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TECHNICAL AND PROCESS RISKS
IN
5 AND 6 STOREY WOOD-FRAME BUILDINGS
OF RESIDENTIAL OCCUPANCY

Prepared for

Building and Safety Policy Branch
Ministry of Housing and Social Development
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DISCLAIMER

This technical report is prepared by **GHL** CONSULTANTS LTD (GHL) 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's opinion is based on the science of fire engineering and a review of the available literature and is inherently limited by the short timeframe (September - November, 2008). Work of this nature would normally require substantial research for a significantly greater duration. GHL's work shall not be construed as exhaustive. There may be other relevant considerations for the Code change proposal not identified by GHL. At the time of report writing, GHL has recommended that BSPB 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 understood that a public consultation process has been 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 5 and 6 storey 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 contained in this report. GHL 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's work or any Building Code or construction regulation change. Should this report be made available to other organizations that have regulatory capacity in construction of buildings and structures, this disclaimer shall equally apply. By preparing this report, GHL does 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:

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1.0 BASIS OF REPORT

Background

GHL Consultants Ltd (GHL) has been requested by the Building Safety and Policy Branch (BSPB) of the Ministry of Housing and Social Development to prepare this technical report for the Mid-Rise Wood-Frame Residential Construction project. The scope of this report is to identify and comment on the process and technical risks relating to the Code change to permit 5 and 6 storey wood-frame buildings in BC, specifically focusing on fire safety requirement of Division B, Part 3 of the Code. It is the BC Government's responsibility to ensure that all aspects of the Building Code are appropriately addressed in amending the Building Code.

Definition of Risks

- **Technical Risk**
  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 Part 3 of Division B without significant defect.

- **Process Risk**
  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 BC Building Code.

Methodology

We have identified the technical risks based strictly on the fire safety objectives of the Building Code. Analysis of the technical risks is based on a qualitative approach, whereby the risk associated with a 5 or 6 storey wood-frame building is compared to that of a 4 storey wood-frame or 6 storey light steel-frame building. No quantitative risk analysis was performed, given that the National Building Code of Canada and the adopted BC Building Code are not written based on a quantitative risk analysis.

The process risks are identified based in part on GHL's professional experience, as well as input received from the Technical Advisory Group meetings held by BSPB during the period of September - November, 2008. GHL has also reviewed the joint AIBC and APEGBC letter submitted to BSPB regarding technical considerations for the proposed Code change.

Assumptions

- **Combustible Construction**
  The work presented in this report assumes traditional wood-frame construction employed in BC as requested by BSPB; however, with respect to Part 3 of Division B, the term “combustible construction” is used in the Code, as Part 3 only distinguishes construction as being “combustible” or “noncombustible”. Typical combustible construction in BC is “platform framing” construction, or commonly known as wood-frame construction. It should be noted, however, that combustible construction could potentially include other types of combustible material and that GHL has only been retained to address conventional BC wood-frame construction.

- **The Building Code**
  The terms “Building Code” and “Code” in this report generally refer to the British Columbia Building Code 2006 (BCBC) unless otherwise indicated. The BCBC 2006 is based on the National Building Code of Canada 2005 (NBCC) with no substantial changes related to this project.

- **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.

2.0 RISK ANALYSIS

Technical Risks

The BC Building Code is essentially a consensus document that regulates construction standards in the Province of BC. The Codes are written and revised through each NBCC Code change cycle in an effort to better manage risks in buildings. As an objective-based Code, the BC Building Code 2006 objectives, which are found in Section 2.2 of Division A, identify the risk areas that the Code recognizes. The required level of performance with respect to each Code objective is then set out in the acceptable solutions in Division B. The acceptable solutions define the boundary between "acceptable" and "unacceptable" risks and are used to evaluate alternative solutions. In this regard, a "Code compliant" or "Division B complaint" building does not mean the building is risk-free; rather, it means that the risks have been managed to a level that is deemed acceptable.

