2020 GUIDELINES TO EVALUATE PROPOSED DEVELOPMENT OVER DESIGNATED UNDERMINED LANDS IN THE TOWN OF CANMORE, ALBERTA

These guidelines are to be used in conjunction with
Canmore Undermining Review Regulation AR34/2020 (as amended from time to time)

April 1, 2020

PART A: INTRODUCTION AND PURPOSE OF THE GUIDELINES

1. INTRODUCTION

Surface and underground coal mines were developed on the south side of the Bow River Valley between Pigeon Mountain and the Town of Canmore from the 1880s to the late 1970s. Coal was primarily extracted by underground mining, however some surface exploration and mining also occurred. Subsidence, surface features of past mining activity and the presence of coal seam outcrops all present potential concerns for the Town, developers, builders and future residents.

The Natural Resources Conservation Board has approved a variety of urban land uses on lands where mining hazards may be present, subject to an assessment of the suitability of the area for development and the taking of any necessary remedial actions. These guidelines have been prepared to assist in the evaluation of these lands.

This version of the guidelines is an update from the July 30, 1997 *"Guidelines to Evaluated Proposed Development for Undermined Lands in the Town of Canmore"* previously published to accompany the Canmore Undermining Review Regulation AR114/97 that regulate development within certain designated lands. This update reflects advances in both site understanding, extensive field data and the state of the art in addressing mine subsidence hazards, and to accompany an update to the regulations approved by the Province of Alberta in 2020.

These guidelines have been prepared to be used in conjunction with Canmore Undermining Review Regulation AR34/2020 (as amended from time to time).

A special thank you to the people that contributed to preparing and writing these guidelines for approval by the Province of Alberta:

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2. PURPOSE

The purpose of these guidelines is to establish a staged process which provides for progressively increasing levels of confidence and confirmation as to whether a surface development may be undertaken without jeopardy to public safety and without incurring an unacceptable risk of damage appropriate to the anticipated use of a property as a result of development potentially impacted by previous mining activity within the designated lands identified by the Canmore Undermining Review Regulation AR34/2020 (as amended from time to time). The flow chart in Appendix II outlines how such a staged process aligns with typical planning processes.

The guidelines adopt an engineering risk assessment approach which involves investigation, establishment, refinement of zones of undermining hazards to development and consideration of mitigative techniques and precautions appropriate to the specific circumstances on phases of the development. Assessing potential impacts to development above mine workings is a geotechnical concern that focuses on how the surface of the ground may potentially deform due to physical changes or collapse of mines below or near the development under consideration.

Geotechnical assessments and other engineering endeavors inherently carry an element of risk of failure or unacceptable performance, and these guidelines are similar to other engineering guidelines in that risk generally cannot be completely eliminated in all situations or conditions.

The goal of these guidelines is to provide a clear and reasonable procedure to guide assessments for developing undermined lands. Natural and man-made subsurface risks exist on virtually all land under development, and this is the case in Canmore. The outcome of assessments performed according to these guidelines should be a clear understanding of subsurface risks and the intent for safely mitigating them for their intended uses as known on the date of the assessment. As with other geotechnical hazard assessments such as steep creeks, earthquakes and landslides, risk is not eliminated, but quantified and managed to reasonable levels.

Rather than being an absolute indicator of where a development may or may not occur, or the extent or type of mitigation required, the hazard zone concept is used to highlight those areas of land where greater investigation and engineering may be required prior to proceeding with development or construction. At the final stage of investigation and planning, precautions to be taken and mitigation actions required will be determined based on the specific conditions under consideration and nature of the development proposed.

The staged approach provides the opportunity to determine the need for, and level of detail of, investigation of a site prior to the commitment of large expenditures by the developer, allowing an analysis of economic viability of the development. It also provides confidence that a specific development incorporates appropriate considerations regarding public safety.

Part B of the guidelines provides details of the technical evaluation process. Appendix I describes typical critical coal mining parameters that may result in surface instability and other hazards over undermined lands. This includes, but is not intended to limit, potential hazards to be considered by the Undermining Engineer. The type of work to be considered and the level of detail expected at each stage of the process are outlined in Table 1. A flowchart outlining the various types of undermining assessments generally appropriate to various stages of planning certainty and applications is provided in Appendix II.

3. IMPLEMENTATION

These guidelines are to be read and utilized in conjunction with the Canmore Undermining Review Regulation AR34/2020 (as amended from time to time). While these guidelines are not written in the format or context of provincial law or regulations, the premise of these guidelines is based on undermining assessments and reports outlined herein being undertaken for all forms of:

a) "conservation reserve", "community services reserve", "environmental reserve", "municipal reserve", "municipal and school reserve", or "school reserve" all as defined by Division 8 of Alberta's *Municipal Government Act* (as may be amended from time to time);
b) "development" as defined within Section 616(b) of Alberta's *Municipal Government Act* (June 28, 2019 printing, as may be amended from time to time);
c) "highway" defined as a provincial highway under the *Highways Development and Protection Act* (as may be amended from time to time);
d) "public utilities" as defined within Section 616(v) of Alberta's *Municipal Government Act* (June 28, 2019 printing, as may be amended from time to time); and,
e) "road" as defined within Section 1(1) of Alberta's *Municipal Government Act* (as may be amended from time to time),

with the understanding that "developer" as may be referenced in these guidelines or in the Canmore Undermining Review Regulation AR34/2020 (as may be amended from time to time) means a person or entity or government that undertakes any of the above forms of improvements, maintenance, renovations or construction within, on, over or under any of the lands defined as belonging to the "designated lands" identified within the Canmore Undermining Review Regulation AR34/2020 (as may be amended from time to time). Generally, the developer as defined herein is responsible for the costs of undertaking undermining assessments and mitigation as applicable for the improvements, maintenance, renovations or construction being considered.

