The Stabilisation of Combe Down Stone Mines:

Good Practice Guide

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by Alan Francis, Mike Hope and Professor David Adamson

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Bath and North East Somerset Council
10 Palace Yard Mews
Bath BA1 2NH
www.combedownstoneminesproject.com

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Contents

Image Opposite page,
Hand drawn map of underground findings by Neville Redvers-Higgins of Oxford Archaeology

List of Appendices

List of Figures

Foreword

When a utilities contractor accidentally broke through into the mines back in 1989 and brought the subterranean world to the attention of the wider community, no-one could have foreseen the train of events that would be put in place. In the midst of fear for the safety of themselves, their homes and their community, it was difficult for many residents to imagine a future for the village of Combe Down when there appeared to be no funding available to rectify the situation.

Following the establishment of a new Government fund and the subsequent completion of a major engineering project that pushed technical boundaries to new limits, was at its peak the largest mass foam concrete infill project in the world and had the largest mine shift in England, today the village is safe.

The Combe Down Stone Mines Project began in a small way in 1999. By 2009, when the access shaft on Firs Field was filled in, the project had saved over 700 houses which were built over shallow mine that had become unstable.

The remarkable success of the project is largely down to the extensive partnerships involved in its delivery, the involvement of the Community and to the commitment of the hundreds of men and women who worked on it. Bath & North East Somerset Council and the Homes and Communities Agency are very proud of the project and to have saved the village and delivered the project on time and to budget and with an exemplary health and safety record.

It was considered that the history behind this extraordinary project and the good practice experience and knowledge gained throughout should be captured and passed on to a wider audience. Consequently, Bath & North East Somerset Council and the Homes and Communities Agency commissioned two publications - this book, which focuses on good practice in the technical and management aspects of a successful major project, and a commemorative book packaged with films (including a 3D laser fly-through) relating the history of the mines and their stabilisation. 'The Stabilisation of Combe Down Stone Mines – the saving of a village' – ISBN 978-0-9563829-3-4.

We trust that the reader will find this book to be both relevant and helpful to future construction and engineering projects.

Councillor Paul Crossley Leader of Bath & North East Somerset Council

Robert Napier Chairman of Homes & Communities Agency

Preface

Too many construction and civil engineering projects receive adverse publicity due to running late and/or being massively over budget. To the layman it may seem that such projects are always late or over budget. However, throughout the construction industry there are many successful projects (even if very few of these make headline news outside the specialist technical press). The Combe Down Stone Mines project is one of those successful projects.

This publication endeavours to convey aspects of good practice from the project as a case record contribution to the Construction industry's knowledge base. It focuses on organisational good practice, particularly from a Client and Funder perspective, and makes reference to the 'Client Best Practice Guide' (ICE, 2009). Detailed technical consideration of good practice and innovation is outside the intended scope of this book.

The Combe Down mine stabilisation project was funded by the Land Stabilisation Programme, LSP, operated by the Homes and Communities Agency (formerly English Partnerships). The client for the project and designated Mine Owner was Bath and North East Somerset Council. Their commitment to supporting the sharing of good practice by sponsoring the production of this publication is gratefully acknowledged.

Along with HCA and the Council there are many people and organisations that need to be thanked in capturing the history of this project. As authors, we have endeavoured to list all those organisations who allowed us access to their staff and information in Appendix E; however we need to express special thanks to the following individuals for their assistance, support, encouragement, editorial advice, sustenance and late nights:

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John Harvey and John Lister Mine Managers

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Finally, one special thank you to Richard Clark (Associate Director of DTZ (Bristol Office)) for providing the authors with logistical support (meeting rooms, offices, tea, coffee and biscuits) for research, drafting and editing to take place.

We trust you find it an interesting read.
Alan Francis, Mike Hope and Professor David Adamson

Chapter 1
Introduction

The undertaking of large engineering projects that have some combination of major environmental, heritage and social/community issues as significant factors, risks and constraints, alongside finance, is an increasingly common occurrence. This book seeks to convey aspects of good practice experience on these matters that will be of interest to engineering and construction practitioners and to participants of other schemes. The experience is presented in the context of this particular major project (£100m+), for which the engineering challenge was stabilisation of extensive underground mine workings beneath the village of Combe Down, Bath. However, the applicability of this experience is certainly not limited to that type of project.

The 'Client Best Practice Guide' (ICE 2009) identifies key project stages and factors that influence successful projects.

Some of these key factors are:

- Clear, well-communicated strategic objectives.
- Effective management of risk and opportunity, and plans to mitigate problems.
- Good change management.
- Strong and realistic project planning and resourcing augmented with appropriate flexibility, creativity and innovation.
- Involving the right people from the right organisations with shared objectives aligned to the project vision.
- Committed, clear, strong leadership with authority, and good governance.
- Realistic budget and achievable programme with appropriate risk provision.
- Good stakeholder engagement.
- Legacy/decommissioning considered at strategic intent stage.

It is widely accepted that dealing with risk and uncertainty is critical to many of these project factors and is present at all the key stages of a scheme (planning, development, implementation, operation and legacy/decommissioning). For example, the management of risk and opportunity assists schemes by:

- Reducing the likelihood or consequence of negative events.
- Identifying opportunities that would have a positive consequence.
- Identifying and understanding complex multiple cross-organisational risks.
- Supporting cost control.
- Developing best value through optioneering approach.
- Providing visible and auditable governance.
- Protecting reputation and stakeholder confidence.
  (after ICE, 2009)

The identification and management of risk and uncertainty, coupled with the pro-active use of that information to set project priorities and interim goals, has been a key factor in the life of the Combe Down Stone Mines project, and is a theme running through this book.

Notwithstanding the importance of dealing with risk, the key success of the project is achieving the strategic objectives. These were the protection of life and property in Combe Down from the high risk of mine collapse and the blight that risk previously brought to the local community. The entire project community, including the regulatory authorities and other stakeholders who contributed to it, can take pride and credit for their contribution to achieving that success, and all the more for that being achieved on programme, within budget and with excellent health and safety performance in a hazardous underground environment.

Chapter 2
Project Background and Strategic Intent

Background to the Project

Bath and the stunning countryside surrounding it is one of England's most beautiful places to visit. Bath is a unique city with hot springs, Roman baths, a historic abbey and its Georgian crescents and buildings. It is also the location of an extraordinary engineering project, which has taken place over the past 10 years, with links to that building heritage.

Bath's Georgian buildings are famous for being built in Bath Oolite, commonly referred to as 'Bath Stone'. This stone was mined and extracted from areas surrounding the city, during the 18th and 19th centuries.

Situated to the south of the City are the wards of Combe Down, Lyncombe Hill and Monkton Combe. From 1731 high quality stone was extracted from large deposits below these areas. The overall extraction rate from within the Combe Down Stone Mine was high, at 85% void, with only 15% residual stone pillars (over 3,700 in total) left to support the roof of these shallow mine workings for the future.

Stone mining in Combe Down ceased by the mid 1800s, and the mines were left in an abandoned state. At the time of abandonment there was little concern over the long-term stability of these mines. The overlying area had few dwellings built on it and remained largely undeveloped. However, over the next 100 years, the village of Combe

Fig. 2.1. An engineer in Combe Down Stone Mine (This picture of the Mine pre-dates the LSP Programme and Health and Safety procedures.)

Down developed into a major suburban area of Bath, populated with homes, schools, business premises, a church, an important Ministry of Defence establishment, a major highway (the A3602) and an associated network of roads. Beneath the roads lay pipes and cables for electricity, gas, water, drainage and communications. Indeed, the gas mains running through Combe Down are vital in supplying large areas of the city.

After many years the roof and pillars of the old mine (Fig. 2.1) were losing the struggle to support the mine void and were collapsing. This threatened large areas of the village over the mine workings with sudden collapse, including over 600 homes. The project task was to mitigate the huge potential risk to life and property of such collapse in a manner that also accommodated major environmental, heritage and social/community factors with due regard to economic good value.

The mine itself had some typical features and some that were quite unusual and perhaps unique, for example:

- Very shallow depth, generally between 3 to 6 m, although deeper in isolated areas and with a thin overburden of roof rock (where collapses/failure had already occurred). This increased the likelihood that roof collapses into the mine would result in collapse of the ground at the surface and beneath building foundations.

- Highly variable and haphazard geometry and abandonment history including 'pillar robbing' – over-extraction of stone taken from the sides of remaining support pillars, after normal mining ceased (Fig. 2.2).

- Inherent variations from one part of the mine to another relating to sequence, methods and height of mine workings, mine roof spans between pillars and roof sag or deflection (Figs. 2.2, 2.3 and 2.5).

- Different physical, mechanical and chemical characteristics of the limestone rock. The stone that was mined was known as Oolite and the roof rock was termed 'Bastard Stone'.

- The presence of geological features in the roof such as joints, fractures and open fractures (gulls), so the rock is far from being a solid mass.

- Groundwater and/or surface water infiltration, which materially influenced the weathering of the stone and rate of deterioration in the mine.

Over time, the mine conditions deteriorated, through either natural weathering or pillar 'robbing' to the point where they were becoming unsafe. It was assessed that collapse might occur as catastrophic failure of pillars, as well as more conventional void migration by roof collapse between pillars (crown hole collapse). One pillar

Fig. 2.2. Example of 'pillar robbing' (This picture of the mine pre-dates the LSP programme and Health and Safety procedures.)

failure would throw load onto adjacent pillars, which could cause those pillars to fail, giving a potential for sudden, progressive collapse to occur over a substantial area of the mine. The potential for failure was assessed as a significant risk to life and property and led to property blight throughout Combe Down village and potential for much greater blight following the predicted major collapses in future.

The engineering assessment of the mine concluded that one of the chief mechanisms by which stabilisation would be effective was through the confinement of the pillars e.g. by filling the voids around the pillars, so enhancing pillar strength and enabling pillars to remain weight supporting in the future. Filling the mine would also restrict the potential for void migration by roof collapse.

In the early 1990s a team from the University of Bristol led by Dr Brian Hawkins carried out an underground survey of the mine and its condition. Fig. 2.3 shows mine survey work. Whilst various areas of the mine were accessible for this survey, large areas were not, and neither was the actual mine perimeter. A potential risk to public safety was evident from this early survey but not the full extent and nature of the risk. Following the results of this survey the then Bath City Council resolved to take on responsibility for safety matters 'for the duration of the works' and an early application for funding for the stabilisation of the Mines below Combe Down was made from the then Government's Derelict Land Grant Programme.

Opinion for the scheme was divided. Some local residents and businesses wanted urgent action due to the difficulties being experienced in selling and insuring property. Others did not want undue publicity as this would blight property values further. In addition, the proposed solution of infilling, using a pulverized fuel ash mix, was strongly opposed by nearly all the residents on health and safety grounds. This application failed, largely as at the time the appraisal produced a negative cost benefit.

Stabilising the mines raised other stakeholder issues and complications:

- The surrounding countryside is characterised with a variety of high quality natural habitat, including designated Sites of Special Scientific Interest, and the mines themselves were particularly significant for a variety of bats, including Greater and Lesser Horseshoe Bats. Infilling the mine completely would have destroyed the natural habitat of these legally protected species.

Fig. 2.3. Mine survey work. (This picture of the abandoned mine pre-dates the LSP programme and Health and Safety procedures.)

- The hydrogeology of Combe Down is important because water that infiltrates the rocks covering the area emerges into the valleys below as springs, some of which are harnessed for drinking water, most notably by Wessex Water at Tucking Mill. The site is part of a legally protected groundwater Source Protection Zone. Stabilisation of the mine had to be undertaken in such a way as to not disrupt the drainage of the site nor contaminate the springs.

- The mines themselves have historic interest, the Archaeology being of national significance and English Heritage needed to be involved in agreeing any form of stabilisation.

- HM Inspector of Mines (HMIM) was particularly concerned about the condition of the mine and the access into it. HMIM issued an instruction, in 2001, to stop any further access into the mine until underground support strengthening measures were implemented.

- Due to incidences of crown hole collapse and the potential for surface building excavations to induce underground collapse, the HSE issued Prohibition notices on further building work above the mines.

- Means of project delivery became a major concern to the residents with regard to worksite locations, impact of vehicles, noise and dust on the area and surrounding environs, which is a designated 'Conservation Area'.

- Design life and durability of the stabilisation have an effect on post-infilling maintenance and the residual obligations on the Council and on the residents (or their mortgage and insurance providers) over the following years.

On 1 April 1999 the Department of the Environment Transport and the Regions (DETR) announced a new Land Stabilisation Programme (LSP), which specifically addressed the problem of communities at risk from abandoned non-coal mine workings. The LSP (originally administered by English Partnerships, now the Homes and Communities Agency, HCA) provided funding to local authorities to help and assist them to stabilise mine areas that had been left hazardous by abandoned non-coal mine workings. The establishment of LSP was the catalyst that enabled the Combe Down Stone Mines stabilisation project to become a reality. The LSP enabled the benefits from reduction of risk to life and property and of the risk of dereliction associated with mine instability to be considered in the project funding appraisal, in conjunction with the usual cost and regeneration benefit factors.

The LSP takes account of the fact

'that abandoned mine working can cause a blighting effect on communities, with urban areas becoming derelict, neglected or unsightly as a result of mine-induced collapse or subsidence. LSP funding is available to Local Authorities and focuses on the removal of blight and enabling investment to regenerate areas where underground mine workings are present. These grants are available for land liable to collapse as outlined in the Derelict Land Act 1982'.

The Combe Down Stone Mines project satisfied key conditions of the LSP in that its main objective was the protection of Life and Property and that the Land to be treated must be likely to become derelict, neglected or unsightly by reason of collapse of abandoned non-coal mine workings.

The overall mine area found to be at risk was eventually identified as 25.608 hectares and affected approximately 650 properties (with over 1,600 inhabitants). In addition to this there were main arterial roads traversing the mine carrying major underground utilities, which served a large proportion of the city.

Strategic Aims of Project

Two of the key tasks of good clients who wish to positively influence the success of their projects are to 'provide strategic thinking, intent and approach' and to 'apply effective leadership and Governance' (ICE, 2009).

From the outset there was an understanding that the mines were large (Fig. 2.4) and that stabilisation would be complex for many reasons, but there was limited knowledge as to the actual size and complexity of the project to guide Bath and North East Somerset Council. Neither was the Council experienced in delivering such large engineering projects. In addition, with the large number of interested stakeholders who were now becoming actively involved in the decision-making processes, with entirely proper but at that time seemingly incompatible aspirations, the project seemed almost impossible to deliver. Therefore, it was important that the Council, in

Fig. 2.4. Aerial Photo. Extent of mine. The red line in the above picture designates what was thought, in 1999, to be the potential extent of the mine area.

consultation with the newly formed residents' project Community Association, and with the assistance of HCA, set out clear objectives and a strategy that would guide the overall success of the project.

The following aims were set out for the project:

The overarching objective of the project was to stabilise the mines to protect life and property in line with LSP criteria and guidelines.

To provide a stabilised scheme that allows the Association of British Insurers (ABI) and the mortgage industry to remove the special conditions applied to properties in Combe Down so that they are treated for insurance and mortgage applications in a similar fashion to other comparable areas in Bath and the UK.

To select stabilisation methods and materials that do not lead to areas of Combe Down being perceived as contaminated or continuing to be 'blighted' or otherwise having long-term environmental or financial liabilities attached to them by the ABI or mortgage industry.

- To avoid properties being included on any register of landfill or contaminated land.
- To protect the bat species and their habitat.
- To safeguard the Combe Down Heritage and environment.
- To avoid contamination of the water outflows from the Combe Down area or the creation of localised flooding at the plateau surface or increased local seepage around the slope that may lead to hill slope instability.
- To mitigate the impact and disruption caused by noise, dust and construction traffic in the area.
- To mitigate any damage to the existing properties in the area due to the consequences of the project work.
- To seek a design solution, to achieve successful stabilisation for at least 100 years.
- To mitigate health and safety issues relating to construction operatives particularly those working underground.

As the project progressed, over its 10-year lifespan, further aims and objectives were added to the original. These were:

- To continually review information to seek improvement to methods, costs and time.
- To appoint independent Project Managers and Cost Managers, in conjunction with the appointed Engineers and Contractors, to deliver the project.
- To periodically review and monitor all aspects of the project to check, through continual improvement, that 'best value' was being achieved.
- To achieve delivery within optimum programme time.
- To achieve delivery within budget.
- To seek to mitigate the strategic health and safety risk of mine collapse through the use of temporary works or short-term actions.

The following chapters describe how the Combe Down Stone Mines project kept to these aims and how the project was delivered. Each of the following chapters commences with a summary of elements of Good Practice contained within it.

Fig. 2.5. An open mine gallery, with discards. (This picture of the abandoned mine pre-dates the LSP programme and Health and Safety procedures.)

Nick Raynsford MP and Don Foster MP on Firs Field in 1998

Chapter 3:
Option Selection, Risk and Funding Assessment

Examples of good practice discussed in this chapter include:

1. Influence of early-stage risk management thinking on project decisions including procurement.
2. Steering Group stakeholders involved in wide-ranging Risk Workshops.
3. Relative rating of risk factors at 'big picture' level (rather than absolute ratings).
4. Quantitative modelling of risk combinations including Monte Carlo analysis.
5. Engagement with the Association of British Insurers, resulting in property insurance being available on normal terms for the years the scheme was underway.
6. Use of upper bound/lower bound comparison study of positively identified conditions (as distinct from assessed or interpolated conditions).
7. Use of GIS tools for live analysis of large quantities of information from disparate sources, including non-digital records.
8. Environmental impacts valued in quantitative financial terms in the economic appraisal, not just in qualitative terms.
9. Early sharing of information with companies in the Construction sector, seeking their feedback on specific technical and commercial issues.

General Chapter Overview

Construction projects typically involve decisions affecting three key parameters of time, cost and performance/quality, often with tensions between them. The Combe Down project initially had challenges on these parameters, notably its plan area was unknown (but large), the mine void height was similarly uncertain, and it was far from certain how best to stabilise it.

Some additional challenges were:

- The mine was in an advanced state of instability, with a village, including over 1,600 people, only a few metres above the mine void roof.
- The area is a Site of Special Scientific Interest (SSSI) and there were three major statutory environmental constraints:
- The mine was home for large numbers of rare and legally protected bats.
- It lies in the groundwater Inner Source Protection Zone of a public water supply.
- There was legally protected archaeological heritage within the mine itself.

The objective, for the Council and the HCA, was to better evaluate the overall mine and options that could be utilised to stabilise it so that the scope, appropriate quality, cost and time could be better assessed, together with risks.

With these challenges in mind, the Council and HCA were keen to understand, as soon as practically possible, the level of overall funding that would be needed for the scheme, including provision for risk.

Key to this was the selection of scope of work to be done and the way in which stabilisation was to be achieved. That selection involved consideration of options and their associated costs and risks.

In addition, an assessment was made of the economic cost if nothing was done, i.e. if the mine was allowed to collapse beneath the village – a 'Do Nothing' option. That provided a benchmark against which the costs and benefits of the various stabilisation options could be compared, by strategic decision makers.

At a different level, many local residents perceived their main risk as the difficulty or expense they had in securing property insurance and mortgage finance on normal terms. HCA assisted with this blight risk by engagement with the Association of British Insurers. The latter agreed their members would maintain normal insurance terms provided a village-wide stabilisation solution was being actively progressed, with funding by the HCA managed through the Land Stabilisation Fund.

The following describes some elements of the approach to this assessment of scope, cost, benefit and risk, to achieve a scheme that could be put to Government as a funding application in June 2004. It commences with the Risk Management process, which was a fundamental part of option selection.

Risk Management

As with many complex projects Combe Down had a large number of stakeholders and their associated views and issues. When these were added to the as yet unknown means of stabilisation and uncertain mine volume, the list of project risks and mutually incompatible stakeholder requirements seemed almost insurmountable. The Steering Group of major stakeholders established by the Council provided a valuable forum for exploring and moving forward with these incompatibilities. In this case there was also an overarching safety priority of protecting residents' lives. Whilst properly representing their respective interests and responsibilities, no stakeholder wished a future fatal mine collapse to be attributable to the project not proceeding due to the single-minded pursuit of their interests.

Whilst the Engineers, Mine Managers and Miners set about the mine investigation and emergency works, the Risk Managers worked in conjunction with them and the many stakeholders to document and assess all the risks in manageable categories. The aim was first to understand the views of each stakeholder and then to bring stakeholders together in an 'inclusive process' to share these views. This facilitated an improved mutual understanding of the potential incompatibility or conflict between them and extent of compromise needed by all interested parties to produce a successful project.

There were over 50 stakeholders with a legitimate interest in the project. Some of the main stakeholders were:

- Local Community
- Environment Agency
- Natural England
- English Heritage
- HM Inspector of Mines
- Wessex Water
- Local Planning Authority

- Highways Authority
- Association of British Insurers
- Councillors
- Government Departments
- HCA – acting for the Funders
- Ministry of Defence
- Electricity, Gas, Sewerage & Telecoms Utilities
- Bus operator

Throughout 2002 to 2004 the Risk Manager convened a series of individual meetings and larger inclusive workshops with the Stakeholders/Council/Project team and developed a thorough and extensive risk register to capture the potential impacts to the project identifiable at that stage. Mitigation measures were developed for each risk, which provided the Project Manager and Council team with a means to manage each risk and stakeholder issue. The overall project risk assessment process was later used quantitatively to calculate the financial project risk allowance for the funding needs assessment.

The early risk thinking identified risks that needed urgent attention, which could not wait for Main Scheme funding. This risk assembly also led to a re-ordering of risk priorities. For example, the previous risk thinking had given greatest priority to mine zones that were judged most susceptible to collapse–high-hazard areas. That thinking was extended to take account of the risk consequences of a given area collapsing (Fig. 3.1). This thinking led to greater priority for stabilising North Road (A3602), which carried major underground services (including gas), and was crucial for vehicular access to undertake further stabilisation works. A collapse and rupture of gas, electricity, water and drainage services here could have had a considerable impact, on both the local underground and above-ground environment in Combe Down. It would also have had a short-term impact on supplies to a substantial area of Bath City.

The risk register subsequently became a working document throughout the life of the project and was updated at inclusive risk review meetings on a quarterly basis to remove past risks and add new risks. The risk register was exhaustive but it didn't foresee the foot and mouth outbreak in 2001, which disrupted vehicle movements and consequently impacted upon the labour getting to site. The lesson from this is - "expect the unexpected".

Fig. 3.1. Former localised surface collapse. The potential risk of underground services rupture by collapse led to early stabilisation work to North Road.

In addition to risk management, the project would go through periodic reviews of the Council's 'Overview and Scrutiny Committee', whereby it would be interrogated by all political parties for approach and Best Practice.

Process for Funding Application

In order to provide a robust funding assessment and application, the options selection process and development of the detailed Cost Plan for the lead option (and others) were underpinned by a rigorous risk analysis methodology.

