Service Nova Scotia & Municipal Relations (SNSMR)

Guidelines on Abandoned Coal Mine Subsidence for Municipalities in Nova Scotia

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1. Introduction

1.1 Project Scope and Objective

AECOM was retained by Service Nova Scotia & Municipal Relations (SNSMR) , on behalf of a Steering Committee comprising representatives from Service Nova Scotia and Municipal Relations (SNSMR), the Department of Natural Resources (NSDNR) and the Department of Labour and Workforce Development (NSDLWD) and several municipalities, to address matters pertinent to abandoned underground coal mine workings through the preparation of four (4) specific deliverables:

- A Best Practices Guide for Land-Use Planning on Areas with Abandoned Underground Coal Workings;
- A Best Practices Guide for Building and Construction Standards on Areas with Abandoned Underground Coal Workings;
- A supporting Compendium presenting key science-based reference literature; and
- A written project report.

The prime intent and purpose of the two guides was to provide municipalities within Nova Scotia with a set of guidelines to assist in discharging their responsibilities to specifically address (i) land-use planning and (ii) building construction issues, all related to the hazards of abandoned underground coal mine workings. There was also a focus on enabling the municipality to address public safety and determine appropriate utilization of their land resources to meet the best public interest in such areas. The compendium would provide a list of supporting technical papers for future reference.

During the course of preparing the above noted deliverables it was mutually decided that the land use planning and building best practices information would be combined in both of the first two deliverables which would now take on a different focus:

- A Brochure to Inform the General Public; and
- A Booklet to Inform and Guide Municipalities in Best Practices on both Land-use Planning & Building & Construction Standards.

This Report forms the final deliverable of the project and summarizes the work done and encompasses all deliverables. This report, as structured, reflects the proposal scope as follows:

- Introduction: scope, context and progress meetings;
- Overview of Abandoned Mine Subsidence;
- Review of Jurisdictions: for both land use planning and for building construction aspects;
- Development of Best Practices for Nova Scotia: again for both municipal planning and building construction aspects;
- Compendium of Technical references;
- Sustainability component; and
- Summary.

1.2 Project Context

Nova Scotia has significant natural resources of energy, particularly abundant coal reserves. The Province played a major role in the development of Canada, the abundant coal resources fueling much of the industrial expansion during the 19th and early 20th centuries most of it being mined by underground methods. It has long been known that underground coal mine operations induce a lowering or subsiding of the ground surface with accompanying deformations and induced tensile and compressive strains in the surface rocks and soils. Typically such subsidence occurs within one year of the completion of active mining although a small amount of residual movement (maybe less than 10% of the total) can occur up to five (5) years after completion of mining [National Coal Board, 1975].

In turn, any structure existing on this subsiding ground will also move with the ground beneath it with varying degrees of structural damage depending for example on the age, condition and type of structure. No structures are exempt from damage due to subsidence; although, precautionary measures may mitigate/reduce the severity of this impact with special attention being given to more rigid structures like brick, concrete, buildings, as well as other infrastructure and facilities such as pipelines, electrical cables, reservoirs/dams, [National Coal Board, 1975].

Nova Scotia has experienced mining related subsidence over the centuries as a result of both active and abandoned workings. For example, in the Sydney Coalfield when active underground mining took place under the Town of Glace Bay from the 1900s to 1950s, the Town in conjunction with the Dominion Steel & Coal Company (DOSCO) maintained subsidence records along Main Street and the sewer running along it. Reports of damage to structures such as dwellings and larger buildings in Glace Bay were also investigated and ground movement monitored by DOSCO in Glace Bay in the 1930's and 1940's. These activities mainly related to active company workings but those operations gradually moved off shore over the early twentieth century such that by the late 1970s active mining was all located under the Atlantic Ocean. As a result, active subsidence under municipal lands ceased at that time but reports of “things going bump in the night” and of ground movement events however continued in the Sydney Coalfield, if on a less frequent basis. Such continuing instances are known as abandoned mine subsidence and were not confined to the Glace Bay but also impacted areas of New Waterford, North Sydney, Sydney Mines, Florence, Birch Grove, Donkin and Port Morien, etc. Each of these towns experienced similar subsidence related events to varying degrees, as did the other active coalfields across NS, which include the towns of: Inverness, Mabou and Port Hood and Westville, Stellarton and Springhill. These longer term ground movements from abandoned mainly shallow underground coal mines are recognized around the world as real, as potentially damaging to infrastructure and as largely unpredictable in timing, nature and extent [Society of Mining Engineers (SME) Handbook 1992]. Their basic characteristics are however well known there being two types: sinkhole subsidence and 'sag' subsidence with accompanying features of cracking and humping of ground and structures. Wherever there has been former shallow underground coal working these features can suddenly appear depending on the site specific circumstances and they are no respecters of property ownership, creating from time to time “car crunching” potholes in our roads, or open holes in fields and woods or sags that damage homes and even occasionally large buildings like schools.

In addition to the underground coal mines that were operated by mining companies, each of the coalfields of Nova Scotia were also exploited to some degree by illegal 'bootleg' mines. These illegal mine workings were generally exploited at very shallow depths and as a result pose a significant risk of subsidence. Unfortunately, these illegal mining activities were not mapped and there are very few if any mine plans or records of these operations. Some of these bootleg mines have been successfully restored through surface reclamation coal mining activities (1980 – current). As a result, these lands are again available for sequential land use activities including recreational, residential development and in some cases reforestation, e.g., Halfway Road, Sydney Mines & Inverness Beach, Inverness. Unfortunately, however, there are still extensive areas in and around some municipalities where undocumented illegal coal mine workings continue to pose subsidence hazards.

Subsidence from historical abandoned coal mines is a challenge for government organizations whose jurisdictions give them responsibility for maintaining standards to ensure public safety. In addition to highway authorities, railway and utility companies, our municipalities increasingly face related key questions pertaining to land use planning and zoning and building construction standards in subsidence prone areas. This is the topic of this study which gives consideration not only to assessing the current status of these matters within NS but also to looking to the principal countries that have already dealt with such matters for examples and helpful pointers to best practice.

Nova Scotia to date has not adopted a formal approach to address abandoned coal mine subsidence. Other jurisdictions like the UK, USA and Australia have to varying degrees developed policies, practices and regulatory tools to address damage resulting from coal mine subsidence and to develop land use plans for subsidence prone lands. These jurisdictions have gained experience dealing with the larger and more predictable issue of active subsidence caused by current, active underground coal mine workings but subsequently have developed protocols to deal with subsidence over abandoned coal mine workings. For example, in New South Wales (NSW) Australia major buildings erected in sinkhole-prone (subsidence) areas require stringent precautionary measures to allow for a sinkhole appearing within 5m of the building. Such structural precautionary measures can be quite onerous and expensive. Typically the UK and Australia have adopted formal legislation to compensate property owners for damage done by coal mining subsidence and have developed substantial technical and administrative resources to ensure compliance. In contrast the USA relies more on self-funding property insurance programs. Some municipalities elsewhere have addressed abandoned mine subsidence issues, including two municipalities in western Canada and Whangarei in New Zealand.

The challenge for this study therefore is to tailor some of the measures adopted in various parts of the world to suit the conditions of NS and develop a more formal approach and best practice guidelines.

1.3 Project Progress

Project progress can be outlined by summarizing the specific meetings held at approximately monthly intervals, as follows:

Table 1 - Project Progress Meetings

Date	Purpose	Present	Main Outcomes
April 26, 2010	Project Initiation	NS Steering Committee AECOM Core Team	Confirmed scope, contacts, deliverables, no value added tasks.
May 25, 2010	Interim Review	NS Steering Committee AECOM Core Team	Presented findings, confirmed approach, refined understandings.
June 18, 2010	Informal Progress Review	NS & AECOM Project Managers only	Presented initial draft brochures, refined direction. Postponed completion to end of August – vacations.
July 28, 2010	Informal Progress Review	NS Steering Committee AECOM Core Team	Accepted compendium finalized draft brochures, agreed direction to complete. Draft report end August, completion September – vacations.
October 5, 2010	Presentation of Draft Report	NS Steering Committee AECOM Project Manager	Presented findings Agreed path to completion

2. Abandoned Coal Mine Subsidence

The study began by summarising the basic characteristics of abandoned coal mine subsidence. This information was then used to prepare the corresponding sections of both the brochure and booklet deliverables.

2.1 What is Abandoned Coal Mine Subsidence?

2.1.1 Characteristics

Whenever coal is mined underground a void is left by the mining process. It can either be supported and left open, partially filled (backfilling or stowing) or allowed to collapse behind the active working face. It is the latter that is the prime cause of subsidence, for as the immediate roof rock directly above the mine opening collapses into the mine void, the subsequent layers of rocks above the mine will sag or lower until this ground movement reaches the surface. This surface deformation or lowering is called mining subsidence. It occurs mainly during and in the months immediately after coal extraction (active mine subsidence) or some portion of it can occur many years later (abandoned mine subsidence). Sometimes the latter occurs when the support left in the mine deteriorates and fails, again allowing roof rock to collapse and triggering another more local subsidence process.

Coal has been mined in Nova Scotia since the 1600's and both active and abandoned coal mine subsidence has been experienced in the various coalfield areas, see Figures 2-1 and 2-2. These areas affected by historical underground coal mining can still sometimes exhibit abandoned coal mine subsidence which presents as either sinkhole subsidence (i.e. open holes) or sag/trough subsidence (i.e. shallow saucer-shaped depressions).

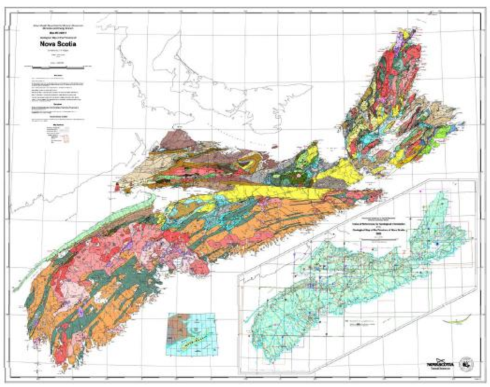


Figure 2-1 - NS Geological Map

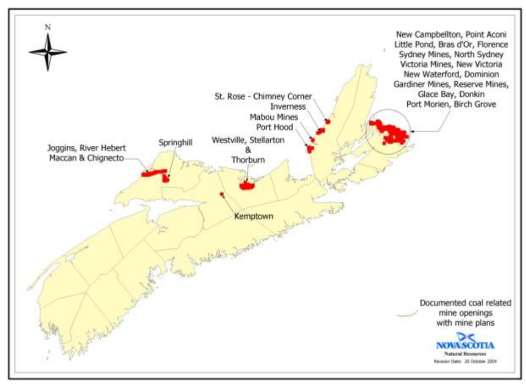


Figure 2-2 - Areas in NS with Documented Coal Mine Workings

The magnitude and extent of such subsidence effects on surface development depend in turn on the characteristics of the underground mining and the intervening rocks and soils. For example, the depth and size of underground mining excavation (width, length and height), type of rock and geological structure, groundwater conditions, as well as type- of construction and condition of surface structures, can impact the magnitude and extent of subsidence impact on development. Subsidence events can occur many years after mining has ceased. It is very difficult to predict where and when these events will occur because of the unknown details and condition of the underground workings. Despite these limitations general guidelines and generic precautionary and remedial approaches are available.

Sinkhole subsidence is due to the collapse of a mine roof underground that creates a cavity which steadily works its way upward. If not arrested by strong rock, it can eventually reach the surface as a sinkhole. Typically a sinkhole has bell-shaped walls, are 1 – 6m deep and 0.6 to 5m diameter or even larger, and usually occur over shallow underground workings of depth less than 50m. A surface reclamation coal mine excavation in 2004 in Cape Breton exposed a series of sinkholes

Photo 2-1 - A Developing Sinkhole, Sydney Mines, NS

which were about 4m from the surface as shown in Photo 2-1.

Sag Subsidence is a gentle saucer-shaped depression over a broad area often outlined by a ring of tension cracks. Sags are typically 0.5-1.0m deep and 10 to 500m in diameter. There are three main causes: roof caving over openings in the mine, crushing of mine pillars, or punching of mine pillars into soft floor or roof rock. The effects are similar to those over active mine workings but can occur long after mining ceased. A significant example in NS occurred in Town of Dominion, CBRM in 2002, more than 80 years after mining ceased, see Photo 2-2. The modes of mine subsidence are shown schematically in Figure 2-3 by Bruhn, 1978.

Photo 2-2 - Sag Subsidence, Dominion, NS

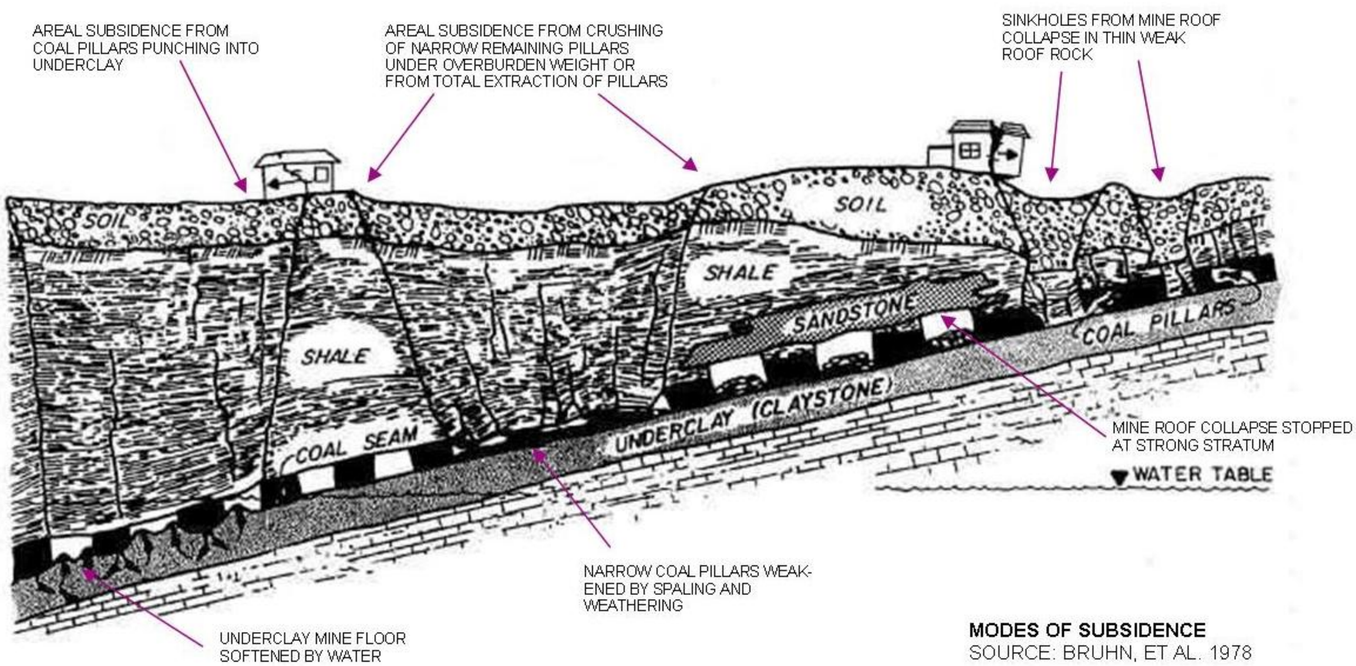


Figure 2-3 - Modes of Subsidence

2.2 Justification for Addressing the Issues of Subsidence in Nova Scotia

2.2.1 Historical Occurrences

Over the years, isolated subsidence events have continued to occur over abandoned coal mines in Nova Scotia. They take the form of open holes/sinkholes and occasionally sag events. These events can impact the safety of the general public in that locality and it is important to continue to consider this and update our approach. The justification for addressing the issue of subsidence in Nova Scotia is therefore to protect the public from safety hazards while also protecting investments in infrastructure and to support municipality planning work.

The following statistics provide some historical information (up to 1994) on the extent of abandoned underground coal mine workings in Nova Scotia and the documented subsidence events which occurred between 1986 – 1994:

- Seventeen (17) communities have abandoned mine workings;
- Approximately 20,000 residential properties are undermined, between 1986 and 1994;
- The following subsidence events were reported:
  - Twenty (20) homes were damaged;
  - Five (5) homes had significant damage; and
  - Fifty-three (53) cases of property damage.

This background information provides justification to increase awareness, alert and advise interested parties about mine subsidence in Nova Scotia. Several more recent examples are listed below.

2.2.2 Case Studies

2.2.2.1 MacDonald High School, Dominion, CBRM

In October 2002 a sag subsidence event happened in the town of Dominion, Nova Scotia, which severely impacted the MacDonald High School (a fully functional two-storey building). However, this first subsidence event caused virtually no impact to either the adjacent Community Arena or MacDonald Elementary School. Notably, a second similar event a few weeks later did severely impact a local Pensioners Hall. Fortunately no injuries were incurred and both impacted structures were subsequently demolished. Photos 2-3 and 2-4 illustrate damage to the High School.

Photo 2-3 - East End of Damaged High School

Photo 2-4 - Damage to MacDonald High School Dominion, NS

2.2.2.2 Foord Seam, Stellarton

Periodically over the decades shallow coal mine workings in the areas of Stellarton and Westville in the Pictou Coalfield of mainland NS have experienced abandoned coal mine subsidence impacts. The proximity of shallow workings tosurface development can be seen in Photo 2-5 taken At the Pioneer Coal surface coal mine on the Foord Seam in Westville, NS. The impact of some of these can be seen on properties in the a part of Westville, NS, as sag events in 1941 & 1989, see Photo 2-6.

Photo 2-5 - Shallow Workings

Photo 2-6 - Sag Subsidence in Westville, NS - 1941 & 1989

2.2.2.3 Dominion St, Glace Bay

Since the 1950's there have been periodic subsidence events impacting a section of Dominion Street, Glace Bay CBRM in a zone located a few hundred metres west of the intersection with Steele's Hill Road. These events have typically taken the form of holes suddenly opening up in the pavement impacting up to 10m of pavement which partially collapses into shallow abandoned bootleg (illegal, unrecorded) coal mines less than 8m beneath the street. Sometimes these collapse events have impacted adjacent single family residences. In the 1960s an investigation was made by the province and some of the workings mapped and supported. Since then the collapses have migrated to adjacent areas of unsupported bootleg mine workings. Presumably the continual vibration from the regular traffic on the well-used street has had an impact on the rate of ground collapse. The most recent collapse was in 2007, see Photos 2-7 and 2-8, and was excavated by CBRM and backfilled and compacted and made safe.

Photo 2-7 - Proximity of Sinkhole to Homes

Photo 2-8 - Proximity of Top of Bootleg Mine

2.3 How Coal Mine Subsidence Causes Damage

2.3.1 Coal Mine Subsidence Effects

2.3.1.1 Mine Subsidence Damage

Most development on undermined lands does not incur any harmful subsidence. However, as can be seen from the photos above, in some cases damage can occur. Information on such damage and its prevention follows.

How Mine Subsidence Causes Damage
Abandoned mine subsidence causes damage because structures respond to movements of the ground on which they are built. As the foundations which provide support for the walls and columns of the structure follow movement of the ground due to subsidence, failure commonly propagates upward into the main part of the structure. The effects of mine subsidence on a structure are divided into three groups depending upon the type of ground movement which caused the damage: compression effects, tension effects and slope or tilt effects.

Photo 2-9 - Subsidence Cracking

Surface Structural Effects
Surface structures respond to movement of the ground on which they are built. As foundations follow movement of the ground they are built on, failure may occur through cracking or tilting and then damage commonly propagates upward into the main part of the structure. Mine subsidence can cause the following ground movement effects:

- Compression features (mostly resulting from sag subsidence) e.g., buckling of pavement or pipes;
- Tension features e.g., cracking, loosening and pulling apart of ground, masonry, etc (e.g., see Photo 2-9);
- Slope or tilt effects e.g., reversing flow in drains; and
- Distortion effects, e.g., doors and windows wedging or jamming.

The magnitude and extent of surface structural effects depends not only on the movement of the ground but also on the type, size, complexity and orientation/location of structure.

Signs to Look For
These effects can cause cracking in plaster walls, cracking in brick walls, separation of pipes, windows and door frames to move and jam, and cracking in floor slabs, see Photos 2-4 to 2-9 above and Photo 2-10 below for typical examples.

Photo 2-10 - Interior Structural Damage in a Large Structure from a Sag Subsidence Event

Preventing Subsidence Damage
Approaches to prevent subsidence damage include avoidance (land use controls), filling the mine, excavating the underground mine workings through modern surface reclamation mine operations followed by surface land restoration, or collapsing the underground workings by blasting or with excavators and backfilling the void (Photo 8).

2.3.2 Non-Mining Causes of Similar Damage

In lands undermined by abandoned coal mine workings most structural damage to residential properties is *not* caused by mine subsidence. It is important to be aware of structural damage which closely resembles damage caused by mine subsidence but may in fact result from other factors, including:

- Sulphates reacting with cement;
- Shrinkable or expanding clay;
- Differential settlement in the structure which may be caused by numerous situations:
  - Settling of poorly compacted soils or erosion of soils;
  - Uplift or heave due to expanding bedrock or fill;
  - Clay soil shrinkage due to lowering of water table e.g., from wells, trees roots or dewatering from adjacent activity, and
  - Sinking into bedrock cavities e.g., naturally occurring limestone or gypsum caverns;
- Altering of conditions owing to poor drainage of soils;
- Rust damage;
- Thermal effect; and
- Poor construction.

2.3.3 Outcome

The above information was condensed into a proposed brochure for distribution to provide information to the general public, see Appendix B.

3. Review of Various Jurisdictions

3.1 Existing Policy with Respect to Land Use Planning and Abandoned Mine Subsidence

The next stage of this investigation was to review the policy, legislation and practice utilized elsewhere in Canada and internationally to address abandoned coal mine subsidence starting with land-use planning followed by criteria to address building and development on lands impacted by mine subsidence. This information formed a basis for development of best practice guidelines in Nova Scotia.

3.1.1 Information Gathering – Land Use Planning

3.1.1.1 Canada

3.1.1.1.1 Nova Scotia

The initial approach in obtaining information on current practices and policies on how subsidence issues are addressed in NS in land use planning was to evaluate the current or baseline provisions used in the province with respect to development in areas with potential for mine subsidence. To do this the following municipal and provincial land use by-laws and building codes were reviewed:

By-laws

- Cape Breton Regional Municipality Municipal Planning Strategy;
- Cape Breton Regional Municipality Subdivision By-Law;
- Cape Breton Regional Municipality Building By-Law;
- Cape Breton Regional Municipality Building Inspection Checklist;
- Town of New Glasgow Building By-Law;

- Town of Stellarton Building By-Law; and
- Municipality of the County of Pictou Building By-law.

Building Code

- Government of Nova Scotia Building Code Act Consolidated; and
- Town of Westville Amendments to Building Code Regulations.

In addition to reviewing the documents listed above to determine the policy and regulatory context, AECOM also performed interviews with the following stakeholders:

- Dave Smith, MURP, MCIP, Assistant Provincial Director of Planning Municipal Services Division, Service Nova Scotia and Municipal Relations;
- Roland Burek, Senior Planner, Pictou County DPC;
- Doug Foster, MCIP, LPP Director of Planning, Cape Breton Regional Municipality;
- Jason Macdonald, MCIP, Director of Planning and Development, Town of Amherst;
- Penny Henneberry Director of Planning and Development, Municipality, County of Cumberland; and
- Brian Herteis, P. Eng, Director of Engineering and Public Works, Town of Springhill.

These stakeholders were asked to provide comment with regard to what they felt the impetus of the initiative to develop 'NS best practices' was, how they have been affected by subsidence, what impact future policy documentation may have on their municipality and what the expectation was with regard to addressing subsidence within the Province and their individual municipality. The results of these conversations gleaned the following points:

- The municipal representatives appreciated the exercise to disseminate suggested policy direction to accompany the release of related maps and information by Nova Scotia Natural Resources;
- This exercise will likely assist development on undermined lands or allow for mitigation of hazards which currently are not being addressed;
- Getting direction regarding what makes up a comprehensive Geotechnical Report was requested;
- A possible method to place legal instruments on land titles to ensure future owners are aware of subsidence issues was also requested;
- Challenges where identified relating to forcing single lot residential builders/occupiers to complete a costly geotechnical assessment with regard to the added expense it may have to private home builders;
- Provision of definitions regarding the types of subsidence and how this can manifest into a development issue were desirable;
- A discussion of the dangers of subsidence as requested to be included in the municipal material so the issue can be easily relayed and understood by municipal councils;
- A concern over sensitivity to ensure the work does not significantly impact a housing market which is already depressed in many areas of the province as raised;
- Some direction was sought on the issue of bootleg mine subsidence; and
- A balanced approach was sought to ensure that the Province provides ongoing policy and regulatory support on the issue and does not take this opportunity to simply download this challenge on municipalities.

3.1.1.1.2 Review of Nova Scotia Municipal Bylaws

Municipal building bylaws and where applicable subdivision bylaws, were reviewed for those Nova Scotia municipalities which are located within a coalfield or coalfields and therefore have potential for abandoned coal mine subsidence within their municipal planning area. Bylaws were reviewed for municipalities in the following Nova Scotia Counties: Cape Breton County, Pictou County, and Cumberland County.

The four (4) municipal building bylaws and the one (1) subdivision bylaw reviewed from municipalities in Nova Scotia with coal fields within their municipal planning area do not have requirements or regulations with respect to mine subsidence. However, the Cape Breton Regional Municipality Municipal Planning Strategy (February 20, 2010) does contain a policy on subsidence (pages 9-14 and 9-15) and makes it clear that "The CBRM is not responsible for subsidence and is not liable for property damage occurring as a result of subsidence." It also states that the CBRM is willing to act as a conduit for information as follows:

> "... with accurate information supplied and interpreted by the Province, the CBRM would be prepared to establish a system of public notification for prospective developers interested in, or about to, construct in communities and neighbourhoods identified by the Province as being:
>
> - Above abandoned mine workings; or
> - Within a range of influence that subsidence would be a possibility should they collapse.
>
> The CBRM would not accept responsibility for the accuracy of such information. It would only be a conduit to provide the Province's information to those most likely to be developing in the former mining communities. The purpose of the information would be simply and strictly to inform prospective developers."

3.1.1.2 Review of Other Jurisdictions – Canada

Canada currently has a very small underground coal mining industry and in recent years active subsidence has occurred only in isolated remote rural areas (west of Campbell River BC, north-west of Grande Cache Alberta and under the ocean (Cape, Breton, NS). However, it is known that abandoned coal mine subsidence has been an issue in other municipalities in Canada with two of note which were reviewed: Canmore, Alberta and Nanaimo in Vancouver Island, British Columbia.

3.1.1.2.1 Canmore, Alberta

Within the Alberta context, the impetus for creating a legislative framework for undermining was due to an extensive real estate development called the Three Sisters Mountain Resort and was officially adopted by Canmore Council in 2004. Due to the large footprint of the development and the coal mining which had occurred within the area, the municipality and the developer were at odds over the potential impact and required mitigation caused by developing on undermined lands. This situation evolved to the point where the Province of Alberta stepped in and created a provincial regulation specific to undermining in the Canmore area: the Alberta regulation 114/97 Municipal; Government Act Canmore Undermining Review Regulation. In effect, this requires: (i) a developer to engage a professional engineer to prepare an undermining report in designated areas of Canmore; (ii) within the undermining report there must be a compliance certificate completed by a second, independent, professional engineer; and (iii) the developer must carry out mitigation measures as outlined in the geotechnical report.

Also the developer in designated areas of potential mine subsidence "must obtain insurance coverage of the type, in the amount and for the period of time, satisfactory to the Minister to insure against claims for damage arising from undermining and related conditions," This approach is similar to the American model where some states exert jurisdiction and legally compels developers to acquire subsidence insurance based on a geotechnical report reviewed and accepted by the province. It should be noted that this subject legislation is specific to the Canmore area only.

3.1.1.2.2 Nanaimo, BC

The City of Nanaimo in British Columbia treats areas undermined in the same regard as other hazard lands in the municipality such as area affected by flooding, erosion and land slips This hazard land designation is created at the highest policy level within the Municipality's Official Community Plan where the requirement for conducting geotechnical assessments on lands affected by underground mining is defined. This requirement is facilitated through enabling provincial legislation such as the *Local Government Act* and the *Land Title Act* which gives the municipality the legal means to require mitigation plans for development on hazardous lands and the ability to control development by enacting instruments on land titles. Following the high level policy in the Official Community Plan the City of Nanaimo Development Services Building Inspection Division, has published guidelines for the preparation of a geotechnical report to confirm that land may be used safely for the intended use without risk of hazards.

The Guideline requires a geotechnical report to confirm the land may be used safely for the intended use without undue risk of hazards. The Report shall be prepared at the cost of the applicant by a professional engineer registered in British Columbia with qualifications and experience in geotechnical engineering. The Engineer shall inspect the property, supervise the geotechnical site investigations and the Report shall clearly state all relevant restrictions, conditions and/or limitations to the proposed development of the land. The geotechnical site investigations and the Report shall be completed in accordance with good engineering practice and minimum criteria are stated generically, such that subsidence is included and setbacks and restrictions are addressed but few specifics are outlined.

3.1.1.3 Other Jurisdictions international

An important component for the development of best practices in Nova Scotia is to assess practices being used globally. Therefore a broad literature search was conducted to obtain information related to land use planning provisions and building code provisions for development over lands with potential for subsidence. The following jurisdictions were reviewed: Australia, New Zealand, United Kingdom, and the USA.

3.1.1.3.1 Australia & New Zealand

<u>New South Wales</u>

The Mine Subsidence Compensation Act 1961 (as of March 28, 2010) of New South Wales confirmed the Mine Subsidence Board (MSB),established by the the Mine Subsidence Act 1928 and superseding other previous legislation: the Mine Subsidence (Amendment) Act 1948 , the Mine Subsidence (Amendment) Act 1951 and the Mine Subsidence (Amendment) Act 1957]. The MSB is an independent body operating for the local community in areas of coal mining in NSW. They provide compensation if improvements on the surface are damaged by mine subsidence (mainly from coal mining), prevent damage by ensuring new developments are compatible with the risk of mine subsidence, and eliminate the risk of danger from mine subsidence. The Mine Subsidence Board is not responsible for approving mining activity.

One principle reason the MSB exists is that in NSW owners can’t get insurance for subsidence – it is an “excluded event” in policies and action through the Courts takes too long. The MSB addresses areas of conflict between mine subsidence and new development by making them Mine Subsidence Districts (a full map of the areas included in these Districts can be found on their website). Within those areas, Surface Development Guidelines are applied, using the Building Code of Australia. All applications for Development are then assessed against those Guidelines.

The MSB jurisdiction covers designated Mine Subsidence Districts, which in turn are located in various municipal council districts. It is mandatory to obtain the Mine Subsidence Board’s approval to subdivide or erect or alter any improvements on land that is within a proclaimed Mine Subsidence District. However, where a council does not require a building application, the Board will deem approval for those improvements. The MSB have issued a “Guide for Council Staff” which is included in Appendix F for reference.

Surface development guidelines set by the MSB include development controls which involve the Board setting subdivision, building and construction guidelines, which are developed and introduced for the protection of homeowners. They are designed to ensure that homes and other structures will tolerate the expected levels of subsidence, thus minimizing the risk of being damaged. Guidelines set by the Board cover both the nature and class of improvements and include the height of a building, the type of building materials used, construction methods including types of footings and reinforcement and any special conditions. Construction guidelines vary from area to area depending on the coal mining activity and the expected amount of subsidence.

Queensland, Australia

In April 2003 the Queensland Building Services Board instigated a review of the causes of footing and slab movement see Appendix F. The review focused on design and construction of footings and slabs including legislation and standards as well as skill levels and education of practitioners. It also considered the escalating costs to BSA's statutory insurance fund. Emphasis is placed on the property owner to provide proper maintenance of their land and properties and on the contractor retained by them to provide such services, whose obligations are laid out in detail.

Whangarei District, New Zealand

The New Zealand (National) Building Act requires that the Whangarei District Council refuse the granting of building permits here mine subsidence is defined as a hazard. The New Zealand Building Act allows the Whangarei District Council to issue a building permit for a hazards area (subject to mine subsidence) after a geotechnical survey is conducted by a certified soils engineer. Sub-division and land use requests associated with building development, will require an appropriate engineer’s report, under the Whangarei District Council Policy for Building & Subdivision in Mining Zones, (1982) reference Appendix A report by Tonkin and Taylor (1999). Typically no building will be permitted within 20 m of a mine shaft, crown hole or mine entrance unless it can be demonstrated that the hazard can be mitigated or that building damage can be prevented. In all areas which are undermined, building design and construction must make allowances for potential subsidence.

The 1982 Policy refers to mining subsidence zones, and requires that:

- In Zone 1 all building permits are to be issued under Section 641A of the Local Government Act and are to be issued: (a) For the repair or replacement if any buildings are damaged by accident. (b) Generally for the extension or addition to service rooms only (as defined in NZSS 1900 Chapter 4). (c) For the erection repair or extension of any out-house, garage, shed or carport (up to 50 sq.m in area). (d) For the erection repair or extension of any porch or terrace, or (e) For the erection repair or extension of any fence or garden wall, including retaining walls. The structure is to be designed to minimize the effects of any subsidence and/or is to be relocatable. No further subdivision is allowed in Zone 1 unless such subdivision makes specific provision for the removal of the subsidence hazard; and
- In Zones 2 and 3 all building permits are to be granted for building using normal domestic type building construction in the normal manner with the proviso that the design and type of construction be certified by a Registered Engineer as being suitable to minimize the effects of any possible mining subsidence. All buildings other than normal domestic buildings be the subject of special consideration and all permits are to be issued under Section 641(a) of the Local Government Act.

3.1.1.4 States in the USA

States within the USA impacted by coal mining subsidence include: Alabama, Illinois, Indiana, Kentucky, Maryland, Ohio, Pennsylvania, West Virginia, and Wyoming. Many of these states place a legal obligation on the part of property owners to acquire mine subsidence insurance if they reside over undermined lands. This is a complex situation where some states require it and in others homeowners can opt out of buying this insurance. The obligation is typically placed on the insurance companies or state operated subsidence insurance funds to provide subsidence insurance as a special rider on homeowner insurance policies. The homeowner can purchase subsidence insurance as a rider to the standard homeowner policy (nominal fee) or they can opt out of purchasing this subsidence insurance. To opt out the homeowner must sign a waiver releasing the state from further compensation in the event of subsidence damage. Some states provide a re-insurance program whereby they pay the insurance company for subsidence damage claims above the value of the small fee paid by the homeowner. Other states operate their own independent subsidence insurance plan with similar opt out clauses. The information regarding where underground mining has occurred is provided at the state level in most situations. As the individual states regulate this aspect, besides notification in some jurisdictions, the regional municipalities are not required to provide this service to residents. However, most municipalities have the requirement for a geotechnical report to accompany the engineering drawings during the development permitting process.

3.1.1.5 United Kingdom of Great Britain

In February 2002, the UK Department for Transport, Local Government and the Regions issued their “PG14 Planning Policy Guidance Development on Unstable Land”. This document sets out the broad planning and technical issues to be addressed in respect of development on unstable land; Annex 1 developed that guidance in relation to landslides and unstable slopes. Annex 2 of PG14 “Subsidence and Planning” deals with problems caused by subsidence. This guidance advises that:

- Local planning authorities should identify areas where consideration may be needed of the potential impact of subsidence on development;
- Within these areas, policies should seek to minimize the impact of subsidence by controlling or restricting development where appropriate;
- Policies in development plans should outline the consideration which will be given to subsidence, indicating any information that will be required to be provided in support of planning applications; and
- Where appropriate, planning applications should be accompanied by a stability report which demonstrates that the site will not be affected by subsidence or that the development will be able to withstand the effects of any subsidence that takes place.

Appendices advise on causes and distribution of subsidence, relevant research on subsidence potential on a national and locally targeted basis, mitigation of subsidence and treatment of mine openings, appropriate data systems for information on mined ground and on the contents of stability reports.

Annex 2 of PG14 concludes that the government minister responsible looks to local planning authorities and developers to implement the advice in the annex. Both parties should work together to agree on the measures necessary to assess and mitigate the potential risks of subsidence. Early consideration of potential subsidence and its mitigation will allow the safe, efficient and cost-effective redevelopment of previously developed land consistent with the principles of sustainable development. The detailed policies and practices to be adopted by local planning authorities to implement the guidance in the annex are, however, for them to determine in the light of local circumstances. The national government will monitor the effectiveness of this annex and keep it under review. Annex 2 includes Appendix 2C “Mitigation of Subsidence and Treatment of Mine Openings”, Appendix 2D giving information on supporting data base systems and Appendix 2E which outlines the requirements of a “stability Report” which is equivalent to the Geotechnical Report above. These three are included in Appendix F for reference.

Local Planning Authorities, landowners and developers are supported in implementing the above national policies by another government body, the Coal Authority which was established by the British Parliament in 1994 to undertake specific statutory responsibilities associated with: licensing coal mining operations in Britain; handling subsidence damage claims which are not the responsibility of licensed coalmine operators; dealing with property and historic liability issues, such as treatment of mine water discharges; and providing public access to information on past, present and future coal mining operations.

The Coal Authority is the public body which deals with surface hazards arising from past coal mining activities such as shaft collapses, collapses of shallow mine workings, gas and water emissions from former coal mines and the spontaneous combustion of coal in the ground. The Authority deals with about 600 such incidents nationally every year. Their emergency call out service deals with these incidents on a 24 hour basis every day of the year. Upon receiving a report of a suspected coal mining hazard, they arrange for the situation to be made safe, without consideration of responsibility. The Authority responds to surface hazard reports by making them secure, on a without prejudice basis, investigating the cause of incidents and carrying out a permanent treatment where the Authority has a responsibility to do so. There is a 24 hour emergency number.

3.1.2 Summary of Findings

3.1.2.1 Nova Scotia

Presently municipal building bylaws and subdivision bylaws do not have requirements or regulations with respect to mine subsidence, although CBRM's municipal planning strategy does includes a – statement on subsidence. This statement is that CBRM is not responsible for subsidence and is not liable for property damage occurring as a result of subsidence but that it is willing to act as a conduit for information provided by the Province to the public.

3.1.2.2 Other Jurisdictions

UK and Australia have comprehensive subsidence compensation legislation funded by coal mining operations which covers subsidence damage from both active and abandoned coal mine workings. They also provide substantial publically funded organizations to administer and implement the compensation requirements.

This is not the case in United States or Canada. Some states of the USA have self-funding subsidence insurance programs to compensate property owners from both active and abandoned coal mine workings. Canada currently has no such programs. Abandoned coal mine subsidence has municipal recognition in both Canmore, Alberta where a geotechnical report, an independent review of geotechnical reports and appropriate insurance must be provided by developers and in Nanaimo BC where a geotechnical report alone is required.

The district of Whangarei in New Zealand has progressed similarly to Nanaimo in BC, Canada where there are policies which require geotechnical engineer reports but also define subsidence hazard zones.

3.2 Existing Codes with Respect to Building in Areas with Abandoned Mine Subsidence

A review was then conducted to examine existing building code best practice with respect to coal mine subsidence, that are being used in Nova Scotia, other jurisdictions, in Canada, UK, NSW in Australia and the USA. This information formed a basis for development of best practice guidelines in Nova Scotia.

