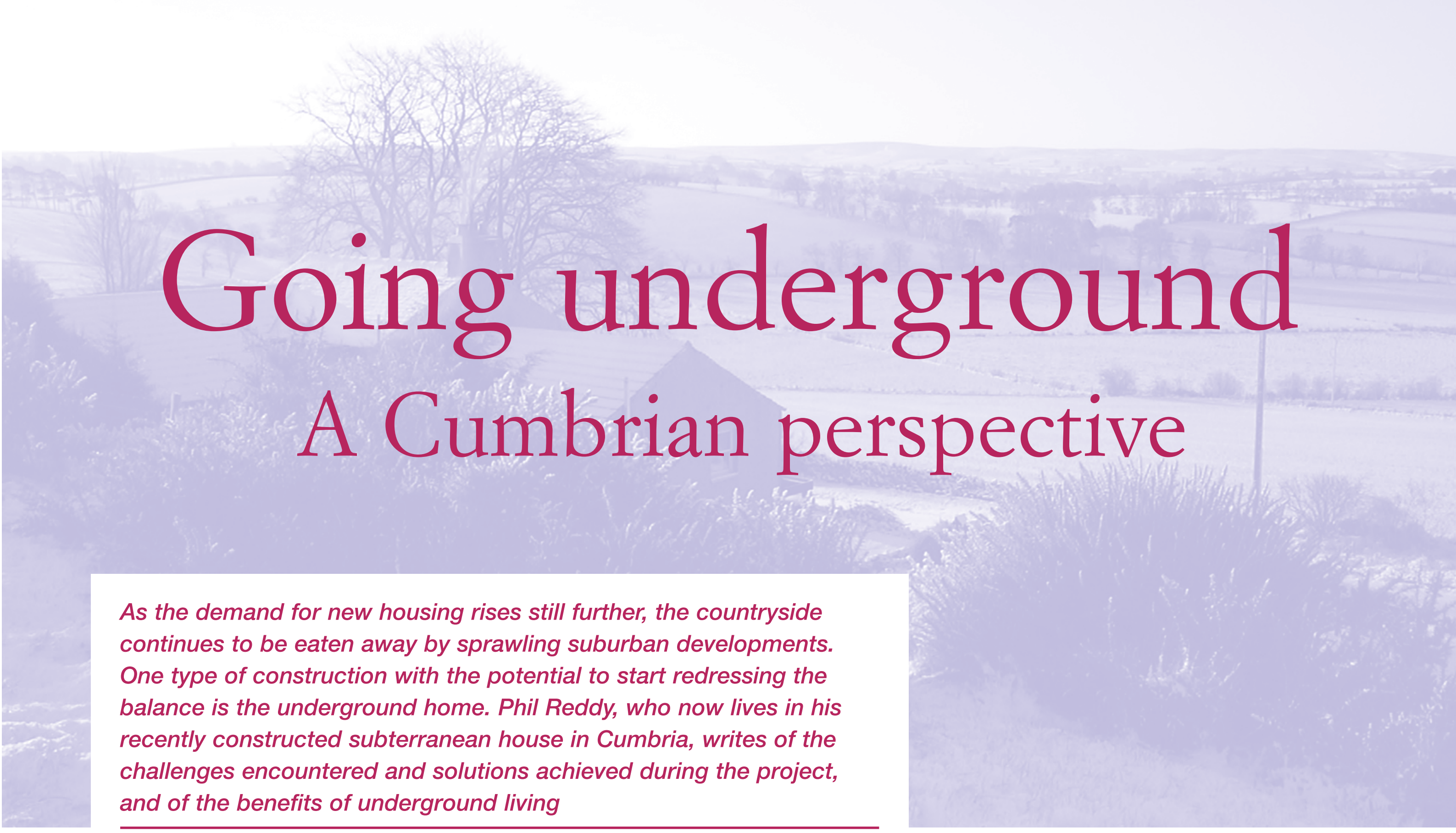

Going underground

A Cumbrian perspective

As the demand for new housing rises still further, the countryside continues to be eaten away by sprawling suburban developments. One type of construction with the potential to start redressing the balance is the underground home. Phil Reddy, who now lives in his recently constructed subterranean house in Cumbria, writes of the challenges encountered and solutions achieved during the project, and of the benefits of underground living

