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CLIMATE RISK INSTITUTE
Institute for Catastrophic Loss Reduction
Building resilient communities
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PIEVC META ANALYSIS

VOLUME 3: THE ROLE OF CODES AND STANDARDS

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Table of Contents

1. Purpose of this Volume

To achieve the intended long-term performance of infrastructure assets, the professionals who plan, design, build, operate, and maintain them need to integrate climate change adaptation considerations into workflows and management frameworks. Infrastructure codes and standards can play important roles in this regard, by specifying structural design, material, maintenance, and performance requirements that improve how climate-related hazards and conditions are considered in infrastructure development and management processes.

Since 2016, with core financial support from Housing, Infrastructure and Communities Canada (HICC), Canada's National Codes and Standards System has developed numerous new infrastructure standards, updated existing ones, and provided future-projected (climate change-informed) climate design values for the National Model Building Code of Canada, all to improve the climate resilience of our buildings and infrastructure.

This Volume (3) of the PIEVC Meta-Analysis reports on the findings of research focused specifically on better understanding: (i) whether and how codes and standards have been used by or referenced within PIEVC-based climate change vulnerability and risk assessments (CCVRAs), (ii) whether and how codes and standards have helped inform adaptation recommendations or actions related to these assessments, and (iii) opportunities to advance the role of codes and standards in PIEVC assessments and adaptation processes more generally. Findings from the Desktop Review of PIEVC assessments are reported in Section 3. Section 4 provides findings from interviews conducted for the set of PIEVC Case Studies (Volume 2). Drawing upon information from both the desk-top and interview-based analyses, Section 5 highlights opportunities to improve climate risk assessment and adaptation processes through new or revised codes and standards. First, Section 2 provides a brief introduction to infrastructure codes and standards and their role in fostering the climate resilience of infrastructure systems.

2. Codes, Standards, and Climate Resilient Infrastructure

What are standards?

According to Standards Council of Canada (SCC; 2024), a standard is a document that provides a set of agreed-upon rules, guidelines or characteristics for products, processes, or services. Standards establish accepted practices, technical requirements, and terminologies across and very diverse range of fields. They can be mandatory or voluntary and are distinct from Acts, regulations and codes; although standards can be referenced in these legal instruments.

Most standards aim to achieve an optimum degree of order or performance within a given context. Because they are easy to recognize and reference, standards enable organizations to ensure their products and services are developed and delivered in a consistent and defensible fashion (SCC, 2024).

Standards can be either voluntary or mandatory:

- they are voluntary when organizations are not legally required to follow them but may choose to follow them to meet customer or industry demands;
- they are mandatory when they are referenced within laws or regulations, often for health or safety reasons (SCC, 2024).

Standards are distinct from codes, acts, and regulations:

- Codes are broad in scope and intended to carry the force of law when adopted by a provincial, territorial or municipal authority; *voluntary standards* can become mandatory through reference in one or more Codes.
- Acts are statutes that establish control or directives based on legal authority, generally based on the development of related regulations.

- Regulations are statutory instruments with binding legal effects; *voluntary standards can become mandatory* when referenced in one or more regulations (SCC, 2024).

There are many types of standards, including:

- Performance standards, used to evaluate the ability of products, including infrastructure components and systems, to meet required levels of performance, by modelling or directly testing them under specified service conditions.
- Design standards**,** used to specifying design or technical characteristics of a product, including infrastructure components and systems.
- Management system standards, used to define and establish organizations quality and condition policies and objectives, including, e.g., with respect to the maintenance of infrastructure.
- Service standards, used to specify the requirements for a service and establish its fitness for purpose. There are service standards for infrastructure-related services of, e.g., municipal utilities (SCC, 2024).

How can standards enhance the climate resilience of infrastructure?

Standards can help enhance the climate resilience of infrastructure in various ways.

Design and Construction: Standards can specify infrastructure designs that better withstand extreme weather events, such as floods, wind events, or heatwaves. This can include specifying materials, designs and construction methods that improve durability and/or performance.

Vulnerability and Risk Assessment: Specific standards may require or support the conduct of vulnerability and risk assessments that consider climate-related hazards and the effects of climate change, helping identify vulnerabilities and changing levels of exposure, to inform decisions about infrastructure locations and designs.

Monitoring and Maintenance: Standards can establish protocols for ongoing monitoring and maintenance, ensuring that infrastructure remains functional and resilient over time, especially as climate conditions change.

Adaptability: By incorporating flexibility into design standards, infrastructure can be more easily modified or upgraded in response to evolving climate conditions and scientific knowledge.

Interoperability: Standards can help ensure different systems and technologies work together, facilitating a coordinated response to climate impacts across various sectors, such as transportation, energy, and water management.

By following climate change-informed standards, communities can create infrastructure that is not only robust against current climate hazards but also resilient and adaptable to future changes.

3. Findings of the Desk-Top Review

Main codes and standards-related findings of the desk-top review relate to the use of codes and standards to define impact thresholds for PIEVC assessments, vulnerabilities stemming from infrastructure designs based on climatologically outdated codes and standards, and opportunities for codes and standards to increase the resilience of assessed infrastructure assets.

Use of codes and standards to establish impact thresholds for assessments

Many PIEVC assessments indicate that infrastructure assets will be impacted by climate change because the climate load(s) for which they were designed - the "climate design load(s)" - will be more frequently and/or significantly exceeded over time; **impact thresholds** will be triggered.

As Figure 1 depicts, PIEVC assessments identify **vulnerabilities** if, over the anticipated service life of the infrastructure, climate loads may exceed the structural or performance capacity of the system. The point at which the climate load exceeds capacity – whether structural capacity to sustain the load, or capacity to otherwise provide the same level of service – is called the **threshold value.**

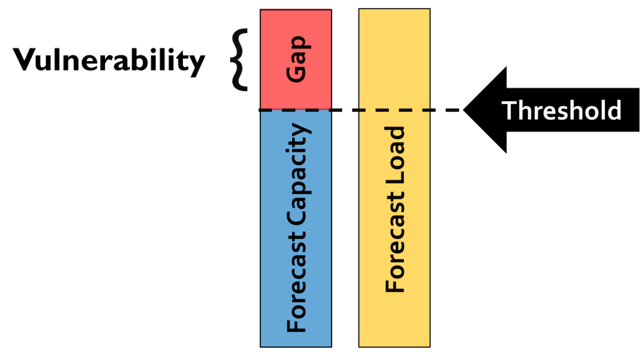

Figure 1: Defining thresholds in PIEVC Assessments

For example, an assessment may identify 'extreme heat' as a concern for the performance of a building because of the capacity of its heating, cooling and ventilation (HVAC) system. The assessment team must therefore define the specific extreme heat condition they will assess, e.g., daily maximum temperature > 35°C, and determine the current and future likelihood of its occurrence.

The specific measure(s) of hazard condition(s) for use in PIECV assessments (e.g., >35°C in the example above) should be, where possible, informed by the original design reports of the infrastructure in question, since these reports generally specify the code or standard upon which the design was based and, therefore, the specific climate design value(s) used.

Our desktop analysis indicates mixed results in this regard. Of the 72 reports reviewed, 26 reference the specific code(s) or standard(s) used to inform the choice of impact threshold(s) for their assessments, while 46 do not. In some cases, reports lack these references because assessments teams were unable to access the design documents of the infrastructure they assessed. In other cases, assessment team opted to use indices and thresholds from prior, comparable PIEVC assessments[1] or based on other information.

