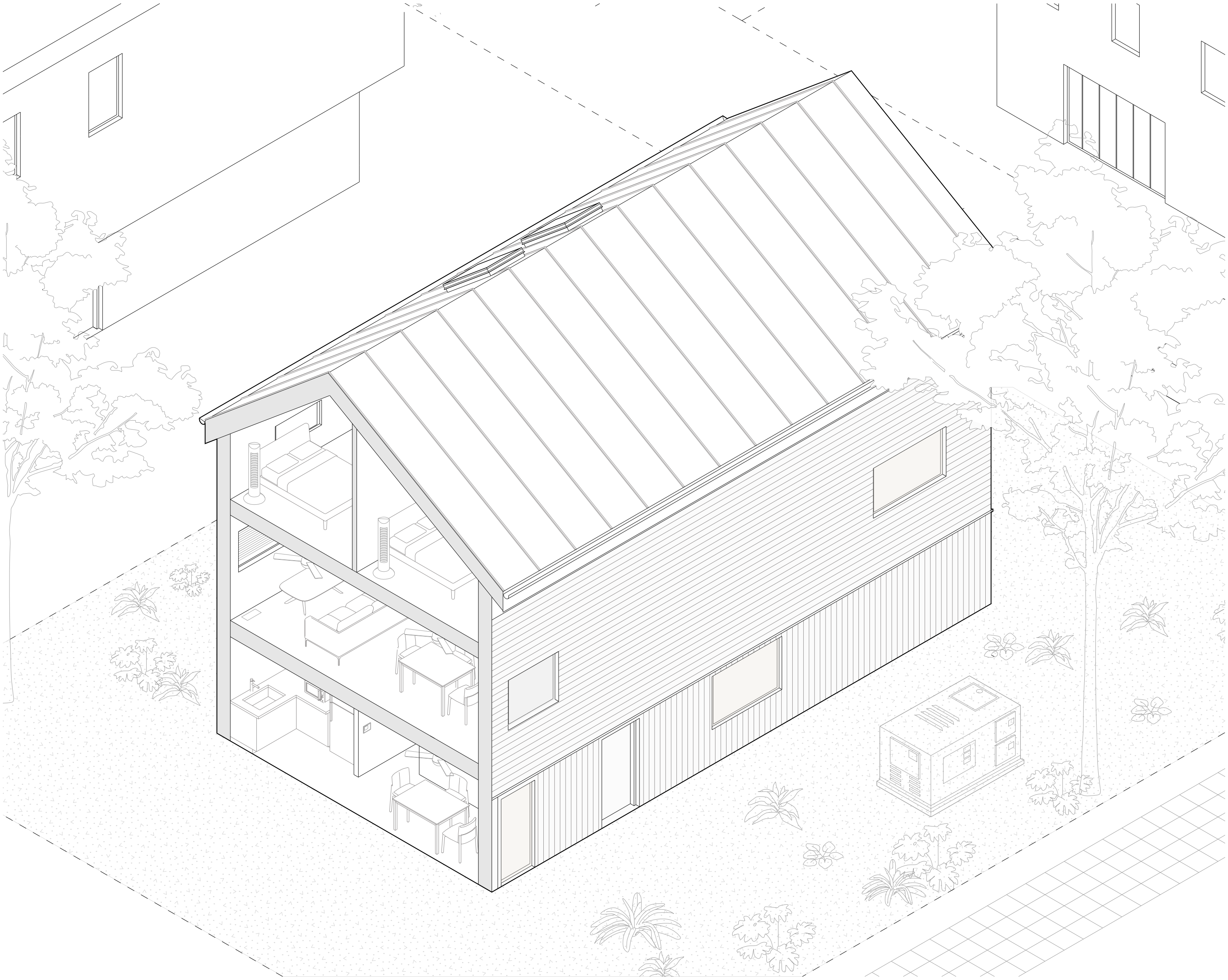

# Climate Resilience Guide

Housing Design Catalogue
June 2025

Ha/f Climate Design

Ha/f Climate Design was founded to halve the emissions of the built environment this decade. We partner with designers, builders and policy makers on capacity building, research, industry education, and policies to address the whole life cost and carbon impacts of buildings, landscapes, and infrastructure.

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# Contents

# 1.0 / Introduction

## Current State

Climate change is one of the greatest challenges of our time, driving rising temperatures, extreme weather, and shifting precipitation patterns that disrupt ecosystems, economies, and communities. The built environment—responsible for a significant share of greenhouse gas emissions—is both a contributor to climate change and vulnerable to its impacts.

Canada is warming two to three times faster than the global average (*Canada's Changing Climate Report*, 2019). This is largely due to Arctic amplification, where the loss of reflective ice and snow leads to faster warming in northern regions. The effects are already visible: thawing permafrost, shrinking glaciers, rising sea levels, and more frequent wildfires, floods, and heatwaves. These changes threaten infrastructure, public health, and the economy, underscoring the urgent need for climate-resilient housing and urban planning.

Climate resilience is the ability of buildings, communities, and systems to withstand, adapt to, and recover from climate-related risks. As climate change accelerates, the built environment must be designed to reduce risks, protect people, and remain functional over time.

In addition to acute climate hazards, long-term conditions and shock events such as poor air quality, water contamination, sudden cold snaps, and power outages are also intensifying. These cascading impacts pose serious risks to public health, infrastructure, and daily life. Building climate resilience means proactively addressing both immediate and prolonged climate-related challenges—minimizing disruption, protecting occupants, and ensuring homes and communities remain safe and functional in a rapidly changing climate.

## Housing Design Catalogue

The Housing Design Catalogue features over 50 prototypical housing designs, including detached accessory dwelling units, townhouses, rowhouses, and multiplexes, for seven distinct regions of Canada. The designs were developed by regional architecture and engineering firms to comply with applicable building codes, planning, and zoning requirements while prioritizing energy efficiency, accessibility, livability, and climate resilience. Housing Design Catalogue drawings are intended to be near permit-ready, but do require the user to adapt them for the requirements of their specific site, including location specific climate risks, which this guide is intended to support.

## How to Read this Guide

This guide provides climate resilience and adaptation strategies for housing, including designs selected from the Housing Design Catalogue. These strategies are intended to help housing better withstand the increasing challenges of a warming planet while supporting reduced carbon emissions and enhancing human and environmental health.

Design strategies are organized into three categories—building, interiors and systems, and site—each addressing recommended measures for durability, energy efficiency, and occupant wellbeing. Strategies are aligned with identified climate risks such as extreme heat, wildfires, drought, permafrost thaw, flooding, and storms, and should be reviewed in consultation with a Qualified Professional to determine the most appropriate approaches for your region and site conditions.

Each strategy is assessed using a low–moderate–high impact rating, which reflects its relative effectiveness in reducing climate-related risks and enhancing resilience. This allows for comparison across strategies and helps support informed decision-making. Impact ratings are meant as a high-level comparison of different strategies to address each specified climate risk. The actual impact of specific strategies will vary depending on the presence and severity of individual risks at a site and therefore, comparison of strategies across different climate risks, including prioritizing strategies, should be conducted in consultation with a Qualified Professional.

This guide is meant to be used alongside the prototypical design drawings produced as part of the Housing Design Catalogue. The prototypical drawings are at a level of detail typically expected for building permit, excluding aspects which must be finalized for a specific location or preference such as site plan, grading, cladding selection, heat loss calculations, and others. Alongside other technical resources, this guide will support users making design decisions to go from the prototypical to a construction-ready drawings set. When making material selections or other design choices to finalize a site and building design, users should work with a Qualified Professional to review and discuss which of the recommended resilience strategies best suit the location and project goals.

For additional information on how to incorporate these strategies into a catalogue design, including the definition of a Qualified Professional, refer to the User Guide and the Housing Design Catalogue Terms and Conditions.

# 2.0 / Overview of Climate Risks

**Climate Zones**

| | |
|---|---|
| 8 | Coldest climate, typical of northern Canada, including Nunavut, and parts of NWT and Yukon |
| 7b | Very cold climate, including colder areas of Quebec, northern Manitoba, and parts of the Yukon and NWT |
| 7a | Very cold climate, including northern Ontario, parts of northern Quebec, and interior Prairies |
| 6 | Cold climate, covering most of the Prairies, central Canada, and large parts of Atlantic Canada |
| 5 | Moderate climate, including parts of southern Ontario, southern Quebec, and coastal Atlantic regions |
| 4 | Mildest climate, typically in coastal regions of British Columbia |

*Map of Canada showing the location of the National Energy Code of Canada for Buildings (NECB) climate zones 4, 5, 6, 7a, 7b, 8. From National Research Council Canada (NRC). (n.d.).*

## Climate Zones in Canada

The National Energy Code of Canada for Buildings (NECB) divides Canada into climate zones based on heating degree days (HDD), a measure of how much heating is required in a location over a year. The zones are determined by HDD 18°C, which is the total number of degrees below 18°C across all days in a year when the temperature is lower than that threshold. This classification helps inform building insulation, HVAC system requirements, and energy efficiency standards for different regions of Canada.

### Canada

Across **Canada**, increased temperatures will affect human health due to heat stress and vector-borne diseases. Sea level rise and more extreme high water events will increase the risk of coastal flooding in some coastal communities, affecting infrastructure and heritage sites.

### British Columbia

*Primary concerns:*
*Wildfires*
*Flooding*

**British Columbia** faces distinct climate risks, including heatwaves and wildfires that threaten public safety, ecosystems, and air quality, particularly in interior regions. The province is highly vulnerable to flooding from heavy rainfall, snowmelt, and rising river levels, with events like atmospheric rivers causing significant damage. Coastal areas are increasingly at risk of sea-level rise, storm surges, and erosion, while droughts stress water resources critical for agriculture, hydropower, and ecosystems. Recommended measures include fire-smart siting, moisture-tolerant assemblies, and enhanced onsite drainage.