For example, a property owner (e.g. homeowner, condo board, landlord, etc.) registered on title would be responsible to maintain, upgrade, rebuild, modify, renovate or construct a development in accordance with the latest undermining report applicable to their property. Similarly, a public utility or road or highway owner (e.g., utility owner, government, etc.) would be responsible to maintain, upgrade, rebuild, modify, renovate or construct new or existing utilities or public infrastructure in accordance with the latest undermining report applicable to their property, or be responsible to obtain and adhere to a new undermining report for their project as appropriate.

It is acknowledged that undermining report based legal caveats are currently not able to be registered against highways, public road allowances or public road parcels, and therefore it is the responsibility of the owner of such property (generally municipal, provincial or federal government bodies) to implement measures such that recommendations arising from undermining reports applicable to these lands are addressed, including access or operation agreements with entities like public or private utilities that may utilize these types of parcels for their purposes to be responsible for undermining report responsibilities that may affect their infrastructure.

TABLE 1
GENERAL PROCESS TO EVALUATE PROPOSED DEVELOPMENT OVER DESIGNATED UNDERMINED LANDS IN THE TOWN OF CANMORE, ALBERTA

1. Data Review and Analysis

- research of sources of technical information
- collection of copies of mine abandonment plans and georeferenced images in a Geographic Information System (GIS).
- preparation of surface feature maps, and 3-D geological models of each mined seam
- preliminary site reconnaissance and map verification
- preliminary hazard zone mapping

2. Field Reconnaissance and Site Investigation

- preparation of detailed site-specific field reconnaissance maps
- detailed site reconnaissance
- preparation of a program to investigate surface and subsurface conditions
- conducting preliminary site investigation including excavations, trenching, drilling, monitoring, testing and other required work

3. Data Evaluation and Assessment

- reporting of field reconnaissance findings and their implications
- updating of geological models with drilling data, and of hazard zone mapping to reflect field reconnaissance and investigation findings
- identification and assessment of mitigative measures and/or the need for more investigation
- finalizing site investigation and probable mitigation requirements
- calculation or estimating of ground deformations due to future mine subsidence

4. Final Report and Definition of Approval Terms

- developing and carrying out specific site investigations to determine foundation design requirements.
- updating ground deformation estimates
- preparation of specific recommendations on mitigation for individual developments
- construction of mitigation measures required in conjunction with road and municipal infrastructure including "as built" existing mitigation details
- final report of findings, mitigation requirements and "as built" existing mitigation details

4. PROCESS UPDATE

Based upon the experience gained since 1997, the state of the art of analysis of undermining considerations in the designated lands in Canmore has advanced considerably. Advances have included the application of a probabilistic risk assessment approach to development evaluation.

The July 30, 1997 *"Guidelines to Evaluated Proposed Development for Undermined Lands in the Town of Canmore"* were largely based on developing preliminary constraint zone mapping with three (3) broad categories: no constraint, medium and high constraint. While the constraint zone mapping system served the purpose of establishing the preliminary feasibility of the Three Sisters project and enabling a conceptual plan to be prepared for the purposes of NRCB Decision No. 9103, it was clear that more specific site assessments was necessary for detailed development planning. The constraint zoning system, based as it was on the simplistic interpretation of a limited range of mining parameters and types of development, was suited to conceptual planning work generally used for Area Structure Plans or many Land Use applications but had limited value in more detailed development evaluations.

The described approach herein replaces the earlier "point estimate approach" used in the past for Undermining Reports in the designated area in the past (before approximately mid-2000s). In the "point estimate approach" potential future ground movements over old mine works used a reasonably conservative set of assumptions to provide an estimate, and structures were then designed to accommodate that amount of subsidence. This approach did not allow for the fact that the probability of the future subsidence event is usually small, nor did it account for the fact that there is a possibility that subsidence could exceed the estimated value.

The probabilistic risk assessment approach process gives a more reasonable basis for estimated subsidence because it recognizes the uncertainties that are involved in assessing the current state of the soils or rock surrounding the old mining works, and the uncertainties in the methods that are used to link the state of the mine workings to the probable subsidence. The probabilistic risk assessment approach also considers the consequence of subsidence in terms of damage or impairment of intended land use, not simply the magnitude of subsidence used previously. Once the likelihood and consequence of a range of subsidence magnitudes are known, it is possible to then respond to that information in a more effective way in the design of the development than would be possible if only a single estimate of subsidence was determined using the "point estimate approach". Thus, the probabilistic risk assessment approach offers the potential for more rational planning of land use and subsidence mitigation alternatives.

