

# **APPENDIX D**

## **JURISDICTIONAL EXAMPLES OF HAZARD MANAGEMENT FRAMEWORKS**



## D-1 COMPARISON OF HAZARD MANAGEMENT FRAMEWORKS

The three hazard management frameworks all have advantages and disadvantages relative to the others. These are summarized below:

- Table D-1 summarizes the advantages and disadvantages of the hazard threshold framework.
- Table D-2 summarizes the advantages and disadvantages of the risk threshold framework.
- Table D-3 summarizes the advantages and disadvantages of the combined hazard and risk framework.

**Table D-1 Advantages and disadvantages of a hazard-focused framework.**

| Advantages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Disadvantages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
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| <ul style="list-style-type: none"><li>• <b>Precedent:</b> There is strong precedent for using hazard threshold frameworks to develop prescriptive tables that determine what is permitted based on the hazard probability. Land-use decisions made based on these tables are consistent, and the tables are familiar to most professionals who have worked on land use in British Columbia.</li><li>• <b>Transparency:</b> Tables can be developed for a wide variety of hazard types, and most types of development applications are included in the existing tables. Also, other types of hazards and development applications can be added, as needed. The tables are prescriptive, which facilitates clear documentation and justification for decisions.</li><li>• <b>Consistency and ease of use:</b> All that is needed for application review are the development decision tables and maps of the hazard extent for the selected threshold encounter probability for each hazard type. Once the maps are available, all developers, land-use planners, engineers, and staff reference the same maps and tables. In contrast with a risk assessment, there are no other parameters to estimate, assume, or debate.</li></ul> | <ul style="list-style-type: none"><li>• <b>Inflexibility:</b> Site-specific factors that affect the hazard, exposure, or vulnerability to the hazard (e.g., mitigation measures, variations in hazard characteristics within a hazard type) are ignored, and there is no systematic process for incorporating these factors into decisions about variances or exemptions. Proponents are also unable to use vulnerability-reduction measures to demonstrate a development is safe for the use intended.</li><li>• <b>Existing risk is not reduced:</b> Although the tables could help RDEK to slow population growth within the hazard zones, use of the tables does not explicitly promote or incentivize the reduction of existing risk. Detailed hazard studies may lead to area specific mitigation outcomes that reduce existing risk.</li><li>• <b>Not applicable to group risk:</b> In some densely populated hazard areas, it is possible for individual risk to be tolerable, but societal (group) risk to be intolerable due to a probability of high consequences. Hazard-focused frameworks cannot support decisions requiring consideration of group risk.</li></ul> |

**Table D-2 Advantages and disadvantages of a risk threshold framework.**

| Advantages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Disadvantages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> <li>• <b>Flexibility:</b> The risk threshold framework is more flexible than the hazard acceptability framework, particularly where hazard avoidance is impractical. It allows development proponents to implement measures that reduce vulnerability and exposure (e.g., mitigation measures, non-structural measures) to meet the risk tolerance thresholds, and to demonstrate a favourable benefit-cost ratio. The framework is not limited to a predefined list of hazard types and can consider the total risk to development where multiple overlapping hazards exist.</li> <li>• <b>Incentive to mitigate risk:</b> Adoption of risk tolerance thresholds for development approvals creates incentives to reduce risk.</li> </ul> | <ul style="list-style-type: none"> <li>• <b>Requires specialists to assess risk:</b> Few registered professionals (e.g., engineers, geoscientists, or planners) in British Columbia are experienced in risk assessment. Therefore, specialists in risk assessment are needed, and these specialists can be challenging to find. It may be feasible to reduce this disadvantage in areas where existing detailed assessments are used to develop prescriptive policies (e.g., a rules-based framework that can be followed without additional risk analyses).</li> <li>• <b>Inconsistency:</b> It may be difficult to apply a risk threshold-based policy consistently. Risk assessments require several parameters to be estimated and justified. These parameters are always uncertain, and different risk analysts (even among experienced risk analysts) may assign different values to each parameter. It is possible to standardize risk parameters, as has been done for risk estimation in Switzerland (EconoMe, FOEN, 2023), to improve consistency, but this would be a very involved and costly undertaking for a local government. Inconsistency in risk estimates can lead to conflicts and inconsistencies in development approval decisions, as well as potential legal challenges.</li> </ul> |