### Alberta

*Primary concerns:*
*Wildfires*
*Drought*

**Alberta**'s main climate risks include more intense and frequent heatwaves, droughts, and wildfires, which threaten forests, agriculture, and public safety. Heavy rainfall and rapid snowmelt can lead to flash flooding, impacting infrastructure and urban areas like Calgary. The province's reliance on water-intensive industries, including agriculture and energy, makes managing water resources critical in the face of increasing variability in precipitation and glacial retreat. In Alberta, design responses include fire-resistant materials, defensible landscaping, and water conservation systems.

### Saskatchewan and Manitoba

*Primary concerns:*
*Drought*
*Extreme heatwaves*

**Saskatchewan and Manitoba** face significant climate risks, including more frequent and intense heatwaves, droughts, and wildfires due to rising temperatures and drier conditions, which threaten agriculture, water supplies, and public health. Heavy rainfall events increase the risk of flash flooding, impacting infrastructure and rural communities, while extreme weather like storms and tornadoes becomes more unpredictable. In these regions, resilient design strategies focus on wind-resistant envelopes, rainwater management, and effective cooling systems.

# 2.0 / Overview of Climate Risks

**Ontario and Quebec**
*Primary concerns:*
*Extreme heatwaves*
*Flooding*

**Ontario and Quebec** share many similar climate risks, making it reasonable to couple them for certain discussions, though each province has unique nuances. Both face heatwaves that strain urban systems and public health, flooding from heavy rainfall and snowmelt affecting major rivers (e.g., the St. Lawrence in Quebec and the Ottawa and Grand Rivers in Ontario), and extreme weather events like storms. Coastal erosion is more relevant to Quebec's Gulf of St. Lawrence communities, while Ontario's Great Lakes region experiences shoreline flooding and erosion due to fluctuating water levels. Northern areas of both provinces are affected by permafrost thaw, though it is more pronounced in Quebec. Key design strategies to address the primary climate risks faced by Ontario and Quebec include effective cooling strategies and elevated mechanical systems in flood-prone areas.

**Atlantic Canada**
*Primary concerns:*
*Storms*
*Flooding*

**Atlantic Canada** faces significant climate risks, including coastal flooding and storm surges from rising sea levels and intensifying hurricanes, as well as heatwaves, droughts, and inland flooding from heavier rainfall. These impacts threaten infrastructure, fisheries, agriculture, and vulnerable communities, while warming oceans disrupt marine ecosystems. Designs for the Atlantic provinces consider materials and assemblies that are flood-, rain-, and wind-resistant.

**Yukon, Northwest Territories, Nunavut**
*Primary concerns:*
*Permafrost thaw*
*Wildfires*

In the **Yukon, Northwest Territories, and Nunavut**, rapid warming is leading to permafrost thaw, which destabilizes infrastructure, alters ecosystems, and releases stored greenhouse gases. Communities are increasingly vulnerable to coastal erosion and flooding due to rising sea levels and melting sea ice, threatening traditional ways of life and food security. Warming temperatures and changing precipitation patterns also increase the risk of wildfires and disrupt wildlife habitats, further impacting Indigenous communities that rely on the land for sustenance and cultural practices. Many of the risks that affect these territories also apply to northern parts of other provinces. Design strategies in northern regions often include raising buildings on piles or adjustable foundations to prevent heat transfer to thaw-sensitive permafrost and to maintain long-term structural stability.

## Longterm Conditions & Shock Events

This section covers four major long-term conditions and shock events in Canada—air quality and smog, water quality, cold snaps, and power outages—that may be triggered or worsened by the climate risks outlined above. These events represent extended or cascading impacts that go beyond immediate hazards like flooding or wildfire, and they can pose serious risks to occupant health, safety, and comfort over time. The design strategies presented in this guide can help mitigate the consequences of these events and support longer-term resilience.

**Air Quality & Smog**
*Aggravated by:*
*Extreme heatwaves*
*Wildfires*
*Drought*
*Storms*

Climate change is worsening air quality through heatwaves, wildfires, and drought. Extreme heat increases smog, while wildfire smoke spreads harmful pollutants over vast areas. Drought intensifies dust storms, and storms re-suspend contaminants. Poor air quality threatens respiratory health and urban livability.

**Water Quality**
*Aggravated by:*
*Wildfires*
*Drought*
*Permafrost thaw*
*Flooding*
*Storms*

Rising temperatures, wildfires, and extreme weather are degrading Canada's water quality. Wildfires and flooding introduce contaminants, while drought concentrates pollutants and fuels toxic algal blooms. Permafrost thaw releases heavy metals, and storm surges threaten freshwater supplies, increasing risks to drinking water and ecosystems.

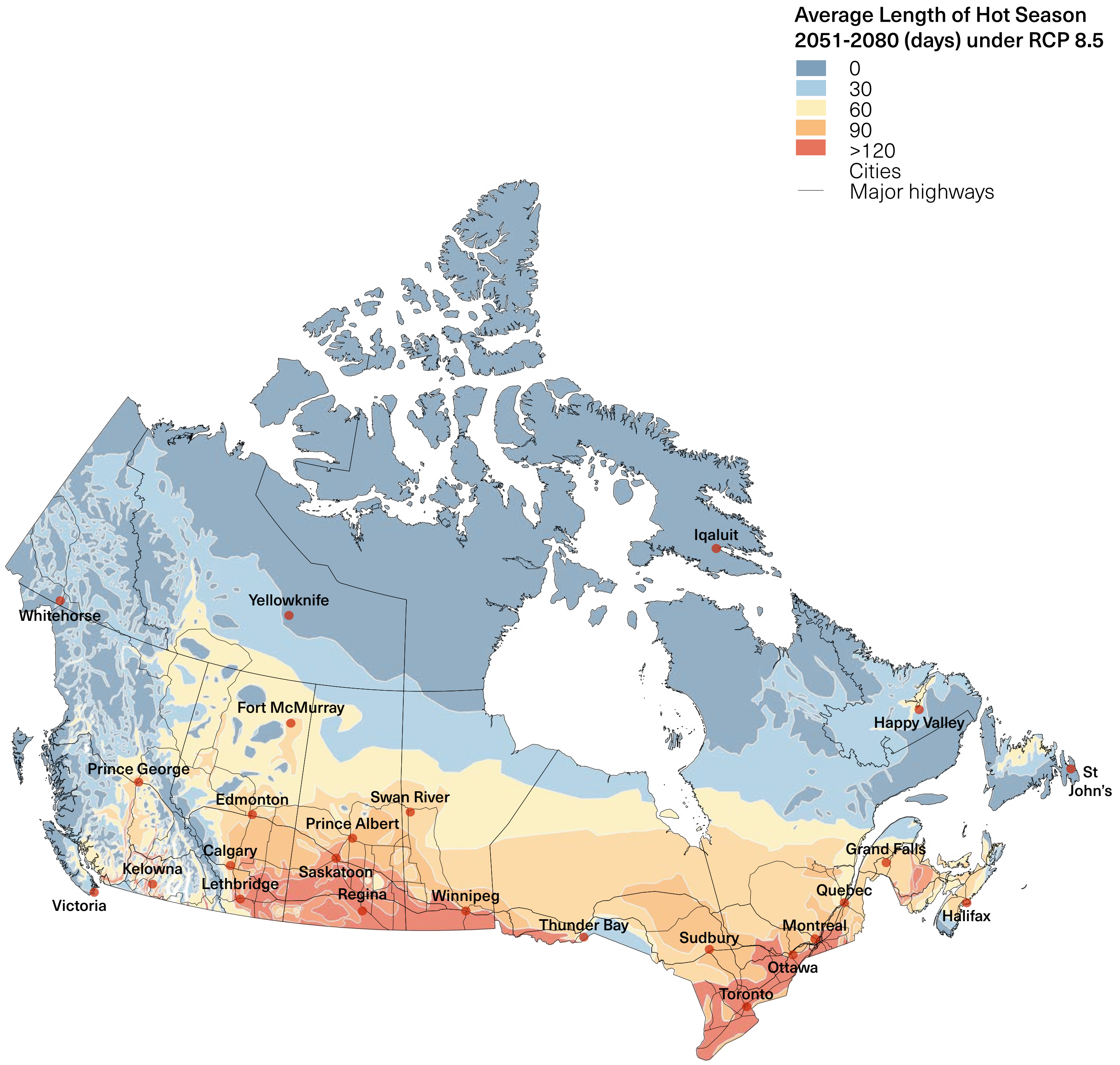
**Cold Snaps**
*Aggravated by:*
*Extreme heatwaves*
*Permafrost thaw*
*Flooding*
*Storms*

Sudden extreme cold events are becoming more unpredictable due to Arctic warming and polar vortex disruptions. Heatwaves and permafrost thaw destabilize atmospheric patterns, while storms can trigger severe snowfall, ice storms, and dangerous flash freezes. These events strain infrastructure, disrupt transportation, increase energy demand, and pose serious health risks.

**Power Outages**
*Aggravated by:*
*Extreme heatwaves*
*Wildfires*
*Drought*
*Flooding*
*Storms*

Extreme weather is making power outages more frequent and severe. Heatwaves overload grids, wildfires damage power lines, and drought threatens hydropower. Flooding and storms disrupt infrastructure, leaving communities vulnerable to prolonged blackouts that impact heating, cooling, and emergency services.

# 3.0 / Extreme Heatwaves



*Map of Canada showing average length of hot season. From Prairie Climate Centre. (2019). Climate Atlas of Canada.*

Extreme heatwaves are prolonged periods of excessively high temperatures, often worsened by humidity, that exceed seasonal averages. They are becoming more common in Canada, causing heat-related illnesses, energy strain, and wildfire risks. Regions most at risk include southern British Columbia, Alberta's prairies, and urban centers like Toronto and Montreal, where the urban heat island effect amplifies temperature extremes.

Future heatwave severity is projected using Representative Concentration Pathway (RCP) scenarios, which model different greenhouse gas (GHG) emission levels. RCPs are used to understand the impact of changing GHG concentrations over time due to human activities. RCPs range from RCP 2.6 as the low-emissions scenario to RCP 8.5 as the high-emissions scenario. Higher RCPs (e.g., RCP 8.5) predict more frequent and intense heatwaves. The average length of hot seasons from 2051 to 2080 (shown as number of days) under RCP 8.5 is presented on the map on page 10. This mid-to-late century window was selected as it reflects a future yet foreseeable period, anticipating the projected increase in temperatures and heatwave risk due to climate change.