5. RISK ASSESSMENT REQUIREMENT

As more extensive field data within the designated area was collected since 1997, and with the last two decades of field review, assessments and design experience in hand, the approach to undermining assessment has continued to evolve and now uses an application of risk assessment to development evaluations.

Subsidence over mine workings is a process that is uncertain both in time and in magnitude. As time since mining passes, the occurrence of subsidence events becomes much less likely but remains uncertain. This uncertainty must be taken into account, along with the other variables of depth, rock type and mining configuration in the design procedures. Estimation of the magnitude of improbable events in engineering design is quite common. Designing for large, infrequent storm events and earthquakes face similar challenges and are managed in similar ways. However, subsidence is generally not a recurring event but a process that, if it occurs, leads to greater future stability. There is also a clear physical maximum deformation that can result from an event or series of events, and this maximum is determined as part of the risk assessment process. Therefore, treating subsidence for design purposes in same way as similar natural hazards like earthquakes or infrequent storm events may produce results that are unnecessarily conservative.

Building codes and other industry engineering standards are based on the concept of “acceptable risk” which involves establishing minimum standards that work to balance the costs of subsidence-resistant construction or ground treatment against the chance of incurring unacceptable losses in future events.

The risk of a given subsidence event is a product of the likelihood of a hazard occurring and its consequence (the exposure and the cost in terms of safety or damage). The likelihood and magnitude of a hazard can be estimated by applying engineering principles and the exposure and consequences can be estimated considering the use of the land (e.g. parkland, golf courses, low-rise residential housing, larger commercial structures, utility infrastructure, etc.). Risk, the combination of these values, can be managed through mitigation measures at the source or the consequence of the hazard (e.g. ground stabilization, structural design, etc.) such that it is below the acceptable threshold for the specific structure or land use. Where a hazard due to undermining exists, it is a requirement that an appropriate risk assessment be undertaken as a part of an undermining assessment report, with the level of risk assessment work commensurate with the level of planning application being considered.

Utilizing a 50-year period, which is typical of the design service life of most utility infrastructure, and is also how long many structures, on average, have useful service lives (without material or significant maintenance or renewal), probabilities can be determined.

Accordingly since approximately 2005, a probabilistic risk assessment approach has been used to determine the potential ground settlement values and subsidence risk to structures and utilities that could arise as a result of undermining near proposed developments, along with determining safe, appropriate, practical and economic mitigation measures. Subsidence estimates derived from this approach provide probabilistic values, and the subsidence estimates for general panel subsidence should be determined at the 90th, 95th, 98th and 99th percentiles of probability. This equates to the general panel subsidence impact estimates derived having a 10%, 5%, 2% and 1% chance accordingly of being exceeded in a 50-year design period.

The resulting values were adopted for consideration in the design of structures and utilities placed over ground that could be impacted by undermining. The general panel subsidence estimates consider various material, spatial and temporal parameters as stochastic variables, such as, but not limited to:

1) Depth of the workings;
2) Thickness of rubble;
3) Panel width; and,
4) Time elapsed since mining.

It is recommended that general panel subsidence estimates at the 90th percentile of probability be adopted for design of developed areas with the exceptions noted below. Developed areas typically included, but are not limited to, landscaped areas, parks, roadways, pathways, surface improvements, street furniture, drainage ditches, storm culverts, aesthetic features, irrigation, shallow utilities, easements and other improvements that are generally accessible by the public.

Lower values of percentile of probability could potentially be used for some landscaped areas, unimproved park spaces, golf courses, mountain bike parks, conservation areas, environmental reserves, wildlife corridors, unpaved trails or similar types of uses, depending on the consequence of subsidence in terms of damage or impairment of the human use being considered for a parcel of land.

It is recommended that general panel subsidence estimates at the 95th percentile of probability be adopted for design of buildings, structures and deep utilities (water, sanitary and buried storm sewers) placed on ground that could be impacted by undermining, a value typical for hazards and improvements of this type.

For “Group B2” buildings as identified in the 2019 Alberta Building Code if placed on lands within the designated area that are impacted by undermining, consideration should be given to using 98th percentile of probability to determine general panel subsidence estimates, similar to the underlying reasoning behind the code considerations for Group B2 buildings or Alberta’s flood risk management guidelines for Class 2 buildings (hospitals, medical facilities, extended care facilities, etc.).

Residual risks to loss-of-life are to be considered in all the above, and no occupied structure within a developed site should pose a risk to the public that would present exceeding an annual risk of mortality of 1:100,000 due to general panel subsidence. The mitigation of undermining features within the 500 m safety zone outside of the developed site as contemplated in Part B, Section 3.4 below is specifically excluded from being required to meet this annual risk threshold and do not require formal risk assessment.

PART B: GUIDELINES

All technical work should be conducted or supervised by a qualified professional engineer licensed in Alberta with experience in the applicable technical discipline (herein after referred to as an "Undermining Engineer" for convenience purposes). All testing, analysis and other laboratory work should be performed by agencies employing qualified workers with appropriate experience and using industry standard methods and technology.