**Table D-3 Advantages and disadvantages of a combined hazard- and risk-focused framework.**

| Advantages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Disadvantages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> <li>• <b>Hazard Understanding:</b> Mapped hazard zones show how hazard characteristics change across the fan, giving applicants a clearer picture of risks.</li> <li>• <b>Transparency:</b> Hazard mapping helps development applicants understand likely requirements upfront.</li> <li>• <b>Focussed Site-Specific Assessment:</b> If watershed-scale assessments are available with sufficient detail, it allows QPs to concentrate on site-specific conditions.</li> <li>• <b>Knowledge Build for Authorities:</b> Shifting assessments from authorities to QPs enables approving authorities to compile assessments into a maintained knowledge base of hazard areas.</li> </ul> | <ul style="list-style-type: none"> <li>• <b>Broader-Scale Analysis:</b> Assessments often require watershed-scale studies beyond the boundaries of a single property.</li> <li>• <b>Duplicated Effort:</b> Independent applicants may repeat similar assessments, increasing overall effort unnecessarily.</li> <li>• <b>Limited QP Availability:</b> Similar to the risk threshold framework, applicants may struggle to find QPs with the necessary risk assessment expertise.</li> <li>• <b>Capacity Demands on Authorities:</b> Approving authorities still need the baseline understanding and resources to incorporate and manage applications.</li> </ul> |

## **D-2 HAZARD THRESHOLD FRAMEWORK**

### **D.2.1. Ministry of Transportation and Transit**

The BC Ministry of Transportation and Transit (MOTT; previously BC Ministry of Transportation and Infrastructure) is one example where a hazard threshold has been implemented. In 2009, MOTT produced a guidance document titled Subdivision Preliminary Layout Review. The policy document specifies a maximum tolerable hazard probability for various natural hazard types that could have life-threatening effects. Where life-threatening or catastrophic events are known to be a potential hazard to a building lot, QPs should consider events with an occurrence probability of 1 in 10,000 years. For large-scale developments, QPs must consider the same 1:10,000-year events and must also consider the total risk to the new development (Clague et al., 2014).

### **D.2.2. District of Squamish**

The District of Squamish is an example of a location where an initial hazard threshold was established to evaluate the construction of a mitigation structure to protect existing and future development in the area. A panel of risk experts was formed by the District of Squamish Council in 2013 to provide opinions related to the Cheekeye River debris flow hazard, triggered by an application for OCP amendment. The panel opined on the volume and frequency of future landslides, the character and volume of the 10,000-year landslide and the possible effects of climate change on future landslides (Clague et al., 2014). The panel concluded that the 1:10,000-year landslide was the appropriate event for estimating the largest debris flow that could affect the Cheekeye Fan and that it could carry 5.5 million m<sup>3</sup> of material. The panel recommended that, regardless of future development, existing development should be protected from large volume, low probability events and from small volume, high probability events. It was anticipated that events of different hazard probabilities would dominate risk to individuals on different parts of the fan, and the entire spectrum of events should therefore be considered.

The panel's policy recommendation was to consider up to a 10,000-year hazard scenario when considering the construction of a debris flow barrier. However, the District's development approvals are based on meeting risk tolerance thresholds, which are further described in Section .2 (Combined Hazard-Risk Threshold).

### **D.2.3. Fraser Valley Regional District**

To improve our understanding of the Fraser Valley Regional District's (FVRD) implementation of hazard policies, we completed an interview with a staff planner during the project. In the early 1990s, the Fraser Valley Regional District<sup>33</sup> (FVRD) developed a series of tables with hazard probabilities per hazard type (often called "Cave Tables") to guide land use decisions (Cave et al., 1990; Cave, 1992). In 2020, the FVRD published the tables as Hazard Acceptability Thresholds for Development Approvals. The FVRD engaged with QPs in developing the tables.

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<sup>33</sup> The Fraser Valley Regional District was called the Regional District of Fraser-Cheam at that time.