3.2.1 Information Gathering

3.2.1.1 Review of Nova Scotia

3.2.1.1.1 Building Code

A baseline assessment was completed of the current situation in Nova Scotia relating to legislation controlling building in areas with potential for mine subsidence. Five (5) sections from the Nova Scotia Building Code (Sections 1.4.1.3, 1.4.1.4, 2.1.1.5, 2.1.1.6 and 2.1.1.7) require the property owner to inform and ensure that professional architects and/or professional engineers have been retained during the permitting process where required (Reference: Nova Scotia Building Code Regulations made under Section 4 of the *Building Code Act* R.S.N.S. 1989, c. 46, effective September 1, 2010. The Code stipulates situations where a geotechnical investigation must be conducted.

Under the Nova Scotia Building Code there are occasions where geotechnical investigations or mitigation measures for building apply although not specifically relating to mining subsidence. The Nova Scotia Building Code Regulations indicates where the owner applying for a building permit is required to retain professional services in the following sections:

> **Section 1.4.1.3 Required Information, sub section (1)** (e): the owner names engineer, other designer, constructor, etc.to the *authority having jurisdiction;* (f): the owner describes any special *building* systems,

materials and *appliances*; and (g) the owner provides such additional information as may be required by the *authority having jurisdiction;*

Section 1.4.1.4 Letter of Undertaking when Professional Required to Design: the owner submits letter of undertaking for construction and for any design by an engineer to the *authority having jurisdiction*;

Section 2.1.1.5 Professional Design and Review: the owner to ensure that an architect and/or professional engineer is/are appointed for design work;

Section 2.1.1.6 Design Regulations for Structural Components: the owner ensures that professional engineer is appointed to design structural component;

Section 2.1.1.7. Site Conditions, Size, or Complexity Requiring Professional Design and Inspection: allows the *authority having jurisdiction* to require professional involvement;

Section 2.2 Obligations of a professional: outlines obligations of engineers, etc.; and

Part 3 Amendments to the Nova Scotia *Building* Code Schedule "A" Letter of Undertaking, Confirmation of Commitment by Owner to the Municipal Authority Having Jurisdiction - Field Review of Construction, Preamble : Initial the disciplines that apply to this project. All disciplines will not necessarily be employed on every project): □ *Building* Design □ Structural □ Plumbing □ Mechanical □ Electrical □ Geotechnical □ Fire Suppression System; also **Schedule "A-7" Field Review of Construction, Inspection Commitment Certificate: Geotechnical Design Requirements.**

These are the only sections in the NS Building Code where professional requirement is stipulated. The intent of the code is, the owner who is building or modifying a structure and is making application for a building permit ensures/proves to the authority (Municipality) that he (owner) has engaged a professional or professionals . The professional determines if a geotechnical investigation is needed, thus where abandoned coal mine subsidence issues occur these allow for a geotechnical engineer to investigate and report.

It is also noted that the following sections of the National Building Code for Canada, 2005 whilst not explicit about abandoned coal mine subsidence are relevant:

Section 4.1.2.2 Loads Not Listed – requires engineering design to take into account all loads, forces or other effects based on the most appropriate information available;

Section 4.2.2.4 Altered Subsurface Condition – any such alterations noticed during construction require re-assessment by an engineer; and

Section 9.4.4 Foundation Conditions – reference to design requirements for allowable bearing pressures.

3.2.1.1.2 <u>Other Developments</u>

It is noted that outside of the provincial jurisdiction, a considerable number of land parcels within the Federal jurisdiction are being remediated under the Enterprise Cape Breton Corporation (ECBC) Mine Site Closure Program. This is project managed by Public Works & Government Services Canada (PWGSC) and includes remediation of abandoned mine sites on federal crown land in Cape Breton lands covering both legal and illegal workings. As part of this program ECBC has developed program specific protocols for assessing abandoned coal mine subsidence which use a three hazard zone system based on a depth (D) to extraction height (M) ratio (D/M), values of D/M less than 6 are a high risk of sinkhole subsidence, 6-12 moderate risk and more than 12 a low risk. It is hoped that the protocols will be made public in the future.

3.2.1.2 Other Jurisdictions in Canada

Canmore, Alberta Canada

Alberta regulation "114/97 Municipal Government Act Canmore Undermining Review Regulations" requires developers to engage a professional engineer to prepare an undermining report in designated areas within the Canmore Coal Field in accordance with guidelines. Within the undermining report there must be a compliance certificate completed by an independent professional engineer and the developer must carry out mitigation measures outlined in the report. Also the developer in a designated area of potential mine subsidence must obtain insurance coverage of the type, in the amount and for the period of time, satisfactory to the Minister to insure against claims for damage arising from undermining and related conditions.

Nanaimo British Columbia Canada

The City of Nanaimo Development Services Building Inspection Division "Guidelines for the Preparation of Geotechnical Report" requires a geotechnical investigation to confirm that land may be used safely for the intended use without risk of hazards, including that of mining subsidence. Also, the Nanaimo Community Plan, Section 5.3, describes natural hazard areas and also provides some requirements for when a geotechnical report is required:

> *"Where development is proposed on land with abandoned coal mine workings, it will be subject to a geotechnical assessment certified by a professional engineer with expertise in this field, confirming that the land may be developed and used safely for the development as proposed. Geotechnical assessments should be prepared in accordance with the City's Guidelines for Preparation of Geotechnical Reports. Where a Geotechnical Report certifies that land within a natural hazard area or lands subject to abandoned coal mine workings may be used safely for the use intended, development approval will be conditional on:*
> - *Implementation of all conditions contained in the Report respecting siting, structural design, maintenance or planting of vegetation, placement of fill, etc.;*
> - *The landowner covenants with the City to use the land only in the manner determined in the Report and the covenant is registered under s. 219 of the Land Title Act; and*
> - *A covenant is registered granting the City relief from any liability for any claims associated with the land use."*

3.2.1.3 Other Jurisdictions

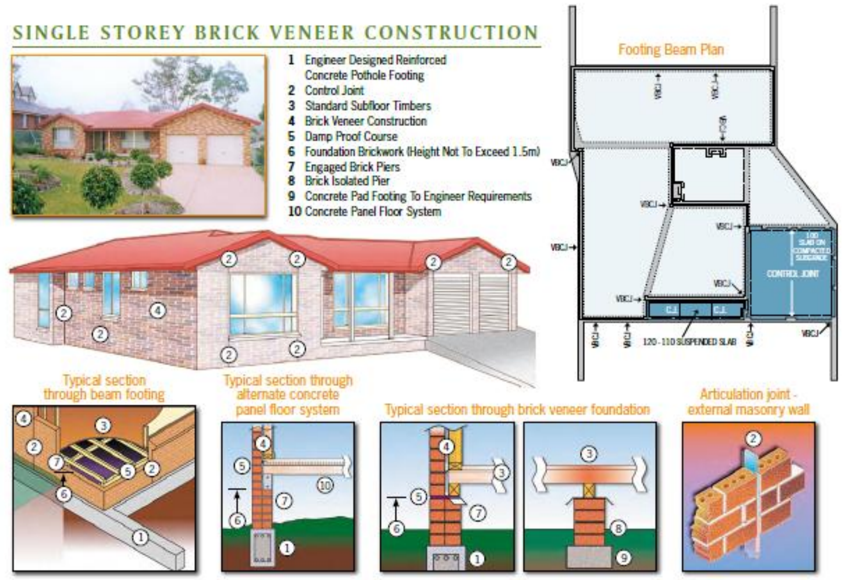
Australia

Australia's National Building Code Section 2870 Residential Slab & Footing Constructions requires a minimum of one borehole or one test pit and a further minimum of three boreholes or three test pits investigation for residential lots in areas with deep-seated movements. Also, section 2810 of AS Building Code classifies building lot sites subject to mine subsidence with site subject to landslip, collapse activity and coastal erosion. These sites are classified as "P Sites" and only professional engineers with length experience designing foundations for "P Sites" are eligible to submit concrete foundation designs.

New South Wales, Australia

The Mine New South Wales Mine Subsidence Board (MSB) was referred to in section 3.1.1.3.1 above. The MSB's mandate is to assess, administer and pay valid compensation claims for damage arising out of coal mining subsidence (whether from active or abandoned mine workings) from a special Mining Subsidence Compensation Fund funded by coal mine operators. The compensation is to restore to pre-existing condition for any damage that arises from subsidence and to meet the expense incurred as a result of such damage in: (i) building retaining walls or bolting together or underpinning or otherwise supporting, raising or repairing buildings and walls; (ii) altering the approaches to or the levels of lands or buildings; (iii) raising, lowering, diverting or making good roads, tramways, railways, pipelines, bridges, fences, sewers, drains or other improvements; and (iv) compensation for any damage to household or other effects that arises from subsidence, except where the subsidence is due to operations carried on by the owner of the household or other effects.

Surface development guidelines set by the MSB include development controls which involve the Board setting subdivision, building and construction guidelines, which are developed and introduced for the protection of homeowners. They are designed to ensure that homes and other structures will tolerate the expected levels of subsidence, thus minimising the risk of being damaged. They cover both the nature and class of improvements and include the height of a building, the type of building materials used, construction methods including types of footings and reinforcement and any special conditions, see Inset. Construction guidelines vary from area to area depending on the coal mining activity and the expected amount of subsidence. The MSB also has requirements for buying property and building in a subsidence district requires foundation footing designs and other specified building components of residential buildings be designed by certified qualified professional engineers.



Inset

Queensland, Australia

Queensland Building Service Authority (BSA) has a policy that builds on the Australian national Building Code with very specific foundation design requirements for “P Sites”. In April 2003 the BSA Board instigated a review of the causes of footing and slab movement. The review focused on design and construction of footings and slabs including legislation and standards as well as skill levels and education of practitioners. It also considered the escalating costs to BSA's statutory insurance fund.

Preliminary findings of a research project commenced in May 2003 identified two areas that required special attention. They were: Engineering Investigation and Design and Construction Practices. After informing industry of the review in September 2003, the Queensland Building Services Board recently endorsed a new Policy for Rectification of Building Work in residential construction. This includes work that causes footing and slab movement. A Fact Book was prepared, see Appendix F, distributed throughout Queensland, is aimed at ensuring that all participants in the building industry are properly informed about, and understand how to comply with, the no fault provisions of the new policy. Similarly, a further BSA education initiative will endeavour to ensure homeowners are made more aware of their responsibilities for the ongoing maintenance of their homes. Emphasis is placed on the homeowner to provide proper maintenance of their land and properties and on the contractor retained to provide such services. Contractors obligations are laid out in detail.

Whangarei, New Zealand

The New Zealand Building Act requires Whangarei District Council to refuse the granting of building permits subject to one or more natural hazards where mine subsidence is defined as a hazard. The New Zealand Building Act allows the Whangarei District Council to issue a building permit for a hazards area subject to Mine subsidence after a geotechnical survey is conducted by a certified soils engineer. Sub-division and land use requests associated with building development in mining zones, will require an appropriate engineer’s report, subject to Policy for Building in

Mining Zones (1982) and Building Control in the Kamo mining district (Tonkin and Taylor 1999). Typically, no building will be permitted within 20 m of a mine shaft, crown hole or mine entrance unless it can be demonstrated that the hazard can be mitigated or that building damage can be prevented. In all areas which are undermined (zones 1, 2 and 3) building design and construction must make allowances for potential subsidence. Some requirements include a hazard report and subsidence zoning. The 'Building Control Policy for Building In The Kamo Mine Zones, December 1995', reflects the NZ Building Act 1991. Three zones are specified which indicate the different depths of cover: Zone 1 indicates the area where there is a possibility of crown-holing and major subsidence due to there being less than 10 t cover, where t = seam thickness; Zone 2 indicates (a) areas where there is up to 10 metres of cover and "medium" subsidence is possible and (b) areas where there has been 2 seam pillaring and greater than 100 metres of cover exists. Possible problems associated with this zone would be surface settlement, horizontal strains and subsidence fracturing; and Zone 3 indicates areas where there is greater than 100 metres of cover. Although this is a low risk zone, it is possible for buildings to be affected by minor subsidence. The zones indicate the best information the Council has to date.

The Policy also requires that no building work is permitted where the risk of subsidence is increased by the proposal. All Building Consents for building work in mining zones are to be considered in terms of Section 36(2) of the Building Act. Construction methods used are to be compatible for any possible subsidence that may occur. The following rules must be followed:

Zone 1	Building consents are only to be issued for: Repair of existing buildings; minor extensions to existing buildings; erection of single storey accessory buildings not exceeding 50m2 in area (e.g., carports, garages etc); erection of fences, walls and retaining walls; and Single storey housing that can be transported intact, constructed using light weight building materials with the proviso that buildings or part thereof, located within a 20 metre radius of air shafts and mine entrances are supported with a full geotechnical appraised by a suitable qualified engineer. Building Consents are to be issued only to the owner of the property, under Section 36(2) of the Building Act, with an entry on the Certificate of Title to the land that a building consent has been issued in respect of a building on land subject to subsidence.
Zones 2 and 3	In all cases construction methods adopted must allow for potential subsidence and may require specific design. Proposed Building Works or part thereof located within a 20 metre radius of air shafts and mine entrances are to be supported with a full geotechnical appraisal by a suitably qualified engineer. The Council may issue Building Consents to the owner of the property, under Section 36(2) of the Building Act, with an entry on the Certificate of Title to the land that a building consent has been issued in respect of a building on land subject to subsidence. Please note that although the rules are the same for both Zones 2 and 3, it is useful to maintain these zones to indicate the different potential for damage to a property owner considering development of the land.

United States

Professor Syd Peng in his established reference text "Subsidence Engineering: (1992) states that there were 70,000 abandoned coal mines nationwide in the USA, at that time, having undermined eight (8) million acres of land including of which more than 25% has been impacted by subsidence. The expansion of housing and industry and supporting infrastructure has required the use of many areas underlain by such abandoned workings.

Several mechanisms such as progressive deterioration of pillars, mine floors and mine roofs can lead to surface subsidence long after active mining has finished. He outlines the types of such subsidence, its causes, surface structural damage and its prevention/control, prediction of such subsidence which is complex and almost impossible in terms of predicting its timing. In terms of prevention of structural damage he gives options for both design to resist subsidence and for flexibility to accommodate it as well as relocation of a structure to areas where there is adequate pillar support. Subsidence abatement can be done locally by point support (gravel or cementious fill) or by aerial backfilling entire neighborhoods.

United Kingdom

TABLE 2E1. Ground stability declaration form

Site Name	Site Address	Proposed Development

CATEGORY	QUESTION	YES/NO /?/N/A
Competent person	Has the report been prepared by a Geotechnical Specialist, as defined by the ICE Site Investigation Steering Group?	
A. Site history	Has the site been affected by known historical subsidence?	
	Is the site underlain by strata which may contain natural cavities or be liable to subsidence due to adverse foundation conditions?	
	Has there been previous development on the site such as mining or industrial development that could result in underground cavities or made ground?	
	Is mining or underground excavation proposed beneath the site?	
	Have any previous ground investigation reports and/or borehole records from this or nearby sites been consulted?	
	Have any cavities, broken ground, made ground or other adverse foundation conditions been identified beneath or near the site?	
B. Site inspection	Has a detailed site inspection been carried out? Does the land within or adjacent to the site bear any geomorphological evidence of former, on-going or incipient subsidence?	
	Does the site or neighbouring property bear any evidence of structural damage or repairs that might be associated with subsidence or evidence of mine entries?	
C. Ground investigation	Has a ground investigation been carried out?	
	Have any cavities, broken ground, made ground or other adverse foundation conditions been identified beneath or near the site?	
	Have their locations and dimensions been properly identified?	
Assessment of subsidence	Is the information under A, B and C above adequate to assess the likely effects of subsidence on the site?	
	Can subsidence be reasonably foreseen within or adjacent to the site within the design life of the proposed development? Have the potential effects of subsidence on existing or proposed development been assessed?	
Mitigation measures	Have mitigation measures been proposed with respect to subsidence?	
	Are these designed to reduce the effects of any actual or potential subsidence to an acceptable level?	
	Are they likely to have any adverse effects on other adjacent sites, eg by affecting the groundwater regime?	
Name, qualifications and signature of person responsible for this report	Full Name	
	Qualifications	
	Geotechnical Specialist?	
	Signature	
	Company Represented	

In February 2002, the British Government's Department for Transport, Local Government and the Regions issued Annex 2 Planning Policy Guidance Note 14 Development on Unstable Land. This includes Appendix 2C "Mitigation of Subsidence and Treatment of Mine Openings" which summarizes UK policy as follows: The risks to land use and development from potential subsidence can generally be minimized either by the use of appropriate foundations and design of buildings and structures to cope with expected movement or by ground treatment measures to reduce the level of subsidence to acceptable levels. While it will seldom be necessary for development to avoid areas of subsidence risk entirely, the mitigation measures can be costly and planning policies that specify uses that will not be affected by the expected levels of subsidence may be appropriate in some circumstances. In addition, the nature and characteristics of mine openings and other similar features may require their treatment for public safety reasons, whether or not development is planned on the site. Appendix 2D gives information on supporting data base systems and Appendix 2E outlines the requirements of a "stability Report" which is equivalent to the Geotechnical Report above. Appendices 2C, 2D and 2E are in Appendix F for reference. Stability reports would be expected to cover a basic range of issues and there could be some merit in including a standard ground stability declaration form as illustrated in Table 2E1. This Table indicates the main categories of investigation which need to be covered and the report would be expected to provide detailed supporting information for each of the items listed that are appropriate to any particular development proposal. The report should identify the information used, reach conclusions on the potential for subsidence to occur and make recommendations for mitigation measures if considered necessary.

3.2.1.4 Design Philosophies

In general there seem to be three main philosophies in design of structures to mitigate subsidence effects on structures in areas prone to coal mine subsidence. These methods are: (1) to build rigid structures which resist ground movement effects;, or (2) to build-in flexibility to accommodate ground movement due to subsidence; or (3) to relocate the structure to a more stable area where there will be little or no subsidence impacts (Peng, 1992). The choice of option depends upon site specific considerations although New South Wales, Australia favours the second in low rise residential structures as explained in the following paragraphs.

In a paper entitled "A Reappraisal of Structural Design Concepts in areas subject to Ground Movement" Appleyard, 1995 promotes the use of flexible design for mitigating active subsidence in low-rise structures less than 7.2m high and 2 or less stories. He quotes from a 1991 paper by White and Page which described a study aimed at producing a structure with sufficient flexibility and articulation to accommodate large ground curvatures whilst at the same time providing sufficient resistance to lateral loads. They concluded that resulting house designs that have evolved from consideration of these and other parameters are therefore resistant not only to the normal dead, live, wind and seismic loads, but also to highly reactive soils and mine subsidence". White and Page in a later paper in 1998 describe a demonstration residential low rise structure designed to mitigate active subsidence effects which considered two philosophical approaches. The first is to make the structure sufficiently stiff that it does not follow the ground curvature. This may involve the slab alone or the slab wall system may also be designed as a series of stiff composite structural elements. No movement means no cracks. The second philosophy is to allow the structure to move freely to minimize any stress in the masonry by suitable articulation and other detailing. No stress means no cracks. They conclude that while both approaches have merit, the second philosophy was chosen for two reasons: cost and the appeal of no stress in the masonry. It is a more foolproof approach when the system is in use. The paper describes a masonry housing system which is capable of withstanding the effects of a longwall mining event ("doming" and "dishing" curvatures as well as residual tilt). The housing system consists of a pre stressed concrete raft slab, and a light steel framing system, combined with masonry external and internal walls. The system is detailed so that the movements between the articulated masonry elements are accommodated by the flexible attachments to the supporting frame. Lateral stability is provided by masonry shear walls in conjunction with a ceiling diaphragm system. The series of tests simulated a range of surface curvatures and tilts, and no tests produced any significant distress in the masonry or other walling components.

In 2001, Appleyard noted that the publication and implementation of the Graduated Design Guidelines achieves an objective sought by the Mine Subsidence Board for many years. The Guidelines provide a framework for the uniform assessment of building applications by the Board's Officers, a framework which is based on current building industry best practice as defined by relevant design codes and regulatory legislation. They note that the major considerations for design in mine subsidence areas are as follows: Design for subsidence; Design to accommodate strains; Design to accommodate curvature; and Design to accommodate tilt. It is important to acknowledge that some geological conditions are present but often hidden which may induce subsidence stepping such as along fault or fissure lines, and may require a detailed site investigation to define them, especially for buildings with large footprints or water, sewerage and drainage services.

In general terms, ground strains are transferred into footing systems by friction beneath and beside the footing elements. The obvious solution, therefore, is to reduce such friction and - wherever possible - separate the footing structure from the soil. This may be achieved by providing a slip layer between the structure and the ground to allow the ground to move without damaging the structure. The use of concrete slab on grade footing systems is now (2001) close to 90% in NSW with preference to the waffle raft system as the preferred reinforced concrete slab footing system.

Design to accommodate curvature resulted in a series of spreadsheets were created which set out values of deflection which would result from curvature radii of 0.25 km - 25.0 km when applied to building lengths of 10, 20, 30 and 40 m. The final values were correlated with acceptable construction methods, limited to three (3) types: CF Clad Frame; AMV Articulated Masonry Veneer; and AFM Articulated Full Masonry.

The Guidelines define three (3) levels of design responsibility are defined:

Level 1 - The design may be carried out by a builder, a qualified Building Designer, or a Professional Designer;
Level 2 - Design of the structure must be certified (not necessarily carried out) by a Consulting Civil and/or Structural Engineer in accordance with the site specific mine subsidence parameters; and
Level 3 - Approval is unlikely to be issued by the Members of the Board due to known mine subsidence parameters with consideration only on a case specific basis.

Note - all levels require the design drawings to be submitted to the Mine Subsidence Board for approval.

3.3 Summary of Findings

Approaches for dealing with coal mine induced subsidence have developed differently in the various jurisdictions where underground coal mining has occurred. Legislation has long been enacted in the United Kingdom and New South Wales, Australia requiring formal compensation for coal mining subsidence and this same legislation also obligates the government to provide funding to operate the agencies that address subsidence. In the United States special insurance programs can be required, some states have self-funded insurance programs while some other states operate the subsidence insurance as a re-insurance program operated by private insurance companies. Three (3) examples were identified of specific municipalities which address abandoned coal mine subsidence specifically: Canmore, Alberta; Nanaimo, BC; and Whangarei, New Zealand. The former has provincial legislation in place and all require geotechnical reports on lands for development where subsidence hazards prevail. Whangarei also has rules which prescribe three levels of subsidence hazard zones. A similar approach has been taken during remediation of abandoned mines on federal crown land in Cape Breton lands on where program specific protocols have been developed for assessing abandoned coal mine subsidence which use a three hazard zone system.

Presently there is no direct trigger in Nova Scotia requiring a geotechnical investigation for subsidence mitigation measures defined in the Nova Scotia Building Code. Elsewhere, an engineers' report and/or a geotechnical report is a common requirement in building permitting processes in subsidence areas, for example in: Canmore, Alberta; Nanaimo, BC; UK; Australia; NZ and some states in the USA. These reports take into account relevant information, including that on abandoned underground coal mine workings and abandoned underground openings. These reports may take a different name such as hazard report, stability report, etc. The professional determines if a geotechnical investigation or structural design measures are needed and this would include any case where subsidence is an issue. Several examples are available of the expected content of such reports and of the categorization or zoning of subsidence risk, see Appendix F.

Some jurisdictions also provide detailed information on design for developments in subsidence areas. This information can vary from subsidence-resistance design to subsidence-accommodating design to relocation depending on site specific considerations. The latter are favoured in New South Wales Australia for active coal mine subsidence for low rise residential structures. It is however noted in this report that Australia does not have the issue of major ground frost to deal with that exists in Nova Scotia.

4. Development of Best Practices for Nova Scotia

Following completion of the research described above the best practices applicable for Nova Scotia were developed. The process used to develop the best practices was to identify the current situation in Nova Scotia and compare this to practices identified elsewhere. Best practices were to address three aspects:

(i) Identifying the hazard location and type (i.e., subsidence characterization); and
(ii) How land use planning and zoning should accommodate the existence and mitigation of such hazards; and
(iii) How building codes should accommodate the mitigation of these subsidence hazards, in terms of both precautions to prevent damage and remedial action to address damage.

The best management practice process and outcomes are outlined in the sections below. One goal of these best practices is to increase awareness, alert and advise interested parties that information exists on historic mine sites in Nova Scotia. Two (2) specific guides have been produced: (i) a brochure for public information Appendix B based upon Section 2 above and (ii) a booklet for guidance of municipalities in Appendix C, based on Section 4 below. The guides contain the salient points of the discussion in sections 4.1 and 4.2 below.

4.1 Development of Best Practices for Nova Scotia - Land-Use Planning

The direction regarding how to regulate development on undermined lands from a planning and bylaw perspective began with presenting the best practices to the Steering Committee and having them respond as to the pro's and con's of each potential option. Factors considered included: relative merits for introducing policies, bylaws, or even amendment of provincial legislation. One (1) key intent was the desire to continue to hold harmless the province and municipalities on issues of subsidence. From this dialogue a mutually agreeable direction was pursued for policy framework development. This direction proposes several levels for consideration to develop a protection and mitigation framework for abandoned coal mine subsidence hazards.

The first level proposed was to modify Municipal Planning Strategies where high level policy would be incorporated to allow more specific direction to be enacted in lower municipal planning documents as the best initial means to accommodate the issue of hazard Lands. For example, pages 86 and 87 from the City of Nanaimo's Official Community Plan provides a good reference for how Municipal Planning Strategies can be amended to incorporate high level policy on subsidence, which move beyond the more cautious approach taken by Cape Breton Regional Municipality's Municipal Planning strategy. In Nanaimo, these aim to protect life and property from both natural and man-made hazards, including mining subsidence as follows:

- Where development is proposed on land with abandoned coal mine workings, it will be subject to a geotechnical assessment certified by a professional engineer with expertise in this field, confirming that the land may be developed and used safely for the development as proposed;
- Geotechnical assessments should be prepared in accordance with the City's *Guidelines for Preparation of Geotechnical Reports*; and
- Where a Geotechnical Report certifies that land within a natural hazard area or lands subject to abandoned coal mine workings may be used safely for the use intended, development approval will be conditional on:
  - Implementation of all conditions contained in the Report respecting: siting, structural design, maintenance or planting of vegetation, placement of fill, etc.;
  - The landowner covenants with the City to use the land only in the manner determined in the Report and the covenant is registered under s. 219 of the *Land Title Act*; and
  - A covenant is registered granting the City relief from any liability for any claims associated with the land use.

The second level after the Municipal Planning Strategy is to amend Land Use Bylaws to include three (3) new items:

(i) A schedule of maps which shows where underground mining has occurred in municipalities, provided by the provincial government;
(ii) A regulation in the appropriate land use zone identifying the need for a geotechnical evaluation, if the proposed development falls within an area over underground mining; and
(iii) A schedule outlining the requirements for an acceptable geotechnical report completes the regulatory tools suggested for the land use planning components.

The third level would be at the development/building permit stage, suggested as another stage in the development process where a geotechnical report can be requested by a municipality. If this is addressed in the Municipal Planning Strategy as a potential avenue for addressing the subsidence issue, the project team determined the municipalities would now have the required authority to require such documentation prior to issuing a building permit.

This approach was the framework upon which the booklet to inform NS municipalities was made, see Appendix C, the different sections of which are now outlined.

4.1.1 Proposed Allocations of Responsibility

An initial aspect to be addressed must be to make clear an answer to the following question: who is responsible if coal mining subsidence occurs in the Province of Nova Scotia. The basic response is: first that the responsibility to address impacts from subsidence and property damage occurring as result of subsidence and for liability for abandoned mine workings rests with the landowner; and second by provincial policy the Province and/or municipalities assume no responsibility for subsidence and is not liable for property damage occurring as a result of subsidence, except on land owned by them.

A further consideration is responsibility for abandoned coal mine subsidence issues on Crown lands. The answer here is that these are excluded from the scope of work here as (i) Federal authorities are exempt from building permits on federally owned land and (ii) the Province of Nova Scotia exerts its own level of control over development on provincial crown lands, including those impacted by abandoned coal mine subsidence.

Finally, the division of responsibility for NS provincial government departments and municipal governments for addressing the issue of mine subsidence needs to be made clear, as outlined in Table 2.

Table 2 - Provisional Allocation of Responsibility

	SNSMR1	**NSDNR2**	**NSLWD3**	**Municipalities**
Land Use Planning	Set NS Policies Advise Municipalities	Provide technical information on location of underground coal mine workings to department, municipalities and public	N/A	Land use planning strategy By-laws Implement and enforce
Building Code	Policy input	Policy Input	Building policy and legislation	Building inspection and enforcement of building code
Public Information on coal mine subsidence matters	Set policy Guidelines to provincial departments General Information to public	Source of information: mine plans, geology, related information	Employers responsible to address ground stability related to subsidence as a potential workplace hazard	Distribute Brochure Implement booklet guidelines
Public Queries on coal mine subsidence matters	Address land use planning policy matters	Address technical inquiries from the professional / private sector (but does not include individual landowners).	N/A	Address all public inquiries (including individual landowners) Direct policy matters to SNSMR Direct technical inquires through property owner to private sector.

[1] SMSMR – Service Nova Scotia & Municipal Relations
[2] DNR – Nova Scotia Natural Resources
[3] NSLWD – Nova Scotia Labour & Workforce Development

4.1.2 Municipal Practice – Proposed Land Use By-Laws

Implementation of the information in this report requires that municipal land use bylaws be amended to include three (3) additional items:

(i) GIS mapping information identifying areas which have underground coal mine workings;
(ii) The requirement to complete a geotechnical report; and
(iii) The outline content of the geotechnical report.

Municipalities can add regulations in their land use bylaws which reference a schedule of maps showing areas of abandoned underground coal mines and indicating requirements for a geotechnical report for any proposed development. Typically where a new occupancy classification of an existing building is proposed a geotechnical report may also be required. The latter could include an outline of the elements to be included in a geotechnical report as presented in Section 4.3 of this report below.

An example land use regulation is as follows: "For any development proposed to locate within an area identified as having experienced underground coal mining or is prone to possible subsidence as illustrated in Schedule A (or otherwise as identified) a geotechnical report in a manner outlined in Section .... (to be identified) will be required. Accessory buildings to the main use, not used for human habitation, may be exempt from this requirement".

4.1.3 Notification of Undermined Lands

It is proposed that each municipality located within a coalfield area or areas should establish a system of public notification for prospective developers interested in, or about to, construct in communities and neighbourhoods identified by the Province as being located in an area of abandoned underground coal mine workings.

The notification of undermined lands follows the process outlined below:

Notification to Municipalities	The Province of Nova Scotia (NSDNR) will provide notification of lands undermined by abandoned coal mines to all affected municipalities.
Municipal Incorporation of Data	All affected municipalities can incorporate undermined lands data into their Geographical Information Systems (GIS) database and Land Use Bylaws. Overarching policies may be incorporated in Municipal Planning Strategies.
Notification to Private Land Owners	All affected municipalities can provide notification to private land owners, through the approval of development permit process, if the lands are undermined. Municipalities can take on the responsibility to notify all existing land owners if they are undermined by underground coal mine workings.
Receipt by Land Owners	The landowner is responsible for obtaining professional advice from the private sector to interpret the underground mining information.

4.1.4 Requirement for a Geotechnical Report

It is common practice in many other jurisdictions to require a geotechnical report or equivalent signed by a professional engineer in the early stages of permitting new development of property impacted by abandoned coal mine subsidence. The following sections outline the proposed guidelines for when such a report is not and is required.

4.1.4.1 When a Geotechnical Report is Not Required

Existing Development on Undermined Lands	There are no special requirements for existing developments as this is a condition known to be "legal non-conforming"
Applications for Single Lot Development (inc. Ancillary Buildings)	Applications for single lot residential development (including ancillary buildings) on lands subject to abandoned underground coal mines are not required to provide a Geotechnical Report however the completion of one may be required by the municipality.

4.1.4.2 *When a Geotechnical Report is Required*

Applications for New Commercial , Industrial, or Multi-Lot Residential Development

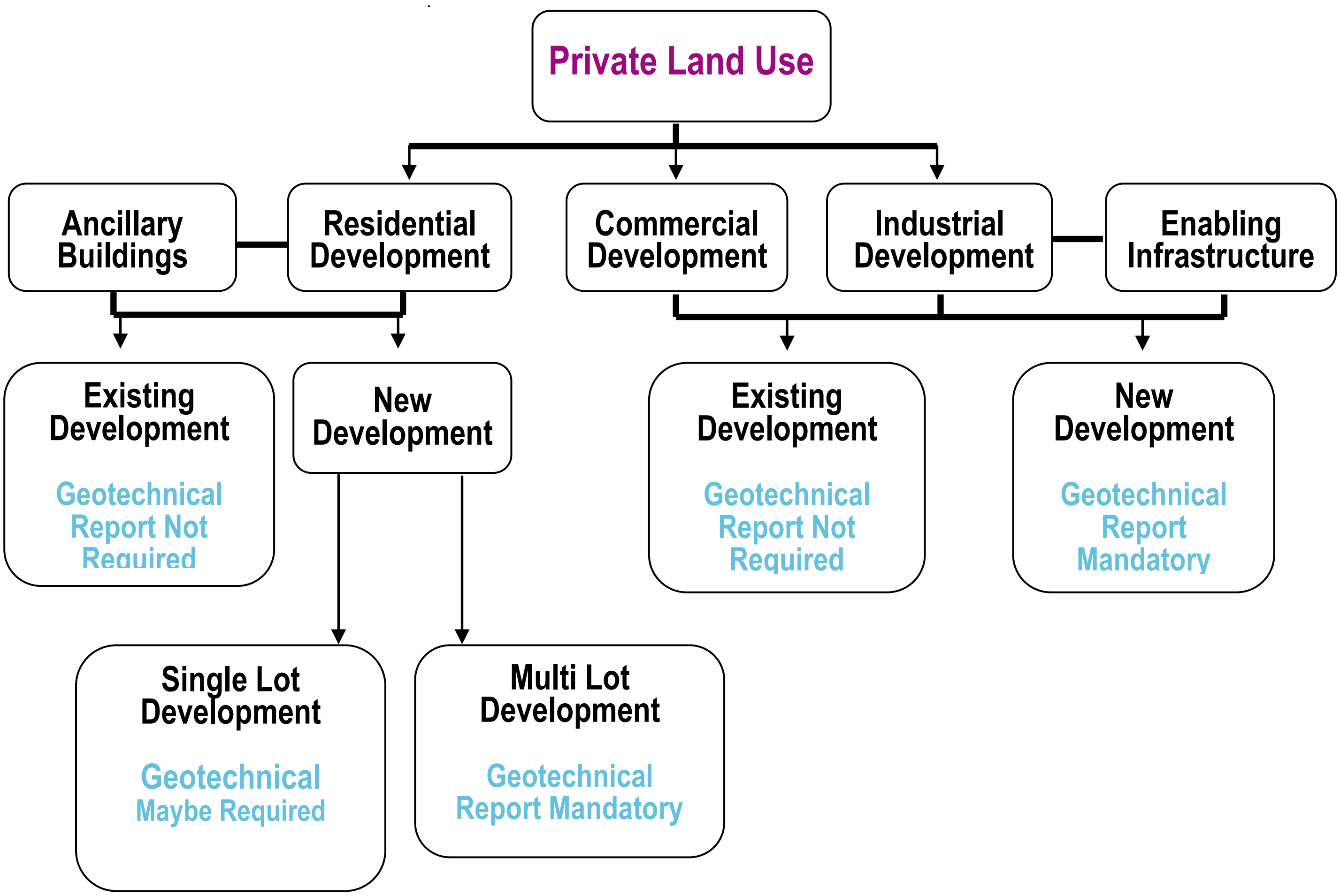
Applications for new commercial, industrial, apartment buildings and multi lot residential developments in undermined areas are required to provide a Geotechnical Report that includes a mining site assessment, prepared by a professional engineer.

Enabling Infrastructure

All enabling infrastructure (e.g., roads, transmission lines, pipelines, etc.) related to new industrial development in undermined areas will require a Geotechnical Report that includes a mining site assessment, prepared by a professional engineer.

4.1.4.3 *Proposed flow chart for need for a geotechnical report*

The flowchart below illustrates the information from Sections 4.1.4.1 and.2. On subsequent discussion with the Steering Committee it was decided that in the case of both the public information brochure and the municipalities information booklet this chart took up a lot of space and the information conveyed could be done much more succinctly with simple text. This was subsequently done – see Appendices B and C. IT is included here for completeness.



4.1.5 Role of a Geotechnical Report

Mining Impact Assessment

Geotechnical Reports for lands impacted by abandoned underground coal mine workings must be prepared to include a mining site assessment, which typically is a desk study with a field visit but no intrusive site work and should address at least the following:

Field Visit:
Visual inspection of the property (lands and structures) and adjacent lands.

Background Information:
Review relevant information on abandoned mine workings in that locality and appropriate technical reference information:

- **Mining Factor**
  Describe strata section; mine workings details (seam by seam); mine water; and potential development of surface subsidence;
- **Site Factor**
  Outline site characteristics e.g. site geology, topography, drainage etc.;
- **Structure Factor**
  Discuss the type and condition of existing and proposed structures and their expected response to potential mining subsidence; and
- **Time Factor**
  Discuss timing and duration of mine workings, any previous subsidence events and scheduling of proposed developments on the lands, etc.

Qualitative Preliminary Risk Assessment:
Assessment of potential hazards (e.g., associated with both subsidence ground movement and possible release of mine water and/or gases); assess potential severity and probability of occurrence for sinkhole and sag subsidence for all workings and summarize risks.

Assessment of Mitigation Measures:
Summary of previous or existing mitigation measures and outcome; assess need for future mitigation, type and extent required to reduce subsidence to acceptable levels.

Summary & Findings:
Outline work done, principal conclusions and recommended way to proceed to incur least risk of potential abandoned mine subsidence effects with and without mitigation measures; further studies and design requirements.

Geotechnical Reports Should Recommend

The measures specified in a Geotechnical Report, can and will be taken to ensure the development and its associated land uses incur least risk of adverse effects and are able to safely withstand the hazard. As such, a Geotechnical Report should recommend how from a mining perspective the land may be used safely for the intended development over its projected life, taking into account adjacent land uses.

Approval of Development

Where a Geotechnical Report concludes that land subject to mine subsidence may be used safely for the use intended, development approval will be conditional on implementation of all conditions contained in the Report respecting: siting, structural design, maintenance or planting of vegetation, placement of fill, etc., and on the landowner agreeing to covenant with the municipality, within the land title, to use the land only in the manner determined in the Report.

Safety Matters

Mine subsidence can cause conditions which are very hazardous. Consider signage noting dangers of entering any area that is suspicious or that has been designated or fenced off as a subsidence hazard area.

If you suspect mine subsidence on your land please call your local planning office.

4.2 Development of Best Practices for Nova Scotia - Building Codes and Inspection Building Code Practice

Building code standards were examined for how they addressed subsidence issues associated with abandoned coal mines in Nova Scotia. There are no specific subsidence requirements, apart from the ability in some circumstances to require a generic geotechnical report (which could theoretically consider subsidence hazards).

The widespread reliance of many other jurisdictions on the geotechnical report to specifically address abandoned coal mine subsidence where subsidence hazards merit is noted. The corresponding building codes sometimes reflect this. The UK has a checklist for the geotechnical report and New Zealand outlines its content requirements. In jurisdictions where coal mine subsidence regularly impacts significant numbers of landowners in many districts, like New South Wales, the geotechnical report may refer to detailed design guidelines which have also been developed for mitigation of coal mine subsidence impacts, see Section 3.2.1.4 above. It is noted however that the climate there does not include severe winter conditions found in Nova Scotia and hence major ground frost seems not to be a major consideration.

