Groundsure
LOCATION INTELLIGENCE

Investigating and Managing Past Mining Risks for Land and Property

White paper

Introduction

This white paper will explore the scale and nature of former metal mining, with particular focus on the often complex array of features across the Devon and Cornwall landscape. We will consider how data and innovation is driving new understanding to assist developers and homebuyers to consider the lie of the land and how it could impact their investment or make decisions to ensure project feasibility.

We outline some case studies of how we have interpreted the risks on the ground and helped to ensure that developments have remained on track in a secure and cost-effective manner.

Mining risk and properties

The UK has a long history of surface and underground extraction, with over 60 different minerals being mined, quarried and extracted at some point in time. Among the most well-known include limestone, sandstone, ironstone, chalk, tin, clay, as well as an assortment of metalliferous and semi-precious materials. Each has its own different characteristics and can pose their own unique problems.

For legal professionals and developers, non-coal mines present very clear and present risks because:

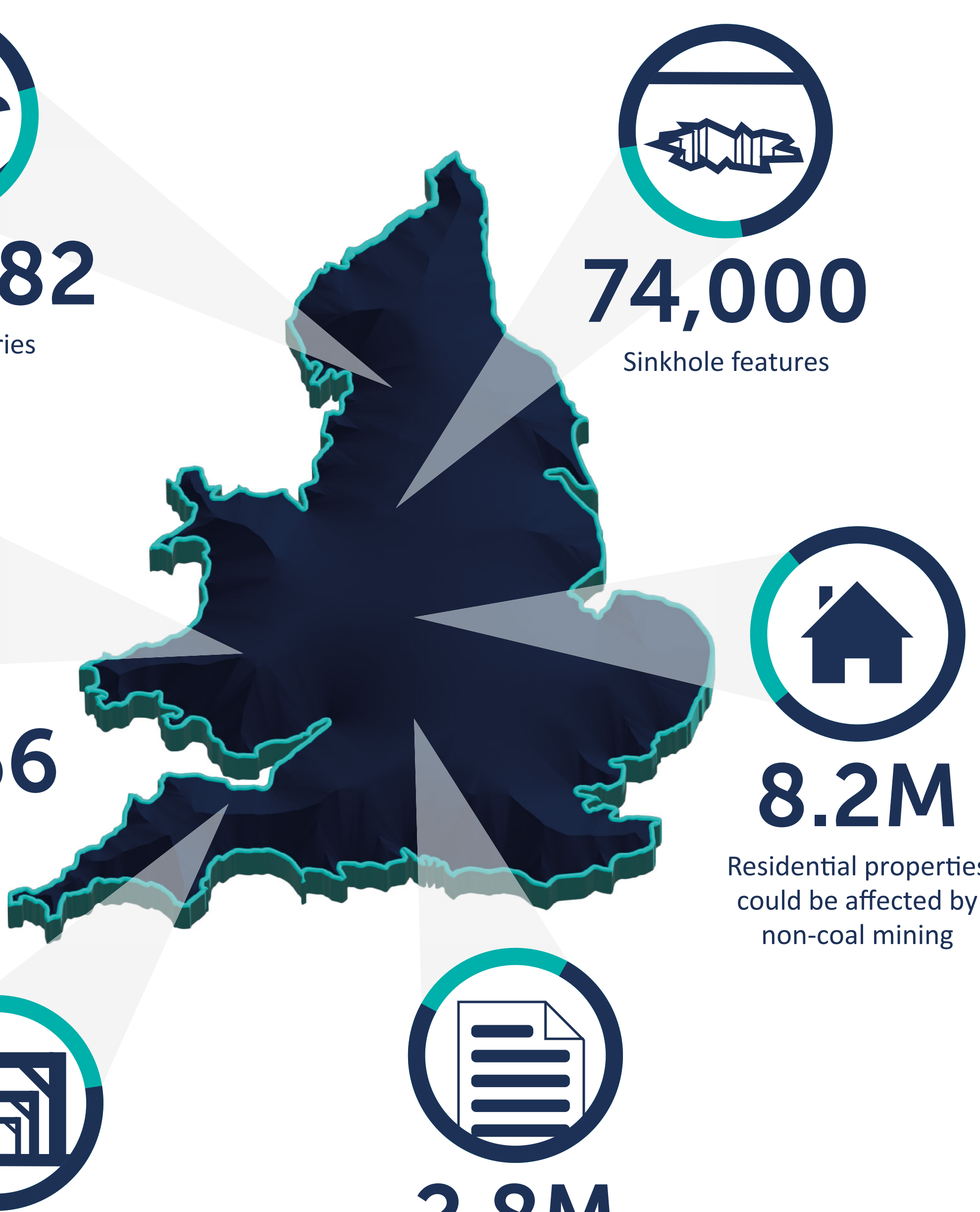
a) They are usually shallower and more informal workings than coal seams, so closer to the foundations and gardens of properties.

b) While homeowners may be able to get insurance cover for their property, with a very high excess or renewal for known subsidence, this does not apply to their gardens in the main.

c) As our climate changes with locally heavier downpours, new mines are being revealed through collapses and sinkholes. Lenders are now responding with greater concern to their longer-term exposure to the security on their lending.

d) Many of these are located in urban areas and have been built over so they are not obvious in the way a coal slag heap, pit head or a river would be – so conveyancers cannot and should not rely on “local knowledge”

Non-coal mining risk



390,482
Recorded quarries

74,000
Sinkhole features

866,266
Recorded pits

8.2M
Residential properties could be affected by non-coal mining

35,777
Specified non-coal mines in England and Wales from historic land use data

2.8M
Reported non-coal mining features

Mining or ground stability can affect many property transactions

- **22%** of all properties will need a non-coal search report
- **39%** of all properties will need a non-coal and CON29M search report
- **40%** of all properties will need a non-coal, CON29M and Cheshire Salt Search report

A search report will provide the basis for a more detailed mine risk assessment and, if needed, more intrusive ground investigations.