Appendix A provides a full listing, by asset class, of PIEVC assessment reports that specify the codes and standards used to inform the choice of assessment threshold values, and the specific climate indices and values they referenced.

Outdated codes and standards are linked to vulnerabilities

Many assessment reports (64/72) include findings that tie – sometimes *explicitly* but more frequently *implicitly* – specific infrastructure vulnerabilities to the use of now outdated codes and standards, most often because of prescribed climate design values[2] for which the likelihood of exceedance has increased over time.

Ideally, PIEVC assessments would provide explicit and *specific* indication of any shortcomings in the codes and standards that governed or govern how the assessed infrastructure was planned, designed, developed, or managed, and thereby contribute(d) to one or more climate-related vulnerabilities. In particular, they would identify the code(s) or standard(s) in question, specifying, for example: (a) the magnitude of the climate event for which the system was designed and the basis of this design value within the referenced standard; (b) changes in the design event and how this deviates (or not) from the guidance of the referenced standard; (c) potential implications of outdated design values for the asset and its delivery of services; and, (d) whether required adjustments to the related code or standard can be accomplished through updates to the

[1] This practice is generally discouraged since even if two assets are of a similar nature or located in nearly the same location, they may have been designed using different climate load assumptions.

[2] Or methods for computing these values, assuming that historical frequencies of climate events of different magnitudes could also be the basis for computing the likelihoods of these event types during future time periods; i.e., assuming static (as opposed to changing) climate conditions.

specified design values (including through use of future-projected values based on data from ensembles of downscaled climate model outputs) or may require other modifications as well.

However, in many cases the findings in PIEVC assessment reports lack the level(s) of specificity indicated above and may therefore be less useful for informing modifications to the codes and standards in question.[3] Along these lines, the excerpts below illustrate findings that link outdated or otherwise inadequate codes and standards to climate change-related infrastructure vulnerabilities and risks, but lack the level of specificity needed to formulate a particular change:

- "Information on existing pipe capacity was not available to the assessment team. In the absence of these design specifications, discussions [about past impacts on the system] were used to understand the potential impact of increased loads [under climate change] and determine the design standard is likely outdated."
- "The electrical components of the asset [are vulnerable because they] were designed to operate within specific temperature ranges [based on the standard of the day]." (The temperature range was not specified in the report, nor was the name or year of the specific standard.)
- "The design approach has typically been based on historical values for these climate variables and design standards outlined by the Canadian Standards Association; however, historical data does not necessarily reflect future climate conditions and available design standards do not necessarily account for local climate conditions or regimes." (The names and years of the design standards are not provided.)

[3] In fairness, PIEVC assessments have not to date been carried out first and foremost with this particular objective in mind.

Opportunities for codes and standards to increase infrastructure resilience

Though PIEVC assessment reports vary considerably in how and to what extent they characterize linkages between specific codes and standards and the climate-related performance of the infrastructures they assess, nearly all PIEVC assessments include in their reports the *general recommendation* that related codes and standards be revised to better consider climate change. Most PIEVC practitioners clearly appreciate the *potential* for codes and standards to improve the resilience of infrastructure systems but are little focused[4] on providing codes- and standards-related recommendations tailored to inform particular modifications to these instruments, including, for example, to local standards in accordance with national guidelines for the use of future-projected climate information.[5]

Though the PIEVC assessment reports themselves do not *explicitly* identify many new opportunities for codes and standards to advance infrastructure resilience (beyond updates to the design values they reference), Section 5 synthesizes assessment report and interview results to describe a range of potential opportunities for new climate resiliency-focused standards and guidelines.

4. Findings from Case Study Interviews

Interviews conducted with PIEVC practitioners and asset owners (see Volume 2, Case Studies) directly addressed the role of codes and standards in PIEVC assessments, climate risk assessment

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[4] A function of the ToRs of PIEVC assessments and the lack of resourcing to support more in-depth consideration of the design basis of the assessed infrastructure systems.

[5] Charron, I. (2016). A Guidebook on Climate Scenarios: Using Climate Information to Guide Adaptation Research and Decisions, 2016 Edition. Ouranos, 94p.; Cannon. A. J. et al. (2020). Climate-resilient buildings and core public infrastructure 2020: an assessment of the impact of climate change on climatic design data in Canada. Environment and Climate Change Canada, 106p.

more generally, and infrastructure resilience. Participants were asked about their awareness of climate resiliency-focused standards, the role of codes and standards in PIEVC assessments, and codes and standards as enablers and barriers to climate resilient infrastructure.

Awareness of climate change-informed standards

Most participants were generally aware of several initiatives currently focused on incorporating climate change considerations into codes and standards, but few had detailed knowledge of the climate change-informed codes or standards of most potential relevance to their areas of practice or mandates, respectively.

The Northern Infrastructure Standardization Initiative (NISI) was touted by several respondents during an interview regarding a PIEVC assessment of community assets in the Yukon. One respondent commended NISI for making its standards free of charge. However, further discussion revealed NISI standards may be little used until they become referenced in relevant codes and other regulations.

Various interviewees confirmed they had knowledge of efforts to update climate design values in the National Model Building Codes. Across all respondents, various asset owners and practitioners said project design engineers are unlikely to consider climate change until the regulator in their jurisdiction (province or territory) makes it an explicit requirement.

Notably, none of the respondents raised, without prompting, the growing set of climate resiliency-related standards developed outside the above-mentioned initiatives (NISI, National Model Building Code). For a full list of resiliency standards supported by Housing, Infrastructure, and Communities Canada (HICC), the Standards Council of Canada (SCC), and the National Research Council (NRC) – developed by accredited Canadian Standards Development Organization – see Appendix B.

Codes and standards as facilitators of adaptation actions

Several respondents emphasized the importance of promulgating more process- and performance-based standards to foster flexible and context-specific approaches to climate risk assessment and adaptation. Two of these respondents considered the PIEVC Protocol a useful model, where a future national standard of Canada could be developed for climate and *infrastructure* risk assessment, specifically. As one PIEVC practitioner noted, "climate change vulnerability and risk assessments should follow a basic roadmap or set of rules, but also allow [the flexibility] to adjustment based on context, data availability, and the decisions the assessment is meant to support." Another practitioner said that while the ISO 14090 series of standards provides a good general basis for climate risk assessment and adaptation, the PIEVC Protocol (and family of resources) provides more specific supports and examples that are particularly helpful to practitioners focused specifically on infrastructure and natural assets.

Respondents representing two different major asset owners indicated that while national-level, climate change-informed codes and standards provide an important basis for updates to their provincial, territorial and local equivalents, in some cases provincial and local codes and standards have taken the lead.

Finally, despite a call by certain respondents for more national standards supportive of adaptation, relatively few expressed any general awareness of the large set of standards, specific to climate resilience, listed in Appendix B.