The preferred strategy for NS is therefore base building code requirements on the need for a geotechnical report as outlined in the previous section. Any recommendations of such a report for design to mitigate coal mine subsidence effects could be based on consideration of the experience elsewhere as outlined above and in the remainder of this section below. In addition it is considered beneficial to also provide a checklist for building inspectors in NS to use as appropriate to identify where coal mine subsidence is an issue and the status of any previous consideration of it.

4.2.1 Building Codes and Inspection

Taking a lead from several other jurisdictions which amend existing check-lists for inspection to accommodate mitigation of coal mining subsidence hazards, a checklist has been developed as follows below. This list is for use by building officials to help ensure the issue of underground mining has been adequately considered within the building permitting process.

Table 3 - Checklist for Consideration of Mining Subsidence Issues

Development Permit Checklist	Yes	No	Comment
1. **Is the proposed development located within an area in the integrated Land Use Zoning Map designated by NSDNR as being mined by underground workings?**			
2. **Has the property owner been notified of the potential underground mining?** 3. **Has a Geotechnical Report been conducted for this property?**			
4. **Has a mining impact assessment been included in the Geotechnical Report?**			
5. **Has the developer incorporated the recommendations of the Geotechnical Report into the plans for the development?**			
6. **Is there any indication of previous ground movement on the property, either visual, anecdotal or in the Geotechnical Report?**			
7. **Have potential mining subsidence effects been adequately dealt with in the application?**			

4.2.2 Prevention and Control of Mine Subsidence Damage to Structures

Some additional aspects for engineers to consider in geotechnical reports relating to mitigation measures follow.

4.2.2.1 Design Philosophies

In general there are three main philosophies in design of structures to mitigate subsidence effects on structures in areas prone to coal mine subsidence, these are: (1) to build structures to resist subsidence ground movement effects or (2) to build-in flexibility to accommodate ground movement due to subsidence; or (3) to relocate the structure to a more stable area where it will there will be little or no subsidence impacts (Peng, 1992). The choice of option depends upon site specific considerations, although it is noted that experience in New South Wales favours the second in low rise residential structures, as explained in section 3.2.1.4 above.

In order to aid stakeholders in Nova Scotia in their professional consideration of abandoned coal mine subsidence, the following list of scientific references is offered as a guide to information on general design philosophies pertaining to the design of structures in areas with potential for mine subsidence.

Table 4 - Sources of Information on General Design Philosophy for Designing a Structure to Prevent Damage from Mine Subsidence

Author	Year	Title	Synopsis
Appleyard, L.D.	1995.	A Reappraisal of Structural Design Concepts in Areas Subject to Ground Movement	This paper identifies the need for a common design philosophy to deal with ground movement and discusses how wind loads lie within the same order of magnitude and can be included in a coordinated process.
Bray, I.J.	1991.	Case Studies - Design of Buildings Subject to Mine Subsidence	This paper outlines a design process and philosophy for the design of buildings subject to mine subsidence. The objective is to be able to design an economical building which is structurally safe with architectural details designed to minimize non-structural damage.
Bray, I.J.,	1988.	Design of Buildings for	This paper examines procedures for the design of mine

Branch, S.E.T.		Mines Subsidence	subsidence resistant buildings and typical details are presented
Fawcett, P.	1988.	Successful Design for Mine Subsidence: the Clasp Experience	This paper outlines the development of the CLASP system and the means adopted for dealing with subsidence effects
Galvin, J.M.	1988.	Conference on Buildings and Structures Subject to Mine Subsidence - Keynote Address	This paper provides an overview of mine subsidence hazards, policies used in New South Wales, effects of subsidence and general philosophy for design.
Mine Subsidence Board	Current web-page	A Guide to Designing for Mine Subsidence	This pamphlet outlines design philosophies for various types of subsidence.
National Coal Board	1975.	Subsidence Engineers Handbook	Chapter 6 of this text book presents general structural precautions to be used when designing in areas prone to mine subsidence.
Peng S.S.	1992.	Surface Subsidence Engineering	This textbook presents general design philosophies for the prevention of structural damage associated with mine subsidence.

4.2.2.2 Specific Design Measures

In addition to noting the vast experience in New South Wales outlined in Section 3.2.1.4 above and the fact that applying such to Nova Scotia would require adapted for Nova Scotia winter conditions, the following list of some potential methods which can be considered for use in mitigation of coal mine subsidence is offered as a guide to professional engineers in preparing a geotechnical report or subsequent design reports:

1. **Fill shallow underground workings** with cement grout or backfill for local abatement of potential subsidence;
2. **Place Structure on pile foundations** based on solid ground beneath the mine workings to avoid subsidence impacts;
3. **Make Structure strong** to resist any subsidence effects;
4. **Make the structure flexible** to accommodate subsidence effects with minimum damage;
5. **Locate/relocate structure on solid pillars** of unworked coal to avoid/minimize subsidence risk;
6. **Orientate the Structure** with respect to likely subsidence movements to minimize impact;
7. **Use flexible joints** in pipes, cables, etc. To accommodate subsidence movement and avoid damage;
8. **Make the structure relatively small less than 30m across**, not more than three stories high and using a slab-on-grade foundation;
9. **Trenches filled with suitable compressible granular material** are installed outside the perimeter of concrete foundations to compensate and relieve compressive strain on foundation footing and walls. Properly design exterior trenches are required for both the length and width of the structure;
10. **Reinforced Concrete Anchoring Slabs** installed on top of a flexible foundation in buildings subject to large horizontal strain either along the short or long axis of the structure resist failure because the strain is not transferred to the structure. The reinforce concrete slab (80 to 120 mm thick) with tension reinforcing bars placed on layer of poly liner over 150 mm of sand performs as a ridged structure and horizontal and vertical forces are dissipated in the flexible sand layer;
11. **Slotting** should be made along the interior walls or along the lines where height or shape or both change. The height in each unit separated by the slot should be uniform. The idea is to divide a complex structure into separate independent sub-units. Temporary walls or posts should be erected on both side of the slot;
12. **Levelling by underpinning and pinning** is accomplished by installing and using hydraulic or screw jacks at strategic points around the base or foundation of a structure to be impacted by coal mining subsidence. These

are then used to adjust and maintain the structure level as it subsides; it is especially useful when predicted subsidence subjects the structure to sloping and/or curvature impacts;
13. **Levelling with springs** is utilized in order to keep houses level during underpinning, springs are installed at the places where ground steps are likely to occur. Several groups of springs installed under the floor joist may be needed;
14. **Reinforcing with Tension Rod or Tension Cable** can be used to tighten a house structure at the roof beam or floor joist levels. The tension rods and cables must be firmly tightened at the ends and supported at regular intervals. Steel tension rods and cables are designed to resist and compensate for the effects of curvature and tensile strain on the walls of a structure;
15. **Wall Shoring and Internal Bracing** is utilized as a method to prevent and compensate for toppling and collapse of or tilling of masonry walls. Interior wall bracing is designed to maintain the stability of the interior load bearing walls;
16. **Reinforced Concrete Beams** when surface deformations are extreme, reinforced concrete beams may be installed around the house structure at the basement level. Reinforced concrete beams are excellent for resisting horizontal strain and negative curvature, and if beams are installed at the floor joist or roof beam level, they can also cope with the problems associated with positive curvature; and
17. **Foundation Bracing Beams** can be installed to reduce the transversal moment of a longitudinal wall, especially if the building does not have transversal walls or the distance longitudinal walls is large, transverse reinforced concrete bracing beams resist transversal moments due to subsidence.

Similarly, In order to aid stakeholders in Nova Scotia in their professional consideration of abandoned coal mine subsidence, the following list of scientific references is offered as a guide to support the above with information on specific measures to prevent structural damage as a result of mine subsidence.

Table 5 - Sources of Information Regarding Specific Design Measures for the Prevention of Structural Damage from Mine Subsidence

Author	Year	Title	Synopsis
Appleyard, L.D.	2001	A review of the formulation and implementation of Graduated Design Guidelines for Residential construction in mine subsidence areas of New south Wales	The publication and implementation of the Graduated Design Guidelines by the Mine Subsidence Board provide a framework for the uniform assessment of building applications by the Board's Officers, a framework which is based on current building industry best practice as defined by relevant design codes and regulatory legislation.
Arch, B.,	1991.	Brickwork for Mine-Subsidence-Prone Sites	This paper provides information on how brickwork for domestic scale buildings can be designed to perform adequately on mine subsidence prone sites
Bell, F.G., Fox, R.M.	1988.	Ground Treatment and Foundations above Discontinuous Rock Masses affected by Mining Subsidence	This paper examines foundation treatment methods to overcome problems from mine subsidence , particularly subsidence associated with long wall mining
Li, J., Cameron, D.A.	1995.	Analysis and Design of House Footings Subject to Ground Movements	The paper outlines a method for analysis of raft slab subject to mining induced ground movement
Lin, P.M., Peng, S.S., Tsang, P.	1990.	Dealing with Subsidence on Abandoned Mine Lands	Presents a case study in Germany where a house was re-levelled using precision hydraulic equipment.
Mine Subsidence Board		Designing for "Pothole" Subsidence	This pamphlet outlines design measures to address pothole subsidence
National Coal	1975.	Subsidence Engineers Handbook	Chapters 8 and 9 in this textbook present structural

Board			precaution measures for designing with respect to mine subsidence.
Peng S.S.	1992.	Surface Subsidence	Chapter 6 in this textbook discusses the prevention and control of surface structural damage associated with mine subsidence.
White, R.J., Page, A.W.	1998.	Development and Full Scale Testing of a Mine Subsidence Resistant Masonry House	This paper provides the results of a test conducted to study the behaviour of a purpose designed masonry residence when subjected to deformations of a long wall mining event. The specific design measures used in the test house are presented and evaluated.

5. Compendium of Technical References

A list of science-based references was developed and populated with findings from the research described in **Section 3** above. The objective of this compendium of references is to capture all relevant science-based documents identified during the study and to provide a list of resources of relevant practices used for improved decision making, planning and management of abandoned underground coal workings, and on building in these areas, see Appendix D which is list of more than 100 different technical references cross-referenced as follows: land-use planning; structural aspects; hazard characterization; compensation/insurance; and mine cavity remediation.

6. Sustainability Report

Given the changing global context of the considerations of abandoned coal mine subsidence and the ever-increasing awareness of the reality of global climate change, there is an increased need to address the related aspects of sustainability. The scope of work therefore included a sustainability component. In response to this, AECOM prepared a report called: “Preparing for Climate Change in land use planning for rehabilitated coal mines in Nova Scotia”, with sections on: purpose; impacts of climate; and policy response change and proposed approach for responding to climate impacts (including management of risks) . This is included in Appendix E.

6.1 Overall project sustainability

AECOM has a range of sustainability policies that cover all aspects of our business, however, in undertaking this project we endeavoured to review these and see what additional activities could be undertaken.

As part of the initial project establishment, a high-level review was undertaken of the project’s environmental and social footprint. Given the brief duration of the project and its limited scope – limited to office-based work and travel related to client visits – it was determined that the main impact from this project is greenhouse gas emissions. Accordingly, AECOM has calculated its greenhouse gas emissions inventory and purchased offsets for these emissions.

6.2 Greenhouse Gas Emissions Inventory

AECOM has reviewed its operations in relation to this project and determined that there are two (2) main sources of greenhouse gas emissions: electricity use associated with office work and vehicle travel to client meetings.

Greenhouse gas inventories were calculated using activity data (what people actually due) and emissions factors (greenhouse gas intensity of each action). As a result of having a comprehensive project plan that outlines the tasks in detail - hours to be worked and travel undertaken - we have high confidence in the activity data. For emission factor data we used average Canadian Fleet efficiency for car-based travel and an AECOM sustainability report was

used for office-based emissions.[1] The total calculated emissions from this project were estimated as equivalent to 1.45 tonnes of carbon dioxide.
The detailed results of the greenhouse gas emissions inventory are provided in Table 6-1 below. Recognising that there are uncertainties around emissions estimates, AECOM included a 20% conservative factor, which is consistent with industry good practice.

Emissions from office work	0.95
Emissions from car-based travel	0.50
Sub-total emissions	**1.45**
Conservative factor (+20%)	0.29
Total emissions	**1.74**

Figure 6-1 - Greenhouse Gas Emissions Associated with this Project

In its proposal, AECOM indicated it would offset all emissions associated with this project. Accordingly we have purchased two tonnes of carbon offsets from ZeroCO2. These offsets fully meet the Voluntary Carbon Standard, and are considered "Gold Standard." This purchase means that AECOM has fully offset its emissions associated with this project and includes a "real conservative factor "of over a third of the project's total emissions.

7. Summary

AECOM was retained by Service Nova Scotia and Municipal Relations and worked closely with a Steering Committee comprising representatives from three provincial government departments and several municipalities, to address matters pertinent to abandoned underground coal mine workings. The prime intent and purpose was to provide municipalities within Nova Scotia with a set of guidelines to assist in discharging their responsibilities to specifically address (i) land-use planning and (ii) building code application related to the hazards of abandoned underground coal mine workings. There was also a focus on enabling the municipalities to address public safety and determine appropriate utilization of their land resources to meet the best public interest in such areas.

These goals were achieved by a study with four principal outcomes:

- A Brochure to Inform the General Public;
- A Booklet to Inform and Guide Municipalities in Best Practices on both Land-use Planning & Building & Construction Standards;
- A Compendium listing many supporting technical papers for future reference; and
- This Project report.

The basic characteristics of abandoned coal mine subsidence are characterized around the two (2) basic types: sinkhole and sag subsidence. This information was then condensed into a proposed brochure for distribution to provide information to the general public, see Appendix B.

A review of current practice in Nova Scotia and in other impacted jurisdictions around the world was undertaken. In terms of land use planning it revealed that provincial legislation and municipal building bylaws and subdivision bylaws in Nova Scotia do not have specific requirements or regulations to address abandoned coal mine subsidence issues whereas many jurisdictions do. The UK and Australia have comprehensive subsidence compensation and administration legislation funded by coal mining operations which cover mitigation and remediation of subsidence damage from both active and abandoned coal mine workings. This is not the case in United States or Canada. Some states of the USA have self-funding subsidence insurance programs to compensate property owners from both active and abandoned coal mine workings. Many states require geotechnical reports to support development in

[1] *The Sustainability Report used was for Australia on the basis that the work undertaken is broadly consistent between AECOM offices. Compensation was made for differences in greenhouse gas intensity between Canada and Australia.*

such impacted areas. Canada currently has no such compensation or insurance programs, although abandoned coal mine subsidence has municipal recognition in both Canmore, Alberta and in Nanaimo BC. Both require a geotechnical report, Canmore also stipulates an independent review of geotechnical reports and appropriate insurance must be provided required by developers.

In terms of building code application there is no defined trigger in Nova Scotia requiring a geotechnical investigation for subsidence mitigation measures in the Nova Scotia Building Code. Elsewhere, a geotechnical report is a common requirement in building permitting processes in subsidence areas, for example in: Canmore, Alberta; Nanaimo, BC; UK; Australia; NZ and some states in the USA. These reports take into account relevant information, site assessment, subsidence assessment, need for mitigation measures, geotechnical investigation or special structural design considerations. Three examples were identified of specific municipalities elsewhere which address abandoned coal mine subsidence specifically: Canmore, Alberta, Nanaimo, BC in Canada and Whangarei in New Zealand. The former has provincial legislation in place and all require geotechnical reports on lands for development where subsidence hazards prevail. Whangarei also has rules which prescribe three levels of subsidence hazard zones. A similar approach has been taken during remediation of abandoned mines on federal crown land in Cape Breton lands on where Mine Workings Protocols have been developed which use a three zone hazard mapping system.

The review of current practice in land use illustrated significant differences between Nova Scotia and elsewhere, mainly in the lack of specific reference to abandoned coal mine subsidence in Nova Scotia provincial legislation, municipal bylaws and building code application. A mutually agreeable direction was developed for best practice in land use policy development comprising three levels:

- To modify Municipal Planning strategies to accommodate the issue of abandoned coal mine subsidence to protect life and property from both natural and man-made hazards;
- To amend Land Use Bylaws to include three new items:
  - A schedule of maps of areas of coal underground mining in municipalities, provided by the provincial government, and
  - A regulation in the appropriate land use zone or a general development regulation identifying the need for a geotechnical report to ensure safety of proposed development within an area with underground coal mine workings, including minimum report requirements; and
- To amend the development/building permit stage to allow means of notification of land owners at an early stage when their property is shown as being undermined by coal workings and on the need for a geotechnical report.

The direction for best practice in building code application was based on first the widespread reliance of many other jurisdictions on the geotechnical report to specifically address abandoned coal mine subsidence where subsidence hazards merits it. The preferred strategy for NS is therefore to supplement building code requirements in abandoned coal mine subsidence impacted areas with the need for a geotechnical report where hazards merit it. When such a report refers to design guidelines developed elsewhere for mitigation of coal mine subsidence impacts, they must be placed in the context of the major ground frost and severe winter conditions found in Nova Scotia. Further, it is considered beneficial to also provide a checklist for building inspectors in NS to use as appropriate to identify where coal mine subsidence is an issue and the status of previous consideration of it.

These best practices and the supporting information have been incorporated into a booklet for guiding and infirming municipalities in these matters, see Appendix C.

Issues not specifically addressed but for possible consideration in future include:

- Relative merits of a self-funding insurance scheme for land owners in NS; and
- Impact of proposed best practices on land values.

8. References:

Table 6 – References in Text (Reference: Appendix D – Compendium of References)

Alberta Regulation 114/97 Municipal;	Current web-page	Alberta Government Act Canmore Undermining Review Regulation
Appleyard, L.D.	1995.	A Reappraisal of Structural Design Concepts in Areas Subject to Ground Movement. MINE SUBSIDENCE TECHNOLOGICAL SOCIETY **(**A Society of the Institution of Engineers, Australia)**.** Proceedings of the third Triennial Conference on Buildings and Structures subject to Mine Subsidence. Newcastle, 5th to 7th February 2 1995**.**
Appleyard, L.D.	2001	A review of the formulation and implementation of Graduated Design Guidelines for Residential construction in mine subsidence areas of New south Wales. MINE SUBSIDENCE TECHNOLOGICAL SOCIETY **(**A Society of the Institution of Engineers, Australia). Proceedings of the 5th Triennial Conference Coal Mine Subsidence 2001: Current Practice & Issues, Maitland, 26th to 28th August 2001
Bruhn, R.W., and others	1978	Subsidence Over the Mined-Out Pittsburgh Coal" American Society of Civil Engineers (ASCE) Spring convention, Pittsburgh, ASCE Preprint 3293, pp 26-55.
Cape Breton Regional Municipality	Current web-page	Municipal Planning Strategy (February 20, 2010); and Official Community Plan.
City of Nanaimo	Current web-page	Development Services Building Inspection Division "Guidelines for the Preparation of Geotechnical Report"
Hartman, H.L., senior editor	1992	SME Mining Engineering Handbook. Society for Mining, Metallurgy & Exploration, Inc. Littleton, CO.
Mine Subsidence Board New South Wales Aust.	Current web-page	A Guide to Designing for Mine Subsidence.
National Coal Board (UK)	1975.	Subsidence Engineers Handbook (out of print)
Peng S.S.	1992	Surface Subsidence Engineering. Society for Mining, Metallurgy & Exploration, Inc. Littleton, CO.
Queensland Building Services Board	Current web-page	Fact Book Engineering Investigation and Design and Construction Practices
Tonkin and Taylor	1999	Reference Number: 17464, October 1999. Report Prepared for: Whangarei District Council, Report Prepared By: Tonkin & Taylor Ltd.
UK Department for Transport,	2003 Current web-page	"PG14 Planning Policy Guidance Development on Unstable Land" & Annex 2 of PG14 "Subsidence and Planning"

Local Government and the Regions		
Whangarei District Council	1982	Policy for Building & Subdivision in Mining Zones,
White, R.J., Page, A.W.	1998.	Development and Full Scale Testing of a Mine Subsidence Resistant Masonry House; MINE SUBSIDENCE TECHNOLOGICAL SOCIETY **(**A Society of the Institution of Engineers, Australia) Proceedings of the Conference on Buildings and Structures subject to Mine Subsidence; Maitland, 28th to 30th August 1988

Appendix A

Agreement

REQUEST FOR PROPOSALS 60139406, OUTLINE AGREEMENT 4600012944

Development of Best Practices Guide: Land Use Planning and Building Construction Standards for Sites with Abandoned Underground Coal Workings

Sponsored by the Department of Service Nova Scotia and Municipal Relations

THIS AGREEMENT made this 13th day of April, 2010

BETWEEN:

HER MAJESTY THE QUEEN in right of Her PROVINCE OF NOVA SCOTIA,
represented by the Minister of Economic and Rural Development
(hereinafter referred to as "the Minister")

OF THE FIRST PART

- and -

AECOM CANADA LTD.
(hereinafter referred to as "the Supplier")

OF THE SECOND PART

In consideration of the mutual promises contained in this Agreement, the parties covenant and agree as follows:

1. **SERVICES**
   1.1 The Supplier shall, during the period commencing on the 19th day of April, 2010, and ending on the 19th day of July, 2010, provide the services to the Minister as outlined in Schedule "A" attached hereto.
   1.2 The Supplier shall perform the work under the direction and always to the satisfaction of the Minister.
   1.3 When anything is required to be done by the Minister, it may be done by anyone duly authorized to act on behalf of the Minister.

2. **PAYMENT**
   2.1 Subject to article 2.3 the Minister, for the satisfactory performance of the services referred to in article 1.1, shall pay the Supplier in respect of the period during which services are performed in accordance with the fee structure and work estimate set out in Schedule "B" attached hereto.
   2.2 The Minister shall remit to the Supplier the amount of any outstanding invoices due to the Supplier under article 2.1 after presentation by the Supplier to the Minister, on each instance, of a statement, certified correct and approved by the appropriate officer of the Minister, showing *inter alia*, that the Supplier performed the services during the period in respect of which the amount is to be paid.
   2.3 Notwithstanding anything else contained in this Agreement, unless prior written approval of the Minister is obtained, the total amount payable to the Supplier under the Agreement shall not exceed fifty thousand dollars ($50,000.00) in Canadian funds (not including taxes) and no work in excess of this limitation shall be undertaken.
   2.4 The Supplier shall maintain appropriate accounting records for the services provided under this Agreement and shall make available to the Minister such accounting records for audit purposes as the Minister may require.

3. **TERM OF AGREEMENT**
   3.1 The term of this Agreement shall be as defined in article 1.1 of this Agreement.
   3.2 Notwithstanding article 3.1, this Agreement may be terminated by the Minister upon giving at

least thirty (30) days notice in writing to the Supplier.

3.3 Notwithstanding articles 3.1 and 3.2, this Agreement may be terminated by the Minister without further liability, damage or cost, if, in the opinion of the Minister, the Supplier has breached or defaulted or failed to comply with any of the terms and conditions of this Agreement and has failed to remedy the same after being given five days notice in writing to remedy the breach, default or failure.

3.4 Completion by the Supplier of the services outlined in article 1 or termination of the Agreement by the Minister in accordance with article 3.2 or 3.3 shall in no way relieve or be deemed to relieve the Supplier from any ongoing duties, obligations or liabilities which may arise from this Agreement, including but not restricted to those set out in articles headed Confidentiality, Rights in Data, and Liability and Indemnity.

3.5 In the event of termination, in accordance with article 3.2, the Minister will pay the Supplier an amount calculated under the terms of payment for all work performed and accepted together with such further amount as will in the opinion of the Minister compensate the Supplier for reasonable expenses continuing after the date of termination, less any amounts that have been previously paid to the Supplier under article 2.

3.6 The parties may by mutual consent extend this Agreement by giving written notice of an intent to do so on or before the termination date defined in article 1.1 of this Agreement.

4. COPIES

4.1 In the event of termination of this Agreement or of the completion by the Supplier of the services outlined in article 1, the Supplier shall deliver to the Minister all materials including, but not restricted to, all research, reports, papers, tapes, slides, films, photographs, audio-visual material, and all input data or other information submitted to the Supplier or developed by the Supplier in the performance of this Agreement, whether in draft or completed form.

5. CONFIDENTIALITY

5.1 The Supplier shall keep private, treat as being confidential, and not make public or divulge during as well as after the term on this Agreement, any information or material to which the Supplier, its staff or its agents becomes privy as a result of acting under this Agreement without having first obtained the Province's explicit consent. The Supplier shall provide information or material strictly and solely to those individuals who are assigned to the performance of this Agreement.

5.2 The Supplier, on its own behalf and that of its staff and its agents shall take appropriate precautions to safeguard information and material to which they are privy as a result of acting under this Agreement from unauthorized viewing or access, theft, tampering, sabotage or unauthorized copying or transmission. The Parties agree that the information relating to subsidence is presumptively highly sensitive and requires secure safeguards.

6. RIGHTS IN DATA

6.1 All research, reports, papers, material, audio-visual material and information forming part of or produced in the performance of this Agreement and all copyrights, patents, trademarks, industrial designs and other property rights arising therefrom, are the sole property of the Minister, and are hereby assigned by the Supplier to the Minister, provided that the pre-existing intellectual property rights in materials and information belonging to the Supplier shall remain with the Supplier. The Supplier also waives all claims to moral rights in respect of that which is assigned.

6.2 The Supplier shall not divulge, release or publish any such research, reports, papers, material, audio-visual material or information, in whole or in part, without first having obtained written permission from the Minister. The Minister reserves the right to publish or release in whole or in part, to publish an amended version and not to publish or release at all, or to use or not use as the Minister may deem fit, any research, reports, material, audio-visual materials, or information produced in the performance of this Agreement.

6.3 The Supplier shall ensure that the Minister has all licenses required for any software that may be used pursuant to this Agreement.

6.4 The Supplier hereby grants to the Minister a non-exclusive license in perpetuity to use any computer software, designs or similar materials of a generic nature to which the Supplier holds copyright, and that may be included in any work product delivered to the Minister under this Agreement.

6.5 Notwithstanding the above, the copyright to any computer software, designs or similar materials of a generic nature bearing the copyright of the Supplier that may be used in the performance of the Supplier's services under this Agreement, or that may be included in any work product delivered to the Minister, shall remain with the Supplier. The Supplier shall not claim a copyright to any material which is not legitimately the Supplier's work, and shall not claim a copyright to any work developed using the Minister's funds or to any work which is unique to this Agreement. The Minister may modify any such materials as required, so long as the Supplier's original copyright notification is not deleted or changed. The Minister shall not permit any party other than the Province of Nova Scotia to make use of such material without the permission of the Supplier.

7. INDEPENDENT CONTRACTOR

7.1 It is understood and agreed that this Agreement is a contract for the performance of a service and that the Supplier is engaged as an independent contractor and is not nor shall be deemed to be an employee, servant or agent of the Minister.

8. COMPLIANCE WITH LAWS

8.1 The Supplier shall give all the notices and obtain all the licenses and permits required to perform the work. The Supplier will comply with all laws applicable to the work or performance of the Agreement.

9. WORKERS' COMPENSATION

9.1 The Supplier shall comply with the Nova Scotia *Workers' Compensation Act.* Prior to receiving payment under this Agreement, the Minister may require the Supplier to submit a Workers' Compensation Board (WCB) Clearance Letter indicating that all WCB assessments have been paid.

10. LIABILITY AND INDEMNITY

10.1 The Minister shall not be liable for any injury or damage (including death) to the person or for the loss of damage to the property of the Supplier in any manner based upon, occasioned by or in any way attributable to the Supplier's services under this Agreement unless such injury, loss, or damage is caused solely and directly by the negligence of an officer or servant of the Minister while acting within the scope of his or her employment.

10.2 The Supplier shall use due care in processing the Minister's work. The Supplier shall not be liable for any indirect or consequential damages related to the services performed under this Agreement unless caused by the Supplier's negligence.

10.3 The Supplier agrees that it shall at all times indemnify and save harmless the Province, its Ministers, officers, employees and agents from and against all claims, demands, losses, costs, damages, actions, suits or other proceedings of any kind based upon injury, including death, to any person, or damage to or loss of property arising from any wilful or negligent act, omission or delay on the part of the Supplier, its servants or agents in carrying out this Agreement.

11. PERFORMANCE

11.1 The Supplier shall faithfully, honestly, and diligently service the Minister during the period of this Agreement.

11.2 It is understood that the Supplier shall provide office space equipped with such furniture, together with such staff and other services and equipment as may be necessary for the carrying out of the services required under this Agreement. The Minister may provide at his discretion and for such time period as the Minister deems appropriate, office space and facilities to the Supplier as may be necessary for the carrying out of all or part of the services required under this Agreement.

11.3 The Minister reserves the right to demand that the Supplier replace any individual who is working on the project and who is found to be unsuitable in the Minister's sole discretion.

11.4 The Supplier represents and warrants that its employees, subcontractors and agents shall be duly qualified, trained, experienced and prepared to perform the obligations under this Agreement. Obligations shall be performed with reasonable diligence, care, skill, attention and professional acumen and in a prompt and timely manner.

11.5 The Supplier represents and warrants that all services, goods and deliverables shall be in compliance with regulatory or industry standards and practices.

12. TITLE AND ACCEPTANCE

12.1 Except as otherwise provided in this Agreement, title to the product defined in Schedule "A" attached hereto or any part thereof shall vest in the Minister upon delivery to and acceptance by the Minister. Upon any payment being made on account of materials, parts, work in process, or finished work, title to the goods and services so paid for shall vest and remain in the Minister, and the Supplier shall be responsible therefor, it being understood and agreed that such vesting of title in the Minister shall not constitute acceptance and shall not relieve the Supplier of its obligations to perform the work in conformity with the requirements of this Agreement.

13. PRODUCTS TO BE DELIVERED

13.1 Under this Agreement the Supplier will deliver the items as referred to in the Schedule "A" attached hereto to the Minister, and these items shall conform to the format and standards established by the Minister during the course of the Agreement and conveyed to the Supplier by notice.

13.2 No work shall be considered complete until it has been accepted and approved in writing by the Minister.

14. FORCE MAJEURE

14.1 The Supplier shall not be liable for failure to provide the services outlined in Schedule "A" if such failure is due to causes beyond its reasonable control if and only if the Minister is notified within five (5) days in writing of the existence of such a failure, its causes and the reasons for its being beyond the reasonable control of the Supplier.

15. FUNDING

15.1 Notwithstanding anything else contained in this Agreement, this Agreement is subject to:

(i) there being sufficient monies available in the appropriation to enable the Minister to make payment;

(ii) Department of Finance, not having controlled or limited expenditure under any appropriation referred to in (i)

16. ASSIGNMENT

16.1 The Supplier shall not assign or sublet this Agreement, in whole or in part, without the written permission of the Minister.

17. NOTICES

17.1 All notices under this Agreement shall be deemed duly given; upon delivery, if delivered by hand; or three days after posting if sent by registered mail, receipt requested; to a party at the address set out in this Agreement or to such other address as designated by a party by notice in accordance with this Agreement. Nothing in this section shall prevent notice from being given by any other means.

The Minister	The Supplier
c/o Contract Administrator Nova Scotia Procurement 6176 Young Street PO Box 787 Halifax, Nova Scotia B3J 2V2	c/o Shawn Duncan AECOM Canada Ltd. SH400 (PO Box 576 CRO) 1701 Hollis Street Halifax, Nova Scotia B3J 3M8

18. TIME SHALL BE OF THE ESSENCE

18.1 Time shall be of the essence of this Agreement, provided that the time for completing any of the work that has been or is likely to be delayed by reason of Force Majeure may be extended at the Minister's discretion if the other terms of this Agreement are satisfied.

19. ENTIRE AGREEMENT

19.1 This Agreement and the Schedules attached or referred to constitute the whole Agreement between the parties unless duly modified in writing and signed by both parties. No representation or statement not expressly contained in this Agreement shall be binding upon either party.

19.2 The Schedules attached to this Agreement form an essential part of this Agreement and should there be any conflict between the general terms and conditions of the Agreement and the Schedules then the Schedules govern the Agreement interpretation.

20. GOVERNING LAWS

20.1 This Agreement shall be construed and interpreted in accordance with the laws of the Province of Nova Scotia.

21. CONSENT TO BREACH NOT WAIVER

21.1 No term or provision of this Agreement shall be deemed waived and no breach excused, unless such waiver or consent shall be in writing and signed by the party claimed to have waived or consented. Any consent by any party to, or waiver of, a breach by the other, whether expressed or implied, shall not constitute a consent to, a waiver of, or excuse for any different or subsequent or a continuation of the same breach unless expressly stated.

22. PARTIAL INVALIDITY

22.1 If any term or provision of this Agreement shall be found to be illegal or unenforceable, notwithstanding, this Agreement may, at the Minister's option, remain in full force and effect and such term or provision shall be deemed removed from the Agreement.

23. DEFINITION OF SUPPLIER

23.1 References to the Supplier shall include employees, servants and agents of the Supplier, independent contractors to the Supplier and employees, servants, agents and independent contractors of assignees if the Agreement or its performance is assigned.

24. SECURITY AND PRIVACY

24.1 The Supplier shall comply with all security and privacy procedures and policies of the Minister as they may be, from time to time, forwarded to the Supplier.

25. AUTHORITY

25.1 The signatories of this Agreement personally warrant that they have the full power and authority to enter into this Agreement on behalf of their respective principals and that the person signing this Agreement on behalf of each has been properly authorized and empowered. Each party further acknowledges that it has read the Agreement, understands it, and agrees to be bound by it.

26. OFFERS OF EMPLOYMENT

26.1 Each party to this Agreement, throughout the term of the Agreement and for a period of six months thereafter, undertakes that, without the prior written approval of the other party, it shall not induce any employee(s) of the other party to terminate his or her employment with the other party.

27. EFFECTIVE DATE

27.1 This Agreement shall take effect as if it has been executed by both parties on the 19th day of April, 2010.

IN WITNESS WHEREOF the Minister and the Supplier have caused this Agreement to be executed by their respective officers duly authorized in that behalf on the dates hereinafter set forth.

WITNESSED BY:

DATED AT Halifax, Nova Scotia,
this 10th day of May, 2010.
AECOM CANADA ~~LTD~~.

Witness

~~for the~~ Supplier

DATED AT Halifax, Nova Scotia,
this 11 day of May, 2010.
HER MAJESTY THE QUEEN in right of Her Province of Nova Scotia

Witness

for the Minister

SCHEDULE A

This schedule of the Agreement describes the services to be carried out and products to be delivered by the Supplier, and supplementary conditions relating thereto.

This schedule incorporates the following:

A.1 Request for Proposals

Request for Proposals 60139406 issued by the Minister in February, 2010 is incorporated herein by reference and describes the services to be performed and products to be delivered.

A.2 Supplier's Proposal

The Proposal submitted by the Supplier dated March 15, 2010, is incorporated herein by reference.

The Supplier proposes to provide all professional engineering services required to prepare Best Practice Guidelines for Land Use and Building Construction Standards for Sites with Abandoned Underground Coal Workings.

Supplier Initial: ____________ ED Initial: ____________

SCHEDULE B

This schedule to the Agreement describes the payment terms for each phase of the project and planned delivery dates.

B.1 Payment

The total amount payable under this Agreement is defined in article 2.3 of this Agreement. It shall be invoiced as follows:

Three invoices to be submitted as per the schedule listed below. Payment will be released upon approval of the user Department.

One third after Task 4	Interim Meeting with Steering Committee
One third after Task 6	Development Compendium of Science – based references
One third after Task 7	Final Report

Payment will be made under the provisions of article 2. of this Agreement.

B.2 Work Plan

The project work plan submitted by the Supplier is included in this Schedule by reference.

Supplier Initial: ________ ED Initial: ________

SCHEDULE C

PERSONAL INFORMATION INTERNATIONAL DISCLOSURE PROTECTION ACT

The Supplier acknowledges and confirms that it is a "service provider" as defined in the *Personal Information International Disclosure Protection Act*, SNS 2006 c. 3 ("PIIDPA"), that it has read and understands its obligations as a service provider thereunder and that as a service provider it is legally bound by the obligations imposed on it by PIIDPA. It is a condition precedent to the Minister entering into the Agreement with the Supplier that the Supplier irrevocably undertakes, covenants and agrees to be bound by and comply with the obligations imposed on it as a service provider under PIIDPA.

The Supplier further covenants, warrants and represents to the Minister that it will not at any time provide or allow the release of personal information to which it has access in its capacity as a service provider to the Minister in response to any "foreign demand for disclosure" or permit or allow the "unauthorized disclosure of personal information" as each of those terms are defined in PIIDPA.

The Supplier shall implement and strictly enforce security arrangements that will ensure that all personal information that it collects or uses on behalf of the Minister is protected at all times from unauthorized access or disclosure and shall confirm in writing to the Minister, upon request, the details of such security arrangements. The Supplier also agrees to implement and enforce any additional security procedures as may be required by the Minister from time to time to protect the personal information that the Supplier collects or uses on behalf of the Minister. The Minister shall be authorized, upon giving prior written notice to the Supplier, to enter the premises of the Supplier during normal business hours for the purpose of conducting an audit of the security arrangements referenced herein.

All personal information that the Supplier obtains or becomes aware of while providing services to the Minister is not and shall not be or be deemed to be the property of the Supplier. The Supplier acknowledges and agrees that it will not, either directly or indirectly, acquire any rights to use or own any such personal information other than the right to use it for the sole purpose of fulfilling its obligations to the Minister under the Agreement.

Supplier Initial: ____________ ED Initial: ____________

AECOM

Appendix B

Brochure for General Public Use

Introduction

The purpose of this brochure is to inform and provide guidance to stakeholders involved in the development of lands undermined by underground coal mines. Most new development over these undermined lands in the coalfields of Nova Scotia over the last few decades has been achieved with no harmful effects of mine subsidence. There have however been a few well publicized exceptions which illustrate what can happen. These guidelines therefore take a precautionary approach to new development on lands undermined by coal mines in Nova Scotia.