As discussed, it is not possible to provide a quantitative risk analysis to compare the risk levels numerically, given that it is not the basis on which the Code was developed. If a quantitative approach is to be taken, it would be an immense undertaking in that every aspect of the Code would need to be re-assessed quantitatively. In many instances, this task may be very difficult, if not impossible, to carry-out; however, it is possible to provide a risk assessment based on a qualitative approach. Recognizing that Division B defines the boundary between acceptable and unacceptable risks, one may approach the project by comparing a 5 or 6 storey wood-frame building to other types of construction already contained in Subsection 3.2.2 of Division B. This means of analysis is appropriate and is the approach often employed when alternative solutions are developed. Further discussion on qualitative risk analysis and development of alternative solutions is found in Appendix A A-1.2.1.1.(1)(b) of the Code.

In a qualitative risk analysis, the steps are generally as follows:

1. Identify the objectives of the Division B requirements; this identifies which risks are relevant.
2. Evaluate the level of performance of the Division B requirement in achieving the objectives of the Division B requirements.
3. Evaluate the performance of the alternative solution relative to the objective.
4. Compare the performance between the Division B solution and the alternative solution.

For the 6 storey wood-frame project, the same approach was taken. In our analysis, we compared a 6 storey wood-frame building to a 4 storey wood-frame and a 6 storey light steel-frame building of residential occupancy, which are 1h fire rated buildings defined in Subsection 3.2.2 of Division B.

We begin the risk analysis by summarizing the risk areas that are defined by the fire safety objectives of the Code, which are listed below.

- **OS1 Fire Safety**

  An objective of the Code 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 the 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 Code 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 Code 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 these objectives, the technical risks can be established as summarized in Table 1 below. Again, there may be other technical risks that are not addressed by the current BC Building Code 2006; however, they are outside the scope of GHL's work and are not specifically recognized by the Code.

Table 1. Technical risks on fire safety addressed by the BC Building Code 2006.

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

Based on the technical risks identified, the following analysis for a 5 or 6 storey wood-frame building can be provided:

- **Risk of Ignition:** *Will not likely increase.*
  The risk of ignition will not likely increase provided the gross floor area in a 5 or 6 storey wood-frame building remains the same as the maximum permitted area for a 4 storey wood-frame building under Article 3.2.2.45. The Article derives building area based on dividing the gross floor area of 7200m^2 by the building height. For example, a 1 storey wood-frame building is permitted a building area of 7200m^{2}and a 4 storey wood-frame building is permitted a building area of 1800m^2. The Code manages the risk of ignition by maintaining the same gross volume in wood-frame constructions. Using 7200m^2 as the acceptable level of performance, a 5 or 6 storey wood-frame building should be limited to 1440m^2 and 1200m^2 in building area respectively, in order to maintain the same level of performance. By maintaining the same gross floor area, and given the same occupancy classification of Group C, the risk of ignition – the probability of ignition and the consequential losses – will not likely increase, as the use and the characteristics of the wood-frame building remains the same.

- **Risk of Fire Spread beyond Point of Origin:** *Will not likely increase.*
  Generally, there are two forms of fire spread in a building: interior and exterior (through unprotected openings). The current BC Building Code addresses fire spread by implementing sprinklers and fire separations. Sprinklers are active fire protection systems which are reliable and effective in controlling the growth and spread of a fire. On the other hand, fire separations are passive; they independently provide a barrier against spread of fire, with or without the operation of sprinklers.

  Given that a 5 or 6 storey wood-frame building will be sprinklered and that the same degree of fire separations will be provided as inherent with Group C occupancies, the risk of interior fire spread will not likely increase. This is because both the active and passive fire protection systems will offer the same level of protection against interior fire spread, independent of the building height. Sprinklers in a 5 or 6 storey wood-frame building will be based on NFPA 13, as NFPA 13R is limited to 4 storeys. As sprinklers are designed on a per floor area basis and NFPA 13 is a more stringent standard than NFPA 13R, sprinklers can be expected to offer a greater level of protection than that offered by NFPA 13R, which is permitted for a 4 storey wood-frame building.