Living underground has a long history – early man was using caves many millennia ago and man has continued to make use of underground shelters ever since: Derinkuyu in Turkey and Cappadocia in Italy are two examples. This article describes a newly built underground house in Cumbria, which proclaims itself as the first such house in the county. In fact you only have to travel a few miles further down the Eden valley from the new house to find a riverside cave dwelling cut into the local sandstone, a home that was inhabited until a few decades ago. But, regardless of the truthfulness of the claim, the house does represent a new approach to housing for Cumbria and is of interest to many as a result.

Why live underground?

Living underground has two big environmental advantages in the modern age:

- it makes energy conservation more straightforward as a result of the stable temperature below ground
- it minimises the loss of green space since being underground, the roof remains available for plants.

Less significant are the benefits arising from being sheltered: freedom from noise, from electromagnetic radiation, from the effects of wind and rain, etc. These are offset, in theory at least, by lack of light, and possibly by lack of air and of escape routes, and by the potential problem of water ingress. An incidental effect of building underground is that the structure has to be stronger than is the case for a conventional house, bringing with it benefits of longevity and of mass. This solidity, and the fact that most of the building is covered mean that maintenance costs should be lower than for a conventional house.

The underground house

This particular building had its genesis in the desire of the owners to live in a house that was environmentally friendly, and the belief that a new build would be simpler and produce better results than modifying an existing property. Given that environmental friendliness means minimising energy use in particular, the decision to focus on being underground was reached quite quickly. Research into this type of building showed that, although the technique is used quite often in places like the United States and Australia, it was almost unheard of in the UK although there is a British Earth Sheltered Association, and a tiny number of properties, among which the Hockerton Housing Project near Nottingham is an excellent exemplar.

The Hockerton Housing Project is a community consisting of a terrace of five single storey houses set into a shallow slope, with an earth bank or berm covering the roof, rear and side walls. This particular community aims to be as self-sufficient as possible in terms of both energy and water and sets out life-style criteria that members of the community agree to.

For more information, see www.hockerton.demon.co.uk

Finding a possible site proved straightforward. An example of a drumlin – a glacially produced ridge – running broadly east to west provided an ideal location, particularly since it had a number of small, disused quarries cut into the southern slope. The ridge itself is a layered mixture of sandstone, shale and limestone, the sandstone having been laid down around 350 million years ago as part of an estuarial system. Agreement was quickly reached to purchase the area around one such quarry, subject to planning permission being granted.

The lack of any real experience of earth-sheltered buildings in the UK meant that the selection of an architect was based upon environmental credentials. Discussions with the architect led to the decision to use a management contract for the build process rather than the more conventional tendering process. The management contracting approach was particularly relevant for this type of build. In a conventional situation, drawings and other information about the building are sent to a number of main contractors who are invited to tender. The time provided for consideration of a bid is normally relatively short and none of the tenderers would have been involved in the design process. Given that the building was something completely outside the experience of any of the builders or trades people in the region, and the uncertainty associated with the need to excavate the quarry as well as the importance of waterproofing, it is highly likely that all bids would have carried a large risk premium. In contrast, the management contracting approach involves the nominated contractor working closely with other members of the design team – architect, quantity surveyor, structural engineer and client – from an early stage. The contract itself is then let in discrete works packages on the basis of competitive tendering, or, where appropriate, by using nominated sub-contractors.

Planning permission

The project's chances of success were rated as less than 10% when first discussed on site with the chief planning officer, but after careful work to explain what was being done and why, and on making a full planning application in order to better illustrate the plans, permission was given. This was materially helped by the fact that the plans included a veterinary facility.

The buildings

The project involved two buildings, the first being a 49 m^2 single storey building for use partly as a garage/store, and partly as a veterinary workspace for treating small farm animals, principally sheep. This building is located close to the road and has two faces that are not earth covered, a south facing wall and the front wall/doorway. The other two walls and the roof are underground.

