrella'.

Influencing Factors

Influencing factors are rarely associated with the cave itself, and where they are, such as localised changes in lithology, they are often uncontrollable. The form of a cave, particularly how it interacts with the external environment beyond, can be influenced, such as through the addition or removal of doors, partition walls, shutters or other features that control the internal environment, particularly air flow. Dumped materials also tend to retain moisture, raising humidity level within caves and restricting air flow. Providing it is not playing a structural role, its removal is generally to the significant benefit of a cave.

If a cave's environment experiences a rapid and unusual change, it is likely that exceptional external factors are at play. As a rule of thumb, caves that lie beneath buildings or impermeable surfaces are drier than those that do not, as rainfall does not percolate directly from the surface. The height of the local water table will influence the levels and distribution of moisture within caves, increasingly so with climate change. In principle proximity to infrastructure, such as roads and tramlines, can influence the stability of caves, although few issues have been recorded to date. Construction may also either directly or indirectly impact upon caves, often requiring bespoke engineered solutions account for the presence of caves (see Part E for more information).

CASE STUDY 6: Surface Erosion and Prevention

N.B. The below is summarised from the report 'Conservation of the cave statues in the Nottingham sandstone' (T. Waltham, 2006), with a full copy accessible at 972_mercianv16p4 (emgs.org.uk).

Daniel's Cave is one of a series of 19th century ornamental caves created as garden features for Alderman Thomas Herbert (see Case Study 5). In the late 20th century, it became clear that statues and wider cave, which has a doorway and window holes open to west, were suffering from erosion, with carved elements particularly vulnerable.

Previous research indicated that rates of sandstone weathering were directly related to exposure to outdoor weather, in relation to the nature of access and the distance of stone from openings. Research also showed how rates of weathering are associated with cyclic changes in atmospheric conditions, specifically those that induce wetting and drying of the weak clay cement that bonds grains of sands in the Chester Formation sandstone.

In response, the East Midlands Geological Society fitted wooden doors and shutters to the cave's openings late in 2005. The fittings aimed to reduce air circulation in and out of the cave in times of changing weather. Their frames were cut to follow closely the irregular rock profile of door and window openings, but did not provide tight seals, as a complete lack of air circulation can allow growth of mosses and fungus on the exposed rock.

Measurement of weathering rates after the frames were fit indicated that **weathering was reduced to around one tenth** of its rate before the doors were installed. Rates of weathering were measured by weighing sand grains caught in trays that had fallen off from a measured area of wall enabling a mean rate of wall retreat to be derived.

Monitoring Period	Weathering Rate (mm/year)
November '96 – March '97	0.110
March '97 – December '97	0.080
Doors Installed November 2005	
December '05 – April '06	0.005
April '06 – October '06	0.040
October '06 – December '06	0.002
December '06 – April '07	0.003
April '07 – August '07	0.007

Table 1: Weathering rates or rock adjacent statues

Additional measurements taken on a section of wall within the corridor cave leading to the adjacent "Haddon Hall stairs", further demonstrated that rates of weathering were reduced and that proximity to open-air entrances was an important factor.

Natural exfoliation of sandstone on an exposed cave ceiling at Castle Rock

Depending on the environmental conditions of a cave there may be a desire to change the regime in order to accommodate a use. The associated options and considerations are discussed more in Part E. Although limited published evidence exists about the short- or long-term impacts of environmental changes, the vast majority of caves will survive best when their natural environmental conditions are sustained and remain stable. As such, great care should be taken in deliberately changing the environmental regime of a cave.

Vandalism

Regrettably, many caves have been subject to various degrees of vandalism in the past. Their soft rock is receptive to graffiti and structural damage. Many decorative features have also been defaced in the past, leading to some owners necessarily restriction public access.

Controlling unwanted access to caves is an important part of their preservation. Those within buildings with public access may need to be restricted, and other exposed to the open air can be protected through the introduction of security railings or doors. Solid doors or hoardings can change the environmental conditions of a cave, for better or worse, so it is important that any new fixtures are designed around the cave's conservation needs.

Part D- Using your Cave

Every cave in Nottingham can fulfil a useful purpose. Most can accommodate some form of semi-regular use, however, due to their remarkable attributes, intensive uses are less common and even fewer are likely to be suitable for regular public access.

The appeal of caves as short-term event spaces is also increasing, with a growing number used for a wide range of activities that require short term and intermittent access. These vary from tastings, gigs and performances to the hosting of short films. Although ephemeral, the events have the chance to bring greater numbers of people in contact with a wider proportion of the city's caves.

Nonetheless, with many in private ownership, public access to caves remains highly limited, and only a fraction more are put to regular use. Many will likely continue to sustain simple uses such as for storage or remain vacant. As such, maintaining caves and attracting new uses that offer people a means of virtual and/or physical access, is essential to ensuring the full potential of the city's caves is realised.

Use is primarily driven by the characteristics of a cave and Parts A – D of this guide set out some important steps through which owners can familiarise themselves with their key attributes. Armed with the understanding, a number of suitable uses may present themselves and the solution likely lies in a blend of options.

Low intensity domestic uses of a cave may require few if any alterations, whereas commercial and or public uses of a cave will likely require some professional advice, enabling works and in some circumstances formal permission.

Establishing Uses

Each individual cave is likely to present its own challenges and opportunities which will influence the type and frequency of viable end uses. As such, it is useful to keep an open mind about what uses a cave might be capable of when drawing up ideas and undertaking preliminary assessments. It is important to recognise that many caves can be adapted in order to enable a use, and many issues can be overcome and mitigated with preparation and careful planning.

This guidance takes a four-step approach to identifying and establishing a use:

1	**Determine the Current Use**
2	**Identify Potential Options**
3	**Enabling Uses**
4	**Securing a Use**
5	**Resourcing**

Step 1: Determine the Current Use

Determining your cave's current use is an important first step. The Town and Country Planning (Use Classes) Order 1987 classifies uses of land and buildings into various categories known as 'Use Classes'.

You may need planning permission to change from one Use Class to another, although there are exceptions. If an application is required, planning policy is clear that heritage assets, including caves, should be put to viable uses that are consistent with their conservation.

However, as different requirements and building regulations apply to different Use Classes, some may be harder to practicably meet in caves. As such, if you are intending to change use it is worth understanding what any requirements will be and in turn whether the cave will be able to accommodate them. Planning permission is not required for maintaining an existing use.

Advice can be sought from the City Council's Planning Department or an independent building surveyor, structural engineer or architect. A guide to use classes can be found at https://www.planningportal.co.uk/info/200130/common_projects/9/change_of_use.

Step 2: Identify Potential Options

From scientific testing to gin bars, Nottingham's caves can find a wide range of sustainable uses. As caves increasingly re-find applications in the city, viable options will become clearer and more attainable. Although caves are adaptable, adhering to the principle that the use must be engineered to fit the cave, rather the cave engineered to fit the use is key to success. For this reason, creative uses that are able to work around the individual characteristics of their host cave are increasing, offering a greater diversity of options than perhaps previously considered.