The scale of mining in South West England

18,024

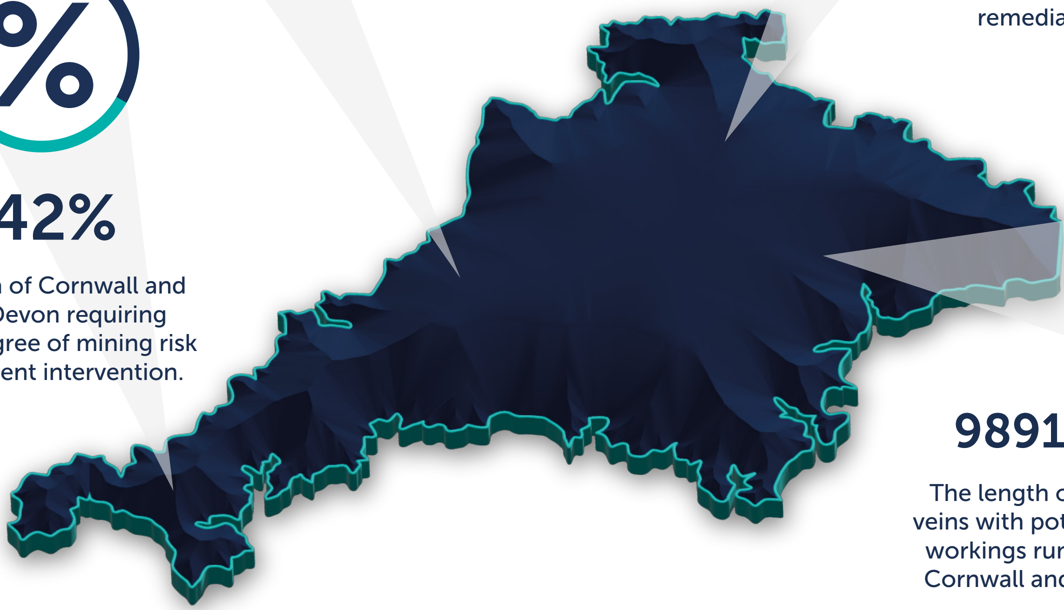
The number of tin, copper and other metal mining shafts in Cornwall and West Devon.

1666

The number of mining features that Groundsure has overseen through remediation.

42%

The area of Cornwall and West Devon requiring some degree of mining risk assessment intervention.



9891.9 km

The length of mineralised veins with potential for mine workings running beneath Cornwall and West Devon.

The Impact on property

Many old, informally built shallow mines were just dug out with shovels or mechanical excavators from the surface. Some may have had short shafts with adits at the surface, but others were just dug out from the topsoil. Minerals were extracted whilst they were viable and were then closed once exhausted with little consideration given to remediation.

Many open features such as shafts, bell pits or linear surface workings, were backfilled with a mixture of mineral spoil, felled timber, prop supports and any general waste available to the miners from the extraction process to prevent entry and provide a degree of safety.

The issue with using organic, unconsolidated material to secure a hole, is that by its very nature pockets of air remain within the fill. Add to this the fact that the properties of organic materials such as wooden timbers, felled fauna and in some cases dissolution-prone minerals like limestone mean that at some point in the future, natural decay will set in.

When timber rots away it will also leave voids within the fill, making the structural integrity of this primitive remediation scheme less than secure. The material falls into the void and this process repeats over time until the void appears at the surface. The additional weight of wet soil, floodwater or saturated superficial deposits can increase the load to a critical level.

The first that anyone may know about these voids from the surface could be sagging in the garden or tarmacked road surface, before a crownhole or sinkhole could open up indiscriminately in and among properties built over and around it decades before. With rainfall and natural movement, these workings, infilled and timbered areas have over time inevitably eroded and collapsed, revealing crown holes where the soil falls into the rock excavated below.

The role of climate change

Climate Change is affecting the UK in a number of ways. Even with immediate, sustained, and very rapid reductions in greenhouse gas emissions globally, the latest UK climate projections (UKCP18) suggest the country will experience an additional warming of around 0.6°C between now and 2050 to an average of 1.7C warmer at the maximum.

Summers will be much drier than they are today, putting more stress on already parched regions such as the South and East, there will be generally wetter winters in the north and west. But in general, the amount of moisture is increasing due to atmospheric heating and this can create locally heavier downpours almost anywhere, which can filter more aggressively into the soil and impact more soluble rocks quicker.

These collapses could now accelerate due to the impact of climate change. Because of the use of poor quality, decayable materials to fill these holes, a rise in rainfall, including locally heavy deluges and elevated groundwater levels can have a major impact on their structure and weaken it faster.

Following periods of exceptionally high rainfall, there has been a corresponding increase in the number of crown holes revealed, exposing old mines and pits.

The winter of 2013-14 was especially bad, potentially the wettest since Met Office records began nearly 250 years ago. During this period, the BGS reported that they were called out to a five-fold increase in sinkhole collapses since the storms had begun. Half of these were due to natural ground conditions like soluble rocks and running sand eroding within the rock structure, **but the other half was due to man-made activity, much of which came from non-coal mining activity that had revealed itself following rainfall.**

Conversely, periods of drought, more likely in the south and the east of the UK with the 2050 climate projections, will accelerate cracks in the soil, allow water to penetrate quicker and form new pathways for subsidence and eventual collapse.

What has been mined

Across the UK, and over thousands of years, many different types of resources including coal, metals and stone have been extracted from the ground below our feet. Coal was, of course, crucial to powering the industrial revolution but a multitude of minerals beneath our land and property has been quarried and mined to provide the raw material for construction and manufacturing.

Hydrocarbons	Metalliferous	Stone	Evaporites
Coal	Ironstone	Limestone	Gypsum
Petroleum & Gas	Hematite	Sandstone	Potash
	Lead Ore	Fluorspar	Anhydrite
	Tin	Igneous Rock	
	Copper	China Clay	
	Tungsten	Coprolite	
	Umber	Calcite	
	Alum	Celestite	
	Arsenic	Dolerite	
	Barium	Fireclay	
	Gold	Marble	
	Manganese	Mice	
	Ochre	Fullers Earth	
	Zinc	Sand & Gravel	

While coal is the most prevalent legacy mining risk currently searched in the UK, non-coal mining including the above minerals is proven to have a far more extensive impact across the country but is the least known.

For more on this, go to our *Hidden Hazards white paper* on non-coal mining impacts which provides some exclusive data on how it could significantly impact land and property in many urban areas.

In this white paper, we will be focusing on the Metalliferous minerals in the above table, which have a long history of extraction in the SW of England, specifically Cornwall and Devon.

How do these mine features appear?


Timber Lined Shaft


Two nearby shafts

During preparatory ground works for new developments or for house extensions, former mine workings can be revealed in a variety of forms. Above shows two examples of mine shafts exposed during site works. The image on the right shows that sometimes they can be very close together!


Stope - Void where rock has been removed


Tunnel

The above images show examples of underground mine workings such as tunnels, and stope-ing which is essentially the void left behind when the rock containing the deposits has been removed, with perhaps only a few pillars left to support it.