### Implications for Housing

Heatwaves pose significant challenges for housing and infrastructure by increasing cooling demands, which can strain energy grids and lead to power outages. Homes without adequate insulation, shading, or air conditioning become dangerously hot, particularly for vulnerable populations such as seniors or those with pre-existing health conditions. Additionally, extreme heat can degrade materials like asphalt and concrete, reduce the lifespan of buildings and roads, and increase the risk of structural failures. Designing homes with passive cooling strategies, heat-resistant materials, and energy-efficient systems is essential to mitigate these risks and ensure occupant safety.

# 3.0 / Extreme Heatwaves

## Design Strategies

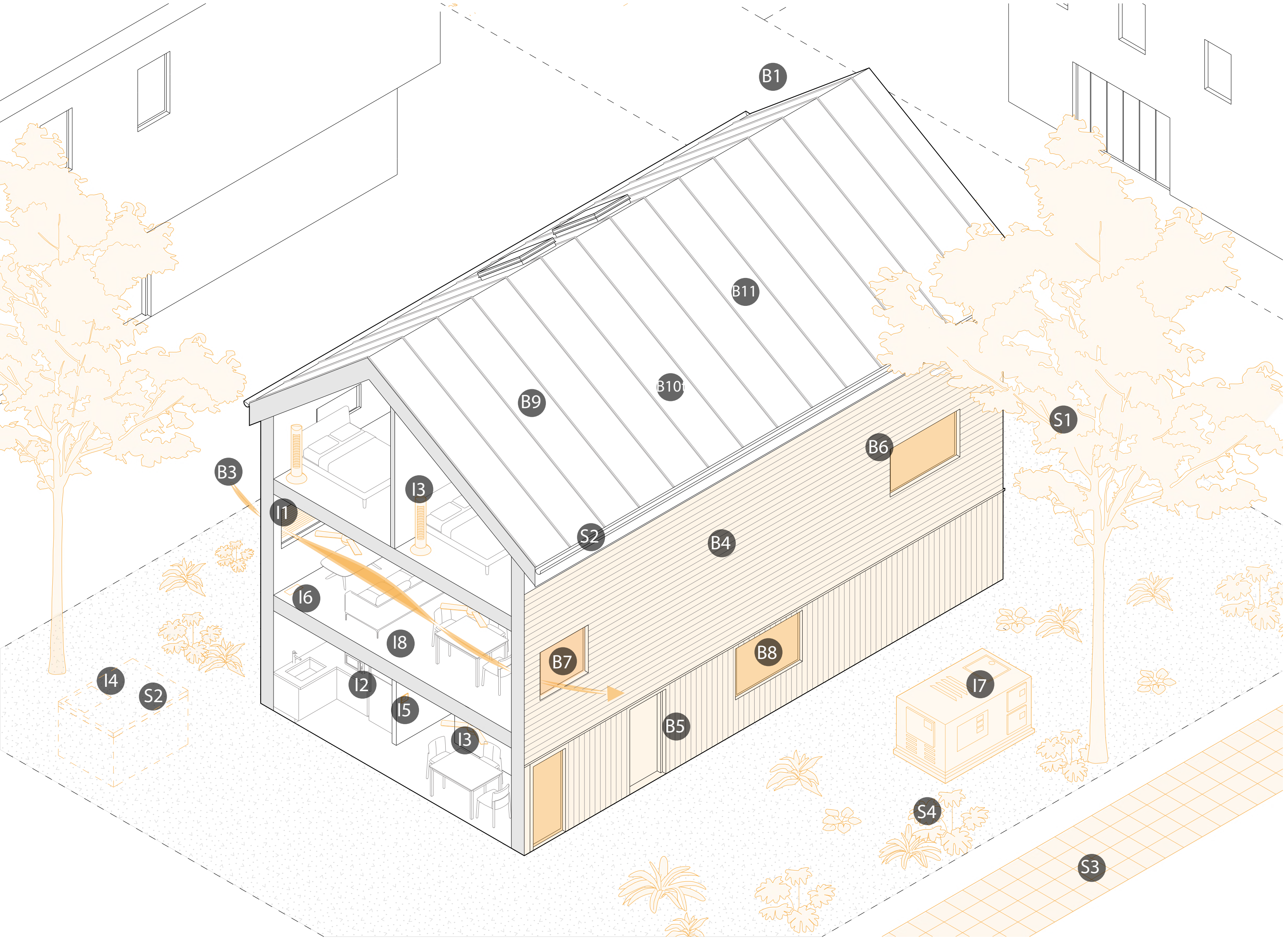


*Image of prototype Catalogue House with strategies to address extreme heatwaves. See following page for detailed descriptions of design strategies.*

+++ *high impact* ++ *moderate impact* + *low impact*

### Building

| | | |
|---|---|---|
| B1 | Building orientation, shape, and massing<br>Design layouts that optimize solar gain in winter and minimize overheating in summer | +++ |
| B2 | Exterior shading (not pictured)<br>Add elements (awnings, louvers, overhangs) to block direct sunlight and reduce cooling loads (see User Guide) | +++ |
| B3 | Natural ventilation<br>Incorporate operable windows and ventilation pathways to improve airflow and reduce mechanical cooling | +++ |
| B4 | High thermal envelope performance<br>Reduce heat gain and cooling needs during heatwaves with high-performance insulation | +++ |
| B5 | High airtightness<br>Optimize the envelope to limit hot air infiltration in order to maintain cooler indoor temperatures in extreme heat | +++ |
| B6 | Optimized window-to-wall ratio (WWR)<br>Balance daylighting needs and thermal performance by limiting excessive glazing | +++ |
| B7 | High efficiency windows<br>Install double- or triple-glazed, low-emissivity windows to improve insulation and reduce heat loss or gain | +++ |
| B8 | Low SHGC on glazing<br>Specify low Solar Heat Gain Co-efficient on door and window glazing, particularly on South and West | +++ |
| B9 | Cool roofs, walls, and paving surfaces<br>Use reflective materials to reduce heat absorption and mitigate urban heat island effects | +++ |
| B10 | High albedo, light-coloured building materials<br>Choose materials that reflect sunlight to maintain cooler building surfaces | ++ |
| B11 | Green roofs (not pictured)<br>Incorporate to enhance insulation, manage stormwater, improve biodiversity, and mitigate urban heat effects | +++ |

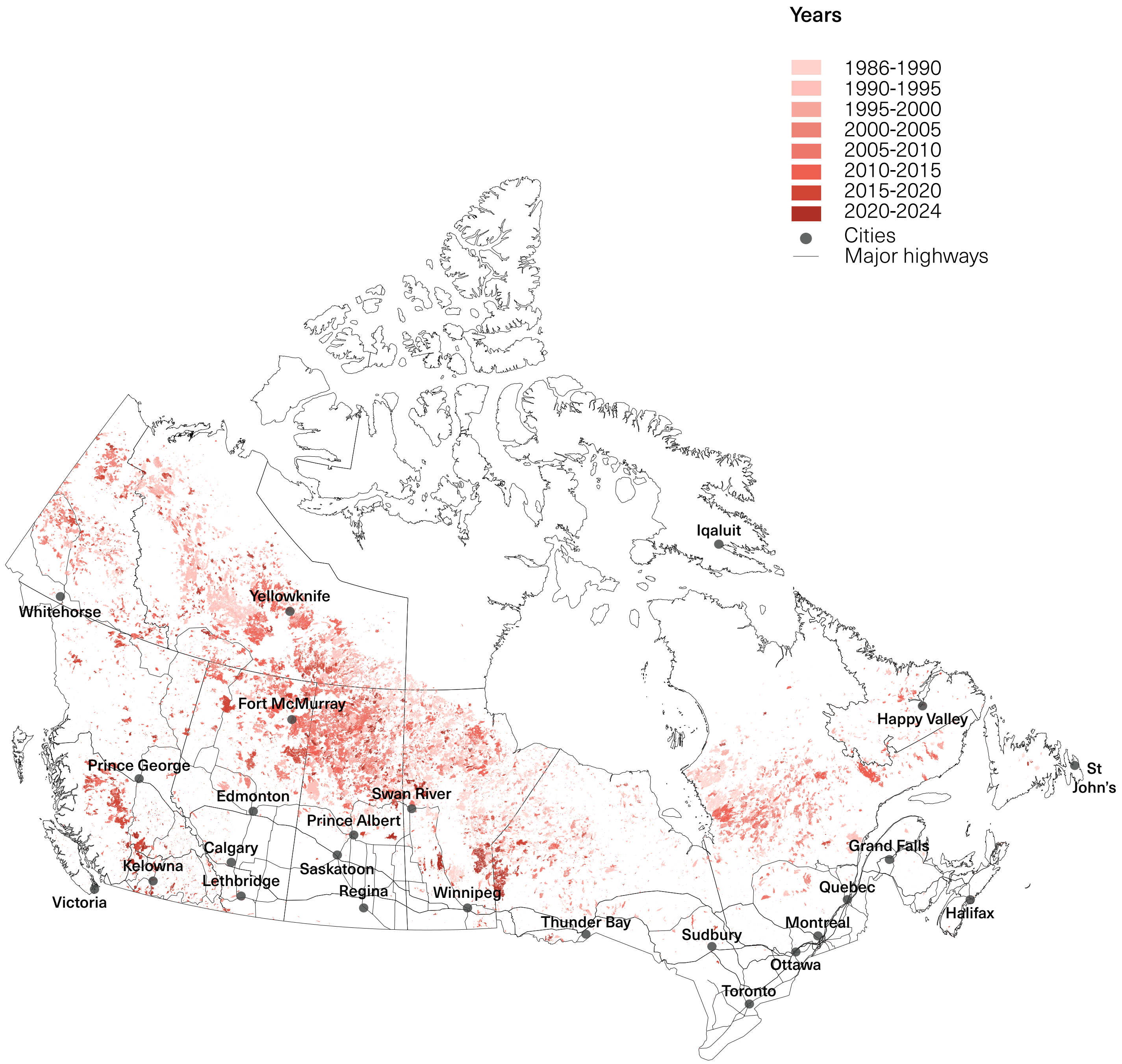
### Interiors & Systems

| | | |
|---|---|---|
| I1 | Interior shading<br>Use blinds, shades, or curtains to control indoor temperatures and reduce reliance on mechanical cooling | ++ |
| I2 | High-efficiency lighting, equipment, and appliances<br>Select ENERGY STAR-rated or other high efficiency products to lower energy use and reduce waste heat | + |
| I3 | Ceiling or portable fans<br>Utilize fans to improve comfort and reduce the need for energy-intensive air conditioning | ++ |
| I4 | Water supply during power outages<br>Include backup water storage systems or gravity-fed supplies for resilience during service interruptions | + |
| I5 | Humidity monitors or thermostat controls<br>Install smart systems to maintain optimal indoor humidity and temperature levels | ++ |
| I6 | Mechanical cooling (to supplement natural ventilation)<br>Provide high-efficiency air conditioning or air source heat pumps to ensure thermal comfort in extreme heat | ++ |
| I7 | Power backup generator<br>Ensure continuity of critical systems during power outages by integrating backup energy sources | ++ |
| I8 | Minimized “waste” indoor heat production<br>Use efficient systems and layouts to reduce heat from lighting, appliances, and equipment | ++ |