Outdated codes and standards can pose obstacles to adaptation

Several respondents noted that codes and standards can pose obstacles to advancing climate resiliency if they "lock in" outdated assumptions about the climate and may therefore need to be updated on a more frequent basis. For example, based on their 2010 PIEVC assessment of two Toronto area dams, the asset owner intended to implement upgrades, as required, based on an anticipated set of climate change-informed design and performance standards. Since 2010, several research initiatives have been launched, including a 2022 study by CSA Group on Climate

Change Adaptation for Dams. However, at the time of writing, Ontario provincial standards and bulletins have yet to incorporate climate change, and no national guidelines for climate change and dam adaptation had been released.

In other cases, the complete lack of standards can present a barrier to the use of innovative solutions. For example, standards do not yet exist for designing and implementing Nature-based Solutions (NbS). This has resulted in many engineers avoiding NbS because of concerns over the potential for legal liability resulting from the use of "un-codified" practices; approaches that have yet to be formally described and recognized as safe and defensible practice through Canada's formal standards-setting processes.

Resiliency benefits discounted if not substantiated

A respondent from a major provincial asset owner indicated, "the transition from design to construction can often lead to 'value engineering' [that removes resiliency measures] if their significance and benefits are not adequately communicated or understood during the [design-to-construction] handover process." Various respondents emphasized the need to demonstrate the "return on investment" of any resiliency measure, because of the persistent reality of competing financial priorities.

5. Opportunities for new Guidelines and Standards

Drawing on the desktop analyses conducted for Volume 1, and insights from case study (Volume 2) respondents, this Section describes opportunities for new guidelines and standards that could help reduce climate change and infrastructure-related vulnerabilities or otherwise improve the management of related risks. Opportunities are organized according to three categories: 1) Management and Assessment Process-Related Standards; 2) Technical Resiliency Standards; and, 3) Accreditation Standards for new Personnel Credentialling.

1. Management and Assessment Process-Related Standards

Emergency Management: A recommendation common to most PIEVC assessments is that infrastructure owners and operators better coordinate with relevant emergency management personnel to ensure risks exacerbated by climate change are adequately understood and reflected in the emergency management plans of the organization; particularly with respect to infrastructure access, repairs, and the continuity of critical services. Canada has a national standard for emergency preparedness and response, CAN/CSA-Z731-03 (R2014). Others similar standards exist for specific sectors, like CAN/CSA-Z246.2-14 for the oil and gas sector. It is not clear whether these standards adequately support the effective consideration of climate change in emergency preparedness and response planning. ***There is an opportunity*** to review these standards and their influence on practice, and to adjust or augment them as needed with new climate change-related guidance. Furthermore, by better bridging between emergency management and climate risk assessment practitioner communities in standards-setting processes, further insights can be gained into the emergency scenarios for which preparedness and response capacity should ultimately be built, and into the relative merits of investing in resiliency, and specific disaster prevention and mitigation measures up front.

Forensic Analysis: Forensic analysis of infrastructure failures, and critical reductions in service levels associated with the impacts of extreme weather events is a useful tool for understanding infrastructure vulnerabilities and informing resiliency planning. PIEVC practitioners frequently express interest in opportunities for improving access to forensic information. Forensic analyses of climate-related impacts require multidisciplinary teams, clear processes for the collection, management, and analysis of data, and, ultimately, common approaches for describing and reporting on failure mechanisms. Currently, there is no common standard in Canada for carrying out and reporting on climate and infrastructure-related forensic analyses. ***There is an opportunity*** to further consider the usefulness of a climate and infrastructure forensic analysis standard for Canada, and eventually pursue its development.

Climate and Infrastructure Risk Assessment: The main standard for climate change risk assessment is ISO 14091. This standard is not particular to infrastructure systems. The PIEVC Protocol and Family of Resources constitute the most comprehensive known set of guidance particular to climate change and infrastructure risk assessment. Furthermore, the PIEVC Protocol is well tested, having been applied many hundreds of times across Canada, as well as abroad. ***There is an opportunity*** to consider standardizing key aspects of the PIEVC Protocol and/or other parts of the Family of Resources (Large Portfolio Assessment Manual, PIEVC Green Protocol). The Protocol was recently updated (2024) to reflect the evolution of PIEVC practice and climate risk assessment terminology, respectively, over recent years. Through a number of respondents expressed interest in a PIEVC-based standard, the same practitioners argued that any such standard should maintain comparable flexibility as the Protocol itself.

Furthermore, ***there is an opportunity*** to develop targeted guidance documents to better support PIEVC and other climate risk assessment practitioners with specific aspects of the climate risk assessment process, or with assessments of mixed (old and new) systems, as follows:

- *Consequence Scoring*: Volume 1 highlights the periodic use by PIEVC practitioners of overly ambiguous consequence criteria, definitions and metrics. More specific guidance could be provided for how to develop clearer consequence criteria, definitions, and metrics; and an information circular could be developed to help demonstrate the misleading information that can result from using overly ambiguous consequence criteria, definitions, and metrics.
- *Risk Treatment*: Various respondents noted the need for further guidance or standards to support the evaluation and implementation of specific risk treatment options once these options are identified through PIEVC or other assessment processes. As evidenced by Appendix B, various standards are being developed to help address this gap. But there remains a need to develop further asset- and hazard-specific guidance and standards of this nature (see, e.g., "Technical Resilience Standards" below).
- *Cascading Impacts and Risks*: Various PIEVC practitioners identified the need for more guidance on how to assess cascading impacts and related risks. While the PIEVC Green Protocol describes the use of impact chains for this purpose, there have been few examples

of its application. There remains a need to help advance best practice and develop standardized methods for assessing and communicating about cascading climate impacts and risks in general and cascading climate-and-infrastructure related impacts and risks in particular.

- *Assessing Integrated "New and Old" Infrastructure Systems*: Increasingly, climate change risk assessments are being conducted on *proposed* infrastructure – at the conceptual and design stages – as opposed to assessing mostly *existing* systems and the risks they pose because of climate change. Though this is an important step towards improving the climate change resilience of infrastructure, many new assets themselves rely on already existing, older systems. For example, a new wastewater treatment plant designed to withstand threats exacerbated by climate change may still be vulnerable if serviced by a network of older sewers with significant inflow and infiltration. New guidance could seek to better support the assessment of climate change risks related to integrated "new and old" infrastructure systems.

2. Technical Resiliency Standards

Volume 1 concludes that the level of detail in the climate adaptation recommendations of PIEVC reports varies considerably and, in some instances, may not support immediate action. Meanwhile, infrastructure standards are being updated and new ones developed specifically to address the threats posed by climate change, with linkages to specific climate hazards, vulnerabilities, and related risks. In certain instances, these new and updated guidelines and standards may present immediately actionable solutions for mitigating risks identified by PIEVC assessments. ***There is an opportunity*** to (1) help ensure the growing set of resiliency standards (Appendix B) are better known and properly reference by PIEVC practitioners, and, (2) ensure further resiliency standards are prioritized and developed based on risk-informed insights gained through PIEVC and other climate change risk assessment processes. Already, a database of climate resiliency codes, standards, and guidelines is under development by Housing, Infrastructure, and Communities Canada (HICC). ***There is an opportunity*** to consider linking this HICC database with, for example, other digital resources of the PIEVC Practitioners Network.