1. DATA REVIEW AND ANALYSIS

Data review and desk-top assessments are generally used for Area Structure Plan and Land Use level of development applications, as outlined in the flowchart in Appendix II. There may ultimately also be several undermining reports for a particular area, for example undermining assessment might initially review the high level concept outlined in an Area Structure Plan, while a later undermining assessment report might look at a specific area within an Area Structure Plan for a Land Use application. Some limited amount of detailed data evaluation as described in Part B, Sections 2 and 3 below may be necessary for an Area Structure Plan or Land Use level assessment, and this is left to the judgement of the Undermining Engineer to determine.

1.1. Research of Sources of Technical Information

The Undermining Engineer should research all available information on surface and underground coal mines, processing facilities and other mining related features on all lands within the proposed developed area and within 500 meters of its boundaries. Sources and types of information would include:

- Geology of Canmore, Geological Survey of Canada, Department of Energy, Mines and Resources;
- Canmore structure sections, Geological Survey of Canada, Department of Energy, Mines and Resources;
- Bureau of Economic Geology, Geological Survey of Canada, Department of Mines, Canmore area;
- Geological and Natural History of Canada, Geological Map of Part of the Cascade Coal Basin;
- Alberta AER Coal Mine Atlas ST45 abandonment plans, and local maps;
- Mine maps, cross-sections, and other mining data from local sources;
- Maps Alberta, topographic maps, and aerial photographs;
- Information available from local persons having knowledge of mining history and developments in the Town of Canmore if appropriate, along with research in the Canmore Museum or similar facility;

- Previous undermining assessment reports undertaken in the subject area that may be available via registered caveats on subject and nearby titles or on file with the Town of Canmore and/or Province of Alberta.

1.2. Geological Model and Base Map Preparation

Based on the technical information obtained under Part B, Section 1.1, the Undermining Engineer should prepare the following maps:

1.2.1. Geological Model

A 3-D geological model of each seam that could impact the assessment should be constructed using mining or geological modeling software or other Computer Aided Drafting and Design (CADD) modeling software. The basis of the model should be made by digitizing elevation data on the respective mine abandonment plans. Since the roof of the mine in many locations has collapsed, the floor of the mine should be modeled. The elevation data from the abandonment plans should be supplemented with surveyed elevations of drilling intersections with the floor of the mine as they become available.

In addition to the floor of the mine, other data from the drilling investigation should also be included in the 3-D model, including the top of any rubble pile or void. These parameters can be useful in estimating backfill volume during mitigation programs.

It is recommended that any 3-D models developed be retained within the internal files of the Undermining Engineer for a minimum of 10 years following the date of publication of the final Undermining Report as described in Part B, Section 4 below for future reference.

1.2.2. Surface Features Maps

A map on a topographic base should be prepared showing the location and areal extent of all existing and reclaimed surface coal mines, reject and waste piles, and so far as they are known, coal outcrops, existing and demolished mine buildings, roads, rail lines and associated structures, portals, shafts, adits and sink holes, cracks, fissures, areas of subsidence and other evidence of ground movement or instability so far as all such may be determined to potentially impact the assessment being undertaken.

1.2.3. Seam Maps

A map of each mined coal seam that could impact the assessment showing georeferenced images of mine abandonment plans, mining limits, extent of extraction, extraction thickness, seam gradient, elevations, faults, geological cross section lines and any other significant structural geologic features. These maps should also show any existing or planned development and civil infrastructure, where possible.

1.2.4. Geological Cross-Sections

Cross-sections should be drawn through the development area such that the cross-section lines are approximately parallel to the true-dip of the strata and no more than 200 meters apart, and as frequent as necessary to reflect changes in geological structure across the development area. At least one (1) cross section should be drawn through any given development area under review showing adjacent mining that could affect the development. In some circumstances, longitudinal sections may also be necessary to show cross-structure faulting or details of mining on vertical seams. The cross sections should be generated from the 3-D geological model and show drilling intersections in the vicinity of the section as well as existing or planned development and civil infrastructure.

The cross sections should be updated in conjunction with the geological model.

1.3. Preliminary Site Reconnaissance and Map Verification

A reconnaissance of the property should be conducted to verify the information shown on the base mapping, where possible. New information should be added, and corrections made where errors or inaccuracies are discovered within the final Undermining Report as described in Part B, Section 4.

The objectives of the site reconnaissance and map verification program are:

- To identify subsided areas, sink holes, cave-ins, or other surface abnormalities potentially caused by mining and to locate all such areas accurately on the field reconnaissance map;
- To examine all locations where maps show the existence of openings to the surface including ventilation or other shaft, slope, and adit portals;
- To assess whether there is evidence of mine workings present in areas for which there are no mine maps or other records;
- To identify coal seam outcrops/sub-crops and the presence of fault outcrops/sub-crops;
- To correlate the underground mine working plans with the surface features identified during reconnaissance and property inspection; and
- To maintain and continuously improve on the existing/known Seam Map information.

The preliminary site reconnaissance should focus on areas of shallow mining and those near coal seam outcrops and prospect sites. These areas should be walked systematically in 10m spaced transects.

1.4. Preliminary Hazard Zone Mapping

Maps and accompanying undermining reports should be prepared defining the extent and the nature of potential risks or constraints that previous coal mining activity has created or may create for future development or public safety arising from mine works below or near the development area, and also have consideration of any hazards arising from appropriate surface features. Hazard maps are a valuable tool for initial development planning and their use is encouraged. In this application it is useful to create defined areas or zones within which a similar magnitude of hazards exists. These zones should initially consider the unmitigated hazards, but as development planning and execution advances, they may be refined and annotated to identify areas within which hazards can be or have been mitigated to risk criteria which are appropriate to the development under consideration.