### Site

| | | |
|---|---|---|
| S1 | Planting with shade trees<br>Strategically place native or adaptive trees to reduce heat island effects and provide cooling shade | ++ |
| S2 | Water capture<br>Install rainwater harvesting systems like barrels or cisterns to reduce runoff and support irrigation | +++ |
| S3 | Permeable pavers<br>Use porous paving materials to allow water infiltration, reducing surface runoff and minimizing flooding risks | +++ |
| S4 | Xeriscaping<br>Utilize drought-tolerant plants and minimal irrigation to create water-efficient landscapes | ++ |
| S5 | Reduce heat island effect (not pictured)<br>Limit paved areas, surface parking, and other site conditions that contribute to urban heat island effect | +++ |

# 4.0 / Wildfires



*Map of Canada showing wildfires from 1986 to 2024. From NRCan, ESRI Canada, and Canadian Community Maps.*

Wildfires are uncontrolled fires that burn through forests, grasslands, and other vegetation, often exacerbated by extreme heat, drought, and human activity. In Canada, wildfire risks are particularly high in British Columbia, Alberta, and northern regions of Ontario and Quebec, where dry conditions and increased lightning activity create ideal conditions for ignition. Wildfires pose threats to ecosystems, air quality, and human health, with smoke-related respiratory issues and evacuations becoming more frequent. The wildfire season in Canada is lengthening, with fires growing larger and more destructive due to climate change.

The map on page 14 illustrates the geographic distribution and frequency of wildfires across Canada from 1986 to 2024, highlighting regions with recurring fire activity.

### Implications for Housing

Wildfires threaten housing and infrastructure through direct damage from flames and heat, as well as secondary impacts such as smoke infiltration and loss of power. Homes located in fire-prone areas must incorporate fire-resistant materials, defensible space landscaping, and airtight construction to minimize smoke intrusion. Infrastructure, including roads, power lines, and communication systems, must be designed to withstand higher temperatures and reduce the spread of fire. Urban planning strategies, such as creating buffer zones and carefully managing development in wildfire-prone areas, are essential to protect communities and ensure resilience in the face of increasing wildfire risks.

# 4.0 / Wildfires

## Design Strategies

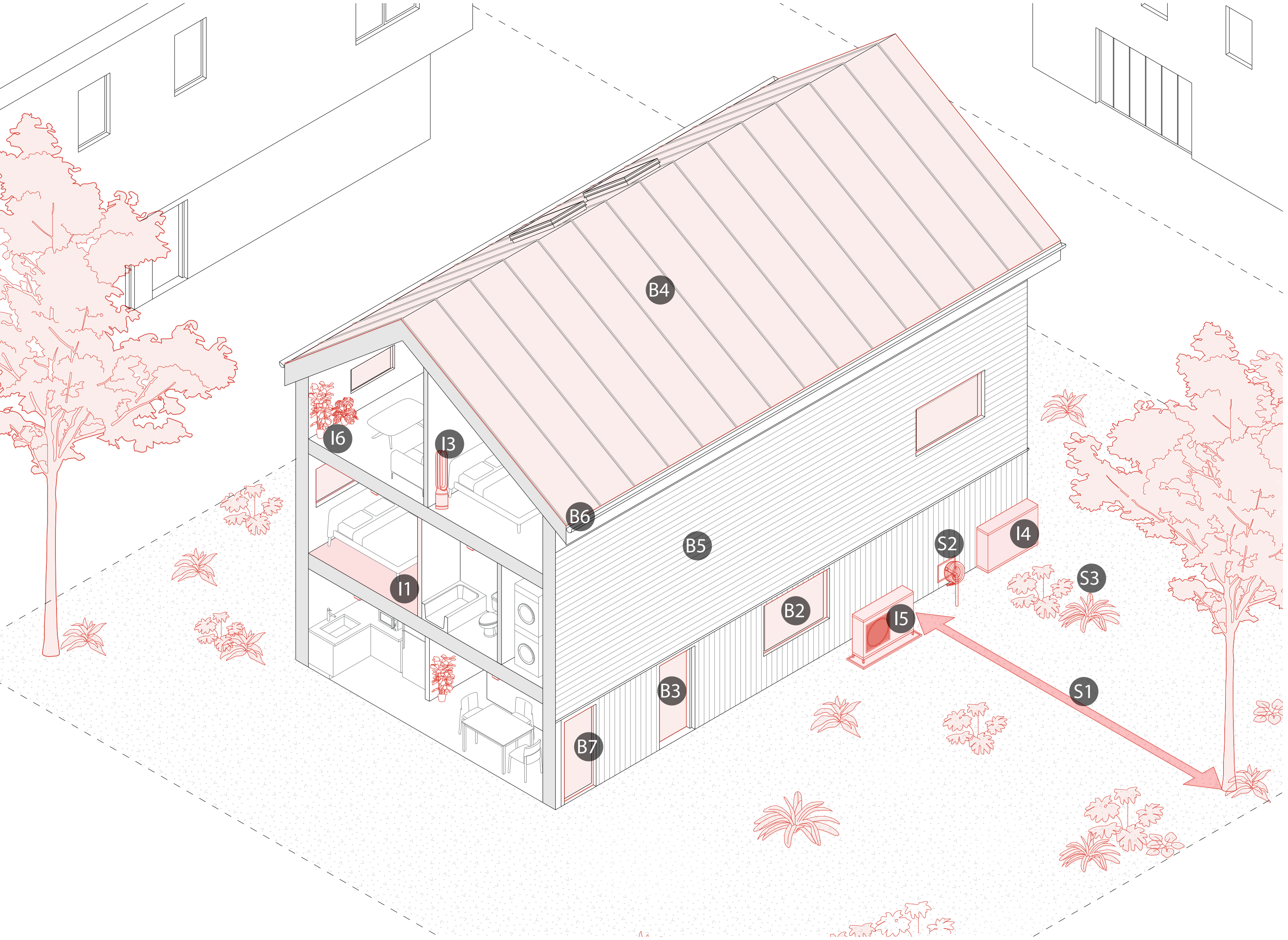


*Image of prototype Catalogue House with strategies to address wildfires. See following page for detailed descriptions of design strategies.*

+++ *high impact* ++ *moderate impact* + *low impact*

### Building

| | | |
|---|---|---|
| B1 | Common building area for clean air refuge (not pictured)<br>Include a designated space with sealed air systems to protect occupants during smoky or hazardous air | ++ |
| B2 | Air barrier sealed tempered windows<br>Use well-sealed windows with tempered glass to enhance fire resistance and reduce smoke infiltration | +++ |
| B3 | Fire-rated and air barrier sealed exterior doors<br>Install exterior doors with certified fire ratings and proper seals to block fire and smoke infiltration | +++ |
| B4 | Fire-retardant roof materials<br>Use materials rated for high fire resistance, such as metal, tile, or treated shingles, to reduce fire vulnerability | ++ |
| B5 | Fire-retardant exterior wall materials<br>Use materials like treated wood, fire-rated insulation, and non-combustible cladding for critical components | ++ |
| B6 | Mesh debris screens (3mm) in gutters, eaves, and vents<br>Install fine metal mesh screens to prevent embers from entering vulnerable areas of the building | ++ |
| B7 | High airtightness<br>Reduces infiltration of wildfire smoke and outdoor pollutants by minimizing air leaks in the envelope | +++ |
| B8 | Chimney spark arrestor (if a woodstove is present, not pictured)<br>Equip chimneys with spark arrestors to prevent embers from escaping and igniting nearby materials | ++ |