Adit - Mine Drainage Tunnel


Spoil Heap

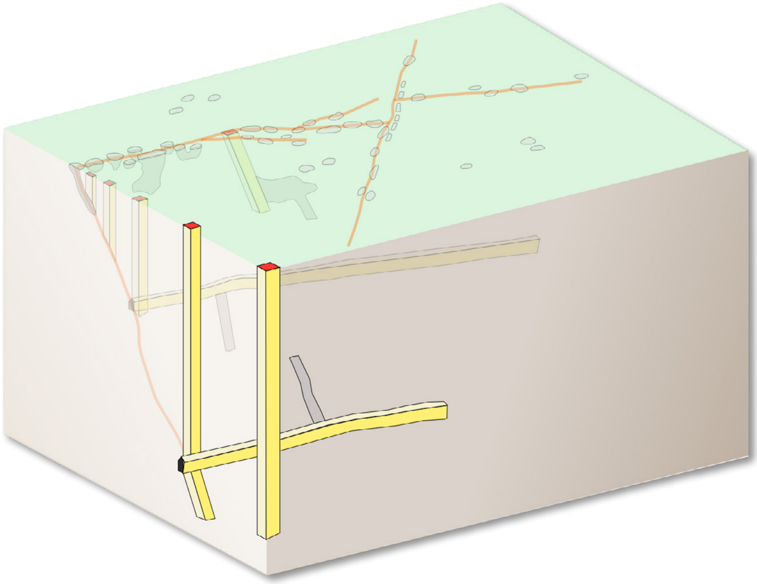
The left hand image above is an Adit, which is essentially a tunnel used to drain water from the mine. To the right is an image of a spoil heap, in this instance relating to china clay mining. Where such heaps have been flattened and built on they may be recorded as mine waste mounds or artificial ground.

For more information visit:
www.groundsure.com/mining-risk-assessment
Email: info@groundsure.com *Tel:* +44 (0)1209 218 861

How mines develop over time

Before we can start to get a more modern, sophisticated view of how a mine system looks underground, we need to refer to more simplified maps and charts to get an idea of what mining looked like over time.

Lode or mineralised Vein



The very first stages of a mine are typically very poorly documented. The initial mine workings are concentrated around where the mineral vein or lode outcrops at the surface as per the left hand image above. The band of red to orange soils, clays and gravel provides an indication of where the mineralisation or the ore is located below. The difference in colouration, perhaps due to the oxidation (or rusting) giving an indication of where the metals are concentrated.

In the schematic on the right, the outcrop is shown as the wiggly red/orange lines. Near the ground surface and along the course of this wiggly line, we may expect to see multiple pits or shallow mine workings, as the early miners would look for its location by digging a series of pits until they uncovered evidence of mineralisation and then start to go deeper.

Once mineralisation was encountered, this would be chased deeper underground with the use of shafts and tunnels, as you can see highlighted in yellow and grey in the schematic. As all the metal is excavated near the surface, the only choice was to go deeper.

How mines develop over time *(continued)*

Also this could lead to the discovery of higher grade deposits which hadn't been degraded by the process of weathering such as those near the ground surface.

As we move forward again in time, the mine shafts get deeper and are located progressively further away from where the mineralised vein outcrops at the surface. This is because of the Geology in Cornwall, where the mineralisation has concentrated within fractures or faults within the rock mass. These tend to be steeply dipping or inclined, meaning that as you follow the orange line underground it follows a diagonal line, in this instance coming closer towards us with depth.

The later mining activity tends to be focussed on accessing workings at progressively greater depths. With time this was facilitated by improved mining techniques, uses of explosives and the ability to effectively dewater a mine using steam power. These later shafts are located further away from the where the mineralization was seen at the surface and they also tended to increase in size and depth to accommodate the use of ever more powerful steam engines, pumps and lifting equipment.

Due to their size and relative recent use, the later shafts are often shown on the OS plans, and details regarding their present stability may be known.

We may expect that these later larger and more modern shafts present the greatest risk, however as they are often much better recorded the risks are known, this is certainly not the case for the early surface and shallower workings.

Although only relatively shallow, early mine workings were often dug and subsequently infilled prior to any formal records. As such they can present significant risk to home buyers and developers which can remain hidden until excavations begin. That's why it is so essential to have the appropriate searches and investigations which can help identify such risks early in the transaction or development proposal.

History of mine records

At Groundsure, our first task begins with compiling the historical record which may comprise early editions of the ordnance survey, along with old mine plans and sections. However, it is critical to know that this may only represent a fraction of the mining activity at the time of production, and each plan presents us with a small snapshot in time.

For example **it wasn't until 1840 when the first Mine Records Office was established in London**, creating a centralised location for depositing plans of mines when they were abandoned. It wasn't until even later in 1872 that the Coal Mines Regulation Act and the Metalliferous Mines Regulation Act came into action, making it a legal requirement to deposit a plan within 3 months from the date of a mine being abandoned.

However, non-coal mines were not actually required to deposit plans if there had been less than 12 men employed below ground. Surprisingly, this exemption was continued in all subsequent legislatiaon up until 1993.

By this time, many thousands of mine workings had already been abandoned, likely filled in, would never be officially recorded and would soon be lost to local memory.

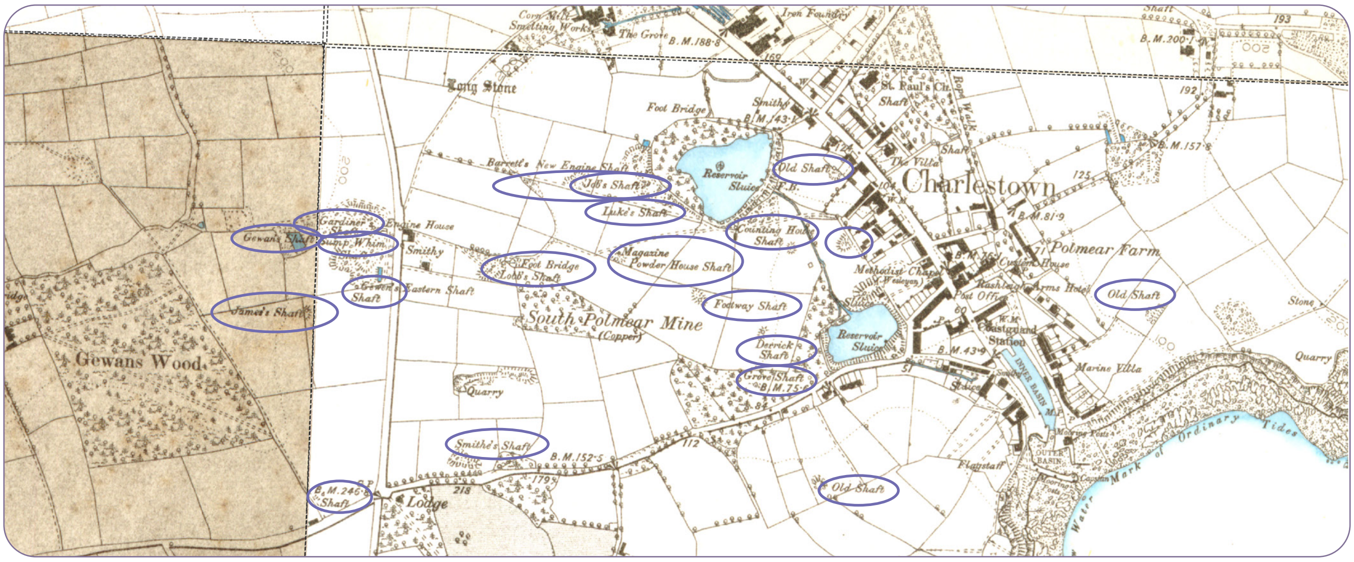
As time progressed, more detailed plans showing surface features and underground mining extent were produced, allowing for a good fit to modern maps. If we are fortunate, this may be accompanied by cross-sections giving us an idea of the scale of the underground extraction. It is essential to use multiple lines of evidence, as a single plan can be misleading or inaccurate for many reasons.