Hazard zone boundaries determined by the Undermining Engineer should be based on an appropriate framework and methodology, developed from site specific observations and data that can be reviewed, with consideration to all of the mining hazards mentioned in this guideline as well as the potential uncertainty associated with historical records which may be used. The hazard zone boundaries should be independently verifiable by the third-party reviewer based on this framework, methodology and site data, allowing for some influence of the Undermining Engineer's specific site experience. It is acknowledged that hazard boundary mapping can vary between different Undermining Engineers, depending on available dataset, interpretation and investigation.

Delineation of these hazard zone boundaries is, at this point, considered preliminary and subject to change as a result of more detailed work which may be conducted pursuant to the Field Reconnaissance and Site Investigations identified in Part B, Section 2 of these guidelines.

Maps of the development area should be prepared to identify the preliminary hazard zones for use in development and neighborhood planning and subsequently included in the Undermining Report, but caution is expressed here that hazard zone boundaries can change based on subsequent investigation or details of the development being considered, inclusion of new data, and mitigation economics or methodology, and therefore land use boundaries or development areas should not be solely predicated or based on preliminary hazard zone mapping.

2. DETAILED FIELD RECONNAISSANCE AND SITE INVESTIGATIONS

2.1. Objectives

Detailed field reconnaissance and site investigations are generally used for subdivision, development permit or building permit level of development applications, as outlined in the flowchart in Appendix II. There may also be several undermining reports for a particular site, such as a subdivision level undermining assessment that looks at the road layout, parcels and utilities within a subdivision, while a later more site specific undermining assessment report looks at a specific parcel for a development permit or building permit application.

The objectives of an approved program for the detailed field reconnaissance and site investigations may include the following:

- To identify subsided areas, sink holes, cave-ins, or other surface abnormalities potentially caused by coal mining and to locate all such areas accurately on the field reconnaissance map;
- To examine all locations where maps show the existence of openings to the surface including shaft, slope, and adit portals;
- To check mine map accuracy by reconciling drill hole findings with mapped information, including areas of stable pillars;
- To assess whether mine workings exist in areas for which there are no mine maps or where minable coal exists beyond the recorded limits of the mine on the abandonment plans;
- To identify the presence of fault outcrops and the surface location of mined coal seam outcrops and other coal seam outcrops;
- To ascertain the type, nature, thickness, and geotechnical character of the individual strata overlying the workings in each seam and of the strata immediately below the lowest mined seam; and
- To update the 3-D geological model.

2.2. Preparation of Detailed Site-Specific Field Reconnaissance Maps

Within the development area there may be various individual projected developments, and it is not necessary for field reconnaissance and site investigations to proceed concurrently on each development site. Sites may be studied on an individual basis related to specific development plans. A field reconnaissance and site investigation program for specific development sites will be based on a field reconnaissance map or booklet of map tiles showing:

- The proposed area of project development; and
- The sites of shafts, mine portals, subsided areas, sink holes, cave-ins, prospect sites, fissures and near-surface extraction as shown on the maps of the mine workings in each seam or exploration maps.

The detailed site reconnaissance of a development should be conducted such that the development area is systematically walked on 10 m spaced transects across the entire area with the intent of recording features which may indicate mining-related disturbance, including those features indicative of subsidence caused by underlying and nearby underground mine workings.

2.3. Program to Investigate Surface and Subsurface Conditions

The initial program of site investigations should include the excavation of test pits and trenches and the drilling of open and/or cored holes. Investigation of subsurface conditions by surface geophysical methods should include use of appropriate assessment techniques. Each type of investigation should be located to optimize the relevant information obtained regarding underground conditions.

Drill holes should be located in a pattern that permits confirmation of coal seam map accuracy, particularly in relation to defining shallow and subcrop limits of mining. Drill holes should also be used to investigate areas in which mining is not shown on mine plans but may exist with the intent to confirm limits of mining. Detailed stratigraphic log descriptions should be generated for each hole to a minimum depth of 3 meters below the lowest mined seams. Drilling methods should be selected such that rubble formed during collapse of mined panels can be penetrated fully to the floor of the mined seam. Reverse –circulation air rotary drilling is an example of a drilling method that has been successful in this regard in the Canmore mines.

Where conditions permit, down-hole video inspections should be performed to confirm the presence and extent of open void and rubble within or above mined seams, since it can be difficult to accurately measure these solely by drill rig behavior.

Directional surveys of drill holes should be considered for all holes deeper than 40 m due to observed drill hole deviation in the dipping strata of the Canmore area.

Surface geophysical investigation methods continue to advance and should be considered in areas where shallow mining may exist but should be used as an additional tool (if appropriate), not a replacement for a drilling program.

The elastic constants of each strata type immediately above and below each mined seam should be determined. Testing such as uniaxial compressive and tensile strength tests are recommended.

