GHL CONSULTANTS LTD

Read Jones Christoffersen
Consulting Engineers

Building and Safety Policy Branch
Ministry of Housing and Social Development
Amending the BC Building Code to Permit up to and including 6 Storeys of Wood-Frame Buildings of Residential Occupancy

Stage 1 Report

Building Code Provisions for Residential Buildings and Identification of Technical and Process Risks

October 29, 2008

Prepared by

GHL Consultants Ltd.	Read Jones Christoffersen Ltd.
Suite 950, 409 Granville Street	Suite 300, 1285 West Broadway
Vancouver, BC V6C 1T2	Vancouver, BC V6H 3X8
Andrew Harmsworth	Grant Newfield
Gary Chen	Leslie Peer
	Douglas Watts
GHL File: BSP-3517.00	RJC File: 100419.P000 100419.P001

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SUMMARY

Stage 1 Report - Building Code Provisions for Residential Buildings and Identification of Technical and Process Risks

As part of the recent initiative to amend the current BC Building Code (BCBC) to permit up to and including 6 storeys of wood-frame buildings of residential occupancy, GHL Consultants Ltd (GHL) and Read Jones Christoffersen Ltd (RJC) have been requested by the Building and Safety Policy Branch of the Ministry of Housing and Social Development to prepare the following technical report aimed at identifying and addressing technical issues with respect to the proposed Code change. In this Stage 1 report, a summary of the current BCBC provision for residential buildings relating to fire safety, structural and building envelope is provided, and the technical and process risks related to the proposed Code change are identified.

The acceptable solution in Division B, Part 3 currently does not permit combustible buildings of residential occupancy in excess of 4 storeys. Division B, Part 4 and Part 5 for structural and building envelope requirements do not currently restrict height of combustible buildings. Therefore, from a technical risk perspective, the primary concern in limiting combustible buildings to 4 storeys is due to Division B, Part 3 limitations.

Based on GHL and RJCs research, technical and process risks with respect to the Code change proposal are identified. It is identified that, generally, the technical risks are not likely to increase, while there are a number of issues relating to process risks that should be addressed prior to the Code change. These issues relate largely to the readiness of the construction industry in general in delivering a 5 or 6 storey wood-frame building that is in compliance with the Code as well as of good engineering practice. Key recommendations for addressing the process risks are provided in this report.

The Stage 2 report to be released in October will further identify the Code change recomm-endations, and recommendations to changing or adding technical standards and guidelines relating to construction of 5 or 6 storey wood-frame buildings, though some of these recommendations are identified in this Stage 1 report.

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ABBREVIATIONS

AHJ	Authority Having Jurisdiction
AIBC	Architectural Institute of British Columbia
APEGBC	Association of Professional Engineers and Geoscientists of British Columbia
BC	British Columbia
BCBC	British Columbia Building Code
BCIT	British Columbia Institute of Technology
BEEP	Building Envelope Education Program
BEP	Building Envelope Professional
BSPB	Building and Safety Policy Branch
CANCEE	Canadian National Committee on Earthquake Engineering
CMHC	Canada Mortgage and Housing Corporation
CP	Certified Professional
CAN/ULC-S101	Fire Test Standard “Fire Endurance Tests of Building Construction and Materials”
CSA	Canadian Standards Association
CSA O86	CSA Standard “Engineering Design in Wood”
EWP	Engineered Wood Product
FRR	Fire-resistance rating
GHL	GHL Consultants Ltd
Group C	Residential occupancy as defined in the 2006 BCBC
GWB	Gypsum wallboard
HPO	Homeowner Protection Office
IRC	Institute for Research in Construction
NBCC	National Building Code of Canada

NFPA	**National Fire Protection Association**
NFPA 13	**NFPA Standard "Installation of Sprinkler Systems"**
NRC	**National Research Council**
OSB	**Oriented Strand Board**
RJC	**Read Jones Christoffersen Ltd**
SEABC	**Structural Engineers Association of British Columbia**
STC	**Sound Transmission Class**
Struct.Eng	**Designated Structural Engineer**
UBC	**University of British Columbia**
ULC	**Underwriter's Laboratory of Canada**
ULC-S101	**Fire Test Standard "Fire Endurance Tests of Building Construction and Materials"**

DISCLAIMER

This technical report is prepared by GHL and RJC for the Ministry of Housing and Social Development. The purpose of this report is to provide a professional opinion to the Ministry on the proposed Code change to permit up to and including 6 storey wood-frame buildings of residential occupancy. The formulation of GHL and RJC's opinion is based on the science of fire, structural and building envelope engineering, review of the available literature and preliminary consultation which are inherently limited by the short timeframe (August 15, 2008 – September 5, 2008). The work of this report is limited by the timeframe, which would normally require substantial research for a significantly greater duration. The work as presented in this report is based on GHL and RJC's knowledge as competent practitioners in their respective fields. GHL and RJC's work shall not be construed as exhaustive. There may be other relevant considerations for the Code change proposal not identified by GHL and RJC. At time of report writing GHL and RJC have recommended BSPB to retain qualified professionals to address other requirements such as including but not limited to construction fire safety, as well as electrical and mechanical systems of building design. Additionally, it is assumed that a public consultation process is being carried-out in conjunction with this report. The BC Government shall be solely responsible for the act of amending the BC Building Code to permit up to and including 6 storeys of wood-frame buildings of residential occupancy, or making any changes to any provisions in the Building Code. It is the BC Government's sole discretion to adopt, consider or accept in part or in full the work of GHL and RJC contained in this report. GHL and RJC shall not be responsible for any loss of any kind that may arise due to any construction, building, or structure as a result of GHL and RJC's work or any Building Code or construction regulation change in British Columbia, or anywhere. Should this report be made available to other organizations that have regulatory capacity in construction of buildings and structures for anywhere this disclaimer shall equally apply. By preparing this report GHL and RJC do not express explicitly or implicitly any social, economical or political opinion, or any other non-technical opinion, as it relates to the Code change proposal. This report is intended to be purely technical in nature. Any inquiries on this report shall be directed to the Ministry:

Manager
Building and Safety Policy Branch
Office of Housing and Construction Standards
Ministry of Housing and Social Development
5th Floor, 609 Broughton street
PO Box 9844 Stn Prov Govt
Victoria, BC V8W 9T2
Email: building.safety@gov.bc.ca

1.0 BASIS OF REPORT

1.1 Stage 1 Report

As part of the recent initiative to amend the current BC Building Code (BCBC) to permit up to and including 6 storeys of wood-frame buildings of residential occupancy, GHL Consultants Ltd. (GHL) and Read Jones Christoffersen Ltd. (RJC) have been requested by the Building Safety and Policy Branch (BSPB) of the Ministry of Housing and Social Development to prepare the following technical report aimed at identifying and addressing technical issues with respect to the proposed Code change. It is anticipated that the report will be issued in 3 stages summarized as follows:

- **Stage 1** Summarize current Code provisions with respect to residential buildings and identify the technical and process risks with the Code change.
- **Stage 2** Provide a proposal outlining the Code change.
- **Stage 3** Provide a finalized report that incorporates input and comments from stakeholders that reviewed the Stage 1 and Stage 2 reports.

This report is the Stage 1 report. The purpose of this report is to provide a summary of the existing Code provisions for buildings of residential occupancy and identify key technical and process risks that may result due to the Code change.

The objective of this Report is to provide the following:

- A summary of the Code provision for residential buildings with respect to fire safety, structural, and building envelope requirements.
- Identification of technical and process risks associated with the Code change focusing on fire safety, structural and building envelope issues.
- Preliminary comments on approach to addressing technical and process risks.

1.2 Role of GHL and RJC

The role of GHL and RJC as consultants to BSPB is to identify, to the best of our professional knowledge, fire safety, structural and building envelope issues relative to the proposed Code change as specifically requested by BSPB. The sole purpose of GHL and RJC's work is to provide the BC Government our opinion on 5 and 6 storey combustible buildings of residential occupancy should it become permitted in BC. GHL and RJC are retained to address conventional wood-frame construction typical in BC; we have not been retained to address any other types of combustible construction.

1.3 Role of the BC Building Code

The BCBC is the Building Code for British Columbia, except Vancouver where it is governed by the Vancouver Building Bylaw. The BCBC is the regulation that governs building construction in BC. The 2006 BCBC is the edition of the BCBC currently in effect, and it is an objective-based Building Code. Code compliance with the 2006 BCBC is achieved by demonstrating compliance with the Code objectives. It is noted that the design of a technically sound building depends upon many factors beyond simple compliance with the Building Code. The 2006 BCBC has the following five broad objectives, which are further refined into specific objectives that translate into Code requirements:

- Safety
- Health
- Accessibility for persons with disabilities
- Fire protection of building and facilities
- Energy

As an objective-based Code, the 2006 BCBC provides two avenues for Code compliance. One is prescriptive through meeting the acceptable solutions in Division B. The other is by alternative solutions, which often requires technical substantiation to demonstrate that a proposed design will achieve a level of performance that meets the minimum required by the Building Code. Division A Appendix A-1.2.1.1.(1)(a) and (b) further clarifies Code compliance via acceptable solutions and via alternative solutions.

As an objective-based Code, the BCBC does not restrict the design and construction of a building to the acceptable solutions. The Code provides an opportunity to achieve Code-compliance through alternative solutions should it be desired. It is known that 5 and 6 storey wood-frame buildings have been built previously under equivalencies and alternative solutions, often as a "podium" structure where the first storey is noncombustible of commercial use and the remaining being residential wood-frame.

However, in the absence of an acceptable solution in Division B to specifically recognize 5 and 6 storey combustible buildings, designers and AHJs alike are not given a clear basis for the design and review of such buildings. This is because the majority of the Code requirements are largely predicated upon the construction Article determined in Subsection 3.2.2., which is determined based on building characteristics including sprinkler provision, building height, building area, and occupancy classification. Therefore, without an acceptable solution to recognize the constitution of 6 storey combustible buildings, it is difficult for designers and AHJs to justify such building, as well as any related alternative solutions, because it is difficult if not impossible to provide an analysis for a design not specifically defined in Division B.

1.4 Public Interest Decision

Changing the Building Code is a public-interest decision. The BCBC has been changed and revised since its first enactment in 1973. The act of enacting and revising the Building Code is defining the acceptable minimum level of performance for buildings in British Columbia. Risk is generally defined as the product of probability of failure and the consequences. Division B of the Building Code defines the boundaries between acceptable risk and the "unacceptable" risks referred to in the statements of the Code objectives. That is, any risk remaining once the applicable acceptable solutions in Division B have been implemented represents the residual level of risk deemed to be accepted by the broad base of British Columbians who have taken part in the consensus and legislative processes used to develop the BCBC. Therefore, by changing the Building Code to permit up to and including 6 storeys of wood-frame buildings of residential occupancy, it is an act to acknowledge and accept risks associated with the Code change.

1.5 Methodology

GHL and RJC were formally requested by BSPB to prepare the Stage 1 report on August 15, 2008, with a given timeframe of 3 weeks. The work of GHL and RJC as presented in this report is based primarily on our professional experience as well as review of key literature possible during the 3 week timeframe, as well as incorporation of input from key stakeholders from the Technical Advisory Group and Stake Holders' meetings held in September 2008. During the time of report writing, we also conducted consultation with key stakeholders for the purpose of establishing the technical and process risks that are identified in this report. Organizations that we have consulted include:

- City of Vancouver, Office of the Chief Building Official
- Resort Municipality of Whistler, Permit and Licensing Department
- FPInnovations Forintek Division
- Homeowner Protection Office
- National Home Warranty
- Travelers Guarantee Company of Canada
- Lombard Canada
- Building and Safety Policy Branch
- Structural Engineers Association of British Columbia

GHL and RJC have also reviewed the joint AIBC and APEGBC letter submitted to BSPB regarding technical considerations for the proposed Code change.