From 2001 the project had convened regular risk workshop events, with all interested parties. The objectives of the workshops were to review the scope, impacts and benefits of each option, and to check that relevant risks were identified and prioritised appropriately. They also enabled the multiple stakeholders to see how the risks associated with their particular interest fitted into the overall risk picture. This understanding of the 'big picture' built on the participation of key stakeholders in the Steering Group and was an important part of developing the understanding and acceptance by stakeholders that a solution to save the village would need adjustment and refinement of their normal preferred requirements in a Planning Application situation. The mutual incompatibility of stakeholders' preferred requirements was one of the main risks to finding a viable solution in the early stages.

This collective appreciation of the 'big picture' by stakeholders was helped by use of an approach that gave relative quantitative ratings to each aspect or factor influencing the scheme, as distinct from each aspect having an isolated absolute numerical rating.

The tool used was a weighting system: a limit of 100 points was available for the sum of all the ratings, and those points were allocated to the various factors. The workshops and Steering Group discussions on relative allocation of points assisted the building of greater consensus and mutual appreciation amongst stakeholders. The relative approach enabled better differentiation of highly critical factors from important though less critical ones. The contrast between critical factors and high-profile factors with less fundamental importance was also made clearer, in a way that stakeholders could respect.

Another beneficial feature of the relative approach is that it avoids the tendency that can arise in absolute scoring for a topic with multiple factors to acquire a higher cumulative score than a more critical topic with few scored factors. For example, the cumulative total score for an aspect with 6 factors scoring 2/5 greatly exceeds that for an aspect with a single factor scoring 5/5, but the latter is usually more critical.

A similar relative-ranking principle was used at various points in the project, notably for quantitative assessment of the quality aspects of the £multi-million main construction tenders.

Options at Funding Assessment Stage

At initial funding appraisal stage a wide range of options for mitigating the risk to life and property were considered. Four mitigation options were selected by Government for full economic appraisal, plus the 'Do-Nothing' option. These options were:

1. **Do Minimum - Bulk infill of 100% of the mines complex** - complete infilling of the mines through an underground operation. No provision for environmental mitigation.
2. **Combined infill stabilisation (the eventual lead option)** - infilling of 80-90% of the mines (predominantly foamed concrete) with 20-10% environmental void for bats, plus provision for archaeology and groundwater.
3. **Structural support of the mine**s - by strengthening pillars and constructing new intermediate pillars, plus roof support.
4. **Controlled collapse** - evacuation of residents, mines destroyed in a controlled manner, followed by redevelopment of the area.

Other options considered in some detail but not included in the final 'short-list' included:

5. **Infilling by surface drilling and grouting** - method of working was considered unsafe for the mine circumstances here.
6. **Infilling using predominantly PFA** - was less attractive financially than foamed concrete infill, once account had been taken of risk, including measures required to gain acceptance from the Environment Agency, in relation to perceived chemical risk to the groundwater Source Protection Zone, and acceptance from the community in relation to health issues.
7. **Infilling predominantly with gravel or sand** - too expensive.

Risk estimation and allowance were deemed critical to the funding application, which systematically sought to avoid optimism bias in the submitted cost estimate, and the corresponding higher risk of subsequent cost over-run.

One of the key uncertainties/risks was the extent of the area that would need stabilising (Fig. 3.3). For a given volume, a bigger area would need more time to access and stabilise. Information from historical surveys was fairly good, but only where void height and continuity for man access had enabled surveys in previous decades (prior to modern health and safety practices). This gave a deceptively encouraging impression that the area that had been mined was well known. To better understand this risk an upper bound/lower bound comparison study was undertaken – contrasting the area known to have been mined with the area known not to have been mined. The zone of uncertainty identified on the map of Combe Down between these bounds was subdivided and rated for likelihood and risk. The study identified that there was a considerably higher likelihood of the mined area being greater than that previously used for cost estimates, rather than of it being less. The implication for cost was that there was (a) little likelihood of cost being less and, if it was, then not much less, (b) a much greater likelihood of cost being greater and, if so, of being significantly greater.

This upper/lower bound study led to revision of the primary cost estimate parameters, with an improved and justifiable basis for the revised estimate of mine area and infill volume, and reduced risk of those parameters being exceeded. This was a useful systematic tool for addressing potential optimism bias.

The existing project Geographical Information System, GIS, was a very valuable and

Fig. 3.2. Ground penetrating radar.

time-saving tool when undertaking this upper/lower bound study of data from a myriad of historical maps and document sources, plus large quantities of borehole and other subsurface ground information.

This type of evidence-based upper/ lower bound study has applicability in many other fields of uncertainty, e.g. ground contamination remediation. It is quite distinct from an approach based primarily on optimistic/pessimistic assumptions about factors or parameters.

Another outcome of the upper/lower bound study was that it showed up an area where uncertainty could be greatly reduced by a modest quantity of further geophysical and borehole investigation (Fig. 3.2). In the event, a cost of about £80,000 for the further focused investigation enabled a reduction of £8 million in the estimate for the funding application, without delaying the programme.

Experience was gathered from the then active emergency stabilisation works, from the existing contractor, engineering team, Mine Manager and Council team, to refine scope, cost and risk estimates.

In addition, in order to enhance risk thinking, to refine the cost estimate and to increase confidence in them, the assistance of the Construction sector was sought (see Chapter 5). The views of the industry assisted in the preparation of an estimated scheme that the industry would be willing to price and tender on.

Quantitative Estimation of Overall Financial Risk

The quantitative financial risk of the various options was assessed in considerable detail for option selection and as part of the economic appraisal.

Quantitative assessment of risk was undertaken through a mixture of standard Risk Analysis and Management of Projects (RAMP) methodology (appropriately refined to meet the demands of the project) and Monte Carlo analysis. The detailed risk register produced was linked through to a financial risk allowance for each stabilisation option for the project, based on residual risk, i.e. that remaining after mitigating actions had been undertaken. Costs for risks assessed as having a greater than 90% (>90%) chance of adverse impact were included in the primary estimate of cost rather than being provided for in the risk allowance. However, these greater than 90% risks remained in the qualitative risk register, for the purpose of their ongoing management and mitigation.

For each less than 90% likely (<90%) risk in the risk register the probability of occurrence was assessed and the minimum, maximum and most likely impact in the event of occurrence were estimated. A Monte Carlo analysis with 10,000 iterations was undertaken in order to model a wide range of combinations of risk occurrences and associated cost impacts. The resulting cost/probability distribution curve was used to assess risk contingency allowances at various degrees of confidence, for each option.

The calculated risk allowances, modelled at various degrees of confidence, were as given in Table 3.1 below.

Table 3.1. Risk Allowance Cost Estimate1 (from Monte Carlo Simulation of <90% likely risks2)

% confidence of non exceedance	Stabilisation Option £			
	Lead option	Do minimum	Structural	Controlled Collapse
50%	£16m	£15.8m	£33m	£15.6m
80%	£21m	£20m	£41.2m	£19.2m
90%	£23.9m	£22.5m	£46m	£21.2m
99%	£40.9m	£31.6m	£67.3m	£29m

Notes:
[1] Risk cost only, excluding primary cost estimate.
[2] 90% likely risks included in primary cost estimate, not in risk allowance.

Risk allowance at 90% confidence levels of not being exceeded was included in the funding application, with the overall risk cost allowance for the proposed Lead Option thus being set at £23.9 million.

The modelling methodology used to generate these figures simulates multiple interactions between, and combinations of, different risks. However, by its very nature it does not identify a risk value for each risk or risk category. This was considered most relevant for overall risk assessment and management at scope definition and funding assessment stage. However, for detailed management and perception of the risk allowance during the subsequent construction stage, a value linked to each individual risk register item, but still compatible with the overall analysis at funding application stage, would have assisted visualisation of the individual risks.

The values at 99% confidence of not being exceeded indicate an upper limit on assessed risk cost for that option, effectively a maximum potential risk cost, as they represent an extreme adverse combination of risk items. However, at these levels the limitations of the modelling are more significant.

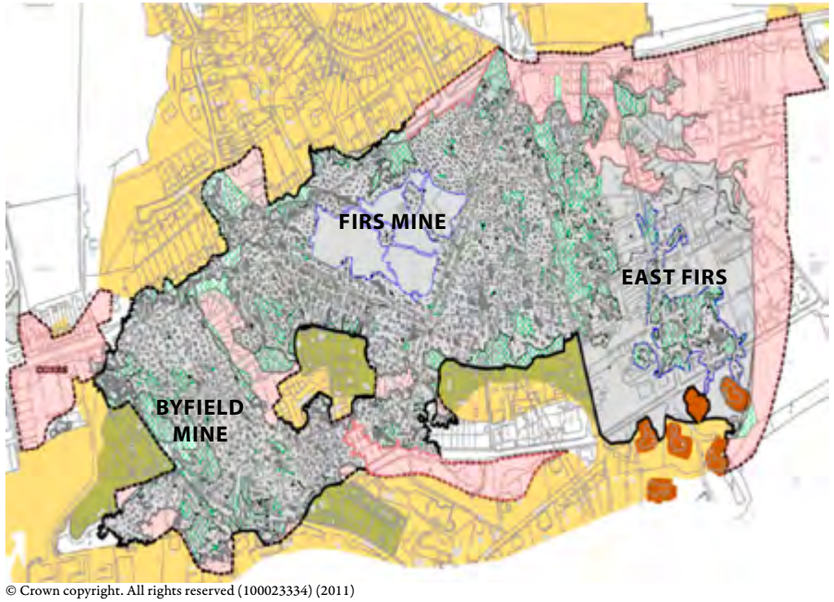


Fig. 3.3. Plan of Combe Down Stone Mine at funding application stage.
Mine extent: approx 1.1km x 0.4km. KEY: Grey & green dot shading: known mine area (height of mine often uncertain); pink shading: estimated mine area (height totally unknown).

At the conclusion of the funding assessment, the estimate of void was circa 565,000m^3 with the estimated cost for the proposed lead option being £134 million. This figure excluded allowance for future inflation and any costs previously spent on the emergency and investigation works. Risk allowances, as previously outlined, equated to £23.9 million. The estimated void was circa 200,000m^3 greater than originally thought back in 2001.

Central Government Funding of £154 million was approved in early 2005; this total included an allowance for inflation and previously incurred costs. The line items of the approved funding application led to the individual budgets that the project was subsequently managed against throughout the construction stage. To this funding, the Council committed a further £7 million pounds, giving an overall budget of £161 million pounds for the scheme. A further £6 million pounds was added to this in 2009 to include additional mines identified at the MOD site Foxhill.

Economic Appraisal

The economic appraisal was undertaken in 2004 to inform funding judgements by central government in accordance with Treasury 'Green Book' procedures.

As noted previously, the fundamental driver for this project under the Land Stabilisation Programme, LSP, was the protection of life and property coupled with reduction of blight and avoidance of dereliction that would stem from future collapse of the mine. Avoidance of those future impacts was a primary 'benefit' of the project. The economic appraisal compared that and other benefits of stabilising the mines with the cost of doing the stabilisation. It also took account of many other impacts and benefits, both temporary and permanent, notably the impact on the statutorily protected bats, archaeology and groundwater resource.

The various options were compared with each other and with a 'Do-Nothing' scenario in which collapse was assumed to take its course.

The economic appraisal was done in two stages: an Initial appraisal, followed later by a full appraisal of the options short-listed for detailed economic analysis.
The initial appraisal considered many widely different notional scenarios for avoiding impact on life in addition to many different ways of stabilising the mines. These scenarios included, for example:

- Assessing the economic impact of abandoning the village and building a new one elsewhere (assuming a site could be found).
- Demolition of the hundreds of properties underlain by the mines coupled with

enforced collapse of the mines then redevelopment of new properties in the same place.

- Stabilisation by infilling underground with various choices of material, e.g. foamed concrete, sand, pulverised fuel ash (pfa), stone, material from china clay workings.
- Stabilisation by drilling and grouting from the surface.
- Stabilisation by structural support.
- Combinations of the above.
- 'Do Minimum' (basic stabilisation ignoring other factors such as bats, archaeology and water resources).
- 'Do Nothing' - allow collapse to take place and deal with the aftermath.

These scenarios had varying degrees of social, environmental and engineering practicability. However, their relative economic standings were important and helpful to put the engineering stabilisation options into a broader context, to assist judgements on policy and funding. Relative risk was taken account of in the assessment, as were the varied impacts of the scenarios on bats, archaeology and water resources.

The full appraisal compared a smaller number of short-listed options in more detail. Four mitigation options were selected for this, by the government department funding the LSP. These options were:

1. Do Minimum–bulk infill of 100% of the mines complex.
2. Combined infill stabilisation.
3. Structural support of the mines.
4. Controlled collapse.

In addition the 'Do Nothing' option and a variant of it, the 'Do No More' option, were assessed, as these provided the base case. The 'Do No More' case took account of the fact that a limited amount of emergency stabilisation works had been undertaken whilst the main scheme scope and funding were being assessed, so the potential impact of future collapse had already been reduced in some areas, and some funds had already been expended on those works.

The main benefits of the scheme were primarily the avoidance of the death, injury and disruption associated with future collapse of the mine in the coming decades. Three types of collapse were modelled: minor, major and progressive (the last being one pillar failure leading to sudden progressive collapse of several neighbouring, already weakened, pillars). The likelihood of each type of collapse occurring over future time, and an average impact of each, in terms of death, injury and disruption, were assessed by the Consulting Engineers and Mine Managers. Over-pessimistic assessments were avoided. For example, progressive collapse was assessed as potentially affecting up to 25 dwellings, but an assumption of 3 dwellings was used in the appraisal.

Quantitative economic valuation of the three key 'environmental' factors in the appraisal is of particular interest here.

Valuation of bat impact

A societal approach was taken, using the potential financial liability under law from destruction of bats and their habitat as an indicator of the willingness of society to protect them. A value of £5,000 per bat was used, based on legal advice on the potential level of fines and the nature of this particular case. (It is noted that prison is also a potential liability but no attempt was made to value that.) Other approaches such as 'revealed preference techniques' and a literature research at European and international levels did not enable a general 'economic value' of a bat to be identified for the scheme.

Valuation of archaeology impact

Research and consultation with the relevant government department at the time (2004) indicated a need for a 'contingent valuation' approach to be used for ascribing a monetary value to the archaeology. Contingent valuations use a questionnaire-based tool to estimate an individual's value of some unpriced (non-market) goods or service. A proxy approach was used for quantifying the economic impact of losing/retaining the archaeology by estimating its non-use value. The most relevant non-use value is 'existence value'–the value that people derive from the knowledge that the site exists, even if they never plan to visit it.

The project used a proxy derived from work carried out by Navrud & Ready (2002) valuing the cultural heritage of a World Heritage site, the Fes Medina in Morocco, as part of a World Bank project. Surveys found that those visitors to Morocco who do not go to the Fes Medina (i.e. non-visitors) placed a value on the site's existence based on their appreciation of that type of site and to some extent on the possibility that they may visit it in the future. The surveys found that their willingness to pay was about US$30 per person per visit. It was considered appropriate to use this value for Combe Down, which is also part of a World Heritage Site, and it was known that local non-visitors derived pleasure in the existence of these historical mines.

Assessment of the number of applicable people was based on a proportion of residents in the area, rather than of visitors as in the case of the Fes study, as Combe Down is not part of the main visitor trail in Bath. The proportion of residents was taken as 53%, based on a study in the Newcastle area of UK, which explored the willingness of residents to pay for the restoration of historic buildings in their town via extra Council Tax. A proportion of visitors to Bath would have been much higher, and unconservative.

In addition a value allowance was made for visits to a future heritage interpretation centre about the mines, valued at £1 per visit. It is noted that some of the comprehensive recording of the archaeology in the mines prior to and during the works is planned to be available in the interpretation centre.

Valuation of groundwater resources

The mines lie in an Inner (groundwater) Source Protection Zone, the most protected zone, which relates primarily to nearby public water supply springs. The economic valuation was made on the basis of the predicted compensation to the water company if these particular springs were to become unavailable due to the works. Whilst this economic valuation approach may be applicable elsewhere, the value is likely to vary considerably from one water resource to another. Potential legal/fine costs and allowance for the intrinsic benefit of retaining a water resource for generations into the future were other factors considered.

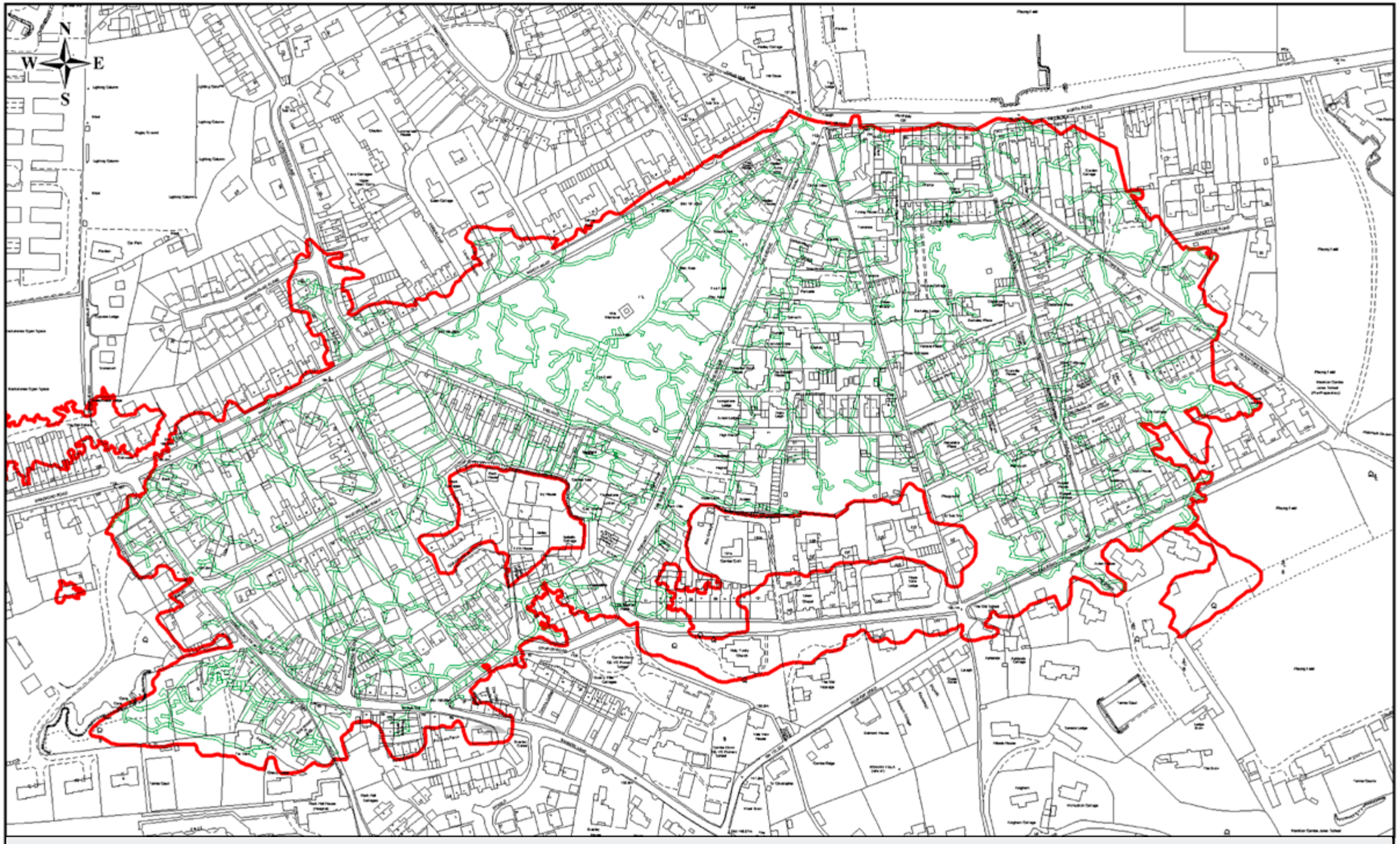
It is emphasised that these valuations were to assist their inclusion in the economic appraisal on a monetary basis. It is not implied that the legal protection, conservation and sustainability issues for these environmental aspects can be fully equated to monetary amounts in this way. Nevertheless, the ability to include these environmental aspects in the main quantitative economic analysis, alongside the qualitative commentary on their significance, was far preferable to relying solely on the qualitative input.

Criticality tests

To check the potential significance of sources of project uncertainty, a criticality assessment was included in the economic appraisal. A 'critical' variable was defined as one for which a 1% change in its value produced a change in option net present cost, NPC of 1.0% or more; a 'significant' variable was one for which a 1% change in the value of the variable produces a change in option NPC of between 0.5% and 1.0%.

Scenarios were modelled for combinations of the identified critical or significant variables to check their sensitivity to combinations of both more pessimistic assumptions that could increase costs and more optimistic assumptions about mine collapse impacts if nothing were to be done. The Monte Carlo approach to modelling uncertainty was used as part of this sensitivity check. This process aided judgement about whether alternative options could become economically preferable under such scenarios. The outcome showed that the selected option of combined infill stabilisation, incorporating appropriate protection for bats, archaeology and water resources, remained the lead option even when a number of risks were taken into account.

In summary, the risk process provided a robust budget and management arrangements that greatly assisted the delivery of this project.



PROJECT:

Combe Down Stone Mines Project

TITLE:

Extent of the Combe Down Stone Mines

LEGEND:

- Mine Extents
- Underground Roadways

Bath & North East Somerset Council

Combe Down Stone Mines Project

Bath and North East Somerset Council

1 : 3500 (At A4)

Chapter 4:
Client Role, Project Governance and Involvement of the Community

Examples of good practice discussed in this chapter include:

1. Project-specific Community Association established by the Council as a company limited by guarantee, but independent of the Council.
2. The Steering Group of stakeholders established.
3. Council decision that a full Environmental Impact Assessment (EIA) be conducted, despite an EIA not being legally required at that time.
4. Major Projects Directorate established by the Council as the project activity intensified.
5. Contingency planning for a potential major mine collapse with fatalities above and below ground, in a live village.
6. Live risk register, including quarterly risk review meetings.
7. Extensive communication plan.
8. Involvement of Community Association representatives in tender interview panels for Consultants and Contractors.
9. Monthly funder meetings with HCA team.
10. A separate Project Management Consultant and a Cost Management Consultant.
11. Project extranet for management and to control issue of documents.
12. Beneficial continuity of senior staff in the Council, Contractor, the Consultants and HCA.

Background Prior to 2000

When Bath and North East Somerset Council was formed in 1996, the monitoring of the mines was carried out by an engineer in the Highways Dept. In 1998 there was an appointment of an Interim Director in Economic and Environmental Development who took on the role of raising the profile of the needs of the project, and working with Central Government and its Agencies to establish funding for mine stabilisation. Internal funding was allocated to progress this, an Administrator was appointed and a small team of other officers started working part-time on this problem.