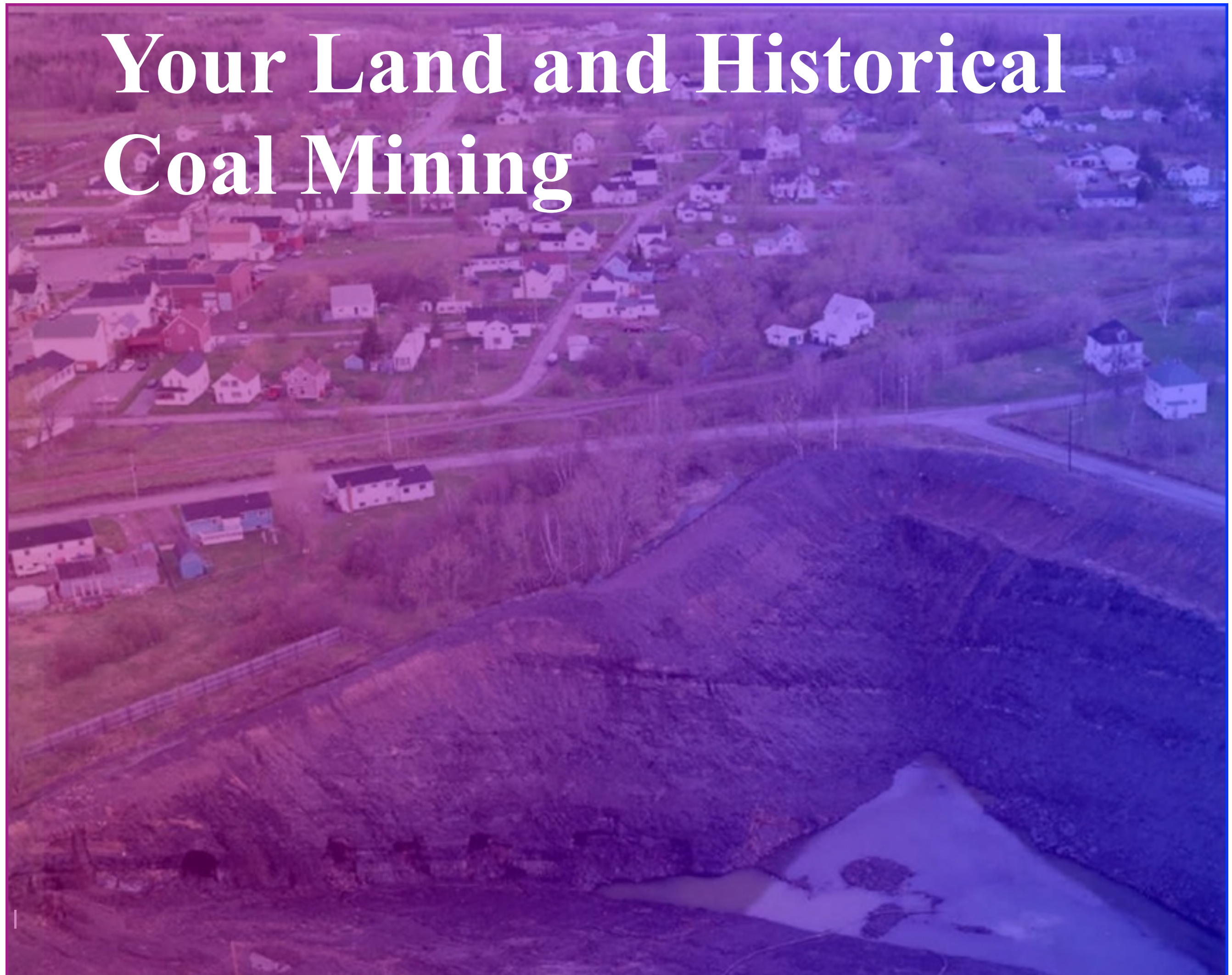
What is Subsidence?

Coal has been mined in Nova Scotia since the 1600's. This activity has left many areas affected by historical underground coal mining. Such undermined lands may be affected by events known as mine subsidence with two types: sinkhole subsidence (i.e. open holes) and sag or trough subsidence (i.e. shallow saucer-shaped depression). Subsidence effects on surface development depend on the depth and size of mining excavation (width, length and height), type of rock and geological structure, groundwater conditions, as well as type, construction and condition of surface structures, etc. Subsidence events can occur many years after mining ceased. It is very difficult to predict where and when these will occur because of the unknown details and condition of the underground workings. Despite these limitations general guidelines and generic precautionary and remedial approaches are available.

Sinkhole Subsidence

Sag Subsidence

Your Land and Historical Coal Mining



NOVA SCOTIA

Service Nova Scotia and Municipal Relations

AECOM

When is a Geotechnical Report is Required

Who is Responsible?

Within the Province of Nova Scotia responsibility for property damage occurring as result of subsidence from abandoned coal mining resides with the landowner — the Province and municipalities assume no responsibility for subsidence and are not liable for property damage occurring as a result of subsidence .

Information for Landowners

As landowner, if you are applying for a building permit in affected municipalities you may be informed if there is undermining on your property. Depending upon the type of development you may then be required by the municipality to provide a geotechnical investigation. You are responsible for obtaining professional advice from a professional engineer to complete such a geotechnical investigation.

Existing properties have no requirements for a geotechnical investigation unless you intend to change the use of a building or an unsafe condition is found to exist .

Preparation of a Geotechnical Report

Where required, a Geotechnical Report must be prepared and stamped by a Professional Engineer.

Mine Subsidence Damage

Most development on undermined lands does not incur any harmful subsidence. In some cases damage can occur (see photographs below of the MacDonald High School in Dominion, NS and house in Westville, NS). Information on such damage and its prevention follows.

How Mine Subsidence Causes Damage

Abandoned coal mine subsidence causes damage because structures respond to movements of the ground on which they are built. As the foundations which provide support for the walls and columns follow movement of the ground, then movement may commonly propagates upward into the main part of the structure and failure may occur. The effects of mine subsidence on a structure are divided into three types depending upon the type of ground movement which caused the damage: compression effects, tension effects, and slope or tilt effects.

Signs to Look For

These effects can cause cracking in plaster walls, cracking in brick walls, separation of pipes, windows and door frames to move and jam, and cracking in floor slabs (as shown in the photographs of interior of MacDonald High School, Dominion NS).

Preventing subsidence damage

Approaches to prevent subsidence damage include: avoidance (land use controls); filling the mine; or excavating/collapsing workings and backfill; and/ or structural modifications.

Non-Mining Causes of Similar Damage

In lands undermined by coal mine workings most structural damage to residential properties is *not* caused by mine subsidence. It is important to be aware of structural damage which closely resembles damage caused by mine subsidence but may in fact be caused by other factors, including: poor construction, sulphates reacting with cement, shrinkable clay, differential settlement, altering of conditions owing to: poor drainage; rust damage; thermal effects; soil heave or shrinkage; and sinking into natural bedrock cavities.

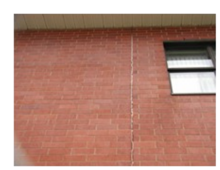
Approval of Development

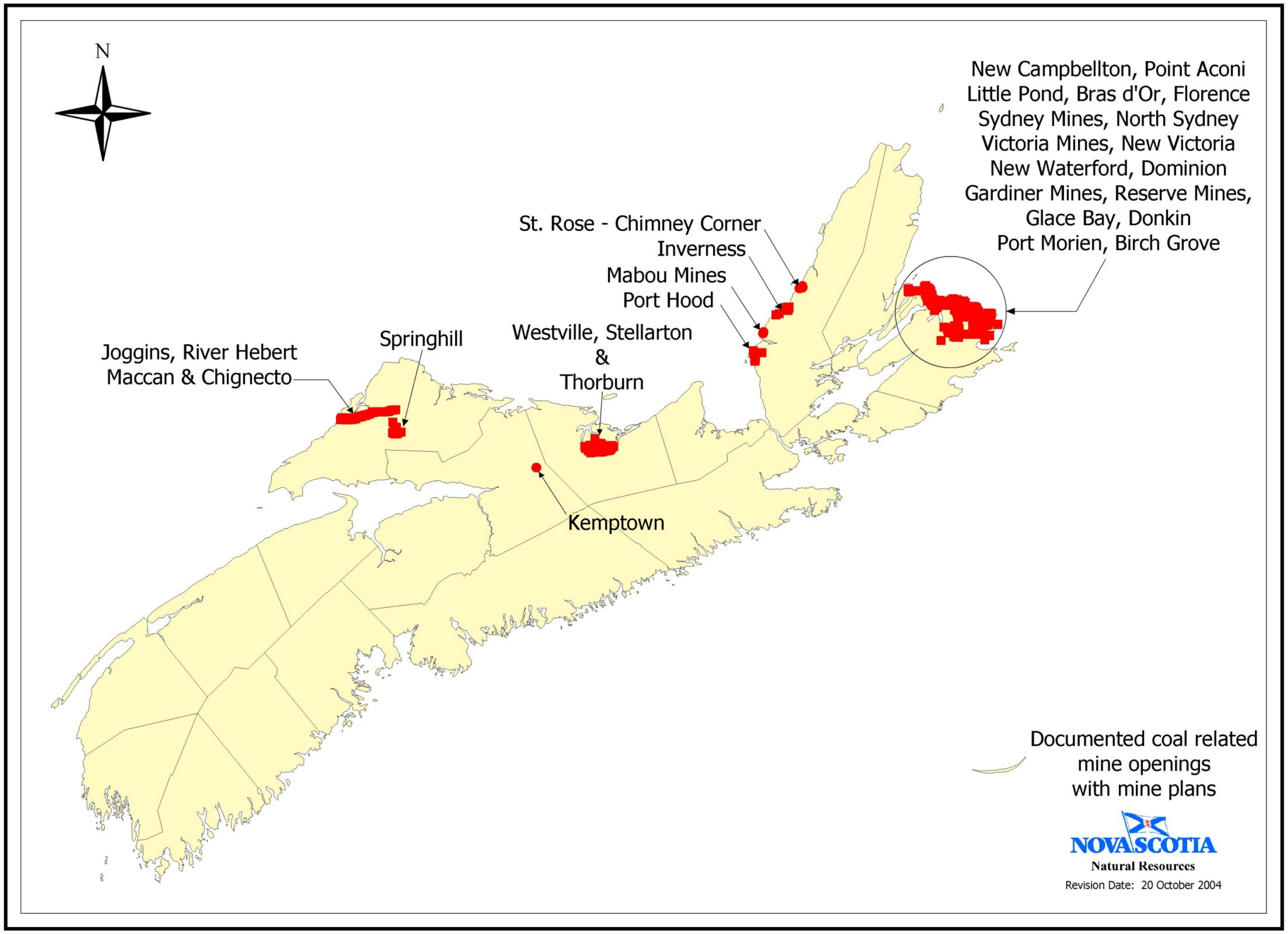
Where a Geotechnical Report concludes that undermined lands may be used safely for the use intended, development approval will be conditional on: implementation of all conditions contained in the Report respecting: siting, structural design, maintenance or planting of vegetation, placement of fill, etc.) and on you as Landowner agreeing to use the land only in the manner determined in the Report.

Safety Matters

Mine subsidence can cause conditions which are very hazardous. Do not enter any area that is suspicious or that has been designated or fenced off as a subsidence hazard area.

If you suspect mine subsidence on your land please call your local planning office.




N
New Campbellton, Point Aconi
Little Pond, Bras d'Or, Florence
Sydney Mines, North Sydney
Victoria Mines, New Victoria
New Waterford, Dominion
Gardiner Mines, Reserve Mines,
Glace Bay, Donkin
Port Morien, Birch Grove
St. Rose - Chimney Corner
Inverness
Mabou Mines
Port Hood
Westville, Stellarton
&
Thorburn
Springhill
Joggins, River Hebert
Maccan & Chignecto
Kemptown
Documented coal related
mine openings
with mine plans
NOVA SCOTIA
Natural Resources
Revision Date: 20 October 2004

AECOM

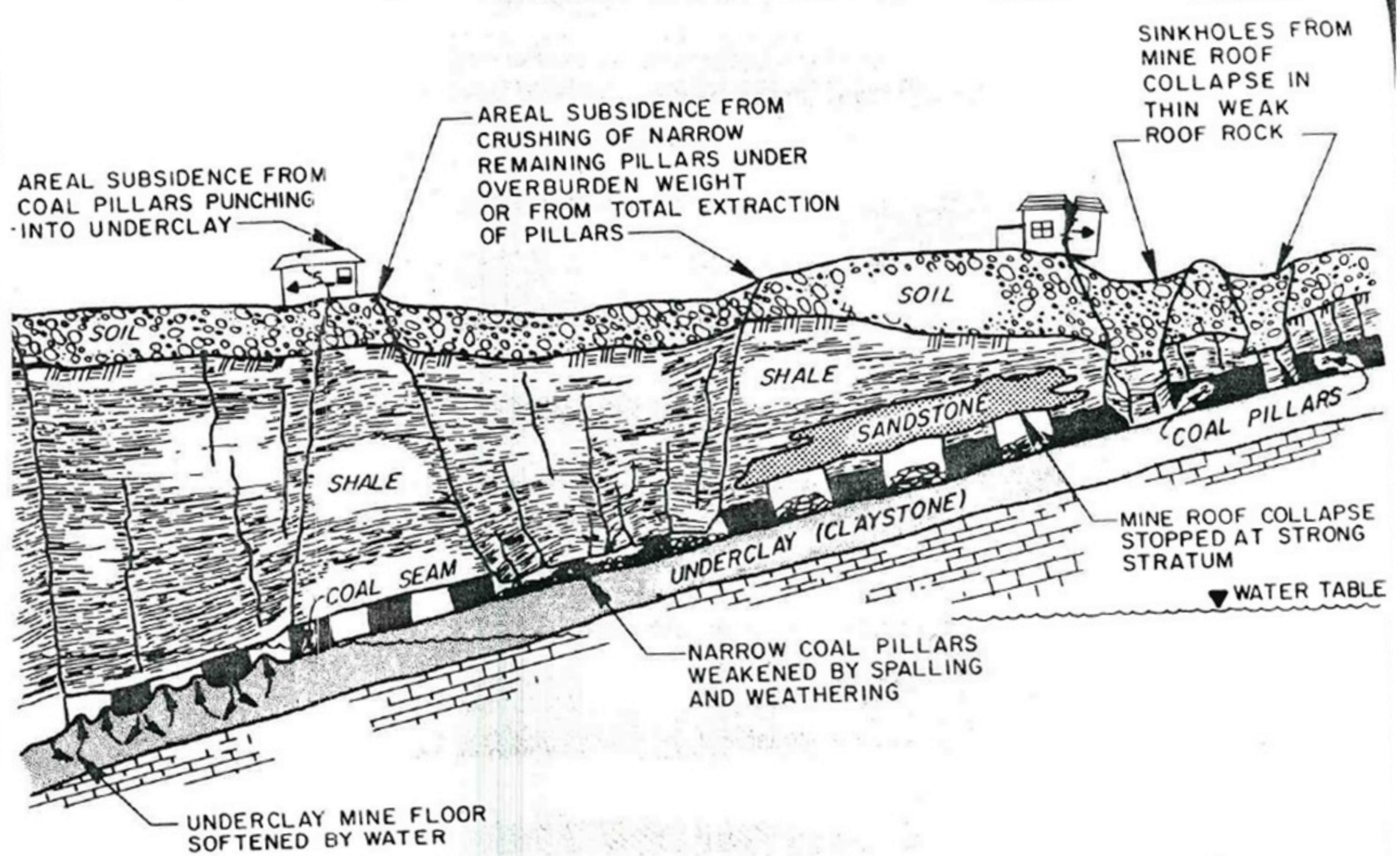


Fig. 3 Modes of Subsidence
(Source: Bruhn, et al. 1978)

Reference: Bruhn, R. W., and others, 1978, "Subsidence Over the Mined-Out Pittsburgh Coal," American Society of Civil Engineers Spring Convention, Pittsburgh, ASCE Preprint 3293, pp. 26-55.

Appendix C

Booklet for Municipalities

Land Use Planning for Lands Undermined by Abandoned Coal Mines

Information for Municipalities

The purpose of this information is to inform and provide guidance to municipalities to manage the development of private lands in areas with potential for mine subsidence resulting from abandoned coal mines. This information is focused on land-use zoning and development requirements in areas with potential for such subsidence.

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page

The goal of these best practices are to increase awareness, alert and advise interested parties that information exists on historic mine sites in Nova Scotia. The responsibility for remediation and liability for abandoned mine openings rest with the land owner. It is based upon a Report prepared for Service Nova Scotia & Municipal Relations called "Guidelines on Abandoned Coal Mine Subsidence for Municipalities in Nova Scotia" by AECOM in September 2010.

1. Purpose of this Booklet

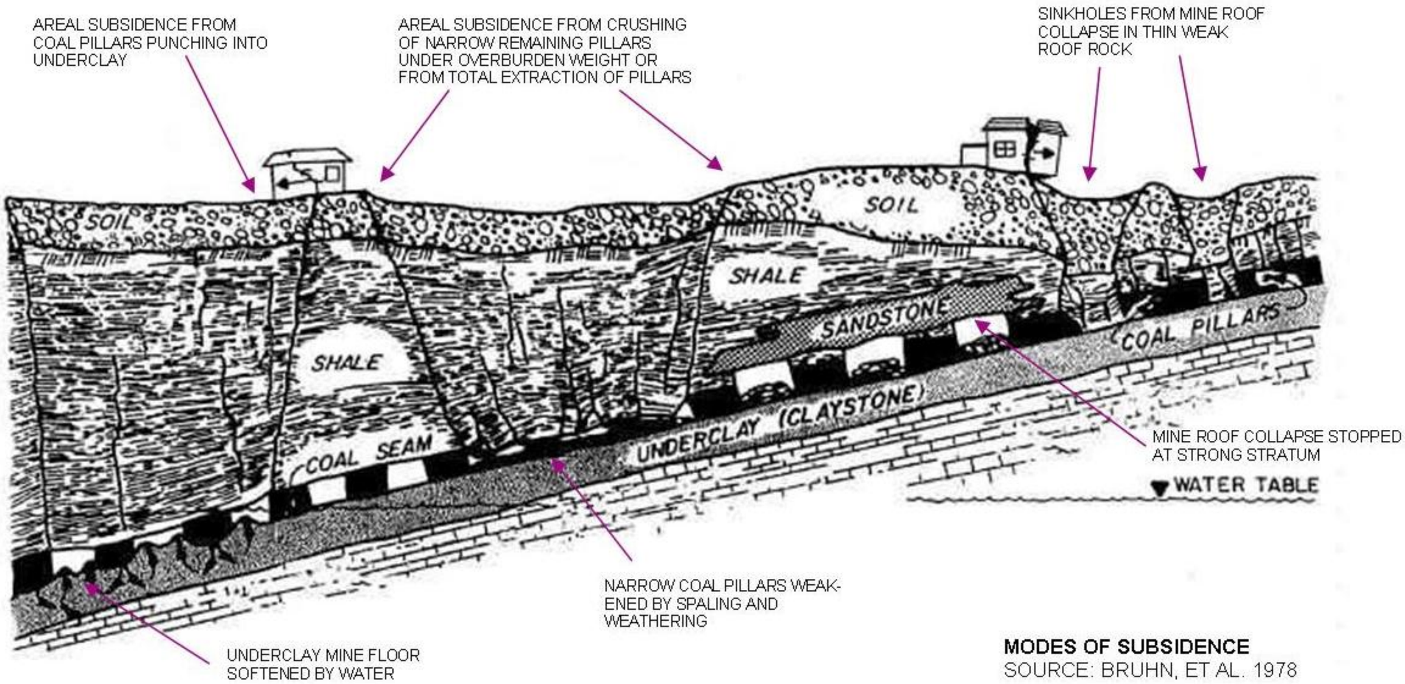
The purpose of this booklet is to provide municipalities with information on how to manage the development of lands in areas with potential for mine subsidence to occur as a result of abandoned coal mines.

2. The Issue of Subsidence from Abandoned Coal Mines

Typically there are two main types of subsidence over abandoned underground coal mines: sinkhole subsidence and sag (or trough) subsidence. The magnitude and extent of subsidence impact on development depend on the depth and size of underground mining excavation (width, length and height), type of rock and geological structure, groundwater conditions, as well as type- of construction and condition of surface structures. Subsidence damage can occur over many years after mining had ceased, their effect on the surface reduces as depth to the workings increases. It is very difficult to predict where and when these subsidence events will occur because of the unknown details and condition of the underground workings as well as the geotechnical conditions in the overlying rock strata. Despite these limitations general guidelines and generic precautionary and remedial approaches are available.

Sinkhole subsidence is due to the collapse of a mine roof underground that creates a cavity which steadily works its way upward. If not arrested by strong rock, it can eventually reach the surface as a sinkhole. Typically a sinkhole has bell-shaped walls, are 1 – 6m deep and 0.6 to 5m diameter or even larger, and usually occur over shallow underground workings of depth less than 50m. A surface reclamation coal mine excavation in 2004 in Cape Breton exposed a series of sinkholes and one was about 4m from the surface as shown here.

Sag Subsidence is a gentle saucer-shaped depression over a broad area often outlined by a ring of tension cracks. Sags are typically 0.5-1.0m deep and 10 to 500m in diameter. There are three main causes: roof caving over openings in the mine, crushing of mine pillars, or punching of mine pillars into soft floor or roof rock. The effects are similar to those over active mine workings but can occur long after mining ceased. An example seen of the time lapse between closure of a mine and a subsidence event in NS occurred in the Town of Dominion, Cape Breton Regional Municipality (CBRM) in 2002, over 80 years after mining had ceased.



Reference: Bruhn, R. W., and others, 1978, "Subsidence Over the Mined-Out Pittsburgh Coal," American Society of Civil Engineers Spring Convention, Pittsburgh, ASCE Preprint 3293, pp. 26-55.

2.1.1 Coal Mine Subsidence Effects

2.1.1.1 Mine Subsidence Damage

Most development on undermined lands does not incur any harmful subsidence. However, as can be seen from the photos above, in some cases damage can occur. Information on such damage and its prevention follows.

How Mine Subsidence Causes Damage

Abandoned mine subsidence causes damage as structures respond to movements of the ground on which they are built. As the foundations which provide support for the walls and columns of the structure follow movement of the ground due to subsidence, failure commonly propagates upward into the main part of the structure. The effects of mine subsidence on a structure are divided into three types depending upon the type of ground movement which caused the damage: compression effects, tension effects, and slope or tilt effects.

Subsidence cracking.

Surface Structural Effects

Surface structures respond to movement of the ground on which they are built. As foundations follow movement of the ground they are built on, failure may occur through cracking or tilting and then damage commonly propagates upward into the main part of the structure. Mine subsidence can cause the following ground movement effects:

- Compression features (mostly resulting from sag subsidence) e.g. buckling of pavement or pipes
- Tension features e.g., cracking, loosening and pulling apart of ground, masonry, etc, see Photo above
- Slope or tilt effects e.g. reversing flow in drains.

- Distortion effects, e.g. doors and windows wedging or jamming.

The magnitude and extent of surface structural effects depends not only on the movement of the ground but also on the type, size, complexitiy and orientation/location of structure.

Signs to Look For

These effects can cause cracking in plaster walls, cracking in brick walls, separation of pipes, windows and door frames to move and jam, and cracking in floor slabs, see Photos below for typical examples.

Interior structural damage in a large structure from a sag subsidence event.

Preventing subsidence damage

Approaches to prevent subsidence damage include: avoidance (land use controls); filling the mine; excavating the underground mine workings through modern surface reclamation mine operations followed by surface land restoration; collapsing the underground workings by blasting or with excavators and backfilling the void; and/or structural modifications.

2.1.2 Non-Mining Causes of Similar Damage

In lands undermined by abandoned coal mine workings most structural damage to residential properties is *not* caused by mine subsidence. It is important to be aware of structural damage which closely resembles damage caused by mine subsidence but may in fact result from other factors, including:

- Sulphates reacting with cement
- Shrinkable or expanding clay
- Differential settlement in the structure which may be caused by numerous situation
    - Settling of poorly compacted soils or erosion of soils;
    - Uplift or heave due to expanding bedrock or fill;
    - Clay soil shrinkage due to lowering of water table e.g. from wells, trees roots, or dewatering from adjacent activity;
    - Sinking into bedrock cavities e.g. naturally occurring limestone or gypsum caverns
- Altering of conditions owing to poor drainage of soils
- Rust damage
- Thermal effects,
- Poor construction.

2.1.3 Outcome

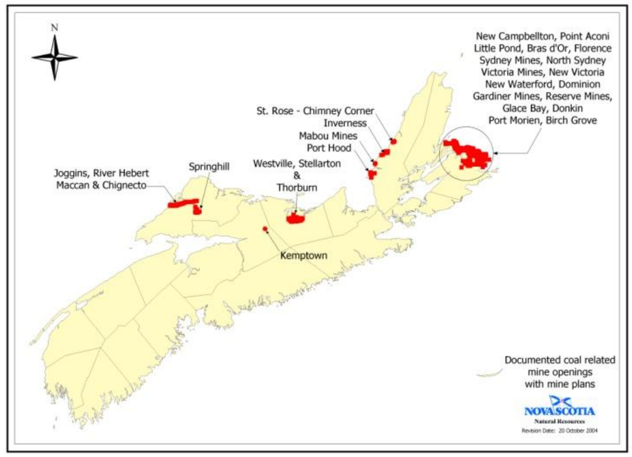
The above information was condensed into a brochure for distribution to the general public to provide information, entitled “Your Land & Historical Coal Mining”.

3. Current Practices

3.1 Municipal Plans and Building Permitting

Municipal building bylaws, and where applicable subdivision bylaws, were reviewed for those Nova Scotia municipalities which are located within a coalfield or coalfields and therefore have potential for abandoned coal mine subsidence within their municipal planning area. Bylaws were reviewed for municipalities in the following Nova Scotia Counties:

- Cape Breton County: New Campbellton, Point Aconi, Little Pond, Bras D'Or, Florence, Sydney Mines, North Sydney, Victoria Mines, New Victoria, New Waterford, Dominion, Gardiner Mines, Reserve Mines, Glace Bay, Donkin, Port Morien, Birch Grove & Broughton;
- Victoria County: Port Hood, Mabou Mines, Inverness & Chimney Corner;
- Pictou County: Kemptown, Westville, Stellarton, & Thorburn; and
- Cumberland County.



3.1.1 Review of Nova Scotia Municipal Bylaws

Municipal building bylaws, and where applicable subdivision bylaws, were reviewed for those Nova Scotia municipalities which are located within a coalfield or coalfields and therefore have potential for abandoned coal mine subsidence within their municipal planning area. Bylaws were reviewed for municipalities in the following Nova Scotia Counties: Cape Breton County, Pictou County, and Cumberland County.

The four (4) municipal building bylaws and the one (1) subdivision bylaw reviewed from municipalities in Nova Scotia with coal fields within their municipal planning area do not have requirements or regulations with respect to mine subsidence. However, the Cape Breton Regional Municipality Municipal Planning Strategy (February 20, 2010) does contain a policy on subsidence (pages 9-14 & 9-15) and makes it clear that "The CBRM is not responsible for subsidence and is not liable for property damage occurring as a result of subsidence." It also states that the CBRM is willing to act as a conduit for information as follows:

> "... with accurate information supplied and interpreted by the Province, the CBRM would be prepared to establish a system of public notification for prospective developers interested in, or about to, construct in communities and neighbourhoods identified by the Province as being:
>
> - above abandoned mine workings; or
> - within a range of influence that subsidence would be a possibility should they collapse.
>
> The CBRM would not accept responsibility for the accuracy of such information. It would only be a conduit to provide the Province's information to those most likely to be developing in the former mining communities. The purpose of the information would be simply and strictly to inform prospective developers."

3.1.2 Review of Nova Scotia Building Code

A baseline assessment was completed of the current situation in Nova Scotia relating to legislation controlling building in areas with potential for mine subsidence. Five (5) sections from the Nova Scotia Building Code (Sections 1.4.1.3, 1.4.1.4, 2.1.1.5, 2.1.1.6 and 2.1.1.7) require the property owner to inform, ensure that professional architects and/or professional engineers have been retained during the permitting process (Reference: Nova Scotia Building Code Regulations made under Section 4 of the *Building Code Act* R.S.N.S. 1989, c. 46, effective September 1, 2010. The Code stipulates situations where a geotechnical investigation must be conducted.

Under the Nova Scotia Building Code there are occasions where geotechnical investigations or mitigation measures for building apply although not specifically relating to mining subsidence. The Nova Scotia Building Code Regulations indicates where the owner applying for a building permit is required to retain professional services in the following sections:

Section 1.4.1.3 Required Information sub section (1) (e): owner names engineer, other designer, constructor, etc. the *authority having jurisdiction* (f) owner describes any special *building* systems, materials and *appliances*, and (g) owner provides such additional information as may be required by the *authority having jurisdiction.*

Section 1.4.1.4 Letter of Undertaking when Professional Required to Design: owner submits letter of undertaking for construction and for any design by an engineer to the *authority having jurisdiction*.

Section 2.1.1.5 Professional Design and Review: owner ensures that a architect, professional engineer is/are appointed for design work.

Section 2.1.1.6 Design Regulations for Structural Components: owner ensures that professional engineer is appointed to design structural component.

Section 2.1.1.7. Site Conditions, Size, or Complexity Requiring Professional Design and Inspection: allows the *authority having jurisdiction* to require professional involvement.

Section 2.2 Obligations of a professional: outlines obligations of engineers, etc.

Part 3 - Amendments to the Nova Scotia *Building* Code Schedule "A" Letter of Undertaking, Confirmation of Commitment by Owner to the Municipal Authority Having Jurisdiction - Field Review of Construction, Preamble : Initial the disciplines that apply to this project. All disciplines will not necessarily be employed on every project): □ *Building* Design □ Structural □ Plumbing □ Mechanical □ Electrical □ Geotechnical   □ Fire Suppression System; **Schedule "A-7" Field Review of Construction, Inspection Commitment Certificate: Geotechnical Design Requirements**

These are the only sections in the NS Building Code where professional requirement is stipulated. The intent of the code is, the owner who is building or modifying a structure and is making application for a building permit ensures/ proves to the authority (Municipality) that he (owner) has engaged a professional or professionals . The professional determines if a geotechnical investigation is needed, thus where abandoned coal mine subsidence issues occur these allow for a geotechnical engineer to investigate and report.

It is also noted that the following sections of the National Building Code for Canada, 2005 whilst not explicit about abandoned coal mine subsidence are relevant:

- **Section 4.1.2.2 Loads Not Listed** – requires engineering design to take into account all loads, forces or other effects based on the most appropriate information available.
- **Section 4.2.2.4 Altered Subsurface Condition** – any such alterations noticed during construction require re-assessment by an engineer
- **Section 9.4.4 Foundation Conditions** – reference to design requirements for allowable bearing pressures.

3.1.3 Summary of Findings

Presently there is no direct trigger in Nova Scotia requiring a geotechnical investigation for subsidence mitigation measures defined in the Nova Scotia Building Code. Elsewhere, an engineers' report and/or a geotechnical report is a common requirement in building permitting processes in subsidence areas, for example in: Canmore, Alberta;

Nanaimo, BC; UK; Australia; NZ and some states in the USA. These reports take into account relevant information, including that on abandoned underground coal mine workings and abandoned underground openings. These reports may take a different name such as hazard report, stability report, etc. The professional determines if a geotechnical investigation or structural design measures are needed and this would include any case where subsidence is an issue.

4. Proposed Best Practices for Nova Scotia

4.1 Proposed Allocations of Responsibility

An initial aspect to be addressed must be to make clear an answer to the following question: who is responsible if coal mining subsidence occurs in the Province of Nova Scotia. The basic response is: first that the responsibility to address impacts from subsidence and property damage occurring as result of subsidence and for liability for abandoned mine workings rests with the landowner; and second by provincial policy the Province and/or municipalities assume no responsibility for subsidence and is not liable for property damage occurring as a result of subsidence, except on land owned by them.

A further consideration is responsibility for abandoned coal mine subsidence issues on Crown lands. The answer here is that these are excluded from the scope of work here as (i) Federal authorities are exempt from building permits on federally owned land and (ii) the Province of Nova Scotia exerts its own level of control over development on provincial crown lands, including those impacted by abandoned coal mine subsidence.
Finally, the division of responsibility for NS provincial government departments and municipal governments for addressing the issue of mine subsidence needs to be made clear, as outlined in Table 1

Table 1. Provisional Allocation of Responsibility Table

	SNSMR[1]	NSDNR[2]	NSLWD[3]	Municipalities
Land Use Planning	Set NS Policies Advise Municipalities	Provide technical information on location of underground coal mine workings to department, municipalities and public	N/A	Land use planning strategy By-laws Implement and enforce
Building Code	Policy input	Policy Input	Building policy and legislation	Building inspection and enforcement of building code
Public Information on coal mine subsidence matters	Set policy Guidelines to provincial departments General Information to public	Source of information: mine plans, geology, related information	Employers responsible to address ground stability related to subsidence as a potential workplace hazard	Distribute Brochure Implement booklet guidelines
Public Queries on coal mine subsidence matters	Address land use planning policy matters	Address technical inquiries from the professional / private sector (but does not include individual landowners).	N/A	Address all public inquiries (including individual landowners). Direct policy matters to SNSMR Direct technical inquires through property owner to private sector.

[1] SMSMR – Service Nova Scotia & Municipal Relations
[2] DNR – Nova Scotia Natural Resources
[3] NSLWD – Nova Scotia Labour & Workforce Development

4.2 Notification of Undermined Lands

It is proposed that each municipality located within a coalfield area or areas should establish a system of public notification for prospective developers interested in, or about to, construct in communities and neighbourhoods identified by the Province as being located in an area of abandoned underground coal mine workings.

The notification of undermined lands follows the process outlined below.

Notification to Municipalities	The Province of Nova Scotia (NSDNR) will provide notification of lands undermined by abandoned coal mines to all affected municipalities.
Municipal Incorporation of Data	All affected municipalities can incorporate undermined lands data into their Geographical Information Systems (GIS) database and Land Use Bylaws. Overarching policies may be incorporated in Municipal Planning Strategies.
Notification to Private Land Owners	All affected municipalities can provide notification to private land owners, through the approval of development permit process, if the lands are undermined. Municipalities can take on the responsibility to notify all existing land owners if they are undermined.
Receipt by Land Owners	The landowner is responsible for obtaining professional advice from the private sector to interpret the undermining information.

4.3 Municipal Practice – Proposed Land Use By-Laws

Implementation of the information in this booklet requires that municipal land use bylaws be amended to include two additional items: GIS mapping information regarding areas which have been undermined; and the requirement to complete a geotechnical report. Municipalities can add regulations in their land use bylaws which reference a schedule of maps showing areas of abandoned underground coal mines and indicating requirements for a geotechnical report for any proposed development. The latter could include an outline of the elements to be included in a geotechnical report as presented in Section 4.3 of this booklet below. Typically where a new occupancy classification of an existing building is proposed a geotechnical report may also be required. An example land use regulation is as follows: "For any development proposed to locate within an area identified as having experienced underground coal mining or is prone to possible subsidence as illustrated in Schedule A (or otherwise as identified) a geotechnical report in a manner outlined in Section .... may be required. Accessory buildings to the main use, not used for human habitation, will be exempt from this requirement".

4.3.1 When a Geotechnical Report is Not Required

Existing Development on Undermined Lands

There are no special requirements for existing developments as this is a condition known to be "legal non-conforming".

Applications for Single Lot Development (inc. Ancillary Buildings)

Applications for single lot residential development (including ancillary buildings) on lands subject to abandoned underground coal mines are not required to provide a Geotechnical Report however the completion of one may be required by the municipality.

4.3.2 When a Geotechnical Report is Required

Applications for New Commercial , Industrial, or Multi-Lot Residential Development

Applications for new commercial, industrial, apartment buildings and multi lot residential developments in undermined areas are required to provide a Geotechnical Report, that includes a mining site assessment, prepared by a professional engineer.

Enabling Infrastructure

All enabling infrastructure (e.g. roads, transmission lines, pipelines, etc.) related to new industrial development in undermined areas will require a Geotechnical Report, that includes a mining site assessment, prepared by a professional engineer.

4.4 Preparation of a Geotechnical Report

Mining Impact Assessment

Geotechnical Reports for lands impacted by abandoned underground coal mine workings must be prepared to include a mining site assessment, which typically is a desk study with a field visit but no intrusive site work and should address at least the following:

Field Visit:

Visual inspection of the property (lands and structures) and adjacent lands

Background Information:
Review relevant information on abandoned mine workings in that locality and appropriate technical reference information

- ✓ **Mining Factor**
  Describe strata section; mine workings details (seam by seam); mine
- ✓ water; and potential development of surface subsidence
- ✓ **Site Factor**
  Outline site characteristics, e.g. site geology, topography, drainage, etc
- ✓ **Structure Factor**
  Discuss the type and condition of existing & proposed structures and their expected response to potential mining subsidence
- ✓ **Time Factor**
  Discuss timing and duration of mine workings, any previous subsidence events and scheduling of proposed developments on the lands, etc

Qualitative Preliminary Risk Assessment:
Assessment of potential hazards (e.g. associated with both subsidence ground movement and possible release of mine water and/or gases); assess

potential severity and probability of occurrence for sinkhole and sag subsidence for all workings and summarize risks.

Assessment of Mitigation Measures:

Summary of previous or existing mitigation measures and outcome; assess need for future mitigation, type and extent required to reduce subsidence to acceptable levels.

Summary & Findings

Outline work done, principal conclusions and recommended way to proceed to incur least risk of potential abandoned mine subsidence effects with and without mitigation measures; further studies and design requirements.

Geotechnical Reports Should Recommend

The measures specified in a Geotechnical Report, can and will be taken to ensure the development and its associated land uses incur least risk of adverse effects and are able to safely withstand the hazard. As such, a Geotechnical Report should recommend how from a mining perspective the land may be used safely for the intended development over its projected life, taking into account adjacent land uses.

Approval of Development

Where a Geotechnical Report concludes that land subject to mine subsidence may be used safely for the use intended, development approval will be conditional on implementation of all conditions contained in the Report respecting: siting, structural design, maintenance or planting of vegetation, placement of fill, etc., and on the landowner agreeing to covenant with the municipality, within the land title, to use the land only in the manner determined in the Report.

Safety Matters

Mine subsidence can cause conditions which are very hazardous. Post and follow signage noting dangers of entering any area that is suspicious or that has been designated or fenced off as a subsidence hazard area.

If as a landowner you suspect mine subsidence on your land please call your local planning office.

5. Building Code Practice

5.1.1 Building Codes and Inspection

Taking a lead from several other jurisdictions which amend existing check-lists for inspection to accommodate mitigation of coal mining subsidence hazards, a checklist has been developed as follows below. This list is for use by building officials to help ensure the issue of undermining has been adequately considered within the building permitting process.

Checklist for consideration of mining subsidence issues

Development Permit Checklist	Yes	No	Comment
1. **Is the proposed development located within an area in the integrated Land Use Zoning Map designated by NSDNR as being undermined?**			
2. **Has the property owner been notified of the potential undermining?** 3. **Has a Geotechnical Report been conducted for this property?**			
4. **Has a mining impact assessment been included in the Geotechnical Report?**			

5.	**Has the developer incorporated the recommendations of the Geotechnical Report into the plans for the development?**			
6.	**Is there any indication of previous ground movement on the property, either visual, anecdotal or in the Geotechnical Report?**			
7.	**Have potential mining subsidence effects been adequately dealt with in the application?**			

5.1.2 Prevention and Control of Mine Subsidence Damage to Structures

Some additional aspects for engineers to consider in geotechnical reports relating to mitigation measures follow.

5.1.2.1 Design Philosophies

In general there are three main philosophies in design of structures to mitigate subsidence effects on structures in areas prone to coal mine subsidence, these are: (1) to build structures to resist subsidence ground movement effects;, or (2) to build-in flexibility to accommodate ground movement due to subsidence; or (3) to relocate the structure to a more stable area where it will there will be little or no subsidence impacts (Peng, 1992). The choice of option depends upon site specific considerations, although it is noted that experience in New South Wales favours the second in low rise residential structures, as explained in section 3.2.1.4 above.

In order to aid stakeholders in Nova Scotia in their professional consideration of abandoned coal mine subsidence, the following list of scientific references is offered as a guide to information on general design philosophies pertaining to the design of structures in areas with potential for mine subsidence.