1.6 Assumptions

COMBUSTIBLE CONSTRUCTION

The work presented in this report assumes traditional wood-frame construction employed in BC as requested by the Ministry. This assumption is consistently used with respect to structural and building envelope discussion in this report as the respective Parts of the Code are more specific on the type of material and construction technique. However, with respect to Part 3 of Division B, the term "combustible construction" is used as the Code requirements in Part 3 are founded on the basis of combustible versus noncombustible construction materials, notwithstanding that the typical combustible construction in BC is wood-frame construction as limited by other Codes, standards and engineering requirements outside of Part 3 of Division B. The terminologies "combustible construction" and "wood-frame" can generally be considered as interchangeable; except with respect to fire safety, it should be noted that combustible construction could potentially include other types of combustible material through alternative solutions and that GHL and RJC have only been retained to address wood-frame construction.

SCOPE OF CODE CHANGE

The work also assumes changing the Building Code with respect to fire safety, structural and building envelope requirements in Division B, Part 3, Part 4 and Part 5, respectively. GHL and RJC have not been requested to provide work relating to any other aspect of the Building Code outside of Parts 3, 4 and 5 of Division B, as well as construction fire safety. It is noted that other requirements, such as occupant safety due to building usage and accessibility, as well as health requirements contained in Part 3 of Division B, are not part of the scope of GHL's work.

It is assumed that the proposed 5 or 6 storey wood-frame building will not be a high building as defined in the Building Code. High buildings imply significantly more complex firefighting techniques which are outside the scope of this report. High buildings are defined in Division B, Clause 3.2.6.1.(1)(d) as buildings with the uppermost floor level is more than 18m above grade.

The authors also recognize that there are issues relating to the aging population and difficulty of evacuation; however, this is a separate topic applying to all buildings, combustible or noncombustible, not just 5 and 6 storey wood-frame buildings.

ALTERNATIVE SOLUTIONS

This report relates to accepted solutions of Division B of the Code. This report is not intended to preclude Alternative Solutions to address elements outside the scope of this report, or different solutions to that provided in Division B. For example, this report is not intended to preclude Alternative Solutions for highrise buildings or other occupancies; it simply recommends Code changes in Division B to facilitate 5 and 6 storey wood-frame residential buildings.

2.0 CODE PROVISIONS FOR RESIDENTIAL BUILDINGS

2.1 Fire Safety

The 2006 BCBC permits both combustible and noncombustible construction for buildings of residential occupancy. In general, there are 3 categories of Group C (residential) buildings provided in Subsection 3.2.2. as summarized below:

1. Combustible Construction, Up to 4 Storeys, 1 Hour FRR, Sprinklered
2. Noncombustible Construction, Up to 6 Storeys, 1 Hour FRR, Sprinklered
3. Noncombustible Construction, Unlimited Height and Area, 2 Hour FRR, Sprinklered

Currently, combustible construction is limited to 4 storeys while noncombustible buildings are permitted up to 6 storeys if the building is 1 hour fire rated, and unlimited if it is 2 hour fire rated. The assumption is that in large buildings (i.e., those permitted with unlimited height and area), 2 hour FRR is necessary in terms of addressing lengthier evacuation process and fire service response. For 1 hour rated buildings, the assumption is that the performance of 1 hour FRR is appropriate for evacuation and rescue operations based on the limitation placed on building area and height. For this reason, this report does not envision high buildings as defined in the Code.

The general concern with combustible construction is that combustible material may be exposed to and subsequently support the growth of fire. Therefore, not only would the integrity of the combustible construction be affected by fire, the construction material itself may also become a source of fuel. There is also a significant concern with fire spread within combustible void spaces. This is particularly true with balloon-framing techniques that were popular in the early 1900's; however, much of this has been addressed through fire blocking and fire stopping requirements in the Building Code. In terms of understanding the origin of the building height and area limitations on combustible buildings it is necessary to conduct a brief review the history of this part of the Building Code.

Prior to the 1900's, there was no national or provincial Building Code or government-based regulatory framework for construction of buildings in Canada. Buildings were generally built to meet the safety requirement of insurance underwriters. In BC, combustible buildings of 5 and 6 storeys are known to have been built during this time and some are still in existence today. The first edition of NBCC was introduced in 1941. In BC, it was used as the model Code for municipal building bylaws until the first province-wide Building Code enacted in 1973. The 1973 BCBC adopted the 1970 NBCC. Although the BCBC has since been changed about every 5 years in synchronization with the NBCC Code change cycle, much of the prescriptive requirements of the Code have remained unchanged as the fundamental principles of fire engineering have not changed since the first edition of the NBCC.

Combustible buildings were originally limited to two storeys and of residential occupancy and have subsequently been limited to 3 storeys since the 1965 NBCC. Note that in the 1965 NBCC the term "combustible" building was specifically used in Part 3 and that there is no specific reference to "wood-frame" in this Part, although wood-frame is the typical combustible building in BC. In terms of BCBC, combustible residential buildings have been limited to 3 storeys since the 1973 edition (1970 NBCC). The building height limitation is in recognition of the risks associated with combustible construction. The Code also limited building area based on (a) the number of storeys (b) the number of streets the building faces and (c) whether the building is sprinklered. In general, with increasing building height, the permitted building area is decreased; with increasing number of streets the building faces, the permitted building area is increased. These two factors largely reflect the ease of accessing the building for emergency response purposes. Finally, by sprinklering the building, the Code allowed doubling the area permitted in the unsprinklered building area limits. This is to recognize the advantage of sprinklers in many aspects of building fire safety. As summarized in Table 1, for a sprinklered 3 storey building of residential occupancy, the permitted building area for combustible construction is 15% of that permitted for noncombustible construction.

Table 1

Summary of sprinklered 3 storey buildings of residential occupancy permitted under the 1970 NBCC. The unit for area is square foot in the 1970 NBCC; the values in this table have been converted and rounded to metric.

	Building Area			**Fire-Resistance Rating**
	Facing 1 Street	Facing 2 Street	Facing 3 Street	
a. Combustible 3 storey	$1080 m^2$	$1350 m^2$	$1620 m^2$	1 hour
b. Noncombustible 3 storey	$7200 m^2$	$9000 m^2$	$10,800 m^2$	1 hour
% = a / b	15%	15%	15%	

There is limited justification for the building height and building area values prescribed in the 1970 NBCC. Similarly, there is also no apparent justification for the selection of the 15% as the ratio for permitted building area between combustible and noncombustible construction. Despite that the figures were selected with limited technical justification, it is most likely that the values made social sense in terms of the practical needs of residential buildings at the time, and taking into consideration the fire safety prospects of the buildings in terms of fuel load, occupant load and firefighting capabilities as they relate to building height and area. The 3 storey combustible residential construction article remained essentially unchanged until the 1985 NBCC, though in the 1980 NBCC, the building areas were converted to metric, for which the building areas were slightly increased.

The Code has traditionally recognized the effectiveness of sprinkler protection, and has permitted a doubling of allowable building area. However, there appears to be no rationale for the 'doubling'. Given that sprinklers increase the level of fire safety in a building dramatically, controlling between 70% and 98% of all fires[1] (depending on the analysis and degree of monitoring and supervision), the selection of doubling seems arbitrary and probably conservative. For example, there seems to be no logical reason why the allowable building area was not quadrupled. It is significant that with the introduction of monitoring and supervision of sprinkler systems, increasing the reliability from approximately 70% to between 95% and 98%, there was a relaxation on all unoccupied roof fire ratings, but no commensurate increase in allowable building area. As discussed below, the increase from 3 storeys to 4 storeys in the 1990 NBCC (adopted as 1992 BCBC) was clearly in part predicated on the effectiveness of sprinklers, but it is not evident why the increase was limited to 4 storeys.

In the 1990 NBCC, the category "Residential Buildings, 4 Storeys, Sprinklered" was first introduced as Article 3.2.2.36. in the Code. The building placed a building area limitation based on the number of storeys as well as the number of streets the building faces; this was later revised in the 1995 NBCC to be based on the building height only in view of the mandatory sprinkler requirement in this Article. The 4 storey combustible building of Group C occupancy remained unchanged to the current 2006 BCBC. The Code change justification for introducing 4 storey combustible buildings in the 1990

[1] Richardson, J.K., 1985, "The Reliability of Automatic Sprinkler Systems", NRC, http://irc.nrc-cnrc.gc.ca/pubs/cbd/cbd238_e.html, last accessed October 9, 2008.

NBCC is probably one of the few technical justifications on building height and area released by NRC. The document entitled “National Building Code of Canada 1985 - Third Series of proposed Changes” dated August 1988 provides the justification for moving from 3 to 4 storeys in ‘Proposed Change No. 3-30’. Proposed Change No. 3-30 states in summary:

- The 1985 NBCC recognizes the safety of 1 hour rated construction for noncombustible buildings of up to 6 storeys.
- In view of the fact that the basic tests for fire-resistance rating are not predicated on the type of construction but are performance based, it was considered that the increase in height from 3 to 4 storeys for combustible buildings but whose area would be approximately 20 per cent of that for a noncombustible building is a conservative approach.
- Consideration is also based on the model Codes in the US which permits 4 storey residential buildings to be constructed with 1 hour rated wood-frame construction. Studies of the fire death rate in multi-family residential buildings in the US indicate that it is very low and that wood-frame construction has not been identified as a problem.

As clarified by Proposed Change No. 3-30, it is evident that NRC had considered the technical risk with respect to moving from 3 to 4 storeys. The change was made based on the 20% ratio between the building area of combustible and noncombustible building, which was viewed as being conservative, as well as the statistics from the US for such type of buildings. The commentary further acknowledges that the fire-resistance rating is a performance measure of building material’s endurance in a fire and that the rating is not predicated on whether the material is combustible or noncombustible. In essence, NRC recognized that a 4 storey combustible building built in full compliance with the Code will provide the same performance in a fire as a 4 storey noncombustible building. However, in addressing the risks of using combustible material, the 20% ratio was selected, which was determined as appropriate. The Code change commentary specifically states the conservativeness of this approach and does not indicate limitation on applying the 20% ratio for higher combustible buildings. The new Article 3.2.2.36. in the 1990 NBCC also included two significant changes:

- The ratio between the permitted building area for combustible and noncombustible construction increased from 15% when the building was 3 storeys under earlier editions of the NBCC to 20% for 4 storeys building in the 1990 NBCC.
- Sprinklers became a mandatory requirement for 4 storey combustible buildings of Group C occupancy, whereas it was optional in the 3 storey combustible building of Group C occupancy in earlier editions of the NBCC.

The increase for the ratio from 15% to 20% is likely due to recognition of sprinkler systems; however, this was not explicitly stated in Proposed Change No. 3-30 in the Code change documents.

Clearly, it appears that there is no technical justification for the selection of 15% or 20% ratios noted. There is also no justification for the building heights and areas limits that were established when the NBCC was first written. But similarly, there is also no justification to argue the contrary; that is, based on the performance of the combustible buildings that have been built since the 1900s, they have generally been found to be acceptable. In effect, the BCBC as it has evolved to its current state represents the level of risk that the public may have been arbitrary subjected to, but has since been and is willing to continue to tolerate and accept in BC.