The tables include annual hazard probability categories against types of development, ranging from minor repair to subdivision and rezoning (see Figure -1 and Figure -2). A companion table, with levels 1 to 5, describes the development approval conditions. Together, these tables determine whether an application for a specific type of development would be approved, along with the conditions under which it would be approved, based on the hazard probability of the site. While the FVRD framework does not explicitly evaluate risk, risk concepts are implicitly incorporated through the creation of specific frameworks for different hazard types, where more destructive hazards are managed more conservatively. Within a given hazard type, the framework applies the same decision criteria irrespective of the destructiveness of the hazard.

|   |                                                                                                                                        |
|---|----------------------------------------------------------------------------------------------------------------------------------------|
| 1 | Approval without conditions relating to hazards.                                                                                       |
| 2 | Approval, without siting conditions or protective works conditions but with a covenant including "save harmless" conditions.           |
| 3 | Approval, but with siting requirements to avoid the hazard, or with requirements for protective works to mitigate the hazard.          |
| 4 | Approval as #3 above, but with a covenant including "save harmless" conditions as well as siting conditions, protective works or both. |
| 5 | Not approvable.                                                                                                                        |

**Figure D-1 Responses to guide land-use decisions (FVRD, 2020; Cave et al., 1990; Cave, 1992).**

### Debris Flow/Debris Torrent

Debris flows and torrents are rapid, saturated flows of coarse debris and mud, damaged trees, stumps, and smaller organic material. These flows may be contained in steep creek channels or they may spread out on debris fan surfaces. Debris flows and torrents can be life-threatening and damage or destroy property.



**Table 4**

|                              | 1:50 | 1:50-1:200 | 1:200-1:500 | 1:500-1:10,000 | <1:10,000 |
|------------------------------|------|------------|-------------|----------------|-----------|
| Minor Repair (<25%)          | 5    | 2          | 2           | 1              | 1         |
| Major Repair (>25%)          | 5    | 4          | 2           | 1              | 1         |
| Reconstruction               | 5    | 5          | 4           | 3              | 1         |
| Extension                    | 5    | 5          | 4           | 2              | 1         |
| New Building                 | 5    | 5          | 4           | 3              | 1         |
| Subdivision (infill/extend)  | 5    | 5          | 5           | 4              | 1         |
| Rezoning (for new community) | 5    | 5          | 5           | 5              | 1         |

**Figure D-2 Example hazard acceptability threshold used for development approval decisions in the FVRD (2020).**

Throughout the FVRD, bylaws have been used to create hazard DPAs based on the results of various overview hazard studies. Generally, the DPA guidelines describe the nature of the hazard and identify areas where further study by a QP would be required. Where required, a QP

completes a site-specific hazard assessment and proposes the approval rating level from 1 to 5. In specific areas of the region, the FVRD is completing more detailed hazard studies following OCP updates. In these areas, hazard mitigation will be prescribed in advance, with a QP study only needed if applicants disagree with the prescribed hazard mitigation measures. Where there are no DPAs, but the area is known to include hazards, the building department requires site-specific reports completed by QPs under Section 56 of the Community Charter and a covenant on title.

Guidelines in the DPA permit peer review of a QP study at the discretion of staff, with the cost covered by the applicant; however, this has been rarely applied. While staff at the FVRD do not assume the responsibilities of QPs, reviewing a typically high volume of reports in a given year helps FVRD staff compare the relative quality of each report they receive. They also rely on FVRD's Geohazard Assurance Statement for Development Approvals, which follows the Engineers and Geoscientists of BC's (EGBC) Professional Practice Guidelines on Legislated Flood Assessments in a Changing Climate in BC (EGBC, 2018) and Landslide Assessments in BC (EGBC, 2023).

FVRD staff described how they will be addressing challenges with the Hazard Acceptability tables in 2025. The categories of development (e.g., minor renovation, subdivision) are rigid and do not include changes to a parcel, such as the addition of an accessory dwelling unit. Land alteration, such as soil movement that does not accompany a development, is also not currently included.

## D-3 RISK THRESHOLD FRAMEWORK

### D.3.1. District of North Vancouver

In 2009, the District of North Vancouver (DNV) was the first local government in Canada to formally adopt and apply landslide risk tolerance thresholds for individual risk<sup>34</sup>. The risk tolerance thresholds were used to make decisions about mitigation for relatively small landslides (i.e., those affecting one or a few homes) that could impact existing residential development.