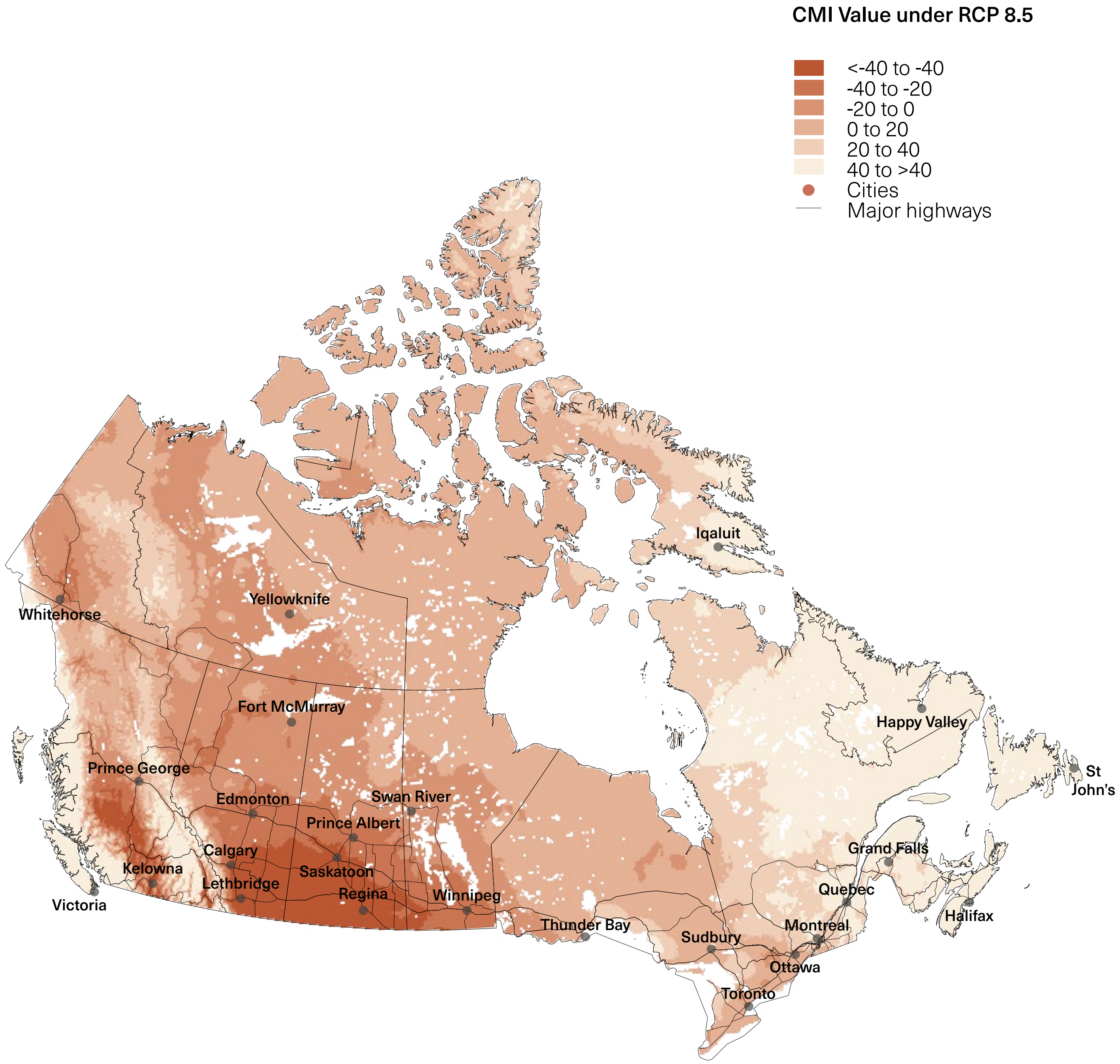
### Interiors & Systems

| | | |
|---|---|---|
| I1 | Low volatile organic compound materials<br>Select building materials and finishes with low VOC emissions to promote healthier indoor air in long term | ++ |
| I2 | High-efficiency air filtration media (MERV 11 or higher, not pictured)<br>Promotes indoor air quality | +++ |
| I3 | Air cleaners with high-efficiency particle air (HEPA) filters<br>Provide portable air purifiers with HEPA filters to further enhance indoor air quality in refuge areas | +++ |
| I4 | Power storage<br>Incorporate battery storage systems to provide backup power during grid disruptions | + |
| I5 | Air source heat pumps (provided as option in most regions)<br>Install efficient heat pumps for heating and cooling that improve air quality by dehumidifying and filtering it | ++ |
| I6 | Indoor plants<br>Add indoor plants for air purification and air purifiers | + |

### Site

| | | |
|---|---|---|
| S1 | Setback from combustible sources (10m or greater)<br>Ensure structures are at least 10m from flammable vegetation, outbuildings, or fuel sources | ++ |
| S2 | Outdoor water fixtures<br>Install easily accessible hose bibs or sprinkler systems to assist in fire suppression and property protection | +++ |
| S3 | Fire-resistant vegetation<br>Landscape with native, drought-tolerant, and low-flammability plants to minimize wildfire risk | ++ |

# 5.0 / Drought



*Map of Canada showing drought conditions through CMI. From NRCan, CFS.*

Droughts are prolonged periods of low precipitation that lead to water shortages, affecting ecosystems, agriculture, and human communities. In Canada, droughts are most pronounced in prairie provinces like Alberta, Saskatchewan, and Manitoba, but they are also increasingly impacting regions such as southern Ontario and British Columbia due to changing climate patterns. Droughts can disrupt water supplies, harm agricultural productivity, and increase wildfire risks, with cascading effects on local economies and ecosystems.

Climate Moisture Index (CMI) measures drought conditions by comparing precipitation and potential evapotranspiration to determine if a region has a moisture surplus or deficit over time. The map on page 18 presents projected CMI values across Canada under RCP 8.5, showing areas expected to face increasing moisture deficits by the end of the century.

### Implications for Housing

Droughts and water shortages place significant stress on housing and infrastructure by limiting access to potable water and straining municipal water systems. Landscaping and outdoor water use, such as irrigation, become less sustainable, particularly in water-scarce regions. For housing, this necessitates the adoption of water-efficient fixtures, rainwater harvesting systems, and greywater reuse technologies to reduce demand. Infrastructure must also adapt, with investments in drought-resistant landscaping, advanced water management systems, and robust infrastructure to support equitable water distribution and conservation efforts.

# 5.0 / Drought

## Design Strategies

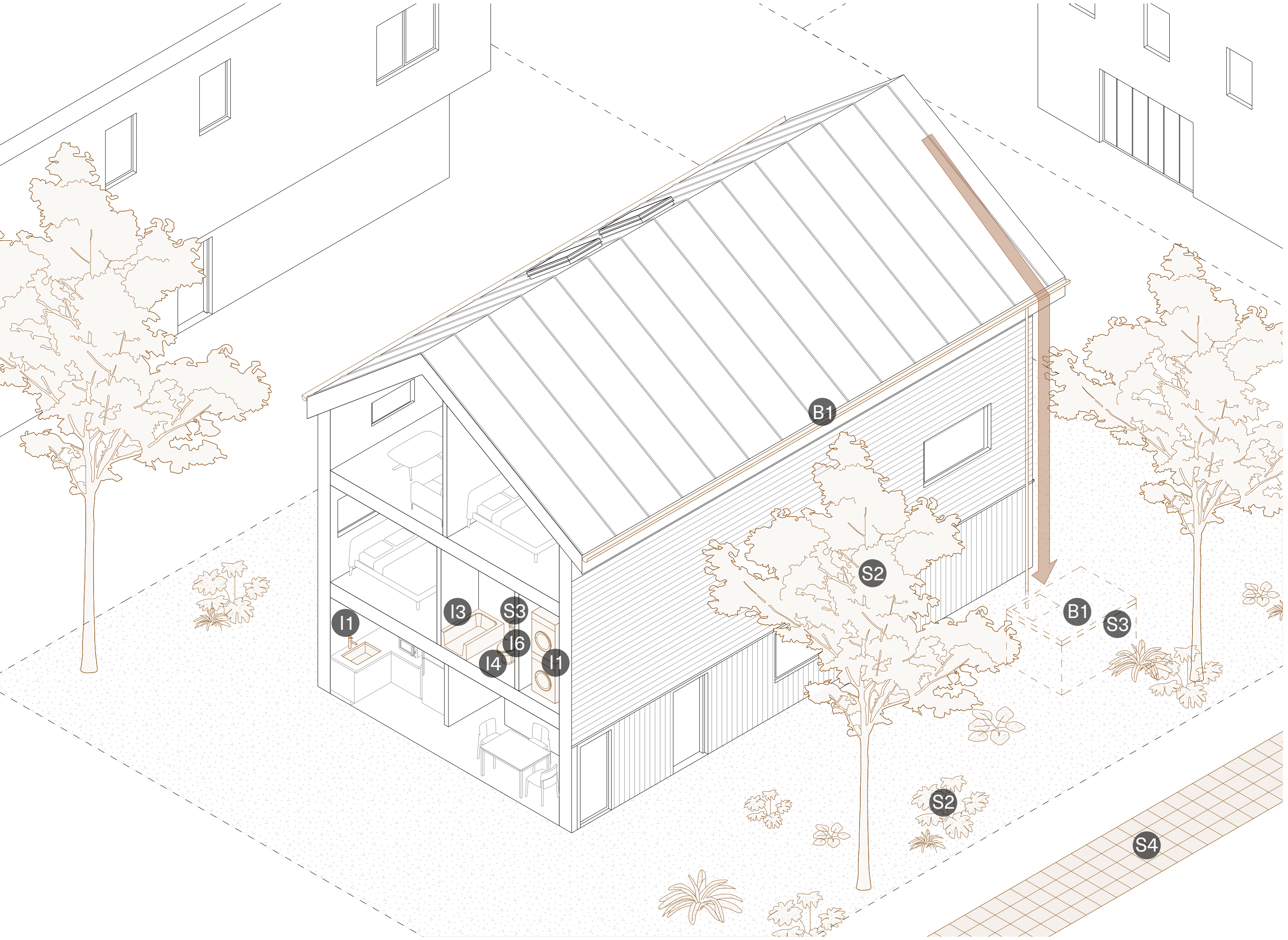


*Image of prototype Catalogue House with strategies to address drought. See following page for detailed descriptions of design strategies.*

+++ *high impact* ++ *moderate impact* + *low impact*

### Building

| | | |
|---|---|---|
| B1 | Rainwater harvesting system<br>Incorporate cisterns or tanks to collect and store rainwater for onsite reuse | +++ |
| B2 | Green roofs (not pictured)<br>Incorporate to enhance insulation, manage stormwater, improve biodiversity, and mitigate urban heat effects | +++ |