In the 1998 BCBC for sprinklered buildings, the requirements for large buildings to face more than one street and the 9m limitation to the uppermost floor for 4 storey combustible buildings were removed. The Code change from the 1992 BCBC further recognized the increasing acceptance of interior fire fighting for sprinklered buildings.

Table 2 presents a comparison between the 3 categories of residential buildings permitted in the 2006 BCBC as noted in the beginning of this section.

Table 2
A comparison of the 3 categories of residential buildings permitted in the 2006 BCBC. The building area permitted in Article 3.2.2.45. for a combustible building is 20% of that permitted under 3.2.2.43 for a 4 storey noncombustible building. See also schematic illustration in *Appendix A*.

Article	Bldg Height	Bldg Area	Sprinkler	FRR of Floor and Structure	Construction
3.2.2.42.	Unlimited	Unlimited	Yes	2 hour	Noncombustible
3.2.2.43.	6 Storeys	6000m^2	Yes	1 hour	Noncombustible
	4 Storeys	9000m^2			
3.2.2.45.	4 Storeys	1800m^2	Yes	1 hour	Combustible

2.2 Structural

Under the current 2006 BCBC which is based on the 2005 NBC, structural requirements are covered under Part 4 of Division B. There are few limitations in this section with respect to the maximum building height that can be constructed with conventional wood framing. It was always well understood by the structural engineer that the limitation on building height was generally due to requirements related to the fire and one did not need to consider the potential challenges of building taller wood structures under Canadian Codes. Thus, as the wood industry for residential building evolved, Building Code provisions were made based on the type of residential structures that were being built and how they performed. And for years now, our experience has generally been limited to the performance of wood structures up to 4 storeys in height.

In conjunction with the Building Codes, material Codes such as wood, steel and concrete evolve such that each Code is coordinated and can be used in conjunction with Part 4 of the specific referenced Building Code. As Building Codes evolve and change, the committees of material Codes are required to closely review and react to the changes in new Building Codes such that the material Codes can be applied to reflect the requirements of the Building Code. Each material Code is updated and revised such that they are coordinated with and can be referenced to the current Building Code.

For wood, the building and material Code provisions to date have evolved based on the past experience and performance of wood-frame buildings up to 4 storeys in height. Past experience has shown that the Code provisions have generally led to buildings that are safe. More recently, material Codes have shifted to reliability based design to increase the uniformity of safety for all building materials. For wood, reliability based design coupled with extensive research and testing has generally resulted in higher capacities for wood with less conservatism in design. From previous to current Codes, wood capacities have tended to perform well within residential structures up to 4 storeys. However, there are other factors which impact the capacity of wood which are inherent in the nature of the material. Construction practices, workmanship, detailing, field reviews, the effects of other materials which may add strength, types of systems (i.e., seismic systems, wall systems, floor systems, etc), and shrinkage to name a few all have an impact on the capacity of wood and are not dealt with effectively by Code provisions. These factors can all have an adverse effect on the capacity of wood elements which only gets compounded when increasing these structures from 4 to 6 storeys. For example, vertical loads in stud walls and posts will increase 50% in lower floors. Sheathing requirements, notching for electrical and plumbing, load sharing, bearing, and tolerances will all play an increased role in the actual capacities of the walls and posts. Overall shear and moment forces due to wind and seismic activity will increase 50 to 200 percent in lower shear walls where again notching, workmanship, types of systems, shrinkage and details will all effect the strength. The general result will be that the overall safety of these taller and heavier structures will decrease if such inherent factors are not adequately addressed. So it is important to keep in mind that Building Code provisions as well as the wood material Code CSA O86 have evolved based on the performance of wood structures up to 4 storeys in height. The potential structural challenges associated with taller wood buildings have not been addressed as Code provisions for fire have limited wood structure to a maximum of 4 storeys.

From a material capacity point of view, there should be few impediments to allowing wood building to exceed 4 storeys. Wood elements are analyzed and designed with material Code provisions similar to that of other materials such as steel and concrete. Currently, there are a number of counties and districts in the US that allow residential wood building up to 5 storeys in height, and 6 storeys is being discussed. Other countries around the world also have experience with wood buildings higher than 4 storeys, but we must keep in mind, many of the construction practices and forms of construction are not recognized through Canadian standards. So it is important to realize that although there are few technical changes required in the Codes to allow for 6 storey wood buildings, the greatest risks will result from the detrimental effects due to the process risks compounding as the structures become taller and heavier. Furthermore, as the buildings become taller and heavier, the inherent nature realized in conventional wood-frame systems will play a less significant role. Just extrapolating what is currently practiced for 4 storey buildings to 6 storeys is not enough to maintain a uniform level of safety.

As far as Part 4 of Building Code currently stands, the only real limitations on height for wood structures falls under the seismic provisions of Table 4.1.8.9 where maximum height limits for different systems in different seismic zones range between 15m to no limit. As an example, for a typical Vancouver project utilizing nailed wood shear walls, a height limit of 20m would generally be imposed. It may well be that the 15m and 20m limitation in the Building Code will limit the height of wood based lateral systems that can be constructed in some of the higher seismic zones within BC. Proposed changes to these limits are beyond the scope of the BCBC and would only appropriately be considered for revision by CANCEE (Canadian National Committee on Earthquake Engineering) who advises on Part 4 of the NBCC for all seismic provisions.

As far as the wood material Code CSA O86.1 currently stands, the design for ultimate limit states and serviceability limit states is similar to that of steel and concrete and thus should generally not limit the framing systems referenced to 4 storeys. From a technical point of view, providing that a clear load path with elements designed and detailed in accordance with the material Code, there should be few concerns with potentially designing 5 to 6 storey wood buildings. However, there are a number of design considerations lending themselves to good practice that would need to be further explored in consideration of taller wood buildings. These include, but are not limited to items such as:

- Appropriate seismic provisions or guidelines consistent with other material Codes.
- Guidelines providing a level standard of practice for 5 and 6 storey buildings.
- Appropriate workmanship / tolerance guidelines. The effect of workmanship and tolerances will play a larger role in taller wood structures and deserve consideration. Currently, there are no workmanship clauses in the Wood Code.

- Appropriate independent peer reviews for both design documents and reviews during construction.
- Considerations for hybrid structures – wood-frame building with concrete, steel or masonry elements.
- Considerations for shrinkage. Higher building will result in large movements resulting from the drying and shrinkage of wood.
- Consideration for higher lateral loads, movements and potential vibrations due to wind and seismic loads coupled with the effects of shrinkage, workmanship, and types of lateral systems used.

Although some of these considerations may be dealt with through Code provisions, many of them will need to be dealt with through changes to the processes in which these structures are designed, detailed and constructed.

2.3 Building Envelope

The 2006 BCBC [in Division A, 1.3.3.2.(1)(c)] requires the application of Division B, Part 5 “Environmental Separation” for all Group C, *residential occupancies* exceeding 3 *storeys* in *building height*. Division B, Part 5 itself though, does not include any language that explicitly references the height of a building employing a light wood-frame structural system. The history of the development of Part 5 explains the nature of the ‘performance based’ language within this Part, and the reason that height is not explicitly addressed.

The adoption of an ‘objective based’ Code structure with the 2005 NBCC (and 2006 BCBC), did not significantly impact the language in Part 5, as it was developed using a ‘performance based’ approach. In editions of the NBCC prior to 1980, Part 5 was entitled ‘Materials’, and did not focus specifically on ‘building envelope’ issues. With the 1980 NBCC (and the subsequent 1985 and 1990 versions, adopted as BCBC in 1981, 1987 and 1992 respectively), Part 5 was renamed “Wind, Water and Vapour Protection”, and although quite simple in form and content, outlined minimum necessary performance requirements for the building envelope. The 1995 NBCC (adopted as BCBC in 1998) re-titled Part 5 as “Environmental Separation”, and expanded the scope of the described performance requirements. In the 2005 NBCC (and 2006 BCBC) a section on Sound Transmission was moved in to Part 5, which, as an exception to the rest of the Part, is written with prescriptive requirements.

Although Part 5 was created to be a performance Code, reference has often been made in the appendix to the prescriptive requirements in Part 9. In the 1980 through 1990 NBCC, reference was made in appendix note A-5.7.1.1. to the prescriptive requirements in Part 9 as a *“guide for installation of exterior claddings, vapour barriers, thermal insulations, sheathing papers, flashings and fastening devices”* for simpler buildings. In the 1995 NBCC only a comparison is made at A-5.5.1.2.(2) that the Part 5 approach allows more flexibility than the equivalent requirements in Part 9. In the NBCC 2005, with the addition of Section 5.9 Sound Transmission, reference is made at A-5.9.1.1.(1) to tables in Part 9 as a source of values to satisfy the requirements in Part 5, although any other references to Part 9 are gone.

While the more prescriptive sections in Part 9 may make reference to material and system requirements, the same can not be said of Part 5 (aside from the section on sound transmission). Within the performance structure of Part 5, there has never been any explicit language that addresses, or creates any limitations, based on the height of a building employing a light wood-frame structural system.

3.0 RISKS ASSOCIATED WITH CODE CHANGE

3.1 Fire Safety

Section 2.1 presented a summary of the current Code provisions relative to residential buildings of combustible and noncombustible construction. This section presents GHL's preliminary comment on the technical and process risks on fire safety relative to the proposed Code change. The Code change proposal is not part of this report; it will be forthcoming in the Stage 2 Report. However, out of the analysis that has been conducted thus far, it is anticipated under the new Code that a 5 or 6 storey wood-frame building would have the characteristics as presented in Table 3. The characteristics are presented here for discussion purposes.

Table 3
Characteristics of the Proposed Code Change Building.

Characteristic	Proposed	Rationale
Building height	Maximum 6 storeys	▪ Public interest
Building physical height	18m to uppermost storey floor	▪ Technical risk ▪ Building is not a high building
Building area	$1440m^2$ for 5 storeys; $1200m^2$ for 6 storeys	▪ Technical risk ▪ Maintain the 20% ratio to that permitted for noncombustible buildings
Construction material	Combustible	▪ Public interest
Floor and mezzanine FRR	1 hour; 2 layer GWB	▪ Technical risk ▪ Process risk
Loadbearing members FRR	1 hour; 2 layer GWB or 1 layer with heavy timber	▪ Technical risk ▪ Process risk
Sprinkler system	Yes, to NFPA 13 standard	▪ Technical risk
Exterior cladding	Noncombustible or combustible cladding meeting Clause 3.1.5.5.(1)(a) and (b).	▪ Technical risk

TECHNICAL RISKS
Technical risk is defined by BSPB to mean: *exposure to loss arising from activities such as design, engineering, and construction processes and includes the following risk areas: fire safety, seismic, structural shrinkage, sound transmission, building techniques, moisture, material shrinkage, etc.*

In general terms, with respect to fire safety, this can be paraphrased to mean the level of risk associated with a building that is built in full compliance with Division B, Part 3 without significant defect. In terms of fire safety, the technical risk is a measure of the probability for fire to occur and the consequential losses.

In general, based on the effectiveness of a mandatory sprinkler system, it can be easily argued that a sprinklered building is safer than an unsprinklered building. Where a sprinkler system may not suppress a fire, it can generally control the spread and growth of fire such that in conjunction with fire separations required by the Code, will provide a greater level of safety than an unsprinklered building with respect to occupant safety and fire service response. It can be demonstrated that the risk of a sprinklered 6 storey building is less than that of an unsprinklered 3 storey building. With respect to failure of a sprinkler system, this is inherently addressed by limiting the ratio of building area between combustible and noncombustible buildings of the same height to 20%.