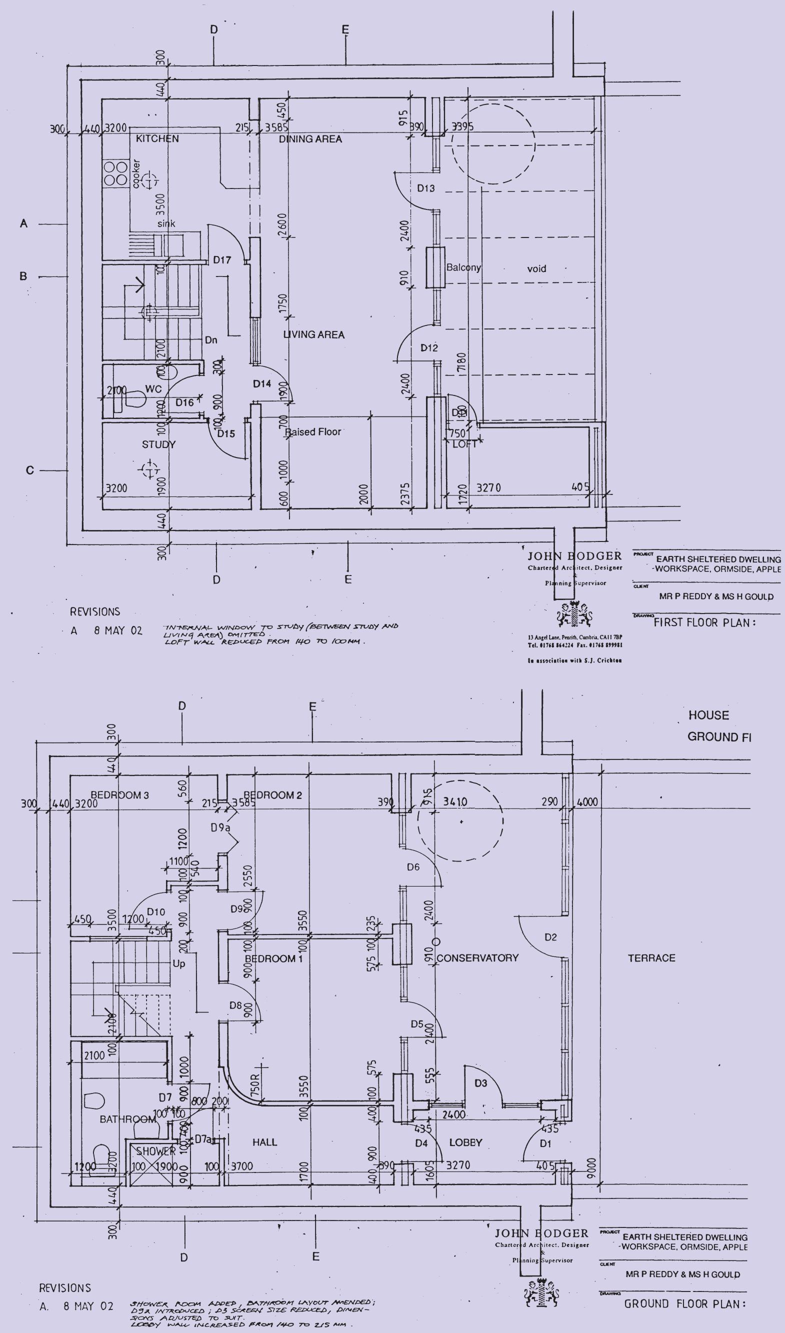

Figure 1 The architect's plans of the two storeys of the main building

The second building is a two-storey house of 157 m^2 set into the enlarged quarry space. A full height double-glazed conservatory fronts the house across most of its width, with a narrow roofed area over the entrance and lobby on the western side. This leads into the conservatory, and through the main front wall of the house into the hall. Downstairs there are three bedrooms, a bathroom and a shower room, with the main staircase in the centre at the back. Two of the bedrooms open into the conservatory through large triple-glazed openings. The third bedroom has a connecting door to bedroom two and a window to the stairwell. Upstairs there is a study, a toilet and a large open plan kitchen and living area, with a balcony at first floor level within the conservatory; there is also a loft above the entrance lobby. The loft contains two items of plant: a ventilation system incorporating a heat exchanger, and a hot water system with integral heat pump.