After an emotive meeting with local residents in July 1998, the Council appointed Community Relation Consultants to facilitate discussion; this was a successful appointment (and is a practice to be recommended). As a consequence of their report, the Planning, Transport and Environment Committee of the Council agreed to set up a Combe Down Stone Mines Project Community Association (CDSM CA). This Association played an active and important role over many years and is described later in this chapter.

In addition, the consultants' report recommended the establishment of a Steering Group Committee to be attended by the Council, HCA, other Government departments and all interested stakeholders. 44 members attended the initial meeting.

The Steering Group would go on to meet throughout the project every 3 to 4 months. The Steering Group reported to the Council. It was not a decision-making body as its primary role was co-ordination and liaison to assist cross-party working. There were no formal Minutes as such, but questions, answers and actions were recorded. Initial meetings raised numerous questions as to how and what would happen. As the project progressed and information was provided and passed to all, the meetings became more of a progress update. This group was believed to be the first of its kind to include various Government Departments, who liaised and coordinated throughout.

Fig. 4.1. Early workshop meeting.

Council Role from 2000

Whilst the Council became the named Mine Owner, responsible for health and safety matters, it did not legally own the mine. The mine itself is owned by the property owners whose individual properties stand over it. Council ownership was limited to open spaces and surface of the highways. Therefore, a strategy and process was needed to gain permission from each property owner to allow the stabilisation to take place. The Council team spent long hours tracking down owners to achieve this as some properties were rented.

The Council had been through a bad experience with a major project, related to budget, time and quality issues. It therefore wanted to develop a structure that could successfully manage the Combe Down project.

Realising that this would be another large project, the Council set up a dedicated team to manage it, headed by a Project Leader, who has remained with the project throughout. Decisions were either delegated to the Project leader or referred to higher Officers in the Council, at Director level or elected members. Initially, there was a committee structure but as the project progressed a cabinet was formed headed by an elected member with specific responsibility for the project.

The Council team included a specialist civil engineer who liaised with the Engineering Consultant. The Council appointed an external Engineering Consultant, whose role would be to investigate the mine, develop a solution, seek a planning consent, and manage and procure the works.

Other appointments were for Bat Consultant, Archaeology, Risk Management, Planning Advice and Cost Management Consultants.

As the project developed and began to increase in magnitude, the Council brought in additional resources. By 2005, the Council placed the project under the control of a new project Directorate (Major Projects). This Directorate was headed up by a new Director who had extensive experience in Major Construction projects. The Project Leader and other existing team members transferred to this new Directorate and the team expanded in size to include an Operations Manager who was responsible for day-to-day site activities and liaison with Consultants.

In addition to this enhanced structure, HCA and the Council agreed that this size of project required dedicated Project and Cost Management Consultants. These new roles were tendered through the Official Journal of the European Union, OJEU, and both appointments began in October 2005. The Council's Operations Manager was responsible for managing these Consultants.

From the outset, emphasis was placed on ensuring that decision making was transparent, and with so many stakeholders involved, the method of decision making was publicised in advance.

In addition to its care for the interests of its residents, two of the key aims of the Council's governance were: review of the financial risk management on the scheme, and contingency planning for incident response if the risk of a major mine collapse materialised before stabilisation works could be completed. Financial risk management included reviewing the expenditure plans and change management for the scheme, both expenditure eligible for LSP funding and that funded by the Council. Whilst the vast majority of the expenditure was funded by the LSP, the more minor proportion was still a substantial budget in absolute terms, as the project was so large. An important part of the project governance related to identifying expenditure into these two categories so that appropriate authorisation by the relevant funding entity was confirmed early.

Other Council Departments assisted the project team: the Legal Department providing advice on Mineral Workings Act and Procurement; Finance, responsible for payment of suppliers/contractors/consultants and formulating claims for funding from HCA; Internal Audit, who provided peer overview of processes and audit of procurement processes and financial transactions; Highways, interface with highway issues throughout Combe Down; and Health and Safety, emergency management group.

The following is a summary of Council structure and organisation:

- Ownership–the Council Chief Executive was named as the Mine Owner's representative under the mining regulations and the project used the Mineral Workings Act to secure access to the mine, in particular if ownership consent was not forthcoming.
- Weekly progress report meetings with 'Dashboard' reporting held with Contractor and Design team.
- Monthly project and cost management review meetings.
- Monthly Director Reviews where project reports were presented and discussed, and actions and decisions were taken.
- Monthly Project Board where Councillors and other Council departmental officers, including Audit, were briefed on the project and the outcome of the Director Review meetings. Project Board was the mechanism for establishing cross-departmental alignment, the highest point of the Project's Governance.
- Quarterly risk meetings, which reviewed project risk register and Council risks and developed revised risk management plans.
- Quarterly Steering Group meetings to liaise and inform stakeholders on project progress and receive their feedback.

- Communication–an extensive communication plan was developed and implemented involving newsletters (produced in collaboration with the Community Association Board), which were widely distributed among stakeholders, interested parties and residents.

  Liaison with the press/TV was carried out mainly by CDSM project officers with input/assistance from the Council's press office. Approximately every two years the team organised a media day, where members of the local press were invited to visit the site for an update on the project and were also given the opportunity to go underground and record footage/take photographs of the mines.

  A Project Information Centre, in a rented former shop (Fig. 4.2), was open on Wednesday evenings and at various other times throughout the project. Up-to-date project information was displayed there.

  The CDSM project's website was established by the Council from the early stages of the project. The website was a way of expressing the story of the mines including their history, ecology and technical aspects as well as acting as an additional method for circulating project updates and fact sheets.
- Monthly funder meetings with HCA to review Project Management and Cost reports, change control, risks and actions.

Fig. 4.2. Combe Down Stone Mines Information Centre.

- Appointment of Cabinet Member with responsibility for the project, Project Champion (Councillor), Project Sponsor, Project Leader and Operations Manager.
- Financial control systems, bespoke reporting systems, change control, use of project extranet to manage and control issue of documents change sign off, instructions, etc.

Change orders involving costs less than £20,000 were delegated to the Operations Manager (and/or Project Leader). Values of less than £10,000 were further delegated to the NEC Project Manager. Values above £20,000 were referred to Director level and Project Board.

Ultimately, all changes under LSP funding needed to be agreed with HCA. HCA were informed of all change decisions, through monthly update meetings or daily communication with Council team when applicable. Therefore major decisions were not taken in isolation and the risk of a change not being signed off was largely mitigated. Speed of decisions and mutual confidence in the process was critical and whilst this could be a long process, it proved robust.

- Collation of invoices for submission of payment applications to HCA.
- Retention of project staff. The Project Leader remained with the project throughout the 11 years of the project. This was one of the key contributions to Combe Down being a success.
- Team building and profiling. All Council team members and consultants were individually profiled. This process supported the development of a balanced team structure.
- GIS recording and analysis.
- Co-ordination with other Council departments (e.g. planning, legal, highways, health and safety) to facilitate resources being available when outputs were required from them, e.g. enough resources to handle a very large planning application and its consultations.

The Planning Process

The CDSM project created a number of unusual planning challenges as the proposal did not fit into the normally recognised categories. The majority of the work took place underground and virtually nothing was to be seen on completion of the project. The above-ground temporary work-site compounds were the most visible elements and these would normally not require planning permission as they are permitted under the terms of the Town & Country Planning 'General Permitted Development Order 1995' (GPDO). It was also fairly unusual in that at the time of the submission of the detailed planning application neither the full extent of the works nor the detailed methods to be used to stabilise the land and the associated environmental mitigation measures were fully identified, largely as the final choices would depend on further information gained from future underground access. The application therefore had to be based on the best information available at the time, and incorporate relevant conditions.

The Local Planning Authority (LPA), in granting permission, needed to phrase the planning conditions in such a way that they would give the certainty required in a planning permission but also allow some flexibility over the period of the implementation of the scheme to enable changes to the proposals found to be necessary as underground survey work proceeded. In practice, this was achievable for many but not for all matters, for example in relation to archaeological and bat mitigation. As a consequence, supplementary planning applications were submitted during the life of the scheme.

Early on during the project it was decided that an Environmental Impact Assessment (EIA) should be carried out and that the Planning Application for the stabilisation works should be accompanied by an Environmental Statement (ES). Legal advice was received that this was not a requirement under the relevant Environmental Impact Assessment Regulations. Nevertheless, it was decided that it was appropriate to subject the scheme to the rigour of an EIA and to submit an ES with the Application, as it provided a detailed analysis of all the aspects of the project that the LPA needed to consider in assessing the proposals, some of which were high-profile environmental aspects. This proved to be a wise decision in addressing stakeholder concerns.

Prior to the submission of the planning application extensive studies were carried out for the Council by the Engineering Consultant in order to formulate a strategy for the stabilisation and to inform the ES.

During this period the Council proceeded with emergency stabilisation works in some areas assessed to be particularly dangerous. This was done under the provisions of the GPDO, which permit the carrying out of such works without the need to submit a planning application.

The main planning application submitted was approved on 18 June 2003. Thanks to the very extensive pre-submission consultation, there were no objections to the application, an important signal of progress in consultation with stakeholders. This permitted the carrying out of the stabilisation of the mines (Main Scheme Stabilisation) subject to many conditions. As each subsequent application was approved, it superseded and subsumed the previous permission, with the conditions, appropriately amended, being rolled forward.

The conditions varied in their nature, some requiring compliance prior to the start of Main Scheme works on site (e.g. construction of the access to the Firs Field work-site), some imposing ongoing compliance requirements (e.g. noise and dust control), some requiring information to be submitted for approval during the works (e.g. work-site restoration schemes) and some requiring compliance on completion of the works (e.g. presentation of archaeological recording).

Extensive consultation with statutory consultees, as appropriate, was carried out by the LPA for each application. In particular, the Environment Agency (EA), English Nature/Natural England and English Heritage (EH) were fully involved in the processing of the applications, as were the local highway authority, Wessex Water and the CDSM Community Association. Local residents and property owners were notified in advance of the applications.

Four further applications were made throughout the life of the project in relation to revisions to bat gallery provision, archaeological changes and completion of the Firs Field and other surface areas.

Community Association

The Combe Down Stone Mines Community Association, CDSM CA, was set up as a company limited by guarantee. This constitution was recommended by legal advisors. CDSMCA had a Board and an independent chairman (a part-time but demanding role). The Board consisted of nine directors elected by residents, two Council Officers, one Director from Wessex Water, one representative from the Ministry of Defence and two from local industry. A secretary was appointed by the local community, and the Council gave extensive support. The MOD and water company had particular local relevance. The MOD had adjacent property affected by similar mining, and the water company had a major office and depot nearby (not over the mine) as well as owning the nearby public water supply springs previously referred to.

The CA Board was one of the primary means of high quality two-way consultation with local residents, in addition to the liaison and communication roles often served by local associations. The CA Board initially met weekly, from May 2000, with a monthly public meeting, and a day's 'team-building'. Meetings in the early days were often confrontational. At the peak of the controversy (around 2001) there were some 700 members of CDSMCA, the numbers of which subsequently remained fairly constant. Membership was free in order to encourage widespread involvement.

The aims of CDSMCA were:

- Successful stabilisation, thus removing risk.
- Removal of mortgage and house/premises insurance restrictions.
- Avoidance of contamination.
- Protection of heritage, water outflow, bats and other fauna.

The work of the Board included critical examination of all proposals, ensuring that residents were kept informed and were as fully protected as possible, especially with regard to legal and insurance matters. They engaged constructively in consultations, risk workshops, confidential tender processes, Steering Group meetings, and other activities, with a balance and understanding that, as for other stakeholders in this project, departure from their preferred requirements was essential if a viable solution was to be found. However, there were of course considerable tensions, inevitable when people are concerned about their homes and feel they are not to blame for the cause (so 'someone else' must be). The Board members' task was sometimes onerous.

Notably, as the project progressed and peoples' anxieties were allayed, attendance at meetings declined and their tenor became increasingly more collaborative. Crucially, the CA and its Board were assured and impressed by the readiness of Council and HCA officers and the procurement team (including designers and contractors) to meet with residents and discuss issues openly, both formally and informally.

The Board had an active and important role in:

- The appointment of consultants and the main contractor –tenderers were asked to give presentations to the Board, and representatives from the Board were invited to take part in tender interviews and to make site visits.
- Active involvement in the funding process, e.g. the project was informed that this was the only project of its kind where Board members had been able to sit in, and contribute to, the Government funding decision committee meetings.
- The finalisation of the funding application. In this instance, a resident, who was a Partner in a local Quantity Surveying practice, met with the Council and the Cost Consultant and was taken through the preparation and calculation of the funding assessment, in order to add assurance to the Community that a robust approach had been taken.
- Communication to and from local residents, formally and informally. This included helping good quality information dissemination, even though not always good news, and so helped reduce unnecessary concern from incorrect information and rumour.
- Questioning, and often challenging, the project team, funders, Councillors and other stakeholders on matters of concern to residents.

The involvement of Board members in confidential tender processes worked well, for example, participation in contractor and consultant tender interviews and appraisal of parts of tender submissions for the main contractor appointment. It helped provide a

depth of consultation that is felt to have greatly enhanced community confidence in the project team and in the genuine nature of the consultation, in addition to the value of their contribution and perspective in these processes. Initial questioning in some quarters about the potential for increased risk of confidentiality 'leaks' from tender processes was found not to be an issue.

It is important to note that from the start of the work of the CA, it was strengthened by the working practices of all involved in the project, as well as vice versa. For example, it was part of the induction process for all on the project to be asked specifically to communicate and be responsive to local inhabitants during day-to-day contact such as conversing while walking around the surface, and responding quickly to question or complaint. One member of the contracting company noted "we weren't just engaged, we became part of the community". Response to damage was rapid; for example, when a concrete pumping pipe burst and sprayed cars with concrete, washing down and repeated employment of a professional car valeting service was used until all car owners were reasonably satisfied. The cohesive nature of the many organisations involved was important as a mutually confident context for this community involvement. One useful tool in this communication was the consolidation of information and data on the project extranet, once this was set up. There were specific bulletins on matters of particular importance.

As the project continued, the mood and input of the local people, both as individuals and through the CA, became very supportive through open and frank debate. Clearly, then, the CA was a successful mechanism and its support was gained through open discussion, debate, communication and trust.

Chapter 5:
Planning the Main Project and Innovation

Examples of good practice discussed in this chapter include:

1. Identification and management of risk in initial stages – with a combination of exploratory investigation and urgent stabilisation works.
2. Underground 'blocking' strategy to subdivide mine, increase interim stability during the years of construction, and provide the infilling treatment 'cells'.
3. Foamed concrete–several innovations and extensions of previous UK practice and experience.
4. Development of new underground equipment.
5. Remote monitoring of concrete placement.
6. Use of GIS in active management of the construction works.
7. Earned Value Analysis system.
8. Development of a new 'reach-over' drilling rig.
9. Early procurement of batching plant to facilitate economies, better quality control and trialling of foamed concrete.
10. Early information sharing and consultation with Construction industry

General Overview

Many stabilisation schemes combine a need both to extend initial investigation and subsequently to treat an area, as the work progresses. Many other projects, e.g. refurbishment schemes, share this characteristic, though rarely over an area in excess of 20 hectares

A schematic cross section through part of the mine is shown in Fig. 5.1. In many areas the roof had partially collapsed between pillars, above the main mine void, a void often partly filled by loose 'discard' rock debris. This roof collapse occurred by successive blocks of the jointed rock falling out of the mine roof–leading to the mine void extending up towards the surface. It also led to slabs of rock sagging down into the mine void, with gaps above them. Another relevant feature of the mine that influenced stabilisation planning was that the pillars were spaced very irregularly in plan. They were also highly variable in size, height and shape, and often had chunks missing due to partial collapse or bursting under their load. Their poor condition had often been exacerbated by 'robbing' of the pillars for their stone by the historical miners, when they abandoned the mines some hundred or so years ago.

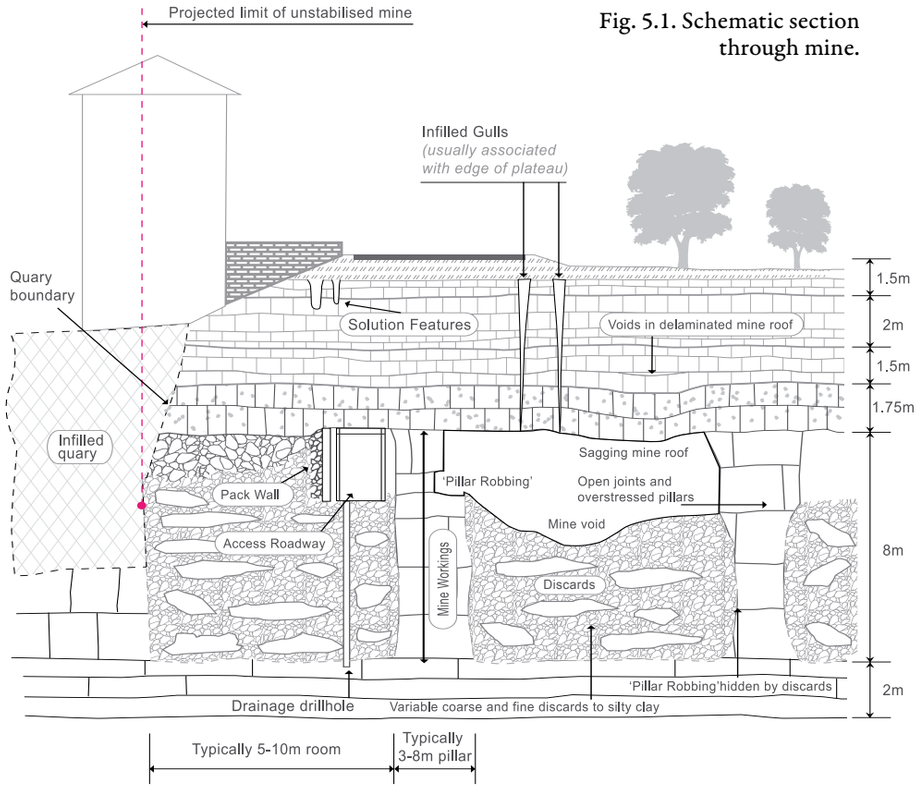


Fig. 5.1. Schematic section through mine.

Fig. 5.2. Timber roadways used in early investigation stage.

Fig. 5.3. Steel supported underground access roadway. Note: not straight, to miss pillars.

Another feature of the Combe Down mines was the variable thickness and nature of loose discard stone throughout the mine and the challenge of how to stabilise it sufficiently.

Throughout the option appraisal and function analysis process carried out between 2002 and 2003 (Chapter 3), a predominantly underground scheme using a foamed concrete infilling, with limited surface involvement, was found to be the most practical and economically sound method of stabilisation.

Planning the Work

In order to plan the work, and enable the appraisals, the engineers needed to ascertain better the size of the mine that the project was confronted with. The early survey work carried out in past decades was extremely useful but only covered approximately half of the expected mine area. Previous boreholes and some old records also provided useful information, but left huge uncertainty. Therefore, the initial phase of work was to explore the mine to assess the size of the project more accurately.

In 2001 the Principal Inspector of Mines wrote to the Council to prohibit entry to the mine, except by HMIM permission, until safe underground 'roads' were established. HMIM also encouraged recruitment of experienced miners (they largely came from South Wales) and contracting staff.

Timber roadways were commenced to provide a safe route into the mine and for assessing its size and condition better (Fig. 5.2).

Once the mine parameters were known the mine would then be subdivided into compartments, using timber and steel roadways to form manageable stabilisation blocks. The safe roadways would be used to form these compartments and to provide access for shuttering, pump lines, stowing, material access, etc.

Initiating the Work

There was some early consideration as to whether to drive straight roadways, as this would ease underground movements and mechanisation. In order to do this, existing pillars would have needed to have been removed, due to the haphazard layouts of the mine support pillars remaining from the original mining. The Mine Manager considered it far too dangerous to take out existing support pillars and advised against driving straight roadways. This concern related to the small amount of roof cover to surface and the perilous state of the mine. Hence roadway construction snaked its way through the mine avoiding all existing support pillars (refer to Fig. 5.3). This decision was vindicated during the bat mitigation works at the nearby Grey Gables stone mine in 2006. Here, during the construction of an underground tunnel link, a need arose to partially remove the side of a pillar in order for the tunnel to connect 2 separate mines. At this point the cover to surface was some 12 metres and at surface level there was a rugby playing field, i.e. much less severe conditions than at the main Combe Down mines. Within minutes of attempting to cut away the pillar, a roof fall was induced. The steel roadway buckled under the fall but kept the workforce safe. The collapse choked on itself and did not break through to the surface. The collapse was repaired with injected foamed concrete. Had there been limited cover, as is common in the main mine area, then it was likely that such a collapse would have broken through to give a ground collapse at the surface.

Whilst driving the investigation roadways some particularly hazardous areas became visible to the engineers and Mine Managers and this prompted a review of strategy. Whilst the project still needed to investigate the mine, the Project team now had direct and up-to-date physical knowledge of the mine condition and of the imminent dangers it posed. In the light of this, it was concluded that the mine could collapse not only in small areas but also progressively over a large area, i.e. one area collapsing would put greater strain on adjacent pillars, which could lead in turn to their collapse and a 'domino' effect of progressive collapse. This was assessed to be so hazardous that it needed attention that could not await main scheme funding. With this first-hand knowledge the engineers and Mine Managers formulated a plan to carry out some permanent stabilisation earlier than envisaged plus some shorter term temporary stabilisation to inhibit progressive collapse of some larger areas.

This early stabilisation was further emphasised following a risk workshop, in 2003, as the position of underground services in North Road was identified as having potential for causing a catastrophic incident, if the mines collapsed. In this instance a scheme for advance stabilisation of North Road was implemented and was carried out during 2004/05.

The temporary solution was resolved by arranging the roadway layout into blocks,

Fig. 5.4. Re-useable timber shuttering fixed to roadway uprights to contain foamed concrete within designated stabilisation areas.

to inhibit progressive collapse. This blocking arrangement assisted in the design and filling of final stabilisation areas.

It became clear that these roadways served far more than just to enable safe initial investigation. They would have multiple functions, e.g. for safe underground access for surveying and workforce, access for material delivery, the encirclement of areas to form stabilisation areas, and importantly as a potentially temporary stabilisation to the roof above, to mitigate potential 'domino effect' pillar collapses. The choice of material for main access roads became steel, with timber being used only for short-term use roadways. Whilst the steel roadways were not designed to take the entire permanent load, they would support the roof to stop a major or progressive collapse in that area.

The roadway and blocking then helped the creation of suitable sized stabilisation areas. Timber shuttering could be clamped to the steel uprights (Fig. 5.4). Timber stub roads were formed into each area to allow pipes for concrete placement to be installed high up into crown/roof holes or gulls. Breather pipes were installed to check when concrete placement reached the top of the roof collapse zones, so pumping could stop.

The roadways needed to vary depending on the conditions found in that particular part of the mine. The need for flexibility in construction in order to respond to the considerable variety of conditions across the mine had a major influence on risk thinking and on the procurement approach that would be best suited to managing that risk.