In general, it is not possible to provide a quantitative analysis of the technical risk as the creation of the NBCC was not based on a quantitative approach originally. Providing a quantitative analysis based on fire statistics would be impossible as 6 storey combustible buildings do not currently exist in BC. It would also be difficult to draw a reasonable comparison to 6 storey combustible buildings in other countries as the Code and construction practices in other countries may likely be different from that of BC. Therefore, it is necessary to employ a qualitative approach by comparing the risk between a 4 and a 6 storey residential building of combustible construction. A comparison to a 5 storey combustible building is not necessarily needed as the analysis for 6 storeys would include that of 5 storeys.

The technical risks addressed by the 2006 BCBC are described in the Code objectives found in Division A, Section 2.2. “Objectives”. The Code objectives define fire safety issues that the Code intends to address. Division B Part 3 is based on fire engineering principles that the Code employs in addressing the objectives prescriptively. The Code objectives relating to fire are as follows:

- **OS1 Fire Safety**
  An objective of [the 2006 BCBC] is to limit the probability that, as a result of the design or construction of the building, a person in or adjacent to the building will be exposed to an unacceptable risk of injury due to fire. The risks of injury due to fire addressed in this Code are those caused by:

  OS1.1 – fire or explosion occurring
  OS1.2 – fire or explosion impacting areas beyond its point of origin
  OS1.3 – collapse of physical elements due to a fire or explosion
  OS1.4 – fire safety systems failing to function as expected
  OS1.5 – persons being delayed in or impeded from moving to a safe place during a fire emergency

- **OP1 Fire Protection of the Building**
  An objective of [the 2006 BCBC] is to limit the probability that, as a result of its design or construction, the building will be exposed to an unacceptable risk of damage due to fire. The risks of damage due to fire addressed in this Code are those caused by:

  OP1.1 – fire or explosion occurring
  OP1.2 – fire or explosion impacting areas beyond its point of origin
  OP1.3 – collapse of physical elements due to a fire or explosion
  OP1.4 – fire safety systems failing to function as expected

- **OP3 Protection of Adjacent Buildings from Fire**
  An objective of [the 2006 BCBC] is to limit the probability that, as a result of the design or construction of the building, adjacent buildings will be exposed to an unacceptable risk of damage due to fire. The risks of damage to adjacent buildings due to fire addressed in this Code are those caused by:

  OP3.1 – fire or explosion impacting areas beyond the building of origin

From the objectives, the following areas of technical risk can be established as summarized in Table 4.

Table 4
Technical risks on fire safety addressed by the 2006 BCBC.

Technical Risk	Code Objective
Ignition	OS1.1, OP1.1
Fire spread beyond point of fire origin	OS1.2, OP1.2
Fire spread to neighbouring buildings	OP3.1
Failure of sprinkler system to function as expected	OS1.4, OP1.4
Occupants not being able to recognize fire	OS1.4, OS1.5, OP1.4
Occupants not being able to evacuate the building	OS1.4, OS1.5, OP1.4
Fire Service unable to conduct effective firefighting operation	OS1.2, OS1.3, OP1.2, OP1.3, OP3.1

There may be other technical risks; however, those risks are not identified as they are not addressed by the current 2006 BCBC. As the method of analysing technical risk to draw comparison to a building currently permitted by the Code, it is not appropriate to identify risks outside the scope of the BCBC. Notwithstanding this, the risks being addressed by the Code objectives are in general agreement with the fire engineering principles recognized in Canada and internationally.

Based on the technical risks identified above, the following is an analysis of the risk with respect to the characteristics of the Proposed Code Change Building presented in Table 3. The reader is reminded that the following risk analysis is based on comparing a 5 or 6 storey wood-frame building to a 5 or 6 storey noncombustible building such as using light steel-frame permitted in Division B. It may be that certain aspects of the current Division B requirements may not address all current concerns, such as design of exit systems to account for aging population. However, such concern is globally applied to all buildings, combustible or noncombustible. Therefore, the authors have taken the approach to consider the existing Division B requirements as being the acceptable minimum level of performance in BC, irrespective of whether certain requirements may not address all current considerations. For discussion purposes, it may be useful to reference the schematics in *Appendix A*.

- **Risk of Ignition:** *Not likely to increase.*
  By limiting the building area to 1440m^2 for 5 storeys and 1200m^2 for 6 storeys, the Proposed Code Change Building will effectively have the same gross floor area of 7200m^2 as currently permitted for the 4 storey combustible Group C building. As total floor area is not increased, the occupant loads are not increased. And given the occupancy is not changed, the risk of ignition due to human activity will not likely increase. Ignition of fire due to non-human activities in the building will not likely increase, as the building volume remains relatively the same.

- **Risk of Fire Spread beyond Point of Origin:** *Not likely to increase.*
  The current 2006 BCBC addresses fire spread by creating fire compartments, which include suites, public corridors and exits which are separated from each other by fire separations (walls and floors constructed to achieve the requite FRR as defined in the Code and determined by ULC-S101). As the gross floor area of the Proposed Code Change Building is not being increased from what is currently permitted, and that the requirement for interior fire separations will still apply, the risk of fire spread will not likely increase. With respect to fire spread in void spaces, this is adequately controlled by current fire blocking as is shown by the acceptability of unsprinklered 3 storey construction. For 5 or 6 storey combustible buildings, there may be an increased concern with fire spread in attics if sprinkler systems fail; however, this can be addressed by additional fire blocking. With respect to exterior fire spread through windows, combustible exterior cladding permitted for combustible buildings may lead to greater risk of fire spread; until this has been better-analysed, use of noncombustible cladding or

the limited types of combustible cladding permitted for noncombustible buildings would address this risk. Finally, although not specifically addressed by the Code objectives, comment of smoke spread is appropriate. For a 6 storey wood-frame building (not a high building), with proper fire separation and fire blockings, spread of smoke would be no different than a permitted 6 storey steel stud building.

- **Risk of Fire Spread to Neighbouring Buildings:** *Not likely to increase.*
  Exposure protection will not be affected by the Code change. However, as part of the project, it will be recommended that the 5 and 6 storey combustible buildings use noncombustible exterior cladding to address the risk of vertical fire spread. By limiting the risk of vertical fire spread on the exterior surface of the exterior wall, the risk of fire spread to neighbouring buildings due to radiation and convection heat transfer will not likely increase.

- **Risk of Failure of Sprinkler System to Control / Supress Fire:** *Likely to decrease*.
  The NFPA 13 standard will be the applicable sprinkler standard for 5 and 6 storey combustible buildings of residential occupancy. NFPA 13R is limited to buildings 4 storeys in building height. As sprinklers work on a per floor area basis and independent of whether the building is combustible or noncombustible, the risk of sprinkler failure leading to delays in fire alarm activation and control of fire spread and growth is likely decrease.

- **Risk of Occupants Not Able to Recognize Fire:** *Not likely to increase.*
  Occupant response to fire cues and decision-making prior to evacuation will not likely increase based on a mandatory central fire alarm system and sprinkler system for the building.

- **Risk of Occupants Not Being Able to Evacuate the Building:** *Not likely to increase*.
  As the total gross floor area is not being increased, the total occupant load will also not increase. Travel time to an exit is anticipated to decrease due to smaller building area (floor plate) as a result of permitting greater building height. Since the occupant load per floor will decrease, queuing at exits will be likely to decrease. Travel time within exit stairs will likely increase due to 2 additional storeys; however, as the exits will be separated by 1 hour fire rated construction, the increase in travel time within exits will be insignificant in terms of the overall evacuation process. Note that a 6 storey noncombustible 1 hour rated building is currently permitted by the Code and is permitted to have 6000m^2 building area. Generally, greater floor area means longer travel distance and travel time. Greater area also means greater occupant load which would generally result in greater queuing at exit facilities. Therefore, by comparison, the approach for 6 storey wood-frame would seem conservative, specifically considering that both combustible and noncombustible buildings would require a 1 hour FRR and that the rating is not predicated on the type of construction material.

- **Risk of Fire Service Unable to Conduct Effective Operation:** *Not likely to increase.*
  In comparison to a sprinklered 4 storey residential building of combustible construction and a sprinklered 6 storey residential building of noncombustible construction, the Proposed Code Change Building is not likely to result in an increased technical risk with respect to the effectiveness of firefighting operation. Traditional unsprinklered 3 storey wood-frame construction relied on exterior firefighting operations. With the advent of buildings protected with monitored and supervised sprinkler systems the Code, and related firefighting practices have shifted to reliance on the sprinkler systems and interior firefighting access. This is reflected in Code changes eliminating the requirement for fire rated roofs in unsprinklered buildings; eliminating the requirement for access openings for firefighting in sprinklered buildings; removal of the requirement for larger buildings to face streets and introduction of 4

storey 1 hour construction; and the removal of 9m height limit. These changes all reflect that the Code does not anticipate exterior firefighting of sprinklered wood-frame buildings, in recognition of the reliability and effectiveness of automatic sprinkler system. Hence, the primary change from 4 to 6 storeys is Fire Department access up an additional 2 storeys of interior stairs. However, this is in part mitigated by the reduced floor area from maximum 1800m² at 4 storeys to 1200m² at 6 storeys, as well as the consideration that the operation would be no different than that of 6 storey steel-frame building with a 1 hour fire rated construction.

Firefighting as well as search and rescue operation would be no different from the current operation for a 6 storey noncombustible building or a 4 storey combustible building. By limiting the permitted building area for combustible building to 20% of that permitted for noncombustible building, which is what the Code currently employs, the technical risk with respect to use of combustible material is addressed. There is no foreseeable increase in risk with respect to the effectiveness of fire service operations, particularly considering that the Proposed Code Change building will be sprinklered (to NFPA 13). Four storey wood-frame buildings typically have unsprinklered attics. Extension to 6 storeys will require attics and balconies be sprinklered, as is already required by NFPA 13.

There is a risk of fire spread due to combustible exterior cladding for 5 and 6 storey buildings and balcony fires; however, this can be mitigated by imposing measures to limit flame spread on exterior cladding and use of automatic sprinklers in balconies.

As the building is over 3 storeys, standpipes will be inherently required by Code.

For rural areas where the Fire Department may have limited firefighting capabilities, the BCBC appendix commentary already notes that this can be addressed through either requiring mandatory sprinklers or imposing restrictions through municipal zoning bylaws. With respect to the sprinkler option, the Proposed Code Change building will be sprinklered. Where the local Fire Department lacks the capability of properly supporting the sprinkler system, additional measures such as emergency power generator, fire pump, and on-site water supply can be used to enhance the reliability of sprinkler system, in conjunction with enforcement of proper maintenance of sprinkler system.

Based on the above, a 5 or 6 storey wood-frame building of residential occupancy following the area ratio of 20% will not likely pose a greater technical risk than a 4 storey wood-frame building of residential occupancy currently permitted by the 2006 BCBC. In essence, the performance of a 6 storey combustible building and a noncombustible building both of residential occupancy will be the same when fire separations, structural fire-rating and exits are provided with the 1 hour FRR. This is because the fire-resistance rating, as a measure of endurance in a fire, is not predicated on the building material. However, to address the risk associated with use of combustible material, it is proposed to limit the allowable building area to $1440m^2$ for 5 storeys and $1200m^2$ for 6 storeys, consistent with the 20% ratio currently in place for the permitted building area between combustible and noncombustible residential buildings.