The balcony provides shade for the bedrooms, which are cooler by virtue of being on the ground floor. Although the house is above the road, it is sheltered by a pre-existing bank, which also gives privacy to the bedrooms, conservatory and patio area. The view from the living room and balcony is extensive, as Figure 2 shows.

The ground floor and parts of the upper floor are tiled, with most of the upper floor being covered with a solid maple floor using material reclaimed from a disused tobacco factory in Glasgow.

Light

Light pipes are used to bring light from above into the kitchen, stairwell and study; these are tubes of highly reflective material that bring light from above to diffusers set into the ceiling. One is also fitted into the vet workspace. Light also reaches the stairwell through a glazed screen in the wall between the living room and landing. At the front of the living area, two openings match those in the bedrooms below and lead to a balcony in the conservatory space, with a spiral staircase at one end and access to a small loft room over the lobby at the other.

Figure 2: View from the site to the south

Energy use

A small photovoltaic system with a capacity of just over 500 W is installed in place of tiles over the lobby area. This acts as a secondary source to the mains supply. Given the limited capacity of the system, surplus capacity is not being sold back to the grid. The owners are considering the option of installing a wind generator on the site in future, in which case, surplus electricity would be sold. A high proportion of low energy light fittings have been used and high efficiency appliances fitted to the kitchen. The ventilation system continuously pumps fresh air into the house and expels stale air, transferring up to 90% of the heat to the incoming air. At its highest speed, the system can replace the entire volume of air in the house in two hours. The hot water system is larger than a standard tank at 300 litres, it is highly insulated and is fitted with a fan-assisted heat pump. This draws air into the room from the adjacent conservatory at the top of the apex this forms with the front wall. Heat is then transferred to the water in the tank and the cooled air expelled back into the conservatory. An immersion heater in the top 100 litres provides additional heating if required.

The house has no heating system, being designed to conserve energy and to make use of the Sun's heat. The house has walls of high-density concrete that are 44 cm thick and the floors and roof are 30 cm thick. The whole structure is surrounded by 30 cm of insulation. In operation, the house will act like a giant storage heater.

Building work lasted from April to October 2002, so the first few months were relatively cool. The house has also been drying out, a process that will take longer than for a conventional house because of the large amount of concrete used, and because all moisture has to come through the inside of the house. The ventilation system has played an important role in keeping moisture at acceptable levels. A data logger was installed in March, which tracks the temperature at four points in the house every ten minutes.