Another invaluable resource are the early Ordnance Survey plans which began to be produced in the early 1800's onwards.

Building a site profile using historic mapping site records

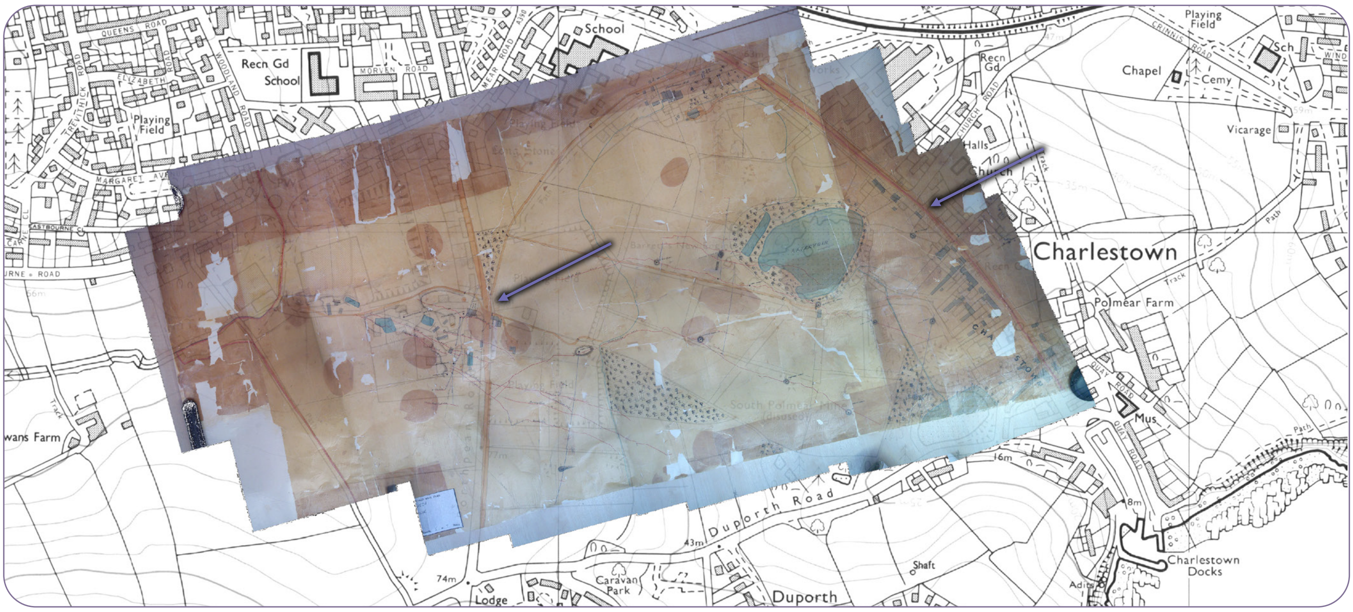
Location: South Polmear Mine

This plan shows us an extract of an Ordnance Survey Plan from 1990. On the right hand side is the harbour of Charlestown. Just off the centre, the South Polmear Mine is labelled and is shown as disused. The only other clue left on the OS map of the mining activity is Barrett's Engine Shaft shown just to the north. Other than that you could be forgiven for thinking there isn't much of a mining risk to the area.



Building a site profile *(continued)*

If we go back in time more than a century before the 1990 OS map, the above edition provides us with a greater insight into the true extent of mining activity in the area, as highlighted above. Now over 20 shafts can be seen. Much like the tip of an iceberg, each of the shafts or mounds visible at the surface only give us a hint of the activity which has occurred underground. To really understand that, we need to start to compile old mine plans too.