Flood Protection Standards: Among the most frequently reported risks across PIEVC assessments are those associated with extreme rainfall and flooding. In response, most PIEVC reports make recommendations for how to address the potential impacts of flooding through:

- **Design measures** for specific asset types.
- **Remedial measures,** like (re)installing infrastructure components based on an upwardly-adjusted freeboard.
- **Management measures**, like the more routine cleaning of culverts, to prevent blockages that lead to overflows.
- **Policy measures,** like encouraging lot-level control strategies to reduce runoff.
- **Additional study,** like investigating design reserve capacity of the drainage network to handle changing hydrology driven by more severe local rainfall events.

Standards related to flooding need to target both broad-scale issues – to help ensure that, e.g., community-level planning better reduces flood risks – and site-specific opportunities – like flood protection measures for particular asset types.

Several guidelines and standards now exist to help address or understand risks related to climate change, flooding, and infrastructure in Canada, including CSA W204:19 Flood resilient design of new residential communities, CSA W210:21 Prioritization of flood risk in existing communities, CSA PLUS 4013: 19 Development, interpretation and use of rainfall intensity-duration-frequency (IDF) information: Guideline for Canadian water resources practitioners, and CSA 503:20 Community drainage system planning, design, and maintenance in northern communities. Few references were made to these guidelines and standards in the PIEVC assessments we reviewed, despite their frequent identification of flooding among the highest risk hazards. ***There is an opportunity*** to encourage future PIEVC assessments to consider these new flood protection guidelines and standards, and to recommend their use to help address the risks prioritized for treatment. Furthermore, ***there is an opportunity*** to develop further flood protection standards, asset-type-by-asset-type.

Standards for Nature-Based Solutions (NbS) and Low Impact Development (LID): As discussed above (Section 4), the lack of standards for NbS has encumbered implementation of such measures. PIEVC practitioners reported the rejection by regulators of innovative climate resilience approaches like living shorelines because of the lack of related standards. ***There is an opportunity*** to consider moving from guidelines (see Appendix B, numbers 43-49) to standards to support different aspects of professional practice in this domain.

In the Marda Loop Case Study (see Volume 2), the PIEVC assessment included a recommendation for the use of permeable pavers. Because permeable pavers had at that time not yet been used in Calgary, the recommendation was met with skepticism about the feasibility of maintaining the pavers and sustaining their permeability. Though Calgary was ultimately able to work with experts to develop its own guidelines for the care and maintenance of pavers, smaller municipalities will not generally have the resources to develop similar guidance. ***There is an opportunity*** to develop national standards for the design and maintenance of various low impact development techniques, including consideration of the impacts of climate change on their performance and return on investment.

Standards for Priority Design-Related Risks to Institutional Buildings: Thus far, more buildings assessments have been conducted using the PIEVC Protocol than have assessments of any other category of infrastructure. Reportedly, Public Services and Procurement Canada (PSPC) itself has used the Protocol for more than 180 federal building assessments. Though buildings may be vulnerable to numerous types of climate hazards and climate change-related impacts, high intensity short-duration rainfall and heat events contribute to the largest numbers of high-risk ratings across PIEVC assessments of buildings. High risks associated with rainfall are primarily related to roof and site drainage systems; those associated with heat events often relate to the underperformance of HVAC systems (cooling), health threats to outdoor workers, and the premature degradation of building materials. ***There is an opportunity*** to build off existing national guidelines in these areas (see Appendix B, numbers 9, 11, 12 for example) to set new standards of Canada.

Leveraging NISI Standards in Northern PIEVC Assessments: NISI has produced numerous highly relevant resources for infrastructure practitioners working in Northern Canada. Infrastructure practitioners practicing in northern jurisdictions need to develop further awareness of these resources, and of their utility for northern PIEVC assessments and related recommendations.

There is an opportunity to consider whether a guidance document could be prepared to make direct linkages between steps of the PIEVC Protocol and, for example, BNQ 9701-500, "Risk-based Approach to Community Planning in Northern Regions." Such a document could be useful for infrastructure projects particularly at the conceptual design stage, since BNQ 9701-500 focuses on community planning and therefore supports decision-making related to, for example, locating new assets; PIEVC results can help inform such processes.

Furthermore, ***there is an opportunity*** for PIEVC assessments conducted in Northern Canada to improve upon the specificity of their recommendations, making it more likely the recommendations can be implemented, by consulting and drawing upon one or more of the northern hazard-specific management standards developed through NISI. For example, in communities for which erosion is identified as a high-priority risk, PIEVC assessment teams should likely consult CSA W205, "Erosion and Sedimentation Management for Northern Community Infrastructure" to help inform their recommendations and plans. Under NISI, hazard-specific risk management standards have also been developed for the snow-overload of buildings, coastal storm surge, and permafrost thaw. All NISI standards are included in Appendix B.

3. Accreditation Standards for Organizations to Certify Climate Resiliency Professionals

As the demand in Canada for climate risk assessment and resiliency services threaten to outstrip the supply of personnel experienced in such work, those who procure these services are likely to be interested in ways to more reliably distinguish between well- and less well-qualified service providers. Already, certain procurement offices in Canada have advantaged bidders who can demonstrate inclusion of, e.g., one Infrastructure Resiliency Professional (IRP) qualified professional as part of their proposed team.

Meanwhile, as the profile of IRP- or similarly-credentialled professionals continues to grow, so too will the need for more training and credentialling capacity. Furthermore, market demands might prompt credentials like the IRP to transition into full-fledged certifications. ***There is an opportunity*** to consider whether a new personnel certification standard could help advance the more rapid upskilling of the Canadian workforce – by allowing for more organizations to be credentialled to deliver training and to certify – providing Canada's infrastructure resiliency professionals with better-recognized skills and knowledge to compete in the climate and low carbon resiliency marketplace at home and abroad.

6. CONCLUSION

Canada's National Adaptation Strategy (NAS) provides the roadmap for a climate-resilient Canada with a strong economy that can thrive in the global transition to net-zero emissions. The backbone of the Canadian economy, our built and natural infrastructure, is therefore a crucial area of focus for the NAS, and a key medium-term objective is to ensure "[a]ll infrastructure-related standards and related technical guidance are embedded with sustainability and climate resilience considerations."

This paper has related the publicly available body of climate and infrastructure risk assessment work carried out by PIEVC practitioners to the availability, updating, and use of infrastructure- and climate resilient infrastructure (grey and natural)-related standards. In so doing, it has also identified potential new types of standards that could be developed to support risk-informed climate resiliency practice, based on the results of recent PIEVC assessments, and on interviews with the practitioners and proponents of a subset of these assessments.

As outlined in Section 5, there are a range of important opportunities that should be considered to better inform the practice of climate and infrastructure (including PIEVC) risk assessment in

Canada through improved knowledge and use of existing climate resiliency-related standards, and, potentially, through the development of new, targeted standards. Similarly, PIEVC assessments and the robust network of PIEVC practitioners have helped to provide important insights into potential priority types of future, infrastructure and climate resiliency-related standardization.