With respect to the abovementioned technical risks, other than the risk of ignition, it has been seen that with the use of automatic sprinklers, the risks have substantially decreased based on review of the fire statistics obtained from BSPB. Qualitatively, the statistics suggest that when a building is sprinklered, irrespective of the type of construction and the building height, the number of fire-related fatalities and injuries in buildings have significantly reduced and that there is no evidence to suggest a sprinklered 5 or 6 storey wood-frame building would expose the building and its occupants to a greater risk and that should there be an increase in risk, the statistics would suggest that such risk would be marginal in all of the areas identified by the BCBC, other than the risk of ignition.

PROCESS RISKS

Process risk is defined by BSPB as to mean: *processes that are not clearly defined, are poorly aligned with business objectives and strategies, do not satisfy stakeholders' needs, or expose assets to misappropriation or misuse. Process risk includes the following risk areas: industry readiness and competency in areas of both design and construction, readiness of warranty providers to provide insurance in accordance with Homeowner Protection Act, Fire Department capabilities, etc.*

In general terms, this can be paraphrased to mean practical concerns with constructing a 6 storey combustible building of residential occupancy – the risks associated with the unavoidable inability for the industry to deliver a building that is in full compliance with the BCBC. The process risks presented below are developed through consultation and interviews with two AHJs in BC, the Homeowner's Protection Office, 3 warranty providers, and researchers at Forintek.

At this stage, the following five general areas of process risk are identified:

- **Qualification of Design Professionals**

  A major concern raised by many interviewees is the need for qualified professionals. Currently, the Letters of Assurance do require a professional qualified in structural engineering, but do not specifically require a professional qualified in fire safety or building envelope design. Education in Building Code requirements is provided to Architects, but this is limited. Significant additional Building Code education is provided in the Certified Professional Course, but it is not specific to wood-frame construction, and the use of Certified Professionals is only optional and limited to Vancouver and Surrey. Nor is it clear that the Certified Professional Training addresses the intricacies of wood-frame construction.

  The increased complexity of 6 storeys, combined with the trend for unusual architectural elements, the impact of shrinkage on fire separations, fire blocking and fire stopping, the increased reliance on firewalls may necessitate the requirement for a professional engineer with expertise in fire engineering. It is noted that APEGBC has recently been given legislative approval to designate and regulate specializations and is developing Fire Protection Engineering as a recognized discipline. APEGBC has already developed a draft "Guidelines for Fire Protection Engineers" which is expected to be adopted by the Council in the near future. Therefore, there is a willingness to create a new Fire Protection Engineer designation and it is recommended that a Fire Protection Engineer be required as part of the design for 5 and 6 storey wood-frame buildings.

- **Qualification of Design Reviewer / AHJ**

  It is identified that with the proposed Code change to permit up to 6 storeys of wood-frame buildings of residential occupancy in the Building Code, significantly more complex buildings may be proposed as alternative solutions. This may include proposals for mixed occupancies, use of other types of combustible materials (given the Code is not specific on the type of construction), use of mixed combustible and noncombustible materials, creation of interconnected floor spaces and increase in building height. Development of these alternative solutions will require a thorough understanding of the fire science and fire engineering principles. As compliance with the objective-based Code can be achieved through either the acceptable solutions or the alternative solutions, it would be necessary that design reviewers or

AHJs have similar qualifications as that of design professionals. Although there is no regulatory framework currently in place, certain municipalities have addressed review of designs following either acceptable or alternative solutions through one of the following two means, both of which are considered appropriate:

- Peer-review through a 3rd party qualified professional.
- Employment of a qualified fire engineer competent in Building Code.

Both of these approaches are currently considered as appropriate solutions to address the process risk with respect to qualification of reviewers, though the peer-review approach is often considered as being more independent.

- **Readiness of Warranty Providers**
  Interviews with three major warranty providers in BC indicates that insurance for 5 or 6 storey wood-frame buildings of residential occupancy will be highly dependent on the competence and qualification of contractors. The warranty providers indicate that they would insure buildings initially based on contractors that have a demonstrated acceptable record with 4 storey wood-frame buildings.

- **Readiness and Qualification of Contractors / Trades**
  Construction of a 6 storey wood-frame building is not significantly different from 4 storey wood-frame; however, there is a significant concern anticipated with some contractors' ability to construct 4 storey wood-frame buildings and the same concern extends to 6 storey wood-frame buildings. The increase to 6 storeys increases the need to appropriately follow the correct design; therefore, the risk of unqualified contractors may increase. There is currently no process for qualification of contractors or the trades related to framing gypsum wallboard fire separation and fire blocking. Training for fire-stopping is available but is of little use without proper qualifications of those responsible for framing, fire blocking and fire separations.

- **Reliability of Membrane-based Fire Separation**
  Reliability of fire separation and fire protection of structural members is not an objective of the Building Code. However, the Code has traditionally addressed certain critical areas of reliability of construction indirectly through for example requiring 1.5 hour rated fire separation around parking garages and requiring concrete or masonry construction for firewalls and the horizontal fire separation of Division B, Article 3.2.1.2.

  The concern for wood-frame construction in general is the reliance on the fire separations as exposed wood would directly fuel a fire. Laboratory tests clearly show that a single layer of gypsum wallboard on wood joists can achieve a 1 hour FRR; however, there is little validation of actual constructed separations in the field. Recent NRC testing has shown that single layer designs are very susceptible to improper joint construction, improper attachment of the gypsum wallboard and improper installation. However, 2 layer designs have been shown to be significantly more robust. It is significant that tests in Japan, Europe and New Zealand, including the recent full scale 6 storey timber-frame project in the UK (T2000), have indicated the need for increasing durability of GWB-based fire protection.

  Further, with the increased use of engineered wood product such as OSB in the industry, there is a significant concern that pre-mature failure of the structural members due to fire may lead to progressive failure of the building. EWP-based loadbearing members are typically protected by Type X GWB which derives the fire-resistance rating from the moisture content of the wallboard. In some instances, an assembly with a single layer of Type X GWB protecting EWP joists can receive a 1 hour FRR from the CAN/ULC-S101 fire test after repeated testing or through different laboratories, as the fire test standard does not currently regulate repeatability of test result and furnace conditions. Although EWP presents an excellent solution in terms of structural and shrinkage aspects of building design, these products are significantly more susceptible to fail in a fire than the traditional sawn lumber due to the manufacturing process of EWP. EWPs use carbon-based polymers to hold wood together which can loosen structural integrity at low heat as the polymers decompose.

In view of these factors, it is considered that a one layer system may be inappropriate, specifically considering that gypsum wallboard may be subject to damage during the lifetime of a building and more often are incorrectly replaced. Based on these considerations, it is recommended that floor assemblies and wall assemblies of exits be required to use a 2 layer GWB design, unless the framing members are heavy-timber as defined in the Code. Although this concern applies equally to 4 or 6 storey buildings, it is appropriate to review it at this time for 5 and 6 storeys.

Further, with a STC requirement of 50 and guidelines recommending STC 55, the two layers of gypsum wallboard are usually required for sound purposes.

3.2 Structural

Technical Risks

Technical risk is as defined under Section 3.1 above. In application to 'Structural", this can be paraphrased to mean the level of risk associated with structural requirements that are built in compliance with Division B, Part 4 without significant defect.

The technical risks recognized by the 2006 BCBC are stated in Division A, Section 2.2. "Objectives". The Code objectives provide a clear outline of the structural requirements that the Code addresses. The objectives relating to Division B, Part 4 Structural Requirements area as follows:

- **OS2 Structural Safety**

  An objective of [the 2006 BCBC] is to limit the probability that, as a result of the design or construction of the building, a person in or adjacent to the building will be exposed to an unacceptable risk of injury due to structural failure. The risks of injury due to structural failure addressed in this Code are those caused by:

  OS2.1 – loads bearing on the building elements that exceed their loadbearing capacity
  OS2.2 – loads bearing on the building that exceed the loadbearing properties of the supporting medium
  OS2.3 – damage to or deterioration of building elements
  OS2.4 – vibration or deflection of building elements
  OS2.5 – instability of the building or part thereof

- **OH4 Vibration and Deflection Limitation**
  An objective of [the 2006 BCBC] is to limit the probability that, as a result of the design or construction of the building, a person in the building will be exposed to an unacceptable risk of illness due to high levels of vibration or deflection of building elements.

- **OP2 Structural Sufficiency of the Building**
  An objective of [the 2006 BCBC] is to limit the probability that, as a result of its design or construction, the building or part thereof will be exposed to an unacceptable risk of damage or loss of use due to structural failure or lack of structural serviceability. The risks of damage and of loss of use due to structural failure or lack of structural serviceability addressed in this Code are those caused by:

  OP2.1 – loads bearing on the building elements that exceed their loadbearing capacity
  OP2.2 – loads bearing on the building that exceed the loadbearing properties of the supporting medium
  OP2.3 – damage to or deterioration of building elements
  OP2.4 – vibration or deflection of building elements
  OP2.5 – instability of the building or part thereof
  OP2.6 – instability or movement of the supporting medium

- **OP4 Protection of Adjacent Building from Structural Damage**
  An objective of [the 2006 BCBC] is to limit the probability that, as a result of the design, construction or demolition of the building, adjacent buildings will be exposed to an unacceptable risk of structural damage. The risks of structural damage to adjacent buildings addressed in this Code are those caused by:

  OP4.1 – settlement of the medium supporting adjacent buildings
  OP4.2 – collapse of the building or portion thereof onto adjacent buildings
  OP4.3 – impact of the building on adjacent buildings

From the objectives, the following areas of technical risk can be established:

Table 5
Technical risks on structural addressed by the 2006 BCBC.

Technical Risk	Code Objective
Failure of building elements	OS2.1, OP2.1, OP4.2
Failure of the supporting medium (soil and rock)	OS2.2, OP2.2, OP4.1
Damage or deterioration of building elements	OS2.3, OP2.3, OP4.3
Issues related to vibrations and deflections	OS2.4, OP2.4, OH4, OP4.3
Instability of the building or part thereof	OS2.5, OP2.5
Instability or movement of the supporting medium	OP2.6

There may be other technical risks; however, those risks are not identified as they are not addressed by the current 2006 BCBC. As the method of analysing technical risk to draw comparison to a building currently permitted by the Code, it is not appropriate to identify risks outside the scope of the BCBC. Notwithstanding this, the risks being addressed by the Code objectives are in general agreement with the structural engineering principles recognized in Canada and Internationally.

The following is an analysis of the risk with respect to the Proposed Building Code Change presented in Table 5:

- **Risk of Failure of Building Element:**
  In general, the risk of failure of elements due to gravity loads is not likely to increase providing sound engineering judgement and generally established design methods are followed. CSA O86 provides a well established reliability based design for wood members which when closely adhered to should not increase the risk of failure. However, for lateral loads due to wind and seismic, the increase in height will have a substantial affect. Current provisions for lateral design in CSA O86 are generally not as advanced as for other materials such as concrete and steel. With regards to seismic, steel and concrete, Codes have for some time evolved the philosophies of capacity design which is just now being introduced into the Wood Code. As well, there are many assumptions required in determining lateral loads, distribution of forces, stiffness's of walls and diaphragms, and philosophies of design. Horizontal forces, deflections, vibrations, and inter-storey drifts will be significantly increased, and the current best practices should be scrutinized in order to ensure the level of risk is not increased. As part of our recommendations, we would propose that APEGBC and SEABC be consulted to provide a "best practices guide" which would establish guidelines to supplement the material Codes and provide design principles which are generally accepted by the engineering community. This guideline would be referenced from the Code, and would provide a minimum standard of practice for the design of 5 and 6 storey wood residential buildings. In addition to dealing with lateral design standards, it will likely need to cover standard practices as well for designing and detailing the gravity system, and establish minimum requirements for workmanship and tolerances which are currently not covered under CSA O86. As well, the guide should address how shrinkage is accommodated for in the design and detailing of the structural systems.