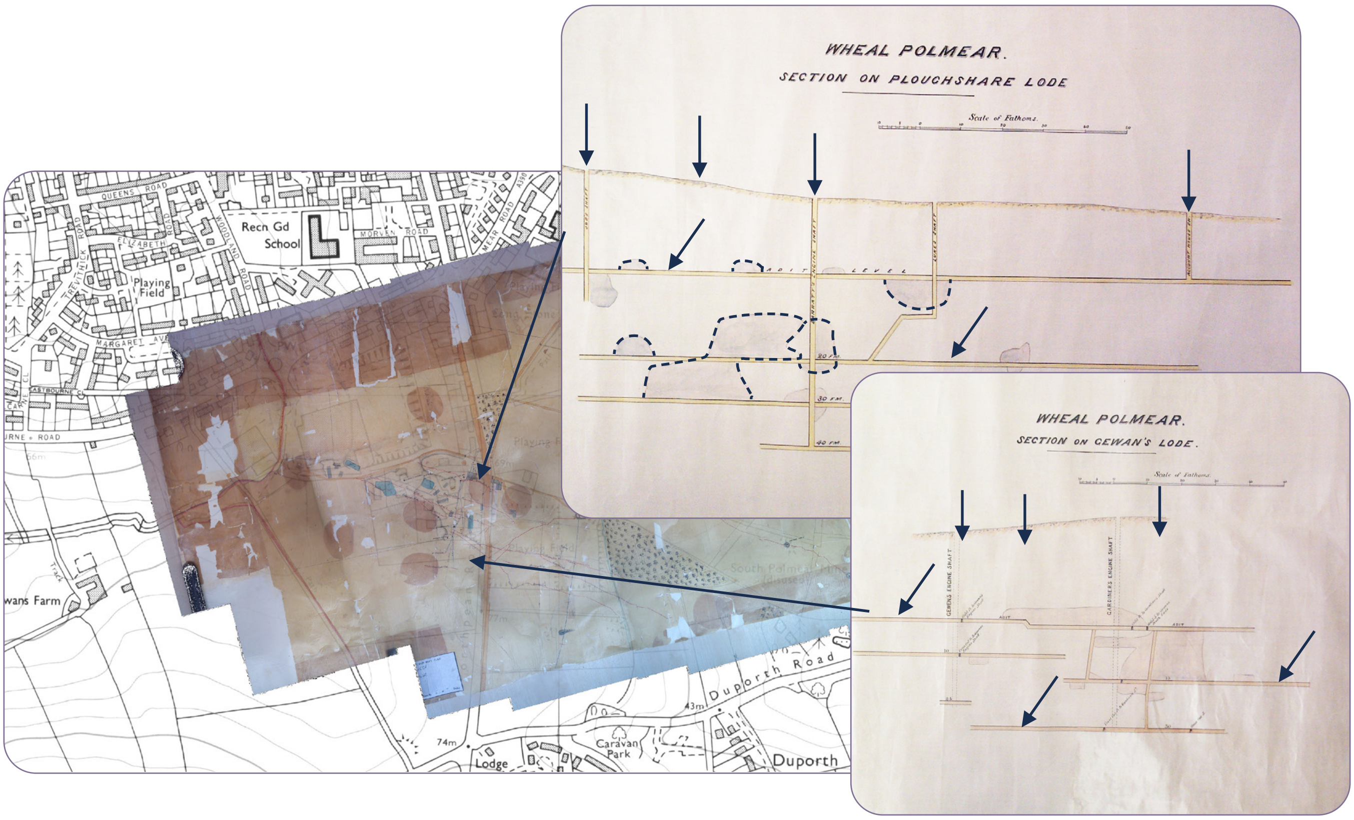


We have now overlaid the fragile, stained mine plan for South Polmear Mine, which is likely to be around 150 years old, to the 1990 Ordnance Survey Plan.

Such plans are not typically publicly available and are often held in private collections, stately homes or have been lost or damaged beyond repair through time. In recent years, county councils have made efforts in digitising their archives. However, Groundsure has one of the most comprehensive archives of such plans which have been collected and compiled over more than 40 years.

In this instance, having a long road marked on the old map helps marry it to the new.

Building a site profile *(continued)*



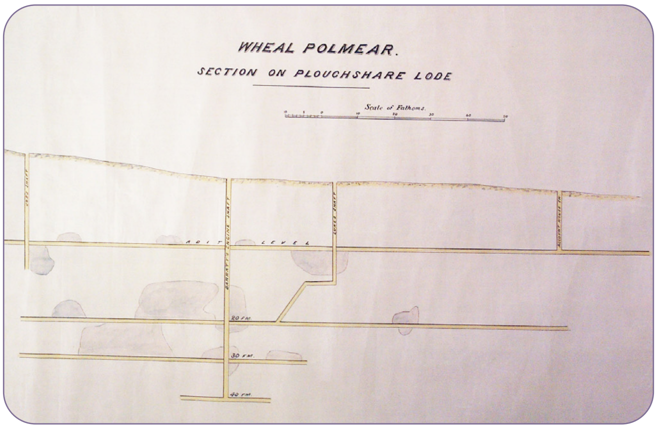
As with any geological cross section, we have the ground surface shown at the top. This is giving an indication of the broad topography of the area. Extending from the surface to deep underground are the shafts. Horizontal across the sections are the Adits and Mine Levels which we can simply think of as tunnels.

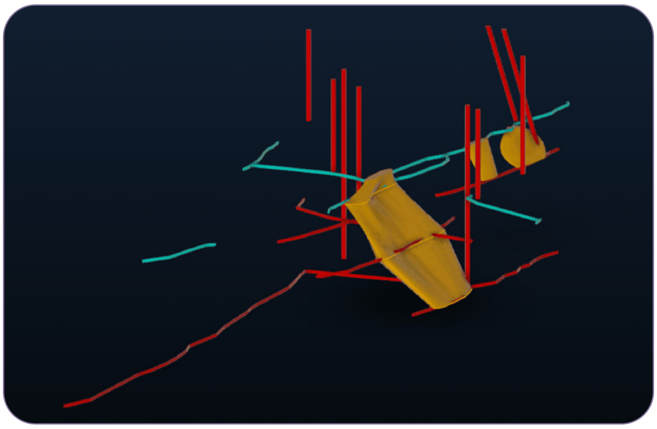
Finally, and crucially, the shaded regions of the sections are showing us the Stope-ing, which are areas where the rock containing the ore such as tin, copper or lead, has been mined out, the rock removed leaving a void behind. Even in a small mine like this, by using the scale we can calculate some of these voids spanned over 200 feet or 60 metres wide.

Every detail shown on any single plan or section has to be carefully fitted and considered to determine what it means with regards to ground stability risk. Until relatively recently this relied upon our search writers to be able to mentally visualise the interaction between these 2D plans and mine cross sections.

Building a site profile *(continued)*

Using both the historical mine plan and the sections we saw previously, we can reconstruct the mine underground.





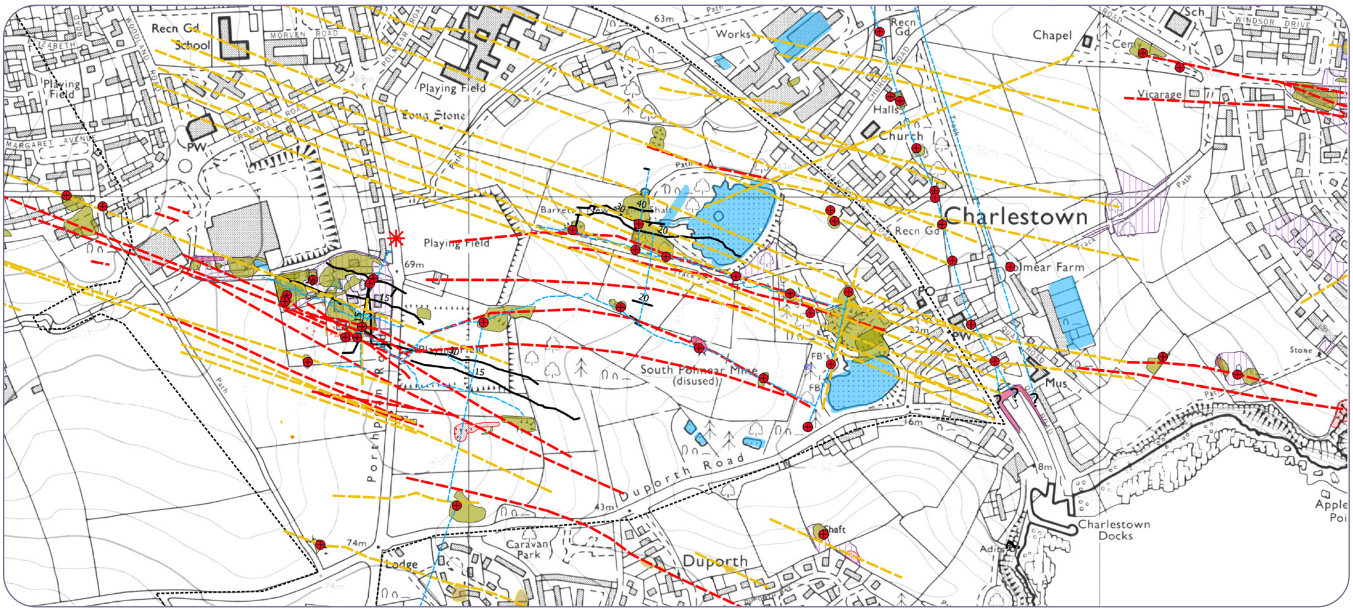
Switching to 3D

Above you can see an interpretation of those same plans and sections. For the purpose of this white paper, we have simplified it and only focused on a small section of the mine.