Figure D-3 summarizes DNV risk tolerance criteria for different applications. The Factor of Safety (FoS) criteria shown in Figure D-3 apply to dwellings founded on potentially unstable terrain, and are not relevant to hydrogeomorphic hazards at Cold Spring Creek and Fairmont Creek.

| Type of application                                                                | 1:10,000 + ALARP | 1:100,000 | FOS>1.3 (static) | FOS>1.5 (static) |
|------------------------------------------------------------------------------------|------------------|-----------|------------------|------------------|
| Building permit<br>(<25% increase to gross floor area)                             | x                |           | x                |                  |
| Building permit<br>(>25% increase to gross floor area and/or retaining wall >1.2m) |                  | x         |                  | x                |
| Rezoning                                                                           |                  | x         |                  | x                |
| Subdivision                                                                        |                  | x         |                  | x                |
| New development                                                                    |                  | x         |                  | x                |

**Figure D-3 Risk tolerance criteria from the District of North Vancouver.**

For minor redevelopment of an existing structure (i.e., <25% increase to gross floor area), the risk threshold is set at 1:10,000. For major redevelopment of an existing structure, the risk threshold is set at 1:100,000. This same threshold is also applied to rezoning, subdivision and new development proposals.

Both of these risk tolerance thresholds refer to individual life loss risk, not group risk. This is appropriate in the DNV context, given that the hazards in the DNV are likely to be relatively localized and will affect relatively few houses during any given event.

Anecdotally, the risk thresholds have been relatively straightforward to meet for existing development through economical mitigation measures such as drainage improvements and

<sup>34</sup> The District of North Vancouver did not adopt group risk tolerance thresholds.

removal of unstable fill slopes. For new development, the levels have been much harder to reach, resulting in the avoidance of landslide hazard zones for development. Significant work was undertaken with a community committee and QPs to develop risk tolerance thresholds in North Vancouver.

Although risk tolerance thresholds were defined for new development, the key decisions that led to the risk-based approach were about where and how much mitigation was required to protect existing homes.

## D-4 COMBINED HAZARD-RISK THRESHOLD FRAMEWORK

### D.4.1. Town of Canmore

In June 2013, heavy rainfall caused flooding on most rivers in southwest Alberta, including damaging debris flows and debris floods on multiple creeks in Canmore. Following immediate response and recovery efforts, Canmore commissioned detailed steep creek hazard mapping and risk assessment, updated policies and bylaws related to development in hazard lands, and constructed structural mitigation on select creeks. Canmore has built a 34-metre-high, water-retaining debris flood mitigation structure on Cougar Creek, which contains a developed fan with over 4,000 residents. Similar to RDEK and the District of Squamish, the mitigation structure is only one element of the comprehensive hazard strategy. Canmore's progress reflects over a decade of effort, with many millions of dollars invested in risk assessment and decision-making process development, and over \$100 million spent on structural mitigation projects.

Canmore's decision-making process for planning and development in hazard lands relies on three key documents that work together:

- **Municipal Development Plan (MDP):** long-term vision and policy direction for the community, including risk tolerance criteria for steep creek hazard areas.
- **Land Use Bylaw (LUB):** implements the MDP vision with legally enforceable rules for development, including steep creek hazard maps relevant for bylaw implementation according to risk tolerance criteria defined in the MDP.
- **Engineering Guidelines:** provide engineering design and construction guidelines for resilient development where permissible under the MDP and LUB.

Figure D-4 provides a flow chart describing how steep creek hazard maps and risk tolerance criteria are used in the development approval process. The steep creek hazard maps, which are hazard-based, define the necessary actions to be taken. The risk tolerance criteria are then used to determine if actions have met requirements. In other words, Canmore uses both hazard and risk thresholds in its decision-making process. A similar approach to that presented in the flow chart could be used throughout the RDEK to manage development on fans, which may or may not have suitable hazard mapping.

Canmore uses two kinds of hazard maps for decision-making:

- **Steep Creek 'study areas':** alluvial fan extents where detailed mapping does not yet exist. These define the likely extent of the hazard, but do not provide information about the intensity of the hazard within it.
- **Detailed hazard zone maps:** hazard maps with four zones: Extreme, High, Moderate, Low, and Residual. These define the extent of the hazard and rate the intensity of the hazard.