High-level shuttering to 'seal' against the mine roof was formed with lightweight blockwork and with rockwool used to seal small crevices, etc.

Floor discard materials occupied a large area of the mine. The discards varied considerably in type and permeability. In assessing the stabilisation of the void the engineers needed to take into account stabilising the discard, without disrupting the

hydrogeology of the area. A pour of foamed concrete could run a long way through the mine and the discard. An accelerator was used to permit some penetration into the discard but to restrict undue flow and loss into it.

For the stabilisation material the most reliable and practicable placement method was pumping a cement/sand mix (grout) with a foaming agent, hence foamed concrete.

Logistically, supplying the stabilisation material to the wide area of the mine was considered to be a problem. Foamed concrete has been used for many years, but no records were found of it ever having been pumped such great distances (950m), or under such exacting conditions, or to anything like such a great volume. To overcome this the grout was pumped from surface from the batching plant, down through a centralised delivery pipe work system, to the underground foaming plant, where it was mixed with the foaming agent and then pumped into the mine void/stabilisation areas (Fig. 5.6).

The foaming agent increased the volume by approximately threefold, giving a density less than 1 and an appearance analogous to a well known chocolate bar with trapped bubbles in it. An organic foaming agent was used. (NB. Some foamed concrete applications elsewhere have used aluminium as a foaming agent. It is noted that it would have been dangerous in this case as hydrogen gas is released, which would have been a severe hazard underground.)

Heat generation during curing of a mix of sufficient strength was a significant problem, exacerbated by the lack of authoritative guidance on maximum tolerable temperatures for foamed concrete, e.g. a British Standard. As stabilisation progressed across the mine, curing temperatures began to rise but were controllable either by restricting the amount poured or by changes to the mix.

Foamed concrete was pumped under pressure, at 10MPa, and was generally placed in 1-metre lifts, constrained behind plywood shuttering secured from the roadway structural supports in the mine. Quality control of the mix was vital, not least because of the problems of removal or improvement of sub-specified material. Devices such as computer-controlled analysis of the mix at the point of delivery and sacrificial web-cams and other sensors in the area being filled assisted this control. In the event, throughout the project, no material had to be removed.

The challenges encountered on the project included:

- **Response to newly discovered voids.**
- **Difficulties around the edges of the void where the floor, deep in loose discarded or fallen rock, met the roof.**

Fig. 5.5. Underground face excavator. (Mine 'discards', visible behind steel sheeting, was partially removed to construct the roadway.)

Fig. 5.6. Foamed concrete being placed within a stabilisation area.

- **Occasional, but never large, collapses from the mine roof (the largest was 200 tonne, March 2005) and collapses through from the surface (one was triggered by a passing vehicle).**
- **Continuous liaison with local house-holders.**
- **Budget control.**

To assist budgetary control, progress was planned and assessed with extensive use of the project GIS system adapted by trained Council and consultant/contractor staff. GIS was used for recording the mine survey data, and the filling, surface geometry and property data, and much other information. Cost-control was effectively tracked, predicted and controlled using a developed Earned Value Analysis (EVA) system, which compared what was done against what was planned and with what would be necessary for successive elements of work. This was much better than the normal simple comparison of what had been completed against the schedule of work, and EVA is especially valuable for such works in which the requirement is expected to change frequently and significantly as the extent of work and conditions are further established during the project.

Between 2002 and 2005 the project focused on particularly critical areas identified through the risk process. The project proceeded in an incremental way with the budget constrained under interim funding arrangements pending Main Scheme funding. The budgets were awarded annually and targeted particular works, but restricted flexibility on the amount of work that could be done. Hence smaller manageable packages were formed that allowed for investigation, temporary blocking and, initial small scale

stabilisation, but with the opportunity to ramp up processes as larger areas were identified and encircled (e.g. the North Road stabilisation previously referred to).

By the time the Main Scheme funding was made available the techniques for roadway driving, shuttering, encirclement, underground delivery, etc., had been tried and tested. The Main Scheme strategy replicated the earlier stages to identify higher risk areas and stabilise these first, though with an orderly progress through the mine for efficient working. There could have come a time, if the money had run out, that some areas may not have been stabilised, and it was preferable for these to be the areas with lesser risk. Thankfully, through continual monitoring of cost, time and quality, plus an ethos of continual improvement, this did not arise, but the risk management strategy took account of the potential for it to happen.

Examples of Innovation

Some examples of innovation in specialist plant and other matters are given below. A key common factor on innovation was the positive attitude of the teams on the project, particularly the Contractors' teams, to look for opportunities for innovation and continual improvement in safety and production practices. This was also encouraged by the target contract arrangements. The job benefited from being large enough to reap the benefit of improvements on later stages of the same project, rather than on the next project. However, the attitude of continual improvement was evident even before the larger contracts were being procured. A key attitude was that small improvements in safety and production practice, which one might term 'incremental innovation', were worth seeking and implementing–they were valued by the ethos as well as for their contribution to mutual benefit through the target contract gain sharing. In that context it is important to note that simple financial incentivising of construction output, e.g. of weekly production rates at a workforce level, was not permitted. It was deemed incompatible with the management of mining health and safety risks. This was a matter that HM Inspector of Mines and the Mine Managers gave clear guidance on, and reflected the unstable state of this old mine–very different from a new mine.

Specialist Equipment

Due to the random layout of the mine pillars and the requirement not to remove any of the pillars, the underground roadways could not be constructed in a straight or regular grid layout. Therefore, the conditions did not suit off-the-shelf mechanisation. The contractors developed small pieces of equipment into purpose-made equipment for excavating roadways, disposal of discard throughout the mine, stowing, foaming of concrete and shotcreting.

Specialist face excavators were developed to drive the headings within the confined underground environment (Fig. 5.7). The final versions of these machines were powered solely by electricity, which removed the issue of emissions and reduced the noise impact on both workers and bats. These machines boosted productivity significantly and improved health & safety conditions, as the periods of exposure to the underground conditions for the men at the working face were significantly reduced.

Previous experience indicated that foamed concrete starts to break down at pumping distances of greater than 280m due to the effects of excessive pressures needed to pump this distance. The Contractor developed unique specialist high production in-line foaming systems for the placement of foamed concrete at distances of up to nearly 1km from the centralised batching plant. The placement of foamed concrete was developed further to allow a sprayed system to be operated to seal mine margins at distant points of the mine, where other technologies could not be utilised. Mini-agitating systems were developed called bullets, which allowed small quantities of foamed concrete to be transported around the mine for the purpose of topping up small voids underground. Monitoring systems were created to minimise the risk of surface concrete shows. These included the use of sacrificial infra-red cameras and sacrificial electrical probes, which would signal when the concrete reached high into the mine roof cavities.

Large bat gallery areas were originally designed to be formed in two stages with the top half initially constructed in the existing void to stabilise the roof and pillars, before the lower part was excavated into the floor discard. Constructing the galleries in this way required excavation of foamed concreted discard and then repeating certain operations carried out in the top half stage. In order to construct the bat galleries in a safer and more efficient way the miners developed a system of installing large sections of steelwork in a single phase of construction. They also developed a method of using shotcrete as a shutter for the foamed concrete stabilisation behind the gallery walls,

Fig. 5.7. Excavator working in a tunnel heading

which led to time efficiencies and safer working conditions. This also saved cost and the contractor benefited from the contract gain position that arose on these works under the target contract, as indeed did the Client's project budget.

The Contractor developed non-mechanical stowing machines to overcome safety concerns with typical pressure pneumatic systems. Based on a Venturi principle, they could be placed either above or below ground, and allowed the aggregate to be entrained within a stream of air as a result of a vacuum system. These 'stowers' were particularly beneficial when placed at the bottom of a borehole or shaft, as they made use of the kinetic energy of the stone as it dropped into the mine. The equipment achieved high placement rates and permitted close monitoring of placement as men could be safely stationed at the placement point.

A number of different drilling systems were developed during the project to overcome the problems faced at the variety of locations where boreholes were required. These varied from accessing back gardens through occupied dwellings (Fig. 5.8), drilling within cellars and confined underground locations. A prime example of this was the design of a 'reach-over' drilling rig, which involved the attachment of a drilling mast to the arm of 360-degree excavator. This allowed boreholes to be drilled in gardens without the need for knocking down garden walls (Fig. 5.9), hence minimising the disruption to the residents and the extent of reinstatement required, as well as saving time and cost.

Procurement of Batching Plant and Site Accommodation

In the early years of the project the main operation on site was to drive underground roadways to assist in the investigation of the mine extent. However, as critical areas of collapse or near collapse were discovered, some infilling was carried out.

The source of base mix for the foamed concrete infilling was by ready mix trucks from local suppliers. The base mix would be delivered to site then mixed with the foaming agent on the surface before being pumped to its final infilling destination (using surface-mounted concrete pumps).

This method created two problems. First, the quality of base mix was impaired as the high cement ratio resulted in high temperatures in the mixer truck, so the material sometimes began to set prior to delivery. The second was that the cost per m^3 was far in excess of the target rate set in the Cost Plan for the overall project. Adding ice to the mix was tried, but this had limited success and further increased the cost of the material.

With the amount of infilling required at the time and the high risk and consequences of North Road collapsing, the Funder and the Council requested an option paper on

Fig 5.8 Rig adapted for limited access into rear gardens.

Fig. 5.9. Reach-over rig.

procuring a batching plant for the project as a whole. The idea was for the batching plant to be used by the incumbent Emergency Works Contractor and then by future Contractors for the Main Scheme.

In 2003, the batching plant could not be placed in the designated work site area (on the Firs Field, the village green in the mined area) as this area was unstable and had no access for heavy vehicles, at the time.

The Council made available a yard about 0.5km from the site, which could be used to set up the plant. A restrictive factor of this yard was that its size constrained the material storage capacity, which limited overall output per day to the equivalent of circa 750m^3 of foamed concrete per day, (m^3 as placed). This was about half the target output for the Main Scheme stage of the project.

The options considered by the team were:

- Do nothing–continue to procure concrete from outside sources, at a higher cost and with early setting quality issues, until Firs Field had been enabled to take the main site set up.
- Rent or procure batching plant at the yard and use small mixer trucks to transport base mix to satellite sites around the mine area. Plant to remain at yard for the whole project.
- Rent or procure batching plant at the yard and use small mixer trucks to transport base mix to satellite sites around the area until such time that Firs Field has been enabled. Following this, the plant would be moved to Firs Field and upgraded to achieve target output of 1,500m^3 of foamed concrete per day. This emerged as the favoured option (Fig 5.10).

The procurement cost of the batching equipment equated to just over a year's rental. With the project due to last a further 6 years the cost of procurement was estimated to save circa £1.25 million against rental. This included taking into account increasing the capacity by purchase of further silos and the like, needed to upgrade the equipment once at Firs Field for the Main Scheme. The Project also had an asset to sell at completion of the project. Rental was also unattractive from a risk perspective. Any programme delay would put the project under further financial strain and risk.

By procuring the batching plant for the early high hazard and emergency works the project saved an estimated £2.25 million on the cost for foamed concrete. In addition, it secured the quality of material required and allowed the Engineer and Contractor to trial different base mix designs much more readily as the project moved forward, as part of the project's continual improvement process. This was a particularly useful benefit as there was little prior UK experience on the use of foam concrete for such substantial underground works.

Fig. 5.10. Main Scheme compound on Firs Field with batching plant and accommodation. North Road on left.

Risks of providing such key plant to follow on contractors, rather than their supplying their own, were managed through the contract and did not pose difficulties. Details of the batching plant were issued at tender stage so that all tenderers understood the capacity and operation of the plant that they would take on, if successful.

A similar approach was taken with the Main Scheme site accommodation (Fig. 5.10). Tenders were invited from 6 contractors to procure rather than hire site accommodation. It is estimated that in this instance a financial saving of £750,000 was achieved.

Contractor Consultation

In order to underpin the accuracy of some key assumptions and estimates being used in the assessment of funding needs, the Council, with assistance from the Engineer and Cost Consultant, sought the views of the Construction sector to systematically gather information from their perspective. In March 2003 an open day was held with interested civil engineering/mining contractors and major suppliers, at which 24 companies were represented. The object of the day was to explain the scheme, the progress to date, the risks and issues faced and the intended way forward. Feedback via a bespoke questionnaire was invited and 13 companies submitted details and information on the following project specifics. This consultation had sufficient substance to constructively influence the approach subsequently taken on these topics by the Council and Project team, which is outlined below:

Procurement route

All respondents recommended the NEC Form of Contract and a target cost option approach. The uncertain nature of the mine and its extent ruled out any lump sum or design and build route. All considered the target option to favour shared risk, to incentivise the Contractor to reduce costs (as there is a share in the benefit of bringing in costs below target, as well as sharing of costs exceeding target) and to encourage a non-adversarial approach. This response aligned with the Council's favoured approach at that time.

Choice of contract terms and conditions

All replies favoured use of standard terms citing increased legal costs and risk uncertainty associated with bespoke terms.

Retention monies and percentages

This received very mixed replies; generally respondents considered retention unnecessary. If it was to be used, either a rolling turnover figure or sectional release of completed areas was suggested. Most respondents proposed an Insurance-based bond or parent company guarantee with a policy for 'zero defects'. Following much deliberation, the project opted for a retention figure of 3%, with sectional release. Defects period was set at 18 months, notably as the Engineer considered that this period was needed to be reasonably confident that environmental issues were not compromised. In addition the Council opted for a performance bond and parent company guarantee (if applicable). The additional cost of such measures was deemed appropriate as part of the overall risk management approach for the size and risk of the contracts involved, for this public sector client.

Supply chain

Contractors were not in favour of the Council team setting up advanced supply contracts for stone, cement, etc. They considered that procuring materials in advance was not essential to secure supply, created a split responsibility on a key part of the works, and inhibited the scope for management skill of the Contractor in controlling materials logistics. Advanced supply contracts were not used for materials. The team designed the solution around materials that were readily available from multiple sources and were not too prescriptive. For example, sand was used in the foamed concrete design, rather than a particular limestone aggregate, which would only have been available from a single source.

Programme

Programme response was mixed but overall a 4-to-5-year programme was considered reasonable by the contractors for the Main Scheme, depending upon volume to be stabilised. With regard to working hours being restricted, the view was mixed but many considered that any restriction would incur some cost and time delays. One respondent was conscious of the surrounding neighbourhood and considered that extended working hours would lead to substantial difficulties for, and problems with, the residents. (NB. 'surrounding neighbourhood' in this case includes hundreds of homes immediately above these shallow mines. Sounds carried well, e.g. the individual movements and radios of cars on the roads at surface were clearly audible in the mine, which was only a few metres below ground.) The outcome of this was a compromise, with main stabilisation work avoiding night hours, with a secondary shift to carry out essential maintenance and line cleaning, and provision for limited night working, if essential. In the event the site worked in harmony with the residents.

Compound set up (drift or shaft entry)

All respondents agreed that for efficiency, the silos would need to be vertical rather than horizontal. This weight of opinion assisted the project to secure agreement with the planners and the residents to change to vertical silos despite their visual impact.

There was mixed response regarding the use of a drift or shaft entry. With regard to access into the mine nearly all replies favoured a drift. Whilst this may have been the most attractive operationally, the Engineers had outlined that the size of the drift required would impact into archaeological areas and risked collapse through the removal of pillars. The project resolved this by having two shaft entries. The existing one was used solely for man access. The other was excavated into a known collapse in Firs Field and became a large, high-capacity material supply shaft. Foamed concrete was predominantly delivered through pipe work in boreholes on Firs Field, down into the mine and then delivered to all areas of the mine.

Resource requirement and welfare size

Resourcing estimates by contractors ranged from 60 to 300 (at peak time). Overall the project planned for 200 operatives on site. This was generally not exceeded, though at its peak there were about 250, which was readily accommodated by a short-term upgrade.

Control of delivery of materials to main site and satellite sites

Control of deliveries was envisaged, for example, with an off site holding area and communication links for call-off of cement, sand and steel deliveries. This related both to security of supply and to temporary impact on the village and traffic system. It reflected the large volumes of material (over 500,000m^3 of void to fill) and a village that is part of Bath's traffic 'experience'. 'Temporary' impact was several years for this project. In the event, a little extra space was made available for a holding area in the site compound, and the contractors managed the operations whereby deliveries were sequenced and up to 3 vehicles were held in a queue on site. In this context it is worth noting that for a time the project was the largest consumer of cement in England.

Insurances

Respondents provided indicative information in relation to levels of insurances sensibly available. Very high insurance levels would have been attractive to the Council in relation to the potential magnitude of risk, but reasonable commercial availability was taken into account.

Comment on placement cost rates for various infill materials

Respondents were ask to provided indicative cost rates for placement of various materials based upon 1,500m^3 placed in a day. The ranges are given here, and were appropriately caveated by respondents.

- Foamed concrete: £35 to £60/m^3
- Pfa grout: £17 to £54/m^3
- Sand infilling: £32 to £86/m^3
- Stone infilling: £31 to £76/m^3

Significant risks

Those identified in responses from respondents were similar to those already identified in the project risk register.

The views of the industry assisted the project in the preparation of an estimated scheme and contractual arrangements that the industry would be willing to price and tender on, as well as checking and refining some of the assumptions for assessing the funding needs.

There were other technical and operational innovations or developments on the project outside the scope of this book. Some of these have been the subject of papers and presentations to Professional Institutions and Learned Societies.

Chapter 6:
Procuring the Supply Team and Key Performance Indicators

Examples of good practice discussed in this chapter include:

1. Separate roles for Project Manager, Engineer/Designer, Contractor, Cost Consultant and Risk Manager worked well.
2. Risk allocation was based on the principle of risks being owned by those best placed to manage them.
3. HCA sought 'best value' at an overall project ('big picture') level.
4. Use of NEC contracts for Contractor and Consultants further assisted collaborative working.
5. Procurement strategy selection took account of the need to accommodate change.
6. 60%/40%Technical & Quality/Financial for appraisal of consultants' and contractors' tenders.
7. Sophisticated quantitative relative rating system for appraising technical & quality tender content.
8. 'Reality check' of financial value of a 'quality' point in tender appraisal.
9. Involvement of Community Association representatives in the tender interviews.
10. Contractor Framework and packaging of main works were used to give client flexibility to award packages in stages and to different contractors.
11. Contractor performance against Key Performance Indicators (KPI) performance used in decisions on award of subsequent work stages under the Contractor Framework - a helpful incentive.

Introduction

This chapter focuses on some of the features of main scheme contract procurement, with emphasis on aspects that may be of interest to other projects. Information is also given on the procurement of other members of the Council's supply team. Some of the thinking that led to a target cost style of contract being selected for the main scheme construction contracts has been discussed earlier in Chapter 5.

From the outset, the Council had envisaged that the project would be Engineer led, together with support from Archaeological and Bat Consultants. At the time of the funding application in 2004 it was considered that the Council team including in-house Quantity Surveying, would manage the project. However, due to the complexities of the scheme and the level of stakeholder issues, the HCA and Council revised this strategy and it was agreed that an external Project Management Consultant should lead the delivery of the scheme. Added to this was the appointment of an independent Cost Consultant to oversee and manage the whole £167 million budget.

The Council made the following appointments to assist in the delivery of the scheme:

- Engineer
- Project Manager
- Cost consultant
- Risk Manager
- Archaeological consultant & recorder
- Bat consultant
- Planning consultant
- Legal advisors
- Mine Managers
- Contractors
- Noise and radon gas monitoring
- Property monitoring
- CDM Co-ordinator
- Various consultants/artists to deliver public art.

Contracts Used

At the outset, Consultants were appointed under bespoke contracts drafted by Council lawyers, and Contractors were appointed using ICE Conditions (utilising either cost reimbursement or a measured schedule of rates).

To regularise contract approach and benefit from its qualities, the NEC suite of contracts was used from 2003, for both Contractors and Consultants. Contractor appointment was based upon Option D (target) using measured Bills of Quantities.

Consultants

Consultants were appointed through a competitive selection process, governed by European procedures, including OJEU, where applicable. In general, six tenders were sought and companies were interviewed.

Price only formed 40% of the overall marking score. Great emphasis was placed upon technical aspects, project culture and how Consultants would enhance the delivery of the project. Accessibility of Directors/Partners was scored highly. This was a project of potential change and it needed personnel who could make decisions and act, with very limited need to refer back to higher management/board level.

Initially, Consultant appointments were based upon lump sums. With a project subject to change, this led to continual scope and fee adjustment issues that wasted a great deal of project time and team effectiveness. The change in strategy to cost reimbursement against budgets for defined tasks occurred in 2002 when fresh procurement of consultants was undertaken, using OJEU procedures. Fees and resources were monitored against agreed resource schedule and reviewed at regular KPI meetings between Client and Consultant. The resultant client/consultant relationship was able to be more constructive, responsive and flexible, and had less risk of adversarial impact on programme.

A view expressed by the HCA during the early years was that best value was sought at an overall project level, and that this overall 'big picture' thinking was needed in the nature of consultants' appointments. They needed to be focused most on facilitating delivery of best value for the overall project, and in particular on setting up the much higher value main scheme construction contracts to deliver best value. This is subtly, but importantly different from the consultants' appointments being set up and managed with a main focus on achieving best value in isolation of their appointment. There are many projects for which the use of best value practices on each and every element and focusing best value on that element will deliver best value for the overall project. However, that is not always the case; in the right circumstances bigger picture vision can give much better value than the sum of 'best valued' parts.

Early Contractor Procurement

Originally, in 2001, works were let under emergency powers and the Contractor was appointed to install timber access roadways. The Contractor was reimbursed on a cost plus arrangement.

This strategy was amended once emergency stabilisation issues arose.

Emergency stabilisation and blocking strategy was identified by the Engineer and the Council in 2002. The Council sought competitive tenders from 6 contractors based upon a measured schedule of rates. The Contract was for £1 million and related to specific high hazard stabilisation and steel access/blocking/encircling roadways. The value of works was dictated by the level of interim funding for that year. In addition to the defined scope, a schedule of rates was included for other items of work; with adjustments depending upon quantity required/installed.

A contract was awarded to a small local specialist contractor, initially for 1 year but with provision for agreed inflationary uplift to extend for a further 24 months to allow flexibility if the work identified proved problematical or other high hazard areas became apparent as more of the mine was accessed.

The Contract, through negotiation and a thorough 'best value' appraisal, was extended for 48 months, up to the end of 2006, 24 months longer than originally planned. The additional extended period occurred following a major rock fall in 2004 and 2005, which led to further emergency stabilisation being necessary, for safety reasons. This allowed for the early set up of the larger site compound to allow maximum daily foamed concrete pours. Approval of these extensions went through Council standing orders with health and safety being a primary reason to maintain the existing workforce. The Council was still subject to the HMIM Enforcement Notices at this time.

The cost of stabilisation up to 2005 was £10 million; from 2005 to the start of Main Scheme in early 2007 the cost was circa £20 million.