You can see the red columns representing the shafts, either vertical or inclined at an angle descending from the surface to deep underground. The Adit levels are shown as the long light blue tunnels and the levels of the mine are shown as the red tunnels. The 3 D model we developed for this mine allows you to pan around and see the yellow highlighted areas which are representing the stope-ing or the voids in the rock between mine levels where the ore has been removed.

Building a site profile *(continued)*

Bringing it all together...



From the historical paper plans, we now have a digital interpretation of those records which we can use within Groundsure's Geographic Information System (GIS). Here you can see the red dots added representing all the shafts, with the black and blue lines the mine levels and adits. Using our understanding of what those same paper archives are telling about the mine, such as using the 3D models, we can start to interpret the risk areas around the features which are recorded.

By knowing where the shafts and underground workings are, we can predict the location of the mineralisation nearer the surface, for which there may be no records of. From this we can interpret the high risk areas and where the earliest mining is likely to have taken place.

How a Developer needs to approach mine legacy sites

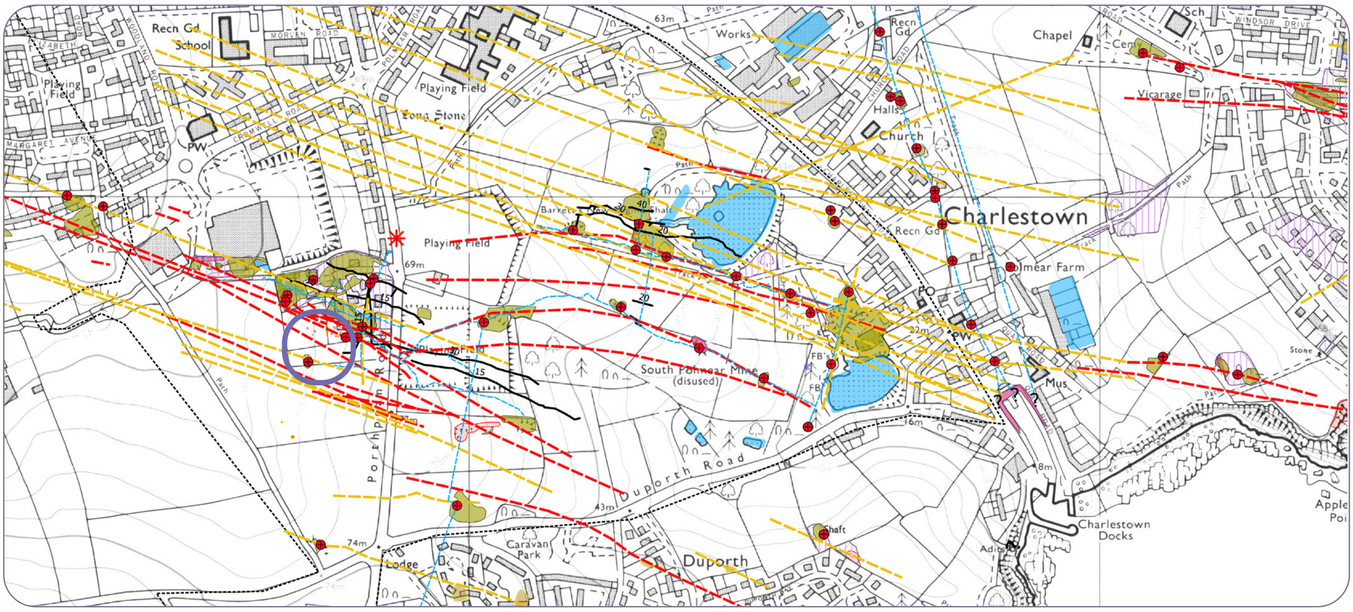
Firstly, when considering a new site, a developer has to undertake a multitude of surveys and assessments including:

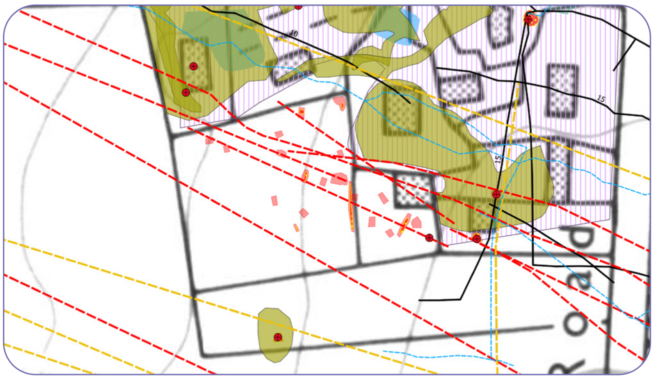
- Environmental and ecological impact
- Tree preservations
- Contaminated Land
- Historical Land Use
- Heritage and Archeology
- Flooding and Drainage
- Traffic and Infrastructure
- Ground Stability
- And many more...

Whether it's for Contaminated Land, or geotechnical purposes, this should always start with a thorough and comprehensive desktop study. This is no different where the site could be affected by former mining activity which may be highlighted in the ground stability data in an *environmental risk assessment* or from one of *our data packs*.

Case Study: South Polmear Mine - Development risks from former mining

We will focus on the area highlighted by the square box which focuses on the site for the proposed development of 30 new homes close to the South Polmear Mine example that we have been following.





Here we have zoomed in on a portion of the 1990 OS map overlaid with our interpretation of mining risk. We can see a number of red dashed lines indicating to us the location of mineralisation near or at the ground surface, and thus likely where surface mining may have occurred.

Case Study: South Polmear Mine *(continued)*

Prior to construction the developer of this site came to us, undertaking desktop studies including a mining search. Based on the indicated risk we conducted a site investigation.

Concentrated in the northern part of the Site you can see a number of red filled shapes, which are often located along the red dashed line. These are the real location of mining features, which were found during the site investigation.