Durability tests should be carried out on seam floor cores to assess the potential extent that such strata may decrease in strength and stability with the passage of time and under the effects of water. If possible, at least one core should be obtained of each mined coal seam in order that the uniaxial compressive strength of uncrushed coal pillars may be determined for evaluation of the current, and potential long-term, stability of coal pillars by comparison with their extent, height, and load to be carried. Where pillars are crushed, it may not be possible to recover core samples. In these situations, it is usually sufficient to determine, so far as possible, the height of the crushed pillar.

2.4. Program Implementation and Other Work

Where voids or rubble zones are identified in or above the mine workings, in a high constraint zone, techniques such as geophysical downhole surveys, and the use of downhole cameras to differentiate between void spaces and collapsed strata, should be considered. Ascertaining void heights, their stratigraphic location, and if practical, their lateral extent is fundamental for an adequate consideration of present and future ground stability.

Water levels in the mines should be determined throughout the year by measuring levels in boreholes. A model based on previous observations with appropriate frequency and sufficient time to capture seasonal fluctuations and/or uncommon events can be utilized if available and reasonable.

Examination of bedrock conditions in pits and trenches and of the cores recovered from drill holes should be conducted by a qualified professional engineer, and the results of such examination should be included in the report. Investigations involving identification of mining voids, or examination of surface features that may have resulted from undermining, should be undertaken by a qualified, experienced, professional engineer.

Subject to findings during field reconnaissance and site investigations, the Undermining Engineer should modify the maps prepared in accordance with these guidelines.

3. DATA EVALUATION AND ASSESSMENT

3.1. Field Reconnaissance Report and Map Modifications

The Undermining Engineer should prepare a report detailing the results of the field reconnaissance and site investigations together with any modified maps relating to the extent of mining or hazard zone boundaries. The report should include an assessment of the hazards to the proposed development and of risks to public safety based on the available information. The report may include an assessment of the potential to mitigate identified risks to achieve appropriate risk based public protection goals using technically feasible methods which are economically acceptable to the developer.

3.2. Additional Site Investigations and Field Tests

The drilling and testing program may reveal underground conditions that require further investigation, such as, for example, the discovery of a mined-out area in a location previously believed to be unmined. Additional site investigations and testing should be conducted to provide the information required to assess hazards/risks associated with these areas. Final maps, reports and other documents may need to be revised to show this new information as appropriate. If errors or unmapped mine works are discovered that are not shown on archived historical maps, they should be identified via a memo and sketch (including a reference to the final Undermining Report) placed on file with the historical maps so that others can become aware of the potential discrepancy, and can consider potential impacts of the discrepancy found for future assessments by others.

3.3. Ground Deformation Estimates

A site-specific ground deformation model should be developed for the site that uses the historical information related to seam thickness and mined panel dimensions along with the present condition inferred from the field work undertaken. It is necessary to estimate the ground deformations above mine workings with consideration given to potential residual settlement for workings which have been or will be mitigated.

This model should be sufficiently developed to estimate future ground deformations. Structural and civil engineers require these to design the structures and infrastructure to accommodate or resist the forces generated during a subsidence event. These ground deformations include total subsidence, tilt, horizontal strain, angular distortion and induced curvature. The model should be calibrated where possible to site surveys and visual evidence of subsidence caused by historical mining.

The model should also be capable of estimating the ground deformations that may occur above mitigated (i.e. backfilled) or collapsed mined panels, since depending on depth, there still may be some potential subsidence (albeit significantly reduced) in this situation. This should reflect the effectiveness of the mitigation program.

In order to estimate the ground deformations, it is necessary to define the limits of the mined panels that could be the cause of subsidence. Pillar stability analysis should be performed to confirm that the factor of safety of intact pillars (or groups of intact pillars) are sufficient to be relied upon in the long term.

3.4. Remedial Actions and Mitigative Measures

A comprehensive report should be prepared detailing the results of the site investigation and field tests together with any modified maps relating to the extent of mining or hazard zone boundaries. The report should include an assessment of the risks to the proposed development including ground deformation estimates, public safety hazards and an assessment of the extent to which the risks may be mitigated.

Recommendations for the application of a specific mitigative measure depend on the type of development proposed and the nature of the risk associated with the hazard zone, and should be based on consideration of the following as a minimum:

- The location of building foundations above or near coal seam outcrops or subcrops, and the location of other facilities constructed in their vicinity;
- Development planned in the vicinity of fault outcrop locations;

- Backfilling and sealing areas of high risk due to the presence of shafts, portals, slopes, and adits used to access underlying coal seams to prevent public access into the mine workings;
- Backfilling areas of high risk due to the presence of mining voids;
- Backfilling voids or other measures to resolve potential problems if flammable or noxious gases are identified by the Undermining Engineer;
- Backfilling and consolidating material in areas containing surface voids, fissures, and slumps after necessary actions have been undertaken to mitigate the conditions which gave rise to the surface void, fissure, opening, or slump;
- Within the specific development site, treating, covering or removing near surface coal or similar carbonaceous materials, to eliminate them as a potential source of fire due to spontaneous combustion or accidental ignition by residents' activities (campfires, barbecues, etc.);
- Consolidating or otherwise mitigating reject and waste piles;
- Not removing water from flooded mines or disposing of controlled storm water into mine workings;
- Designing building foundations to mitigate or minimize within acceptable parameters transference of ground deformations to the structure;
- Investigation and mitigation for the purposes of public safety that may be required on areas adjacent to, and within 500 meters of the boundary of the proposed development where mining activities may impact land use on the development site or safety of residents; and
- Additional mitigations that may be recommended by the Undermining Engineer to be implemented as part of development.