As with any project, cost, timescales, viability and other factors will need to be considered. However, due to their idiosyncratic characteristics, there are a number of specific factors to assess when determining potential uses for a cave:

A. Access: The vast majority of caves have a single point of access that must be used to enter and exit the cave, although former entrances may have been blocked off or demolished. If an access becomes blocked, such as in the case of a fire, there is no alternative means of escape until the issue is resolved.

Some typically more intensive uses will require more than one point of access, to provide an alternative means of escape in the event of a fire or other issue. For this reason, caves with two points of safe access have a significant advantage and are able to attract a wider range of uses.

The location of access points is also a consideration, which in some cases may only be through private accommodation whereas others can be entered from gardens or the street. Notwithstanding, the undertaking of minor works and the introduction of simple safety protocols alongside managing the intensity of a use (see below) can quickly render a cave more accessible (see 'Enabling Uses' below).

Undertaking a simple access audit that identifies the pre-existing physical constraints of a cave, such as the number of entry/exit steps, head height restrictions, passageway widths, internal

changes in level, uneven flooring, trip hazards, the existence of handrails, and so forth, will establish any limitations at an early stage.

B. Intensity and Duration of Use: Consider the duration of time that a person may want to spend in a cave, accounting for its environmental conditions, and for how long this might be comfortably extended to enable a use.

How regularly a cave is used and the duration of a stay has a significant influence upon the ability to secure it a use, especially for non-domestic purposes. Minimising the frequency of visits and controlling numbers of visitors reduces risk and can assist with meeting regulatory frameworks.

C. Capacity: A number of factors govern the capacity of a cave, most obviously its size and shape. Additional thought must be given to the 'exit capacity' for people to leave the cave which is dictated by the size and number of exits. The ability for people to move around or 'circulate' within a cave is a key factor, in conjunction with any furniture, services or other objects required (e.g. lighting, wires, chairs and tables).

D. Appeal: Understanding what makes cave appealing can help broaden and sustain the number of uses it might fulfil. The appeal of a cave can be increased through understanding its heritage significance (see Part C) with its history forming a core part of its appeal. The appeal of an individual cave can also be increased by promoting it in conjunction with other caves, revealing their group value within an extended offer. For this reason tours of multiple caves may be a viable use for many of the city's smaller caves.

E. Condition: A change of use may bring increased footfall and wear and tear, much of which can be mitigated with through enabling works and guidance (see Part F). The potential impact of a change of use upon fragile and vulnerable features of caves, which are often of high interest, must be considered when new uses are introduced into caves.

F. Amenities, Services, Fixtures and Fittings: Many uses require basic service and amenities and these can typically be introduced to many caves (see Part F). Depending on their intensity, duration, and frequency, new uses may require additional amenities beyond a cave. The role of the host building and surrounding areas is key here, providing potential car parking, toilet facilities, catering and other amenities that can help secure a wider range of uses for caves.

G. Target Audience: Considering the interest and abilities of your target audience is also key. Regrettably many caves are challenging or even hostile environments for people with disabilities, and options other than physical access should be considered where this is the case. Target audiences may range from an individual homeowner to groups of school students and tourists, placing varying demands on a cave and their experiences within it.

CASE STUDY 7: Occasional Non-intensive Use

Forming part of a run of late 18th century townhouses along the north side of Derby Road that were converted into commercial and retail use at early stages in their lifetimes, Number 84 Derby Road reveals little of the remarkable caves that lie beneath the building.

Long term tenants Deckchair Hairdressing and Barbering advertise their salon as a relaxed, quirky and unique setting with Nottingham's famous caves beneath the floorboards.

The caves comprise a series of linked chambers accessed via a short stairwell directly off the shop floor. Beneath stone thralls and a barrel drop from above, showing that the building, or a predecessor, was likely used as a tavern at some point in its past. Usefully the cave has good quality brick steps, a handrail and key services (lighting and power) installed.

Accessed directly off the shop floor, the entrepreneurial team have been putting their caves to a variety of occasional uses since they set up shop at Number 84 Derby Road. From offering free access to the caves for any of their clients during the 2018 Nottingham Caves Festival to welcoming educational cave tours as part of the Royal Town Planning Institute Young Planners Conference, the salon has opened its doors to a varied audience of interest groups. The cave has also been used to film music videos and hosted a small concert as part of Nottingham Sofar Sounds, an initiative that brings live music to intimate places.

Images courtesy of Deckchair Hairdressers

Step 3: Enabling Uses

Following an assessment of potential uses, a number of minor works may be required to achieve a use. Planning permission is unlikely to be required, however it is important to consider Building Regulations where applicable.

Some uses will require significant works, such as structural alterations, extensions and new points of access. These are less easily accommodated but should not be ruled out providing there are significant public benefits in undertaking them. Such bespoke works will require the services of an architect, geotechnical, and/or structural engineer and will likely be subject to an application for planning permission. To this end it is highly useful to engage with the local planning authority at the earliest opportunity, with pre-application advice offering proven benefits. Works that can facilitate improved

access and use of caves will likely carry a strong and positive weight in the planning process if a permission is required.

Procedural Measures & Working Practices

Setting out a series of clear and formal procedural measures and working practices to support the use of a cave can significantly improve the prospects of finding and securing uses. Helpfully the measures are non-invasive, having little if any impact upon caves themselves.

Defining and, where necessary, agreeing a clear timetable for a cave's 'hours of operation' can assist in demonstrating the frequency of use, reducing the degree of risk associated with its use.

Formal inductions and briefings for visitors are an important part of the safe use of caves and can help in overcoming health and safety concerns and satisfying building regulations. The provision of personal protective equipment and/or measure to ensure it is worn is another simple way of enhancing a caves eligibility for certain uses.

Any venue accessible to the public should have the relevant safety and emergency protocols in place. Where necessary caves should be staffed by individual with the relevant training and expertise.

Improving Access

Ensuring a cave can be accessed, experienced and vacated safely is a key milestone in finding a use that satisfies the necessary building regulations and insurances. Single points of access can hamper the ability to introduce some new and intensive uses into caves, however physical improvements in tandem with procedural measures can reduce the associated risks. With a practical approach, many problems can be overcome easily enough.

Accessibility can also be quickly improved by undertaking minor works such as the introduction of lighting, handrails, removal of debris, and reinforcing worn surfaces, especially steps, with a suitable material.

The replacement of steps leading into a cave is common, with rock cut steps quickly becoming worn through use. New steps, often in brick, can significantly reduce the risk of trips and falls. However, their introduction can lead to the concealment of historic fabric and the reduction in the height of stair passages. By and large the benefits of increased accessibility outweighs the concealment of the original stone cut steps, but bespoke and sympathetic approaches should be taken.