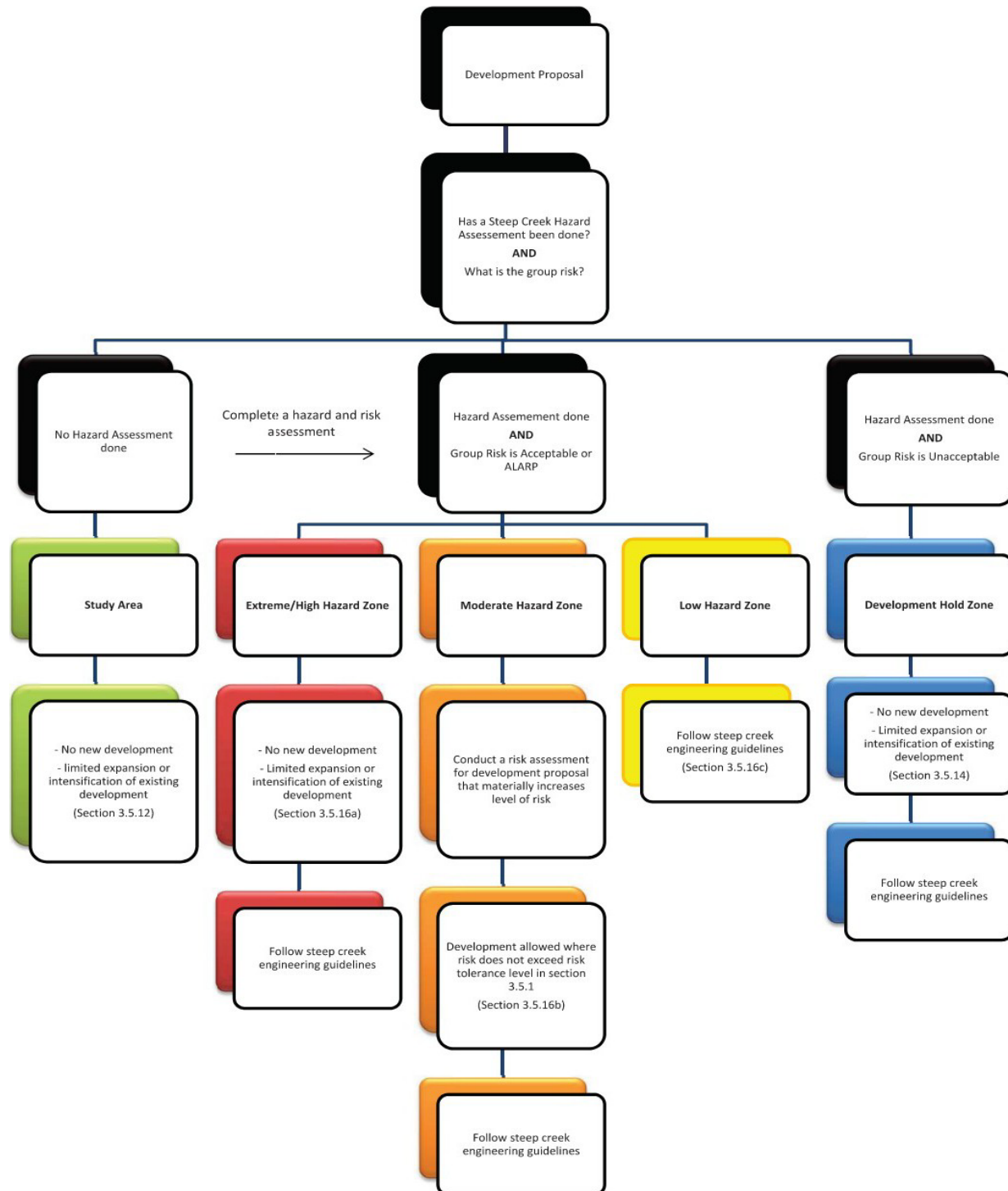


**Figure D-4 Canmore steep creek development flowchart.**

Methods to prepare Canmore's detailed hazard zone maps reflect work from about 2013 to 2018, and use a simplified approach compared to the more recent hazard mapping at Cold Spring or Fairmont Creeks (Section 3.4.3). The maps show the combined maximum credible flow intensities and extents for all studied return periods, and do not show hazard probability or

risk level<sup>35</sup> (in contrast, the Fairmont Hot Springs project area hazard maps are based on both flow intensity and hazard probability, enabling hazard zonation to more closely align with risk levels). The “residual” zone on the Canmore maps shows areas that have been protected by structural mitigation measures.