Appendix A

Table 1: PIEVC Assessments citing specific codes, standards, and related climate thresholds

Assessment Name	Location	Year	Life Cycle Stage	Related code or standard	Threshold value/ climate indices
Roads and Associated Infrastructure					
Marda Loop Climate Change Risk Assessment	Calgary, AB	2022	Renewal and Rehabilitation; Design	National Building Code: 2019 Alberta Edition	Heating degree days (HDD) > 5000 15 min rainfall > 23 mm Annual maximum snow load (cm) exceeding 1:50 year storm for ground snow
				City of Calgary Stormwater Design Guidelines	24h rainfall > 103 mm
British Columbia Ministry of Transportation And Infrastructure – Coquihalla Highway – Hope To Merritt Section	Hope to Merritt, BC	2010	Renewal and Rehabilitation	CAN/CSA-S6-06, Canadian Highway Bridge Design Code	Number of Days with max. temp. exceeding 30°C Days with min. temp. below -24°C Daily temperature variation of more than 24°C Freeze/ Thaw: 17 or more days where max. temp. > 0°C and min. temp. < 0°C Frost: 47 or more days where min. temp. < 0°C Extreme rainfall: > 76mm over 24hrs

					10 or more days where rain falls on snow Freezing rain: 1 or more days with rain that falls as liquid and freezes on contact Snow Storm: 8 or more days with blowing snow Days with snowfall >10 cm 5 or more days with a snow depth >20 cm Wind speed: > 80.5 km/hr
British Columbia Ministry of Transportation and Infrastructure - Yellowhead Hwy 16	Vanderhoof to Priestly Hill, BC	2011	Regular Operation	CAN/CSA-S6-06, Canadian Highway Bridge Design Code	# of Days with max. temp. exceeding 35°C Days with min. temp. below -35°C Freeze/ Thaw: # of days max. temp. > 0°C and min. temp. < 0°C Frost: 47 or more days min. temp. < 0°C Total Annual Rainfall: 406.7mm Extreme High Rainfall: >35mm Sustained Rainfall: ≥ 5 consecutive days with > 3.5 mm rain Snow (Frequency): Days with snow fall > 10 cm 8 or more days with blowing snow
Climate Resilience Assessment Town of Faro Water, Sewer	Faro, YK	2019	Conceptual/ Planning	City of Whitehorse Servicing Standards Manual	24hr 100-yr rain > 64 mm 24hr 5-yr rain > 32.5 mm

and Road Upgrades - Phase 2 & 3				(2007) + Safety factor in less than 30%	
				Buildings	
Forest Lawn Multiplex Climate Change Resilience Assessment	Calgary, AB	2022	Design	National Building Code: 2019 Alberta Edition	Heating degree days (HDD) > 5000 July 2.5% design air temperature > 28 °C Annual number of days with hourly-sustained horizontal load exceeding 0.50 kPa (i.e., 100 km/h; 1:50) > 0.00 15 min rainfall (1:10) > 23 mm; 24hr rainfall (1:50) > 103 mm Max snow load 1:50 exceeding 1.1 kPa = 37.4 cm
				City of Calgary Stormwater Management and Design Manual	24h rainfall (1:5 for minor stormwater systems) > 54 mm 24h rainfall; (1:100 for major stormwater systems) > 93.7 mm
				Enhanced Fujita scale damage indicators and degrees of damage	Annual number of days with wind gusts exceeding 90 km/hr > 4.11 Annual number of days with wind gusts exceeding 110 km/hr > 0.36 Annual number of days with wind gusts exceeding 130 km/hr > 0.00

Climate Change Vulnerability Assessment for Nanaimo Regional General Hospital (NRGH)	Nanaimo, BC	2018	Renewal and Rehabilitation; Regular Operation; Design	BC Building Code (2012)	Wind Pressure: Strong Winds 1/50 [Pa]: 500 Storm Intensity and Frequency: 1/5 Wind Driven Rain Pressure [Pa]: 200 Warmer Winters: Heating Degree-Day Base 18.0 [°C-Day]: 3000 Winter Storm (Ice Storm): Snow Load [kPa]: 2.3 Flooding: 1 in 50 year 1-day rainfall [mm]: 91
Étude de vulnérabilité des infrastructures aux effets climatiques et météorologiques possibles – Laval	Laval, QC	2020	Regular Operation	National Building Code (2010)	Minimum temperatures in January: -26°C Maximum temperatures with a dry bulb in July: 29 °C Maximum temperatures with a wet bulb in July: 23 °C Maximum precipitation in 15 minutes: 23 mm Maximum precipitation in 1 day: 96 mm Strong winds: 81.4 km/hr (1/10 years) and 91.8 km/hr (1/50 years)
Étude de vulnérabilité des infrastructures aux effets climatiques et météorologiques possibles Shawinigan	Shawinigan, QC	2020	Regular Operation	National Building Code (2010)	Minimum temperatures in January: -26°C Maximum temperatures with a dry bulb in July: 29 °C Maximum temperatures with a wet bulb in July: 23 °C Maximum precipitation in 1 day: 102 mm Maximum precipitation in 15 minutes: 22 mm Strong winds: 73.4 km/hr (1/10 years) and 83.9 km/hr (1/50 years)
Coastal Infrastructure					

Xwu'nekw Park Sea Dike Climate Lens Resilience Assessment	Squamish, BC	2019	Conceptual/ Planning	Province of BC Air Quality Health Index Summary (2019)	Wildfire Related Air Quality: # days with Air Quality Health Rating above 7
				Work Safe BC Occupational Health and Safety Regulation 7.27 "Heat Exposure".	Temperature Change: Daily maximum temperature exceeding 38°C
				Integrated Flood Hazard Management Plan (IFHMP)	Sea Level Rise – Coastal Flood Level Increase (2 m by 2100) Sea Level Rise – Dike Overtopping (2.7 m by 2100) Storm Surge – Coastal Flood Level Increase (Increase of ±0.75 m at 200-year return period) Storm Surge – Dike Overtopping (Increase of ±1.5 m at 200-year return period) Wind – Dike Overtopping (Increase in wave runup of 2 m during 200-year return period windstorm)

Belledune Port Authority Climate Change Risk Assessment	Belledune, NB	2020	Regular Operation; Construction	CAN/CSA-C22.3 No.1-10 Overhead Systems.	Wind Gusts: 90 km/hr+ during warm season (April-Sept)
				National Building Code Canada (1960 to 2015)	Climactic Information for Buildings Rainfall Intensity: 2.3 mm/hr for 1 in 5-year Freeze and Thaw Cycles (Annual): 97 days
Transportation Assets Risk Assessments (TARA) to Climate Change, Saint John Ferry Terminal, New Brunswick	Saint John, NB	2020	Regular Operation	National Building Code of Canada	Building Wind Design: prob. of exceeding 1 in 50 yr
Transportation Assets Risk Assessments (TARA) to Climate Change, Caribou Ferry	Caribou, NS	2020	Regular Operation	National Building Code of Canada	Building Wind Design: prob. of exceeding 1 in 50 yr

Terminal, Nova Scotia					
Transportation Assets Risk Assessments (TARA) to Climate Change, Digby Ferry Terminal, Nova Scotia; 2019	Digby, NS	2019	Regular Operation	National Building Code of Canada	Building Wind Design: prob. of exceeding 1 in 50 yr
Transportation Assets Risk Assessments (TARA) to Climate Change, Souris Ferry Terminal, PEI	Souris, PEI	2020	Regular Operation; Construction	National Building Code of Canada	Building Wind Design: prob. of exceeding 1 in 50 yr
Transportation Assets Risk Assessments (TARA)	Wood Island, PEI	2020	Regular Operation	National Building Code of Canada	Building Wind Design: prob. of exceeding 1 in 50 yr

to Climate Change, Wood Islands Ferry Terminal, PEI					
Stormwater and Wastewater Infrastructure					
City of Vernon Stormwater Infrastructure PIEVC Assessment Report	Vernon, BC	2019	Renewal and Rehabilitation	Vernon Subdivision and Development Servicing Bylaw (SDS Bylaw) - Schedule F	Rainfall – 1hr, 5-yr Rainfall – 1hr, 100-yr
Climate Resilience Assessment Wastewater Treatment Plant, Conveyance Upgrades, Outfall Upgrades & Residuals Handling Facility	Tofino, BC	2019	Design	Not specified	"Infrastructure threshold above which, or below which it was deemed the infrastructure performance could be affected were developed through professional judgement based on historic events and current design codes and standards."