Flooring

Flooring works are an important consideration and are often essential to accommodating a new use. Flooring can take the form of an 'additive change' (introducing a new floor surface) and/or a 'subtractive change'. The composition of any new floor surface should suit the environmental conditions of the cave as well as proposed uses.

Works to the floor of a cave can have overriding benefits, reducing trip and slip hazards alongside enabling even and more robust surfaces. Floors can also accommodate services runs, reducing trip hazards and the minimising the visual and physical impact of wall and ceiling mounted fixtures and fittings.

Porous flooring and the retention of a gap around the perimeter of all caves will allow the bedrock to breathe. In terms of surface finishes, inert natural materials such as brick paviours, sand and lime mortar mixes, stone and some synthetics are better options than organic and moisture absorbent materials, such as carpets. Care should be taken not to introduce materials that may chemically erode the sandstone, and advice can be sought from a specialist conservator if in doubt.

The removal of cave material to accommodate a new surface may result in the loss of historic fabric (e.g. earthen floors) which may have archaeological interest. As such its useful to consult a specialist heritage consultant and/or to undertake some investigative works. Importantly, ground surfaces of the cave and surrounding areas should be inspected for the survival of openings that can either be entrances to cave systems or the top section of hand dug wells.

Footfall results in the carriage of sand particles up through the host building, damaging decorative flooring. This can be reduced by simple measures, for example providing boot covers, doormats, the wearing of alternative shoes, as well as brushes or boot scrapers at the cave entrance.

Fitting out and Decoration

Above floor level, the fitting out of caves is generally discouraged as it changes the proportions and environmental properties of the spaces to the disadvantage of their long-term conservation. Use of surfaces finishes such as paint, plaster or impermeable finishes are unlikely to enjoy any degree of longevity due to the humid conditions and friable sandstone surface to which they are attached. Stud walls, partitions and other structures can be used to conceal the surfaces of a cave, but their impacts are not fully understood, especially as their introduction often inhibits monitoring of any effects. Metal or other ferrous fixings into the surface of the cave will deteriorate rapidly and often lead to localised areas of failure in the surface of a cave.

Services

Depending on the proposed use caves may require one or more services to be installed. A rapid assessment of existing installations coupled with the needs of any intended use is a useful undertaking.

WARNING!
Caves are sometimes the route of mains gas, water and electrical supplies and care should be taken not to disturb these. If in doubt, contact the relevant utility board for advice.

Fixed lighting is likely the most important service to enable access and use of caves. For ease and maintenance systems are typically connected to the mains and surface mounted. Dependent on use, electrical outputs may also be introduced in a similar fashion, avoiding the need for the use of extension leads that present as trip hazards when run across floor surfaces. Battery powered options are useful if only occasional access and use is required.

The types of surface mounting and fixing warrant consideration. As naturally humid environments, metal fixings can be subject to corrosion, and therefore the least active metals or plastic fixing should be considered. Buried plastic conduits and armoured cables can be easily incorporated within any improved floors surfaces, reducing trip hazards.

CASE STUDY 8: The Void: Immersive Experiences using Non-Invasive Services and Fixtures

Deep underneath Upper Parliament Street is a small system of caves that are accessible from the basement of escape room company Cryptology. While the many rooms of the old bank building have been put to good use housing a variety of escape room games, the sub-basement caverns have lain unused since the 1960s. That is until Nottingham-based theatre company Chronic Insanity were asked to take over the space and create a series of immersive and interactive experiences that fit into the existing atmosphere in the space.

The Void is the result of this invitation, a dedicated performance and exhibition space that will house the creative endeavours of Chronic Insanity, as well as other artists and performance organisations from the East Midlands and beyond. Films have been screened, plays staged, and interactive experiences produced that have all been designed to complement the environment of the caves, this initial season of work made possible with funding from Arts Council England. By utilising predominantly battery powered and waterproof lighting and sound equipment, and by using the stone benches and other features of the caves unaltered as the setting for each experience, an immersive and theatrical feeling is able to be reliably created in spite of the unconventional environment of the performance space.

In response to the cave being several storeys below ground, and therefore physically difficult to access for some audiences, Chronic Insanity have committed to having digital and on demand versions of every one of their experiences that will be staged in The Void available as an alternative to being physically present in the venue.

Performance at the Void– Courtesy of Chronic Insanity/Joe Strickland

With a series of successful test events, a planned opening to the wider public in early 2023, and a list of theatre companies, musicians, and artists wanting to use the space already forming, The Void is sure to be a unique addition to Nottingham's cultural scene and the only cave in the city currently operating as a consistent venue for live arts and performance. An architect-led scheme, with advice from the City Archaeologist, Conservation Officer and Historic England, led to a minimalist design approach. Physical works to the cave itself were relatively light touch, and largely comprised conservation and repair of parts of the sandstone steps with new part concrete part natural sandstone steps.

Credit: Chronic Insanity/Joe Strickland

Working with Environmental Conditions

Great care should be taken when seeking to alter the environmental conditions of a cave to enable a use, even for short periods of time. If a use doesn't fit the environmental conditions of a cave serious thought should be given to alternatives.

Issues of heating and humidity can usually be overcome through appropriate clothing and guidance issued in advance. Similarly, items stored or used in a cave should account for the environmental conditions, with synthetic materials offering significant advantages over natural options.

Working with seasonal variations in a cave's environment may also enable uses at different times of a year, and environmental monitoring (see Part D) can help identify the optimal periods for specific uses.

More information on changing environmental conditions is provided in Part E.

CASE STUDY 9: Mortimer's Hole Improvement Works

Mortimer's Hole is possibly the most well-known of Nottingham's caves; a long (98m in length) tunnel snaking through the sandstone outcrop beneath the Castle. A key part of Nottingham Castle's visitor offer, Mortimer's Hole has been open to the public through a guided tour since the early 19th century.

The historic ascent up Castle Rock has suffered from both manmade erosion and natural erosion over a prolonged period of time. Open to the elements at its upper entrance and floor, as well as through windows or balconies around the edge of Castle Rock, the soft sandstone has been exposed to the natural elements. Over the centuries wind, rain and snow have led to localised areas of deterioration, however the passageway remains of good condition. Since the medieval period human activity has led to localised areas of erosion, specifically to the route's 220 rock cut steps, most recently by thousands of enchanted visitors which have now mostly been replaced by concrete steps.

Stairs at the Castle – Courtesy of Tracey Whitefoot

As part of a programme of regenerative works funded by the National Lottery Heritage Fund grant in 2016, the former Nottingham Castle Trust manged a series of improvement works to the Castle's

caves in order to enhance their offer and ensure that the attraction could continue to operate at limited risk to both the public and the cave.

A number of health and safety considerations presented themselves as part of the project, including a lack of continuous handrail, poor quality and low levels of light and the location of associated cabling and service runs which were untidy and a possible trip hazard.

An architect-led scheme, with advice from the City Archaeologist, Conservation Officer and Historic England, led to a minimalist design approach. Physical works to the cave itself were relatively light touch, and largely comprised conservation and repair of parts of the sandstone steps with new part concrete part natural sandstone steps.