The majority of these features consisted of pits with bases around 2-3m depth, which would have been dug looking for the mineralisation. However, we also discovered a number of small shafts onto shallow tunnels. Each, if left untreated, could have presented significant issues both in terms of construction and future ground stability.

As the developer came to us at the early stages, all the mining features were easily identified and remediated. Once remediation works were completed, within only a couple of weeks, the developer had a site free from mining risk, allowing for construction without any further issues, delays or unexpected costs.

Case Study: Cuddra Mine - adaptation to housing development plans

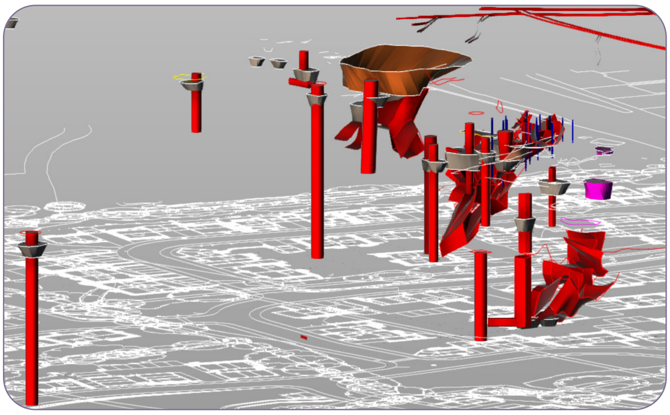
Introduction

A new development of some 200 residential units was proposed in what appeared to be a "green field" site to the house builder. Knowing that historical mining had occurred in the local area, we were approached to assess the potential risk to the site.

An initial desktop mining search conducted on the development site would have revealed four recorded historical mine shafts, which were already shown as "old shafts" by the late 1800's on the Ordnance Survey Plans. We could see the remains of the Cuddra Mine to the NE which had extensive tin and copper workings hundreds of metres underground to the north and west of the site. However, none of the associated mine plans showed any activity in the development site area.

Investigation works & 3D modelling

The initial groundworks unearthed over 30 previously unrecorded shafts and shallow mine workings, so it was clear that the site history was more complex than the available records indicated.



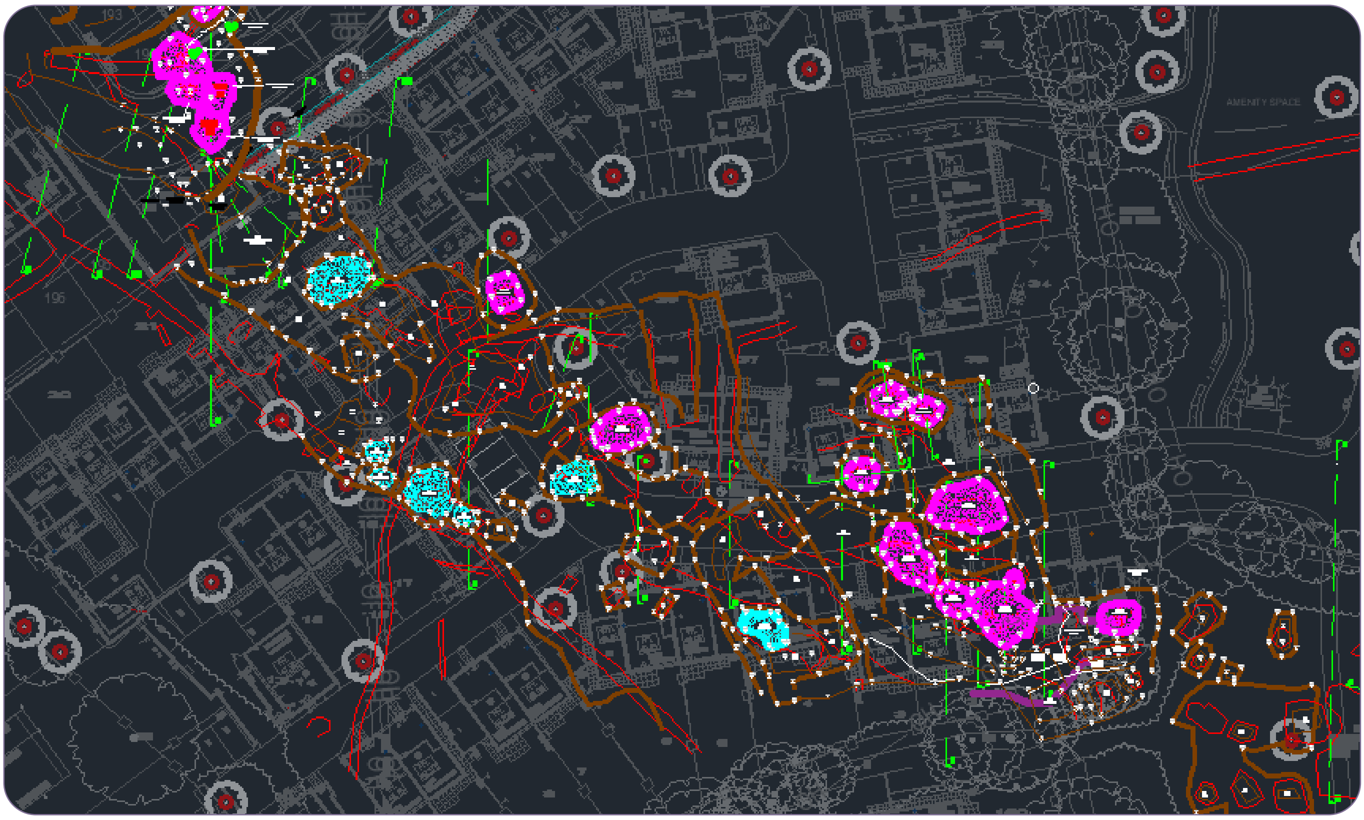
We undertook multiple phases of investigations across the site which required the full resources of our geology team. Multiple boreholes were drilled across the large site, intersecting the underground workings and identifying the areas which were at most risk. Once we had built a sufficient surface and subterranean profile, we created a bespoke and comprehensive 3D ground model of the site, revealing the location of the boreholes we dug and the newly discovered shafts and workings.

Case Study: Cuddra Mine *(continued)*

The above image shows the mining features projected in their exact X,Y location in relation to the development layout plan.

Because the site plan is 2D and 2D, the mining features are projected with their actual elevation hovering above. The red cylinders are shafts, with grey areas showing where they have been concrete filled as part of the remediation. The larger brown area is the edge of a larger excavation, so the developer could see what it was affecting.

The site can also be visualised by an animated fly through of the 3D model:



The 3D ground model was shared "live" with our client as the investigations progressed. It was georeferenced and to scale, so that the effect of mine workings could be easily viewed in relation to the proposed site layout – a powerful tool to visualise the scale and potential impact to units above ground.