  Similarly, the use of 1h rated fire separations in a 6 storey wood-frame building will offer the same level of performance in resisting fire spread as that of a 4 storey wood-frame and a 6 storey light steel-frame building. The performance of fire separations are measured by the CAN/ULC-S101 standard fire test. The test exposes assemblies to the standard time-temperature curve and assigns an hourly rating based on the passing criteria. The standard test is not predicated on the assembly's material of construction. When the fire test determines a fire resistance rating of 1h for a wood stud wall, a steel stud wall, or a concrete wall, all three types of construction are considered as having the same level of fire resistance of 1h based on the fire test; therefore, when a 1h rated fire separation is used in a 6 storey wood-frame building, the separation is considered to offer the same level of protection as that offered by a 1h rated fire separation in a 4 storey wood-frame or a 6 storey light steel-frame building.

  With respect to exterior fire spread through windows (which is not to be confused with fire spread to neighbouring buildings), the use of combustible exterior cladding as is currently permitted for combustible buildings may lead to greater risk of exterior fire spread. Until this situation is analyzed further, use of noncombustible cladding or the limited types of combustible cladding permitted for noncombustible buildings should be considered for 5 and 6 storey wood-frame buildings.

  Finally, with respect to fire spread within concealed spaces, the mandatory application of the NFPA 13 standard will appropriately manage the risk. There may be an increased risk when sprinklers fail; however, this form of risk is already contemplated by the Building Code and can be further addressed through proper fire blocking.

- **Risk of Fire Spread to Neighbouring Buildings:** *Will not likely increase.*
  The Code assumes fire spread to neighboring buildings by means of radiation heat transfer. In order to manage this risk, the Code places a requirement on the allowable size of unprotected openings and exterior wall construction based on the separation distance between two buildings. In doing so, the Code attempts to control the incident radiation heat flux on the exterior walls of neighbouring buildings to be less than $12.5 kW/m^2$, which is the level where wood-based material could undergo piloted ignition. The assumption is that at this radiation level, flying brands could act as the pilot and cause ignition of hot surfaces. Employment of active and passive fire

protection systems effectively lower the radiation level, given that radiation heat transfer is highly dependent on the temperature and size of the emitting surface. By sprinklering the fire compartment, the Code assumes that the temperature will be lower, which is reflected in the doubling of unprotected openings allowed by the Code. Use of fire separations will also generally confine the fire to the compartment of origin such that the size and the number of the emitting surfaces will be controlled. The approach of managing the risk of building-to-building exposure is well established in the current Code and is largely based on the results of the series of NRC tests known as the "St. Lawrence Burns".

Assuming that the same exposure protection approach will be taken in a 5 or 6 storey wood-frame building, the risk of fire spread to neighbouring buildings will not likely increase. This is because the size of exposing surfaces via the unprotected openings will be restricted on the same basis as a 4 storey wood-frame or a 6 storey light-steel frame building. In fact, irrespective of the type of construction, all buildings built in accordance with Division B are all subject to the same exposure requirements of Subsection 3.2.3 of Division B. Further, if the exterior cladding of 5 and 6 storey wood-frame buildings are restricted to be noncombustible or to limited types of combustibles as discussed earlier, this will further limit the risk of fire spread on the exterior wall, thereby reducing the risk of a larger exposing face in a 5 or 6 storey wood-frame building. In this regard, the risk of building-to-building exposure for a 5 or 6 storey wood-frame building can be expected to be less than that of a 4 storey wood-frame building.

- **Risk of Failure of Sprinkler System to Control / Suppress Fire:** *Will likely decrease.*
  As discussed, the NFPA 13 standard will be the applicable sprinkler standard for 5 and 6 storey wood-frame buildings of residential occupancy, because NFPA 13R is limited to buildings that are less than 4 storeys in building height. Given sprinklers work on a per floor area basis and are independent of the building height, the risk of sprinklers failing to control a fire in a 5 or 6 storey wood-frame building will not increase relative to a 4 storey wood-frame or a 6 storey light steel-frame building. Given that NFPA 13 is a more stringent standard, the risk will actually decrease relative to a 4 storey wood-frame building as NFPA 13 requires sprinklering of concealed spaces.

- **Risk of Occupants Not Able to Recognize Fire:** *Will not likely increase.*
  Occupant response time to fire cues and decision-making prior to evacuation will not likely increase based on the mandatory requirement of a central fire alarm and sprinkler systems for a 5 or 6 storey wood-frame building. This is because fire detection system alarm system and occupant behavior are all independent of the building height. Therefore, the risk of occupants unable to recognize fire will not likely increase.