A freestanding, continuous handrail was also inserted, which features downlighting to the underside of the rail and space for concealing service runs for power and WiFi. Other sensitive lighting installations were introduced in certain areas where the handrail solution was less applicable. Importantly the systems provide integrated solutions for multiple issues, and are capable of easy adaptation in the future, offering the attraction an important degree of resilience. Unsightly surface mounted fixings have been minimised, enabling visitors to enjoy a more authentic experience.

Step 4: Securing Uses

Once viable uses have been identified a number of options are likely to have presented themselves, each with carrying requirements. To improve the accessibility and enjoyment of caves it is worth considering a blend of uses wherever possible. Advice from other cave owners can be usefully sought and the city council may be able to offer some basic initial guidance.

Where new uses are proposed, including a change of Use Class, and more involved works are needed, it is likely that some level of professional assistance will be required to ensure any proposal aligns with the relevant regulations. Typically, the process of satisfying such regulations involves mitigation, compromise and some practical thinking by all parties.

Taking Specialist Advice

Depending on the scenario a range of specialists can be engaged to help secure a use for a cave. In most circumstances, specialist input may only be needed from one or two organisations, ensuring costs are minimised.

Types of Specialists	**Services**
Building Regulations	Risk assessments. Advising on suitable often bespoke solutions to adhere to regulations.
Heritage Consultants	Locating caves. Archaeology. Planning permission, listed building consent, scheduled monument consent. Understanding the significance of caves. Impact assessments for development upon caves.
City Archaeologist	Locating caves. Archaeology. Understanding the significance of caves.
Architects	Developing concepts, plans and designs for the re-use of caves and associated property. Creative problem solving. Risk assessments. Applications for planning permission and change of Use Class.
Structural Engineers	Structural survey. Specification of remedial solutions. Engineering calculations. Building regulations.

Environmental Consultants	Recording and monitoring of cave conditions. Advice on mould or algae.
Planning Consultants	Changes of Use Class. Applications for planning permission, scheduled monument and listed building consent.
Surveyors	3D scanning of caves. Plans and drawings.
Health & Safety	Risk Assessments. Health and Safety Policies and procedures. Training.
Geotechnical Engineers, and Engineering Geologists	Assessing cave stability. Cave monitoring. Recommending and designing remedial measures. Advice on geology. Locating caves, through probing and geophysical analysis.

Risk Assessments and Rescue Plans

Risk assessments are an important tool in understanding the challenges of using a cave alongside some of the remedial works that can be undertaken to reduce risk. When you have a specific use in mind a use tailored risk assessment can flag up a cave's suitability and perhaps any measure that might be needed to overcome any issues.

Basic assessments can be undertaken by owners, but more complex caves and those that are subject to public access should employ a professional to complete a risk assessment. Specific detailed risk assessments should be undertaken for certain types of use.

Did You Know…?
The Nottinghamshire Fire Brigade provide an advice service and undertake site inspections. They are able to advise on the drawing up of risk assessments and rescue plans for caves and associated properties.

Assessments will flag up some of the key risks associated with the use of a cave such as slips and trips, low light, head height restrictions, fire, flooding, environment and air quality. The results should inform a series of minor works that can enable safer use of caves, such as signage, handrails and firefighting equipment. It is important that cave users are made aware of risks, through signage, inductions or other means.

Rescue Plans are pre-planned strategies or procedures designed to help safely retrieve someone who has suffered an accident in a cave or is trapped underground in a confined space. Rescue plans provide information about the type and location of equipment that are vital to any rescue process and an assist the emergency services in the case of an incident.

It is recommended that a geotechnical engineer and/or engineering geologist, with local knowledge of the Nottingham caves be appointed as part of the team when preparing the risk assessment for investigating the site for potential caves. A structural engineer may also be required if man made structures exist within the cave.

Insurance

If you are intending to put your cave to use, it would be sensible to consider Public Liability Insurance to protect you from claims by the public, compensation in case of injury, loss or damage to your property (cave) and any legal expenses. Every day and occasional use is likely to be included under your household or business policy, but it is worth checking for peace of mind. Enabling regular and public access, may require additional insurances, but the costs are usually modest and will depend on the frequency and type of use.

Legal responsibility

Caves are sometimes located beneath the confines of the property but are frequently known to extend under neighbouring properties, or even under the public highway in some cases. If the cave extends

outside the site ownership of the cave and legal responsibility for its condition and effect on the neighbouring properties will need to be considered. Legal Advice should be taken to determine liabilities.

CASE STUDY 10: LOST

The Lost Caves are located 8 metres beneath the Mercure Hotel on George Street, Nottingham's oldest Hotel and accessed from 'Lost Property', a secret bar above. The caves were initially encountered as a long bricked up tunnel and over 600 bags of rubble were removed, revealing a succession of chambers.

Lost Property, part of the Curious Venues group, chose to re-purpose the space as an exclusive boutique gin and rum bar bolted on to their existing basement bar offer. Brickwork salvaged from the clear out was used to build a bar to serve guests, and the underground spaces feature chandeliers, faux fur rugs and cushions on rock cut ledges.

(Credit: Curious Venues)

As part of bringing the caves into use the group faced some unique practical challenges and some key health & safety considerations needed to be addressed. Building Consents.com were brought onboard to offer and advice, developing a number of pragmatic solutions that, as a package, helped secure a use for the cave. Accessibility was improved with a new stair access with handrails introduced into the existing narrow entranceway. Mains and safety lighting were introduced along the passageway and via a barrel drop from the floor above.

Due to limited access in and out, the caves needed to be regulated in order to minimise risk. Occupancy is strictly controlled, and the caves are only open to regular access on Fridays and Saturdays limiting the intensity of use. However, the underground space is available for private hire during the remainder of the week.

To regulate access, entry to the cave is via a locked door with CCTV, enabling trained bar staff to greet guests in person and provide them with a short induction when descending into the bar area.

Identifying hazards and protocols en route, the process increases the mystique and adds further intrigue to the visit.

Suitable risk assessments and rescue plans were put in place, accounting for eventualities that might occur both within the caves themselves as well as those spaces that connected with them above.

The bar was a useful model, requiring the introduction of limited services to expand an existing model. The attraction also enables enjoyment of a short to medium term stay by punters, who can move to other less enclosed and warmer areas of the adjacent bar Lost Property above according to their own comfort zones.

Development & Permissions

Many works undertaken to caves or in their vicinity do not require planning permission. However, changes of Use Class (see Part E: Step 1) and more substantial works that amount to 'engineering works' may require one or more permissions. If your cave is a Listed Building and/or Scheduled Monument, then the relevant consent will be required from Nottingham City Council and/or Historic England respectively. The absence of a formal designation does not mean that the cave is not significant enough to merit one, especially as many have never been assessed due to their difficulty in accessing them.