Table 2. Sources of Information on General Design Philosophy for Designing a structure to Prevent Damage from Mine Subsidence

Author	Year	Title	Synopsis
Appleyard, L.D.	1995.	A Reappraisal of Structural Design Concepts in Areas Subject to Ground Movement	This paper identifies the need for a common design philosophy to deal with ground movement and discusses how wind loads lie within the same order of magnitude and can be included in a coordinated process.
Bray, I.J.	1991.	Case Studies - Design of Buildings Subject to Mine Subsidence	This paper outlines a design process and philosophy for the design of buildings subject to mine subsidence. The objective is to be able to design an economical building which is structurally safe with architectural details designed to minimize non-structural damage.
Bray, I.J., Branch, S.E.T.	1988.	Design of Buildings for Mines Subsidence	This paper examines procedures for the design of mine subsidence resistant buildings and typical details are presented
Fawcett, P.	1988.	Successful Design for Mine Subsidence: the Clasp Experience	This paper outlines the development of the CLASP system and the means adopted for dealing with subsidence effects
Galvin, J.M.	1988.	Conference on Buildings and Structures Subject to Mine Subsidence - Keynote Address	This paper provides an overview of mine subsidence hazards, policies used in New South Wales, effects of subsidence and general philosophy for design.
Mine Subsidence Board	Current web-page	A Guide to Designing for Mine Subsidence	This pamphlet outlines design philosophies for various types of subsidence.
National Coal	1975.	Subsidence Engineers	Chapter 6 of this text book presents general structural

Board		Handbook	precautions to be used when designing in areas prone to mine subsidence.
Peng S.S.	1992.	Surface Subsidence Engineering	This textbook presents general design philosophies for the prevention of structural damage associated with mine subsidence.

5.1.2.2 Specific Design Measures

In addition to noting the vast experience in New South Wales outlined in Section 3.2.1.4 above and the fact that applying such to Nova Scotia would require adapted for Nova Scotia winter conditions, the following list of some potential methods which can be considered for use in mitigation of coal mine subsidence is offered as a guide to professional engineers in preparing a geotechnical report or subsequent design reports:

1. **Fill shallow underground workings** with cement grout or backfill for local abatement of potential subsidence
2. **Place Structure on pile foundations** based on solid ground beneath the mine workings to avoid subsidence impacts
3. **Make Structure strong** to resist any subsidence effects
4. **Make the structure flexible** to accommodate subsidence effects with minimum damage
5. **Locate/relocate structure on solid pillars** of unworked coal to avoid/minimize subsidence risk
6. **Orientate the Structure** with respect to likely subsidence movements to minimize impact
7. **Use flexible joints** in pipes, cables, etc. To accommodate subsidence movement and avoid damage
8. **Make the structure relatively small less than 30m across**, not more than three stories high and using a slab-on-grade foundation
9. **Trenches filled with suitable compressible granular material** are installed outside the perimeter of concrete foundations to compensate and relieve compressive strain on foundation footing and walls. Properly design exterior trenches are required for both the length and width of the structure.
10. **Reinforced Concrete Anchoring Slabs** installed on top of a flexible foundation in buildings subject to large horizontal strain either along the short or long axis of the structure resist failure because the strain is not transferred to the structure. The reinforce concrete slab (80 to 120 mm thick) with tension reinforcing bars placed on layer of poly liner over 150 mm of sand performs as a ridged structure and horizontal and vertical forces are dissipated in the flexible sand layer.
11. **Slotting** should be made along the interior walls or along the lines where height or shape or both change. The height in each unit separated by the slot should be uniform. The idea is to divide a complex structure into separate independent sub-units. Temporary walls or posts should be erected on both side of the slot.
12. **Levelling by underpinning and pinning** is accomplished by installing and using hydraulic or screw jacks at strategic points around the base or foundation of a structure to be impacted by coal mining subsidence. These are then used to adjust and maintain the structure level as it subsides; it is especially useful when predicted subsidence subjects the structure to sloping and/or curvature impacts.
13. **Levelling with springs** is utilized in order to keep houses level during underpinning, springs are installed at the places where ground steps are likely to occur. Several groups of springs installed under the floor joist may be needed.
14. **Reinforcing with Tension Rod or Tension Cable** can be used to tighten a house structure at the roof beam or floor joist levels. The tension rods and cables must be firmly tightened at the ends and supported at regular intervals. Steel tension rods and cables are designed to resist and compensate for the effects of curvature and tensile strain on the walls of a structure.
15. **Wall Shoring and Internal Bracing** is utilized as a method to prevent and compensate for toppling and collapse of or tilling of masonry walls. Interior wall bracing is designed to maintain the stability of the interior load bearing walls.
16. **Reinforced Concrete Beams** when surface deformations are extreme, reinforced concrete beams may be installed around the house structure at the basement level. Reinforced concrete beams are excellent for

resisting horizontal strain and negative curvature, and if beams are installed at the floor joist or roof beam level, they can also cope with the problems associated with positive curvature.

17. **Foundation Bracing Beams** can be installed to reduce the transversal moment of a longitudinal wall, especially if the building does not have transversal walls or the distance longitudinal walls is large, transverse reinforced concrete bracing beams resist transversal moments due to subsidence.

Similarly, In order to aid stakeholders in Nova Scotia in their professional consideration of abandoned coal mine subsidence, the following list of scientific references is offered as a guide to support the above with information on specific measures to prevent structural damage as a result of mine subsidence.

Table 2. Sources of Information Regarding Specific Design Measures for the Prevention of Structural Damage from Mine Subsidence

Author	Year	Title	Synopsis
Appleyard, L.D.	2001	A review of the formulation and implementation of Graduated Design Guidelines for Residential construction in mine subsidence areas of New south Wales	The publication and implementation of the Graduated Design Guidelines by the Mine Subsidence Board provide a framework for the uniform assessment of building applications by the Board's Officers, a framework which is based on current building industry best practice as defined by relevant design codes and regulatory legislation.
Arch, B.,	1991.	Brickwork for Mine-Subsidence-Prone Sites	This paper provides information on how brickwork for domestic scale buildings can be designed to perform adequately on mine subsidence prone sites
Bell, F.G., Fox, R.M.	1988.	Ground Treatment and Foundations above Discontinuous Rock Masses affected by Mining Subsidence	This paper examines foundation treatment methods to overcome problems from mine subsidence , particularly subsidence associated with long wall mining
Li, J., Cameron, D.A.	1995.	Analysis and Design of House Footings Subject to Ground Movements	The paper outlines a method for analysis of raft slab subject to mining induced ground movement
Lin, P.M., Peng, S.S., Tsang, P.	1990.	Dealing with Subsidence on Abandoned Mine Lands	Presents a case study in Germany where a house was re-levelled using precision hydraulic equipment.
Mine Subsidence Board		Designing for "Pothole" Subsidence	This pamphlet outlines design measures to address pothole subsidence
National Coal Board	1975.	Subsidence Engineers Handbook	Chapters 8 and 9 in this textbook present structural precaution measures for designing with respect to mine subsidence.
Peng S.S.	1992.	Surface Subsidence	Chapter 6 in this textbook discusses the prevention and control of surface structural damage associated with mine subsidence.
White, R.J., Page, A.W.	1998.	Development and Full Scale Testing of a Mine Subsidence Resistant Masonry House	This paper provides the results of a test conducted to study the behaviour of a purpose designed masonry residence when subjected to deformations of a long wall mining event. The specific design measures used in the test house are presented and evaluated.

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Appendix D

Compendium of References

ID	Author	Year	Title		Land Use Planning	Structural Design	Hazard Assessm	Compensation /	Remediation
1	Galvin, J.M.	1988.	Conference on Buildings and Structures Subject to Mine Subsidence Keynote Address	(1)	✓	✓	✓		
2	Fawcett, P.	1988.	Successful Design for Mine Subsidence: the Clasp Experience	(1)		✓			
3	Bray, I.J., Branch, S.E.T.	1988.	Design of Buildings for Mines Subsidence	(1)		✓			
4	Burgmann, J/B., Phillips, A.B.	1988.	Engineering Design of Major Hospital for Conditions of Mines Subsidence	(1)		✓			
5	Arch, B.,	1991.	Brickwork for Mine-Subsidence-Prone Sites	(1)		✓			
6	Bray, I.J.	1991.	Case Studies - Design of Buildings Subject to Mine Subsidence	(1)		✓			
7	Mead, L.D.	1991.	Modern Underground Coal Mining Techniques and Communities Fair Go…or…Fair Gam	(1)	✓				
8	Braithwaite, P.A., Philllips, A.	1991.	The Bulk Infilling of Mines with Rock Paste to Allow Surface Development	(1)					✓
9	Burton, B.	1995.	Behavior of Structures Subjected to Mine Subsidence	(1)		✓			
10	Li, J., Cameron, D.A.	1995.	Analysis and Design of House Footings Subject to Ground Movements	(1)		✓			
11	Appleyard, L.D.	1995.	A Reappraisal of Structural Design Concepts in Areas Subject to Ground Movement	(1)		✓			
12	Holla, L.	1995.	A Reappraisal of Mine Subsidence Damage to Residential Structures	(1)		✓			
13	Mohammad, N., Lloyd, P.W., Reddish, D.J.	1998.	Application of a UK Subsidence Numerical Modeling Methodology to Some Australian C	(1)			✓		
14	White, R.J., Page, A.W.	1998.	Development and Full Scale Testing of a Mine Subsidence Resistant Masonry House	(1)		✓			
15	Ditton, S.G., Love, A.B.	1998.	Case Study: Remediation of Old Lambton Colliery Workings Beneath Extensions to Wes	(1)					✓
16	Hawkins, G.C., Harve, J.P.	2001.	Stability of Abandoned Mines - Geotechnical Investigations of the Borehole Seam Work	(1)			✓		
17	Masia, M.J.	2001.	Serviceability and Reliability of Structures Subject to Ground Movement	(1)		✓			
18	Appleyard, L.D.	2001.	A Review of the Formulation and Implementation of Graduated Design Guidelines for R	(1)		✓			
19	Davis, P.	2001.	Successfully Managing the Undermining of Major Structures	(1)		✓			
20	Seedsman, R.W., Watson, G.	2001.	Sensitive Infrastructure and Horizontal Ground Movements at Newstan Colliery	(1)					
21	Karmis, M., Agioutantis, Z.	2004.	A Risk Analysis Subsidence Approach for the Design of Coal Refuse Impoundments Over	(1)			✓		
22	Department for Transport, Local Government a	2002.	Planning Policy Guidance Note 14 Development on Unstable Land Annex 2: Subsidence	(1)	✓				
23	B.H. Levelton and Associates LTD.	1992.	Review of Development Policies Development Over Abandoned Coal Mines	(1)	✓				
24	New South Wales Department of Primary Indus	2006.	Primefacts Mine Subsidence	(1)					
25	Property Council of Australia	2006.	Resolving Mine Subsidence Problems in the Hunter	(1)					
26	Turney, J.E.	1985.	Subsidence Above Inactive Coal Mines: Information for the Homeowner	(1)				✓	
27	Crawford, J. et al.		Subsidence Management at New Mineral City Mine, Fort Dodge, Iowa	(1)	✓				
28	Colorado Division of Reclamation Mining & Saf	Acces	Mine Subsidence Protection Program	(1)				✓	
29	Meier, L., Gibson, R.		Approaches to Mine Subsidence in Four U.S. Communities	(1)					
30	Ambrose, D.	2009.	South County News: Mine Subsidence Forces Closure of Benld Elementary School	(1)					
31	Bauer, R.A.	2006.	Mine Subsidence in Illinois: Facts for Homeowners	(1)					
32	U.S. Geological Survey	1999.	Land Subsidence in the United States	(1)					
33	City of Nanaimo	2008	Official Community Plan	(1)	✓				
34	The Coal Authority		Code of Practice for the Management of Disused Tips	(1)	✓				
35	Kohl, M.S.	2001.	Subsidence and Sinkholes in East Tennessee	(1)					
36	California University of Pennsylvania Departme	2005.	The Effects of Subsidence Resulting from Underground Bituminous Coal Mining on Surf	(1)			✓		
37	United Kingdom Department of Trade and Indu	2004.	Coal Mine Subsidence Damage A Guide to Claimants' Rights	(1)				✓	
38	Ohio Department of Natural Resources	2001.	GeoFacts Mine Subsidence	(1)					
39	Spreckels, V., Steinkohle, D.	2000.	Monitoring of Coal Mining Subsidence by HRSC-A Data	(1)					
40	The Coal Authority		Surface Hazard Team Guidance for Stakeholders	(1)					
41	Blodgett, S., Kuipers, J. R.	2002.	Technical Report on Underground Hard Rock Mining: Subsidence and Hydrologic Enviro	(1)			✓		
42	The Coal Authority		Policy Regarding Surface hazards	(1)	✓				
43	Donnelly, L.	2006.	Investigation of Geological Hazards & Mining Risks, Gallowgate, Newcastle-upon-Tyne	(1)			✓		
44	Drecker, P., et al.	1995.	Subsidence and Wetland Development in the Ruhr District of Germany	(1)	✓				
45	State of Illinois Department of Natural Resourc		Underground Mines and Subsidence for Lands Undermined after February 1, 1983	(1)					
46	Mortell, J.F.	1991.	Bulletin 76 Mine Subsidence Insurance	(1)				✓	
47	Marino, G.G.		Pipelines Exposed to Coal Mine Subsidence Face Risk of Serious Damage	(1)			✓		
48	Governor's Center for Local Government Servic		Pennsylvania Municipalities Planning Code	(1)	✓				
49	The Coal Authority		Mining Records and Reports Service	(1)					

ID	Author	Year	Title	📎	Land Use Planning	Structural Design	Hazard Assessm	Compensation /	Remediation
50	Mine Subsidence Board		Mine Subsidence A Guide for Council Staff	📎(1)	☑	☐	☐	☐	☐
51	Mine Subsidence Board		A Guide to Designing for Mine Subsidence	📎(1)	☐	☑	☐	☐	☐
52	Mine Subsidence Board		Designing for "Pothole" Subsidence	📎(1)	☐	☑	☐	☐	☐
53	Mine Subsidence Board		Mine Subsidence a Community Guide	📎(1)	☑	☐	☐	☐	☐
54	Mine Subsidence Board		Appeal Rights and Review Procedure	📎(1)	☐	☐	☐	☑	☐
55	Mine Subsidence Board		Claiming for Mine Subsidence	📎(1)	☐	☐	☐	☑	☐
56	Mine Subsidence Board		Guarantee of Service	📎(1)	☐	☐	☐	☐	☐
57	Mine Subsidence Board		Buying Property & Building in a Mine Subsidence District	📎(1)	☐	☐	☐	☐	☐
58	City of Nanaimo	2010.	Guidelines for the Preparation of Geotechnical Reports	📎(1)	☐	☐	☐	☐	☐
59	Pennsylvania Department of Environmental Pro		Are You on Top of Things? Information on Underground Mining and Mine Subsidence i	📎(1)	☐	☐	☐	☐	☐
60			State of Ohio Hazard Mitigation Plan - Section 2.14 Land Subsidence	📎(1)	☐	☐	☐	☐	☐
61	Pennsylvania Department of Environmental Pro		Illustrated Effects of Mine Subsidence	📎(1)	☐	☐	☐	☐	☐
62	The Coal Authority		Public Safety and Subsidence	📎(1)	☐	☐	☑	☐	☐
63	National Coal Board	1975.	Subsidence Engineers Handbook	📎(1)	☐	☑	☑	☐	☑
64	Karmis, M., Agioutantis, Z.	2007.	Enhancing Mine Subsidence Prediction and Control Methodologies for Long-Term Land	📎(1)	☐	☐	☑	☐	☐
65	The Pittsburgh Geological Society		Land Subsidence in Western Pennsylvania	📎(1)	☐	☐	☐	☐	☐
66	Tonkin & Taylor LTD	2005.	Mine Subsidence Hazard Report Kamo Area, Whangarei	📎(1)	☑	☐	☑	☐	☐
67			Wyoming Multi-Hazard Mitigation Plan - Chapter 14 Mine Subsidence	📎(1)	☐	☐	☐	☐	☐
69	Stephenson, H.G., Van Den Bussche, B., Curry,	1995.	Reclamation, Rehabilitation and Development of Abandoned Mine Land in Canmore, Al	📎(1)	☐	☐	☐	☐	☐
70			Canmore Undermining Review Regulation	📎(1)	☐	☐	☐	☐	☐
71	Bai, M., Kendorski, F.S., Van Roosendaal, D.J.		Chinese and North American High-Extraction Underground Coal Mining Strata Behavior	📎(1)	☐	☐	☐	☐	☐
72	London Department of the Environment, Trans	2000.	Planning Policy Guidance Note 14 Development on Unstable Land Annex 2: Subsidence	📎(1)	☑	☐	☐	☐	☐
73	Waltham, A.C.		Ground Subsidence	📎(1)	☐	☐	☐	☐	☐
74		1997.	Guidelines to Evaluate Proposed Development Over Undermined Lands in the Town of	📎(1)	☐	☐	☐	☐	☐
75	Building Service Authority		Subsidence a New Policy Designed to Help Alleviate the Cost Imposts of Defective Build	📎(1)	☐	☑	☐	☐	☐
76	Nova Scotia Department of natural Resources		Abandoned Mine Openings (AMO) and Underground Coal Mine Workings	📎(1)	☐	☐	☑	☐	☐
77	United States Department of the Interior Burea	1991.	Technology News: Abandoned Mine Lands Program TN #1 Subsidence Abatement Inves	📎(1)	☐	☐	☐	☐	☐
78	Cole, K.	1987.	Building over Abandoned Shallow Mines	📎(1)	☐	☐	☑	☐	☐
79	Zaburunov, S.A		Controlling Subsidence with Stowing: a Case History	📎(1)	☐	☐	☐	☐	☑
80	Steed, C.M.		Curing Cave-ins	📎(1)	☐	☐	☐	☐	☑
81	Bell, F.G., Fox, R.M.	1988.	Ground Treatment and Foundations above Discontinuous Rock Masses affected by Min	📎(1)	☐	☑	☐	☐	☐
82			General Guidelines for the Development of Lands in the Vicinity of Coal Hazards in Albe	📎(1)	☑	☐	☐	☐	☐
83			Nova Scotia Communities Dealing with Subsidence from Underground Coal Mines	📎(1)	☐	☐	☑	☑	☐
84	Lin, P.M., Peng, S.S., Tsang, P.	1990.	Dealing with Subsidence on Abandoned Mine Lands	📎(1)	☐	☑	☑	☐	☑
85	Gray, R.E.		Subsidence over Abandoned Coal Mines	📎(1)	☑	☑	☑	☑	☑
86	Betournay, M.C.		Underground Mining and its Surface Effects	📎(1)	☐	☐	☑	☐	☐
87	Carlson, M.J., Saperstein, L.w.		Efficient use of Additives to Improve Pneumatically Emplaced Backfill Strength	📎(1)	☐	☐	☐	☐	☑
88	Alston, N.P.	1998.	Coal Mining in Urban Areas of Germany and Poland	📎(1)	☐	☐	☑	☐	☐
89	Service Nova Scotia and Municipal Relations	2006.	Statement of Provincial Interest Guideline 2 Flood Risk	📎(1)	☑	☐	☐	☐	☐
90	Peng, S.S.	1992.	Surface Subsidence Engineering - Chapter 6 - Prevention/Control of Surface Structural	📎(1)	☐	☑	☐	☐	☐
91	Peng S.S.	1992.	Surface Subsidence Engineering - Chapter 9 - Subsidence and Structural Damages Abov	📎(1)	☐	☑	☐	☐	☐
92	Jacques Whitford	2008.	Model Wind Turbine By-laws and Best Management Practices for Nova Scotia Municipa	📎(1)	☑	☐	☐	☐	☐
93	Cape Breton Regional Municipality		Building Inspection Checklist	📎(1)	☐	☐	☐	☐	☐
94	Cape Breton Regional Municipality	1998.	Subdivision By-Law	📎(1)	☑	☐	☐	☐	☐
95	Cape Breton Regional Municipality		Building By-Law	📎(1)	☐	☑	☐	☐	☐
96	Town of New Glasgow		Building By-Law	📎(1)	☐	☑	☐	☐	☐
97	Government of Nova Scotia		Building Code Act Consolidated	📎(1)	☐	☑	☐	☐	☐
98	Municipality of the County of Pictou	1998.	Building By-Law	📎(1)	☐	☑	☐	☐	☐
99	Town of Stellarton	1998.	Building By-Law	📎(1)	☐	☐	☐	☐	☐

ID	Author	Year	Title		Land Use Planning	Structural Design	Hazard Assessm	Compensation /	Remediation
100	Department of Municipal Affairs	1991.	Regulations Made Pursuant to Section 4 of the Building Code Act, R.S.N.S.	(1)	☐	☑	☐	☐	☐
101	Predika, R.S. Dawson, R.F. Sephenson, H.G.		Managing Mine Subsidence Risks at the 3 Sisters Resorts Development in Canmore, Al	(1)	☐	☐	☐	☐	☐
102	Mine Subsidence Board		MSB Annual Report 2008-2009	(1)	☐	☐	☐	☐	☐
103	Craft, Jesse L.	1992	Classification of Mine Related Subsidence East of the Mississippi River, USA	(1)	☐	☐	☐	☐	☐
104	Levelton, B.H.	1992	Development over abandoned Coal Mines	(1)	☐	☐	☐	☐	☐
105	Karfakis, Mario G.		Machanism of Chimney Subsidence Over Abandoned Coal Mines	(1)	☐	☐	☐	☐	☐
106	NSW	2007	Mine Subsidence damage to Building Structures	(1)	☐	☐	☐	☐	☐
107	Froese, Corey R.	2008	Mapping and Monitoring Coal Mine Subsidence Using LiDAR and InSAR	(1)	☐	☐	☐	☐	☐
108	CBRM		Landuse By-Law Overall Map	(1)	☐	☐	☐	☐	☐
109	CBRM		Landuse By-Law	(1)	☐	☐	☐	☐	☐
110	CBRM		Municiple Planning Strategy	(1)	☐	☐	☐	☐	☐
111	Consol		Undergrounds Permits and Subsidence Control	(1)	☐	☐	☐	☐	☐
112	NS Muesum of Natural History		Geological history of Nova Scotia	(1)	☐	☐	☐	☐	☐
113		2008	Geological Investigation Report Sydney	(1)	☐	☐	☐	☐	☐
114	University of Hanover, Germany	2000	Monitoring of Coal Mining Subsidence By HRSC-A DATA	(1)	☐	☐	☐	☐	☐
115	Mine Subsidence Board		Graduated Guidelines for Residental Construction New South Wales Vol. 1 & 2	(2)	☐	☐	☐	☐	☐
116			Mine Subsidence Investigation Claim	(1)	☐	☐	☐	☐	☐
117	NSW	2007	Mine Subsidence Damage to Building Structure	(1)	☐	☐	☐	☐	☐
118	Mine Subsidence Board		Mine Subsidence Annual Report 2006-2007	(1)	☐	☐	☐	☐	☐
119			KY-020 - Mine Subsidence Insurance Fund Established	(1)	☐	☐	☐	☐	☐
120	NSW		Applying Risk Principles to the Management of Subsidence Impacts	(1)	☐	☐	☐	☐	☐
121	Tonkin & Taylor LTD.	1999	Mine Subsidence Hazard	(1)	☐	☐	☐	☐	☐
122	Mine Subsidence Board	1997	Guidelines for Coal Mining and Transmission Lines	(1)	☐	☐	☐	☐	☐
123			Novs Scotia Coal Fields	(1)	☐	☐	☐	☐	☐
124			Nova Scotia Local goerment Resouce Hand Book	(1)	☐	☐	☐	☐	☐
125	Mine Subsidence Board		Residential Pavement Repairs	(1)	☐	☐	☐	☐	☐
126	The Pitsburg Geological Society		Land Subsidence in Western PA	(1)	☐	☐	☐	☐	☐
128	Tonkin & Talor	1991	Mine Subsidence Hazard	(1)	☐	☐	☐	☐	☐
129	Wyoming Multi-Hazard Mitigation Plan			(1)	☐	☐	☐	☐	☐
130	OSM Technology Transfer		Final Report and Fact Sheet	(1)	☐	☐	☐	☐	☐
131	Tonkin & Taylor LTD	2005	Whangarei Hazard Report	(1)	☐	☐	☐	☐	☐

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Appendix E

Sustainability Report

PREPARING FOR CLIMATE CHANGE IN LAND USE PLANNING FOR REHABILITATED COAL MINES IN NOVA SCOTIA

Purpose

This appendix is intended to provide an overarching approach to considering the impacts of climate change in land use planning in Nova Scotia. It provides a high level overview of the likely impacts of climate change on the region, some notes on their significance and a synopsis of the Federal and provincial policy response to date. It then details a possible further approach for assessing vulnerability and risk, along with determining which adaptation options may be appropriate. While the assessment and analysis is general, it is focused to some extent on those lands being rehabilitated from abandoned coalmines in Nova Scotia.

While this appendix canvases the issued described above and provides a general approach for use in planning and other related decisions to inform decision-making processes, the scope of this work did not allow for investigation of climate impacts on particular sites, climate modeling, assessments of risks and vulnerabilities associated with particular sites, nor estimations of the potential benefits of adaptation options. Accordingly, this appendix provides a guide for further work rather than an assessment to inform decision-making.

Impacts of climate change in Nova Scotia

The fourth assessment report (2007) of the Intergovernmental Panel on Climate Change (IPCC) found that warming of the climate system is now unequivocal. The IPCC projects that climate change will continue throughout the 21st Century and lead to warmer temperatures, shifting seasons, and more extreme weather events such as storms and droughts.

Climate change impacts operate inconsistently: impacts can emerge either as a modification of the pattern of **extreme climatic events** such as increased intensity, frequency, seasonal shift, range of storms, floods, storm surges or through **gradual changes** such as changes to seasonal or annual patterns of temperature, rainfall, solar radiation and sea level. Although less observable, these changes are important. Gradual changes can also result in **step changes** of a whole system. The timing of step changes is very difficult to evaluate but needs to be considered as the consequences are severe. See figures 1 and 2 for examples of this point.

Figure 1: Damages caused by wind guests

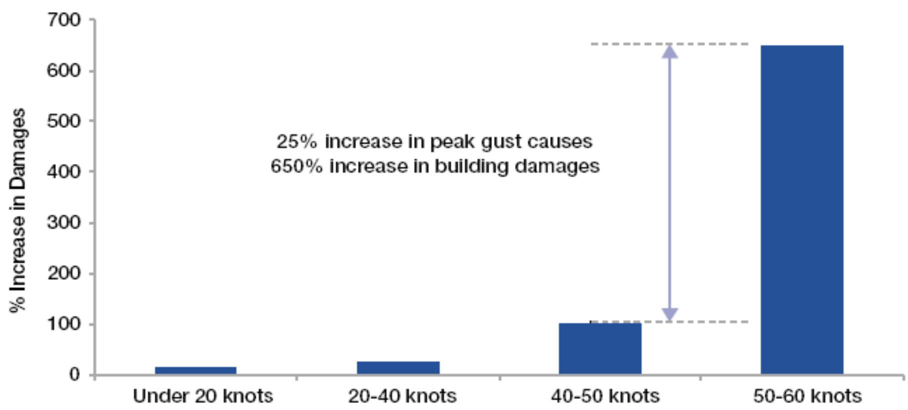


Figure 2: Increases in damages from extreme weather events

Hazard	Cause Of Change In Hazard	Resulting Change In Damage/Loss
Windstorm	Doubling of windspeed 2.2 °C mean temperature increase	Four-fold increase in damages Increase of 5-10% in hurricane wind speeds
Extreme temperature episodes	1 °C mean temperature increase	300-year temperature events occur every 10 years
Floods	25% increase in 30 minute precipitation	Flooding return period reduced from 100 years to 17 years
Bushfire	1 °C mean summer temperature increase Doubling of CO2	28% increase in wildfires 143% increase in catastrophic wildfires

Whether the impacts of climate change occur from extreme events or gradual changes, damage to infrastructure and services are likely to be costly. The assessment of impacts need to not only consider the physical impacts of climate change on a specific type of infrastructure, but also the social, community and economic consequences resulting from the failure of the infrastructure or disruption of the service.

According to Environment Canada, as a result of climate change Nova Scotia will experience more storm events, increasing storm intensity, rising sea level, storm surges, coastal erosion and flooding over the coming decades. In addition, there will be seasonal and yearly variations in precipitation that will combine with higher evapotranspiration to induce drier summer conditions. Finally, there will also be changes to seasonal patterns including periods and dates of frost.

These impacts will threaten a range of sectors, but coastal communities and their infrastructure and industries will be particularly vulnerable. Environment Canada observes that impacts on coastal infrastructure, such as bridges, roads and energy facilities, have already affected trade and tourism in the region, and that some coastal communities have started experiencing saltwater intrusion in their groundwater supply.

Policy Response

Developing a comprehensive and cohesive policy to support adaptation action to climate impacts is difficult. Not only is there uncertainty relating to the nature, severity and timing of impacts, but their significance is also uncertain. To further challenge decision makers, there are only rudimentary tools available for assessing impacts and adaptation options. Additionally, budgets are limited and there is a need to balance levels of risk and response between a number of diverse ecosystems, economic sectors and communities. Finally, decisions made on where and how to spend scarce resources with such competing needs are consistently politically loaded. All levels of the Canadian Government have been activie in wrestling with these difficulties.

Natural Resources Canada is leading the national effort to respond to the impacts of climate change and enhance adaptation action. It has two main thrusts of activities – firstly to provide a mechanism for collaboration between different levels of government, private sector entities, and community organizations on complex adaptation issues that address federal, sectoral, or regional priorities. The objective of this initiative is to equip decision-makers with the information and advice that they need to make policy, operational, and management changes that respond to regional opportunities and threats from a changing climate. In addition, the Federal Government is developing adaptation tools to support decision-making on whether and how to adapt to a changing climate.

In 2009, the Government of Nova Scotia released its climate change plan, *Toward a Greener Future: Nova Scotia's Climate Change Action Plan*. The *Plan* includes practical steps to prepare for and cope with climate changes that can't be averted. Those actions that are particularly relevant for consideration of rehabilitating abandoned coalmines include:

- Action 54: Develop statements of provincial interest on adaptation by 2010 to provide guidance on land-use planning. This is a formal tool, established under the Municipal Government Act, to protect the province's interest in such areas as land use, water resources, and community planning.
- Action 55: Incorporate climate change impacts and adaptation response plans into the strategies and initiatives of all provincial departments by 2012.
- Action 57: Launch a web-based clearinghouse of information and tools to support adaptation to climate change in Nova Scotia in 2009.
- Action 58: Begin work on a provincial vulnerability assessment and progress report on adaptation to climate change in Nova Scotia.
- Action 61: Ensure that design standards and plans for new provincial construction, and for the renewal of existing provincial infrastructure, reflect projected climate trends, not historical records, by 2010.

In 2006, the Canadian Government released a groundbreaking guide (*Adapting to Climate Change: An Introduction for Canadian Municipalities*) for local governments to assist them in adapting to the impacts of climate change. The authors observed that it is prudent for local government's to incorporate climate change risk management into their decision-making processes.

The authors encouraged local government decision-makers to identify no-regrets or low-regrets options (sometimes also referred to as "precautionary principal" or "risk aversion"), particularly for initial climate change adaptation measures. One area in which no regrets actions can be found is land use planning where a comprehensive assessment of current risks would ensure that future uses better suited the immediate locale. The strategy of focusing on no or low-cost measures ensures prudent risk management because it places additional emphasis on areas that are vulnerable to climate change.

<u>Proposed approach for responding to climate impacts</u>

Decisions on land use planning and infrastructure needs to be developed to meet current and future climate conditions. While there is a high degree of confidence that the climate will change in Nova Scotia, there are significant uncertainties about the nature of those changes, their scope and severity. Nonetheless the lack of the capacity to know the future is not an excuse for a failure to take decisions today. Consideration of potential future impacts of climate change needs to be incorporated into planning decisions, as well as infrastructure design and investment decisions. These include:

- Ensuring that before any planning decisions are made or new infrastructure is planned or current infrastructure refurbished that information on projected climate change for the site is compiled and considered. Care needs to be taken, as many of the engineering processes used are historically based and typically exclude future climate projections.

- Ascertaining the impact of the future climate on the business case for new or refurbished infrastructure or planning decisions. It may be unreasonable to build a port for example, to export a cash crop if future climate means that the crop will no longer be viable.
- Ensuring that the use of the site or the infrastructure plan considers what steps may be needed to reduce the impact of climate change and that these are either incorporated into early decision-making or that allowances for the later introduction is ensured.

The proposed approach for consideration of climate change is based on that developed by the Australian Government entitled Climate Change Impacts & Risk Management: A Guide for business and development. The approach taken recognizes the uncertainties involved in making decisions and aims to help businesses and organisations make decisions in spite of them. There are three main steps to this approach.

1. Enumerate risks

   This step involves identifying firstly the region or infrastructure being considered. It could be a town or an electricity supply system. In this case, it is lands previously used as coal mines and now abandoned, but which are going to be rehabilitated.

   It also involves identifying which climate impacts are most pertinent given the location and main activity. In this case, given that studies of the land have not been completed for this task it is difficult to be certain, but a list would likely include changes to sea level rise, storm surge, flooding and other rainfall events given that subsidence is likely to be a materially significant issue.

   These activities are typically undertaken by external actors with knowledge in climate impacts and projections.

2. Prioritize risks

   This step is fundamentally about looking at what the consequences and liklihood are of impacts on the various activities or locales being considered in a typical risk assessment approach where rankings are used to give a total risk score.

	Consequences				
Likelihood	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	Medium	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	High	Extreme
Possible	Low	Medium	Medium	High	High
Unlikely	Low	Low	Medium	Medium	Medium
Rare	Low	Low	Low	Low	Medium

   An assessment is then made about what broad level adaptation options are available and how these might change the risks as previously detailed. This analysis does not provide a suite of adaptation options, but rather highlights where further exploration may be most fruitful.

   Typically this work is completed by stakeholders, with the assistance of individuals with technical capacity on climate change and its impacts.

3. Manage risks

This last phase of work involves identifying real adaptation options – whether they are behavioral, planning based or hard infrastructure change – and assessing them on a cost-benefit or related assessment process. Done appropriately, this analysis should incorporate the range of uncertainties surrounding climate impacts and potential costs. As this is an evolving area of work there are not yet many examples where this analysis has been undertaken.

One example of this analysis was recently completed for the Australia Department of Climate Change and Energy Efficiency. The study looked at a particular coastal community and identified three suites of adaptation action were economically justified, but some actions not for twenty or more years. The details of this study can be found at (http://www.climatechange.gov.au/~/media/publications/adaptation/coastal-flooding-narrabeen-lagoon.ashx).

Given that it is not possible to undertake this assessment for the lands covered by this study, we have included some overarching analysis of typical issues associated with climate change and various land uses/infrastructure types at Table 1. While not comprehensive, this list should prove to be a useful introductory guide for issues to investigate as various land uses are considered for currently abandoned lands.

Table 1: Examples of climate change impacts on infrastructure – considerations for planning

Infrastructure	Climate Variables	Impact
Buildings	Extreme storm, rain and wind events	Storm damage to building structures and materials, impacts to occupant safety, service disruption for commercial buildings and asset life reduction
Water	Changes in rainfall, change in solar radiation, increases in temperature, sea level rise	Reduced capture and storage of water, reduced ground water recharge, and salt water intrusion into freshwater catchments
Energy	Extreme storm, rain and wind events and increased flooding	Damage to energy structures, towers, service disruption to residents and business, and asset life reduction
Information and communications technology	Extreme storm, rain and wind events	Storm damage to communications towers, inundation of support structures, service disruption and repair delays
Sanitation	Extreme storm, rain and wind events, increased flooding, sea level rise and salt water intrusion	Damage to sewage treatment structures and impacts to effectiveness of treatment, waste service disruption, increased community health risks
Transport	Changes rainfall, increased temperatures, changes in ground movement, extreme storm, rain and wind events, and sea level rise	Road surface and drainage deterioration and erosion, inundation, bridge failure, service access limitations, asset life reduction and increased maintenance and repair

Table - Nova Scotia Subsidence Guidelines Project Sustainability Inventory

Total Emissions	tonnes
Emissions from office work	0.95
Emissions from car-based travel	0.50
Sub-total emissions	1.45
Conservative factor (+20%)	0.29
Total emissions	1.74

ZERØCO2 MD

CARBON OFFSET CERTIFICATE

MR. GREG PICKER IS COMMITTED TO THE FIGHT AGAINST CLIMATE CHANGE BY COMPENSATING FOR GREENHOUSE GAS EMISSIONS THROUGH OFFSET CREDITS.

Mr. Greg Picker

In cooperation with the ZEROCO2 team, Mr. Greg Picker has contributed to the development of a wind power project in Turkey through the purchase of Gold Standard certified carbon offset credits. The Gold Standard certification guarantees that selected emission reduction projects represent the best on the market.

This initiative is in the same vein as the best sustainable credit options that benefit everyone. Through this visionary commitment, Mr. Greg Picker has significantly reduced its carbon footprint.

COMPENSATION THROUGH THE PURCHASE OF CARBON CREDITS

The Gold Standard
Premium quality carbon credits

NUMBER OF TONS	NUMBER OF CREDITS	NAME OF PROJECT	TYPE OF PROJECT	CERTIFICATION
2	2	Turkey -Wind Power in the Region of Marmara	Renewable Energy	Gold Standard

CERTIFICATE 072194

OCTOBRE 8, 2010

SÉBASTIEN LÉONARD
PRESIDENT, ZEROCO2

Appendix F

Supporting Information from Other Jurisdictions

Appendix F1 –
“Mine Subsidence – A Guide For Council Staff”, Mine subsidence Board, New South Wales,
Source: current website:
http://www.minesub.nsw.gov.au/templates/mine_subsidence_board.aspx?edit=false&pageID=3968

Appendix F2 –
“A Guide to Designing for Mine Subsidence”, Mine subsidence Board, New South Wales,
Source: current website:
http://www.minesub.nsw.gov.au/templates/mine_subsidence_board.aspx?edit=false&pageID=3968

Appendix F3 –
“Designing for ‘Pothole’ Subsidence”, Mine subsidence Board, New South Wales,
Source: current website:
http://www.minesub.nsw.gov.au/templates/mine_subsidence_board.aspx?edit=false&pageID=3968

Appendix F4 –
“Mine Subsidence – A Community Guide”, Mine subsidence Board, New South Wales,
Source: current website:
http://www.minesub.nsw.gov.au/templates/mine_subsidence_board.aspx?edit=false&pageID=3968

Appendix F5 –
“Subsidence – A New Policy Designed to ehlp alleviate the Cost Imposts of Defective Building Work in Footings & Slabs”, Queensland Building Services Board
Source: current website: www.bsa.qld.gov.au

Appendix F6–
“Planning Policy Guidance Note 14 ‘Development on Unstable Land’, Appendices 2C, 2D, 2E”.
Source: current website:
http://www.communities.gov.uk/documents/planningandbuilding/pdf/147474.pdf

MINE SUBSIDENCE

A GUIDE FOR COUNCIL STAFF

Working with councils for the benefit of the community.

MINE SUBSIDENCE BOARD

Facilitating development which is compatible with mine subsidence.

PUTTING SERVICE AND THE NEEDS OF PEOPLE FIRST

MINE SUBSIDENCE – A GUIDE

INTRODUCTION

This guide has been prepared specifically for Council staff to assist you with issues relating to mine subsidence and the Mine Subsidence Board. It explains the role of the Board, and how this fits in with local councils.