Other smaller Contracts for Grey Gables and Property repairs were based upon NEC Option A–lump sum with activity schedule.

Main Scheme

As the overall scope of the mine remained undefined at the time of tender it was considered that the most appropriate route for procurement would be via a Contractor Framework. This enabled various packages of work to be selected and let in the future under the framework, with a single OJEU process and therefore saved programme time and costs.

An OJEU notice was issued for suitable contractors. 7 contractors were asked to tender based upon drawings, specification and measured Bills of Quantities. Subsequently, 6 tenders were received and 4 shortlisted for detailed comparison before 4 Contractors were identified to be on the Framework.

With regard to financial risk, it was considered that a major uncertainty and risk (the mine extent) should be 'owned' by the Council (and hence the funder). The Council's professional team had the best information about that risk, so the Council was best placed to manage it. The alternative of transferring such a large risk onto the contractors was considered unlikely to deliver good value and potentially unsound in terms of potential future disputes. This was a major factor in the decision to utilise the target cost form of NEC, Option D. This is consistent with the good practice for overall project health: that risk should be held by the entity best able to manage it.

To safeguard the Council, Performance Bonds for 10% of the project value were requested and 3% retention would be held on all Payment Assessments.

The Contract provided a Pain/Gain calculation to incentivise the Contractor to keep costs under tight control, and to seek cost reductions.

The Pain/Gain calculation put into the Contract was as follows:

- Where defined costs varied by 5% from the target, the Contractor received (gained) or paid (pain) 20% of this variance.
- The pain/gain percentage increased to 40% for variance between 5% and 15%.
- Beyond this the pain/gain percentage decreased to 10% share of any variance over 15%.

Fortnightly payment assessments were included in the contract.

Insurance levels were set at £20 million. Additional project insurances were requested to cover the potential damage to properties, as this could occur even with no negligence by anyone, due to the already highly unstable nature of the ground. The value for insurances for the Main Scheme totalled £2.95 million.

The Bills of Quantities identified each individual stabilisation zone/area. The target for the works was adjusted via PM instruction as the works proceeded. However, once a zone was completed, it was re-assessed against the instructions issued and the final measurement of the works in the zone (for target purposes) for sign off and agreement. This allowed the agreement of the target for final account purposes to progress throughout the contract, and proved successful. The Final Account was settled within a matter of months following completion. The defined costs came in at approximately £2.14 million below agreed Target of which the Contractor received a 20% share, the employer benefiting from the 80%.

Under the earlier emergency stabilisation contracts there was some incentive for the incumbent contractor to perform, in order to seek further work in later stages of this huge project. This helped engender a constructive style, with little or no disputes and a flexible approach from the Contractor.

A concern for the Main Scheme was that the appointment of one single contractor for the entire main works would lose any similar incentive and might be detrimental to this flexible approach. For example, the Contractor might feel more inclined to leverage claims or enhance rates. HCA and the Council wanted to reduce the risk of being put in this position or of being 'held to ransom'. The packaging approach formulated for the Main Scheme retained the incentive benefit of securing future packages for much longer into the works.

The packaging within the Main Scheme Tender Document was developed to allow separate worksites for two contractors working concurrently, should that be the best value offer. Concrete operations were to be programmed such that demand moved progressively from the first to the last package over the life of the project. The proposal was for the single site batcher being managed and operated by the package contractor needing the foamed concrete. With two contractors working concurrently, one contractor would have exclusive use of Firs Field access shaft, whilst the other would be working from a smaller work site elsewhere in the village.

Therefore, the main scheme tender documents were split into three distinct packages of work for pricing purposes.

The content of the packages is unimportant for this book. The key aim was that the packages could be organised as follows:

- Packages A + B + C by one contractor, although the intent was not to let as one all encompassing contract at the outset. Package A would be let first. If performance met expectations, Package B would follow on, with Package C being let as Package A moved towards its completion. Cost reductions if more than one package was let to the same contractor were included in their tenders.
- Packages A, B and C capable of being let to two or three contractors working to package programmes that overlap in time but with clearly defined and allocated separate project areas at any one time, thereby facilitating concurrent working. In addition, clear periods for the mixing of foamed concrete at the Firs Field batching plant would be defined for each package. The arrangement allowed multiple contractors to be active with very little overlap or inter-reliance. Clearly it was a more complex arrangement than a single contractor, but was workable due to the large size and the duration of the works (3 years). It could also be cost effective if a contractor would be more proficient at one package than the overall works, as mobilisation was a relatively small proportion of the contractors' costs.

The commercial benefit of tendering Packages A + B + C together by one contractor provided an important 'benchmark' for the project. Tendering for multiple contracts allowed the 'benchmark' to be market tested. Contractors were given the opportunity to submit alternatives in addition to compliant bids.

The main benefits of following this route were:

- To consider options that avoid putting "all eggs in one basket"–of benefit for incentive and in case a contractor under-performs significantly or becomes insolvent. Concurrent Contractors could spread the work packages and reduce the financial risk/reliance on one. If a contractor fails, this can be addressed by replacing the contractor rapidly under the Framework.
- To create opportunity for an element of competition between contractors, subject to Best Practice and Value for Money (BPVM).
- To create opportunity to match specialist contractors to specialist work areas, e.g. bat chambers.
- To create opportunity for wider competition from 'smaller' contractors, without losing the potential benefit of seeing whether larger players would be better value. This could increase the likelihood that the people with specialist underground mine experience within contractors would lead the contractor team and so be more accessible for direct liaison with the Council's professional team. Having that specialist expertise in a subcontractor role was much less attractive to the Council from an early warning and active risk management perspective.
- There was awareness that this package arrangement might also provide an opportunity for the experience, proactive culture and goodwill of the two incumbent Contractors to be included in the Framework, subject to BPVM testing in the market.

Following rigorous tender appraisal the Council took the decision in April 2007, endorsed by HCA, to let the initial Package A to a fairly small Contractor, one of the incumbents.

The tender appraisal was done on the basis of 60%/40% quality/cost. The quality aspects of the tenders were appraised by groups comprising specialists relevant to that topic plus a representative of the Project Manager. Scoring of each quality factor was done simply, e.g. points out of 100. These scores were then transposed into marks in the relative scoring matrix, as each factor contributed a pre-agreed proportion of the overall 60% for quality. Stakeholders were included in the workshops deliberating on relative ratings of quality factors (as noted in Chapter 3). Representatives of the Board of the Community Association were full members of the group appraising community-related factors, and were included on the tender interview panel.

A 'reality check' of the financial value of a 'quality' point helped to inform differentiation in quality scoring and check that it would be of reasonable financial significance. (Financial value was based on the client team's cost estimate, as this quality assessment preceded opening of the financial 'second envelope' part of the tenders.) A blank copy of the quality assessment matrix giving the relative quality ratings is given in Appendix A, together with the formula used for combining quality and cost.

A relevant factor in the tender appraisal process was that senior members of the Council's wide professional team, who were going to have to live with the outcome of the selection to deliver the project, had an active involvement with the procurement and appraisal process. This was in addition to independent and less involved assessors, who provided independent overview and scrutiny and particular inputs, respectively.

Following award, the Contractor's performance was subjected to considerable scrutiny and review, including rigorous weekly reporting and the setting of Key Performance Indicators, KPIs. Having successfully met the challenges of the project, the Contractor was subsequently awarded further packages and completed the works by December 2009. Some project statistics are given in Chapter 9.

Public Art

The Council and HCA commissioned a public art programme to commemorate the project and celebrate the social and natural history of the Mine, its locality and its residents.

A Public Art Consultant was commissioned to develop this work and reported to a Legacy Steering Group, which comprised elected Councillors, local interested groups, residents, Council officers and the Project Managers. The agreed programme included the following;

- Poetry and Pageant: poet/writer in residence.
- Musical Composition: music composer and local primary school performances.
- Sculpture: sculptor/visual artist.
- Public Art Film: film maker.
- Firs Field Installation: stone carver.
- Photographic Artist: including 3D film presentation.
- Commemorative plates/book.
- Gateways within the new boundary wall to be constructed along one side of the Firs Field, incorporating carved text on the entrance paving slabs.

A lesson learnt in this process of procuring Public Art is to allow the public art consultants space and flexibility to encourage artists to be creative and to fully explore the subject as well as the necessity to enforce a robust but workable method for monitoring and maintaining both the programme and budget. In addition, it was recognised that when artists are working closely with a number of stakeholders, particularly those representing the local community, there is a need to ensure that there is clear differentiation between what is an aspiration and what is a firm proposal.

Key Performance Indicators

At an early stage the project used Key Performance Indicators (KPIs) to assess and monitor the performance of Consultants, Advisors and Contractors. Rather unusually, the Council set up KPIs for itself, set by the advisors appointed for the project.

KPIs were assessed on a quarterly basis, through project review meetings between the Council and the individuals or companies concerned, at which both parties marked each other out of 10 as to whether they were achieving the set criteria.

Examples of the criteria set for each role were:

- Contractor–quality of work, health and safety, availability and performance of resources, attitude to claims, contract management, supply chain management, achievement of programme objectives, accuracy of cost information and team integration.
- Engineer/design consultants–expertise, health and safety, resource availability and knowledge base, communication, achievement of programme deadlines and deliverables, quality of design, attitude to fee and any additional claims, team management and team integration.
- Cost consultant/project manager/risk manager–expertise, health and safety, resource availability and knowledge base, communication, achievement of programme deadlines and deliverables, innovation and ideas, programme management, attitude to fee and any additional claims, accuracy of estimates, project and team management and team integration.
- Council–communication, delivery of decision making, health and safety, processing of invoices, accuracy of reporting, empathy, resource management, departmental management, processing of funding applications and team integration.

These reviews identified any remedial actions needed including development of staff (or even replacement) if found not to be performing. Overall a score of 8 was deemed satisfactory, 6/7 required action to improve, and 5 or below required immediate

action and/or change of personnel or company. This process continued throughout the project and became an important part of the procurement structure for the Main Scheme Contracts, in that Contractors had to demonstrate achievement of certain performance criteria in order to be eligible to secure further sections of work.

The Key Performance Indicators used for the Main Contractor under the Main Scheme were:

- Health and safety–the key measurement here was the number of lost working hours as a % of the total hours worked. Trigger threshold: >1% lost hours.
- Bulk concrete infill quality–measured against 28-day strength compliance with specification. Adverse performance was <90% compliance. Concrete pour cubes were taken extensively throughout the life of the project. NB. Concrete is unreinforced mass/bulk infill, not structural reinforced concrete.
- Time–period output performance, using an earned value software tool to monitor cost and output performance. Measured as amount of work planned against actual amount of work delivered within any given month.
- Cost performance–measured invoiced values (defined cost) against target assessment. Generally costs needed to remain below target and therefore there was an incentive to share gain position.
- Change performance–this measurement identified the number of NEC Compensation Events issued within the month relative to the number agreed between both parties as to the agreed adjusted target amount. These data were critical as they fed into the cost KPI, relating to target.
- Environmental–bi-monthly environmental audit carried out by the Engineer to check compliance with the Environmental Management Plan.
- Supply of design data–this measured the timing of design data passed to the Engineer, which related to verification issues, hydrology issues and final close out data. This information was captured by the Contractor and was passed to the Engineer for either further design action or close out.
- Community–assessment carried out by the Community Association based upon simple questionnaire using the Considerate Constructors Scheme terms of reference. In addition, the Contractor was responsible for updating drawing information in the Community information centre. This measurement highlighted any issues relating to property owners and the community in general (e.g. road closure plans, etc).
- Completion of areas–measured against completion of stabilisation zones and the passing of information to the Engineer to allow 'sign off'. The Contractor was incentivised to complete areas early, as retention monies were released based upon such completions.

The Key Performance Indicators were used to assist the Council, HCA and Consultants in deciding to award the remaining contract packages to the chosen Main Scheme Contractor in Christmas 2007, 8 months into the Main Scheme Programme. An example KPI report is included in Appendix B.

Other Performance Measures

Weekly reporting was adopted early on and continued and developed throughout the life of the project with dashboards being brought in under the Main Scheme. This report reviewed all aspects of construction progress and the monthly dashboard would add design, cost, finance and risk issues.

The weekly dashboard identified the following:

- Roadway construction–compared planned length of construction against actual progress and the forecast planned for the current week.
- Progress of shuttering, top blocking, infilling quantities, controlled infilling (which was slower and generally occurred around the mine perimeter/margin), 'uncontrolled' infilling (main pours contained within shuttered areas), roadway backfilling (one of the last operations).
- The report highlighted the number of programme buffer days created, particularly in the first year of the contract. This allowed flexibility as areas could take longer to complete if the void proved to be larger than the original volume assessed by the Engineer. Conversely, an area could be less in volume and complete earlier; therefore the buffer days identified the number of stabilisation areas available to be filled to keep productivity and continuity to an optimum.
- Continual monitoring of weekly performance and outputs.

See Appendix C for sample weekly dashboard report.

Chapter 7:
Working with Stakeholders and Project Legacy

Examples of good practice discussed in this chapter include:

1. Good commitment not only by the project team but also by the regulatory authorities and many other stakeholders, over many years.
2. Development of a planned scheme that responded to stakeholders' aspirations in a way they could feel was reasonable, notwithstanding mutual incompatibility of some aspirations.
3. The removal of a major public safety hazard and blight from potential collapse risk for hundreds of private homes - a significant societal benefit.
4. Greater weight given to long term and irreversible environmental impacts.
5. Active treatment of statutory environmental constraints.
6. Creation of new bat habitats and breeding conditions.
7. Comprehensive archaeological recording.
8. Pre-testing of infill materials and water monitoring to support protection of adjacent public water supply springs.
9. Overall project insurance used successfully.
10. 'Considerate Constructors' awards.
11. The importance of strong workforce engagement.
12. A strong health and safety culture.
13. Collaborative working between Government Departments.
14. Active, positive dealing with the 3 major strands of sustainability - financial, environmental, and societal.

Introduction

The project had to interact with and manage the interests and aspirations of numerous stakeholders in order to achieve success. In many cases the interests of one party were incompatible with those of others. For example, English Heritage initially sought a stabilisation solution that left the mine galleries open and without unnecessary intrusion of construction work. This was an entirely proper aspiration from their perspective. The bat interests also wanted open galleries in large areas of the mine, but generally in different areas from those targeted to be open for heritage reasons. However, this conflicted with the residents and Insurers who were looking for a complete infilling solution. However, leaving the mines to collapse with no intervention was bad for all their interests, quite apart from public safety issues.

A challenge to the project was to identify the best approach to providing for and managing the expectations of the interested stakeholders, which was also consistent with best value principles for funding. 'Best value' is not 'cheapest' it is important to note. Overall, all the stakeholders were listened to and through consultation and discussion a satisfactory overall result was achieved that stakeholders could feel was reasonable, given the combination of circumstances.

Examples of the stakeholders on this project are:

- Natural England
- English Heritage
- Environment Agency
- Local Community–residents and businesses
- Wessex Water
- Local Planning Department
- HM Inspector of Mines/HSE
- Highways Authority
- Association of British Insurers
- Councillors
- Funders
- Statutory undertakers
- Ministry of Defence–Foxhill.

This chapter outlines how some of the major stakeholder issues on the project were resolved.

Greater weight was given to long-term irreversible impact than to temporary or reversible impact, and to aspects with statutory protection. The safety objective to avoid collapse of hundreds of homes into the mine was a key priority of the project.

Bat Habitat

Various bat species had well-established roosts within the Combe Down mine (Fig. 7.1). These included Greater and Lesser Horseshoe bats, Common Pipistrelle bats and Vesper bats.

Fig. 7.1. Bat cluster within the mine.

Bats are protected under the Wildlife & Countryside Act 1981 (as amended) and have European protection under the Conservation (Natural Habitats, etc.) Regulations 1994 (as amended), which implements the EC Habitats Directive in the UK. It is an offence to deliberately capture, injure or kill a European Protected Species (e.g. bat) or to deliberately damage or destroy the breeding site or resting place (roost) of such an animal or to obstruct its access. A roost is protected whether or not bats are present at the time. It is also an offence to deliberately disturb a bat that may significantly affect its ability to survive or the local distribution or abundance of that species. Infilling the mines completely would have destroyed this habitat.

In order to obtain a planning permission to stabilise the mines the scheme needed to seek the approval of Natural England as to how to stabilise the mines whilst preserving the existing bat habitat. Consequently, the Council employed a bat specialist to assist with this process and to monitor bat activity within the mines and surrounding area.

Between 2001 and 2003 bat numbers were monitored. Certain areas of the mine were fenced off as 'Bat only' areas and temporary heated incubators were installed to encourage breeding (Fig. 7.2). For the 2003 planning application it was accepted that the scheme needed to provide the equivalent of 37,500m^3 of stabilised open galleries of various sizes within the mine. These galleries would be either formed by excavating out foamed concreted areas or constructed as voids.

Fig. 7.2. Bat incubator.

To carry out this permanent replacement work the project needed to provide an alternative temporary habitat and to encourage the bats to move away from Combe Down to this temporary location whilst the replacement galleries were constructed. Through consultation with Natural England a suitable site was found at an adjacent mine, Grey Gables, approximately half a mile from the Combe Down mine. Grey Gables was outside the project stabilisation area and not beneath houses or other properties. The plan was to build a new shaft into the Grey Gables mine, install an incubator and provide three new steel roadway adits (tunnels) to link two existing areas of the Grey Gables mine.

In pursuing this temporary location, at the adjacent Grey Gables mines, and through consultation with Natural England, an alternative permanent option was identified, providing better project value. By constructing a tunnel link between Grey Gables and a further adjacent mine, known as Mount Pleasant (Fig. 7.3), this temporary solution became a permanent new habitat location in excess of the 37,500m^3 specified under the original planning application.

Following this revised solution the volume of constructed bat galleries (Fig. 7.4 & 7.5) within the Combe Down mines could be reduced by over 90% to 3,500m^3.

This solution was good for the bats, preferable to residents as many more of them had solid infill rather than open bat galleries under their home, and similarly preferable for insurers and mortgage companies. It was also less costly.

Fig. 7.3

Cut and cover tunnel established at Grey Gables mine to link Grey Gables to Mount Pleasant Mines. Cost of this work was circa £1.3 million. To provide similar volume of constructed galleries in the Combe Down Mines would have been £7 million. Using the temporary location as part of the permanent solution saved the scheme £5.7 million.

Fig. 7.4

Formation of constructed bat galleries for shotcreting.

Fig. 7.5

Remote controlled boom used to shotcrete the constructed bat galleries

Bat monitoring will continue for a further 10 years to record numbers and provide data to support that the habitat remains.

Heritage and Archaeology

Combe Down mines dated back to the early eighteenth century and were of particular historic interest. They have high industrial and archaeological significance, associated with Ralph Allen's innovative mine workings of the time, including the use of cranes and a railway/tramway system underground (Fig. 7.6).

Combe Down is also part of the Bath Conservation Area and the World Heritage Site, and has dozens of listed buildings.

English Heritage, whilst understanding the need to safeguard life and property, were originally seeking to preserve as much of the mine as possible for the future. This is entirely consistent with their responsibilities. Therefore, the project needed to explore ways to stabilise the mines whilst preserving the existing heritage as much as possible and to seek the approval of English Heritage. The Council employed an Archaeological Consultant to assist with this process and to record the whole of the mine workings in detail.

Areas of varying priority were designated based upon an assessment of mining heritage importance.

With regard to Heritage and Archaeology, full recording of the mines was carried out during the stabilisation programme with survey and photographic records taken of the mine topography, roof conditions, recording of mining activities and practices, pillar sizes and their locations (Fig. 7.8).

Fig. 7.6. Historic tramway within the existing mines.

All archaeological finds, and some of the old miners' graffiti, were saved and archived, to be available for future display in a new Interpretation Centre, funded through the project. The information allowed for the production of a 3D 'fly through' DVD to be produced of the mine conditions before stabilisation, for future display in the Interpretation Centre. Trials of video photography and laser scanning were undertaken.

In addition, specially designed techniques were used, including the physical removal of intact sections of stone of particular interest (Fig. 7.7), plus an innovative silicone and resin transfer method that produces high-quality impressions of features, suitable for further analysis and display.

In the early stages of the project, it had been an ambition of English Heritage to leave some galleries in higher priority areas open through the use of structural support. This included an area known as the Grand Canyon (due to its void depth being 6 to 8 metres). However, once the engineers explained how this would need to be constructed and the consequential disruptive impact on the original mine condition, it was clear this did not preserve the mines well, and would cause significant damage.

The choice of stabilisation moved to using sand infilling. This would facilitate re-excavation of the area if at some point in the distant future mankind wanted to re-explore the mine heritage, e.g. when the village was no longer present. However, later in the project the mine condition was deemed too dangerous and unsuitable for this option and consequently all areas were stabilised with foamed concrete. This was greatly regretted by the project team. However, it did underline the benefit of the comprehensive recording process undertaken. The foamed concrete contrasts with the native stone but would not be as easy as sand to re-excavate in the future if so desired. It is noted, however, that foamed concrete is considerably less strong and less dense than normal mass concrete.

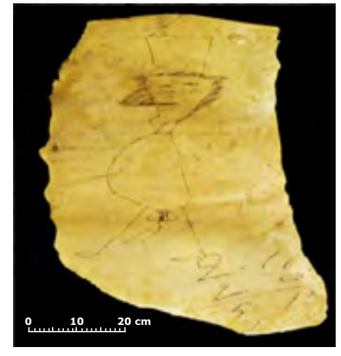


Fig. 7.7. Part of mine graffiti removed for future display.

Fig. 7.8. Deep chambers indicating some of the mining heritage.

Wessex Water/Hydrogeology

Water monitoring has shown that the stabilisation of the mine has not, to date, compromised the integrity of the local water source nor adversely affected the surrounding water table.

In the early years of the project it was foreseen that infilling the mine could adversely affect the water quality at the nearby potable water supply springs at Tucking Mill and also influence the drainage of water through the mines and therefore disrupt the water table or the quantity of water flow to the springs. The mines themselves are well above groundwater level but water drains through them from surface infiltration.

Extensive leachate testing of infill materials, in conjunction with monitoring of the potable water source, established that foamed concrete infilling had a low risk of impacting the water supply quality. However, with regard to the water table, the initial design solution was to infill the roadways and the section of the mine nearest the springs with stone gravel. This approach was aimed at maintaining good vertical water flow through the mine void. On the down side, it was more costly than foamed concrete and would prolong the time needed to complete the infilling of the mine and therefore extend the period of risk of collapse.

Ground water monitoring as foamed concrete infilling progressed during the project indicated that the infilling did not adversely affect the drainage through the mine. Water appeared to be adequately draining down through the existing pillars. Through ongoing consultation with the Environment Agency and Wessex Water, in the light of the groundwater monitoring, the project was able to fill more areas with foamed concrete rather than stone. As part of the risk management for this change of drainage strategy, provision was made for sinking post-completion drainage wells from the surface through the mine infill, if monitoring indicated they were needed.