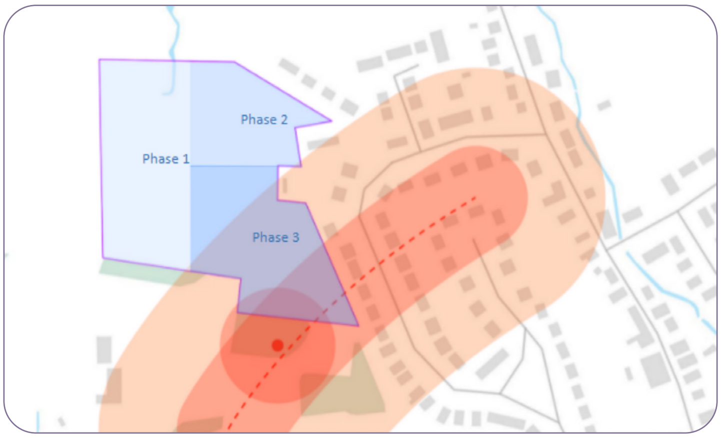
Case Study: Cuddra Mine *(continued)*

Remediation approach

Once we started to uncover the shallow workings at the development site, we quickly discovered that the roof of the workings were only 2-3m below the ground surface and this was directly under one of the main access roads. This can be clearly seen in the left hand photo above.

The right hand picture above shows the view inside the same stope, showing the large void within. The grey material on the left is the spoil which is collapsing into the void from a collapse in the roof. The stope extends at least another 7m depth from surface onto deeper workings, presenting a significant risk.

You can just imagine the impact this could have had if it was not identified at an early stage.



Case Study: Cuddra Mine *(continued)*

By reconstructing our site investigation data live and in 3D as we progressed, we were able to target the high risk areas and predict the location of the completely unrecorded workings. By using our archive of mine plans and Historical OS Data at the desktop stage we identified the key “at risk” areas. Over time and with the thousands of site investigations conducted, we are able to feed in more data, augmenting our assessments with physical observations.

For example with a site marked in the purple outline we can see that the highest risk area is affecting Phase 3, and so at the early stages the construction plan of a development can be amended around this. The developer may choose to construct properties in Phase 1 first, generating cash flow to permit remediation of the features discovered in Phase 3.

This was exactly how work progressed in the previous example, by shifting their construction plan the developer was still able to bring plots to market while the extensive remediation works were undertaken over the course of approximately 6 months affecting what was originally going to be Phase 1 of their site.

Benefits to the client

By sharing such a model with our client, their engineers and the appointed contractors, we were able to provide them with a better insight to the specific risks presented. This helped facilitate an options appraisal for targeted remediation methods, keeping costs to a minimum but also mitigate the mining risk, not just in case of the houses being built but also for where former shallow workings could have affected site access roads.

This enabled our client to adjust their build program so that the high-risk areas could be initially avoided to allow for construction and sale of plots in unaffected areas.

The project underlines how our approach provides an unrivalled understanding of mining risk. The combination of site investigation data, 3D ground modelling and our comprehensive suite of historic Ordnance Survey mapping is matched to paper geological plans and historic land use data. This means that conveyancers and their clients, developers and architects can be confident that an analysis of historic mining risk will be thoroughly investigated, risk mitigated and can enable transactions or site appraisals to proceed with confidence.

Our remediation approach

The case studies demonstrate the importance of delivering a robust and structured project management approach when it comes to assessing ground conditions for either a site development or detailed investigation for a property transaction.

We adopt a careful step by step approach including:

- A desktop search to highlight risk areas throughout the site.
- Design and carry out site investigations - mainly by means of machine excavated trenches and trial pits OR borehole drilling
- Create detailed plans and sections based off the site investigation results - 2D plans and sections as standard and where possible 3D modelling (which can provide greater understanding and visual guides which aid people who may not be experts on mining)
- Create risk zones, indicating highest risk areas and low risk areas - highlight any areas which require further investigation
- Work with the developer with regards to scheduling and targets to carry out any remedial works in a manner that least affects the programme. (Zoning allows the developer to change scheduling if required to target low risk areas while the higher risk areas are dealt with, therefore keeping the development moving forward).
- Strip the site to a natural horizon and inspect for any signs of made ground or backfilled mine workings, covering the risk from unrecorded mine workings.
- Oversee all aspects of excavation and remediation of mine workings.
- Carry out foundation inspections for any new dwellings of the development.

Our remediation approach *(continued)*

- Provide reports for all works carried out - these satisfy planning applications, building control, warranty providers, mortgage & insurance companies.

It is always recommended that the earlier the mining risk is considered, the more cost effective the remediation will be. Tackling known problems that are factored into the schedule of the site is much better than 'firefighting' when unexpected mining issues arise which inevitably creates greater unforeseen costs and time delays.

Many of our sites are relatively low risk (or the mining issues have been dealt with previously) so there can be a significant number of foundation inspections at ongoing development sites.

Remediation costs

Every redevelopment site or investigation for a property transaction comes with its own unique circumstances, both in terms of site profile and building construction and also the relationship with the soil geology and proximity to former mining features. This means that remediation solutions and their final costs are highly site dependent and can vary greatly.

Much depends on the amount of mining within the site boundary. Typical costs could range from low thousands of pounds for small independent sites, up to 7 figure sums for large development sites with larger scale mining issues.

Where we can help

Our expert team of mining consultants provide our conveyancing, consultancy and property development clients with clear insights and assessments into historic mining risk to land and property. Researching and interpreting our data applications and comprehensive historic map library, our consultants ensure a detailed analysis of potential risk goes into each and every mining search or site investigation.

Our geologists, historians and archaeologists have over 40 years experience, with a particularly strong heritage with tin and other metalliferous and stone mining in the south west alongside one of the UK's leading mining data catalogues.

Our skilled team carry out investigations using our bespoke GIS (geographical information system) and survey tools with up to 1cm accuracy, so we can identify recorded features quickly and log unrecorded features precisely.

We pride ourselves on keeping you and your client updated throughout the investigation and will help in any way we can.

Find out more about the range of desktop searches, mine risk assessments and site investigations we offer

Click here

Tel: 01209 218861 Email: info@groundsure.com

Groundsure
LOCATION INTELLIGENCE

Groundsure is a leading UK environmental and climate data authority. We give land and property professionals expert information on risks including land contamination, flooding and ground stability, as well as forward guidance on potential climate risks, to advise their clients in the transaction. We provide high value, property-specific opinions and analysis of land use, turning data into practical, actionable insight.

For more information visit:
www.groundsure.com/mining-risk-assesment
Email: **info@groundsure.com** *Tel:* **+44 (0)1209 218 861**
Address: **Pool Innovation Centre, Trevenson Road, Pool, Redruth TR15 3PL**

groundsure @groundsure