WHAT IS THE MINE SUBSIDENCE BOARD AND WHAT DO WE DO?

The Mine Subsidence Board is an independent body operating for the local community in areas of coal mining in NSW. We:

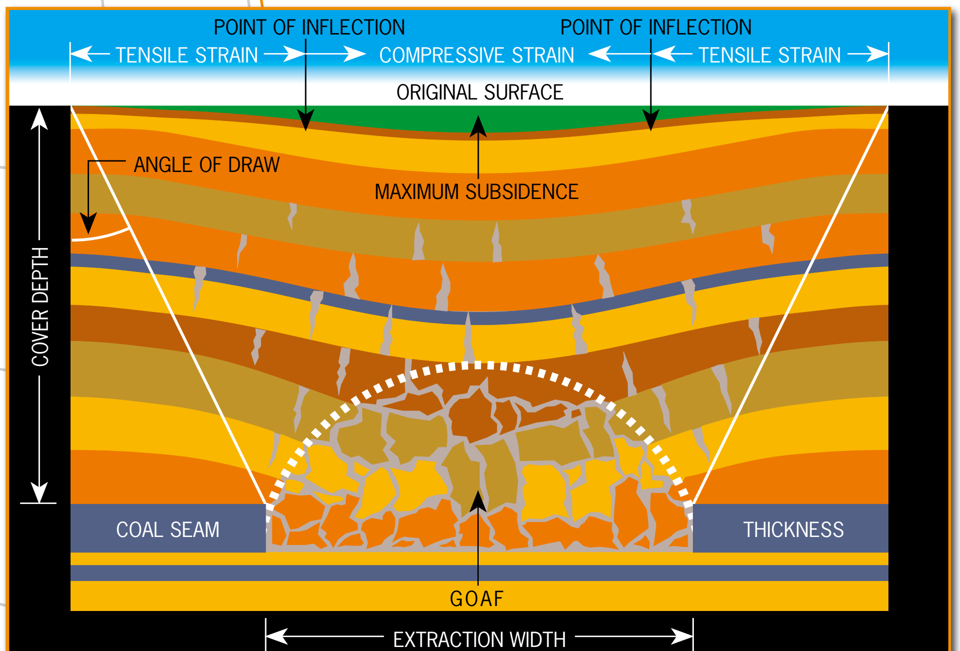
- Provide compensation if improvements on the surface are damaged by mine subsidence
- Prevent damage by ensuring new developments are compatible with the risk of mine subsidence
- Eliminate the risk of danger from mine subsidence
- The Mine Subsidence Board is NOT responsible for approving mining activity.

WHY IS THE MINE SUBSIDENCE BOARD HERE?

- Owners can't get insurance for subsidence – it is an "excluded event" in policies
- Action through the Courts takes too long

HOW DO WE DO IT?

- The areas of conflict between mine subsidence and new development are made Mine Subsidence Districts (a full map of the areas included in these Districts can be found on our website)
- Within those areas, Surface Development Guidelines are calculated, using the Building Code of Australia
- All applications for Development are then assessed against those Guidelines



Not to scale. In this exaggerated diagram, the factors contributing to mine subsidence can be seen.

▲ Potholes from old abandoned mining are repaired by the Board where they present a public or private danger.

WHY ARE LOCAL COUNCIL STAFF SO IMPORTANT TO THE MINE SUBSIDENCE BOARD?

Subsidence is a potential site condition, just like landslip or bushfire threat.

The Mine Subsidence Board helps your ratepayers to avoid future problems with mine subsidence (rather than the Council having to do it, like in other States) by assessing Development Applications to ensure compatibility with the risk of mine subsidence – prevention is always better than cure.

BUT WHAT ARE THE COSTS?

The Mine Subsidence Board does not charge for its development services.

We have even waived the fee for referral of Integrated Development by Council. The time we take to process applications is important to us – we have a Key Performance Indicator of processing 95% of applications within 5 working days. Major construction projects will take a little longer.

WHAT IS MINE SUBSIDENCE?

Subsidence is the lowering or settling of the land's surface after underground mining has taken place.

Not all mining results in subsidence nor does all subsidence cause damage to surface structures. Coal Mines are required to provide detailed information regarding mining and its potential effects prior to mining approval being granted.

Once mining has taken place, the forces in the ground are redistributed and there is a tendency for the void to close. Some of this effect may be transferred to the surface, resulting in mine subsidence.

FOR COUNCIL STAFF

DEEMED APPROVALS:

Where a Council does not require a building application, deemed approval is given. Some minor items of household change do NOT need Mine Subsidence Board approval, prior to Council processing.

These items include:

Improvement	Description	Maximum Size	Cladding	Comments
Access ramps for disabled	Brick/masonry or timber			
Addition of rooms	Steel or timber framed	50 sqm	No masonry	Maximum 1.5m foundation brickwork. No slabs
Advertising structures and signs	Metal or timber			
Amended plans	Mirror reverse, site, window/door locations etc			Minor alterations to plans approved within last 2 years
Aviaries	Steel or timber framed	50 sqm	No masonry	
Awnings	Steel or timber framed	50 sqm	No masonry	
Barbeques		3 sqm		
Cabanas		50 sqm	No masonry	
Carports	Steel or timber framed	50 sqm		
Change of use				No major alterations required
Cubby houses	Steel or timber framed	50 sqm	No masonry	
Decks	Steel or timber framed	50 sqm	No masonry	
Demolition				All types - MSB approval not required
Fences	Timber and metal			Includes pool fencing
Fences	Brick/masonry	2m high		
Fowl house	Steel or timber framed	50 sqm	No masonry	
Garages	Steel or timber framed	50 sqm	No masonry	
Garden sheds	Steel or timber framed	50 sqm	No masonry	
Gazebos		50 sqm	No masonry	
Greenhouses	Steel or timber framed	50 sqm	No masonry	
Internal alterations				Includes doors, windows, ceilings, kitchens, ensuites, toilets, internal partitions
Jetties	Timber and concrete			Predominantly within high water mark
Machinery and hay sheds	Steel or timber framed	120 sqm	No masonry	
Patios	Steel or timber framed	50 sqm	No masonry	
Pergolas	Steel or timber framed	50 sqm	No masonrry	
Pools, spas and saunas	Above ground or fibreglass / prefab. inground	10 m max.	No concrete inground	
Replacement of cladding or roofs			No masonry to walls	
Retaining walls	Masonry and timber	1 m high		
Septic tanks	Domestic purposes only			
Shade sails	Steel or timber posts			
Shop fitouts				Includes doors, windows, ceilings, kitchens, ensuites, toilets, internal partitions, floor coverings
Stables	Steel or timber framed	50 sqm	No masonry	
Water tanks - above & underground		10,000 L		Domestic use

WHAT DOES REQUIRE BOARD APPROVAL?

Some of the items that DO require board approval include:

- Subdivision of land
- Multi storey developments
- Extensions on to an existing home
- Building Applications
- New homes being built in a Mine Subsidence District

(this is not a full list of items requiring Board approval)

DEVELOPMENT GUIDELINES:

The Mine Subsidence Board has a set of development guidelines relating to structures and sub-divisions within districts.

These guidelines are designed to ensure structures will tolerate expected levels of subsidence so that safety is not compromised, can remain in use and in the event of damage occurring, any inconvenience is limited whilst repairs are made.

Our guidelines cover the allowable height of a building, the type of building materials used and the construction methods.

ELIMINATION OF DANGER:

A major role undertaken by the Mine Subsidence Board is the elimination of danger. On occasions, mine subsidence from old shallow mining may cause potholes to occur.

The Board staff are available 24 hours to eliminate this danger immediately.

OUR STAFF ARE HERE TO ASSIST:

The Mine Subsidence Board's staff are here to assist you, with four offices located conveniently in coal mining areas of NSW.

Not only is our website a great source of information, we have a wide range of brochures and other information on mine subsidence to assist you.

Our staff can also assist with technical information on items such as designing for subsidence.

WE APPRECIATE YOUR FEEDBACK:

As part of the Board's commitment to service, we work on continuous improvement to provide the highest standard of customer service. Our staff adheres to a Professional Code of Conduct and a Guarantee of Service.

For this reason we value feedback to assist us in keeping our service to the level and needs of the community and welcome constructive complaints and compliments.

SOME MORE FACTS THAT YOU MAY NOT KNOW ABOUT COUNCILS AND THE MINE SUBSIDENCE BOARD:

- Under s91 of the Environmental Planning and Assessment Act, all development in a Mine Subsidence District is Integrated Development (unless it is Exempt Development)
- Under Clause 66 of the Environmental Planning and Assessment Regulation 2000, Councils are obliged to refer Integrated Development to the Mine Subsidence Board
- The Mine Subsidence Board does not charge fees for its development services
- Councils are required to disclose in their s149 Certificates, whether a property is in a Mine Subsidence District. This is to alert potential purchasers to make further enquiries
- These legal requirements demonstrate the commitment of New South Wales towards protecting ratepayers from the effects of mine subsidence. Teamwork and cooperation between Mine Subsidence Board and Councils helps achieve this.

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PUTTING SERVICE AND THE NEEDS OF PEOPLE FIRST

hdp 2007 cover house photograph courtesy of Montgomery Homes

A GUIDE TO DESIGNING FOR MINE SUBSIDENCE

MINE SUBSIDENCE BOARD

PUTTING SERVICE AND THE NEEDS OF PEOPLE FIRST

A GUIDE TO DESIGNING FOR M

INTRODUCTION

This information is provided by the Mine Subsidence Board as general guidance only and in no way can replace the services of a professional consultant on a particular project.

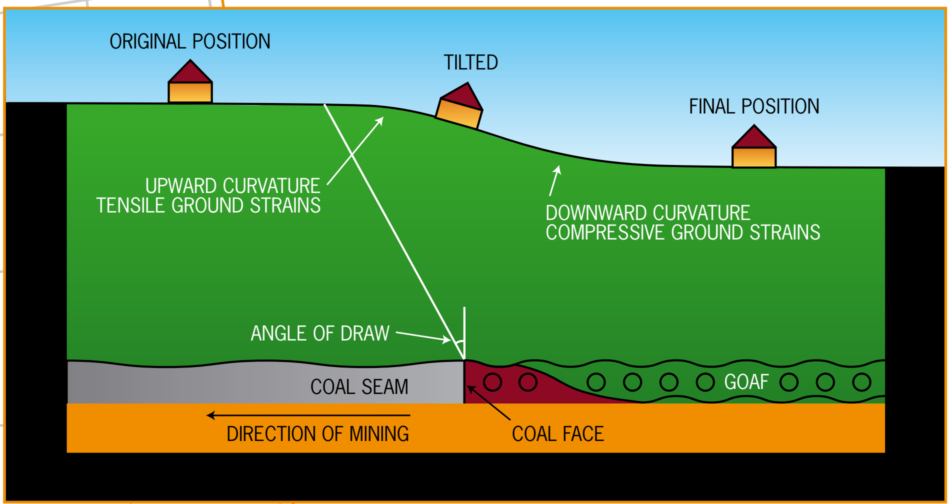
The Mine Subsidence Board is a service organisation operating for the community in coal mining areas of NSW and manages the scheme of compensation as provided for in the Mine Subsidence Compensation Act.

The Act provides for compensation or repair services where improvements are damaged by mine subsidence resulting from the extraction of coal. The Act also gives the Board the responsibility of reducing the risk of mine subsidence damage to properties by assessing and controlling the types of buildings and improvements which can be erected in Mine Subsidence Districts.

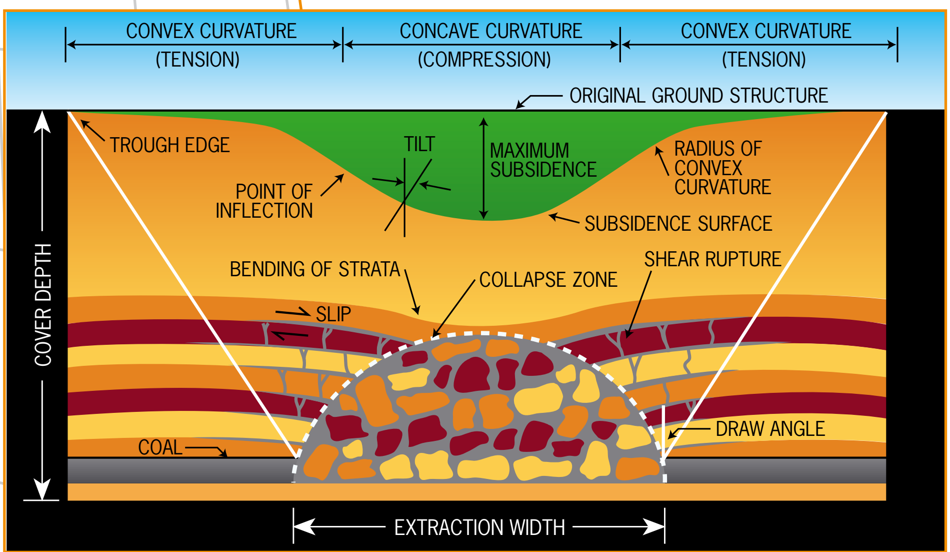
EFFECTS OF MINING

Movement of the ground surface following the underground extraction of coal results in the following:

1. *Vertical subsidence*
2. *Horizontal displacement*
3. *Horizontal strains*
4. *Curvature*
5. *Tilt*



Surface Effects of Longwall Mining - Long Section ▲



Surface Effects of Longwall Mining - Cross Section ▲

Not all mining results in subsidence nor does all subsidence cause damage to surface structures.

Engineering and architectural considerations can significantly minimise the risk of all types of structures experiencing mine subsidence damage. Special design and detailing techniques are adopted to allow structures, including buildings, roads, railways, services, etc, to withstand anticipated movements from earthquakes and unstable foundation material. Mine subsidence is just another form of ground movement that can be designed for. Design principles and techniques that allow structures to accommodate ground movement resulting from mine subsidence have been used extensively in England and Europe since the 1920s and in Australia since the 1960s.

Generally it is the strains and curvature that damage structural elements of buildings. If strains in the ground are transferred into the structure, the tensile and compressive strains may cause building elements to crack, shear or buckle.

Tilt does not normally cause structural damage, however, in severe cases it may affect the usage of a building.

At the design stage it is possible to select a type of structure that, with appropriate detailing, will allow the structure to accommodate these subsidence effects. Designers aim to provide a structure where any damage is non structural and the building remains:

a) Safe - no danger to users
b) Serviceable - available for its intended use
c) Repairable - damaged components economically replaceable

DESIGN OF STRUCTURES

Design for Vertical Subsidence

In general terms, ground subsidence represents a rigid body movement that has no effect on surface structures. As such, it is seldom a significant factor in the design of individual buildings. Structures will be left at a lower level but this normally has no adverse effect on them except in the case of buildings in close proximity to watercourses that may pose a flooding problem. Generally services such as drainage would subside with the building so no differential movement would occur.

Where geological conditions are present which may induce stepping such as along fault or fissure lines, differential vertical movement may be an issue. However, such geological features are often hidden beneath the surface soils and it is unlikely that their presence will be known at design stage unless a detailed site investigation has been undertaken.

This situation is most likely to be of relevance over areas larger than most residential dwelling footprints. Services such as water, sewerage and drainage may require additional care in design and detailing.

Design for Horizontal Displacements

Horizontal movements due to mining occur in such a way that points on the surface move in towards the centre of the subsidence trough. Differential movements result in strains. Overall horizontal movements are generally small except where there are unusual topographical features such as steep slopes, gorges or geological features.

Design for Horizontal Strain

Ground strains occur as a result of differential movement between two points causing a change in length of the surface between the two points. If the length of the surface increases, a tensile strain is induced and if the length of the surface reduces, a compressive strain is created.

Both tensile and compressive strains can generate damage in buildings. In most buildings, the materials are generally weaker in tension than compression, hence tensile forces are the more difficult to accommodate.

Tensile strains can cause cracks in brickwork, internal linings such as plasterboard, pulled joints in pipework, cracks and separation of joints in paving.

Compressive strains can cause spalling of brickwork, crushing of components, closure of door and window openings, buckling of materials, buckling of pipes, paving and other components.

Not all strain in the ground will be transferred into the structure. This is due to a number of factors including foundation type, ground material, the presence of sliding layers, the location and orientation of the mining in relation to the structure and so on.

In general terms, ground strains are transferred into footing systems by friction beneath and beside the footing elements. The obvious solution, therefore, is to reduce such friction and - wherever possible - separating the footing structure from the soil. This may be achieved by providing a slip layer between the structure and the ground to allow the ground to move without damaging the structure.

Footings can be designed to minimise the effect of strains on the superstructure by making them as shallow as possible and by placing them on slip layers. When deep foundations are unavoidable, the forces imposed can be reduced by excavating trenches around the structure. These trenches are placed as near as practical to, and extend to just below the underside of, the foundation. They can be backfilled with a compressible material which is strong enough to support the sides of the excavation but more compressible than the natural soil. This fill will crush and not transfer all of the forces to the foundation. Coke, slabs of expanded polystyrene foam, vermiculite, cork and void formers have been used for this purpose.

Various techniques have been used to allow footings to slip relative to the foundation material. The sides and bottoms of footings and slabs are kept as smooth as practical and are often poured on slip layers that incorporate plastic or bituminous membranes over layers of granular materials (sands). Exaggerated slopes are used on transition zones between stiffening beams and slabs to facilitate shearing actions.

The use of concrete slab on ground footing systems is now close to 90% in NSW with the emergence in recent years of the waffle raft system as the preferred reinforced concrete slab footing system. This is a fortunate outcome as the waffle raft system is ideal as a mechanism for isolation of the superstructure from horizontal ground strains.

Design for Curvature

Curvature results from differential settlement across the ground surface and is considered the most damaging of the mine subsidence parameters to impact on a building. Curvature is normally defined by the deflection ratio or the radius of curvature.

In practice, damage from mine subsidence will often be a result of the combination of curvature and ground strains.

The effects of ground curvature can be minimised by panelling and articulating walls to move without developing strains or cracks or causing doors and windows to jam. Vertical articulation joints are provided at appropriate intervals and at sections where the wall stiffness changes. Damage due to curvature can also be minimised by eliminating brickwork above windows, doorways and arches. If such details are included, special attention must be paid to provision of bond beams and strengthening panels that incorporate arches.

Design for Tilt

Ground tilt results from a differential vertical subsidence between two points that changes the slope of the surface between the two points. Ground tilts that occur during the course of mining operations may be either a temporary or permanent phenomenon depending on their location in reference to the subsidence trough.

Structures subject to tilt are only adversely affected if they remain in a significant permanent tilt at the conclusion of subsidence. This normally occurs when a structure is located on the edge of the subsidence trough.

Small tilts generally do not affect the usage of a building and can be catered for by providing such things as generous falls for services. Tilts over 7 mm/m will start to affect the serviceability of the building and the type of construction will be restricted to allow economical repair. Suspended flooring systems can be relevelled economically where access is available to the supporting bearers and joists.

If sufficient ceiling height has been provided in the original design, and if appropriate detailing has been adopted, it may be possible to relevel floor slabs by adding a topping layer to recover original grades.

Domestic floor slabs are not normally strong enough to withstand relevelling by jacking. Other types of slabs may be designed with jacking points and sufficient strength to be relevelled after subsidence.

Considerable research effort has been expended in recent years in relation to designing footing systems that are capable of being relevelled if unacceptable tilts result from mining operations. This research will continue in an attempt to find solutions to the relevelling issue.

Combined Effects

In reality the damage that occurs to a building is a result of a combination of some or all of these parameters. The deformation of the ground surface as a result of subsidence can lead to both curvature and strain affecting a structure with the possibility of tilts affecting the serviceability.

Generally a building should be designed taking a conservative approach and assuming a full transfer of strains and displacements from the ground to the structure.

OTHER REQUIREMENTS

Pothole Type Subsidence

Where movements of the ground surface occur over old shallow abandoned underground mine workings it can result in a localised depression or 'pothole' in the surface. The majority of these types of subsidence are generally small, however, the design parameter used by the Board is for a potential pothole up to 5 metres in diameter.

For further information on designing for pothole subsidence refer to the Mine Subsidence Board brochure "Designing For Pothole Subsidence".

MINE SUBSIDENCE BOARD REQUIREMENTS

Approval must be obtained from the Mine Subsidence Board prior to any building activity or extensions for sites within Mine Subsidence Districts. The Board may grant unconditional approval of the application or stipulate certain conditions that must be met prior to final approval. In some extreme cases, where the risk of mine subsidence damage is too great, the Board may refuse a building application.

Architectural plans submitted to the Mine Subsidence Board for approval must show the location and detailing of articulation/control joints in brickwork to comply with the requirements of the Building Code of Australia and best building practices.

Please contact any of the Board's offices for further information and advice.

PRACTICE

It is essential that good building practice be complied with in conjunction with any design features. The correct placement and detailing of articulation joints, detailing of brickwork above windows and doors, internal wall detailing and so on are all important to achieve a structure that is capable of handling the subsidence movements.

Some publications relevant to the description and implementation of these best practice procedures are referenced below.

1) Technical Note 61 - "Articulated Walling", Cement and Concrete Association of Australia
2) Techniques 11 - "Articulation Joints & Control Gaps for Full Brick Houses", Clay Brick and Paver Institute
3) Australian Standard AS2870
4) The Building Code of Australia

REFERENCES

1) R.G. Hanson., "Designing For Subsidence". Mine Subsidence Board Annual Review 1988-89.
2) Holla L., "Mining Subsidence in New South Wales - 2. Surface Subsidence Prediction in the Newcastle Coalfield." NSW Department of Mineral Resources.
3) Australian Standard AS2870.
4) The Building Code of Australia.

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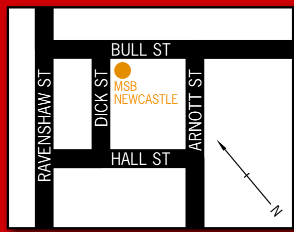

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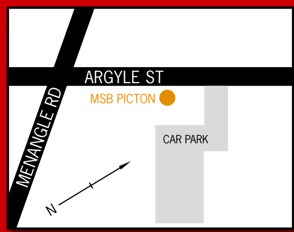

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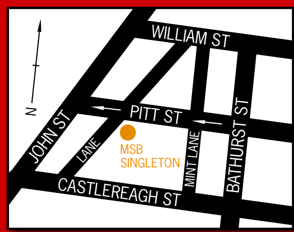

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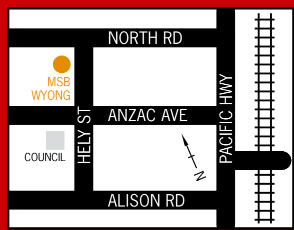

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MINE SUBSIDENCE BOARD

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DESIGNING FOR

"POTHOLE" SUBSIDENCE

MINE SUBSIDENCE BOARD

PUTTING SERVICE AND THE NEEDS OF PEOPLE FIRST

DESIGNING FOR POTHOLE SUBSIDENCE

INTRODUCTION

Engineering and architectural considerations can significantly minimise the risk of all types of structures experiencing mine subsidence damage.

The interaction between structures and a moving ground surface has been a matter of importance to engineers, architects and the community for centuries.

'Structures', includes all types of buildings, roads, railways, drains, services, etc. They can be designed for areas with unstable foundations or that are prone to earthquake loadings, with special design and detailing techniques adopted, to allow the structures to withstand anticipated movements.

Design principles and techniques that allow structures to accommodate ground movement resulting from mine subsidence have been adopted extensively in England and Europe since the 1920's and in Australia since the late 1960's.

MINE SUBSIDENCE BOARD

WHAT IS 'POTHOLE' SUBSIDENCE

Where movements of the ground surface have occurred over old shallow abandoned underground mining it can result in a localised depression, 'potholes' or holes in the ground surface. The majority of these types of subsidences are generally small, however the design parameter used by the Board is 5,000mm (5 metres). Subsidences occur primarily in the Newcastle area, and in parts of Lake Macquarie, Maitland, Hunter Valley, Lithgow and parts of the South Coast region.

At the design stage, it is possible to select a type of structure that, with appropriate detailing, will allow the building to accommodate these subsidence effects. Designers aim to provide a structure where any damage is non-structural and the building remains:

a) Safe - no danger to users
b) Serviceable - available for its intended use
c) Repairable - damaged components repaired economically

Normally the Board's surface development guidelines for building in these areas would be single storey timber or steel frame clad with weatherboard or other similar materials. However, single storey brick veneer or two storey lightweight buildings can only be constructed subject to certain design condition, such as:

1. The building is to be designed for a pothole of nominal diameter 5 metres. It must cater for any subsidence of up to 5 metres in diameter occurring at any location around or under the dwelling and remain safe, serviceable and repairable. The designers must take into account the requirements of Australian Standard 2870.1.
2. Drawings must be submitted prior to the commencement of construction and certified by a qualified structural engineer, to the effect that improvements constructed meet the specification of such final drawings and will be safe, serviceable and repairable if a pothole of up to 5 metres occurs under or near the dwelling.
3. Concrete "raft" or "infill" floors are not permitted by the Board in these areas. Access or crawl space must be provided under the floor to allow for filling by the Board if a subsidence does occur at the property. Non structural concrete floors on the ground are allowed in garages or non habitable areas such as store rooms or laundries.
4. The height of the foundation brickwork is not to exceed 1.5 metres.This height is measured from the finished ground level to the under side of the floor bearers or damp course level.
5. The typical type of floor system which would be approved by the Board is the conventional bearer and joist system which is constructed of either timber or steel. This system can be supported on normal isolated sleeper piers to comply with council requirements, provided they are not supporting load bearing internal walls.

Panel floor systems of lightweight concrete or similar and load bearing walls must be supported on footings which have been designed to span a nominal diameter pothole of 5 metres.

NOTE: The risk of residential structures sustaining damage can be reduced by adopting good building practices and incorporating design features such as the use of articulated joints or panelised brickwork, in accordance with the Building Code of Australia.

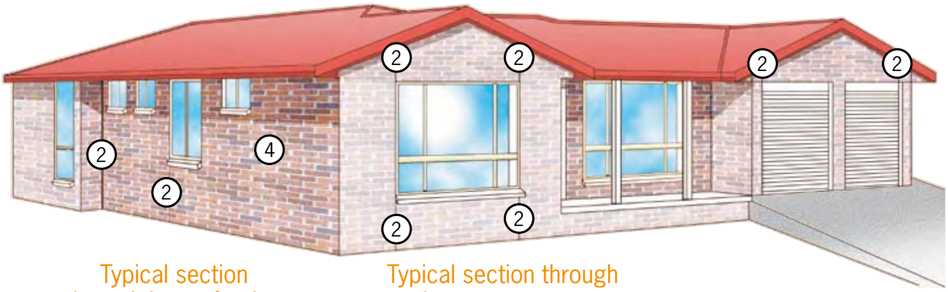
These features should be considered by the designer when detailing structures for pothole areas. If the requirements of the Board have been complied with, the dwelling is covered for compensation under the Mine Subsidence Compensation Act. If mine subsidence damage does occur, the owner simply has to lodge a claim and repairs will be carried out by the Mine Subsidence Board.

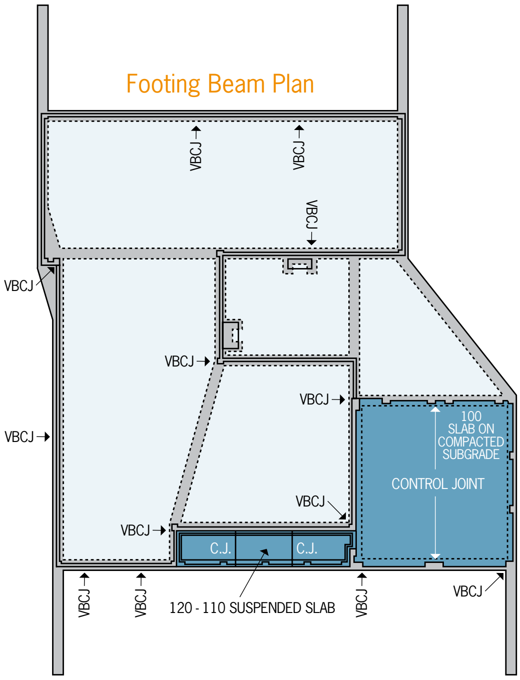
The Board's expert staff would be pleased to assist you with further enquiries or provide you with any of our other brochures

The Mine Subsidence Board will provide interpreter services free of charge to people of non-English speaking backgrounds.

SINGLE STOREY BRICK VENEER CONSTRUCTION

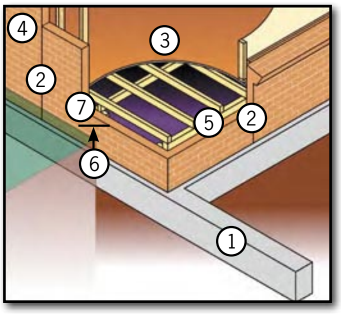
1. **1** Engineer Designed Reinforced Concrete Pothole Footing
2. **2** Control Joint
3. **3** Standard Subfloor Timbers
4. **4** Brick Veneer Construction
5. **5** Damp Proof Course
6. **6** Foundation Brickwork (Height Not To Exceed 1.5m)
7. **7** Engaged Brick Piers
8. **8** Brick Isolated Pier
9. **9** Concrete Pad Footing To Engineer Requirements
10. **10** Concrete Panel Floor System



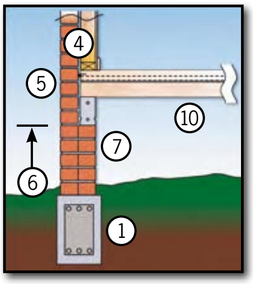


Footing Beam Plan

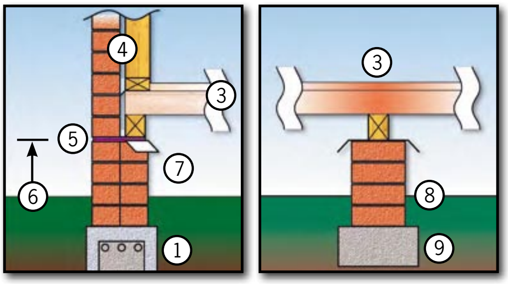
Typical section through beam footing



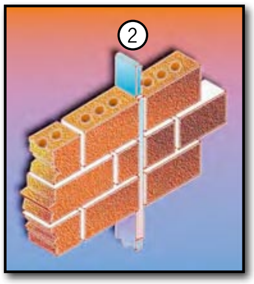
Typical section through alternate concrete panel floor system



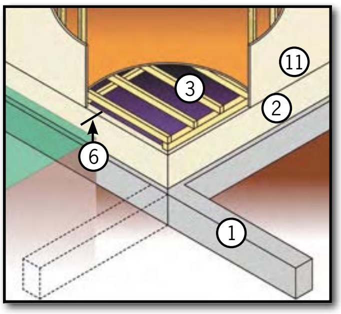
Typical section through brick veneer foundation



Articulation joint - external masonry wall

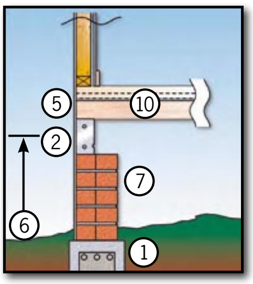


2 STOREY LIGHTWEIGHT CONSTRUCTION

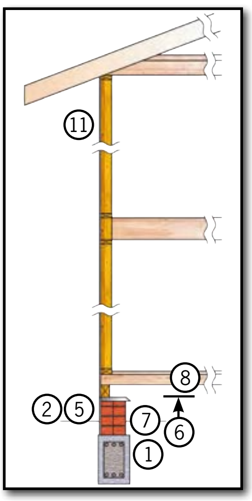


Typical section through beam footing

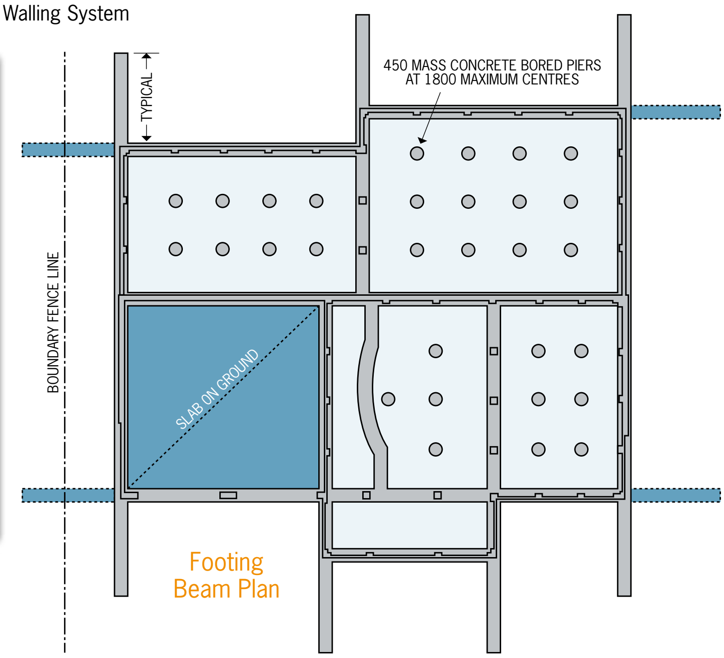
1. **1** Engineer Designed Reinforced Concrete Pothole Footing
2. **2** Control Joint
3. **3** Standard Subfloor Timbers
4. **4** Brick Veneer Construction
5. **5** Damp Proof Course
6. **6** Foundation Brickwork (Height Not To Exceed 1.5m)
7. **7** Engaged Brick Piers
8. **8** Brick Isolated Pier
9. **9** Concrete Pad Footing To Engineer Requirements
10. **10** Concrete Panel Floor System
11. **11** Lightweight Fibre Board Cladding with Applied Finish
12. **12** Lightweight Concrete Panel Walling System



Typical section through alternate concrete panel floor system

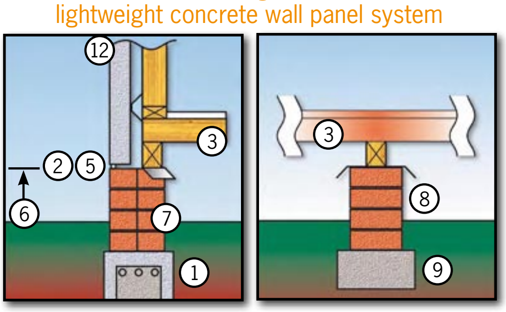


Typical section through 2 storey light weight fibre board clad with applied finish



Footing Beam Plan

Section through alternate lightweight concrete wall panel system



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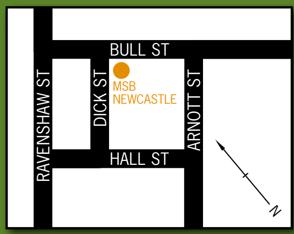

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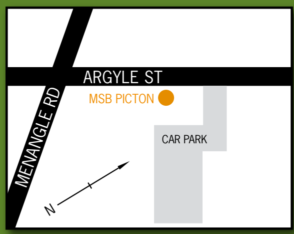

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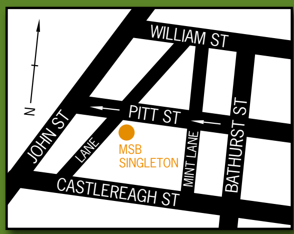

WYONG

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30 Hely Street, Wyong 2259
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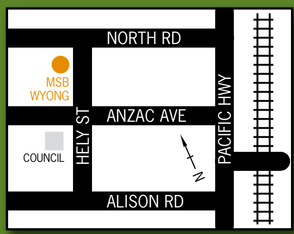
Facsimile: (02) 4352 1757



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MINE SUBSIDENCE BOARD

PUTTING SERVICE AND THE NEEDS OF PEOPLE FIRST

hdp 2007

MINE SUBSIDENCE

A COMMUNITY GUIDE

MINE SUBSIDENCE BOARD

PUTTING SERVICE AND THE NEEDS OF PEOPLE FIRST

WHAT IS MINE SUBSIDENCE?

Mine subsidence may result from current or future mining, or from our heritage of 200 years of coal mining in NSW.

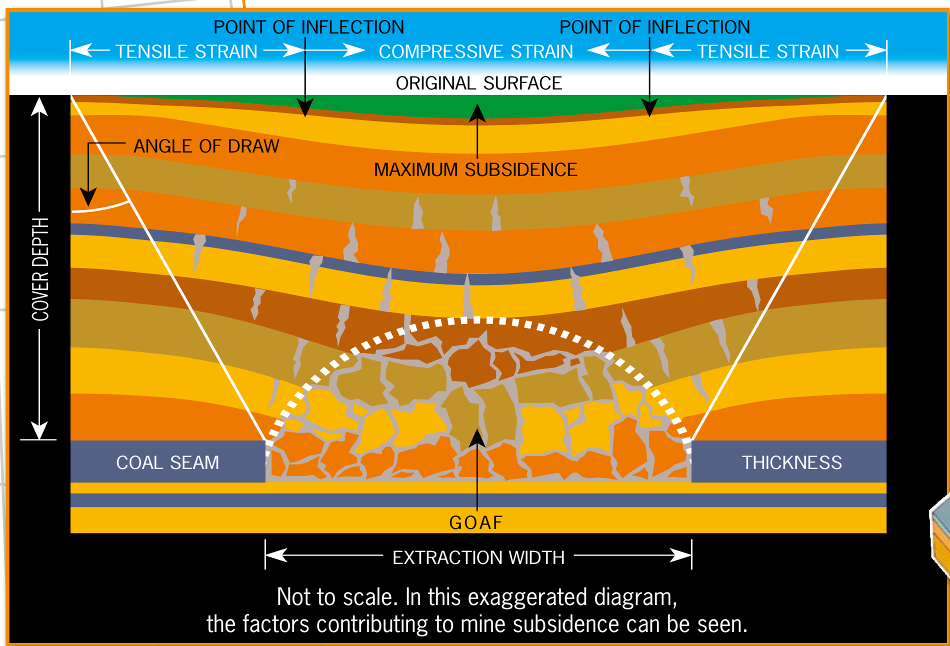
Subsidence can be described as the lowering or settling down of the land's surface. When underground mining takes place, the earth's forces are redistributed and there is a tendency for the void to close. Some of this effect may be transferred to the surface as mine subsidence. The extent to which subsidence occurs in a particular location depends upon the width and height of the coal extracted, its depth from the surface, and the rock types found in the overlying strata.

Not all mining results in subsidence nor does all subsidence cause damage to surface structures. Today's coal mines are required to provide detailed information regarding mining and its effects prior to extraction approval being granted. The amount of subsidence and type of structure will influence the extent of damage that may occur.

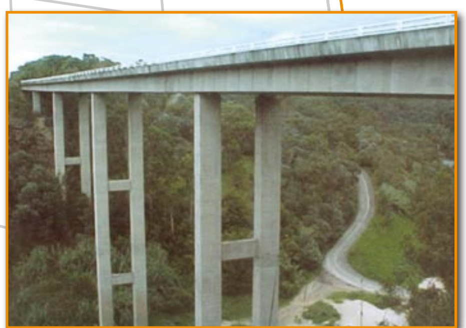
Since the early 1970s, a large data bank of subsidence information has been collected in NSW from field observations. Analysis of that data has led to the development of models to predict subsidence. The surface is monitored for mine subsidence whilst coal extraction is carried out.

Organisations such as the Department of Primary Industries - Mineral Resources and NSW Minerals Council can assist you by providing information on coal mining. The Department of Primary Industries - Mineral Resources is responsible for the issue of mining leases and approval to extract coal.