Hazard zones effectively distinguish decisions as ‘no’, ‘maybe’, or ‘yes’, consistent with the HSE (2001) risk framework. The Extreme/High hazard zone allows no new development, and expansion or intensification of existing development is limited to no material increase in hazard or risk. Lower relative land use intensities are defined for this zone. In the Moderate hazard zone, development can proceed where a risk assessment shows how risk tolerance criteria can be met, as described in the MDP. In the Low hazard zone, development may proceed according to Canmore’s engineering guidelines. However, staff may require a risk assessment where a proposed development may increase the level of group risk above the reference line or has significant economic loss potential.

The MDP defines risk tolerance criteria as follows, and group risk is evaluated based on a society risk evaluation tool (Figure D-5) defines a reference line of increasing and decreasing benefits of risk reduction:

For new development:

- The individual risk (PDI) shall not exceed 1:100,000 (this is consistent with the DNV’s risk threshold for new development).
- Group risk shall be at or below the reference line of Figure D-5. For comparison, the group risk at the reference line reaches 1:100,000 at 100 potential fatalities, meaning that so long as the anticipated number of fatalities for a single event is less than 100, the individual risk threshold of 1:100,000 effectively determines the risk threshold that needs to be met.

For existing development:

- The individual risk (PDI) shall not exceed 1:10,000 (this is consistent with DNV’s risk threshold for existing development).
- Group risk shall be reduced as much as possible to near the reference line of Figure D-5, considering the cost-benefit and cost-effectiveness of the mitigation. For comparison, the group risk along the reference line has a value of 1:10,000 for 10 potential fatalities.

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<sup>35</sup> Holm et. al., 2018. Steep Creek Geohazard Risk and Risk Control Assessment in the Town of Canmore, Alberta.