4. FINAL ASSESSMENT AND DEFINITION OF APPROVAL TERMS

A final Undermining Report shall be prepared which includes a description of all remedial actions and mitigative measures required as well as those completed for the works identified in Part A, Section 3 above. Recommendations for avoidance of specific areas due to investigative limitations, mine conditions, site conditions or uneconomic mitigation should also be made within the final Undermining Report if required. Hazard zone mapping as developed in Part B, Section 2.1 and refined via mitigation (if appropriate) should also be included within the final Undermining Report. Specific recommendations on structural mitigation for individual developments including any further necessary investigations to determine design of the development shall be noted. Documentation shall include all "as built" measures and any monitoring requirements, where necessary and fulfill the requirements of an Undermining Report, as defined in the Canmore Undermining Review Regulation AR34/2020 (as updated from time to time).

APPENDIX I

CRITICAL MINING PARAMETERS THAT MAY RESULT IN SURFACE INSTABILITY

AND OTHER HAZARDS OVER UNDERMINED AREAS

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CRITICAL MINING PARAMETERS THAT MAY RESULT IN SURFACE INSTABILITY AND OTHER HAZARDS OVER UNDERMINED AREAS

Coal-bearing formations are known to underlie some 303,000 square kilometers, or approximately 46 percent, of the province of Alberta in 57 separately designated coal fields. Coal seams may occur singly or in multiples superimposed one on another in a vertical sequence. The seams may lie in horizontal planes or at any inclination up to the vertical. Due to extensive earth movements, the inclination of the seams may change in magnitude and direction over small lateral distances. Seams may intersect the surface and extend to, or lie at, considerable depths below the surface. The seams may extend laterally over many thousands of square kilometers or may occur in isolated pockets. Most identified seams in Alberta lie at depths of up to 900 meters, but nearly all mining has been at depths ranging up to approximately 300 meters below grade. In the Mountain Region, rapid changes in surface elevation result in significant changes in seam depth over small lateral distances.

Individual coal seams range in thickness from a few millimeters to more than 90 meters as a result of thickening caused by earth movements. However, most seams in Alberta are less than 6 meters thick, and most mining has taken place in seam thicknesses ranging from 1 to 3 meters. Seam thicknesses often change within the same mine.

Coal seams lying relatively close to the surface, at depths of up to approximately 50 meters, may have been exploited by the removal and stockpiling of the overlying strata and the formation of open pits. Reject or waste piles may be unstable, or susceptible to self-ignition and fire due to spontaneous combustion of the waste coal product and represent risks to public health and safety. Open pits may have become flooded and contain water polluted by acid-bearing rocks exposed in the pit. Pits may have been backfilled with reject or waste material but with insufficient compaction to ensure complete stability of the restored ground. Areas adjacent to the pits may have been the sites of workshops, processing plants and other mining-related activities and provide sources of additional environmental concerns due to ground contamination from these industrial activities.

Early underground mining took place in coal seams occurring at relatively shallow depths below the surface with access gained by vertical shafts, inclined slopes, and adits sunk, or driven in, from the surface. Mining extraction schemes were generally characterized by irregular layouts and poorly defined areas. The most common mining method, particularly in the Canmore area, was room-and-pillar mining in which a pattern of entries, supported by timber posts and beams, were driven in the coal seam leaving arrays of solid coal pillars, generally of square or rectangular shape, to support the overlying strata. Initial mine development may have recovered 50 percent of the coal but, in many cases, secondary mining extracted part, or all, of the pillars and increased coal recovery to as much as 80 percent. In some locations, longwall mining was used. In this method of mining, coal is produced from a face up to 200 meters wide that is advanced through a panel up to 2000 meters in length. While the objective is to totally mine the coal, in practice I00 percent extraction is not achieved as coal support pillars are left between adjacent longwall panels.

Over time, workings may collapse due initially to the rotting of timber supports in the excavations and subsequently due to failure of the support pillars or pillar remnants. The extent and effects of such collapses are dependent on many factors including:

- The depths of the workings and the types and strengths of the overlying strata;
- The size and shape of the coal pillars and the strength of the coal;
- The height and width of the entries and the methods of entry support; and
- The dimensions of the area extracted and the percentage of coal recovery.

Land overlying abandoned underground coal mine workings may be subject to topographic changes characterized by sudden collapse or by tilt, curvature, and displacements of the ground surface due to the effects of subsidence caused by the collapse of the overlying strata into the voids created by mining. Collapse and the development of sink holes and similar features occurs over shafts, inclined slope portals, and near-surface mine workings. These may cause damage and pose safety risks to people. Differential movements of the ground surface due to subsidence can cause damage to structures and utilities. Subsidence may occur at any time during and after mining activity, even after long periods of apparent stability. In situations where pillars have remained stable but entries have collapsed, the ground surface may be subject to the formation of slumps, openings, and fissures, and be more or less unstable. Subsurface voids may occur in the old workings and represent both zones of instability and potential accumulations of noxious or flammable gases that can be associated with coal. Limited admission of fresh air to the workings may give rise to underground fires if the coal is susceptible to self-ignition and fire by spontaneous combustion. The workings may be flooded, and seasonal fluctuations in water levels may affect the stability of the workings and of the overlying strata. Mine water may be highly acidic and may pollute surface streams if such water discharges to the surface. Particularly in the case of mining activities that took place in the early 20th century, surface hazards due to undermining may occur at unpredictable locations due to the absence of complete mine maps, surveying inaccuracies which do not locate the workings correctly relative to the surface, or to mine maps that do not show the true extent of mining.