Experience both in Australia and overseas has shown that through controlled subsidence it is possible to successfully undermine significant and sensitive structures, eg, bridges, historical buildings, pipelines and railways.



Not to scale. In this exaggerated diagram, the factors contributing to mine subsidence can be seen.



UNDERGROUND COAL MINING METHODS

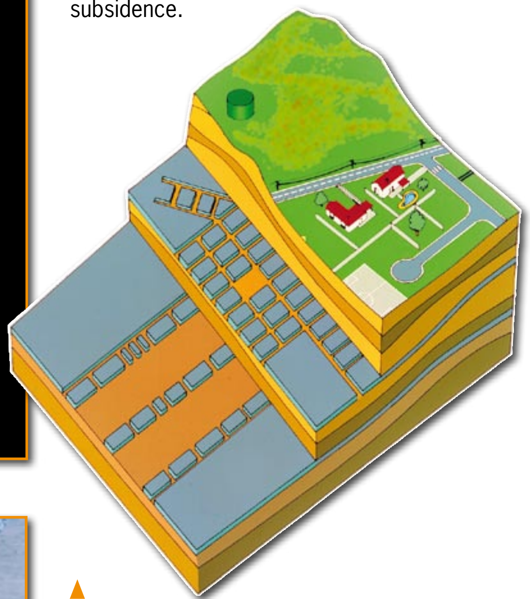
Bord and pillar and longwall mining are the two principal mechanical methods of underground coal recovery. Many variations based on these methods have been developed to suit particular geographical or mining conditions, however, all employ either continuous miners or longwall shearers to extract the coal.

With bord and pillar mining, a series of parallel headings connected by cut-throughs are developed to the furthermost limit of the panel. Once these first workings are completed, the standing pillars and surrounding coal are systematically extracted, working back towards the main access roadways. This part of the operation is called second workings or pillar extraction.

It is possible to limit the surface subsidence by leaving a proportion of the pillars in place to support the overlying strata. This is known as partial extraction.

With longwall mining, two sets of parallel headings are developed between 100-300 metres apart and linked by a connecting roadway at the end furthest from the main access roadway. This becomes the site for installing the longwall equipment, which systematically removes the large block of coal between the headings or gate roads.

In both types of mining, it is the second workings or pillar extraction, that results in mine subsidence.



▲ Achieving compatibility between coal mining and residential development requires an awareness of the needs of both. Bord and pillar workings are shown in the upper seam and longwall mining in the lower.

◄ Mitigatory work by the Mine Subsidence Board allowed this bridge to remain operational whilst undermined by longwall methods.

SURFACE EFFECTS OF COAL MINING

When a seam of coal is extracted over a wide area, the strata will sag to rest on the fallen material ("goaf"). As a result, surface movements occur in both the vertical and horizontal planes. Damage can include fine cracks to brickwork and concrete, opening of joints in internal linings and tilting of structures.

The main components of surface subsidence are:

(a) Vertical Subsidence - is most significant where the elevation of a surface feature is important, such as in low lying areas.

(b) Tilt - differential vertical subsidence between two points changes the slope of the surface and consequently that of any surface features. Features which may be particularly affected include tall structures and gravity-dependent structures, such as gutters, drains, sewers, water and sewerage works.

(c) Strain - different horizontal movements between two points cause a change in the length of the surface. If the length of this surface increases, a tensile strain is induced. If the length reduces, a compressive strain is created. The effects of strain on a surface feature depend very much on its design and the materials selected. For example, weak masonry has a low tolerance to tensile strain, whereas steel has a very high tolerance. Rocks and masonry have much higher resistance to compressive strain than timber.

Structures, such as pipelines and buildings, can be engineered so that they have an increased tolerance to strain. Foundations can be designed to limit the amount of ground strain that is transmitted into the building.

In most cases, the majority of mine subsidence is completed within two years of total extraction occurring. Small levels of residual subsidence can continue for a longer period of time.

▲ Subsidence has caused internal cracking.

▼ The effect of tensile strains from subsidence is clearly shown on this road surface.

DESIGNING FOR MINE SUBSIDENCE

Special design and detailing techniques are adopted to allow structures to withstand anticipated movements from earthquakes and unstable foundation material. That includes all types of buildings, roads, railways, drains, services, etc.

Mine subsidence is just another form of ground movement that can be designed for. Design principles and techniques that allow structures to accommodate ground movement resulting from mine subsidence have been adopted extensively in England and Europe since the 1920s and in Australia since the late 1960s.

Monitoring over many years of structures affected by subsidence has enabled the effects to be better understood. Better prediction of the behaviour of structures has led to improved structural design.

Generally, it is the strains and curvatures that damage structural elements of buildings. Although tilt does not normally cause structural damage, in severe cases it may affect the usage of a building.

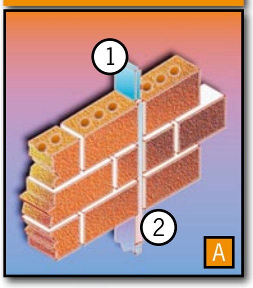
At the design stage, it is possible to select a type of structure that, with appropriate detailing, will allow the building to accommodate these subsidence effects. We require designers to ensure that any damage is non-structural and the building remains:

(a) Safe - no danger to users
(b) Serviceable - available for its intended use
(c) Repairable - damaged components repaired economically

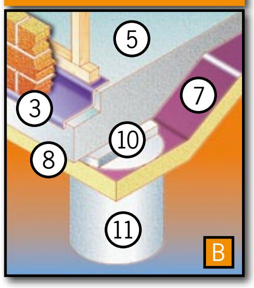
In areas where shallow mine workings exist, design can overcome the risk of pothole subsidence.

In general, mine subsidence damage is minimised by limiting the size of the structure, careful choice of the building materials used and incorporating design details such as flexible joints, slip layers, elimination of brickwork over openings and the requirements of the Building Code of Australia. Buildings can be designed to facilitate ready repairs should mine subsidence damage occur and, in some cases, are designed to be relevelled to overcome tilting.

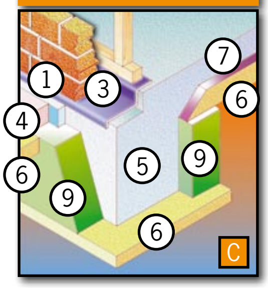
ARTICULATED JOINTS



PIER AND SLAB FOOTING



RAFT SLAB & EDGE BEAM

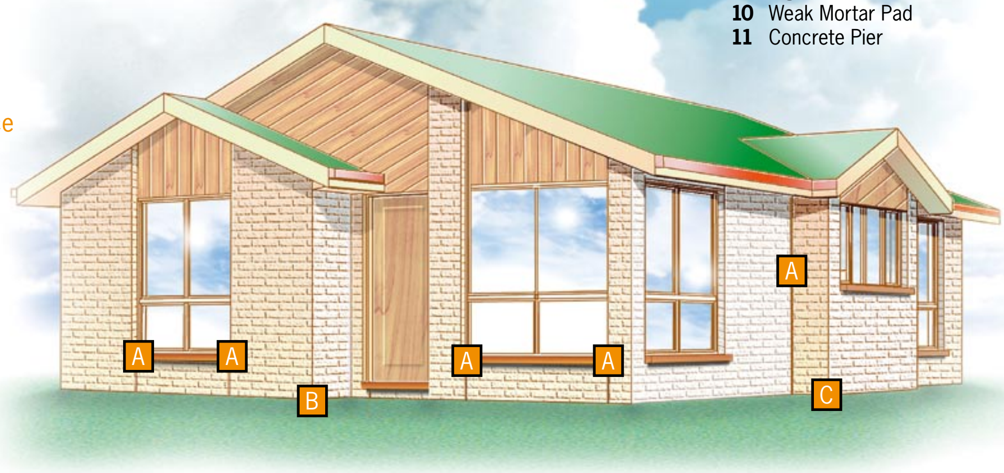


1 Compressible Joint Filler
2 Sealant
3 Damp Course
4 Paving
5 Concrete Slab
6 Sand
7 Waterproof Membrane
8 Sand (Sliding Layer)
9 Compressible Filling (eg. Vermiculite)
10 Weak Mortar Pad
11 Concrete Pier

STRUCTURAL FEATURES DESIGNED TO ACCOMMODATE GROUND MOVEMENT

WINDOWS AND DOORS

Brickwork above openings replaced with in-fill panels (timber, glass, etc)



DEVELOPMENT GUIDELINES

Engineering and architectural considerations can significantly minimise the risk of mine subsidence damage. To assist the community in this matter, we provide surface development guidelines relating to structures and subdivisions within Mine Subsidence Districts. We can also provide advice outside Mine Subsidence Districts. Our development guidelines are designed to ensure that structures will tolerate the expected levels of subsidence so that safety is not compromised, buildings can remain in use and, in the event of mine subsidence damage occurring, any inconvenience to owners and users is limited while repairs are made.

The guidelines cover both the nature and class of improvements and include the height of a building, the type of building materials used and the construction methods. Solid or cavity brick construction is not flexible and can be damaged by low levels of subsidence. In some areas, even brick veneer construction is unsuitable, particularly should high levels of subsidence be anticipated.

Some structures are not specifically designed for mine subsidence, for example, those outside a Mine Subsidence District or those built prior to proclamation of a District. They are however eligible for the full range of our services, including any appropriate work to prevent or mitigate damage from mine subsidence.

We encourage the development of building techniques to allow the widest possible range of designs and material to be available to the building public.

Our staff would be pleased to discuss our surface development guidelines with you.

◄ Type of dwelling approved under the Board's guidelines.

◄ Research and development leads to less damage by using better materials and constructions methods.

WHAT CAN BE THE CAUSE?

Damage to homes can arise from many causes. While it is often thought that mine subsidence is the cause if the property is in a Mine Subsidence District, this is not always the case. Our staff will consider many factors when inspecting a damaged home and discussing a claim with an understandably concerned owner.

Records kept at our District offices will show if the property is undermined and what the likelihood is of subsidence having occurred. Survey marks, if available, will also be checked. However, other factors need to be investigated as damage to surface structures may have many causes.

A problem often experienced is the failure of footings or concrete slabs due to incorrect reinforcement or inadequate compaction of the underlying materials. In some cases, homes may have been subject to unusual loadings, such as earthquakes, or the structural design may be inadequate. (For example, bearers and floor joists may be incorrectly spaced or of inadequate size.)

Changes in drainage patterns or moisture content will lead to ground movement should reactive soils be present. (The reactivity of soils can be determined by having the site classified by a geotechnical engineer.) Homes can be designed and built for reactive sites so that the ground movement will not normally cause any structural damage, although some minor cracking of slabs, brickwork and interior fittings may occur. Australian Standard 2870 classifies wall cracks of less than 1 mm as fine cracks which do not need repair.

Whilst older homes may be subject to the ravages of time, particularly if they have not been properly maintained, it should be recognised that new homes often experience settlement or frame/concrete shrinkage.

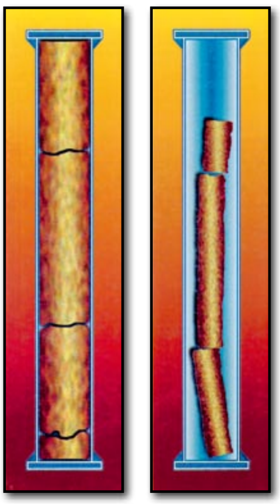
We can provide you with more detail on any of these issues on other causes of damage to homes.

Inadequate footings ▲

No expansion joint in pavers ▲

No reinforcement ▲

Inadequate footings ▲



◄ Reactive soil testing - Soils can expand or contract as moisture content changes, often resulting in significant cracks in buildings.

A COMMUNITY GUIDE

THE MINE SUBSIDENCE BOARD'S ROLE IN THE COMMUNITY

The Mine Subsidence Board is a service organisation operating for the community in coal mining areas of NSW and is responsible for administering the Mine Subsidence Compensation Act. The Act provides for compensation or repair services where improvements are damaged by mine subsidence resulting from the extraction of coal.

The Act also gives us the responsibility of reducing the risk of mine subsidence damage to properties by assessing and controlling the types of buildings and improvements which can be erected in Mine Subsidence Districts. A Mine Subsidence District is used to recognise areas where our expertise and service are likely to be in higher demand due to existing or future coal mining.

Other important roles are the elimination of public and private danger caused by mine subsidence and the provision of a comprehensive and accessible advisory and technical service.

We maintain an active role in liaising with the community, industry and other government departments.

We can assist you if you have any enquiries regarding mine subsidence or if your property has incurred damage as a consequence of mine subsidence.

▲ Repairs in progress. ▼

▲ Potholes from old abandoned mining are repaired by the Board where they present a public or private danger. ▼

▼ Pre-mining inspections record any pre-existing damage.

THE BOARD'S CUSTOMER SERVICES

Our staff can provide you with a range of brochures and other information on mine subsidence as described in this publication.

You will require our approval to subdivide land or to erect or alter improvements within a proclaimed Mine Subsidence District. However, where a council does not require a building application, we will deem approval for those improvements.

Buildings built outside of and prior to the proclamation of a Mine Subsidence District are automatically covered for compensation. However, homes and other structures built in contravention of, or without, our approval, in a Mine Subsidence District, are not eligible for compensation in the event of damage due to mine subsidence.

Homeowners who believe that their improvements have suffered mine subsidence damage should contact our nearest office without delay and request a claim form. Care should be taken to include all information required. On receipt of your claim, one of our technical officers will contact you promptly to begin investigation.

As a guarantee of service, we will offer to carry out pre-mining inspections of residential areas, where subsidence is likely to cause damage. A pre-mining inspection is designed to establish the pre-mining condition of surface improvements which may be damaged by mine subsidence. Pre-mining inspections may range from a visual examination to survey levels and detailed photographs.

A Section 149 Certificate issued by councils and which must be attached to a Contract of Sale when a property is put on the market, gives notice as to whether a property is within a Mine Subsidence District. If it is, most financial institutions will require you to obtain a Section 15B Certificate from us prior to advancing money to purchase a home. This certificate is an assurance that the improvements are eligible for compensation if mine subsidence damage occurs.

On occasions, particularly over old shallow workings, mine subsidence may crack the ground or cause potholes. Should you know of any possible openings to old mine workings, please contact us or call our 24 hour emergency number to enable us to eliminate any danger.

WHERE CAN I GET MORE INFORMATION?

Our expert staff are there to assist you with further enquiries. In addition to our Head Office at Newcastle, we also have five District Offices strategically located in coal mining areas of NSW.

A range of brochures and fact sheets on mine subsidence is available free of charge. These include details on buying and building in a Mine Subsidence District and how to claim for mine subsidence damage. Surface development guidelines can be obtained upon request. Our staff also provide technical information on items such as designing for mine subsidence.

We provide interpreter services free of charge through the Community Relations Commission for people from non-English speaking backgrounds.

A 24 hour emergency service is provided in all districts.

WE APPRECIATE YOUR FEEDBACK

As part of our service commitment, we are dedicated to continuous improvement in providing the highest standard of customer service.

Our staff adheres to a professional Code of Conduct and our Guarantee of Service ensures that we meet the needs of our customers.

Your comments provide valuable information to assist us in keeping our service relevant to your needs.

- Constructive complaints help us identify areas where our service can be improved.
- Compliments reinforce what is well accepted and ensures these areas are maintained.

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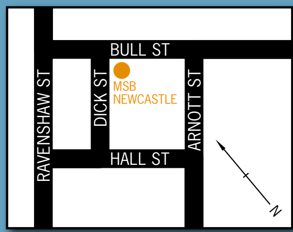

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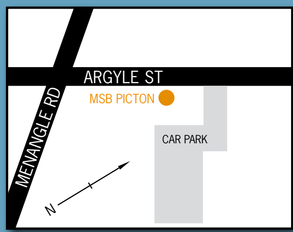

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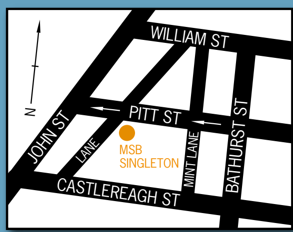

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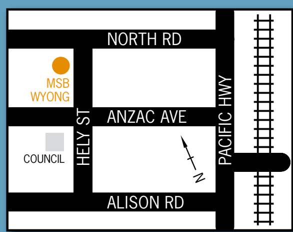

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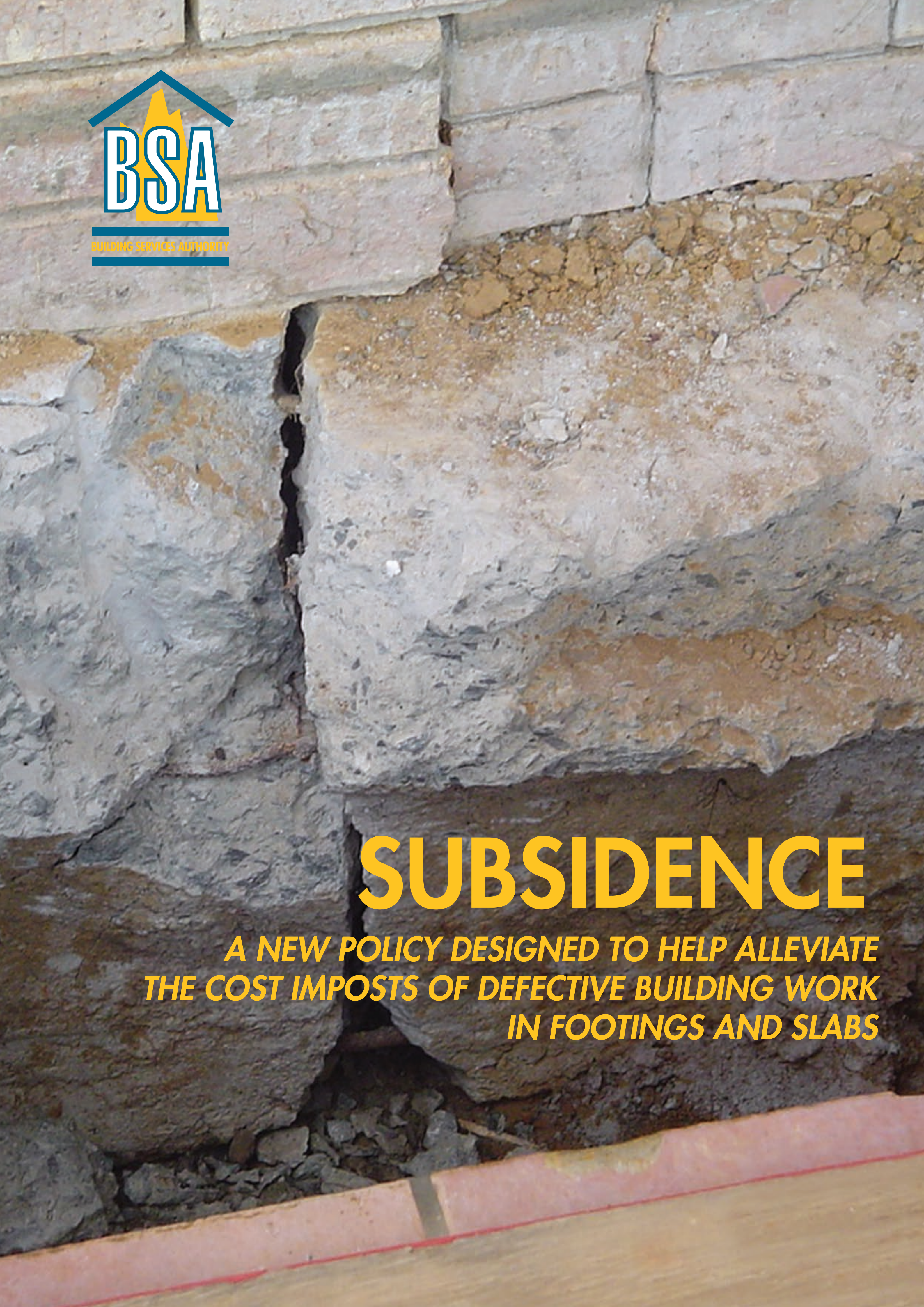
hdp 2007 cover house photographs courtesy of Montgomery Homes



BSA
BUILDING SERVICES AUTHORITY

SUBSIDENCE

A NEW POLICY DESIGNED TO HELP ALLEVIATE THE COST IMPOSTS OF DEFECTIVE BUILDING WORK IN FOOTINGS AND SLABS

THE NEW POLICY - EVERYONE PLAYS A PART.

PLEASE NOTE:
The diagrams and photographic material in this publication are indicative only and are not intended to address specific requirements.

This Fact Book is a guide only and should be read in conjunction with the requirements of the Queensland Building Services Board Policy.

BSA hopes this Fact Book will help you understand the greater responsibilities the new Subsidence Policy places on builders, engineers and homeowners.

In April 2003 the Queensland Building Services Board instigated a review of the causes of footing and slab movement. The review focused on design and construction of footings and slabs including legislation and standards as well as skill levels and education of practitioners. It also considered the escalating costs to BSA's statutory insurance fund.

Preliminary findings of a research project commenced in May 2003 identified two areas that required special attention. They were: Engineering Investigation and Design and Construction Practices.

After informing industry of the review in September 2003, the Queensland Building Services Board recently endorsed a new Policy for Rectification of Building Work in residential construction. This includes work that causes footing and slab movement.

This Fact Book, distributed throughout Queensland, is aimed at ensuring that all participants in the building industry are properly informed about, and understand how to comply with, the no fault provisions of the new policy. Similarly, a further BSA education initiative will endeavour to ensure homeowners are made more aware of their responsibilities for the ongoing maintenance of their homes.

Please read this book, make use of the resources from BSA's web site, ensure you fully comprehend the requirements of the relevant sections of the Building Code of Australia and have an understanding of Australian Standard 2870.

Your understanding and compliance with these requirements and your assistance in ensuring home owners are aware of their own maintenance responsibilities will help minimise the incidence of footing and slab movement. This in turn will reduce your costs for rectification, and ultimately, the burden that industry bears due to problems created by defective work.

RESPONSIBILITIES - EVERYONE HAS THEIR OWN.

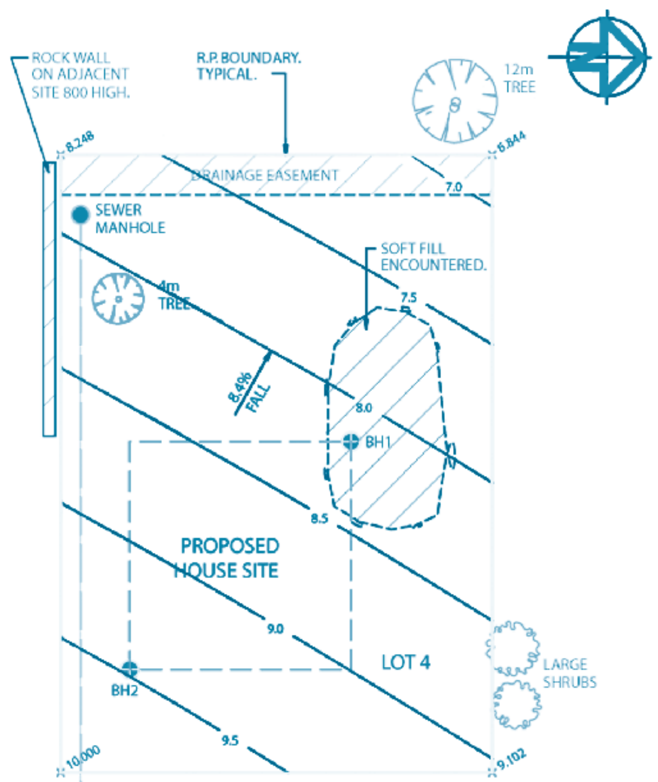
PREVIOUS POLICY

To avoid responsibility for rectification of subsidence under the previous policy, the contractor had only to rely on information provided by an engineer, follow the requirements of the engineer as specified and have the work certified by a competent person.

This is NOT the case now.

Where contracts or preliminary agreements are entered into after 1 September 2004, the contractor must ensure that the engineer is provided with all the information relevant to the construction. The contractor must also ensure that the engineer provides a design ***and certifies that it complies with*** the information the contractor has provided and the requirements of the relevant codes and standards.

Both the performance of footing and slab systems and the continued serviceability of buildings rely on the contractor and the homeowner complying with construction practices and site maintenance conditions. The Australian Standard relies on normal conditions being maintained throughout the life of buildings.



LOT 4, BRUCE STREET, MINIMAX WATERS
R.P. 235 984

CONTOUR PLAN
SCALE 1:200

Both the contractor and the home owner have a duty to know their individual responsibilities.

THE CONTRACTOR'S RESPONSIBILITY.

It is the responsibility of the ***contractor*** to ensure that relative performance in residential construction is achieved by compliance with ***three strategic areas.***

THE FIRST OF THESE STRATEGIC AREAS RELATES TO *SITE INVESTIGATION*

Under this section the contractor must provide the engineer/site classifier with all relevant information and conditions to enable site identification and investigation to be completed.

The information the ***contractor*** must give to the engineer/ site classifier is:

- ❑ Property Description and site address.
- ❑ Evidence to ensure site is correct. i.e. Survey plan and or photograph to assist in correctly identifying the site.
- ❑ The contours of the site.
- ❑ The location of trees on the site and adjoining sites.
- ❑ Location and identification of existing overland flows.
- ❑ The footprint of the proposed building and an indication of platform levels.
- ❑ Location of proposed cut and fill line.
- ❑ Land searches including potential flooding, any underground infrastructure,easements,vegetation and subdivisional fill.

NOTE: For the purpose of the policy the contractor is to ensure that all care is taken to identify any existing impediments that may influence the site classification and the design at the time of the investigation (where possible), e.g. identifying and plotting trees currently existing including any known recently removed trees.

INFORMATION - EVERYONE NEEDS TO KNOW.

This information, noted on the site plan, will assist the engineer to correctly locate test sites over the area of the building platform and to consider the effects of cut and fill operations and any other influences that may affect the proposed structure.

It will also assist in alleviating a key factor in footing failures - that of the design engineer and/or site classifier ***not*** taking into account ***all*** of the conditions of the site and adjacent sites.

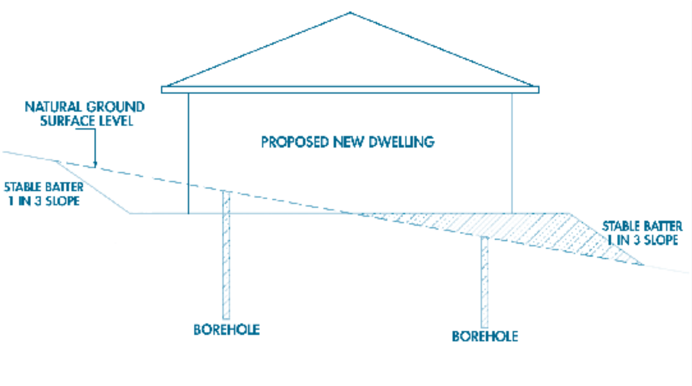
The information provided to the engineer will also assist the ***contractor*** in determining the extent of work required under the contract and who is responsible for that work. For example, the contractor can incorporate into the contract, who is responsible for building and paying for any retaining walls, paths or spoon drains that may be required for site drainage.

This should prevent any contractual arguments.

Other notes in relation to builder responsibility that may be helpful include:

a) The contractor may require that the Site classifier and/or the designer obtain certain information noted on page 3 but not supplied by the contractor. In such instances, the site classifier and/or the designer must satisfy themselves that they have obtained all the relevant information necessary to complete the design ***and*** meet the requirements of the Queensland Building Services Board Policy. The relevant information should be noted in the engineer design certification.

b) Where the owner has engaged the site classifier and/or engineer, the contractor must ensure that the engineer ***certifies*** that the information was obtained and taken into account for the purpose of site classification and/or design, in accordance with requirements of the Queensland Building Services Board Policy.



THE SECOND STRATEGIC AREA OF CONTRACTOR RESPONSIBILITY UNDER THE NEW POLICY IS *SITE CLASSIFICATION AND DESIGN.*

Under this section the contractor must obtain written confirmation from a Registered Professional Engineer in Queensland (RPEQ), that the policy requirements have been met in identifying and classifying the site and in completing the engineers design.

For ***Site Classification,*** the contractor must obtain from the engineer **written** confirmation that:

- ❑ The engineer or their representative has visited the site.
- ❑ The soil testing has been undertaken by a Registered Professional Engineer in Queensland or a soil tester licensed under the *Queensland Building Services Authority Act 1991.*
- ❑ The minimum of two (2) boreholes have been located over the proposed footprint of the building and below the final platform level.
- ❑ Soil samples have been taken for the purpose of laboratory testing where required.
- ❑ A laboratory test and a soil report have been obtained for the design engineer.

For the ***Engineers Design***, the contractor must obtain confirmation that:

- ❑ The design engineer has referenced and taken into account all the relevant information supplied .
- ❑ The design has been certified by a Registered Professional Engineer in Queensland.
- ❑ The design drawings include and detail all the the requirements outlined in paragraph B(b)(x) of the new policy.
  - ❍ selected footing system,
  - ❍ specific site works,
  - ❍ site drainage,
  - ❍ control joints,
  - ❍ retaining wall,
  - ❍ flexible joints in storm water and sanitary drainage

DESIGN - EVERYONE NEEDS TO TAKE CARE.

Where an alternate footing system to that described in Part 3.2 of the BCA is proposed, it must comply with *Performance Requirement 2.1* and *Performance Requirement P2.2.3* in section 2 of the BCA.

Where alternate footing systems other than those recognised by AS 2870 and described in the BCA are proposed, ***the contractor should obtain from the engineer,*** written confirmation of the validity of the design using engineering principles conforming to and deemed to satisfy requirements of the BCA and relevant Australian Standards.

It is noted in AS2870 that the expectations and parameters of the design of all footing and slab systems including alternate footing systems using engineering principles should take into consideration that: *"foundation movement shall be assessed as the level which has less than a 5% chance of being exceeded in the life of the structure which may be taken as 50 years." Clause 1.4.2 AS2870 1996*

Where ***abnormal conditions*** exist on a site it is usual that an engineer classify the site as Class "P" and indicate the expected movement potential depending on the reactive soil characteristics. i.e. A,S,M, H, & E Classifications.

Design of the footing systems on "P" sites shall use conforming engineering principles detailed in AS2870 and the Australian Standard for Concrete Structures - AS3600.

Abnormal site conditions should be identified as part of site identification and investigation and may include:

- ❑ Soft soil - such as uncontrolled fill or development fill sites including soft clay or silt or loose sand. (bearing capacity less than 100 kpa);
- ❑ Landslip
- ❑ Mine subsidence and collapsing soils
- ❑ Soils subject to erosion
- ❑ Reactive sites subject to abnormal moisture conditions
- ❑ Sites that cannot be classified otherwise

Abnormal moisture conditions that affect the site classification for the design assessment may include:

- ❑ Recent removal of an existing building structure
- ❑ Unusual moisture conditions caused by drains, channels, ponds, dams or tanks which are to be maintained or removed from the site. *Canal developments that have deep seated clays are an example where abnormal moisture conditions may prevail over time.*
- ❑ Removal of large trees prior to construction
- ❑ Trees located too close to a footing *(including trees on adjoining sites within the relevant distance of the mature height of the tree from the building depending on site classification).*

Information on drawings for reactive sites shall include site classification, selected footing system and any special sitework or site drainage. *(Clause 1.10 AS2870 1996)*

Additional requirements for H & E site classifications pursuant to *AS 2870 1996, Clause 5.5 - Additional Requirements for Class H & E Sites,* shall be included.

NOTE: Examples of information that should typically be specified is shown in the diagram on page 7 of this document.

CERTIFICATION - EVERYTHING MUST BE RIGHT

THE THIRD STRATEGIC AREA OF CONTRACTOR RESPONSIBILITY UNDER THE NEW POLICY IS *COMPLIANCE WITH THE DESIGN.*

Under this section the contractor must comply with the design and the relevant Australian Standard both during and on completion of construction.

To comply with the design and relevant Standards, ***the contractor must obtain*** the following certification:

- ❏ Certified design drawings and specification to be obtained from RPEQ prior to commencing siteworks and construction.
- ❏ Certification by RPEQ or Building Certifier that the building platform, site drainage and any other special siteworks comply with the certified design.
- ❏ Certification by RPEQ or Soil Tester licensed under the QBSA Act 1991 of compaction tests carried out on controlled fill. Note: Certification to be compliant with relevant standard i.e. AS3798 or AS1289.
- ❏ Certification by RPEQ or Building Certifier that footing and slab systems comply with the certified design and relevant Australian Standards. Certification must include confirmation that the original site classification has not altered. Any altered site conditions or construction requirements not in the certified design ***must comply*** with any instruction from the RPEQ or building certifier.
- ❏ Certification by RPEQ, Building Certifier and/or approval by the local government plumbing inspector that installed plumbing, drainage and stormwater flexibility for the relevant site classification is in accordance with certified design requirements and relevant Australian Standard.
- ❏ Certification by RPEQ or Building Certifier that masonry articulation, site drainage requirements, roof storm water, location of retaining walls and any other special site works have been completed as specified.

Builders are reminded that they have a duty of care to be aware of all aspects of the ***Building Code of Australia 1996 (BCA) Volume 2 Parts 3.1 & 3.2,*** which clearly set out the acceptable construction practices in relation to construction requirements for Site Preparation and Footings & Slabs for residential construction.

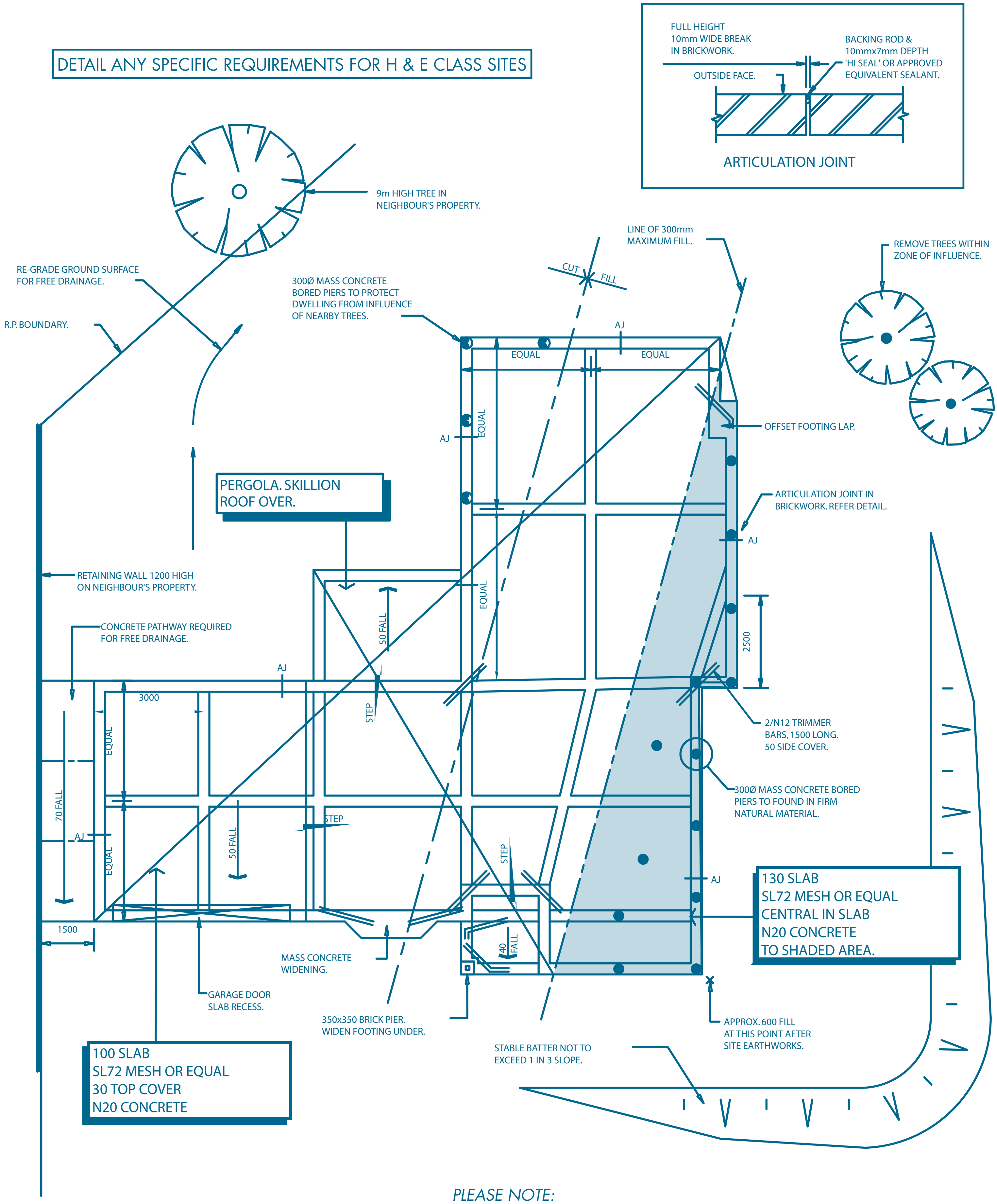
ADDITIONAL INFORMATION

The new subsidence policy document,
an "Owner Information And Responsibility Form" and
Guidelines for: ❏ Site Classifiers
❏ Design Engineers
and
❏ Responsible Certifiers
can be obtained from the "TechInfo" section
of BSA's website at

www.bsa.qld.gov.au

PLEASE NOTE:
The diagrams and photographic material in this publication are indicative only and are not intended to address specific requirements.

TYPICAL SITE INFORMATION REQUIRED



PLEASE NOTE:
The diagrams and photographic material in this publication are indicative only and are not intended to address specific requirements.

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Telephone 5575 7999
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SUNSHINE COAST
Unit 7 WIN Television Centre
Cnr Baden Powell Street
and Maroochydore Road
Maroochydore QLD 4558
Telephone 5479 8500
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TOOWOOMBA
Clestrain Mall
131A Herries Street
Toowoomba QLD 4350
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MACKAY
25 River Street
Mackay QLD 4740
Telephone 4957 4477
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ROCKHAMPTON
164 Berserker Street
Cnr Elphinstone Street
North Rockhampton QLD 4701
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TOWNSVILLE
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Aitkenvale QLD 4814
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Westcourt QLD 4870
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APPENDIX 2C
Mitigation of Subsidence and Treatment of Mine Openings

2C1. The risks to land use and development from potential subsidence can generally be minimised either by the use of appropriate foundations and design of buildings and structures to cope with expected movement or by ground treatment measures to reduce the level of subsidence to acceptable levels. While it will seldom be necessary for development to avoid areas of subsidence risk entirely, the mitigation measures can be costly and planning policies that specify uses that will not be affected by the expected levels of subsidence may be appropriate in some circumstances. In addition, the nature and characteristics of mine openings and other similar features may require their treatment for public safety reasons, whether or not development is planned on the site.

STRUCTURE AND FOUNDATION DESIGN

2C2. For most types of subsidence, it may be possible to design buildings and structures to cope with the movement expected, provided the amount of differential subsidence is not excessive and that the structure is not especially sensitive to differential settlements.

2C3. For small structures such as houses, conventional but reinforced strip or pad foundations may be adequate to resist the effects of minor instances of subsidence. They should be laid on a suitable sliding layer and have compressible materials placed at external vertical faces. However, a raft foundation, as near square as possible, with no projections or indentations that would give rise to stress concentrations, will ride out subsidence better than strip footings. Raft foundations are used to spread the structural load over a wide area when founding on weak or variable ground and to remain intact following ground deformation. They should be close to the surface so that compressive strains induced by ground movements take place beneath them rather than directly affecting the edges. Rafts can be designed to span or cantilever over loss of ground due to the collapse of underground cavities, but are more generally used where old workings or cavities are largely collapsed, the objective being to overcome settlement within the cavity infill.