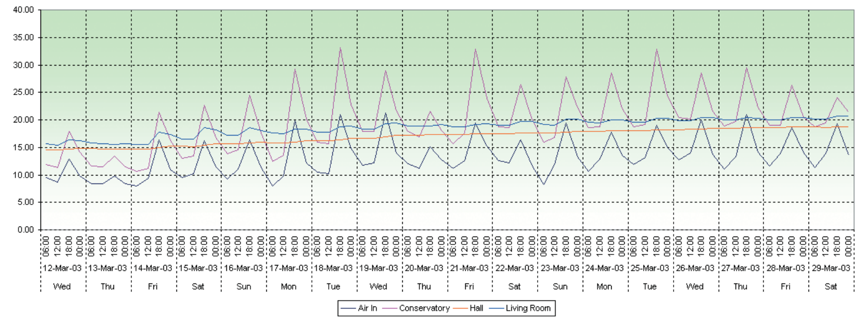

Figure 3 The average six-hourly temperature from 12–29 March 2003

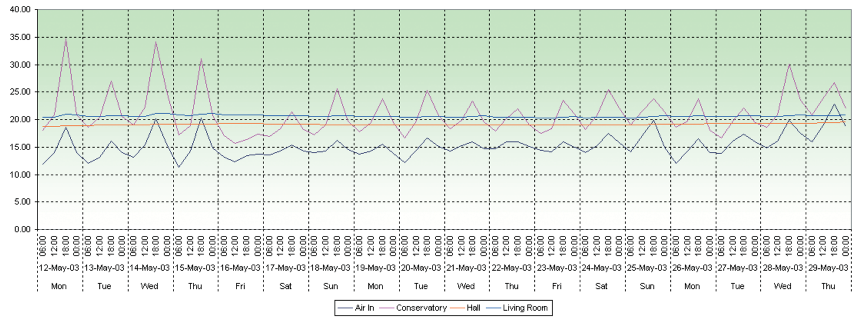

Figure 4 The average six-hourly temperature from 12–29 May 2003

The graph above (Figure 3) shows the average six-hourly temperature for the period from 12 to 29 March 2003, with pulses of energy represented by the top line, which records the temperature at mid-height in the conservatory. The lower line shows the temperature of incoming air, as measured from within the house, on the outside of the metal pipe bringing this air into the ventilation system. The upper of the two middle lines shows the temperature at floor level in the living area, and the lower line shows that at floor level in the hall. All readings are in degrees Celsius.

Although the house had never been cold, it was not always comfortable, so additional heat from a small fan heater was used during the winter months. A dehumidifier was also used. The graph shows very clearly how the energy input during the period covered raised the temperature of the living area by 5°C and that of the hall by over 4°C. The rise in temperature within the house was helped by deliberate use of opened doors to take full advantage of the heat within the conservatory and by limiting the use of windows in the conservatory to lower temperatures there.

Table 1

	Temperature, °C	
	Hall	Living room
12 Mar 03	14.58	15.60
29 Mar 03	18.76	20.64
Temperature rise	4.18	5.04
12 May 03	18.79	20.41
29 May 03	19.54	20.88
Temperature rise	0.75	0.47
Rise between 29 March and 29 May	0.78	0.24
Rise between 12 March and 29 May	4.96	5.28

Figure 4 shows the same period, two months later. The temperature of the two living areas is more stable in the second graph, although the average temperature of both the incoming air and the conservatory are higher in the second period. This reflects deliberate actions to reduce the impact of external energy inputs: by keeping doors closed between the house and conservatory; by using the conservatory windows to allow heat to escape; and to an extent, by using variations in ventilation airflow.

There are no blinds fitted to the conservatory at present, although these will be added in the near future and will provide an additional means of controlling temperatures within the conservatory and therefore the house.

Table 1 summarises the results shown in the two graphs and makes clear the difference between the two periods in terms of the impact on temperatures within the house.

The difference in average temperature between the two periods is shown clearly in Table 2: the average air temperature rose by 16%, while that within the conservatory rose by just 7%, another indication of the control available from the use of windows to dissipate excess heat.

Electricity use within the house and vet space is not separately monitored, though the vet space does not require a great deal of energy. Consumption is currently running at an average of just over 10 kWh per day from the mains supply, with 1.3 kWh being generated by the photovoltaic system. This compares with an average usage of over 16 kWh per day for the owners' previous property, a modern bungalow. In the latter, there was, of course, the additional cost of an oil fired central heating system, at close to £800 per year.

Table 2

	Average temperature, °C	
	Air In	Conservatory
12–29 March 03	13.14	19.61
12–29 May 03	15.24	20.99

Water treatment

Sewage is collected in a standard septic tank at the lowest point in the site, with the outflow being collected in a second tank then pumped up to a parallel pair of vertical reed beds. These feed two horizontal reeds beds in series, which in turn lead to a pond and finally to a soak-away.

Engineering challenges

There were a number of engineering challenges, starting with the nature of the ground itself. A full ground survey would have been expensive, and it was decided that, in view of real uncertainties over planning permission, this was unwarranted. Instead, three trial pits were dug to test ground conditions; these provided reassurance but not certainty. In the event, excavations uncovered voids caused by limestone being dissolved over many millennia, leading to a change in the shape of the vet space / garage to avoid any possible problems. A second uncertainty concerned the hardness of the sandstone, since the quarry had to be enlarged to accommodate the building and access. Fortunately, the rock proved to be relatively soft.