Early indications are that the mine infilling has not adversely affected the conditions for the springs. Monitoring of the water supply and the ground water will continue for 18 months to continue checking that.

Community Issues

At the outset, many villagers seemed much more concerned about the difficulty of obtaining normal house insurance cover for subsidence, and the knock-on effect that had on mortgage finance and the saleability of their house (i.e. blight), than they were about risk of death or injury due to a potential mine collapse. This perspective may have arisen from an attitude that the mines would probably continue as they had done for over 100 years, as any collapses they knew about at the surface were localised and infrequent. However in reality, mine roof falls were occurring quite frequently underground, the mine roof and pillars were unstable, often very seriously, and their condition was deteriorating.

Some villagers started from a view that as they had not caused the problem it could not be their responsibility, so 'someone else' should solve it, at no cost to them and without too much disturbance.

By the end of the process there was widespread appreciation and gratitude amongst residents for the work done to protect them and their homes, of the sensitive way this had been achieved by the project team, and of the quality of communication with them.

The Community have had the blight removed from their properties. The Association of British Insurers has indicated their members will be advised that no special insurance provision needed to be made in relation to the former mines here.

All residents received a project completion pack that identified the area of mine below their property and the stabilisation work that took place. These packs will remain with the property deeds and title as evidence that the work has been carried out and that the mine beneath the property has now been stabilised.

Some properties did suffer damage during the works (fewer than 4% of properties). Where this occurred it was considered due to the meta-stable mine roof condition, for example to changing the interaction between sagging roof rock slabs by the installation of roadways below ground. Each case was assessed to be non-negligent, illustrating the fragile and unstable nature of the mine roof. The project took care to survey all properties before works commenced, in any area; therefore there was evidence to support whether any claimed fault in the structure had occurred. All properties were repaired back to original standard and condition, funded by project insurance. In some instances the residents were so impressed by the quality of local contractors used that they contributed additional finance to enhance the works to their properties.

The local war memorial, which is located on Firs Field, became completely surrounded by the main site compound. Every year safe access was made for the Remembrance Sunday service to allow the local community to pay their respects to the country's fallen heroes.

Throughout the project the general workforce and the community interacted at various events, as well as routinely when walking between sites in the village. This was in addition to the regular Community Association Board meetings, public meetings, newsletters, website and other routine community liaison. See also Chapter 4.

The Contractor received 3 Considerate Constructors awards whilst working on this project, the final one being Gold. Various fundraising activities were initiated; matches played with the local rugby club and the workforce used local businesses, which had

a beneficial impact on the village local economy. As part of the project completion the Community and the workforce joined together one sunny September Saturday to celebrate the successful conclusion of the project. The local infant school made clay models of the miners (Fig 7.9). Poems were commissioned and a special ale brewed (Oolite ale) to celebrate the occasion.

The local area above ground will be returned to its original condition. A few pieces of public art, located on and around Firs Field, will be one of the few visible object left as a tribute to this project. In addition, commemorative plates were commissioned, which, together, formed a map of the overall mine (Fig. 7.10). Plates were distributed to affected local residents. An interpretation centre is planned, as mentioned previously in relation to heritage.

Fig. 7.9. Models of Elywn Davies (longest serving miner on the project–9 years) made by the local schoolchildren.

Health and Safety Issues

The physical hazards on this project were very high, particularly with the potential for the stabilisation works to trigger a collapse of the highly unstable conditions. The working regime put in place on this project was that set out in mining regulations, the Management and Administration of Safety and Health in Mines Regulations 1993 (MASHAM). These specify that the responsibility for all underground and surface operations lies with the Mine Manager, notably in regard to Health and Safety. The statutory appointment of Mine Manager was made by the Council as nominal Mine

Fig. 7.10. Display of commemorative plates that together form a map of the Combe Down Stone Mines.

Owner for safety purposes, initially through the Contractor but predominantly through the engineer. CDM Regulations applied to above ground works not specifically covered by MASHAM.

At an early stage a decision was made by the Main Scheme Contractor to employ experienced underground miners and to pay a set wage with no incentive or additional payment to any individuals for productivity. This was encouraged by HMIM to reduce the risk of temptation for site staff to 'take short-cuts'. The potential consequences if safety margins were shaved even a little were judged too severe for this project. The main incentive for the workforce was continued employment on this and subsequent stages. This was enhanced by the Main Scheme Contractor by pay rates a little above average for such work. Looking back, it is considered that this had several benefits: for example, it enhanced quality of work, avoided potential for resentment from crews working in more difficult/slower mine conditions, reduced risk of accidents and also reduced loss or turnover of staff. The latter was very helpful for retention of project knowledge. The staff turnover rates on the project were generally lower than average. For example, of the Hydrock management team of up to 50 posts, of those who started the project 100% were still in place by the end of it. For miners, the loss of staff over some 9 years averaged just 10%.

One significant aspect that made an important contribution to health and safety and to the project overall, was employee engagement. The culture that existed wihtin the contractor's workforce created a strong team spirit and pride in the job. There was no 'them and us' feeling between the workers and management and this had a positive effect on productivity, quality, health and safety and engagement with the local community.

To reduce underground power outages within the mine, an Uninterruptable Power Supply (UPS) was installed.

There were 20 methane detector heads installed within the mine to continuously monitor conditions.

Grout pump lines were 100% cleaned every 24 hours of the working week to avoid obstruction building up leading to the line blocking or bursting under pump pressure.

All miners had the equipment and checks set out in the Regulations.

Separate shafts for material delivery and man access proved a safe and productive procedure for the mine.

In addition to a general ban on alcohol and drugs on site, random alcohol and drug tests were carried out on all staff, as instructed by the Mine Owner. These were done by a local doctor and practice nurse, with the limit on alcohol being the maximum for driving, 80mg/l of blood. Over a 15-month period, 302 tests for alcohol gave 2 positive results (which led to dismissal). There were 202 drugs tests, of which 4 were positive.

Because of the unstable nature of the rock, listening and watching for movement was especially important. There were many minor falls of rock; the biggest observed was a fall of some 200 tonnes in October 2005. There were no casualties–the men had retreated some 30 seconds before the fall as imminent instability was observed and heard. This emphasised the importance of having experienced and skilled miners carrying out the work, particularly those in the role of lead miner (Foreman).

Over the nine years of the employment of the Mine Manager, 210 Mine Manager's Site Instructions were issued; these had the effective power of Project Manager's Instructions under the NEC contract, and were issued under the cover of a NEC Project Manager's Instruction. The Project was a good example of team integration, with the Mine Manager working alongside the NEC Project Manager and Resident Supervising Engineer actively participating in resolving early warning issues, design issues and site conditions.

Provision for rescue from the mine was set up by the Mine Owner, in case it was ever needed, and practice incidents were conducted (but no real ones thankfully).
The overall safety statistics for the project were as follows:

- Of 1,600,000 down-mine man-hours from January 2005 to July 2009 there were less than 20 Reportable Accidents.
- The down-time lost through injury was 0.5% from January 2005 to mid July 2009, and for the part from July 2008 to June 2009 it was 0.1% on 326,879 man-hours.

These figures put the project in the highest decile of safety statistics for mine operations, despite this project being well above average in risk.

HM Inspectorate of Mines

HMIM, an arm of the Health and Safety Executive, HSE, became involved in the project from 1996 when the Council had a complaint against house builders who were placing concrete in the mine as foundations for new houses; in fact the concrete, poured in via boreholes, was ineffective as it slumped away from the roof of the mine. On 17 June 1996 the Inspector of Mines identified that the safety of those going down into the mine and of those above the surface was held to be at serious risk.

In December 2000, HMIM issued an Enforcement Notice requiring the application of the Mines (Control of Ground Movement) Regulations 1999 to the mine, establishing safe access routes to the underground work area before any further entry was permitted. HMIM also encouraged recruitment of experienced miners and managerial contracting staff with mine experience. Two further Improvement Notices were served on the Council, and on the Mine Manager, shortly after work started underground, requiring that suitable support measures be instigated within 7 days in two particularly high hazard areas.

The use and timing of statutory instruments, notably Improvement Notices, by HMIM were an important contribution to the overall project, particularly in conveying to decision makers, who were generally not from a mining background, just how serious the risk of collapse was now considered to be. Clearly, there was a need for HMIM directives to respond to the steadily increasing risk and awareness of that risk as fresh information became available, but also to be issued in a context in which these directives could be actioned–timing was important and not easy. Whilst these put considerable legal obligations on the Council and Mine Manager, they did assist the Council in demonstrating the extent and urgency of work required. They added statutory weight to the Council's applications for funding of emergency works and subsequently the main works from Government under the Land Stabilisation Programme.

It is important to note that the Mine's Inspector worked with the contractor, engineer and Mine Manager to create a strong health and safety culture within the project. All staff were encouraged to report anything that they considered to be a risk and initiatives were put in place to involve all levels of the workforce in inspecting the works. '123' inspections were particularly useful as a team of three personnel from different levels within the workforce could be selected to inspect the works on any particular week e.g. an Overman, a Lead Miner and a Miner. The name comes from Section 123 of the Mines and Quarries Act 1954 and allowed inspections to take place independently of the team normally tasked with the role, ie. the Mine Manager and Deputy Mine Manager. This process involved everyone in health and safety and is considered to have made a significant contribution to reducing risk to the workforce and the public.

Whilst the Inspector had full access to the site, and to the Mine Managers and site team, he also met regularly with the designated Mine Owner (the Chief Executive of B&NES Council) and the Council's Strategic Director of Major Projects. These meetings provided a forum to discuss health and safety directly with the Mine Owner and his team, and provided the means for health and safety directives to be conveyed quickly to the Mine Managers (who also attended these meetings) and site team. The Inspector used these meetings to update the Owner on his current views on how the project was progressing from a health and safety viewpoint, any legislation issues/pending legislation changes, lessons learnt from other projects and suggested improvements/training that could be made to enhance the health and safety culture.

From the early days of the project through to the completion, the Inspector played a significant and very proactive role and there is no doubt that HMIM was a major contributor to the success of the project and its health and safety record.

Ministry of Defence–Foxhill

The existing Ministry of Defence (MOD) Foxhill site, situated to the north-west edge of the Combe Down Stone Mines, was known to be partly built over mine workings. Thorough investigation of the north-west perimeter of the Combe Down mine identified a solid margin with no visible means of access into or joining the Foxhill Mine. This lack of connectivity was probably due to Fox Hill being deeper than Combe Down.

The MOD approached the HCA and the Council in 2008 to request whether the project could take on the stabilisation of the Foxhill mine, with an area of 5,084m^2, and thereby benefit from utilising the existing site set up, concrete batcher, workforce and known stabilisation methods. In order to do this the MOD would pass funding to HCA who in turn would continue to act as the overall project funder.

An indicative scheme was put together and the Council submitted a further funding application to HCA, in the sum of £6 million, to take on the stabilisation of the Foxhill mine. To utilise the existing concrete batcher on Firs Field the miners excavated a tunnel through the solid margin, inclined down into the Foxhill mine. This provided access for pipe lines and a secondary access and exit point, which allowed a greater number of miners to operate within the area (where only a single access/exit point existed the maximum number of miners permitted in an area was 9).

Work commenced in March 2009 and within the year Foxhill was complete. In addition to the MOD property a further 23 houses in Bradford Road were stabilised. The total amount of foamed concrete poured was 14,204m^3 and 497m of protective roadway were installed. Overall the Foxhill project cost £5.87 million, slightly less than estimated. This final figure compared very well with independent estimates that the MOD had received, which were reported to be in the region of £10 million.

Legacy

Clearly the main legacy is that the Combe Down Stone Mines identified as such a major hazard to life and property in the village have been stabilised. A 100-year design life was used, as stipulated within the LSP funding criteria.

The Engineers, through modelling research and design approach, are confident that the stabilisation will last at least 100 years. For example, tests carried out at Dundee University to support the assessment of the life expectancy of the foamed concrete identified that 100 years should be achievable.

Where open galleries remain, for bat habitat, they are much stronger than the former mine void, completely sealed with shotcrete and surrounded with foamed concrete. Whilst periodic inspections of these areas are needed, they have been designed with an aim that ongoing maintenance will be low, thus reducing the risk of imposing further major costs on future Council administrations.

The monitoring of groundwater conditions for 18 months by the project in relation to the springs, and of the bats and their habitat for 10 years, have been mentioned previously in this chapter.

Decommissioning is not applicable to this project. Recreating a major subsidence and collapse hazard under hundreds of homes is not a provision that was needed.

A possible exception on 'decommissioning' related to the underground mining archaeological heritage being preserved for future generations, not destroyed. A degree of preservation in situ was achieved. However, it will not be as easy as was initially planned for mankind in future to re-excavate the 'heritage' areas of the mines, if they should wish to do so, as the proposed sand infill to those areas had to be modified to foamed concrete infill. This was regretted. Nevertheless, comprehensive study and recording of the heritage were undertaken prior to infilling. That has made the heritage much better known in detail and much more widely available.

Highways and underground services have been made safe by the scheme. Road gulley drainage has not been compromised by the infilling.

The environmental legacy for groundwater resources, for bats and for heritage is of a high calibre. The societal need for hundreds of homes in the village to be saved from blight and from the impact of mine collapse on life and property has been met. This has been done within the planned budget–a budget set in accordance with central government funding criteria. The project is considered a good example of the three strands of sustainability–environmental, societal, and economic–being actively considered throughout the project, and well delivered in the final solution.

Chapter 8:
Was the Project Successful?

By December 2009, the workforce was being disbanded and the main site compound was nearing decommissioning. From early 2010 the residents of Combe Down began to see life return to normal.

What defines a successful project? Being built on time and to budget? Yes, but much more than that. From a client and funder perspective, success criteria focus on operation and use of the project more than on its construction. For example, the Institution of Civil Engineers refers to much broader success criteria in their Client Best Practice Guide (ICE, 2009) including the following:

- Strategic intent achieved?
- Suitable for safe future operation and maintenance?
- Delivered on time?
- Delivered to budget?
- Good allocation between capital and operational expenditure?
- The project improves the situation for stakeholders?
- Long term benefits and value?
- Sustainability of the solution, including its legacy?
- Opportunities for personal development of staff engaged upon the project?

Performance on the Combe Down project is assessed against each of these criteria:

Strategic intent achieved?

Over the past 10 years the project has delivered the strategic intent set out during the early years of the project. The Mines have been stabilised. Property blight has been lifted from the area and concerns over availability of suitable insurance cover and mortgage finance have been allayed. Overall 25.608 hectares of land have been remediated with 649 properties receiving completion statements to retain with their house deeds.

Fig. 8.1. Handing over the first Completion Statement.

Suitable for safe future operation and maintenance?

Safe operation has been achieved by infilling most of the mine (98.5%), with the residual open areas (bat habitat) constructed as strengthened galleries. Access for planned maintenance inspections of the bat galleries has been made safe.

Delivered on time?

Stabilisation was completed by 9 December 2009, 3 months ahead of time. Having highlighted time as a major risk to the increased chance of major collapse and to the escalation of costs, delivery on time was a key project target and risk item. By 2003 an initial programme was produced and this was submitted to HCA as part of the funding application. This programme identified completion of stabilisation as February 2010. All activities were monitored against this original baseline programme.

Delivered to budget?

Yes. In April 2005 central government (now CLG) through HCA granted £154 million towards this scheme to cover all eligible works needed to stabilise Combe Down. Including the additional work at Foxhill mine, the overall budget for the scheme comprised;

• LSP Funding	£154 million
• MOD Foxhill Mine	£6 million
• Council Funding	£7 million
Total	£167 million

The current estimated cost is just under £165 million

Whilst it might seem that the project ran smoothly as originally planned and budgeted, this was far from reality. The funding application was made in 2004 based upon certain assumptions, many of which were found to be different at the point of delivery. The project was therefore continually challenged to achieve the optimum programme and budget. The delivery of the project to budget required continual review and improvement of processes, programme and design. Innovation, design development and best value decisions released funds that were needed to overcome increased volumes, design issues at margins and smaller inaccessible areas. For example, expenditure on creating a large bat habitat in a nearby mine greatly reduced the cost of provision for the bats in the Combe Down mines (as well as creating a bigger bat habitat and pleasing residents by reducing the extent of open bat galleries beneath their homes).

The discipline of the NEC Contract and its early warning process instilled a teamwork and proactive approach to the resolution of issues. Disputes were limited and when the on-site team could not agree on a particular issue, it was referred to a higher tier team comprising Directors of the Council, Contractor and Consultants. This occurred on only two occasions throughout the contract period. The project did have an exceptionally positive culture whereby all parties worked together to provide a successful project.

In total, for the Main Scheme, 576,691m^3 of foamed concrete has been poured into the mine together with 30,000m^3 of stone infill. 14.7km of access roadways excluding stub roadways were constructed. The overall volume of infill, 606,691m^3, was thus 7% greater than the primary estimate at funding assessment stage in 2004 (565,000m^3), but was inside the range of the risk planning. It is interesting to reflect that had the upper/lower bound study not been undertaken at funding assessment stage, the base estimate would have been less than 500,000m^3 (Chapter 3).The final account of the main scheme was agreed four months after practical completion.

Good allocation between capital and operational expenditure?

An aim for the project design, but not a determining factor in option selection, was that ongoing maintenance costs should be low. There will be a need to inspect bat galleries periodically, but this stabilisation design option has little intrinsic ongoing maintenance that will be a burden for the local Council. There are some post construction monitoring costs to check bat and groundwater conditions, but that is considered as effectively part of the main scheme.

The project improves the situation for stakeholders?

Throughout the project the views and interests of the stakeholders were pro-actively sought, considered and managed in the following way:

- All major stakeholders were invited to, and most attended, the quarterly Steering Group meetings discussed in Chapter 4. This was an excellent forum for the wide range of interests to be aired and shared, often with great fervour. It helped mutual understanding amongst stakeholders of the validity and importance of each others' interests, which in turn greatly assisted them to appreciate the merits of scheme proposals from that wider perspective.

- Steering Group members contributed actively in risk workshops, discussed in Chapter 3.

- The very active liaison with stakeholders helped the project team not only to take account of their interests better but also to achieve a more accurate understanding and perception by those stakeholders. This accuracy was much better for all parties than a lack of knowledge or poor understanding (even when the stakeholder was not delighted with the outcome.).

- The Community of householders and local businesses have had the blight removed from their properties.

- Natural England: For bat habitat, the original plan was to produce the equivalent of 37,500m^3 of constructed galleries within the mine. In order to construct these galleries temporary alternative habitat was needed to allow the bat colonies to relocate out of the Combe Down mine. In pursuing this temporary location, by augmenting habitat at the adjacent Grey Gables mines, and through consultation with Natural England, an alternative option was identified, which provided a better permanent habitat and better value. By constructing a tunnel link between Grey Gables mine and the nearby Mount Pleasant mine, this temporary solution became a permanent habitat location in excess of the required 37,500m^3. The amount of constructed galleries within the Combe Down mine was reduced to 3,500m^3. The project has protected and provided a long-term habitat solution for the Greater and Lesser Horseshoe Bats.

- With regard to English Heritage's interests in heritage and archaeology, full recording of the mines was carried out during the stabilisation programme with survey and photographic records taken of the mine topography, roof conditions, recording of mining activities and pillar sizes and locations. Archaeological finds were saved and archived for future display in a new Interpretation Centre. The information allowed for the production of a 3D fly through to be produced of the mine, for future display in the Interpretation Centre.

  In the early stages of the project it had been an ambition to stabilise some areas of the mine with sand, to allow future generations to excavate and explore these areas. However, the mine condition was subsequently deemed too dangerous for this option and consequently all areas were infilled with foamed concrete.

  Turning to the designated Conservation Area and Grade II listed buildings at the surface, these have been protected from future collapse and dereliction, with no significant permanent disruption by the construction works.

- Monitoring of water conditions shows that the stabilisation of the mine has not compromised the integrity of the local drinking water source nor adversely affected the surrounding water table–interests of Wessex Water and the Environment Agency stakeholders as well as the local community. Monitoring of the water source and groundwater has been carried out for several years during the project and will continue for 18 months after completion of site work.

- Any special conditions imposed by the Association of British Insurers or the mortgage industry can be removed from the properties. The insurance companies (and residents) were happier with more solid infill beneath the houses, resulting from the transfer of 90% of the open bat gallery provision to nearby mines that were not beneath houses.

- The Environment Agency does not regard the infilling material used as being a contaminant or waste, so regulatory, mitigation and resident perception issues that are associated with waste and potential contamination risks or liabilities were avoided.

- The local area will be returned to its original condition. Public Art, situated around the area and on Firs Field, will be the only visible evidence of this project. All the residents received a commemorative plate that symbolised the area of mine below their properties.

- Noise and dust were kept to minimum and working hours were well adhered to by the Contractors. The use of low-density foamed concrete reduced the materials quantities and so the number of vehicle deliveries to the site, which in turn assisted in reducing impacts on the local neighbourhood.

- The Health and Safety record on this project has been exemplary. The number of reportable incidents was negligible relative to the man hours expended. This is a credit to all the site operatives, miners, Consultants and to the Mine Managers on the project and their proactive approach to solutions that were safe but effective.

- The nearby Ministry of Defence Foxhill property was stabilised within the overall project programme. The decision to stabilise this area was taken in March 2009, following successful inter-governmental department liaison and decision making. The Contractor and Project Team impressively managed to achieve completion of this within the remaining months of the Main Scheme programme. In addition to the MOD property, a further 23 houses identified as needing attention in nearby Bradford Road were also stabilised during this phase of work. Total amount of foamed concrete poured was 14,204m^3 and 497m of protective roadway were installed. Overall the marginal cost of the Foxhill project was about £5.87 million, just below the expected level and £5 million below independent estimates that the MOD had received for stabilising their site as a stand-alone project.

Long term benefits and value?

This topic has been dealt with in the delivery of strategic aims and improved situation for stakeholders.

Sustainability of the solution, including its legacy?

The project is considered a good example of the three strands of sustainability (environmental, societal, and economic), being actively considered and well balanced throughout the project, and delivered in the final solution. The environmental legacy for groundwater resources, for bats and for heritage is of a high calibre. The societal need for hundreds of homes in the village to be saved from blight and from the impact of mine collapse on life and property has been met. This has been done within the planned budget–a budget set in accordance with central government funding criteria (Treasury 'Green Book').

Opportunities for personal development of staff engaged upon the project?

The project was large, of a high profile, and an intricate interaction of engineering, planning, environment, heritage, social, and financial factors, plus an unusual superposition of mining and construction health and safety regimes. It also involved a large number of employers in both public and private sectors who strongly supported staff development. Given this combination, it is hardly surprising that there have been many professionals of several disciplines who have had opportunities to develop their skills and competence further on this project, and have done so.