- **Risk of Occupants Not Being Able to Evacuate the Building:** *Will not likely increase.*
  The Code's general approach to evacuation in buildings is based on controlling occupant load, providing sufficient means of egress, and managing accessibility, availability and integrity of exit systems. Assuming the gross floor area of $7200m^2$ is maintained in a 5 or 6 storey wood-frame building, the occupant load will not change. Travel time to an exit within a storey will likely decrease due to smaller building area and less queuing at exits as a result of fewer occupants per floor. Travel time within exit stairs would increase due to 2 additional storeys; however, as exits will need to be separated by 1h fire rated construction and travel time within exits will be the same as that of a 6 storey light steel-frame, in our opinion the exit stairs will provide the same level of fire safety. The 1h exit fire separation would offer the same level of protection against fire, irrespective of the material of construction as aforementioned, which will afford an acceptable time for evacuation and for firefighting use.

- **Risk of Fire Service Unable to Conduct Effective Operation:** *Will not likely increase.*
In comparison to a sprinklered 4 storey wood-frame or a 6 storey light steel-frame building, the risk of fire service unable to conduct effective operations will not likely increase for a 5 or 6 storey wood-frame building, provided the building will not be a high building. In sprinklered mid-rise buildings, firefighting is generally conducted in the interior of the building, and the sprinkler system provides adequate relief to firefighting in comparison to unsprinklered buildings. As well, the effects of stack action, which is typically more prevalent in high buildings, will not be significant in mid-rise wood-frame buildings.

  Traditionally, unsprinklered 3 storey wood-frame constructions relied on exterior firefighting operations. With the advent of buildings protected with monitored and supervised sprinkler systems and related firefighting practices, the Code have shifted to reliance on the sprinkler systems and interior firefighting access. This is reflected in several recent Code changes, including:

  - Eliminating the requirement for fire rated roofs in sprinklered 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 1h construction in the BC Building Code 1992 and the subsequent removal of the 9m height limit in the BC Building Code 1998.

  These changes all reflect the fact that the Code does not anticipate exterior firefighting for sprinklered wood-frame buildings and recognizes the reliability and effectiveness of automatic sprinkler systems. Therefore, the primary change from 4 to 6 storeys is access up an additional 2 storeys of interior stairs. However, this is in part offset by the reduced floor area from a maximum 1800m² for 4 storeys to 1200m² for 6 storeys, as well as the consideration that the operation would be the same as in a 6 storey light steel-frame building with a 1h fire rated construction. Further, 4 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. Accordingly, there is no foreseeable risk increase with respect to the effectiveness of firefighting, particularly considering that a 5 or 6 storey wood-frame building will be sprinklered to NFPA 13.

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

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

  For rural areas of BC where the region may have limited firefighting capabilities, the BC Building Code Appendix Commentary already notes that this can be addressed through either requiring mandatory sprinklers or imposing restrictions through Municipal Zoning By-laws. With respect to the sprinkler option, where the region 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 foregoing discussion, a 5 or 6 storey wood-frame building of residential occupancy following the building area restriction formula already employed in Article 3.2.2.45 for up to 4 storeys will appropriately manage the risks which are recognized by the Code through the objectives.

It is noted that fire statistics in BC obtained through BSPB have shown that sprinklers are effective in managing all risk areas addressed by the Code, except the probability of ignition occurring. The statistics suggest that when buildings are sprinklered, irrespective of the type of construction and the building height, the number of fire-related fatalities and injuries in buildings are significantly reduced. The fire statistics would lend us to believe that a sprinklered 5 or 6 storey wood-frame building would not expose occupants to a greater risk than in that of a 4 storey wood-frame or a 6 storey light-steel frame building.