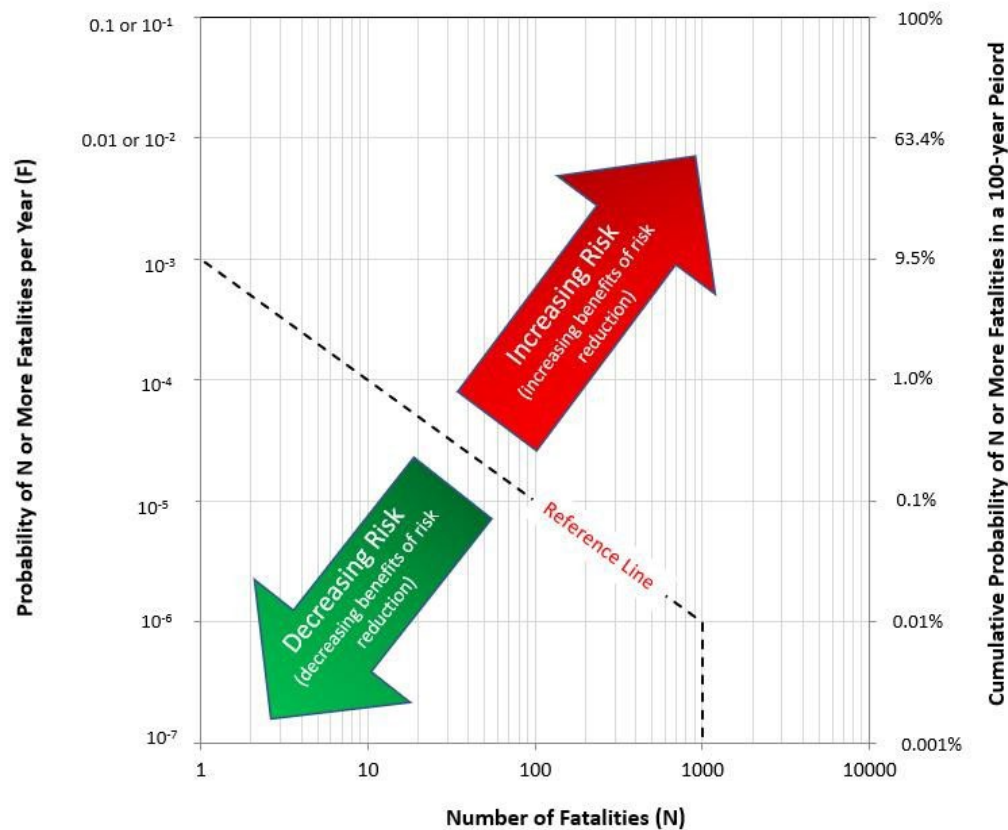


Figure D-5 Societal risk evaluation tool. Modified from Strouth et al. (2022).

#### D.4.2. District of Squamish

A combined hazard and risk framework is also used to manage development on a fan in Squamish, British Columbia. The Cheekeye Fan in Squamish is a desirable location for development; however, extensive studies have found that the fan is susceptible to rainfall and debris flows generated by rock avalanches from a nearby mountain. Debris flow event magnitudes are estimated at up to 5.5 Mm<sup>3</sup> for the upper-bound events. The local government adopted a life loss risk tolerance threshold that needed to be met as a condition for allowing new development on the fan. Currently, the District of Squamish employs various policy elements working together to address the debris flow hazard including OCP hazard policies, a Flood Hazard DPA in the OCP Bylaw that includes a section on debris flow hazard (OCP page 203), mapped hazard intensity categories (OCP Schedule D-1) with corresponding development stipulations, and a Terms of Reference for Natural Hazard and/or Risk Assessments<sup>36</sup>.

Ahead of the 2010 Olympics, the Province and the Squamish Nation signed an agreement that granted the Nation development rights to a portion of land in Squamish, including part of the Cheekeye fan. Development of the area had previously been prohibited, as reflected by the land use designations in the OCP, due to a recognized debris flow hazard on the fan. In

<sup>36</sup> Terms of Reference for Natural Hazard and/or Risk Assessment:  
<https://squamish.ca/assets/Planning-forms/20220912-Terms-of-reference-flood-hazard-assessments.pdf>

approximately 2014, a development partnership applied for an OCP amendment to change the land use from resource and recreational use to residential. Over the next decade, the District of Squamish undertook an expert review of the debris flow hazard and developed hazard-related policies and bylaws to protect existing and new development, as well as to guide the construction of a mitigation structure. Squamish issued interim development policies for the fan in 2014, which have now been incorporated into the updated OCP.

The OCP includes a set of risk tolerance criteria similar to those used by the Town of Canmore:

- Existing development: individual risk <1:10,000.
- New development: individual risk <1:100,000.
- Group risk shall be broadly acceptable or As Low As Reasonably Practicable (ALARP). Where group risk falls in ALARP, the risk assessment must demonstrate why the cost of further reducing the risk is disproportionate to the benefit.

A hazard-based approach was used to define different hazard levels on the Cheekeye fan. The mapping divides the Cheekeye Debris Flow hazard into 5 Zones (C1 to C5) using a composite of hazard intensity across all possible scenarios. Area-wide mitigation of the debris flow hazard is currently under construction, and the policies that apply to each of the hazard zones reflect the current hazard and risk, not the future mitigated hazard and risk on the fan. In the absence of area-wide mitigation, no subdivision, habitable space, or permanent structures are allowed in the two highest hazard categories (C1 and C2). No rezoning or subdivision that will create more than three lots is allowed in moderate hazard zones C3 and C4 until new hazard mapping and appropriate development controls are in place. In the low-hazard zone (C5), rezoning and subdivision creating more than three lots or building permits for more than three dwelling units are allowed with a QP report. Less intensive land uses (other than residential) are also permitted with a QP report.

Once the area-wide mitigation is in place, the OCP policies direct Council to amend the development controls (as above) in the OCP and update hazard mapping. Development will still need to meet OCP risk tolerance criteria.