The construction workforce too used opportunities to develop their skills–for example, coal miners extending their skills in a construction environment and, for many, in a different shallow mine environment and ethos,– one of long-term stabilisation rather than mineral extraction. Diversity of workload allowed the workforce to train in other skills, such as plant operation and shotcreting.

The use of foamed concrete in such large quantities, underground and over such a huge area, provided huge opportunities for innovation and advancing the material science of, the engineering knowledge of and the construction practice with this material. This was one of the leading technical features of the project, and has been the subject of many presentations and discussions in professional institution and learned society meetings. It is hoped that further informative technical papers and perhaps some authoritative UK guidance, (e.g. a British Standard?), will be developed, which draws on and disseminates the knowledge more widely.

Some pointers to personal development opportunities that are needed were also identified. For example, many younger professionals such as engineers, engineering geologists, infrastructure managers, etc. had obtained good training and familiarity in the use of GIS during their studies; but that was not so for many middle/senior professionals. Many of the latter found that they would have liked to have a greater familiarity and skill with GIS, as it was found to be more useful as a tool to assist live project and risk management thinking and scenario planning than many had appreciated it could be.

Many of the Council staff developed skills and experience of a very major engineering project and of a depth of stakeholder consultation and liaison that exceeded their previous experience.

Other Success Criteria

- The project is an example of Government Departments and Agencies working together to achieve significant savings (50%) for the public purse. Ministry of Defence Fox Hill site took advantage of Main Scheme site set up and infrastructure, following liaison with the HCA and the Department of Communities and Local Government, CLG, who were funding the Main Scheme.
- Though primarily driven by emergency works to enhance stabilisation, undertaking investigation and temporary 'blocking' work early on, while an overall scheme was designed and promoted, enabled the scheme to develop a tool box of solutions (which worked) and to train the workforce into the skills needed to carry out the works.
- The early stage release of funds, into annual budgets, dictated the need for flexible procurement. In the early years the contract allowed for potential to extend the completion date by up to 2 years, subject to funding availability and Contractor performance. This provided continuity of safety works, saved on procurement time and encouraged the Contractor to partner with the Client to seek optimum solutions. This incentive approach was taken forward to the Main Scheme whereby the successful Contractor selected from those on the Framework was only given part of the mine to stabilise and was then monitored through KPIs, before being awarded further sections. These would have been awarded to other Contractors on the Framework if that had been considered better value.
- The setting of annual budgets also focussed the whole team into achieving yearly objectives and goals, which in term led to an earlier completion of the project, without any need to compromise safety.
- Retention of crucial team members and therefore retention of knowledge: A large number of the main contributors to the project that started in 2000/01 remained on the project until completion (Contractors, many Consultants, Mine Managers, Mine Inspectors, Council team and Funding team), though of course others were added as the Main Scheme got fully underway in 2005. This continuity is seen as one of the key contributions to the success of this project.
- The role of the funder was extremely important. HCA and their advisers were highly proactive throughout the entirety of the project–supportive, whilst demanding best value.
- The Council Project Team Leader was powerfully instrumental in guiding the project through the Council processes and in diplomatically facilitating the different departments, parties and external stakeholders to act or participate at the necessary times.
- Project culture was important. A totally inclusive process was engendered by the Council and HCA with the Community, the Professional Consultants team and the Contractors. The Council encouraged a culture where all voices were heard and everyone was encouraged to contribute (even when voices were not harmonious).
- The decision of the Council and HCA to share risks with the Consultants and Contractors was highly instrumental in the success of the project. The use of designed solutions and measured Bills of Quantities for each stabilisation area provided adequate control for the Council/HCA to accept a target approach as the most satisfactory, and much preferable to a lump sum solution. A similar target approach was applied to Main Consultant appointments, but without the pain/gain incentive). Efforts were made to devise one but when judged against the 'big picture' of achieving best value on the Contractors' contracts, it was not adopted.
- Pain/gain share was a proactive approach to controlling costs. The Contractor shared in the savings achieved.
- Project extranet was established to track information, reporting, instructions and costs, and to have everyone on the same data track.
- A comprehensive 'no surprises' risk management plan was established, which was continually reviewed throughout the project.
- Time lapse cameras were installed to record the bat gallery construction. This captures some of the skills and teamwork of the miners and workforce

Constructing Excellence

It is interesting to reflect on the project using the guidance from the Construction Clients' Group in the 'Constructing Excellence' Best Practice Guide (Constructing Excellence 2008 a to f). This was published in November 2008, some 7 years after the start of works on site, and only 1 year before completion, so was not available to use as guidance for the project.

Appendix D gives notes about this project for each of the characteristics listed in the six chapters of the Constructing Excellence Best Practice Guide.

Conclusion

The Council and their team are to be congratulated on leading and governing such a major project to a successful conclusion, despite so many competing pressures and interests. The government's Land Stabilisation Programme, administered by HCA, has enabled a village of thousands of people to be saved from dereliction and from the horrendous consequences of damage to life and property that would have resulted from inevitable mine collapse. Great weight was given by the HCA to the quality of risk thinking, risk quantification and risk management, and this has been a key influence on the project's success.

The project was an example of very good thinking and practice on engineering, environmental, project, risk and financial management. In addition, it is a good example of collaborative working co-existing with robust challenge in the search and delivery of overall best value.

It had the benefit of all stakeholders being committed to making it happen, largely because of the safety imperative to avoid the risk to life from mine collapse. The principle that a stakeholder can permit some departure from their normal practice, and limited derogation of their particular interests, in order to achieve a higher overall 'good' is commended, whether that 'good' is in terms of sustainability or in terms of protection of life and property, as in this case.

A remarkable project, thought to be almost impossible to manage and deliver 10 years ago, has been successfully achieved.

Chapter 9:
Interesting Statistics

649 properties were stabilised, the vast majority of which were domestic homes.

The total volume of infill placed was 620,894m^3, enough to cover a football pitch to a depth of nearly 90m.

576, 691m^3 of foamed concrete, plus 30,000m^3 of stone were placed into the Combe Down Stone Mine, plus 14,203m^3 of foamed concrete into Fox Hill Mine. The following were used:

- 178,000 tonnes of cement.
- 90,000 tonnes of sand.
- 98 million litres of water. This excludes water for line washing
- 3 million litres of foaming agent.

More Statistics...

- 14,737m of main roadways: this equated to approximately 2,800 tonnes of steel. 497m of steel roadways placed in Fox Hill.
- 15,000 sheets of plywood shuttering, 2,400 × 1,200mm (each board used twice).
- 8,000 sheets of corrugated steel.
- 90,000m^2 of polythene sheeting.
- 10,000 tonnes of stone, used in underground roadways construction.
- 60,000 lightweight blocks.
- 6,000 rolls of rockwool insulation.
- 350m^3 of concrete sample cubes (over 110,000 cubes taken).
- 2.2 million man hours.
- 344,000 kWh of electricity was used in the Main Scheme. In excess of 600,000 kWh used throughout entire project period.
- 20 miles of rigid pipework for pumped delivery.
- 5 miles of flexible pipework to deliver foamed concrete within stabilisation areas.
- 15 miles of water pipe.
- 10 miles of compressed air lines.
- 60 miles of electrical and communication cabling.

And the trivia

- Over 450 contractor progress reports.
- Over 200 contractor valuations.
- Over 200 cost and progress reports.
- Over 200 EP/HCA progress meetings.
- 24 miles to walk all 8 Main Scheme tenderers around the works.
- Over 2,000 people from the village, plus the project team, attended a Fun Day in Sept 2009 to celebrate approaching completion.

Best Practice Overview

By Professor David Adamson

Guidance for Future Projects.

This was a huge project which, though specialised in its subterranean nature, has many lessons for those who in 2011 and beyond have a part to play in any large infrastructure or building programme or project. It was one of the first to pick up and run so significantly with project management by client-led teamwork with a fully integrated supply-chain, proactively involving not just a surprisingly wide range of decision-makers but also a raft of national and local groups; it followed swiftly the best of the recommendations from the Latham and Egan reviews of the industry.

It is often noted that the UK construction industry is not as good as other industries, or the construction industries of other countries, at bothering to tell others about lessons learnt or, worse, bothering to gain, at no cost, from the experiences of others who have trodden similar project paths before. This book is an example of how experiences can be set out for the benefit of others, and how those others can benefit if they take the time to think about the points made and follow up matters of relevance. Current commercial and financial pressures to abandon high standards for short-term economies make the analysis of team-working and quality/price balance in this book especially important.

Each section in this overview sets out 'handy hints' to people working on projects (with references to the text of this book), note of those who would be pleased to give more information and advice, and a suggested list of those who are specifically invited to take/promulgate beneficial advice on the back of this project if they will take the time to do so.

Although team work and integration ran right through the project, this chapter on 'Best Practice' focuses via the various primary roles that people play by virtue of their talents and training - designers, managers, constructors, suppliers, and perhaps above all in this overview, Clients (in this case the Council and the Government Agency funder).

Clients (including Local Authorities)

1. Establishment of decision-making mechanisms

As often in large projects nowadays, there were many people and groups (over 50 stakeholder groups were identified, see Chapter 3) who had to be, or wanted to be, involved in decision-making, most particularly the various elements of the client, the funder, those whose homes were threatened, many local and national regulatory bodies and groups, mostly involved in environmental matters, and all those involved in identifying, designing, and costing possible solutions, while working along with their suppliers. In this project, the challenge of nailing the decision-making mechanisms was recognised and met head-on right from the early stages, with clear definition of who was authorised to take various levels and types of decision, setting up new bodies as necessary. The Council, set up a Steering Group whose membership and way of working are thought to be unique in Local Government, (Chapters 3 and 4); it was not a decision-making body but was crucial in co-ordination and collaboration while the 'Overview and Scrutiny' committee scrutinised political and 'best practice' issues. A dedicated team for this project was set up specifically in the Council followed by, in 2005, a higher-level Major Projects directorate. The outline organisation referred to in Chapter 4 is worth study.

2. Leadership

As clearly set out in the two national reports on the industry in the '90's, 'clientship' is crucial to the success of projects with clients showing clear leadership, advised by specialists whom they appoint. A first leadership requirement is to set out clearly the end objectives of the project—this may seem obvious but usually different people have different shades of understanding and these differences become dangerous when, inevitably, the project comes under pressure. Given different backgrounds, human natures, professional interests and business drivers, this is not surprising. In this project, leadership at political, project strategy and project management levels was established decisively and clearly, and the aims of the project set out early and kept clear throughout within the context of the necessary re-assessment programme, and the associated need for flexibility (Chapter 2).

3. Establishment of managerial relationships and mechanisms with local and other 'stakeholders'

The project started in a cloud of antagonism and apprehension as local householders suffered both danger and loss of property value, and even within the local community there were sharp disagreements about how best to proceed (Chapter 2). The client recognised this quickly and made a key and cost-effective appointment of community relations consultants; these, working closely with the Council, set up an innovative body, the Combe Down Stone Mines Community Association (CDSMCA) as a registered company with liability limited by guarantee. This had an independent chairman and open, free membership, and had considerable influence on and participation in the project (even including tendering and appointment selection).
A comprehensive website was created to give extensive information and to solicit views, and a Project Information Centre was set up in a former shop (Chapter 4). Worthy of consideration is the successful programme of public art which brought local artists of all kinds into the project with surprisingly beneficial results towards the end of the project (Chapter 6).

4. Quantification of outcomes not usually expressed in monetary terms

Often clients deem it 'too difficult' to bring 'soft' issues into decision-making alongside the achievement of financially definable outcomes. This problem has since been in part addressed nationally, notably in the national report by Constructing Excellence, chaired by Richard Saxon, titled 'Be Valuable' and reinforced by the recent IGT report on Low Carbon Construction which emphasises through-life quality, with its first recommendation being that all procurement should be done on a whole-life basis with realistic carbon pricing. Good examples lie in this project, for example in bio-diversity, bats were priced at £5k per bat, given current stringent legislation and the value of loss of archaeological underground visits made impossible by the works was set at £20 per visit. These quantifications were brought into the extensive use of Key Performance Indicators (referenced all through this book, for example see Chapter 6). Design Quality Indicators were not used as they might now—they hadn't been invented till mid-project.

5. Risk assessment and prioritisation

Given threats to safety and the acute problems of getting data about project requirements from site investigations, the risk assessment and risk prioritisation were hugely important, and afford much 'best practice'. From the start of the project,

especially from the time that the probable funding source was identified, very high priority was given to costing and providing funding of risk; where possible and wise, risk was set against the member of the procurement/construction team best placed to manage that risk: where this was not managerially sensible, the client/funder took on the risk with matched contingency in the budget. The Steering Group gave leadership and guidance to risk assessment and prioritisation, helped by a clever and commendable weighting system (Chapter 3) which let people 'see the wood for the trees' without losing depth of analysis. There was a clear mechanism for updating the risk register, and for involving the CDSM CA and other stakeholders in this process.

6. Setting out, and comprehensive agreement, embedment and maintenance of principles of procurement

The Client and funder decided from the start that the project should be conducted on the principles of transparent consultation, team-work, quality/cost balance, and whole-life management. These principles were made very public to all involved, and were applied to early contractor involvement (for example, during 'industry market preparation' all interested companies/consultancies were brought into a briefing 'open day'), to appointments, the incentive 'pain/gain' system (e.g. it was not applied to work progress rates as that would impair safety imperatives), reporting and communication. Throughout the project, standards in implementing these principles were assessed and reinforced. Examples of this run throughout the book, and are well worth reading and following.

7. Project plan

On this, as on many other civils projects, it was extremely difficult to assess the extent and therefore the length and size of the project: it is worth taking note of how decisions were made sequentially and how it was decided which stages of the works should be openly tendered, how much to be done as 'follow-on' contracts, and how much within a 'framework' (Chapter 6).

Designers, Consultancies and Contractors

1. Site investigation.

Many projects have problems in first assessing what needs to be done; in this project this situation was especially severe as there were safety, environmental, historic and funding restraints in determining the extent and nature of the voids. The solutions are worth learning from (see Chapters 2-3), notably use of 'roadways' and GIS as developed by Council staff (Chapter 5). There was a widespread view among the team that GIS should be more widely taught at first degree level and, more particularly, in the wider application of GIS in CPD; in particular how it can be used to bring together ground data, works progress and future works planning.

2. Assessment of technical risks

The sequential nature of this project, starting with limited work to the most vulnerable areas and to the areas required for underground site investigation access, allowed development of techniques to deal with problems as they arose. The decisions to select a small contractor which specialised in such work (Chapter 6) and the decision to recruit only miners with good experience meant that these could do, and did, much of the technical assessments and developments. This was much helped by high labour retention rates throughout the project: high retention was cost-effective as well as good practice.

3. Initial technical assessments and the development of alternative solutions

The central government appraisal process required the investigation of a wide range of possible solutions. The review, which was of wide interest, narrowed the field of options to 3: the filling of the voids with material including pulverised fuel ash (on which research had continued since the early '60's), filling with a material known to be substantially inert, and a structural support solution. Designers should note and reflect on how designers on this project had a particularly challenging duty not only to develop these solutions technically, but also to fully research (and discuss with the Mine Manager and miners), their risks and then to communicate in good time these clearly to all involved so as to influence decision-making, especially when there was an initially confrontational atmosphere. (refer to Chapters 2 and 4). Recently, it has become more common to encourage young professionals to develop their skills in explaining technical matters to lay people, and to understand the need to do so; in any controversial project this is a high priority. On this project, informed research and communication became good once the design requirements started to be defined and the funding identified.

4. Technical achievements of note and current value.

Technical developments which are of value to those now engaged in comparable projects include:

- techniques for optimising construction of (14,737m of) safe roadways through the voids (Chapter 5),

- pumping 'foamed concrete' for long distances from a centralised batching plant without segregation (Chapter 5). To overcome this problem the base material was pumped to all underground locations and foamed locally at each stabilisation area, using small purpose built foaming pumps. The maximum distance pumped was 950m. Heat control (Chapter 5) was taken into consideration as it could potentially impact on Bat habitats within the mine. There is no generally accepted and authoritative research-based guidance such as a BS on foamed 'concrete', which there should. Many useful lessons were learnt about the pumping pressures to balance dangerous over-pressure against getting enough penetration along fractures in the rock,
- use of GIS as developed by B&NES with specialised form of EVA (Chapter 5),
- a variety of new designs of plant for working underground in such voids (Chapter 5),
- the use of IR cameras embedded in the areas to be filled allowing flow control as filling approached (Chapter 5),
- an innovative set of possible means of drilling through the cap (over 3,500 holes drilled (Chapter 5),
- after much debate, a solution to the challenge of retaining enough space for the bat population while achieving maximum filling of the voids was found, by creating stabilised 'bat galleries'.

Project/Programme Managers and Contractors

The professional advice to the client to manage the project in an enlightened and ultimately more cost-effective way was crucial in this project, and was as set out above, including this note for client: The Client decided from the start that the project should be conducted on the principles of transparent consultation, team-work, quality/cost balance, whole-life management. These principles were made very public to all involved, and were applied to early contractor involvement (for example, during 'industry market preparation' all interested companies/consultancies were brought in, to an open briefing), appointments, the incentive 'pain/gain' system reporting and communication. Throughout the project, standards in implementing these principles were assessed and reinforced. Examples of these principles run throughout the book and are well worth reading and following.

Guidance and execution of procurement of consultancy and of the works. There are several aspects worth noting:

- it was decided early on that tendering should be open to SME's with good specialist knowledge even though the tendered work would represent a large proportion of the contractor's turnover: a major reason was so that the senior managers directing the work should personally have detailed understanding of the issues and be able to make strategic decisions without referral to higher management groups/boards. This was a bold decision: it proved successful. (Chapter 6 et seq). On this project the supply chain was kept remarkably short with much lower rates of sub-contracting than is common; the main contractor generally brought into his company further skills and organisations as needed. This is easier for a long and phased project such as this, but nevertheless is a good model for other projects. Localism of main and sub-contractors was seen as 'beneficial', but not a criterion for appointment.

- soon after the project got going, it was universally agreed to switch from an ICE form of contract to the relatively new NEC (Chapter 5). This is a more open and managerial contract and required contract management leadership to come from a designated appointed 'project manager' rather than from 'the Engineer', just as in building construction work such authority passed from 'the Architect' to a specifically trained and appointed manager. Further, it was agreed to use the standard form of contract, although there was some customisation of schedules which can cause problems. Customisation of standard contracts often causes problems. Therefore, thorough briefing of all members of a design/procurement/construction team is always needed to explain the consequences of such customisation.

- partly as a consequence of there being such a short supply chain and an NEC contract form, it was decided that all contract drawings should be issued directly by the Project Manager, none from the Engineer. To do otherwise is, on many projects, quicker and easier, but it is a matter for careful decision. (Chapter 5).

- incentivisation—'pain/gain': a commendable amount of thought was given to the vexed question of whether there should be incentivisation and if so, how? Often too little thought is given to this although it affects the work and attitudes of most people involved in a project more than is readily admitted. It was decided to have a sliding scale of incentives for ending under/ over budget (Chapter 6) with the sharpest 'pain/gain' sharing of 40% applied for the range 5-15% under/over budget, with 20% share below that range and 10% above it. It was decided not to apply any incentives for productivity rates so that safety would not be adversely affected. (Chapter 5).

- the matters of open communications with the local 'stakeholders', noted above in the Client section para 3, were applied to the possible and actual supply chain. For example, it is still uncommon, but is widely beneficial, to hold open days with briefings during a 'market preparation' stage (Chapter 5).
- for the main works, it was decided to go for a framework of four contractors even though in the event one contractor secured all the work. This is a controversial area, especially for those on the framework not getting work, but as far as the contract was concerned, it worked well. (Chapter 6).

- extensive use of GIS and the project extranet, reinforced by the continuity that resulted from a positive policy to retain staff, offer 'best practice' to all major projects, and they well justified their costs.

Timing, nature and extent of involvement with H&SE/ HM Inspectorate of Mines. There are necessarily conflicts between achieving prompt intervention by safety organisations and maintaining progress with work to achieve safety. Although discomfiting in this project at the time, the firm and speedy interventions by HMIM proved in the end to have been helpful in its timing and extent insofar as by largely banning access to the area they sharply increased the focus and hence the case for funding, and the facility to award limited works contracts under emergency procedures. These matters need careful and rational thought, and responses by managers and by clients. (Chapter 2 notes the main intervention; there was much other interaction).

Affected Communities

Many of the client lessons above also relate to those representing local communities. In particular those relating to:

- development of good and effective representative structures which can keep constituents informed before decisions are made, and allow them to input in a significant way. A good, and probably unique, model is CDSM CA with its limited liability company status, open membership, strong, independent chairman, and working liaison with site managers,

- communications, in particular constituents' use of an interactive project website, access (in read-only mode) to areas of GIS data, representation on client decision-making bodies, even into tender boards and the setting up of a communication office in a shopping area,

- quantification of 'soft' environmental values such as ecology, archaeology, landscape, traffic delay. People not normally involved in procurement of infrastructure will not be conversant with such techniques, nor, in fact, are many professionals even although this is an area of ever greater importance given the changes in Planning laws being introduced in 2011 when local communities take a greater role in deciding on planning applications and on their Conditions. The disproportionate benefits of the multi-faceted Public Art programme are worth noting by Local Authorities,

- one of the lessons noted above is the benefit to a project when consultants communicate, clearly and in good time, the meaning and implications of engineering decisions; by the same token, one of the (usually) helpful factors in project liaison in this project was the ability of enough members of the local community to learn, or in some cases to apply, sufficient knowledge about the engineering and contractual procurement processes to be able to participate effectively.

Authors

Alan Francis BSc MRICS

Alan is a Chartered Quantity Surveyor with over 30 years experience of building and engineering projects. He became involved with the Combe Down Stone Mines project in 2001, when Davis Langdon were appointed as Risk Managers and Client Advisors to the Council. For the next 9 years Alan took a full time role in advising the Council on matters of risk, cost, procurement, contract and project management. He was responsible for preparing the estimate for the funding application, in conjunction with Scott Wilson (and in particular with Alastair Waller and Colin Harris). In 2005, Alan became responsible for delivering both the Project Management and Cost Management services for the project.

Alan was Managing Partner of Davis Langdon's Bristol Office for 14 years. He retired from the Practice in April 2009 and has since become a Sole Practitioner providing Consultancy advice to the Industry.

alan.francis12@btintenet.com

Mike Hope BSc MSc DIC CEng CEnv MICE FCIWEM SiLC

Mike is a chartered engineer and chartered environmentalist with over 35 years experience of engineering and environmental matters in and on the ground. He was involved with the Combe Down Stone Mines project for about 5 years from September 2001, serving as part of the English Partnerships (now Homes and Community Agency) project management team. This was a part-time seconded role from his main job as a Technical Director and subsequently Regional Director of consultants WYG.