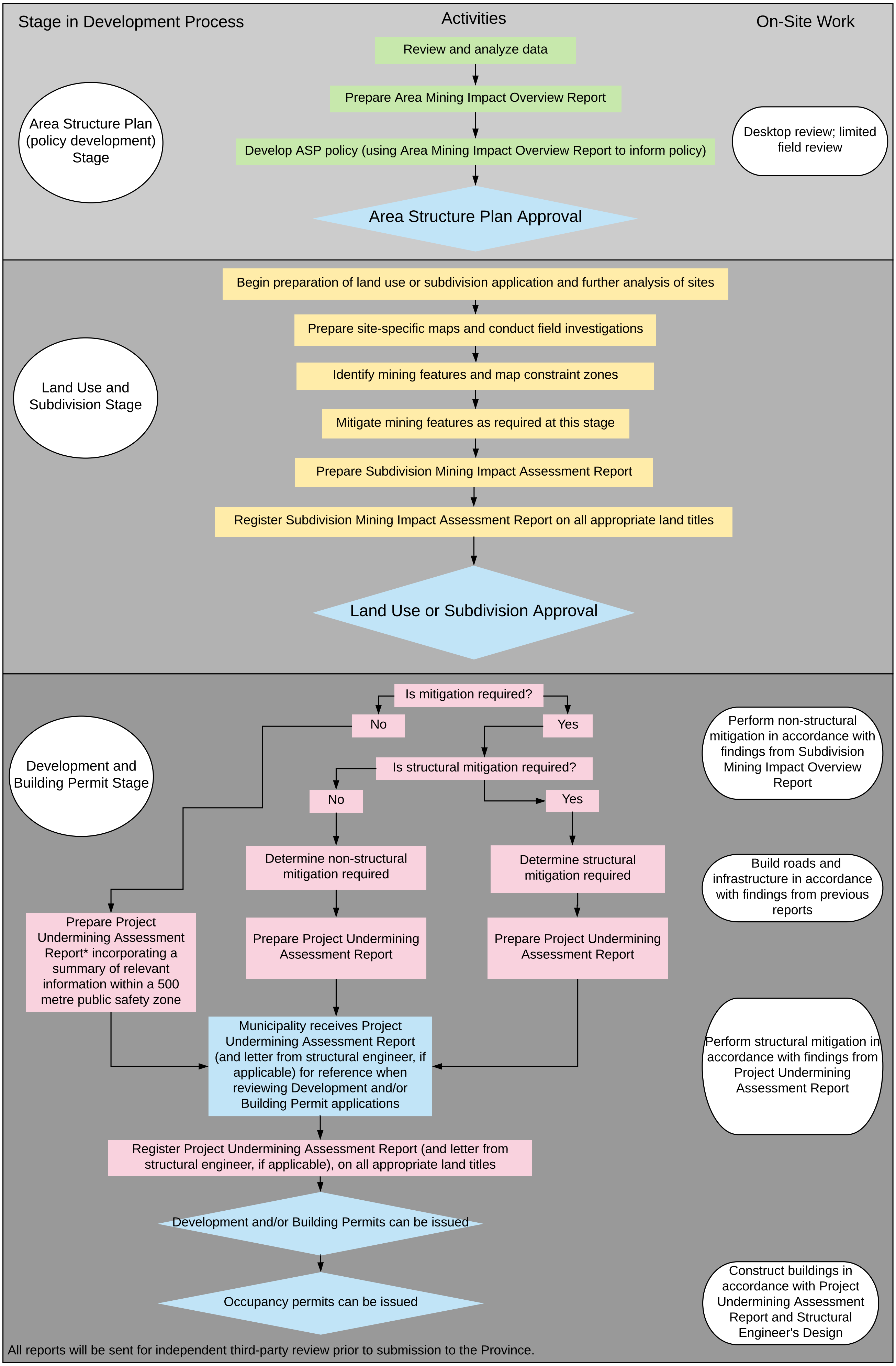
Mine workings at great depths can cause surface subsidence. Coal pillars may deteriorate and lose strength over time and where they are heavily loaded by overlying strata they may collapse. Investigation of the condition of pillars within deep mines is challenging so the prediction of future subsidence risks has greater uncertainty.

In summary, the presence of abandoned underground coal mine workings underlying surface lands developed, or planned to be developed, represents potential hazards to the stability of surface structures and utilities, and risks to public health and safety and should be assessed as proposed herein by professional engineers experienced in this assessment and licensed in Alberta.

APPENDIX II

PROCESS FLOWCHARTS

Undermining Assessment and Permitting Flow Chart



Redevelopment Undermining Assessment and Permitting Flow Chart