Process Risks

Process risk is the risk relating to the use of the Building Code. For this project, it specifically relates to the risks that arise out of constructing a 5 or 6 storey wood-frame building. It is important to recognize that the current Building Code objectives do *not* address process risks. Process risk was specifically asked to be identified, which is aimed at assisting the BC Government in managing the implementation aspects of the project. Identifying process risk is therefore less straightforward than that of technical risk. Our approach has been to consult stakeholders such as AHJs in BC, the Homeowner's Protection Office, warranty providers, researchers at FPInnovations Forintek, as well as process the comments received during the Technical Advisory Group meetings held by BSPB. Out of this process, we have identified the following process risks:

- **Qualification of Design Professionals**
  A major concern raised by many parties is the need for qualified professionals. Currently, the Letters of Assurance require a professional qualified in structural engineering, but do not specifically require a professional qualified in fire safety. Education in Building Code requirements is provided to Architects but is limited. Significant additional Building Code education is provided through the Certified Professional (CP) program, but it is not specific to wood-frame construction, nor does the program include fundamental fire engineering education such as fire dynamics, transport phenomenon and combustion.

  Further, the use of a CP is currently optional and limited to the Cities of Vancouver and Surrey. The increased complexity of 6 storey buildings, combined with the impact of shrinkage on fire separations, fire blocking and fire stopping, and the increased reliance on firewalls may necessitate the involvement for a professional fire engineer. In this respect, we have identified two potential solutions to address qualifications of professionals. One solution is to consider the mandatory involvement of a fire engineer in a 5 or 6 storey wood-frame project. The second solution is to consider the development of a "best practices guide" for 5 and 6 storey wood-frame buildings, which would set forth the standard of care required of professionals in 5 and 6 storey wood-frame buildings. Until an appropriate solution is developed to address this process risk, design professionals are required by APEGBC and AIBC guidelines to diligently ensure that the standard of care required by the public of BC is delivered.

- **Qualification of Design Reviewer / AHJ**
  With 5 and 6 storey wood-frame buildings in the 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 that "wood-frame" is only one form of combustible construction), use of mixed combustible and noncombustible materials, creation of interconnected

floor spaces and proposals for 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 for design reviewers or AHJs to have similar qualifications as that of the design professionals. Although there is no regulatory framework currently in place, certain municipalities have addressed review of designs through peer-review or employment of a qualified fire engineer to act as the AHJ. Both of these approaches are considered as appropriate solutions to address the process risk.

- **Readiness of Warranty Providers**
  Interviews with three major warranty providers in BC indicate that generally, 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 with respect to fire safety, they normally rely on the design professionals, and that they would insure buildings initially based on contractors who have demonstrated good records with 4 storey wood-frame buildings.

- **Readiness and Qualification of Contractors / Trades**
  Construction of a 5 or 6 storey wood-frame building is not significantly different from a 4 storey wood-frame building; 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. Some of the possible solutions to address this risk include greater field review by design professionals and AHJs, 3rd party independent inspection, and more education and training of trades.

- **Reliability of Membrane-based Fire Separation**
  Reliability of fire separation and fire protection of structural members is not an objective of the Building Code. As discussed under the technical risks section of this report, the fire endurance test (CAN/ULC-S101) is a performance test that is not predicated on the assembly's material of construction. Notwithstanding this, the Code has traditionally addressed reliability of construction in certain critical areas of a building indirectly. For example, the Code requires a 1.5h rated fire separation around parking garages and has traditionally required concrete or masonry construction for firewalls and the horizontal fire separation of Division B, Article 3.2.1.2. With respect to wood-frame construction, there is a general concern regarding the reliability of membrane-based fire separations as when the wood-frame is exposed to fire, the frame, being combustible, would directly fuel a fire. Laboratory tests clearly show that a single layer of gypsum wallboard on wood joists can achieve a 1h FRR; however, there is little validation of actual constructed separations in the field. Recent NRC testing has shown that single layer designs are susceptible to improper joint construction, improper attachment of the gypsum wallboard and improper installation. Further, 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. In view of this, it is considered that reliability of fire separations needs to be addressed. Some of the potential solutions include better craftsmanship of GWB installation, greater reviews during construction, and mandatory use of two layer wall assembly systems.

The foregoing section has presented the process risks. The work should not be considered as exhaustive or complete. We understand the Government of BC has been providing opportunities for public consultation during which other process risks may be identified. Some of the process risks may be addressed through Code changes, while others may be best tackled by best practices guides and greater training. It is the Government of BC's responsibility to ensure that the process risks are appropriately managed.