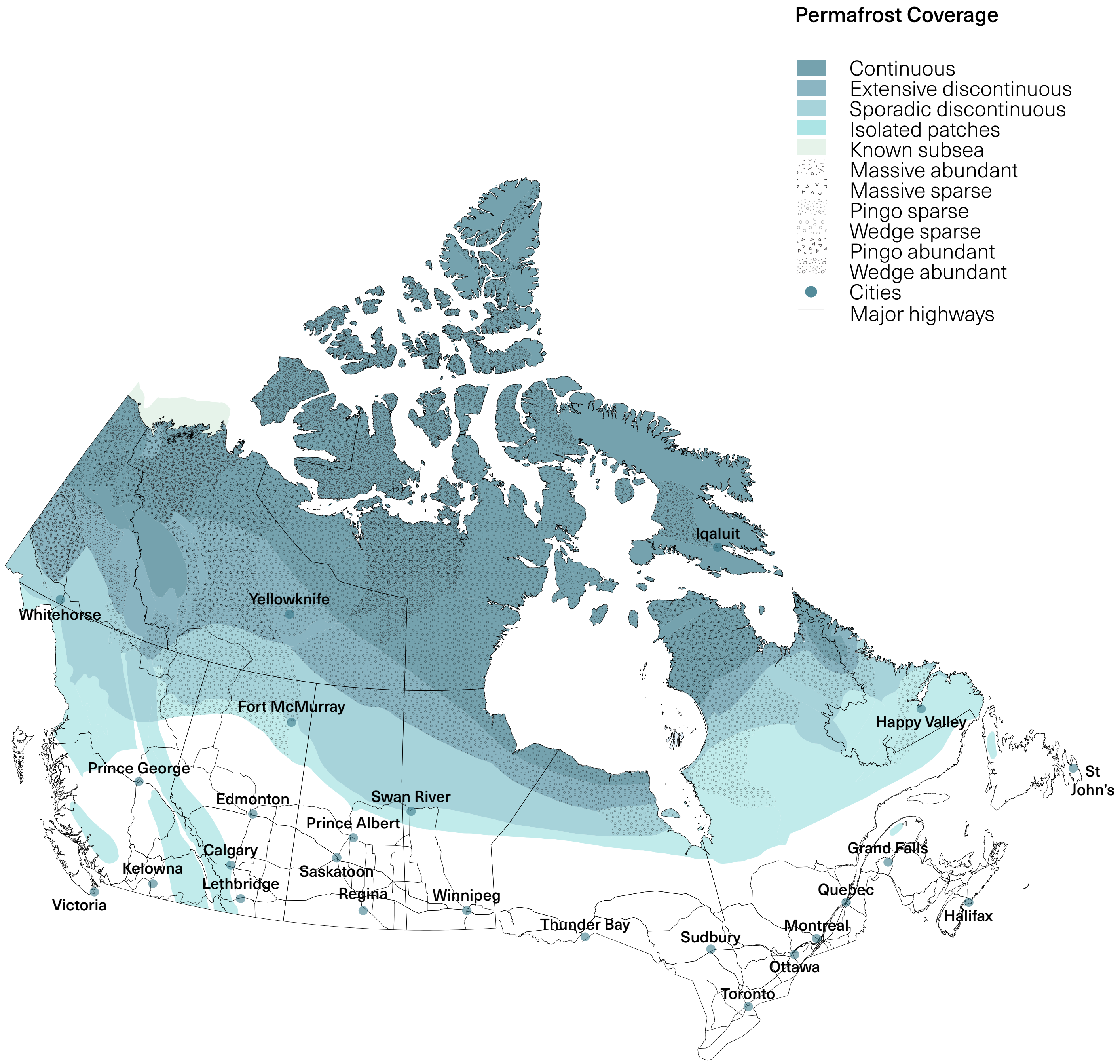
### Interiors & Systems

| | | |
|---|---|---|
| I1 | Low-water-use dishwashers and washers<br>Opt for ENERGY STAR-rated or other high efficiency appliances to minimize water and energy consumption | +++ |
| I2 | Submeters for water monitoring (not pictured)<br>Install submeters to track water use and identify opportunities for conservation | ++ |
| I3 | Ultra-low-flow water closets<br>Use high-efficiency fixtures to significantly reduce water consumption | +++ |
| I4 | Waterless fixtures<br>Specify water-free options like composting toilets or dry urinals for innovative water savings | ++ |
| I5 | Drought monitoring and planning tools (not pictured)<br>Leverage smart systems to track water supply conditions and adapt usage accordingly | ++ |
| I6 | Dual-flush water closets<br>Install toilets with dual-flush options to provide flexibility in water use based on waste type | +++ |

### Site

| | | |
|---|---|---|
| S1 | Restricted water use and grazing (not pictured)<br>Designate areas with limited irrigation or grazing to conserve water and reduce soil erosion | +++ |
| S2 | Xeriscaping<br>Utilize drought-tolerant plants and minimal irrigation to create water-efficient landscapes | +++ |
| S3 | Greywater reuse systems<br>Capture and reuse lightly used water for non-potable applications like irrigation or toilet flushing | +++ |
| S4 | Permeable pavement<br>Install surfaces that allow water infiltration to reduce runoff and recharge groundwater | +++ |
| S5 | Smart irrigation system (not pictured)<br>Install a smart irrigation system to conserve water by automatically adjusting watering schedules | ++ |

# 6.0 / Permafrost Thaw



*Map of Canada showing permafrost coverage. From NRCan, Atlas of Canada, 5th Edition.*

Permafrost refers to ground that remains frozen for at least two consecutive years, typically found in Yukon, Northwest Territories, and Nunavut, and parts of northern British Columbia, Alberta, Manitoba, Ontario, and Quebec. Climate change is causing permafrost to thaw, destabilizing the soil and releasing significant amounts of greenhouse gases like methane and carbon dioxide. Thawing permafrost disrupts ecosystems, threatens traditional ways of life for Indigenous communities, and undermines critical infrastructure in the North.

The map opposite (p. 22) shows the extent and classification of permafrost across Canada, revealing regions most vulnerable to thaw-related impacts.

### Implications for Housing

Thawing permafrost poses severe risks to housing and infrastructure by causing ground instability, leading to structural damage such as foundation cracking, tilting, or collapse. Roads, pipelines, and utility networks are also vulnerable to deformation and failure due to shifting soils. Adapting to these challenges requires innovative building techniques, such as elevated or adjustable foundations, and materials that can withstand ground movement. Improved land-use planning, regular monitoring, and the incorporation of climate-resilient technologies are crucial to mitigating the impacts of permafrost thaw on communities and infrastructure.

# 6.0 / Permafrost Thaw

## Design Strategies

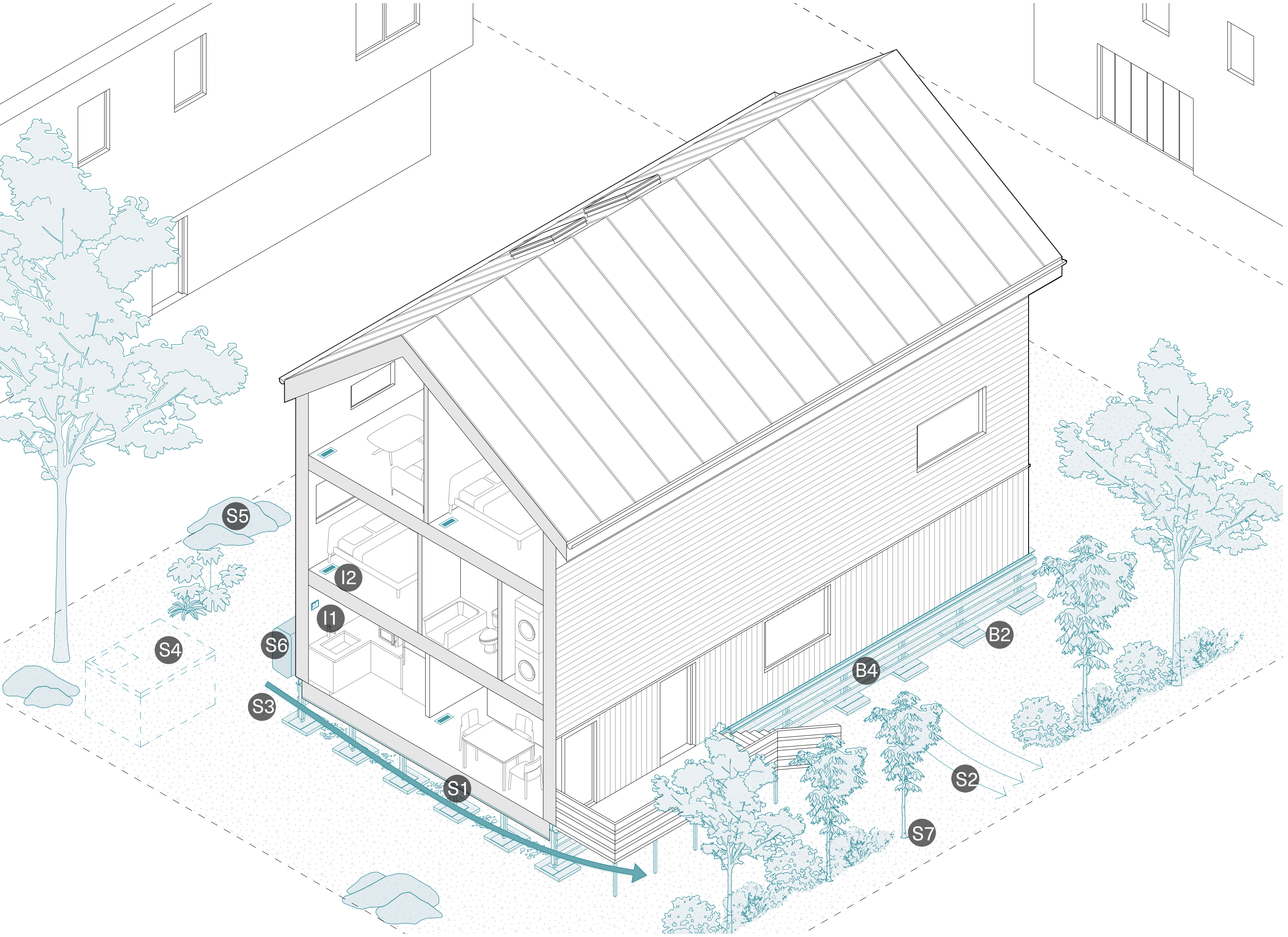


*Image of prototype Catalogue House with strategies to address permafrost thaw. See following page for detailed descriptions of design strategies.*