The Squamish DPA 2 for Flood Hazard in the OCP Bylaw includes a section for Debris Flow Hazard Areas as mapped in Schedule D-1 of the OCP (C1 to C5 Zones). The Bylaw requires a risk assessment report prepared by a QP in accordance with the District's Terms of Reference for Natural Hazard and/or Risk Assessments. The determination of whether to do a quantitative or qualitative risk assessment is made by the QP in consultation with the District and EGBC Professional Practice Guidelines on Legislated Flood Assessments in a Changing Climate (August 28, 2018) and Landslide Assessments in British Columbia (March 1, 2023), and in consideration of the scale of the hazard and proposed development and site conditions. There are minimum requirements for the risk assessment, including that the QP certify that the risk tolerance criteria in the OCP have been met. A compliance and completion report, prepared by a QP, is required to certify that construction or development is in general conformance with the plans submitted with the development permit.

BGC completed the design of a debris-flow barrier for a land developer to meet the District of Squamish risk tolerance threshold. The barrier is designed to protect existing and new development in the Cheekeye debris flow hazard zone. Construction is currently underway, with design and construction costs exceeding \$100 million.

# **APPENDIX E**

## **ON-SITE MITIGATION MEASURES FROM CANMORE**

### **EDCG**



Examples of on-site mitigation measures from the Canmore's Engineering Design and Construction Guidelines are included in Table E-1.

**Table E-1 On-site mitigation measures from the Canmore EDCG.**

| Measure                            | Description                                                                                                                                                                                                                                                                                         | Reference Material                                 |
|------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|
| Minimum floor elevations           | Established to ensure that the habitable space of a development is higher than the modelled flood levels.                                                                                                                                                                                           | Section 9, Pages 9-4 to 9-6, Figure. 9-1           |
| Minimum building opening elevation | The concept is similar to the minimum floor elevation. Building openings refer to window wells, garage doors, door entrances, and the top of foundation walls.                                                                                                                                      | Section 9, Page 9-4 to 9-6, Figure. 9-1            |
| Driveways                          | Driveways sloping towards the building are discouraged                                                                                                                                                                                                                                              | Section 9, Page 9-6                                |
| Raising the Lot                    | The development is not exposed to the hazard when raised above the modelled flood level.                                                                                                                                                                                                            | Section 9, Pages 9-7 to 9-9, Table 9-2, Figure 9-3 |
| Fuel Storage                       | Fuel storage containers, private pumping stations and any other external service installations with mechanical or electrical parts should be raised and secured at or above the minimum floor elevation.                                                                                            | Section 9, Page 9-9                                |
| Temporary flood protection         | Preventing floodwater ingress into a building to minimize the impact of and to give occupants more time to relocate ground-floor contents.                                                                                                                                                          | Section 9, Pages 9-9 to 9-10                       |
| Grading & Drainage                 | Landscaping of a development site or property boundary to direct or divert floodwater away from buildings.                                                                                                                                                                                          | Section 9, Page 9-10                               |
| Basement & Below Grade Spaces      | Due to the potential harm to building occupants, flood-proofing of spaces below the top of the foundation wall should be avoided. Walk-up basements, which feature a sunken entrance or dug-in stairs that extend from ground level down to the basement, should be avoided as an entry/exit point. | Section 9, Page 9-10                               |
| Foundation Design                  | The foundation design should consider the anticipated flood loads, potential debris impact loads, and scouring of foundation walls.                                                                                                                                                                 | Section 9, Page 9-10, Table 9-3, Table 9-4         |

| Measure                         | Description                                                                                                                                                                                                                                                                                                                               | Reference Material              |
|---------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|
| Window Wells                    | The window well drainage system should minimize the likelihood of water accumulation in the well. The contact between the window well and the foundation should be sealed. The top of the window well should extend at least to the Minimum Building Opening Elevation. Grades around the window well must slope away at a minimum of 2%. | Section 9, Page 9-13            |
| Waterproofing Measures          | Waterproofing of foundation walls significantly increases the flood resistance of a building and can be adopted for buildings in steep creek hazard zones.                                                                                                                                                                                | Section 9, Page 9-13 to 9-14    |
| Flood-resilient building design | Flood-resilient buildings, also known as wet-proofing, are designed and constructed to minimize the impact of floodwater entering the building, thereby causing minimal permanent damage, maintaining structural integrity, and facilitating easier drying and cleaning.                                                                  | Section 9, Page 9-14, Table 9-5 |