- **Risk of Failure of Supporting Medium:** *Not likely to increase.*
  Generally, the foundations would be of concrete and would be designed according to the Concrete Code. The foundation design would be coordinated with the requirements of the Building Code, and geotechnical investigation.

- **Risk of Damage or Deterioration of Building Elements:**
  As a result of the increased height of the building, the cumulative effects of workmanship, tolerances, shrinkage, and increased lateral loads may increase the risk of damage to building elements unless careful attention is played to the design, detailing, and coordination amongst the design professionals and trades. In order to mitigate any risk, our recommendation would be that workmanship, tolerances and issues related to shrinkage should be addressed by the "best practices guide" as proposed above. It would also be proposed that potential lateral and vertical movements of each floor would need to be provided and addressed by the design and construction trades such that the risk of damage to building elements would not likely increase.

- **Risk of Issues Related to Vibrations and Deflections:**
  See "Risk of Failure of Building Elements" and "Risk of Damage or Deterioration of Building Elements" above.

- **Risk of Instability of the Building or Part Thereof:**
  See "Risk of Failure of Building Elements" and "Risk of Damage or Deterioration of Building Elements" above.

- **Risk of Instability or Movement of the Supporting Medium:** *Not likely to increase.*
  See section above for "Risk of Failure of Supporting Medium".

PROCESS RISKS

Process risk is defined as per Section 3.1 above. In general terms, this can be paraphrased to mean practical concerns with constructing a 6 storey combustible building of residential occupancy – the risks associated with the unavoidable inability for the industry to deliver a building that is in full compliance with the BCBC. The process risks presented below are based on consultation with local engineers, past experiences, and a review of various papers.

The following general areas of process risk are identified.

- **Qualification of Design Professionals**
  A major concern raised by many local practitioners is that there is not a well established "best practices guideline" for the design and detailing of wood-frame projects. Many practitioners agree that the level of competency, knowledge, and standard of drawings varies substantially within the wood industry. It has been suggested by some of the design community that it would be prudent to require that the responsibility for the design and detailing for 5 and 6 storey wood projects be undertaken by a qualified Designated Structural Engineer (Struct. Eng.) as defined by APEGBC. This may be added as part of the BC Building Code requirements under Division C Part 2 "Administrative Provisions".

- **Independent Concept Review and Independent Construction Review**
  It is also in general agreement, that a registered Struct. Eng. be required to provide an independent peer review of the design documents. The proposed "Best Practices Guide" would be used as a terms of reference. This may include the requirement for a further schedule endorsed by APEGBC to be signed and sealed by the independent reviewer. Furthermore, for critical elements, it is also suggested that independent construction reviews be required by the peer reviewer. The scope for this would need to be established. This requirement may also be referenced as part of the BC Building Code requirements under Division C, Part 2 "Administrative Provisions".

- **Preparation of a "Best Practices Guide"**
  It was generally suggested by a group of local practitioners that a "Best Practises Guide" be prepared to provide guidance where Codes and handbooks are vague. It is also suggested that this may be referenced from the BC Building Code, or its appendix. The content of the guide would need to be agreed upon by the design community but may include items such as:

  - Minimum drawing and detailing requirements
  - A guide for the design and detailing of wood lateral systems for wind and seismic.
  - Provisions for Hybrid Structures, including the integration of other materials and systems into a wood building,
  - Methods to determine, detail for, and document estimated building movements – such as vertical due to shrinkage of wood and lateral movements due to wind and seismic.
  - Minimum workmanship requirements and tolerances.
  - Establishing suitable load paths for forces and systems for both vertical and lateral loads.

- Provisions for the stability of vertical members where drywall is considered to stabilize compression members. Drywall Sheathing may not be suitable as a bracing material for the higher loads, or where it is damaged by water, or lateral loads.
- Recommendations for the design of platform structures (i.e. Wood-frame on top of a concrete building) and transfer of loads to supporting platform.

▪ **An Increased Awareness for all Design Professionals, Contractors and Trades**
It is suggested, that a series of training seminars be provided to all the design professionals, contractors and trades to increase the awareness of challenges related to increasing the current allowable height limit.

▪ **Monitoring and Reporting for New 5 and 6 Storey Buildings**
As part of the initial infancy of a new Code provisions, it is recommended that a government / engineering community develop and endorse a monitoring and reporting program to provide feedback to the design community on the performance of taller wood structures.

▪ **Further Testing and Codification of Wood Lateral Resisting Systems**
The current Canadian Codes and design standards with regards to designing and detailing for lateral loads in wood-frame buildings has only rapidly evolved only over the past 20 years. However, the wood industry still lags other materials with regards to capacity design principals which have been well established for other materials based on testing. A further understanding of shear yielding elements should also be developed similarly to that which has been developed for metal deck diaphragms. Although a best practices guide is recommended to be developed, it is suggested that further testing will be required to assist in developing the design and detailing requirements for wood based lateral resisting systems utilized in seismic zones.

▪ **Licensing of Contractors and Trades**
It is suggested that the necessity to require licensing for trades and contractors involved in 5 to 6 storey building discussed within the design and construction community.

3.3 Building Envelope

TECHNICAL RISKS

Technical risk is defined in Section 3.1 above. In application to ‘Building Envelope’, this can be paraphrased to mean the level of risk associated with ‘environmental separators’ that are built in full compliance with Division B, Part 5 without significant defect.

A quantitative analysis of the technical risk with respect to ‘structural shrinkage, sound transmission, building techniques, moisture, material shrinkage, etc.’ impacts on environmental separators, would be impossible as 6 storey light wood-frame buildings do not currently exist in BC. Because of our unique climate, it would also be difficult to draw a reasonable comparison to the building envelope risks on any 6 storey light wood-frame buildings built in other jurisdictions. Therefore, it is necessary to employ a qualitative approach by comparing the risk between 4 and 6 storey residential buildings and 6 storey noncombustible buildings.

The technical risks recognized by the 2006 BCBC are stated in Division A, Section 2.2 “Objectives”. The Code objectives provide a clear outline of the environmental separation issues that the Code addresses. The objectives relating to Division B, Part 5 - Environmental Separators are as follows:

- **OS1 Fire Safety**
  An objective of [the 2006 BCBC] is to limit the probability that, as a result of the design or construction of the building, a person in or adjacent to the building will be exposed to an unacceptable risk of injury due to fire. The risks of injury due to fire addressed in this Code are those caused by:

  OS1.4 – fire safety systems failing to function as expected [Applies where required life safety systems are incorporated in environmental separators]

- **OS2 Structural Safety**
  An objective of [the 2006 BCBC] is to limit the probability that, as a result of the design or construction of the building, a person in or adjacent to the building will be exposed to an unacceptable risk of injury due to structural failure. The risks of injury due to structural failure addressed in this Code are those caused by:

  OS2.1 – loads bearing on the building elements that exceed their loadbearing capacity
  OS2.2 – loads bearing on the building that exceed the loadbearing properties of the supporting medium
  OS2.3 – damage to or deterioration of building elements
  OS2.4 – vibration or deflection of building elements
  OS2.5 – instability of the building or part thereof

- **OS3 Safety in Use**
  An objective of [the 2006 BCBC] is to limit the probability that, as a result of the design or construction of the building, a person in or adjacent to the building will be exposed to an unacceptable risk of injury due to hazards. The risks of injury due to hazards addressed in this Code are those caused by:

  OS3.1 – tripping, slipping, falling, contact, drowning or collision

- **OH1 Indoor Conditions**
  An objective of [the 2006 BCBC] is to limit the probability that, as a result of the design or construction of the building, a person in the building will be exposed to an unacceptable risk of illness due to indoor conditions. The risks of illness due to indoor conditions addressed in this Code are those caused by:

  OH1.1 – inadequate indoor air quality
  OH1.2 – inadequate thermal comfort
  OH1.3 – contact with moisture

- **OH3 Noise Protection**
  An objective of [the 2006 BCBC] is to limit the probability that, as a result of the design or construction of the building, a person in the building will be exposed to an unacceptable risk of illness due to high levels of sound originating in adjacent spaces in the building (See Sentence 2.1.1.2.(3) for application limitation). The risks of illness due to high levels of sound addressed in this Code are those caused by:

  OH3.1 – exposure to airborne sound transmitted through assemblies separating dwelling units from adjacent spaces in the building

- **OH4 Vibration and Deflection Limitation**
  An objective of [the 2006 BCBC] is to limit the probability that, as a result of the design or construction of the building, a person in the building will be exposed to an unacceptable risk of illness due to high levels of vibration or deflection of building elements

- **OP2 Structural Sufficiency of the Building**
  An objective of [the 2006 BCBC] is to limit the probability that, as a result of its design or construction, the building or part thereof will be exposed to an unacceptable risk of damage or loss of use due to structural failure or lack of structural serviceability. The risks of damage and of loss of use due to structural failure or lack of structural serviceability addressed in this Code are those caused by:

  OP2.6 – instability or movement of the supporting medium

From the objectives, the following areas of technical risk can be established:

Table 6
Technical risks on building envelope addressed by the 2006 BCBC

Technical Risk	Code Objective
Risk of failure of fire safety systems (in environmental separators)	OS1.4
Structural safety risks due to failure of environmental separators	OS2.1, OS2.2, OS2.3, OS2.4, OS2.5
Failure of environmental separators, leading to safety risks	OS3.1
Risk of illness due to indoor conditions	OH1.1, OH1.2, OH1.3
Risk of illness due to high levels of sound	OH3.1
Risk of illness due to high levels of vibration or deflection of building elements	OH4
Risk of damage and of loss of use due to structural failure or lack of structural serviceability	OP2.6

There may be other technical risks; however, those risks are not identified as they are not addressed by the current 2006 BCBC. As the method of analysing technical risk to draw comparison to a building currently permitted by the Code, it is not appropriate to identify risks outside the scope of the BCBC. Notwithstanding this, the risks being addressed by the Code objectives are in general agreement with the building science principles recognized in Canada and internationally.

Based on the technical risk identified above, the following is an analysis of the risk with respect to the Proposed Code Change Building presented in Table 6:

- **Risk of Failure of Fire Safety Systems in Environmental Separators:** *Not likely to increase.*
  Current 2006 BCBC Part 5 provisions require the design of environmental separators to include building materials, components and assemblies to accommodate all loads, and resist any deterioration, that may be reasonably expected, given the exposure. While the exposure, and hence associated loads and deterioration risks, will be increased in taller wood-frame buildings; Part 5 requires that the materials, components and assemblies be designed to accommodate these expected risks.

- **Structural Safety Risks due to Failure of Environmental Separators:** *Not likely to increase.*
  Current 2006 BCBC Part 5 provisions require the design of environmental separators to include building materials, components and assemblies to accommodate all loads, and resist any deterioration, that may be reasonably expected, given the exposure. While the exposure, and hence associated loads and deterioration risks, will be increased in taller wood-frame buildings; Part 5 requires that the materials, components and assemblies be designed to accommodate these expected risks.