Development can be positive for caves, assisting in their conservation, improving access and enabling research into their significance. Equally, development on or near a cave can have negative impacts upon it, reducing access or causing structural damage. Where impact occurs it will be considered in the planning process according to the relative significance of a cave affected.

Nottingham City Council's *Supplementary Planning Document - Management of the Caves of Nottingham* (2019) has been prepared to provide further detail regarding the management of caves in the planning process. The policy will be a material consideration when assessing planning applications or offering pre-application advice, and applicants and their agents are expected to do likewise. http://documents.nottinghamcity.gov.uk/download/7513

CASE STUDY 11: Engineering Solutions to Retain Caves

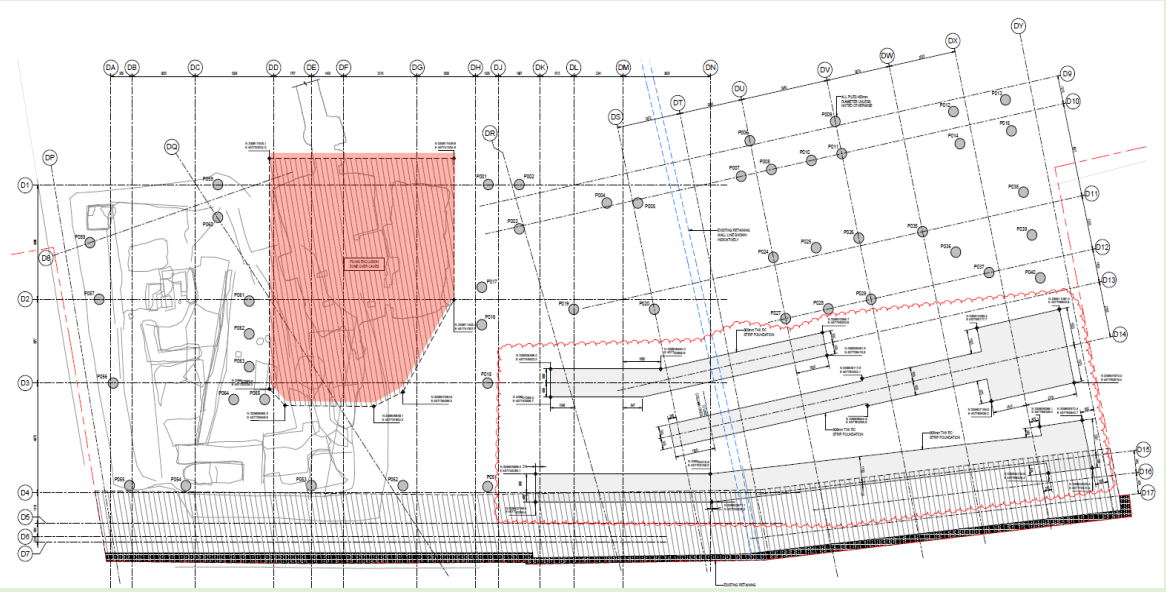
An application was made for 117 apartments with basement car park by Abode Nottingham Ltd at

Numbers 9 - 10 Short Hill And 54 - 56 High Pavement, a prominent position on the Lace Market Cliff. The rear boundary of the site is formed by a brick/sandstone wall that adjoins Malin Hill, an historic route into the early Medieval settlement. The elevated sandstone outcrop has a high potential for caves with one, accessed from Number 56 High Pavement, located within the site itself and several others along the outer edge of the escarpment.

A previous scheme, which would have destroyed the cave in the site, was granted planning permission in July 2014. The permission lapsed and a revised scheme was submitted by Abode Nottingham. Concerns raised by the City Archaeologist, and by statutory consultees Historic England, led to the reduction of car parking provision and the re-engineering of parts of the scheme to enable retention of the cave within the site. Furthermore, the changes enabled retention of the majority of the wall of Malin Hill, a structure of archaeological significance.

A new piling strategy and system of cantilevered, ground and transfer beams were designed to avoid and minimise impact upon the cave as well as the Malin Hill wall. Cave probing was required

to a depth of 6m all foundations including 1 vertical probe at each pile location and 5 probes from the underside of all pad foundations, one vertical and four at 45-degree angles from each cast face.



Piling plan of site with exclusion zone over the known cave within the site

Archaeological excavations conducted by the University of Leicester Archaeological Services down to impact level exposed the original cave entrance.

Initial concerns raised by the City Archaeologist and Historic England regards the development's impact upon caves were overcome, with objections removed in respect to Nottingham Local Plan Policy BE15 - Archaeology - Caves.

Virtual Access

Many caves have restricted access or limited capacity to support anything more occasional access and use. In such circumstances, a cave's potential is not lost, but can be captured through survey and recording, the results of which can be accessed virtually. The benefit of this form of access is that all caves are eligible. Moreover, and the ability to experience them virtually highlights the group value of the resource, to the benefit of all caves whether physically accessible or otherwise.

Previous research, new survey techniques and established platforms for hosting digital information mean that the process of making a cave accessibly virtually is now straightforward and cost effective. Basic techniques, such as **photographic recording, film** and **site-survey**, can be undertaken by owners and are crucial first steps to establishing a basic level of accessibility. Some more advanced techniques that owners may also be able to undertake includes **3D photogrammetry**.

Other more advanced techniques include forms of measured survey, such as **3D scanning.** The results are compelling and achieve a remarkable level of immediate accessibility to a wide range of users. The costs of undertaking scans have reduced considerably in recent years and a number of survey companies in the city now offer it as a standard service.

Once captured, information can quickly be made accessible in a number of ways. The city's Historic Environment Record is a publicly accessible resource that includes a record of all known caves in Nottingham. Information about caves, including descriptions, photographs and digital information,

can be submitted and housed free of charge. Surveys and 3D scans can also be explored virtually on the Nottingham City Council Caves Map website, with some surveys rendered into short 3D videos.