Altona Climate Resilience Assessment of Existing and Proposed Drainage Infrastructure	Altona, MB	2019	Regular Operation; Conceptual/ Planning	National Building Code of Canada (2005)	Frost penetration: 1.51 m depth (0.91 m cover + 0.6 m pipe diameter)
Climate Change Vulnerability Assessment of the Town of Prescott's Sanitary Sewage System	Prescott, ON	2011	Regular Operation	National Building Code of Canada (2010)	Hourly wind pressures for the 1 in 10 and 1 in 50 return periods
Assessment of Town of Welland's Stormwater and Wastewater Collection and Treatment System	Welland, ON	2012	Regular Operation	CAN/CSA-C22.3 No.60826-10 Design criteria for overhead transmission lines	Daily freezing rain amounts: 25 mm or more
Electrical Infrastructure					

Distribution System Climate Risk and Vulnerability Assessment	Ottawa, ON	2019	Regular Operation	CAN/CSA-C22.3 No.60826-10 Design criteria for overhead transmission lines	Ice accumulation of 25 mm; 40 mm
Toronto Hydro-Electric System Public Infrastructure Engineering Vulnerability Assessment Pilot Case Study	Toronto, ON	2012	Regular Operation	CSA 22.3 No. 1 Overhead Systems	Average annual days < -20°C Gusts > 90 km/hr (~2 days / year at Airport)
				CSA C22.1:21, Canadian Electrical Code, Part I	Average annual # of days with T≥ 30°C
Summerside Solar and Storage Integration Project	Summerside, PEI	2019	Design	National Building Code of Canada (2015)	Hourly wind > 84 km/hr.
Airport Infrastructure					
Climate Change Resilience Strategy Saint John Airport, New Brunswick	Saint John, NB	2021	Regular Operation	National Building Code of Canada (1980)	15-min, 10-year precipitation event > 18 mm Hourly wind pressure 1/10, kN/m2 > 0.38; Hourly wind pressure 1/30, kN/m2 > 0.48; Hourly wind pressure 1/100, kN/m2 > 0.59 Ground snow load > 3.0 kN/m2

				National Building Code of Canada (1995)	24hr, 50-year precipitation event > 130 mm Ground snow load > 2.1 kPa Ground snow load > 0.5 kPa
				National Building Code of Canada (2015)	24hr, 50-year precipitation event > 139 mm Hourly wind pressure 1/10, kN/m2 > 0.41 Hourly wind pressure 1/50, kN/m2 > 0.53
Recreational Lands and Nature Based Infrastructure					
PIEVC Assessment of Three City Parks - City of Mississauga	Mississauga, ON	2018	Regular Operation	National Building Code of Canada (2010).	Frost Depth ≥ 1.2 m

Appendix B

Table 2: Climate resiliency standards and guidelines developed by Canada's National Standards System and collaborators

ID #	Standards/Guidance/Tool	Description	Product Type
1	CSA S6:19 Canadian Highway Bridge Design Code	Section 2 (Durability and sustainability) specifies requirements for durability and sustainability that need to be considered during the design process of bridges, culverts, and other structures located in transportation corridors. Local climate change and exposure conditions are brought to the attention of designers and owners.	Standard
2	CSA S7 - Design of pedestrian, cycling and multi-use bridges	New guidelines for the design of pedestrian, cycling and multi-use bridges. Incorporates considerations of sustainability and climate resilience, and includes design based on future climatic design data.	Standard
3	CSA PLUS 4011.1:19 – Technical Guide: Design and construction considerations for foundations in permafrost regions	This guideline is intended to provide more detailed technical information on the attributes of the various foundation systems, selection criteria, ground conditions, and related issues. Topics covered include the distribution of permafrost in Canada, ground temperatures, ice content, salinity, terrain sensitivity, surface hydrology, and the effects of a changing climate on the performance of building foundations.	Guidance
4	CSA A440.3:22 User Guide to CSA A440.2:22, Fenestration energy performance	Applies to the determination of energy performance properties for a variety of fenestration systems and includes the following energy performance properties, applicable to all building types (residential, commercial, and other): overall coefficient of heat transfer (U-factor); solar heat gain coefficient (SHGC); and visible transmittance (VT). Annex B provides some information on how climate	Guidance

		change can affect fenestration product design and application.	
5	Global Building Resilience Guidelines	Fifteen principles developed by the Global Resiliency Dialogue provide a basis for advancing building resilience through building codes. They are intended to help inform the development of building codes and standards that incorporate future-focused climate resilience and respond proportionately to rapidly changing and predicted extreme weather events such as flooding, storms, cyclones/hurricanes, wildfires/bushfires and heatwaves.	Guidance
6	CSA PLUS 4011:19 - Technical guide: Infrastructure in permafrost: A guideline for climate change adaptation	This updated technical guide provides updates on current climate change projections recommended for use in northern Canada; current trends in climate (temperature and precipitation) throughout the North; a range of climate projections available for northern Canada; Up-to-date information on ground temperature trends in permafrost throughout northern Canada; Permafrost conditions critical for infrastructure foundations.	Guidance
7	Coastal flood risk assessment guidelines for building and infrastructure design: supporting flood resilience on Canada's coasts	These guidelines apply to coastal flood risk assessments for building and infrastructure design (including retrofit design) applications in Canada. The document is intended to inform, and provide a technical reference for, a wide variety of users interested in building and infrastructure design in areas potentially exposed to coastal flood hazards 8under present-day and/or future conditions. The guidelines advocate a move toward risk-based approaches to analysis and design for flood resilience.	Guidance

8	National guide for wildland-Urban-Interface Fires	This guide provides guidance on how to break the WUI fire disaster sequence at various points and is intended to enhance life safety and property protection by reducing the wildfire threat posed by the surrounding environment and by enhancing the fire protection provided by structures. The guideline contents include identifying wildland fire hazards and exposure; measures to mitigate fire risk in the structure ignition zone; community planning and resources; and, emergency planning and outreach.	Guidance
9	Climate resilient buildings: guideline for management of overheating risk in residential buildings	Overheating is the result of excessive heat accumulation in building interiors combined with limited means to effectively dissipate this heat to the outdoors. The outdoor environment is the principal cause for this excessive heat, particularly during extreme heat events as occur in the summertime. However, buildings can exacerbate the situation by generating additional internal heat from equipment, lighting, occupants (density) and as well, from the trapping of heat given high levels of insulation, more effective airtightness of envelopes and inadequate space ventilation.	Guidance
10	Practical guidance for private-side drainage systems to reduce basement flood risk: addressing critical information gaps	This guide aims to establish a foundation for developing recommendations on drainage systems, sump pumps, backwater protection, and private-side sewer connections to prevent basement flooding in residential buildings under the National Building Code of Canada (NBC) Part 9. It intends to work alongside CSA Z800-18 to enhance basement flood protection measures for both new and existing structures. The focus is on mitigating flood risk through private-side drainage systems.	Guidance