- **Risk of Failure of Environmental Separators, Leading to Safety Risks:** *Not likely to increase.*
  Current 2006 BCBC Part 5 provisions require the design of environmental separators to include building materials, components and assemblies to accommodate all loads, and resist any deterioration, that may be reasonably expected, given the exposure. While the exposure, and hence associated loads and deterioration risks, will be increased in taller wood-frame buildings; Part 5 requires that the materials, components and assemblies be designed to accommodate these expected risks.

- **Risk of Illness due to Indoor Conditions:** *Not likely to increase.*
  Current 2006 BCBC Part 5 provisions require the design of environmental separators that separate; interior conditioned space from exterior space, interior space from the ground, or environmentally dissimilar spaces; such that they provide acceptable conditions for the building occupants, maintain appropriate conditions for the intended use, and minimize accumulation of condensation in, and the penetration of precipitation into, the building components or assemblies; such that the health or safety of building users will not be adversely affected. While the exposure, and hence associated loads and deterioration risks, will be increased in taller wood-frame buildings; Part 5 requires that the materials, components and assemblies be designed to accommodate these expected risks.

- **Risk of Illness due to High Levels of Sound:** *Not likely to increase.*
  Current 2006 BCBC Part 5 provisions require the design of environmental separators such that dwelling units are separated from; every other space in the building in which noise may be generated by construction with an STC rating not less than 50, and from elevator hoistways or refuse chutes by construction with an STC rating not less than 55. These risks are independent of building height, and are not likely to be affected by constructing taller wood-frame buildings.

- **Risk of Illness due to High Levels of Vibration or Deflection of Building Elements:** *Not likely to increase*.
  Current 2006 BCBC Part 5 provisions require the design of environmental separators to include building materials, components and assemblies to accommodate all loads that may be reasonably expected, given the exposure, and to provide stipulated STC ratings for specific environmental separators. While the exposure, and hence associated loads, will be increased in taller wood-frame buildings; Part 5 requires that the materials, components and assemblies be designed to accommodate these expected risks. The issues associated with provision of the stipulated STC ratings are not related to building height.

- **Risk of Damage and of Loss of Use due to Structural Failure or Lack of Structural Serviceability:** *Not likely to increase*.
  Current 2006 BCBC Part 5 provisions require the design of environmental separators to include building materials, components and assemblies to accommodate all loads, and resist any deterioration, that may be reasonably expected, given the exposure. While the exposure, and hence associated loads and deterioration risks, will be increased in taller wood-frame buildings;

Part 5 requires that the materials, components and assemblies be designed to accommodate these expected risks.

Based on the above, it is shown that within the framework of Part 5 of the 2006 BCBC, a 5 or 6 storey combustible building of residential occupancy following will not likely pose a greater technical risk than a 4 storey wood-frame building of residential occupancy currently permitted. The performance of a 4 storey or 6 storey wood-frame building, both of residential occupancy, will be the same when the environmental separators are designed to accommodate the expected exposure, and hence associated loads and deterioration risks. The building materials, components and assemblies will necessarily be different than they would be in an equivalent 4 storey building, but Part 5 makes it clear that it is incumbent on the designer to reflect on the increased risks, and design accordingly.

PROCESS RISKS

Process risk is defined in Section 3.1 above. In general terms, this can be paraphrased to mean practical concerns with constructing a 6 storey wood-frame building of residential occupancy – the risks associated with the unavoidable inability for the industry to deliver a building that is in full compliance with the BCBC. The process risks presented below were developed through consultation and interviews with other Building Envelope Professionals, the Homeowner’s Protection Office, and 3 warranty providers. At this stage, two general areas of process risk associated with building envelope concerns have been identified; qualifications of project team members and lack of supporting technical information sources, such as best practice guides.

- **Qualification of Design Professionals**

  A major concern raised by interviewees was the need for qualified professionals. Currently, the Letters of Assurance require an Architect to sign off on building envelope issues, but only in the City of Vancouver is there a specific requirement for a professional qualified in building envelope design and review, to sign a separate schedule letter. A Building Envelope Education Program (BEEP) has been provided by the AIBC, but this was limited to an understanding that people attaining the Building Envelope Professional (BEP) designation (that the courses were designed to meet) would be qualified to practice in the design and review of conventional wood-frame construction (to a maximum of 4 storeys). Other building envelope education courses for professionals have been provided by APEGBC, UBC, and BCIT (amongst others), but obviously none of these have been specifically tailored to include sections on reducing building envelope risks associated with the complexities of taller wood-frame construction. If we are to develop professionals capable of dealing with the risks associated with issues such as higher building exposure, and increased shrinkage problems, course contents, and subsequent qualifications for professionals will have to be re-visited. With the recent passage of Bill 10, the AIBC and APEGBC are starting to work toward re-instating a ‘BEP’ qualification. Within this work, an assessment of the skills and qualifications necessary to design and field review the building envelopes of 6 storey wood-frame buildings will become another task they will need to address.

- **Readiness of Warranty Providers / Qualification of Contractors**

  As HPO mandated warranties, created to deal with building envelope failure, rely heavily on the knowledge and skill sets of the Contractors doing the building (along with the professionals on the project team), the three warranty providers interviewed indicated that insurance for 5 or 6 storey wood-frame buildings of residential occupancy will be dependent on qualifying contractors who they believe will be able to mitigate the associated risks. There would be concern with their ability to construct a durable building envelope to deal with the higher exposure created by a 6 storey wood-frame construction. The warranty providers indicated that they would initially only want to insure buildings built by contractors that have a solid record of building 4 storey wood-frame buildings.

- **Readiness of Trades**
  Another major link in the project team identified by interviewees, as needing upgraded skills, are the trades who the contractors will employ to build 5 or 6 storey wood-frame buildings. Trades training programs for Building Envelope Technicians are still in early development, and will need to be revised to provide the skills necessary to address this new building type.

- **Best Practice Guides**
  Technical literature for the industry will need to be updated and expanded to provide the technical resources to focus on the building envelope risks in taller wood-frame buildings. The CMHC worked with the local industry to develop Best Practice Guides, such as “Wood-frame Envelopes in the Coastal Climate of British Columbia”. This document (along with others) will need to be updated to address a taller wood-frame building type. The technical recommendations outlined in guides addressing varying exposures, and shrinkage problems will need to be re-thought to provide the necessary technical information for the industry, in order to lower the risks associated with going taller in wood-frame construction.

CONCLUSION

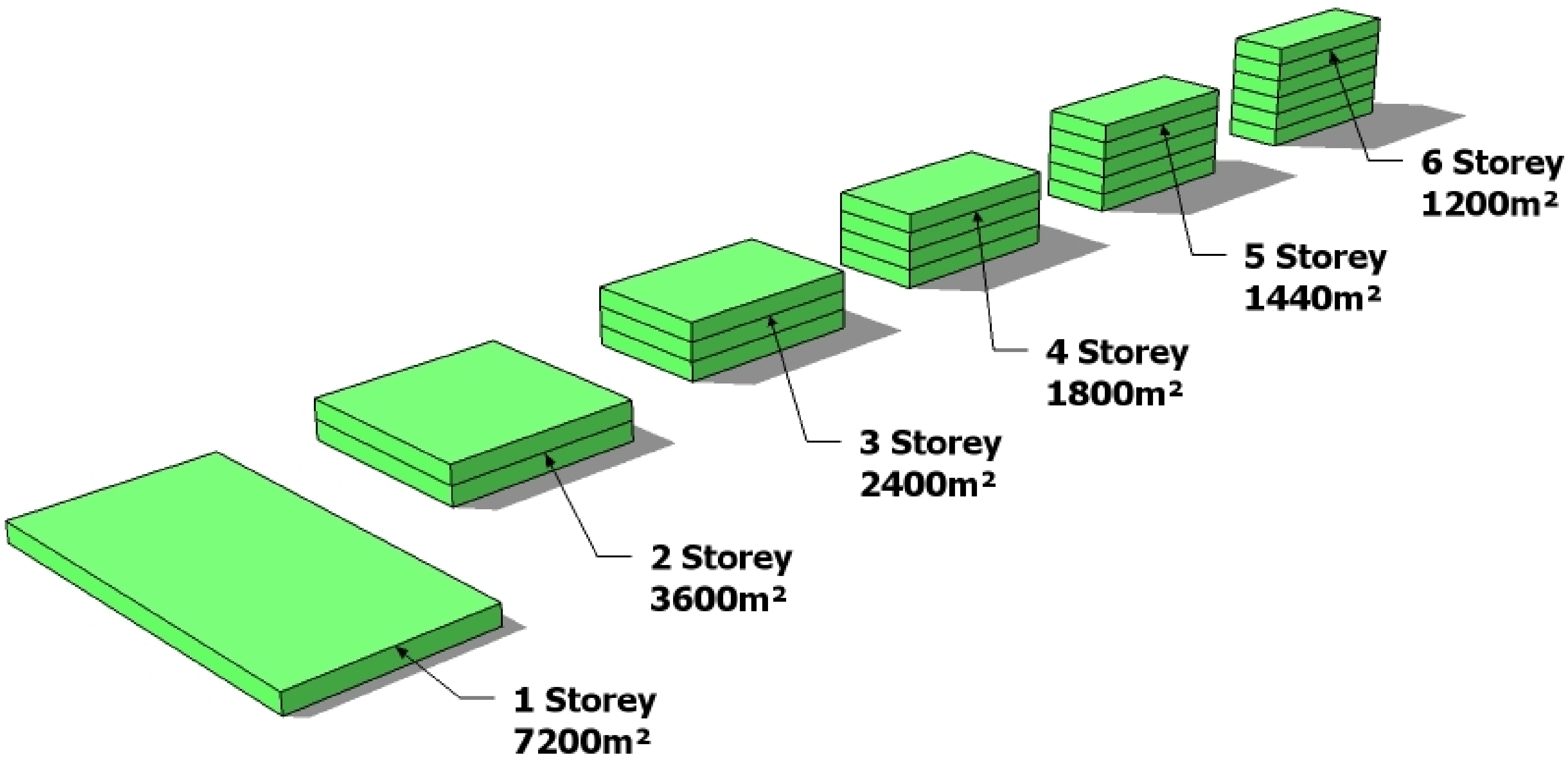
This Stage 1 Report has summarized the existing Code provisions for residential buildings with respect to fire safety, structural and building envelope aspects of the proposed Code change. The report has provided a review of the role of the Building Code and its purpose and objectives in relation to risks in building construction in BC. This report has only specifically identified technical and process risks as requested by BSPB and the identification is based on GHL and RJC's professional experience and limited review of literature and consultation as permitted within the 3 week timeframe of this project.

The report has identified that in general, the technical risks will not likely increase. With respect to Division B requirements, wood-frame buildings are only permitted to be 4 storeys due to Part 3 limitations. In general, it is considered that no significant increase in technical risks would result if the existing philosophy of 1 hour FRR and the 20% ratio between permitted building areas of combustible and non-combustible construction is retained. There are, however, a number of process risks for fire, structural and building envelope design considerations that have been identified, which are not necessarily contingent on the Code change, but rather require other regulatory means of addressing the issues.