Neither building is far beneath the surface and the house is surrounded by rock, yet the need to counter lateral pressure from the back-filled soil, to cope with the large number of openings in the internal walls, and to provide support to the walls on either side of the conservatory, all required careful work by the project's structural engineer. Since the whole building rests on a platform of insulation, there was also a need to reduce the possibility of the house moving forward. A final challenge was to make the structure buildable by locally available tradespeople. The standard approach for a commercial or industrial building would have been to use poured concrete throughout, but it was felt that the accurate shuttering required could be difficult to deliver. The alternative selected was to use high-density hollow blocks threaded over reinforcing bars and filled with concrete for the main structural walls. The front wall is different, being made of solid blocks with an insulation filled cavity. The intermediate floor and roof are of poured and reinforced concrete, onto integral metal formwork. Hidden buttresses provide structural support for the conservatory walls and act to prevent any forward movement of the building. The solution has resulted in a very strong building that was relatively straightforward to produce.

Making the building waterproof should have been straightforward, a standard tanking membrane solution

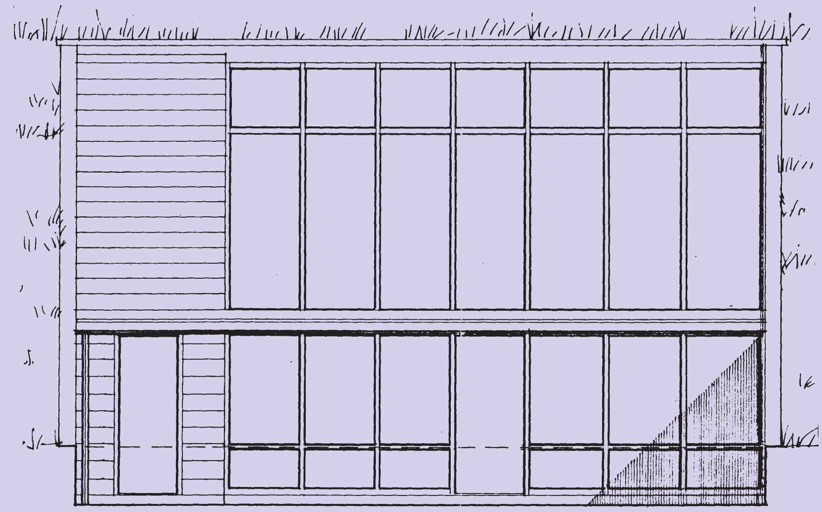

Figure 7 Architect's elevation plan and the completed house, showing the double storey conservatory that fronts the property, maximising the amount of natural light inside

being used. Unfortunately, poor workmanship meant that water did leak into the house for the first five months, a problem that was difficult to isolate but has now been resolved.

Building costs

The overall cost of the project has resulted in a build price per square meter of just over £1200, well within the range for new domestic buildings. Costs have been higher because of the need for two separate buildings and to enlarge the quarry, and to a lesser extent because of the inclusion of photovoltaic and reed-bed systems; however the site was less expensive than normal.

The result

So far, the results are excellent – the house is warming up well, with temperatures varying very little except by choice – the conservatory captures heat extremely well whenever there is any sunshine, heat that can be drawn into the house if required. The light pipes provide valuable additional light at the back of the house, which is flooded with light at the front in any case – sunlight is able to reach the back wall during the latter part of the day for almost half of the year. The ventilation system ensures that the house is full of fresh air, something that is particularly noticeable in the bedrooms. The photovoltaic system is generating increasing amounts of electricity in the summer and the site itself is slowly turning green again.

The vet space is a facility that is far better for everyone than the cramped and difficult conditions at the main practice site, particularly during the busiest time of year, with lambing in progress.

The house is a real example of sustainability, demonstrating both the potential for energy saving and the use of renewable sources. ■

Figure 5 Light floods through the glass into the front of the house

Figure 6 Set into the ridge, the house is surrounded by 350 million-year-old sandstone

Phil Reddy is a tourism specialist working for the Northwest Development Agency on the development and implementation of its newly published Regional Tourism Strategy. Before starting work in tourism, Phil spent many years working with computer systems and was responsible for the design of a real time loss prevention system linking point of sale terminals to cameras and recording systems. He has an MBA from the University of Durham Business School.

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