11	Guide for design of flood-resistant buildings	Guidance to inform flood-resistant design of buildings, including calculating flood loads and choosing an appropriate design flood. The recommended methods, formulas, and approaches provided by this guideline are considered best practices and those that are more easily applied by practitioners.	Guidance
12	Guidelines for improving flood-resistance of existing buildings	Guidance for flood resiliency of five common foundation types: basement, crawlspace, slab on grade, piling, and post/column. The guidelines cover common mitigation techniques including wet and dry flood proofing; other mitigation techniques for temporary and permanent flood barriers; and a discussion of flood resistant materials. The flood resistant techniques in this report are directed at retrofitting existing buildings. .	Guidance
13	Technical Guide for Northern Housing	This technical guide outlines best practices through illustrated booklets for building solutions in house construction in northern and remote regions (i.e. the Arctic and subarctic First Nations and Inuit Nunangat regions). Fourteen overview booklets cover the challenges within sub-regions, and eleven technical booklets cover the house design and construction process.	Guidance
14	CSA Z800-18 - Guideline on Basement Flood Protection	The guideline was prepared to assist relevant stakeholders in the mitigation of basement flood risk for new and existing National Building Code of Canada (NBCC) Part 9 residential buildings.	Guidance
15	CSA Z240.10.1:19 - Site preparation, foundation, and installation of buildings	This updated standard addresses climate change adaptation with revisions and new provisions which include the following: sources for climate data; protection against effects of flooding; deterioration resistance; and addition of a new Annex A on	Standard

		environmental design data and climate change. The standard specifies requirements for the following aspects of building installation: site preparation; permanent foundations; anchorage to resist overturning and pier toppling due to wind; connection of modules in multiple-section prefabricated buildings; and skirting.	
16	CSA S502:21 - Managing changing snow load risks for buildings in Canada's North	Informs communities on measures for safe roof snow removal from existing buildings and for protection of building occupants and assets from overloading risks due to increasing accumulations and weights. Procedures that can reduce risks for roof and building collapses are outlined, including procedures for monitoring heavy snow and ice accumulations, safe removal of snow on roofs when needed, and for maintenance and snow removal planning.	Standard
17	CSA S478-19 - Durability in Buildings	Provides criteria and requirements for the design of a durable building and its building elements and includes provisions for cost analysis and management and for a quality management program for the design, construction, operation, maintenance, repair, and renovation of a building and its building elements.	Standard
18	CSA A440S1-19 - Canadian Supplement to AAMA/WDMA/CSA 101/I.S.2/A440-17, North American Fenestration Standard/Specification for windows, doors, and skylights	Provides simplified methods to calculate the minimum performance levels for resistance to water penetration, wind loads, and snow loads for fenestration products on buildings in Canada. Annex B introduces the issue of climate change and its associated effects on fenestration in buildings. It is anticipated that fenestration designers will need to incorporate changes in climate loads resulting from climate change into the fenestration product design.	Standard

		Annex B provides some information on this topic for consideration by designers.	
19	CSA A440.2:22 Fenestration energy performance	Applies to the determination of energy performance properties for a variety of fenestration systems and includes the following energy performance properties, applicable to all building types (residential, commercial, and other): overall coefficient of heat transfer (U-factor); solar heat gain coefficient (SHGC); and visible transmittance (VT). Annex B provides some information on how climate change can affect fenestration product design and application.	Standard
20	CSA A440.4-19 - Window, Door and Skylight Installation	This updated standard introduces a new Annex H which provides some information on how climate change could impact fenestration product design and application.	Standard
21	CSA A440.6:20 High exposure fenestration installation	This updated standard introduces a new Annex H which provides information on climate change, its potential effects on fenestration in buildings and provides guidance for climate change resilient design for fenestration products and installation.	Standard
22	CSA A123.26:21 - Performance requirements for climate resilience of low slope membrane roofing systems	Requirements for low slope membrane roofing systems (LSMRS) when identified as silver and gold performance level based on the climate severity and resilience requirements. The National Building Code of Canada and the National Energy Code of Canada for Buildings provide bronze requirements for LSMRS.	Standard
23	CSA S500:21 Thermosyphon foundations for buildings in permafrost regions	Requirements for all life cycle phases of thermosyphon foundations for new buildings on permafrost, including site characterization, design, installation, and commissioning phases as well as for monitoring and maintenance phases. Ensure the	Standard

		long-term performance of thermosyphon-supported foundation systems under changing environmental conditions.	
24	CSA S501:21 Moderating the effects of permafrost degradation on existing building foundations	This standard covers strategies to maintain permafrost or mitigate permafrost degradation related to existing buildings or structures, also allows for site abandonment or structure demolition in response to permafrost degradation.	Standard
25	CSA S505:20 Techniques for considering high winds and snow drifting and their impact on northern infrastructure	This standard addresses risks to northern infrastructure due to wind, snow, and snow drifting. It incorporates weather data, climate variables, and relevant projections and forecasts; reducing risk of damage; climate adaptation strategies.	Standard
26	BNQ 2501-500 Geotechnical Site Investigations for Building Foundations in Permafrost Zones	This standard establishes a consistent methodology for performing geotechnical site investigations so that the results can be used to design building foundations with due consideration, in a risk management framework, of the considerations prevailing at the building site, including: permafrost characteristics, and the seasonal and interannual climate conditions as well as the projected climate conditions over the service life of the building foundations.	Standard
27	CSA S520:22 – Design and construction of low-rise residential and small buildings to resist high wind	The standard is aimed at improving the wind resistance of buildings designed according to part 9 of the National Building Code of Canada.	Standard
28	Climate-RCI	Tool for determining climate severity and roof performance requirements, referenced by CSA A123.26:21 - Performance requirements for climate resilience of low slope membrane roofing systems	Tool
29	Hygrothermal database of building materials (HygDbM)	This project examined 34 common building materials in Canada under current and projected	Tool

		future climates, assessing 5 key hygrothermal properties essential for modeling. The materials were categorized into insulation types, wood, masonry, and finishes. Properties tested included thermal conductivity, moisture storage, water absorption, vapor permeability, and air permeability.	
30	CSA W204-19 Flood Resilient Design for New Residential Communities	This standard provides compliance criteria and guidance on the design of flood-resilient new residential communities as it relates to greenfield development only. This standard does not cover flood resilience considerations as they relate to existing development, infill, intensification, or redevelopment. Its application could be insufficient in areas with permafrost, and in areas subject to coastal and lake flooding.	Standard
31	CSA W210:21 Prioritizing flood resiliency in existing residential communities	This standard supports resource allocation decisions regarding flood risk-reduction at the community level, for existing communities. The principles include consideration of flood mechanisms present and interdependency between flood mechanisms in establishing flood risks; the consideration of flood-exacerbating factors such as climate change (future frequency and severity of precipitation), urban intensification, and changes in upstream land uses that affect long-term resilience.	Standard
32	CSA W205:19 Erosion and sedimentation management for northern community infrastructure	This standard pertains to managing erosion and sedimentation risks in northern communities, covering assessment, planning, design, and maintenance of strategies. It outlines procedures for risk assessment, vulnerability, and factors impacting erosion and sedimentation in land use and infrastructure planning.	Standard