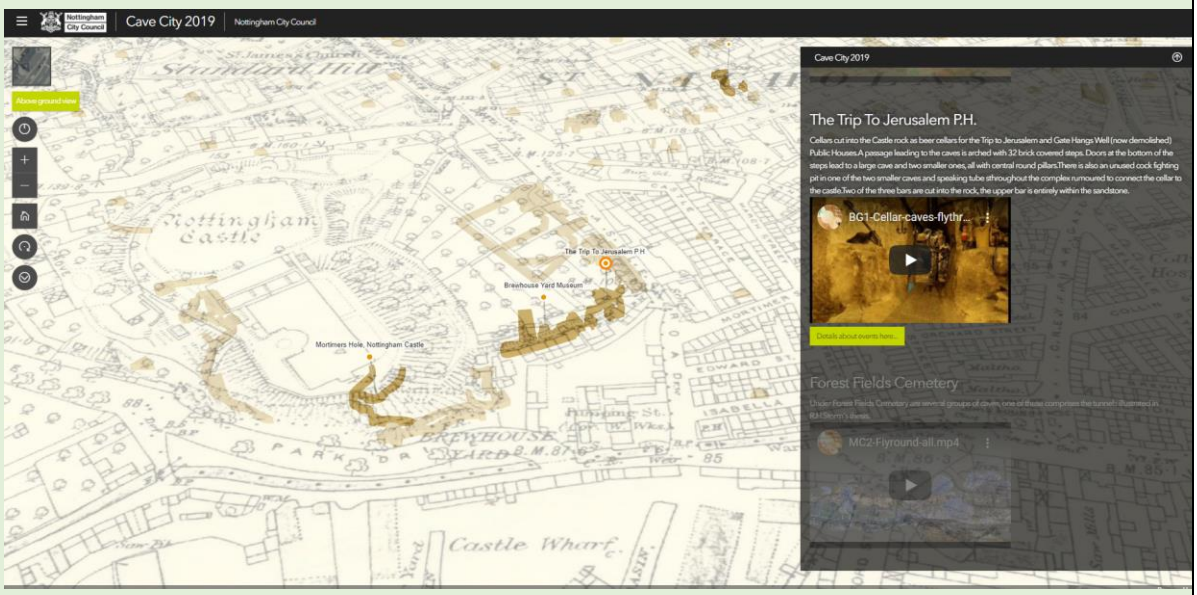
CASE STUDY 12: Nottingham City Council Caves App and Online Map

First released in 2014, the Nottingham Caves App aimed to showcase Nottingham's caves and encourage people to explore the city's one of a kind resource from above ground.

The app, developed by HotKnife, features a Top 10 Caves trail, taking the visitor on a 3-mile walking tour of some of the city's highlights, designed to give special insight into the underground caves. Using state-of-the-art archaeological scanning technology, the app enables unprecedented levels of access into Nottingham's caves, including flythrough videos and 3D modelling. Users are able to visit caves virtually, many of which are usually publicly inaccessible, and explore photographs, panoramic views and historical information.

There are hopes to refresh the mobile app, however, the web app is available via any online web browser, with all of the resources provided in up-to-date mapping of cave locations within the city. When accessed this way, the user is also able to view historical mapping of the city in conjunction with the caves, giving an insight into how they existed over 100 years ago.

Both the mobile and web apps allow users to navigate the cave systems as if they were there, creating a unique visitor experience, including for people who might find a cave otherwise inaccessible.



To access the website, visit: https://geoserver.nottinghamcity.gov.uk/caves/

Step 5: Resourcing

May non-intensive uses of caves will require few additional resources beyond the initial set up phases, however regular monitoring (See Part D) is good practice for all caves and is useful to understand if a new use has altered the conditions within a cave.

More intensive uses of caves, in particular those that require regular access are likely to require more resources. Enabling public access, including through events, can require relatively higher levels of

resources, both in preparation and during periods of access. Although the idea of opening up a cave can be daunting, there are many resources that can assist and the hope is that more caves will come into use as skills, knowledge and capabilities are shared.

A Caves Community

With over 900 known caves in the city there is a large community of owners, tenants, businesses and interest groups with an interest in caves. Some of the key groups in the city include the Nottingham Historical and Archaeological Society, East Midlands Geological Society, Nottingham Young Archaeologists' Club, the Nottingham Civic Society, and The Throroton Society of Nottinghamshire. Although more caves and information about them are increasingly coming to light, there is a pressing need for cave owners to share knowledge, trade experiences, and share resources so that the resource can be promoted in an ever more informed and creative ways. Through the caves festival and other initiatives it is hoped that cave owners and users will come together to promote a very unique part of Nottingham's culture to the benefit of all those with an interest in city life.

Many of the city's premier attractions feature caves, and many more have begun the journey of opening up their caves to the public. If shared, the diligence undertaken to date can be shared and built up, enabling more caves to open up in the future.

Volunteers

Thankfully there is a willing cohort of volunteers who are able to facilitate events and increase knowledge and understanding about caves in the city. The Nottingham Caves Festival relied upon the hard work of volunteers for some events to provide inductions, tours, storytelling and ensure that events could operate safely. For reasons of safety and practicality the ratio of volunteers to visitors for events in caves is often low, requiring greater numbers of trained hands. Nonetheless, opportunities to volunteer for some events during the Caves Festival were oversubscribed, and as access to caves broadens it is hoped that many more enthusiasts will be able to assist in showcasing the city's caves.

Part E- Alterations and Maintenance

The vast majority of caves need only minimal basic maintenance, but some simple steps can help ensure a cave remains in good condition. A basic level of monitoring of your cave (see Part D) and the conditions within it can also identify issues early and avoid irreversible damage. Common considerations and some of the typical works undertaken to address them are discussed below according to some key subheadings.

Common reasons for Alterations	Basic Maintenance
• Structural stability • Dumped materials • Weathering and Exfoliation • Installing services • Mould and staining	• Clearing debris • Cleaning • Monitoring • Altering environmental conditions

Alterations

Many caves have survived relatively unchanged for many centuries, although their extension and alteration has occurred, especially in the oldest examples. Any changes to a cave must be judicious and primarily undertaken to facilitate a use and/or its conservation.

Structural Alterations

Physical changes to the walls, crown, entrances and floors of a cave are likely to have structural implications. Above ground, proposed alterations to buildings above or adjacent to a cave may change the loads exerted upon caves. New development over or in surrounding areas may also impact upon the structural integrity of a cave through disturbance or through placing additional loads upon a cave. In these cases, a geotechnical engineer or engineering geologist should be appointed to advise on the approach to any alterations.

The structural characteristics of caves in Nottingham and their ability to bear loads has been the subject of some previous investigations. Specific studies include Forster (1989), Waltham and Swift (2004) and Holland (1991), as set out in the bibliography.

A structural assessment should consider if the area above the cave is or will be used and for what purpose so loadings applied to the cave roof can be considered. If the cave structure is in reasonable condition and has been untouched from original construction with a reasonable thickness of rock above the crown relative to the span it is likely that the cave will perform adequately under loads applied like those applied during its past use.

Where significant changes to loading is planned it may be necessary to carry out physical investigations into check the thickness of the sandstone above the cave and the presence of caves below or voids in the vicinity.

The geotechnical engineer will consider the effect of additional load on the cave and if necessary, consider transferring additional loads across the cave onto solid sandstone with a designed structural system of reinforced ground beams or steel members above the crown. It may be possible to reduce floor loads onto caves by spanning over small caves with new timber floor joists above the cave roof.

Redundancy

In the past, where caves have been considered of insufficient significance, they have been filled with mass concrete or stone rubble as a simple structural way of transferring load. This approach is classed as engineering works and requires planning permission. It should only be taken with formal agreement with the local planning authority as advised by the City Archaeologist, and as a last resort. If this approach is accepted, caves will need to be recorded prior to works commencing. For more information see the Nottingham City Council's *Supplementary Planning Document - Management of the Caves of Nottingham* (2019).