+++ *high impact* ++ *moderate impact* + *low impact*

### Building

| | | |
|---|---|---|
| B1 | Extended drainpipe from eavestroughs away from the house (not pictured)<br>Ensure downspouts discharge water far from the foundation to prevent localized thawing | ++ |
| B2 | Foundations adapted to permafrost conditions (incl. in some prototypical designs for YK, NWT, NT)<br>Use foundation systems that raise the building above grade (piles, timber/steel cribbing, timber pads, space frame-style frames, etc. suited to local soil conditions and structural requirements | +++ |
| B3 | Wire mesh around building foundations (not pictured)<br>Install wire mesh to deter animals from disturbing or damaging insulation and soil around the foundation | ++ |
| B4 | Use ventilated skirting and floor insulation<br>Avoid solid skirting to allow airflow and prevent permafrost thaw and floor insulation to reduce heat loss | ++ |

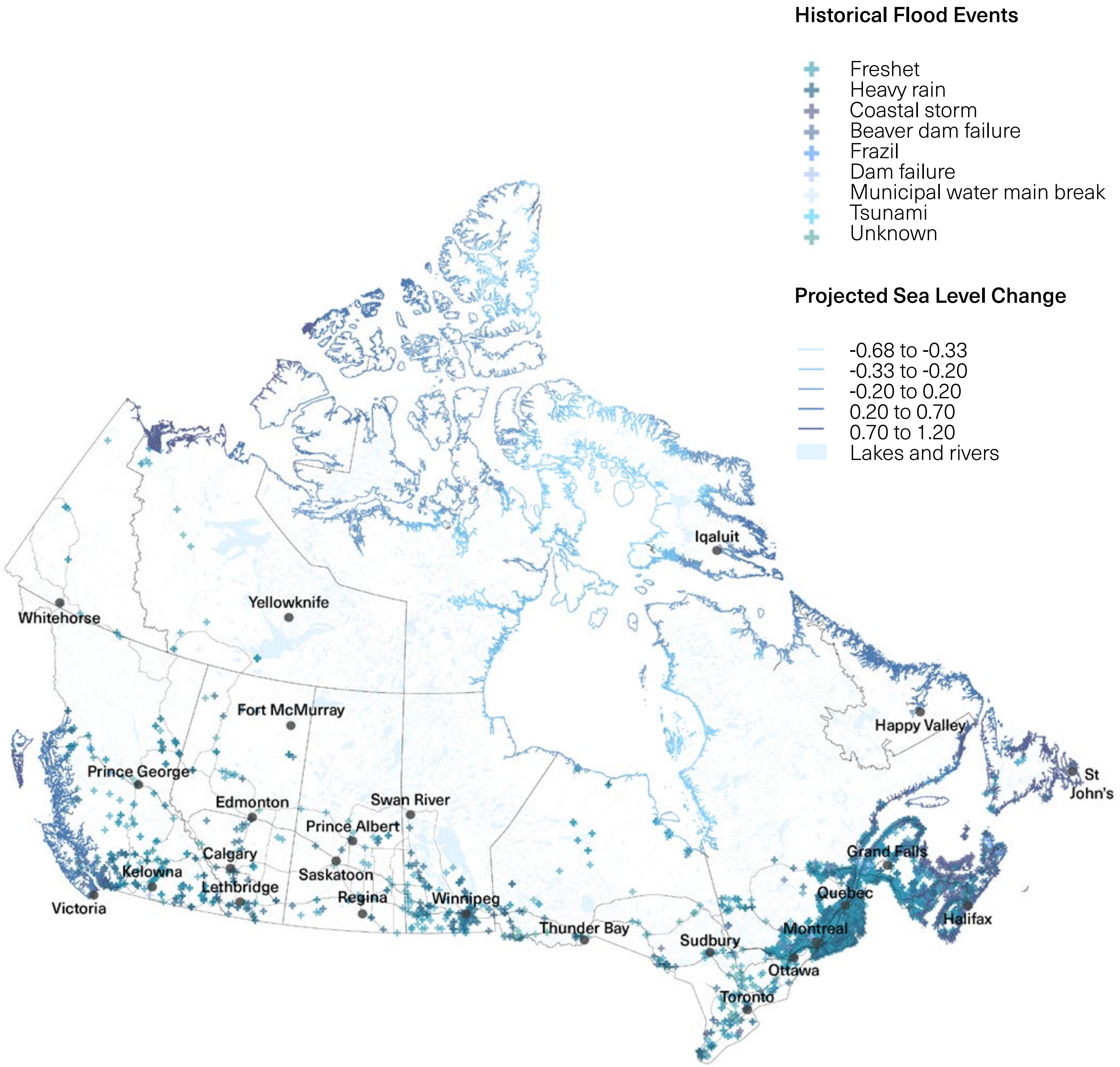
### Interiors & Systems

| | | |
|---|---|---|
| I1 | Water tank overflow light indicator<br>Install visual alerts to detect water overflow and prevent saturation near the building | ++ |
| I2 | Vents to allow cold air access in the winter<br>Incorporate vents to maintain low temperatures under the structure, helping preserve permafrost integrity | ++ |

### Site

| | | |
|---|---|---|
| S1 | Gravel for under house water pools<br>Gravel pads allow water to infiltrate and drain away from house preventing permafrost thaw | ++ |
| S2 | Natural drainage flow<br>Design site grading to direct water away from the building, maintaining permafrost stability | +++ |
| S3 | Airflow under house<br>Elevate buildings to allow air circulation, reducing heat transfer to the ground and preserving permafrost | +++ |
| S4 | Overflow tank<br>Install tanks to capture excess water and prevent ground saturation near the structure | ++ |
| S5 | Shovel snow away from foundation<br>Regularly remove snow around the foundation to minimize ground warming from insulation effects | +++ |
| S6 | Regular checks on heating oil tanks<br>Inspect tanks for leaks to avoid soil contamination and permafrost degradation | + |
| S7 | Natural shading on the southern side<br>Plant vegetation or add structures to limit direct solar heat on permafrost during summer | ++ |

# 7.0 / Flooding



*Map of Canada showing flood events and sea level rise. From NRCan, CanCoast.*

Flooding occurs when water covers normally dry land and takes various forms, driven by climate change and human development. Each type presents distinct risks to ecosystems, economies, and public safety. Coastal flooding and sea-level rise threaten Atlantic Canada and parts of British Columbia due to storm surges, rising seas, and land subsidence. Fluvial flooding from overflowing rivers affects areas like Manitoba's Red River Valley and Ottawa-Gatineau, often worsened by heavy rain and snowmelt. Urban flooding impacts dense cities like Toronto and Montreal, where hard surfaces block water absorption. Ice jam flooding, common in Alberta, the Yukon, and northern Quebec, happens when ice blocks rivers during freeze-thaw cycles.

The map on page 26 highlights historical flood events, including those caused by heavy rainfall, coastal storms, dam failures, etc. alongside projected sea level changes, showing regions at heightened flood risk.

### Implications for Housing

Flooding has profound implications for housing and infrastructure, causing direct damage to homes, roads, and utility networks and rendering areas temporarily or permanently uninhabitable. Coastal flooding and sea-level rise necessitate elevated housing designs, floodproofing techniques, and the strategic retreat of vulnerable communities. Fluvial and urban flooding require investments in green infrastructure like permeable surfaces, stormwater management systems, and flood barriers to reduce runoff and improve drainage capacity. Ice jam flooding highlights the need for enhanced river monitoring and climate-adaptive engineering to mitigate risks in northern regions.