He is currently a Principal Lecturer at Kingston University. He is also a private consultant in the geotechnical, ground environmental and risk fields, based in East Grinstead, Sussex, and a Registered Specialist in Land Condition, SiLC. At Kingston he leads work based learning Masters degree programmes for the Faculty of Science Engineering and Computing. These include the MSc Professional Engineering scheme, developed with the Engineering Council, under which engineers seeking a Masters degree to become CEng can base their study around their work projects, without having to take time away from work to attend the university.

mike.hope72@o2.co.uk

Professor David Adamson FICE, HonFRIBA, F DFC, MA, C Eng, DipHM.

David began his career in the Royal Engineers, engaged in planning and delivering projects in many countries including Malaysia/Thailand, Australia, Canada and Kenya. He commanded a Field/Construction Regiment.

He moved into Higher Education (1987). During this time of his career he found time to be the Client Representative in Latham Construction Industry Board, involved in Movement for Innovation, and wrote a book on 'The Decade of Reform in the Construction Industry 1993-2003'. He was on the Board of CITB/ Construction Skills for 9 years and Chairman of CIC-E. He was Bursar of University of Bristol and then Director of Estates of Cambridge University and then seconded to be Director of Construction policy in HM Treasury/OGC (2005-7), following which he wrote a report to Government on sustainable construction in UK.

David is now a Consultant and lecturer in sustainable construction, abroad and in the UK.

dma23@hermes.cam.ac.uk

Glossary and Abbreviations

ABI Association of British Insurers

The Council or B&NES Bath and North East Somerset Council

Blocking strategy/block Roadway network used to access and encircle an area of mine – a block. Also gave temporary support to roof, which inhibited progressive collapse prior to full infilling.

BPVM Best practice and value for money

CA Community Association, the CDSMCA

CDSM Combe Down Stone Mines

CDSM CA Combe Down Stone Mines Community Association

CDM Construction Design and Management Regulations

CLG UK Government Department of Communities and Local Government, the funding Department for LSP.

Concrete 'shows' Liquid concrete placed underground emerging (unwanted) at the ground surface or in properties – i.e. 'showing' itself.

DETR UK Government Department of the Environment, Transport and the Regions

Discard Mined rock left on floor of mine by historical miners, i.e. discarded. Ranged from boulders to fine sand in size

Drift A sloping roadway to enable 'drive-in' access to a mine from the surface (as distinct from a vertical mine shaft)

Eligible costs Costs eligible for funding under the LSP

EA Environment Agency

EH English Heritage

EIA Environmental Impact Assessment

EP English Partnerships (became part of HCA during project)

ES Environmental Statement, re EIA, for Planning

EVA Earned value analysis

Foamed concrete Concrete placed with an organic foaming agent – resulting in small entrained bubbles and a density much less than that of water, about 1/3 the density of normal concrete

GIS Geographical information system

GPDO General Permitted Development Order

HCA Homes and Communities Agency (predecessor was English Partnerships)

Heading Leading part of a roadway under construction

HSE Health and Safety Executive

HMIM The Mines Inspectorate (Her Majesty's Inspectorate of Mines), part of HSE

ICE Institution of Civil Engineers (also ICE Conditions of Contract)

IGT Innovation and Growth Teams

KPI Key performance indicator

LPA Local Planning Authority

LSP Land Stabilisation Programme – a UK Government fund, operated by HCA

m metre

MASHAM Management and Administration of Safety and Health in Mines Regulations 1993

MoD Ministry of Defence

NEC The NEC family of standard form contracts. (Origin of acronym: New Engineering Contract)

NPC Net present cost

OJEU Official Journal of the European Union

Pa pascal (unit of pressure = 1N/m2)

Pfa Pulverised fuel ash

Pillar 'robbing' Over extraction of stone from pillars by historical miners, often as they abandoned the mine - as they no longer needed the roof fully supported after they had left, but wanted more stone from the pillars

PM The Project Manager role under an NEC contract

QS Quantity surveying/surveyor

RAMP Risk Analysis and Management for Projects – proprietary software

Roadway Underground route for personnel and materials, with steel or timber support to the mine roof

Shotcrete Spray-applied concrete

SSSI Site of Special Scientific Interest

SME's Small and Medium Sized Enterprises

Stowing Process of propelling gravel-sized stone into a void space to fill it

UPS Uninterruptable power system/supply

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Constructing Excellence (2008). Construction Clients' Group, Client's Commitment Best Practice Guide. London: Constructing Excellence,.

a. Chapter 1 Procurement and Integration, retrieved 13 Jun 2010 from www.constructingexcellence.org.uk/sectorforums/constructionclientsgroup/clientcommitments/1.%20Proc%20&%20Int.pdf

b. Chapter 2 Commitment to People, retrieved 13 Jun 2010 from www.constructingexcellence.org.uk/sectorforums/constructionclientsgroup/clientcommitments/2.%20C2P.pdf

c. Chapter 3 Client Leadership, retrieved 13 Jun 2010 from www.constructingexcellence.org.uk/sectorforums/constructionclientsgroup/clientcommitments/3.%20CL.pdf

d. Chapter 4 Sustainability, retrieved 13 Jun 2010 from www.constructingexcellence.org.uk/sectorforums/constructionclientsgroup/clientcommitments/4.%20Sust.pdf

e. Chapter 5 Design Quality, retrieved 13 Jun 2010 from www.constructingexcellence.org.uk/sectorforums/constructionclientsgroup/clientcommitments/5.%20DQ.pdf

f. Chapter 6 Health and Safety, retrieved 13 Jun 2010 from www.constructingexcellence.org.uk/sectorforums/constructionclientsgroup/clientcommitments/6.%20H&S.pdf

APPENDIX A Tender quality scoring matrix (page 1 of 5)

For complete high-res digital files of the appendices please refer to attached CD Rom

COMBE DOWN STONES MINE - MAIN SCHEME CONSTRUCTION TENDER

Tender Quality Evaluation - Max 60% of Tender evaluation (40% financial)

Bath & North East Somerset Council

	QUESTION	RESPONSE CRITERIA	Maximum Marks	Section Weighting	Written Marks Awarded	Interview/ Moderation Adjustment	Respondant: A Overall Marks Awarded	Weighted Section Score	COMMENTS	Assessor
Section A - COMPANY EXPERIENCE										
A.1	Experience of stabilisation of mine workings from underground under the Mines and Quarries Act	Extent of experience 0-5	20							
A.2	Experience of other mine stabilisation works involving:									
	i. Foamed concrete	Extent of experience 0-5	5							
	ii. Gravel stowing	Extent of experience 0-5	5							
	iii. Sand infilling	Extent of experience 0-5	5							
A.3	Experience of working underground involving:									
	i. Shotcreting	Extent of experience 0-5	5							
	ii. Structural steelwork erection: galleries and roadways underground	Extent of experience 0-5	5							
	iii. Drilling and grouting	Extent of experience 0-5	5							
A.4	Experience of large scale civil engineering projects	Extent of experience 0-5	5							
A.5	Experience of high labour/ equipment ratio construction	Extent of experience 0-10	5							
	Total		50	10%						

Scoring Criteria

	Max 5	10	15	20
Exemplary				
Good				
Exemplary				
Average				
Weak				
Poor				
Very Poor				

APPENDIX A: TENDER QUALITY SCORING MATRIX

PAGE 1 OF 5

APPENDIX A Tender quality scoring matrix (page 2 of 5)

See attached CD Rom

COMBE DOWN STONES MINE - MAIN SCHEME CONSTRUCTION TENDER

Tender Quality Evaluation - Max 60% of Tender evaluation (40% financial)

Bath & North East Somerset Council

	QUESTION	RESPONSE CRITERIA	Maximum Marks	Section Weighting	Written Marks Awarded	Interview/ Moderation Adjustment	Respondant: Overall Marks Awarded	Weighted Section Score	A COMMENTS	Assessor
Section B - CAPABILITY										
B.1	Approach to managing the co-ordination of the activities underground	Suitability of approach 0-10	10							
B.2	Approach to effective communication, liaison and co-operation with the project team, subcontractors,suppliers, other contractors, the community and other stakeholders	Suitability of approach 0-10	10							
B.3	Approach to programming design and production information release from the design team	Suitability of approach 0-10	10							
B.4	Approach to resource and activity programming including management and control procedures	Suitability of approach 0-10	10							
B.5	Impressions gained from presentation/ interview, visits to premises and/ or relevant current or completed construction sites (No Tender Deliverable required as 1. 1. 21).	Impression gained 0-20	20							
B.6	References received during the tender pre- qualification process will form the basis of the evaluation for this section (No Tender Deliverable required as 1. 1. 21).	References from PQQ as a proportio of 15 marks	15							
B.7	Underground mine stabilisation works value in pounds and as a percentage of gross turnover for the last 8 years.	Extent of stabilisation works experience based on turnover 0 - 3	3							
B.8	Mining works value in pounds and as a percentage of gross turnover for the last 8	Extent of mining experience based on turnover 0 - 3	3							
	Total		81	15%						

APPENDIX A Tender quality scoring matrix (page 3 of 5)

See attached CD Rom

COMBE DOWN STONES MINE - MAIN SCHEME CONSTRUCTION TENDER

Tender Quality Evaluation - Max 60% of Tender evaluation (40% financial)

Bath & North East Somerset Council

	QUESTION	RESPONSE CRITERIA	Maximum Marks	Section Weighting	Written Marks Awarded	Interview/ Moderation Adjustment	Respondant: Overall Marks Awarded	Weighted Section Score	A COMMENTS	Assessor
Section C - RESOURCES										
C.1	Organogram showing the proposed project and site organisation structure showing names, job titles and interrelationships of all those who would be involved	Quality and detail of organogram 0-10	10							
C.2	CVs for key project staff (includ. off-site staff) showing qualifications and relevant experience	Quality of staff and rele-vance of experience 0-10	10							
C.3	Verification that adequately skilled and competent resources are available in suitable locations to manage and undertake the works. Details are to be provided of the current and forecast	Availability of competent resources 0-5	10							
C.4	Project labour histogram	Histogram provided = 1	1							
	Total		31	20%						
Section D - PROJECT APPROACH										
D.1	Method statement for principal project activities (refer to 1. 1. 19)	Quality of method statements 0-20	20							
D.2	Tender programme (refer to 1. 1. 19)	Quality of programme 0-20	20							
D.3	Outline construction risk assessment (refer to 1. 1. 20)	Quality of risk assessments 0-10	10							
D.4	Details of proposed worksite establishments (including drawings)	Details of work sites 0-10	10							
D.5	Risk register identifying the tenderer's view of the headline risks on the project and proposals to mitigate those risks	Relevance of risks and mitigating actions 0-15	15							
D.6	The types of innovation and added value initiatives that have been introduced previously on similar projects that could be used for the benefit of this project	Relevance and benefit of innovations 0 - 20	20							
	Total		95	15%						

APPENDIX B Example Contractor KPI report 2

See attached CD Rom

APPENDIX B: EXAMPLE EXTRACT FROM CONTRACTOR KPI REPORT

PAGE 1 OF 3

KPI Summary Report

Report to Date 30 Jun 07

Reporting Month	KPI 1 Health & Safety: Lost Hours ratio	KPI 1 Health & Safety: %	KPI 2 Concrete Quality: Non-Conformity of Foamed Concrete (D2.13.3)	KPI 3 Time: Period Output Performance Index	KPI 4 Cost: Cost Performance Index	KPI 5 Non BoQ Items - CEN to CE Quotation %: Cumulative CEN's issued	KPI 5 Non BoQ Items - CEN to CE Quotation %: Cumulative Actual quotations issued	KPI 5 Non BoQ Items - CEN to CE Quotation %: Cumulative % Complete
Apr-07	1	99	90	1.00	0.98		Nil report	
May-07	0	100	93	0.72	1.11		Nil report	
Jun-07	0.5	99.5	93	0.72	1.18		Nil report	
Jul-07	0.7	99.3	91				Nil report	
Aug-07								
Standards Reference	Mine Managers Report: Section 8.1		Specification clause D2.13.3 requires four measures of concrete conformity. Requirement D2.13.3(ii) has been identified as the principal measure for KPI purposes.	Cobra	Cobra	% of CE quotations submitted within 3 weeks of a PMI/CEN (NEC3 cl. 62.3)		
Compliance Measure	>99% of possible working hours achieved.		All 28 day cube strength test results do not fall below the specified characteristic strength	Cobra score <=1.0	Cobra score <=1.0	All CE quotations submitted within 3 calendar weeks of the PMI/CE Notification, except where an extension of time for reply (NEC3 cl.62.5) has been granted.		
Adverse Performance Trigger	<=99% of possible working hours achieved.		>10% of 28 day cube strength test results fall below the specified characteristic strength, and of those >1% fall below the specified characteristic strength less 0.2MPa	Cobra score >1.0	Cobra score >1.0	<100% of CE quotations are submitted within 3 calendar weeks of the PMI/CE Notification, except where an extension of time for reply (NEC3 cl.62.5) has been granted.		

APPENDIX B Example Contractor KPI report 3

See attached CD Rom

Community Relations Scoring

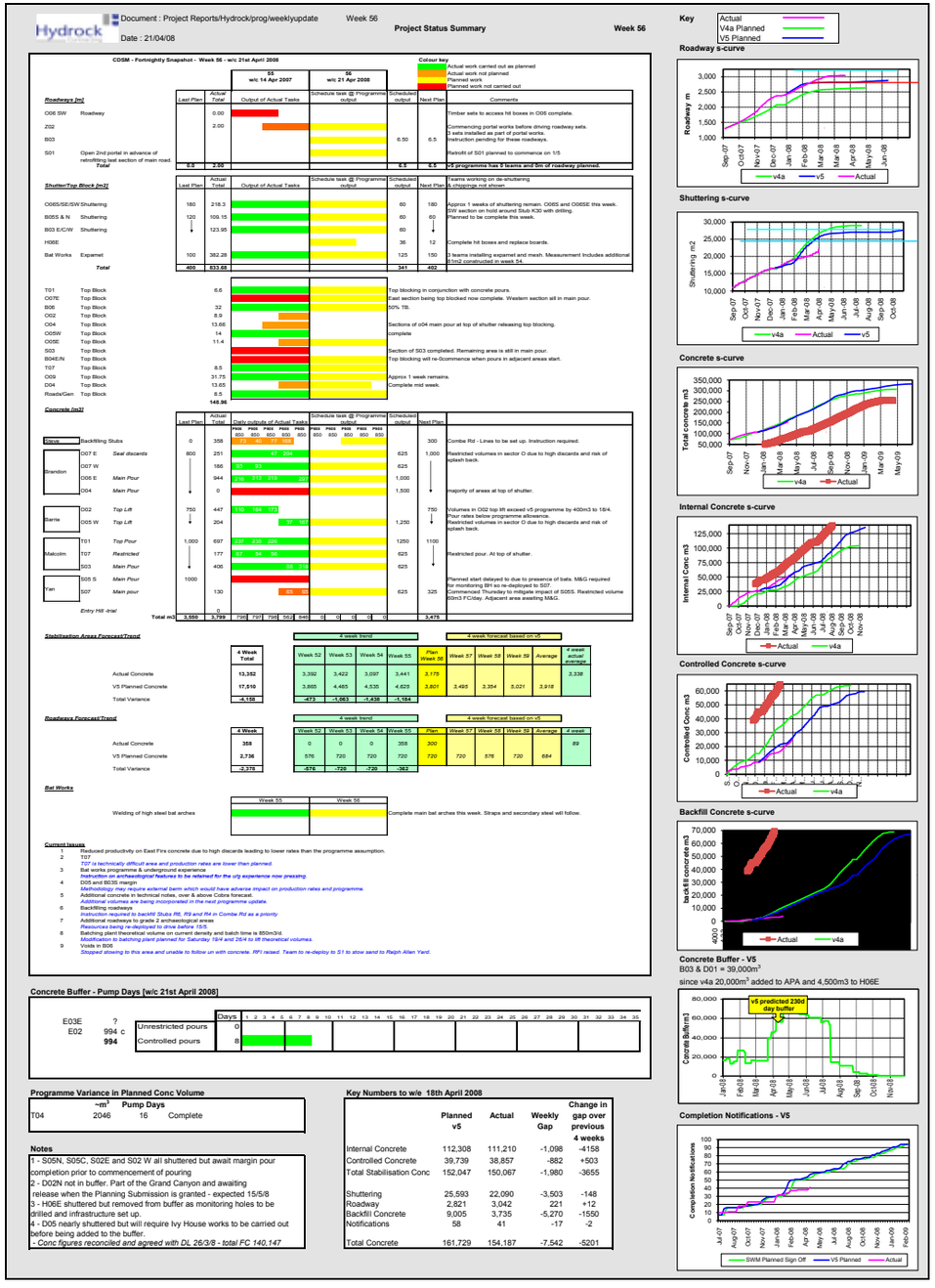
	Very Bad	Bad	Average	Meet Expectations	Exceeds Expectations
	1	2	3	4	5
Consideration to Neighbours and the Community All work is carried out with positive consideration to the needs of residents, traders and businesses, site personnel & visitors and the general public. Special attention is given to the needs of those with special needs	☐	☐	☐	☐	☐
Cleanliness The working sites are kept in good order at all times. Safety barriers, lights and warning signs are maintained in a clean and safe condition. Surplus materials and rubbish are not allowed to accumulate either on working sites or their neighbouring areas. Dirt and dust from construction operation do not cause unnecessary nuisance.	☐	☐	☐	☐	☐
Good Neighbour General information regarding the project and full and regular communications with neighbours, includingresidents, traders and businesses regarding programming and site activities are provided and maintained in an up to date state at all times	☐	☐	☐	☐	☐
Respectful Respectable and safe standards of dress, language and behaviour are maintained by site personnel. Pride in the management and appearance of the site and the surrounding environment is shown at all times.	☐	☐	☐	☐	☐

APPENDIX B: EXAMPLE OF CONTRACTOR KPI REPORT

PAGE 3 OF 3

APPENDIX C Dashboard

See attached CD Rom



APPENDIX C: Dashboard

Size: A3

APPENDIX D Constructing Excellence characteristics

See attached CD Rom

Comparison with Characteristics in the Constructing Excellence Client Best Practice Guide

Comparison of CDSM project practice with the 'characterisitcs' of the Constructing Excellence Client Best Practice Guide, Constructing Excellence (2008)

CE Client Best Practice Guide Characteristic	Evident on CDSM?	Examples / Notes
CHAPTER 1: Procurement & Integration		
a. Transparency in procurement decision making	Yes	*Procurement consistent with public sector Council practices. Involvement of the project Community Association representatives in tender interviews and tender assessment rating of some quality factors.*
b. Selection on best value not lowest cost (i.e. including a quality assessment)	Yes	*60% quality 40% cost for consultants and contractors. Sophisticated relative rating system for balance of quality factors.*
c. Early contractor involvement	Yes	*Yes, though not conventional ECI. Early contractor information sharing and formal consultation. Early stages of underground investigation roadways and stabilisation works, plus works at Grey Gables mine, by different specialist contractors, provided this. This was considered better for this project than ECI by a single contractor.*
d. Integrated and collaborative working principles	Yes	*Strongly yes, particularly both main Contractor relationships. NEC contract forms supported this.*
e. Use fair payment policies	No policy, but good practice	*No written payment policy. However, payment practices were very good. Payment periods under all contracts and for payment of the Council by HCA were well respected. Main Contractor continued this practice with its own supply chain, particularly as fortnightly applications could only be made upon actual invoiced and paid costs from suppliers/ subcontractors.*
f. Use risk management principles and processes	Yes	*Risk thinking and management had a strong influence on decision making from an early stage.*
g. Non-confrontational mechanisms to manage out disputes	Yes	*NEC form used for contractors and consultants for main works. Experience of reimbursement approach on NEC professional services contract was less confrontational than early experience with non-NEC lump sum consultancy appointments andenabled focus to be on seeking best value out of the high cost construction contracts. Hard negotiations still occurred.*
h. Fair employment practices	Yes	*Companies' employment policies and practices re minorities, e.g. people with disabilities and minority ethnicity, were part of all procurement tender quality assessment. The main contractor appeared in the Times Top 100 listing for organisations in the category of 250 to 5,000 employees, during the project, finishing in the top 25 with a highest listing of 4th.*

Note: the Combe Down project planning and the start of construction predate publication of these Constructing Excellence characteristics by many years (Chapter 8).

APPENDIX E List of Organisations

The following organisations worked on and contributed towards the Combe Down Stabilisation Project;

Association of British Insurers
Bat Pro
Bath & North East Somerset (B&NES) Councillors
B&NES - Chief Executive, Directors & Officers of various departments
Bristol Scientific Services
British Geological Survey
CDSM Steering Group
CDSM Community Association
Combe Down Stone Mines Project Team-Bath and North East Somerset Council
Davis Langdon LLP
Denton Wilde Sapte
DTZ Debenham Tie Leung
DTZ Pieda
English Heritage
English Partnerships/ Homes and Communities Agency
Environment Agency
Eversheds
Forkers Ltd
Government Sponsoring Department
HM Inspector of Mines
Hydrock Consulting and Contracting
John Perkins Construction
Mace
Marsh and Associates
Marsh UK
Ministry of Defence
Mouchel/ Mouchel Parkman
Natural England
Norton Rose
BAM Nuttall
Oxford Archaeology
Parsons Brinckerhoff
Provelio
Public Art Project Artists
Scott Wilson
White Young Green/ WYG

Further Information, Publications and Weblinks

COMBE DOWN PUBLIC ART PUBLICATIONS

Andy Croft (editor), *Time in the Shape of a Mine: Poems from Combe Down, 2009*
ISBN 978 -0-95638290 -0-0

Andy Croft, *Combe Down: The Hole Story - an historical pageant, 2009*
ISBN 978 -0-95638290 -1-7

COMBE DOWN HERITAGE SOCIETY PUBLICATIONS

Combe Down Heritage Trail - a walk around Combe Down village and its Surroundings

Combe Down Past and Present, a CD of images of the village in the past and present day

Richard T.A. Irving, *A History of the Byfield Mine, Combe Down* ISBN 0 9550655-0-X

Stanley Wicks, *I remember Tucking Mill – a memoir of his early life* ISBN 0 9550655-2-6

Malcolm Aylett, *The Roman Villa at Combe Down* ISBN 0 9550655-1-8

Richard Read (editor), *Remembering Village Shops* ISBN 978-0-9550655-3-8

Visit the www.combedownheritage.org.uk to order these publications.

WEBLINKS

www.combedownstoneminesproject.com
www.thehumanjourney.net (Oxford Archaeology)
www.combedownheritage.org.uk
www.homesandcommunities.co.uk
www.hydrock.com
www.bathnes.gov.uk
www.scottwilson.com
www.provelio.com
www.davislangdon.com

PUBLIC ART PROJECT

www.heyokah.co.uk (Vik Martin)
www.englishby.com
www.nevillegabie.com
www.alecpeever.com
www.axisweb.org/artist/christophertipping
www.franceslord.com
www.stevegeliot.com
www.literaturenortheast.co.uk/writers/Andy_Croft_A-Z (Andy Croft)
www.autonomic.org.uk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