Introducing Services

In seeking to use caves more intensively and provide more receptive accommodation with amenities, many owners want to introduce services, including some to change the environmental conditions of a cave.

The introduction of **electricity** is key to enjoying a cave, providing light and power. **Water** may be desirable, but drainage is often hard to achieve and so the quantities required are likely easier brought in via a container. The introduction of any **combustible or flammable materials** into a cave, whether via a container or connected supply presents as a significant hazard and specialist advice should be taken.

Works that are most desirable are often associated with introducing appliances and services that reduce **moisture and humidity** within caves and raise **temperatures** to provide more comfortable accommodation, especially where caves form active parts of domestic or commercial properties. Both ventilation and heating have the ability to adversely affect the sandstone fabric of the cave (see Part D).

Depending on existing airflow through a cave, certain regular and intensive uses may require artificial **ventilation** to be installed to remove the additional moisture content added to the air through respiration and cave use.

Heating caves in occasional short bursts is not advisable as the process will cause temperature fluctuations that will not control damp, can exacerbate condensation and surface moisture. This might subject the natural stone fabric to stress leading to more intensive exfoliation. Heat also increases chemical weathering processes.

Dehumidifying caves to excessive degrees may also begin to remove moisture that forms part of the clay bond in the sandstone, so care should be taken to ensure that surfaces do not dry out alongside the air. Some caves have had useful results in using dehumidifiers especially where excess moisture exists.

In all respects, the conservation and maintenance of the fabric of the cave should be paramount when upgrading caves, with any adverse impacts minimised and/or avoided wherever possible. After their introduction, the effect of any services upon the fabric of a cave should be monitored closely (see Part D). Look for signs of new or increased damp, increased levels of surface deterioration (loose sand on surfaces), changes in the appearance and moisture content of the cave surface, and so forth.

Maintenance

As with any building or structure, services should be checked and tested where appropriate. Due to the challenging environments of some caves, this may usefully be undertaken more regularly.

Inspection and Monitoring

It is good practice to visit a cave frequently and examine it for any material changes such as excess moisture, increased weathering and in rare circumstances, structural failure. Due to their unique environmental characteristics, any services introduced into caves should be checked on a regular basis.

If there are concerns over the structural stability a cave's characteristics can be monitored for change. Monitoring can take various forms and can include assessing rates of weathering, moisture or flooding, as well as observing any movement within specific localised areas, such as cracks or areas of weakness. Any such technical exercise should be undertaken by a specialist and combined with monitoring of activity, including the weather, above ground to understand the cause of any issues. Monitoring may be a condition of planning permission where construction works have the ability to impact upon a cave's structural integrity.

Clearing out

Many caves have been used as a dumping ground for materials over extended periods of time. In many instances they proved useful for the disposal of building materials when buildings above were upgraded. Waste materials typically hold high levels of moisture and are unlikely to be beneficial for a cave in the long term. As such the removal of waste materials is desirable, although due to restricted conditions it is often an onerous task that requires patience and determination. If you are undertaking

a large-scale clearance of a cave, it is useful contact the City Archaeologist at an early stage for advice. During the works it would be useful to introduce ramps and protective boarding in places, particularly to stairs to avoid damaging them. Much of the work is likely to be manual, although small conveyor belt lifts can assist. Care should be taken and appropriate PPE worn, as dumped materials often contain sharp objects and other hazardous objects. If in doubt, seek professional guidance.

Older dumped material may survive and some may have archaeological interest, so it is worth keeping an eye out for any unusual objects that either belong to the cave or are associated with the host building.

In some exceptional circumstances, dumped material may be playing a structural role in supporting the cave. As such care should be taken when removing material, and the structure of the cave monitored during and after the process.

Cleaning

Cleaning of the surfaces of caves should be undertaken with great care. Sandstone surfaces naturally exfoliate and brushing them and removing loose fabric is only likely to stimulate the process. This is a particularly serious issue with decorative features and markings. The use of chemicals and/or steam is not advised and may lead to rapid loss of fabric. A silicone surface-zone treatment may help to prevent loss of fabric through low level maintenance such as light dusting. Floor surfaces can be kept clean, and steps should be lightly brushed occasionally to avoid any build-up of grit that may present as a trip hazard.

CASE STUDY 13: Gi Gi Botega

The connected cave system beneath Gi Gi Botega

Set behind the 15th century façade of a former public house, Flying Horse Walk shopping arcade is home to many high-end city centre retailers. Despite centuries of change and re-use, an extensive cave system has remained hidden, until recently.

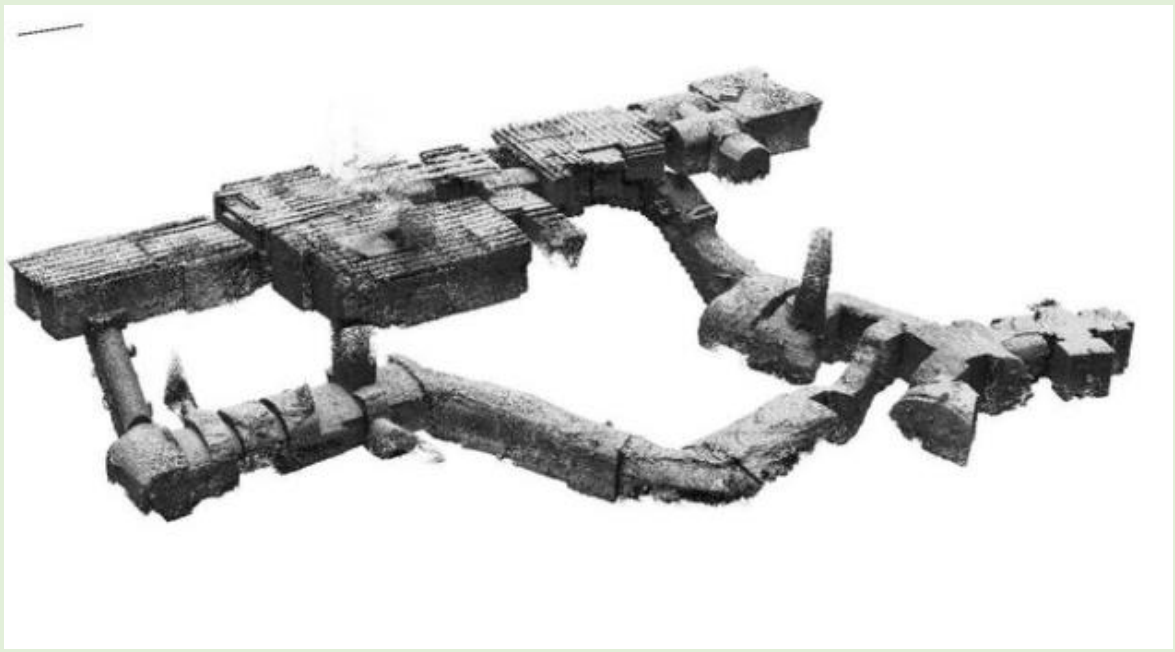
Although known to exist by the museum service, the owners of Gi Gi Bottega, an independent men's and womenswear boutique, were undertaking works to renovate the basement at 15 Flying Horse

Walk in 2017 when they discovered the entrance to a cave set beneath a metal sheet in the ground. Through digging out some 700 tonnes of soil and rubble by hand, they unearthed a series of cave chambers and tunnels, with the oldest section of chambers believed to date back to some time in the Medieval period. The chambers are believed to have been connected to each other in the 19th and 20th centuries.