2C4. Where there are high individual column loads and a competent founding stratum is present at moderate depth, it may be preferable to use heavily reinforced concrete beams designed to span across or cantilever over subsided ground. Where underground cavities are present, the underside of the foundations needs to bear directly on the ground. In compressible or made ground, the beams may bear on concrete pads founded on a competent stratum.

2C5. For heavily loaded structures where the strata at shallow or moderate depth are too weak to support the required loads, piled foundations may be used to provide support. They are used to transfer the structural load through the zone of disturbance and into underlying stable material. They have occasionally been used in areas of shallow underground cavities.

2C6. The design of structures can also assist in their resisting subsidence movements by making them sufficiently flexible. Timber-framed structures are inherently more flexible than rigid concrete or brick-framed ones. Dividing larger structures into smaller units with expansion and compression joints between them provides additional flexibility. These principles have long been used in the CLASP (Consortium of Local Authorities Special Programme) system of flexible construction. CLASP was successfully used by local authorities for a large number of buildings, including schools and hospitals above active longwall mining areas. Gaps or joints can also be introduced into foundations, structures or services to compensate for strains and differential tilting. The provision of compression springs between the foundation and superstructure can combat tilting effectively when combined with the provision for jacking the structure level after movement has occurred.

2C7. For lightly loaded areas such as playing fields, car parks and local access roads, geotextiles (high strength polymer grids) may be used to support the ground as an alternative to expensive ground treatment methods. However, should localised subsidence then occur, action will need to be taken to protect public safety and deal with the subsidence.

GROUND IMPROVEMENT

2C8. The objective of ground improvement techniques is permanently to improve poor ground and so allow the use of more cost-effective foundation methods. They are particularly applicable to ground that is loose, soft or compressible. Such conditions may arise from the natural characteristic of the ground materials, the uncontrolled placement of material in or on the ground (eg made ground) or from broken ground due to the collapse of underlying cavities of natural or human origin.

2C9. The simplest ground improvement technique is the removal of the poor material and its replacement with a suitable inert and stable fill that is capable of achieving satisfactory compaction. Such fills could include controlled deposition of the material removed. Where old mine-workings or natural cavities lie at shallow depth, it may prove economic to excavate down to the voids and either replace the excavated material in a controlled manner or replace it with compacted backfill. This technique is generally limited to depths of about 5m, though occasionally up to 10m unless economic benefit can be derived from the material excavated. Thus opencast extraction of coal can be used as a means of stabilising ground liable to subsidence due to shallow mine workings, provided that any adverse environmental consequences of doing so can be controlled to an acceptable level, as required by MPG 3 *Coal mining and colliery spoil disposal.*

2C10. Larger areas of poor ground generally require treatment *in situ*. The most frequently used techniques are those for compacting back-filled sites where the soil properties are highly variable. They can also be used to improve low-strength natural soils, such as loose granular deposits.

2C11. Pre-loading or surcharge involves placing a temporary bank of soil on the position of a proposed structure in order to compress the ground prior to construction. The weight of the embankment causes settlement of the ground, which would otherwise have affected the structure. The surcharge material will often be subsequently used in landscaping the site.

2C12. Dynamic compaction involves repeatedly dropping a heavy weight (of 5-20 tonnes) onto the ground from a height of up to 20m on offset grid patterns. This technique can improve the ground to depths of 5m or more. The process is generally only cost-effective in treating large areas due to the high costs of plant mobilisation. It also creates significant ground vibration, noise and disruption.

2C13. Vibro-compaction and vibro-replacement involves the compaction of soils using a vibratory poker lowered into the ground. Vibro-compaction is generally only suitable for weak or loose granular soils. For more cohesive material, the hole is filled around the poker with coarse stone, which is compacted (vibro-replacement) and forms a reinforcing stone column in the ground.

2C14. Grouting involves injecting a slurry into the ground under pressure. The grout is used primarily as a filler and its structural properties are often of minor importance. Minimum amounts of cement are used to achieve the required strength. The technique is widely used to fill both natural and mined cavities, as well as in broken ground above mine-workings. It can also be used to compact and strengthen poor quality soils. Chemical or resin grouts may be used to strengthen soils or reduce their permeability. Cement or lime may also be mixed with soft surface soils to stabilise them.

2C15. Grouting is only of significant value where open voids or grout-permeable materials exist within the area of treatment. The technique requires careful control of the grout composition, viscosity and injection pressure. Given correct controls and programming, grout injection can prove an economical and effective approach to ground treatment for a range of underground conditions. It can, however, be difficult to predict accurately the total cost, particularly when treating large volumes of broken ground above mine workings or natural cavities.

TREATMENT OF CAVITIES

2C16. Where the potential for subsidence arises from underground cavities, and excavation and back-filling is not viable, three alternative approaches may be adopted:

- inducing subsidence;
- providing support to the cavity, which remains open; and
- infilling the cavity to prevent excessive ground movement.

Inducing subsidence

2C17. Subsidence may be induced directly by dynamic compaction, as described above, or indirectly by demolishing supporting pillars or the roofs of rooms. Dynamic compaction has been used on a limited basis. Where the mineral can safely be extracted, pillars can be removed on retreat to allow collapse of the workings and subsidence to occur. Pillars may also be demolished by blasting but this is only applicable with small pillars and a high level of extraction (generally greater than 75%). This technique has been used for some mines in France but no examples are known in England, except as a means of blocking access to underground mine cavities.

2C18. Collapsing a mine to induce subsidence has an inherent element of risk. In particular, it is likely to cause damage to on-site and nearby structures, an irregular topography, which may have to be restored by regrading and intermittent surface settlements as the collapsed debris consolidates (unless the broken ground created is treated). Any proposals to treat cavities by inducing subsidence will need very careful consideration after taking appropriate expert advice. The alternative methods of cavity treatment described below are likely to be more effective and more economical.

Providing support to the cavity

2C19. At sites where the risks of subsidence are relatively low, it may be more economical to keep mine or other cavities open than to induce subsidence or infill them. In particular, this may allow the underground cavities to be used for some other purpose, such as the many show caves/mines. It may also allow the continued use of the cavities by bats and the preservation of features of geological, biological and archaeological interest. When considering the use of the techniques described below, the importance of ensuring competent engineering design and supervision cannot be over-emphasised.

2C20. Pillars in mines can be strengthened to provide support to the roof. A number of techniques are available (illustrated in Figure 2C1), including wrapping pillars with wire rope/mesh and spraying with shotcrete, corsetting them with reinforced concrete, buttressing with steel or concrete members, bolting to improve pillar strength and relieving the load by surrounding pillars with artificial columns. Any pillar strengthening should take account of the potential value of pillars as geological exposures or structures of archaeological significance.

2C21. Roof support may be increased by the use of steel or concrete beams with blockwork or steel columns, steel arches and mesh sprayed with shotcrete. Packing, involving the hand placement of rock blocks has often been used to support the roof of coal, ironstone and stone mines. Similarly, masonry or reinforced concrete pillars, walls and piers can be installed or timber baulks can be inserted to slow down the rate of collapse or provide temporary support. The use of rock bolts, dowels and rock anchors to reinforce the rock is a common method of support in underground excavations (Figure 2C1 shows examples), often in combination with welded steel mesh and sprayed concrete. Artificial pillar support may also be provided by placing cones of granular material or low-slump concrete through an array of closely spaced boreholes.

Filling cavities

2C22. Underground cavities can be filled from underground (stowing) or via boreholes from the surface. A number of different techniques is available. Stowing techniques are occasionally used during the mining operation to reduce the impact of subsidence but they can also be used in abandoned mines where access is or can be made available. Depending on the depth and nature of workings, the strength of material used will be governed by whether it needs to support the ground above the cavity or merely to fill it in order to prevent further deterioration.

2C23. Solid stowing is the placing of fractured mine waste or imported fill in the mine void by manual or mechanical means. It was commonly used in older pillar and stall mines both as a means of support and to avoid bringing waste to the surface. Although it was used to some extent in early longwall mining, it is now unlikely to be economically justifiable as a means of reducing subsidence in active mines, as well as posing potential risks to the mining workforce.

2C24. Pneumatic stowing uses compressed air as the transport medium to place material underground. It can only be used in dry accessible workings. Materials which may be stowed include sand and gravel, pulverised fuel ash and colliery spoil. It can produce tightly packed stowing which will prevent subsidence in room and pillar mines and can reduce subsidence by almost half in longwall mining.

2C25. Hydraulic stowing uses water as the transport medium to place granular material in the workings. It is not applicable to active mines where inundation of the working face may occur. Gravel, masonry or other barriers may be required to contain the infill material within the area to be stabilised.

2C26. Coarse-grained fill of suitable size and shape may be used to free fall and form cones within the mine void. This is particularly useful where drainage through the mine must be maintained. Blind flushing uses water to flush granular material down a number of closely spaced boreholes to form overlapping cones of material within the mine. Although complete filling cannot be ensured, it can fill sufficient of the void space that any further roof falls will choke and not progress to the surface. The method is more suitable for inaccessible and flooded workings. However, access to the whole of the land above the workings is required.

2C27. Where mine cavities are not water-filled, the pumped slurry technique may be used. A slurry of sand and water is pumped from a few injection points under sufficiently high pressure to maintain a high flow velocity and keep the sand in suspension. This enables it to flow through the workings. Fewer injection points are required than for blind flushing. However, large quantities of water are required and this may exacerbate any potential groundwater problems.

2C28. As described above, grouting is widely used to fill both mine and natural cavities and to treat broken ground above them (see Figure 2C1). Infill grout is generally composed of pulverised fuel ash and ordinary portland cement in a ratio of between 9 and 12 to 1. Where large voids are present, bulk fillers such as sand and pea gravel may be added. Where grout can flow freely through areas of open cavities, injection hole spacings of 3-6m are common. Injection holes are drilled on a systematic grid, with infill holes once the primary grid has been grouted. Grouting is an expensive method of treating large cavities, though it can be an economical method for areas of broken ground with relatively small cavities.

2C29. The rock paste method (see Figure 2C1) was developed for infilling large and extensive cavities. Low-cost materials (screened colliery spoil and/or pulverised fuel ash with additions of lime or cement) are pumped under pressure down widely spaced boreholes to flow through the mine and fill the cavities. The method is applicable to air-filled or flooded mines and no preparatory work is required inside the mine. The wide borehole spacing minimises the disturbance to surface land use.

2C30. In general the objective is to fill the cavity with material which has sufficient strength to prevent collapses within the mine progressing to the surface to form crown holes. Where total overburden support is required in very shallow cavities, or where lateral support is needed for mine pillars in deeper workings, a pulverised fuel ash/cement paste rapidly develops the necessary strength.

2C31. Depending on the circumstances, a wide range of materials can be used for cavity infilling. Examples include crushed demolition waste, lightweight aerated concrete and waste foundry sand as well as the conventional granular material, pulverised fuel ash and colliery spoil.

TREATMENT OF DISUSED MINE OPENINGS

2C32. Mine openings are a special case in the management of subsidence and underground hazards because of the evident direct threat posed to health and safety. This is recognised in the requirement under the Mines and Quarries Act 1954 for abandoned mine entries to be closed to prevent anyone falling down a shaft or entering a mine opening accidentally. Any mine entry not so closed may be designated as a statutory nuisance under the Environment Protection Act 1990 and the local authority may serve an abatement notice on the owners. However, this requirement relates only to mines abandoned since 1872 and pre-1872 mines accessible to a highway or place of public resort. Thus many mine entries still remain open and unprotected. Small-diameter shafts may be concealed by vegetation. Others were covered at or near the surface with timber or other materials and have subsequently become concealed. Uncontrolled tipping into shafts has resulted in unconsolidated fill that can collapse laterally into mine workings or may pile up on blockages within the shaft above voids in the shaft below.

2C33. Mine openings, both vertical shafts and shallow horizontal or inclined adits, are the most significant cause of ground collapse. Since many are concealed, with no sign at the surface of anything untoward, a significant number of early shafts are unrecorded and unsuspected. While more recent mine openings may have been treated adequately to meet the legal requirements for mine closure, the treatment will not necessarily have been to a standard suitable for specific subsequent use of the site.

2C34. The first requirement in treating mine openings is to locate them. This may be difficult. Indirect methods, such as geophysical techniques can be useful but are not always successful. Excavation of trenches or drilling of boreholes are commonly used site investigation techniques but even these can miss openings. Stripping the surface of the site is the best method but may be too costly or impractical. In any mined area, the site investigation objective must be to achieve a reasonable measure of certainty that mine openings have been located. Additional inspection of the ground is required at the construction stage to ensure that none have been missed. Volume 2/v of the *Review of mining instability in Great Britain* outlines procedures for locating disused mine openings.

2C35. The objectives of treatment of mine openings vary from deterring entry to complete closure. Where no development of land is involved, the minimum requirements of preventing accidental entry may involve relatively simple expedients. For public safety reason, however, the owner, occupier or local authority might carry out treatment to more than the minimum standard to reduce the risk and consequent liabilities. Where development is proposed, treatment should be to a standard suitable for safe subsequent use of the land. The variety of approaches adopted for dealing with disused mine openings is shown in Table 2C1. Some of these are illustrated in Figure 2C2.

2C36. The method of treatment selected for any particular mine opening will depend on:

- the permanence of the treatment works - temporary measures may be cheap initially but the need for maintenance may render them more expensive in the longer term;

- any requirement for continued access to the opening, including the need to vent mine gas in a controlled manner;

- the numbers of openings to be treated - metalliferous mining fields may have large numbers of openings in a limited area;

- the type of subsequent land use - eg protection for occasional visitors near a rural footpath in contrast to built development in an urban area;

Table 2C1. **Types of treatment of disused mine openings**		
General protection (suspected opening cannot be located)	Geotextile grid	
Deterrents to entry	Warning signs Mounds Fences Walls	
Partial closure of opening	Grid Door Beams Cabin	Grille Gate Cage
Complete closure of opening	Cover* Plug*	Cap* Infilling/grouting

Note: *these can be provided with openings such as manholes if access needs to be maintained or to provide for gas or water venting or drainage pipes.

- the budget available, though treatment works should always be suitably designed and executed; and
- the need to comply with the requirements of the Coal Authority in respect of treatment of coal mine openings.

2C37. Prevention of accidental or unauthorised entry to an adit opening may be achieved by low-cost fencing or grilles. These can be specially designed to permit continued use by bats or a gate can be incorporated to allow continued access, eg for inspection. Internal supports may be required to protect against subsidence. If no access is required, an adit can be sealed by a mound or bund of soil, or a masonry wall and the entry can be selectively infilled to prevent subsidence.

2C38. A minimum standard against accidental entry into mine shafts is a sturdy fence and warning notices. However, additional measures are likely to be required in most circumstances to prevent unauthorised entry. The additional need to protect against forced entry through vandalism should also be taken into account. The measures available rangefrom a simple cover, using concrete or wooden sleepers or a proprietary mine cap as a temporary provision where limited use of the land is likely, to provision of a reinforced concrete cap or plug in more demanding situations. A manhole can be included to provide continued access. Where access for bats must be safeguarded, a suitably designed grille can be incorporated. When no future access is required shafts may be infilled and, if necessary, grouted. Even when an opening is permanently sealed, it may be prudent to mark its location to warn future users of the land and the details of treatment should be recorded and stored in an appropriate location (see Appendix 2D).

2C39. In some instances, even diligent searches for recorded mine openings during site investigation may be unsuccessful. This may result from an incorrect record, with the shaft not being there at all, or an unlocated opening may be present on a development site. In such cases, the risk may be low but it is prudent to restrict the loading on the suspect part of the site by using it for open-space - gardens or parking - after strengthening the ground with a geotextile grid. Although this cannot offer complete protection, it will provide sufficient security to allow people to evacuate the risk area in the event of subsidence occurring.

2C40. Treatment of mine openings should be fit for purpose and should not create a false sense of security. The method selected should take account of the characteristics of the location, the use of the land, any need for continued access and the scale of hazard arising as well as the environmental impact of the treatment proposed. Fuller information on methods of treatment is contained in the report of the study of *Treatment of disused mine openings*. A key source of information on treatment of coal mine shafts is the National Coal Board Handbook *Treatment of disused mineshafts and adits*. It is essential that the investigation of sites and the design and execution of any works is undertaken by suitably qualified and experienced people.

APPENDIX 2D
Information on Mined Ground and Mining Data Systems

2D1. This appendix summarises the nature, condition and principal sources of information on mined ground, the types of data system, their preparation and maintenance, limitations and costs. It is specifically directed at information on mined ground but its principles could be applied to systems for recording, maintaining and retrieving data on other forms of subsidence. Authorities with significant numbers of land stability cases may wish to consider developing a suitable information system to hold and transmit relevant data on these matters.

TYPES, CONDITIONS AND SOURCES OF DATA

2D2. Information on mined ground is varied. It includes maps, plans, cross-sections, drawings, aerial and other photographs, geophysical records, written accounts and other documents such as legal agreements, sales ledgers, transport records and newspaper accounts of subsidence. Some of this information is published but a great deal is manuscript material held in archives and files. Useful incidental information can also come from accounts by travellers and historians and personal knowledge of researchers and residents in areas of past mining. Thus mining information is often found amongst a great deal of other data.

2D3. The physical condition of original documents is variable. Early plans may be fragile and unwieldy. They may be valuable historical documents and owners may be reluctant to allow them to be handled, consulted or copied. The accuracy of records varies greatly. Many plans were prepared by specialists such as engineers, surveyors, geologists or other trained professionals. However, a substantial body of information was recorded by less expert observers or has been wrongly transposed from other documents. The scales of maps vary greatly and it may be difficult registering on modern maps the exact positions of features shown on earlier ones.

2D4. Despite the apparent abundance of documentary evidence of mining, significant numbers of unrecorded workings continue to be discovered in the course of site investigations, or when subsidence occurs. Many early mines were either not documented at the time or the records have been lost or destroyed. Only since 1856 has there been a legal requirement to make accurate mine plans and the requirement to lodge abandonment plans at the Mining Records Office was not introduced until 1872. There is still no requirement under the Miscellaneous Mines (General) Regulations 1956 to send plans of mines employing less than 12 people to the Inspector of Mines for the district. In addition illegal and thus unrecorded working is known to have taken place at various times, eg during the General Strike of 1926.

2D5. The records available may not, therefore, give an accurate and comprehensive indication of the distribution of mine workings and mine openings. They can be used, however, to define areas where there is a general local history of mining and where the geological conditions are suitable, within which mining may have taken place. This at least paves the way for further investigation where necessary. The interpretation of mining records requires considerable expertise. It is a matter for properly qualified, experienced specialists such as mining engineers, surveyors or geologists and mining historians.

2D6. Information additional to or in confirmation of past records is obtained in the course of site investigations. Information on the treatment of disused mine workings and openings is widespread in site development records. Only rarely, however has this information been collated and made readily accessible. It is desirable that such information should be recorded systematically and maintained in an accessible form so as to inform future consideration of proposed changes to land use in mining areas.

2D7. Important sources of information on mined ground are the Health and Safety Executive Inspectorate of Mines and the British Geological Survey. The database collated during the review of mining instability in Great Britain, along with those from the reviews of natural cavities and foundation conditions, is available on a commercial basis. The Coal Authority has detailed records of those coal mines for which it has a direct or inherited responsibility, including abandonment plans for mines of coal and associated minerals. It has established a centralised computerised data service. Abandonment plans for other minerals are now lodged with County Record Offices. Many local authorities hold their own records, as do organisations such as Railtrack and British Waterways and a number of long-established mining consultants. The National Association of Mining History Organisations[7], the Institution of Mining History Associations[8] and the National Caving Association[9] have access to extensive knowledge of mined ground.

2D8. However, much of the relevant information is widely dispersed and is not organised for rapid retrieval. Practical problems can arise in securing data including locating them, the absence of indexes, the staff effort involved in retrieving documents, commercial confidentiality and the value of some types of information. Major collections may have access arrangements for enquirers but many smaller sources do not.

2D9. Speedy and thorough compilations of relevant data may thus be difficult and important information may be missed. Searches for information prior to development are often duplicated unnecessarily. There are thus distinct benefits in collating and maintaining information in a readily accessible form that will improve efficiency. A rational and well indexed system vastly improves the usefulness of information.

2D10. The options and feasibility of developing such systems were examined through the then Department of the Environment research programme (Freeman Fox Ltd, 1988). The efficiency and cost-effectiveness of systems for handling collections of data of varying sizes, including manual (card-index) and computer facilities, were examined. In addition a computerised system was developed for a trial area in Cornwall (Freeman Fox Ltd, 1992) to test the feasibility of and best approaches for collecting and collating mining data. Since that time, some authorities have developed their own systems and, while there have been developments in computer software (particularly in the field of geographical information systems), the options identified are still relevant.

TYPES OF MINING DATA SYSTEMS

2D11. Information may be organised into:

- a cross-indexed catalogue of original documents allowing rapid location of the original data, which may be held by the authority or at the owner's premises; or
- a cross-indexed system containing data abstracted from original documents.

7 c/o Peak District Mining Museum, The Pavilion, Matlock Bath, Derbyshire DE4 3NR
8 Department of Economic History, Amory Building, Rennes Drive, Exeter EX4 4RJ
9 27 Old Gloucester Street, London WC1N 3XX

2D12. For a small data system, a simple catalogue may be all that is needed. For large collections, whose records are used frequently, data abstraction may be needed to increase their utility and protect the originals. For widely dispersed collections, a central register of data enables sources to be readily located and protects against the possibility of total loss of the information in its original form. Such systems do not dispense with the need for original documents since these may need to be referred to and re-interpreted during detailed work.

2D13. All such systems can be organised:

- on paper - card index and master map or maps; or
- as a computerised database, with or without facilities for graphical display of information and printing out data and maps.

2D14. The choice depends on cost-effectiveness for the size and frequency of use of the collection and the financial resources available to establish the system. A well designed system of either type will reduce the costs of staff time in locating files. Effective manual systems exist already in a number of places. These may meet the local requirement. However, recent computer and software development has been such that, for all but the smallest databases, a computerised system using a proprietary package may be the most cost-effective. While initial investment may be more costly, subsequent operational costs are substantially smaller. It should not be necessary, however, to commission an entirely bespoke system in order to meet the need effectively. Authorities are not advised to follow this course unless they are sure that it is fully justified within their wider information management strategies.

2D15. Computer systems have the advantage of being:

- easily reproducible for security of data and use in several places or by remote access;
- quicker for entry of new data;
- directly linkable to graphics packages, allowing custom-made maps to be produced quickly; and
- a basis for a geographical information system.

2D16. Possible disadvantages include:

- converting from a manual system is time-consuming and expensive;
- advances in technology and software may cause obsolescence over a fairly short time scale;
- problems due to incompatibility of equipment and software may arise when incorporating digital information or transferring records between organisations;
- computerised information may give a spurious impression of reliability and accuracy; and
- there may be a temptation to devise or purchase over-elaborate systems.

However, it should be noted that some of the disadvantages listed can be minimised or avoided altogether by adopting a standard format such as that developed by the Association of Geotechnical Specialists (AGS) for electronic transfer of geotechnical data from ground investigations. This format is not software-specific and can be used with word processing and spreadsheet applications as well as more complex packages. An evaluation copy can be downloaded from the AGS website - www.ags.org.uk.

2D17. For these reasons the design and operation of any system needs to be approached with a clear understanding of the limitations on reliability of the system and the data contained and of the continuing need to consult original records where appropriate in individual cases.

PREPARATION AND MAINTENANCE OF DATA SYSTEMS

2D18. The preparation of a data system requires the location, collection, collation and storage of data from a wide variety of sources. Records may be difficult to interpret and collection should be carried out by a mining surveyor, engineer, geologist or other appropriate specialist. Archivists and mining historians also have an important role. Much information will have to be located in terms of the National Grid and metricated from a variety of scales and units. This is time-consuming and can be expensive unless automatic methods are used.

2D19. The range of information stored can be as wide as that which is available. However, key categories include:

- mine openings - mainly point data;
- mine roadways and drainage galleries - essentially linear data;
- laterally extensive workings - essentially area data; and
- topographical and geological features within which unrecorded workings may be suspected.

2D20. Some basic sets of relevant data headings are summarised in Table 2D1. Where the information is available, more elaborate systems could include details of subsidence incidents or other relevant features, such as conservation interests, uses of mines and mine openings and any treatment works that have been undertaken to mitigate potential subsidence or to protect against accidental or unauthorised access. It is important that sources of data are recorded so that users of information can assess their reliability and original records can be readily traced.

2D21. Data collection exercises are a relatively expensive investment. Their full value is realised only if, after the initial effort, data is added as it becomes available. It is much more efficient for this to be done by planners, engineers, developers and others lodging data in appropriate databases as a matter of course rather than leaving it to periodic searches or updating exercises. Planning conditions requiring the lodging of completion reports on investigation or remedial or safety treatment can assist in achieving this objective. The information, or at least details of what information is available, then becomes a common benefit for all future users of mining information. For this to be widely achieved, the scope and location of data systems and the nature of information required need to be widely understood.

LIMITATIONS ON DATA SYSTEMS

2D22. The most important potential limitation on the content and use of mining databases is that of confidentiality. Owners of original data may not wish to be disturbed by enquirers and access to original records may not be possible. Where information has a commercial value or is of a sensitive nature, it may be placed in a confidential archive. Alternatively the database may contain only a brief reference to the existence of such information rather than details of its content.

2D23. In such cases, there are limitations on the information that can be supplied to enquirers. It may be possible to secure agreement with the owner of the data on the use to which such data can be put. The owner may agree to:

- the release of generalised but not detailed information;
- the operator of the data system seeking specific permission for release of the data; or
- the identification of ownership of the data so that any enquirer can seek permission directly from the owner.

2D24. The data recorded should be as factual and complete as possible. Interpretation should be left to the user. Guides to users should emphasise that no database of mining information is likely to be complete and that the onus rests on users to ensure that no additional unrecorded features are present in any particular site. Failure to make this clear could give rise to liability on the part of the owner of the data system. In addition, great care is needed in transcribing data from original records to avoid any charge of negligence. The accuracy of original records is, of course, the responsibility of those who made them but users are responsible for how original material is transcribed, interpreted and subsequently used.

COSTS OF DATA SYSTEMS

2D25. The costs of preparing new data systems rest principally in the collation and compilation of information using appropriate expertise. Equipment costs depend on the nature of the system and whether initial outlay can be reduced by using computers acquired for other purposes or by adapting existing systems. In local authority areas where mined ground is very limited, paper records may be cost-effective, though the unit costs of retrieving information may be higher.

2D26. The initial cost of establishing a 1,000-record database on a personal computer using proprietary software could be of the order of £20-25,000, (at 2000 prices) but with low running costs thereafter. In intensively mined areas, the number of records is likely to be larger and the costs of establishment would consequently be several times higher. However, mining data systems already exist for a number of such areas and adapting existing systems may be less expensive. Advantage should be taken of existing facilities wherever possible and care should be taken before decisions are made to develop any completely new systems. There may also be economies in collaborating with other authorities or organisations in developing a data system. Operational and maintenance costs might be defrayed by provision of a chargeable service.

Table 2D1. **Data heading for mine workings**				
Minimum heading for all workings				**Additional Information**
Common to all	**Openings**	**Roadways**	**Workings**	
Identification code Name National Grid reference Mineral(s) extracted Whether directly surveyed Source(s) of information Location of original documentation Date(s) of working Comments	Depth (total) Date of construction Altitude (AOD) Size Shape Inclination Bearing	Line segment – position – width – end points – depths – purpose	Boundary – position – depths (or depth contours) seam thickness vein width method(s) of working	Ground surface profile Type(s) of overburden Thickness of overburden Type(s) of bedrock Groundwater level(s) Additional subsurface information Construction information Adjacent shallow workings Instability incidents Gas problems Existing condition Conservation interests Uses of mine opening Owner/tenant Access Interest groups Treatment: – Type and purpose – Undertaken by whom – Date – Subsequent monitoring

Note: It will not be possible to fill in all headings for all mines and openings. A comprehensive record can be made only for those mines that have been directly surveyed and investigated.

APPENDIX 2E
Content of Stability Reports

2E1. For development in areas potentially liable to subsidence, or that is likely to cause subsidence, a local planning authority may request a ground stability report. This will allow the applicant to demonstrate that subsidence will not unacceptably adversely affect a proposed development or it can be satisfactorily mitigated in the design of the development.

2E2. The preparation of ground stability reports is a technical task demanding a wide range of expertise in engineering geology, geomorphology, hydrogeology, mining, geotechnical engineering and foundation design. Such reports should be prepared by a competent person with proven experience in the fields relevant to subsidence of natural and mining/industrial cavities and due to adverse foundation conditions. Appropriately qualified people would be expected to be chartered members of a relevant professional institution, such as the Geological Society, the Institution of Civil Engineers, the Institution of Mining and Metallurgy the Royal Institution of Chartered Surveyors or other relevant professional institutions. As a minimum, the competent person would be expected to qualify as a geotechnical specialist as defined by the Institution of Civil Engineers' Site Investigation Steering Group.[10]

2E3. The contents of a ground stability report will vary in detail from one site to another depending on the potential causes of subsidence that need to be investigated and the development that is proposed. However, all reports would be expected to cover a basic range of issues and there could be some merit in including a standard ground stability declaration form as illustrated in Table 2E1. This indicates the main categories of investigation which need to be covered and the report would be expected to provide detailed supporting information for each of the items listed that are appropriate to any particular development proposal. The report should identify the information used, reach conclusions on the potential for subsidence to occur and make recommendations for mitigation measures if considered necessary.

2E4. The purpose of the stability report is to present all the information obtained from an investigation in a logical and ordered format and to draw conclusions from the information presented as to the likelihood of subsidence and appropriate means of mitigation where necessary. It is important that any ground stability report should not merely examine the proposed development site in isolation but should examine it within its local context. It is often the case that information from neighbouring land gives the clue to what has happened on a site in the past. Ground stability investigations will normally comprise a desk-study and site inspection followed as necessary by appropriate ground investigations.

2E5. For some sites, a desk study and site inspection may provide sufficient information to enable conclusions to be made on the risk of subsidence and the effectiveness of mitigation measures. In such cases, the local planning authority may determine an application on that basis. Where the threat of subsidence is significant, particularly in the case of shallow mining or natural cavities, conditions may require ground investigation and the implementation of any necessary mitigation measures. For built development, the Building Regulations will ensure that the foundations are adequate to support the building in the event of subsidence.

10 Institution of Civil Engineers' Site Investigation Steering Group, 1993. *Without site investigation, ground is a hazard*. London, Thomas Telford Publications.

DESK STUDY AND SITE INSPECTION

2E6. A desk study is an examination of existing information from a wide range of sources. The objective is to identify and assess the possible ground conditions and to review both the past history of the site and any planned future development that might affect the site. It would normally involve:

- examination of topographical, geological and soils maps, together with any specialised mapping or databases such as those described in Appendix 2B;
- a literature search of information available from public records and technical libraries, including unpublished geological data from British Geological Survey files and mining records held by the Coal Authority and other relevant organisations;
- examination of aerial and other photographs; and
- assessment of information derived from local knowledge relating to past uses or particular problems on a site or in the general area.

2E7. The site inspection is an essential adjunct to the desk study, which helps to provide a check on the results of the desk study and in the appraisal of instability or difficult ground conditions. Detailed inspection should be carried out to identify whether or not there is any evidence of former, on-going or incipient subsidence activity within or adjacent to the site. Points that should be addressed in a site inspection include:

- ground slopes and changes in slope - abrupt changes in ground level may indicate former surface excavation or tipping;
- types and condition of surface vegetation - boggy ground may result from subsidence or indicate the presence of adverse foundation conditions;
- surface hollows, cracks, uneven ground, which may indicate subsidence into solution features or collapsed underground workings;
- damage to structures, such as cracks or repaired cracks in buildings, both on the site and in the neighbourhood, and other evidence of differential settlement;
- present land use, evidence of buried services and remains of structures identified during the desk study but no longer present on site; and
- materials exposed in nearby road or railway cuttings, pits or quarries and natural exposures of soils and rocks.

2E8. Relevant factual information from plans or documents should be presented clearly in the report, by reproducing original material where possible. Where this is not possible, or the material is too bulky, it should be summarised as appropriate and illustrated appropriately with plans, cross-sections and photographs. The sources of all information used should be recorded and references given. The format of the report may vary according to the house style of the competent person and the development proposed but it should contain:

- a factual account describing the site location and topography, summarising the geological and other relevant information discovered and describing any previous development of the site, including mining, and any subsidence history;

- an interpretation of the data, assessing and concluding on the potential risk to the development proposed from subsidence due to natural cavities, adverse foundations or past, present or future mining beneath the site; an essential part of this stage is a detailed interpretation of the geology of the site; and
- recommendations for further action arising from the conclusions of the risk assessment.

2E9. The recommendations will probably fall into one of the following general categories:

- there is a negligible risk of subsidence affecting the site and development may proceed without special precautions related to subsidence;
- there is a risk of subsidence but it cannot be quantified on the basis of a desk study and site inspection and further investigation is needed to define the risk and any need for preventive measures - the site investigation proposals should be set out;
- there is a significant risk of subsidence that has been defined well enough by the desk study and site inspection to design detailed mitigation measures; or
- there is a significant risk of subsidence that requires a full ground investigation to enable mitigation measures to be designed - the nature of the risk should be outlined and typical mitigation measures should be given - the site investigation proposals should also be set out.

2E10. The progression from factual information to interpretation and recommendations should be clear, without gaps in the argument or logical flaws. The report should be written in plain language that is understandable by the non-expert. Conclusions and recommendations should be clear and unequivocal, with no disclaimers that devalue the study undertaken. However, technical interpretations and opinions can vary and there may be more than one valid approach to a problem. Alternative options and their consequences should be identified and assessed in order to arrive at appropriate recommendations.

GROUND INVESTIGATIONS

2E11. Where the desk study and site inspection does not provide sufficient information to discount the risk of subsidence or to design mitigation measures, a ground investigation will be required. It will be designed to fill in the missing factual data identified during the desk study and site inspection. Typically it should confirm:

- the geological sequence and structure of both solid geological and superficial deposits;
- the depth to strata liable to dissolution or to seams which may have been worked;
- the presence extent and condition of any underground natural cavities or abandoned mine workings, particularly mine entrances;
- the presence and nature of any made ground, broken ground or other adverse foundation conditions; and
- the groundwater regime, its potential influence on subsidence and the potential effects on it of mitigation measures.

2E12. The choice of ground investigation techniques will depend on the expected ground conditions and the nature of the proposed development. Direct techniques, such as trial pits, trenches or borehole investigations, involve actual examination of the ground. Indirect techniques, such as various geophysical methods provide interpretations of ground conditions that must be confirmed by direct techniques. These methods will often be supplemented, especially for adverse foundation conditions, by *in situ* testing and by laboratory testing of samples obtained from boreholes, pits or trenches.

2E13. For small sites of up to two or three houses and for most householder developments, the ground investigation is unlikely to be extensive unless the desk study and site investigation has indicated the presence of shallow cavities, extensive broken ground or mine entrances within or in close proximity to the site. For larger sites, however, sufficient boreholes would be needed to establish the general geological structure and the nature and condition of any cavities or broken ground. Geophysical techniques may assist in the targeting of boreholes as well as in providing 3-dimensional interpolation between boreholes. Correlation of strata is enhanced if at least some boreholes are rotary cored and intervening probeholes are subject to geophysical logging.

2E14. Where the investigation shows a site to be liable to subsidence, or where underground excavation is proposed, an assessment will be needed of the extent and nature of likely subsidence and its effects. This should identify:

- the type of subsidence likely, ie excessive settlement due to adverse foundation conditions, crownhole/sinkhole collapse into shallow cavities or general subsidence;
- the magnitude of likely subsidence and whether it will differ from one part of the site to another;
- ground tilt due to differential subsidence;
- ground strains induced by subsidence; and
- the influence of these movements on existing or proposed buildings and structures.

TABLE 2E1. **Ground stability declaration form**

Site Name	**Site Address**	**Proposed Development**

CATEGORY	**QUESTION**	**YES/NO /?/N/A**
Competent person	Has the report been prepared by a Geotechnical Specialist, as defined by the ICE Site Investigation Steering Group?	
A. Site history	Has the site been affected by known historical subsidence?	
	Is the site underlain by strata which may contain natural cavities or be liable to subsidence due to adverse foundation conditions?	
	Has there been previous development on the site such as mining or industrial development that could result in underground cavities or made ground?	
	Is mining or underground excavation proposed beneath the site?	
	Have any previous ground investigation reports and/or borehole records from this or nearby sites been consulted?	
	Have any cavities, broken ground, made ground or other adverse foundation conditions been identified beneath or near the site?	
B. Site inspection	Has a detailed site inspection been carried out? Does the land within or adjacent to the site bear any geomorphological evidence of former, on-going or incipient subsidence?	
	Does the site or neighbouring property bear any evidence of structural damage or repairs that might be associated with subsidence or evidence of mine entries?	
C. Ground investigation	Has a ground investigation been carried out?	
	Have any cavities, broken ground, made ground or other adverse foundation conditions been identified beneath or near the site?	
	Have their locations and dimensions been properly identified?	
Assessment of subsidence	Is the information under A, B and C above adequate to assess the likely effects of subsidence on the site?	
	Can subsidence be reasonably foreseen within or adjacent to the site within the design life of the proposed development? Have the potential effects of subsidence on existing or proposed development been assessed?	
Mitigation measures	Have mitigation measures been proposed with respect to subsidence?	
	Are these designed to reduce the effects of any actual or potential subsidence to an acceptable level?	
	Are they likely to have any adverse effects on other adjacent sites, eg by affecting the groundwater regime?	
Name, qualifications and signature of person responsible for this report	Full Name	
	Qualifications	
	Geotechnical Specialist?	
	Signature	
	Company Represented	

2E15. The ground investigation report, illustrated appropriately with plans and cross-sections, should be similarly organised to the desk study and site investigation report, ie:

- a factual account describing the findings of the ground investigation;
- an interpretation of the field data, in conjunction with the desk study and site inspection findings, to confirm the geological sequence and the potential for subsidence and its potential effect on the development proposed; and
- recommendations for action following the ground investigation.

2E16. The recommendations are likely to fall into one of the following categories:

- that the investigation has shown that the risk of subsidence is negligible and development may proceed without special precautions; or
- that there is a significant risk of subsidence, which will require mitigation measures to allow the development to proceed safely. These measures should be described sufficiently to allow detailed design to proceed.

2E17. The report should reach a clear conclusion on whether there is a potential for subsidence based on a logical discussion of all the data gathered. It should declare the method used to assess potential subsidence. Any recommendations for mitigation measures should be clear and unequivocal and should take account of the risks to people and property, the scale and type of the development and the consequences of subsidence occurring. In order to arrive at appropriate recommendations, alternative options and their consequences should be identified and assessed.

2E18. The desk study and site inspection and ground investigation reports should provide sufficient guidance for detailed design of foundations and other preventive measures to mitigate the potential for subsidence. It is important that there be dialogue between the competent person responsible for assessing the subsidence potential and the designers of any mitigation measures. Developers are therefore encouraged to make the designs available to the competent person to ensure that recommendations of the subsidence assessment have been carried forward fully into the design.