33	National guide for wildland-Urban-Interface Fires	This guide provides guidance on how to break the WUI fire disaster sequence at various points and is intended to enhance life safety and property protection by reducing the wildfire threat posed by the surrounding environment and by enhancing the fire protection provided by structures. The guideline contents include identifying wildland fire hazards and exposure; measures to mitigate fire risk in the structure ignition zone; community planning and resources; and, emergency planning and outreach.	Guidance	
34	CSA S504:19 Fire resilient planning for northern communities	This standard provides a guideline for planning and design of new fire resilient northern wildland urban interface (WUI) community subdivisions and developments only.	Standard	
35	CSA PLUS 4013-19 - Technical Guide: Development, Interpretation and Use of Rainfall Intensity-Duration-Frequency (IDF) Information: Guideline for Canadian Water Resources Practitioners	This guide is designed for professionals working with stormwater, drainage, wastewater, and flood management systems. It offers insights into using rainfall intensity-duration-frequency (IDF) data for water system planning. The guide was updated in 2018 by the Canadian Standards Association to include the latest scientific understanding of climate change and its integration into IDF information.	Guidance	
36	CSA Z800-18 - Guideline on Basement Flood Protection	The guideline was prepared to assist relevant stakeholders in the mitigation of basement flood risk for new and existing National Building Code of Canada (NBCC) Part 9 residential buildings.	Guidance	
37	CSA W211:21 Management standard for stormwater systems	This standard provides requirements and recommendations for management of stormwater systems. It defines a risk-based process for decision makers responsible for the operation, maintenance, and management of stormwater systems.	Standard	
38	CSA W200-18 - Design of bioretention systems.	This standard provides requirements and recommendations for the design of bioretention	Standard	

		systems intended for the management of urban stormwater runoff. Bioretention systems covered by this standard: bioretention with underdrain and with no underdrain; biofilters (impermeable liner); and bioretention planters and bioretention bump-outs (curb extensions).	
39	CSA W201-18 Construction of bioretention systems	This standard covers the construction considerations for bioretention systems intended for the management of urban stormwater runoff.	Standard
40	Guidelines on undertaking a comprehensive analysis of benefits, costs and uncertainties of storm drainage and flood control infrastructure in a changing climate	Guidelines for the assessment of the value of storm drainage and flood control infrastructure including grey, green and hybrid systems. Guidance is intended to inform the assessment of infrastructure investment options, including considerations of uncertainties associated with a changing climate.	Guideline
41	CSA W203:19 Planning, design, operation and maintenance of wastewater treatment in northern communities using lagoon and wetland systems	This standard focuses on the planning, design, operation, and maintenance of intermittent/seasonal discharge lagoon and wetland systems designed for northern regions (above the 54th parallel), where effluent discharge is challenging during colder months. It can also be applied to communities facing similar challenges due to extreme climatic conditions and remoteness. However, the standard does not cover mechanical aeration of lagoon systems, natural lakes, and exfiltration lagoons.	Standard
42	Technical Guide for Northern Housing	This technical guide outlines best practices through illustrated booklets for building solutions in house construction in northern and remote regions (i.e. the Arctic and subarctic First Nations and Inuit Nunangat regions). Fourteen overview booklets cover the challenges within sub-regions, and eleven technical	Guidance

		booklets cover the house design and construction process.	
43	[1]Nature-Based Solutions for Coastal and Riverine Flood and Erosion Risk Management[2]	This report features a synthesis of recommendations, case studies, project photos, design illustrations, and a compilation of referenced technical guidance documents from around the world to advance the use of Nature-Based Solutions (NbS). The report further explores NbS as a coastal, riverine flood, and erosion risk management strategy as well as how it delivers on other environmental and societal co-benefits.	Report
44	Managing Flooding and Erosion at the Watershed-Scale: Guidance to Support Governments Using Nature Based Solutions	The report puts forward three recommendations to support future implementation of NbS for flood and erosion risk management by governments in Canada, supported by findings of this research report. The recommendations include: 1. Development of a consistent approach to integrated watershed management; 2. Allocation of funding to watershed-scale flood and erosion strategies that address high-risk areas; and 3. Routine consideration of NbS for river flood and erosion management.	Report
45	Rising Seas and Shifting Sands: Combining Natural and Grey Infrastructure to Protect Canada's Eastern and Western Coastal Communities	This report outlines the range of practical measures that can be used to protect coastal communities on Canada's East and West coasts from flooding and erosion. Coastal protection measures include (1) grey infrastructure (hard, engineered coastal protection measures); and (2) nature-based solutions (measures that depend on, or mimic, natural systems to manage flood and erosion risk).	Report

46	International Guidelines on Natural and Nature-Based Features for Flood Risk Management	The NNBF Guidelines is intended for practitioners, organizations, and communities seeking to increase the performance of Flood Risk Management (FRM) systems and achieve long-term risk mitigation, increase water infrastructure resilience and sustainability, reduce infrastructure maintenance and repair costs, and, ultimately, increase the value produced by FRM infrastructure investments.	Guideline
47	Natural Infrastructure Framework: Key Concepts, Definitions and Terms[1]	The Natural Infrastructure Framework has been developed to offer a common vocabulary for diverse users, including federal, provincial and territorial governments, interested in Natural Infrastructure (NI), and broader Nature-Based Solutions (NbS). The Framework is intended to be applied across jurisdictions, including Canada's rural and northern areas. This Framework outlines key concepts and terms that.	Guidance
48	Getting Nature on the Balance Sheet: Recognizing the Financial Value Provided by Natural Assets in a Changing Climate[1]	This report calls for the recognition of the financial value provided by natural assets and argues for a revamp of accounting rules to safeguard natural resilience. It provides an overview of progress to date, with specific focus on public sector accounting, reporting and decision-making.	Report
49	CSA W218:23 Specifications for natural asset inventories	This Standard provides minimum requirements for the development and reporting of a natural asset inventory, which is the first step towards natural asset management. This Standard is designed to be sufficiently flexible that it can be applied in any jurisdictional context. It can also be used to include not only natural assets within a given jurisdictional boundary but also those in adjacent jurisdictions that provide important services.	Standard

50	Under One Umbrella: Practical Approaches for Reducing Flood Risk in Canada[1]	This report profiles solutions in a consolidated form — under one “umbrella” — to help Canadians put them into action. The practical solutions outlined in these guidelines and standards can be deployed to limit and/or mitigate flood risks. These solutions range from simple home maintenance and renovations to more sophisticated community-planning approaches and regulations, business-wide activities, and infrastructure upgrades.	Guidance
51	Irreversible Extreme Heat: Protecting Canadians and Communities from a Lethal Future	This guide presents a series of practical actions that Canadians can undertake to reduce extreme heat risks. They fall into three categories: changing behaviour (non-structural), working with nature (green infrastructure), and improving buildings and public infrastructure (grey infrastructure).	Guidance

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