It is believed that part of the space was used by the old Flying Horse Inn for the storage of beer, and there is documentary evidence of the cave being used as an air raid shelter during the Second World War.

Photographs showing an entrance and vaulted brick chamber connecting with a rock cut cave, both filled with rubble and rubbish (courtesy of Angelo Trivigno)

Undeterred by the undertaking, owner and Director Angelo Trivigno saw an opportunity to expand upon what the building could offer to the boutique business. Experts from Italy were called in to monitor temperature and humidity, revealing the perfect climatic conditions for wine storage. Consequently, it was decided to bring them into regular use as a cellar connected to a new wine and cocktail lounge on the building's first floor. With no existing services within the cave, a carefully considered design was produced by DL Design, assisted through the creation of a 3D map of the cellars and cave system.



3D image of the cave system beneath Gi Gi Bottega

Works to make the space usable included installing cabling for lighting and emergency lighting, fire detection, electrical sockets, Wi-Fi, music capabilities, and CCTV cameras.

Spanning 100 metres, the Cantine Dell'Angelo ('Angel Cellars') provide a unique and exciting wine bar and tasting experience. The natural cool environment in the cellars and caves is the best way to age and to taste spectacular wine, whilst the intimate settings will provide a relaxing and personal experience. The caves house both wine and champagne cellars and tasting spaces, as well as smaller private chambers and private dining.

Find out more at: https://www.cantinedellangelo.co.uk/

Removing mould and staining

The geology of the Chester Formation sandstone is known for its consistency, however localised variations in lithology (e.g. areas with iron content or pebbles) can lead to localised areas of staining on walls and ceilings. Previous activity, specifically industrial processes, may have also resulted in the staining of rock. Due to the porous nature of the rock, stains may run deep and their removal by abrasion or chemicals is likely to erode the surface of the rock rather than remove stains. Leaving the stone to naturally exfoliate is likely the best way to treat stains. However, if a stain has developed and appears to be leading to increased weathering of the stone specialist advice from a geotechnical engineer or engineering geologist should be sought.

Moulds and other growths are common to many caves, particularly where there is wood or soft furnishings, and usually thrive where there is some form of food source to support them. Artificial light can further encourage growth, consequently it is advised that should lights be installed these minimise exposure time. Physical or chemical removal may erode the surface of a cave, and should be undertaken with care. Identifying and removing the source of food, be it within the cave or airborne, may reduce or eradicate the issue, in many instances cave growths are natural and can be left in place. However, advice should be sought, as hazardous substances dumped in a cave could lead to potentially harmful growths.

Further information

Bibliography

Charsley, T. J., Rathbone, P. A., & Lowe, D. J. (1990). *Nottingham: A geological background for planning and development.* British Geological Society.

Dobereiner, L., & Freitas, M. H. (1986). Geotechnical Propperties of Weak Sandstone . *Geotechnique, 36*, 79-94.

Forster, A. (1989). Engineering Geology of the Nottingham Area. *British Geological Society Tecnical Report, WN/89/4*, pp46.

Holland, C. (1991). *Model studies of sandstone caves under Nottingham. Unpublished B. Eng. thesis.* Civil Engineering Department Nottingham Polytechnic.

Last, J. (2003). *The Archaeology of English Caves and Rock Shelters: A Strategy Document .* Centre for Archaeology.

Lobb, D. M. (2020). *Assessment of Significance: Caves Associated with the Former Loggerheads Public House, 59 Cliff Road, Nottingham.* Nottingham: Trent & Peak Archaeology.

Sadler, F. (2018). *Project Report Cave City: Nottimgham Underground Festival.* Nottimgham City Council Internal Report.

Stapleton, A. (1904). *Nottingham caves and Nottinghamshire coal.* Nottinghamshire Guardian.

Trent & Peak Archaeology and SLR Consulting. (2020). *The Caves of Nottingham: Desk-Based Assessment and Laser Surveys.* Retrieved from The Caves of Nottingham: Desk-Based Assessment and Laser Surveys.

Waltham, A. C. (1992). The Sandstone Caves of Nottingham. *Mercian Geologist 1992 (13)*.

Waltham, A. C., & Chorlton, I. E. (1990). Rock roof stability in the sandstone caves of Nottingham. *Proceedings of a Conference on the Engineering Geology of Weak Rock, Engineering Group Geological Society* , pp. 528 - 532.

Waltham, T. (n.d.). Retrieved from East Midlands Geological Society: http://www.emgs.org.uk/files/local_geology/16(4)_conserv_statues.pdf

Waltham, T. (2006). *The Sandstone Caves under Notingham.* Retrieved from Open University Geological Society.

Waltham, T. (2007). *Sandstone Caves of Nottingham.* East Midlands Geographical Society.

Useful websites

British Geological Survey Map Viewer: https://geologyviewer.bgs.ac.uk/?_ga=2.176399653.1283934900.1663152590-446594215.1663152590

British Geological Lexicon of Named Rock Units: https://webapps.bgs.ac.uk/lexicon/

National Heritage List for England: https://historicengland.org.uk/listing/the-list/

National Library of Scotland Maps: https://maps.nls.uk/geo/find/#

Nottinghamshire Archives: https://www.inspireculture.org.uk/heritage/archives/

Nottingham Caves Database: https://data.gov.uk/dataset/36b8a2eb-effa-4956-9c5c-1cfb2c050903/nottingham-s-caves-database

Nottingham City Council Planning and Building Control: https://nottinghamcity.gov.uk/information-for-business/planning-and-building-control/

Nottingham Historic Environment Record: https://www.heritagegateway.org.uk/gateway/chr/herdetail.aspx?crit=&ctid=94&id=4756

Nottingham City Council Mapping Portal https://maps.nottinghamcity.gov.uk/insightmapping/

Old Maps Online: https://www.oldmapsonline.org/

Planning Permission - Change of Use: https://www.planningportal.co.uk/info/200130/common_projects/9/change_of_use

Setting of Heritage Assets*:* https://historicengland.org.uk/images-books/publications/gpa3-setting-of-heritage-assets

Statements of Significance: https://historicengland.org.uk/images-books/publications/statements-heritage-significance-advice-note-12/

Supplementary Planning Document: Management of the Caves of Nottingham (2019): http://documents.nottinghamcity.gov.uk/download/7513

Tony Waltham's website and archives: www.geophotos.co.uk

LOCUS

www.locusconsulting.co.uk