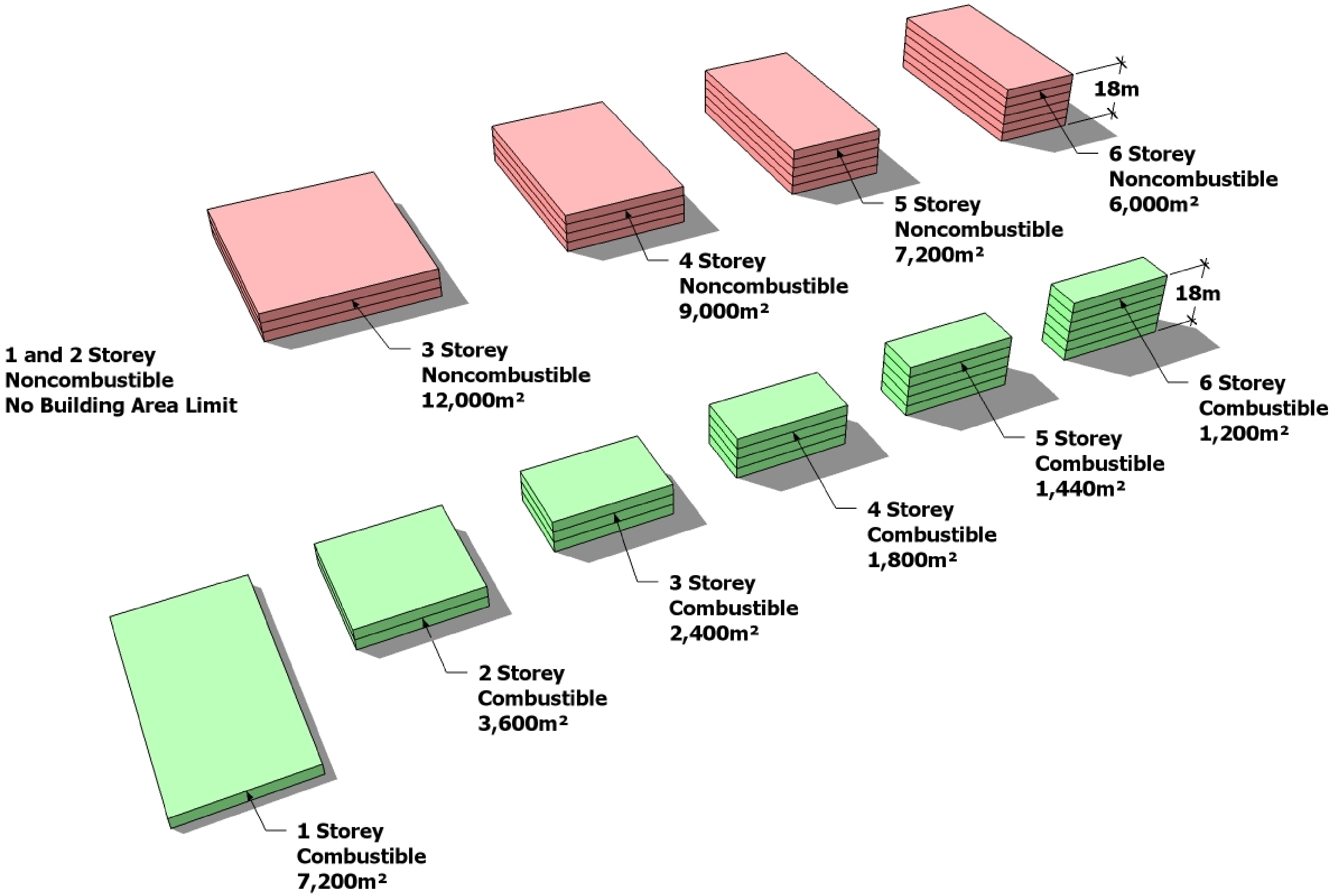
Based on our review to date, we do not foresee any significant issues that would discourage us from proceeding with Stage 2 of this project.

APPENDIX A

Schematic Perspective of Combustible and Noncombustible Residential Buildings



1 Storey
7200m²
2 Storey
3600m²
3 Storey
2400m²
4 Storey
1800m²
5 Storey
1440m²
6 Storey
1200m²


18m
6 Storey
Noncombustible
6,000m²
5 Storey
Noncombustible
7,200m²
4 Storey
Noncombustible
9,000m²
3 Storey
Noncombustible
12,000m²
1 and 2 Storey
Noncombustible
No Building Area Limit
18m
6 Storey
Combustible
1,200m²
5 Storey
Combustible
1,440m²
4 Storey
Combustible
1,800m²
3 Storey
Combustible
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Combustible
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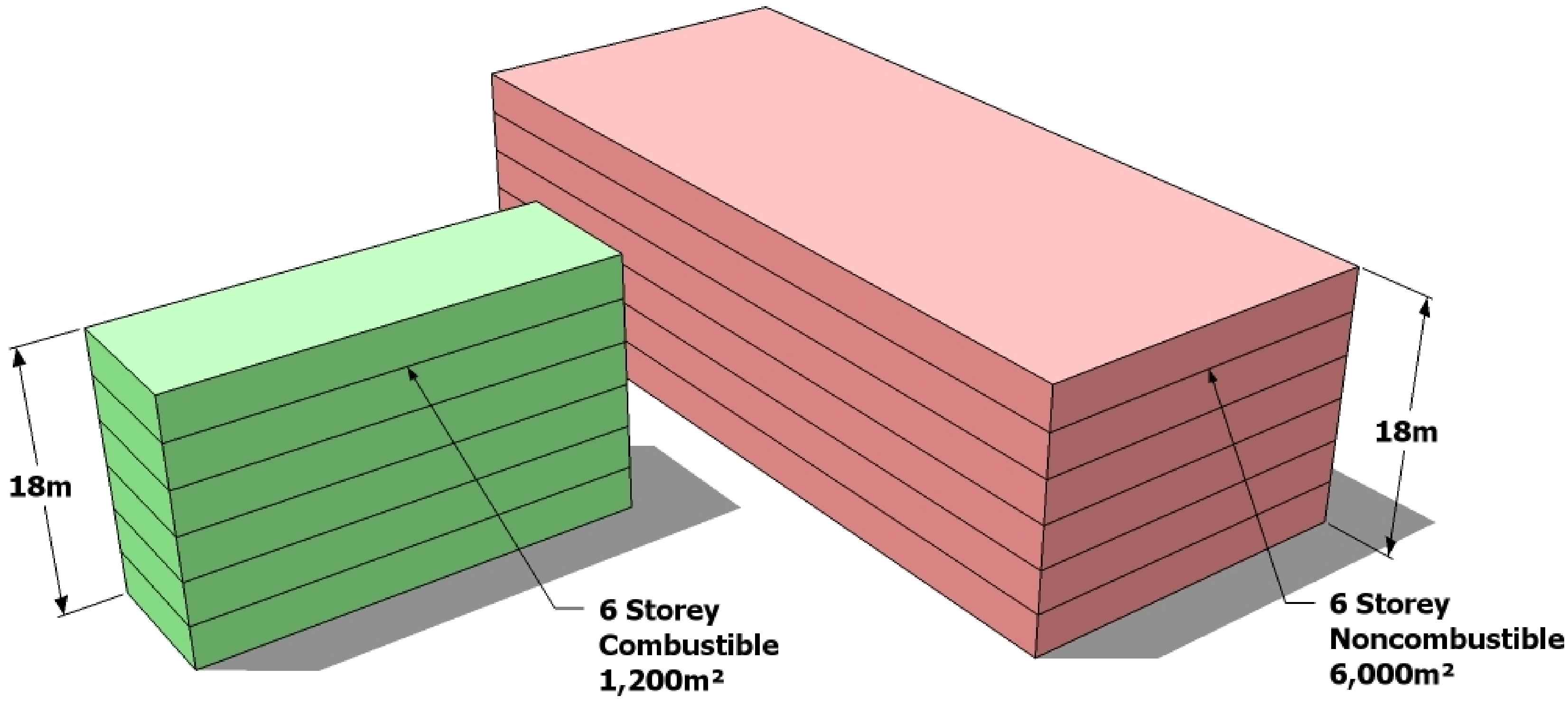
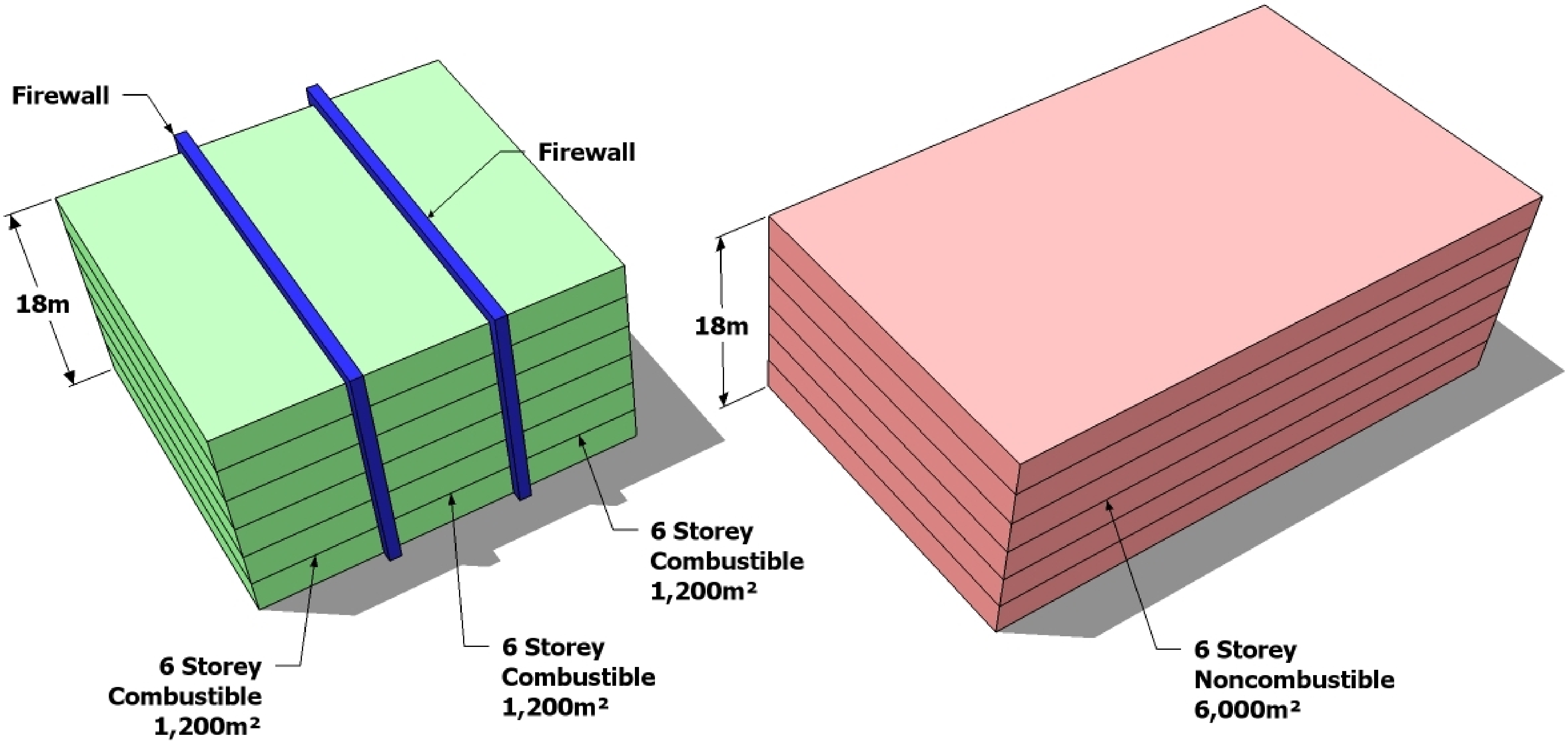
1 Storey
Combustible
7,200m²



Building Area Comparison



Building Area Comparison

(Example of Combustible Buildings separated by Firewalls)