3.0 FUTURE WORK

The foregoing report has provided GHL's opinion on the technical and process risks with respect to the 5 and 6 storey wood-frame project. In our work and through participating in the Technical Advisory Group meetings, we also recommend the following future work for consideration:

- **Building Height and Area**
  The foregoing analysis is based on the existing floor area formula of the Code in Article 3.2.2.45. The formula would result in a building area of 1440m^2 or 1200m^2 for a 5 or 6 storey wood-frame building, respectively. Our review of previous editions of the Building Code and related Code change documents indicates that there is limited technical basis for the area and height limits that are currently prescribed in all combustible constructions of Subsection 3.2.2. It would be appropriate as an additional work to re-examine the height and area limits for combustible construction for all occupancies for greater allowance.

- **Construction Fire Safety**
  As part of this work, GHL has received input from stakeholders of the need to address construction fire safety. In our opinion, provided the gross floor area of 7200m^2 is maintained, we do not see an increased risk of construction fire, given that the same amount of combustibles would be allowed; however, if greater building area were to be explored, then a complementary study on the issue of construction fire safety would be necessary as the combustible load will be effectively increased during the construction stage.

- **Reliability of Sprinklers**
  A study into the reliability of sprinklers and their application in the Building Code (by acceptable or alternative solutions) would also be beneficial. Currently, a number of Code requirements are predicated upon the building being sprinklered. For example, the allowable building area is generally doubled when a building is sprinklered; however, there is no clear information as to the extent designers can rely on sprinklers, whether the Code requirements already appropriately accounts for the risk of sprinkler failure or even if doubling the building area is the appropriate figure. A study of this nature would benefit the formulation of alternative solutions and allow designers and AHJs alike to understand when the benefits of sprinklers can be considered.

- **Aging Population**
  We have received comments concerning assisted living type occupancies which are now classified as Group C. There is a general concern of whether this group of occupants would be exposed to greater risk in 5 or 6 storey wood-frame buildings. Our analysis indicates that in a properly constructed 5 or 6 storey wood-frame building, the risk would be the same as a 6 storey light steel-frame building, or less than an unsprinklered 3 storey wood-frame building. Notwithstanding this, we do agree that the current Code, as a whole, does not address the aging population, which is applicable in almost all occupancies (except probably Group F-2 and F-1 occupancies); ie., the issue of slower evacuation time is as relevant in a 6 storey wood-frame as it is in a 6 storey steel-frame or a 60 storey concrete high rise. A study on this issue will be valuable to the public of BC as the province sees an aging population.

4.0 CONCLUSION

This technical report has been prepared by GHL for the Ministry of Housing and Social Development to identify and provide our opinion on the technical and process risks relative to fire safety aspect of the Mid-Rise Wood-Frame Residential Construction project.

Technical risks are identified by the Building Code objectives. GHL's analysis has focused strictly on the risk areas addressed by the Code objectives. We have taken a qualitative approach to analyze the risks by comparing a 5 or 6 storey wood-frame building of residential occupancy to that of a 4 storey wood-frame or a 6 storey light steel-frame building. In general, our finding is that provided the same gross floor area of 7200m^2 is maintained, ie., 1440m^2 building area for a 5 storey building and 1200m^2 for a 6 storey building, the risks will not likely increase due to the use of sprinklers and fire separations, which are well-established requirements in the current Code. We did find that in order to limit exterior fire spread, noncombustible or limited types of combustibles exterior cladding should be considered. Further, in order to address firefighting, the building should not be a high building.

We have also addressed process risks which are not addressed by the Building Code. At the request of BSPB, GHL has identified the process risks outlined in this report through consultation with key stakeholders as well as processing the input received during the Technical Advisory Group meetings held by BSPB. In summary, the process risks generally relate to the process of constructing a 5 or 6 storey wood-frame building in accordance with the Code. The risks can be managed through either having mandatory regulations in the Building Code or through development of best practices guides and education programs to enhance the understanding of the standard level of care required of professionals and trades in 5 and 6 storey wood-frame buildings.

Areas of future work are recommended.

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This technical report addresses only specific Building Code issues under the GHL/Client agreement for this project and shall in no way be construed as exhaustive or complete. This technical report is issued only to the Authority Having Jurisdiction, the Client, Prime Consultants and Fire Suppression Designer to this project and shall not be relied upon (without prior written authorization from GHL) by any other party.

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