# 7.0 / Flooding

## Design Strategies

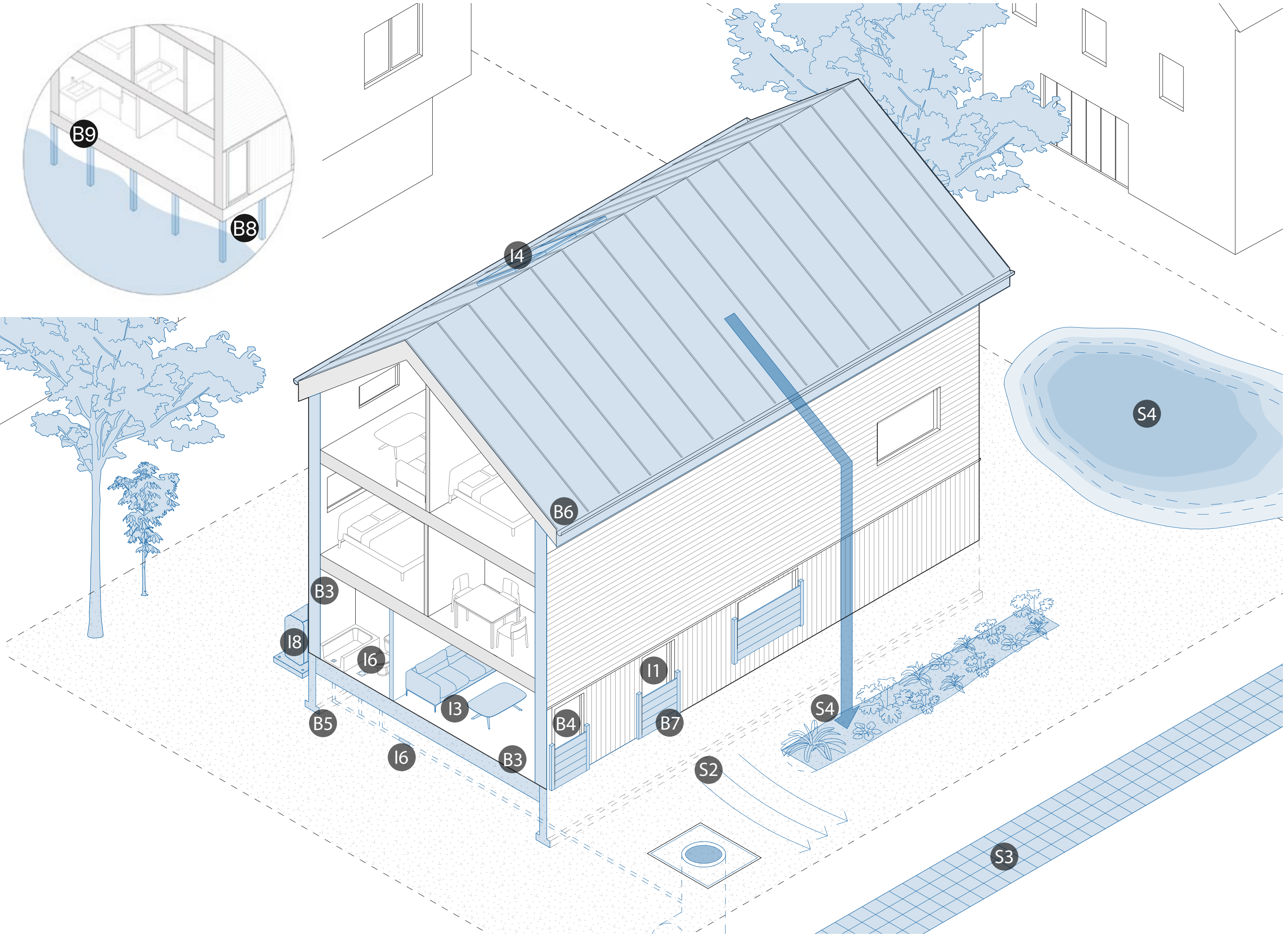


*Image of prototype Catalogue House with strategies to address flooding. See following page for detailed descriptions of design strategies.*

+++ *high impact* ++ *moderate impact* + *low impact*

### Building

| | | |
|---|---|---|
| B1 | Downspouts and sump discharge pipes (not pictured)<br>Direct water away from the foundation (at least 2m) to prevent seepage and reduce basement flooding | ++ |
| B2 | Window wells with covers (if applicable, not pictured)<br>Install protective covers to shield window wells from water intrusion | ++ |
| B3 | Water-resistant materials<br>Use water-resistant materials for floors, walls, etc. to minimize damage during flooding | ++ |
| B4 | Sealants and shields<br>Apply waterproof sealants or install flood shields on walls and openings to block water entry | +++ |
| B5 | Waterproofed foundations (if applicable)<br>Ensure the foundation is sealed with waterproofing materials to prevent seepage | +++ |
| B6 | Roof drainage<br>Increase capacity of roof drainage and rainwater leaders | ++ |
| B7 | Grade-level or elevated access (prototypical designs provide units at or above grade)<br>Build on a slab or elevated foundation in flood-prone areas to keep water out and prevent costly damage | +++ |
| B8 | Elevation on posts, columns, pilings, or stilts<br>Elevate buildings on durable supports for flood-prone areas, especially near coastlines | +++ |
| B9 | Raised floor level and foundations<br>Increase the elevation of the ground floor and foundations to stay above potential floodwaters | +++ |

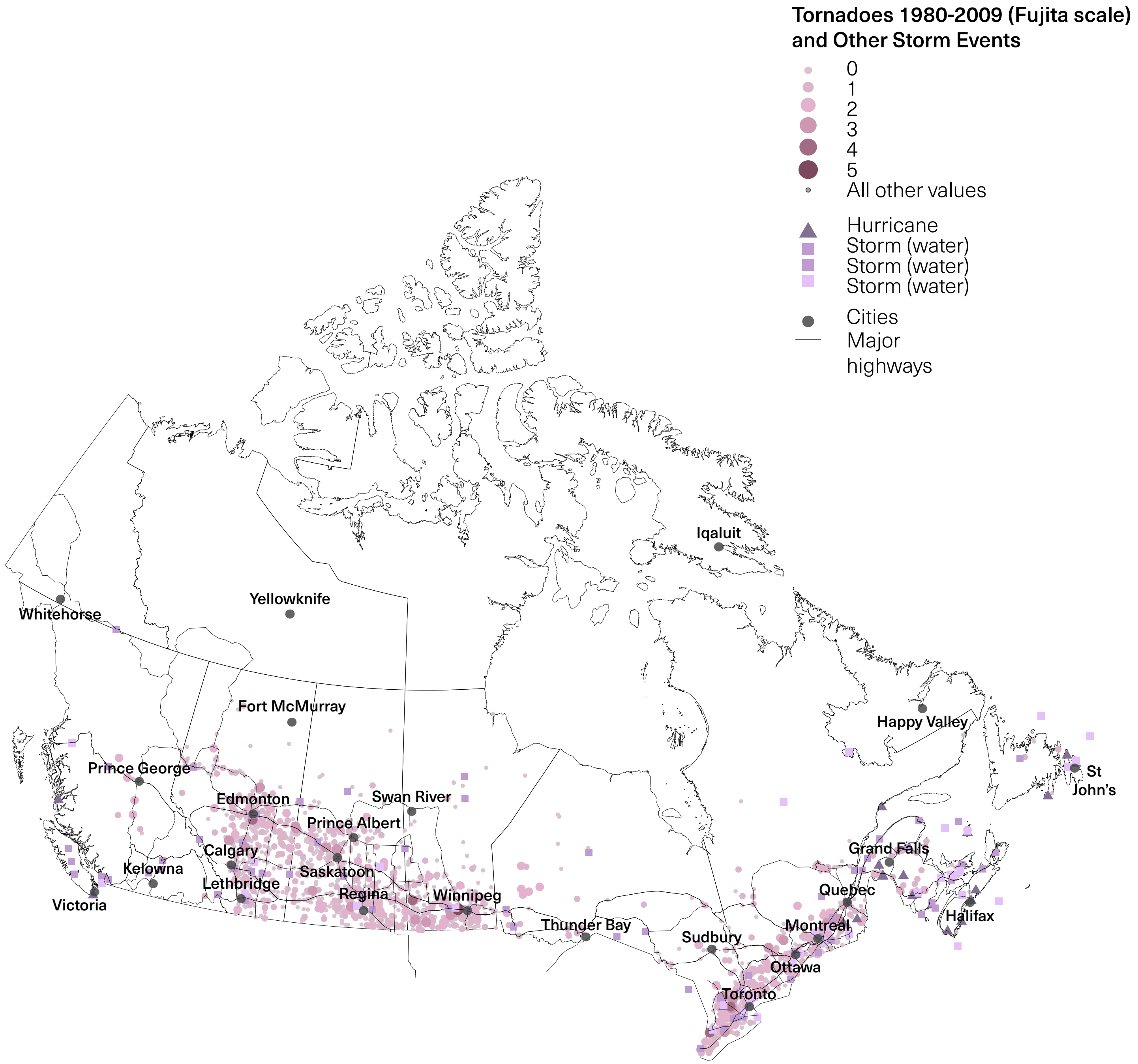
### Interiors & Systems

| | | |
|---|---|---|
| I1 | Waterproof openings<br>Use floodproof doors, windows, and other sealed openings to prevent water intrusion | +++ |
| I2 | Raised flood-sensitive equipment (not pictured)<br>Elevate HVAC, electrical panels, and other critical equipment above potential flood levels | ++ |
| I3 | Water-resistant materials<br>Use water-resistant materials for cabinetry, trim, and furniture to minimize flood damage | ++ |
| I4 | Autonomous power supply<br>Install generators or solar power systems to maintain energy during outages caused by flooding | + |
| I5 | Sump and pump systems (not pictured)<br>Include sump pumps to remove water from basements or crawl spaces efficiently | ++ |
| I6 | Backwater valves<br>Install valves to prevent sewage from backing up into the building | + |
| I7 | Flood vents (not pictured)<br>Incorporate openings to allow water to flow through and reduce structural pressure | +++ |
| I8 | Secure fuel tanks<br>Anchor fuel tanks to prevent them from floating and causing damage or spills during floods | + |

### Site

| | | |
|---|---|---|
| S1 | Coordinate site drainage with municipal systems (not pictured)<br>Ensure proper site drainage and connection to prevent backups during storms | +++ |
| S2 | Site grading (including driveway slope)<br>Slope grading and driveways away from the building to avoid water pooling near entrances | ++ |
| S3 | Permeable pavers<br>Use porous materials to increase water infiltration and reduce surface runoff | +++ |
| S4 | Sustainable drainage systems (SuDS)<br>Incorporate swales, rain gardens, or bioretention basins to manage stormwater naturally | ++ |

# 8.0 / Storms



*Map of Canada showing tornadoes, hurricanes, and storms. From NRCan, ESRI Canada, Canadian Community Maps.*

Storms in Canada include hurricanes, tornadoes, ice storms, and extreme snowfall—each posing distinct risks. Hurricanes and windstorms, especially in Atlantic Canada, cause flooding, erosion, and structural damage. Tornadoes impact southern Ontario, the Prairies, and parts of Quebec with sudden, destructive winds. Ice storms, like the 1998 event in Ontario and Quebec, and more recently the 2022 Derecho in Ontario, lead to power outages, hazardous travel, and fallen trees and lines. Heavy snowfall in eastern Newfoundland, northern Ontario, and interior British Columbia can disrupt transport, strain roofs, and isolate communities. Climate change is intensifying storm patterns, with stronger winds, heavier precipitation, and more frequent extreme events.

The map (p. 30) visualizes storm events across Canada from 1980 to 2009, including tornadoes (classified by Fujita scale), hurricanes, and storms.

### Implications for Housing

Storms, hurricanes, and tornadoes pose significant challenges to housing and infrastructure by exposing vulnerabilities in structural integrity and resilience. Homes must be designed to withstand high wind speeds, using reinforced roofing systems, impact-resistant windows, and anchored foundations. Community infrastructure, such as power lines, communication networks, and transportation systems, requires storm-hardened designs to reduce outages and delays. Flooding and wind damage from hurricanes and storms necessitate elevated structures, storm surge barriers, and drainage improvements, while tornado-prone areas benefit from storm shelters and thoughtful building codes.

# 8.0 / Storms

## Design Strategies

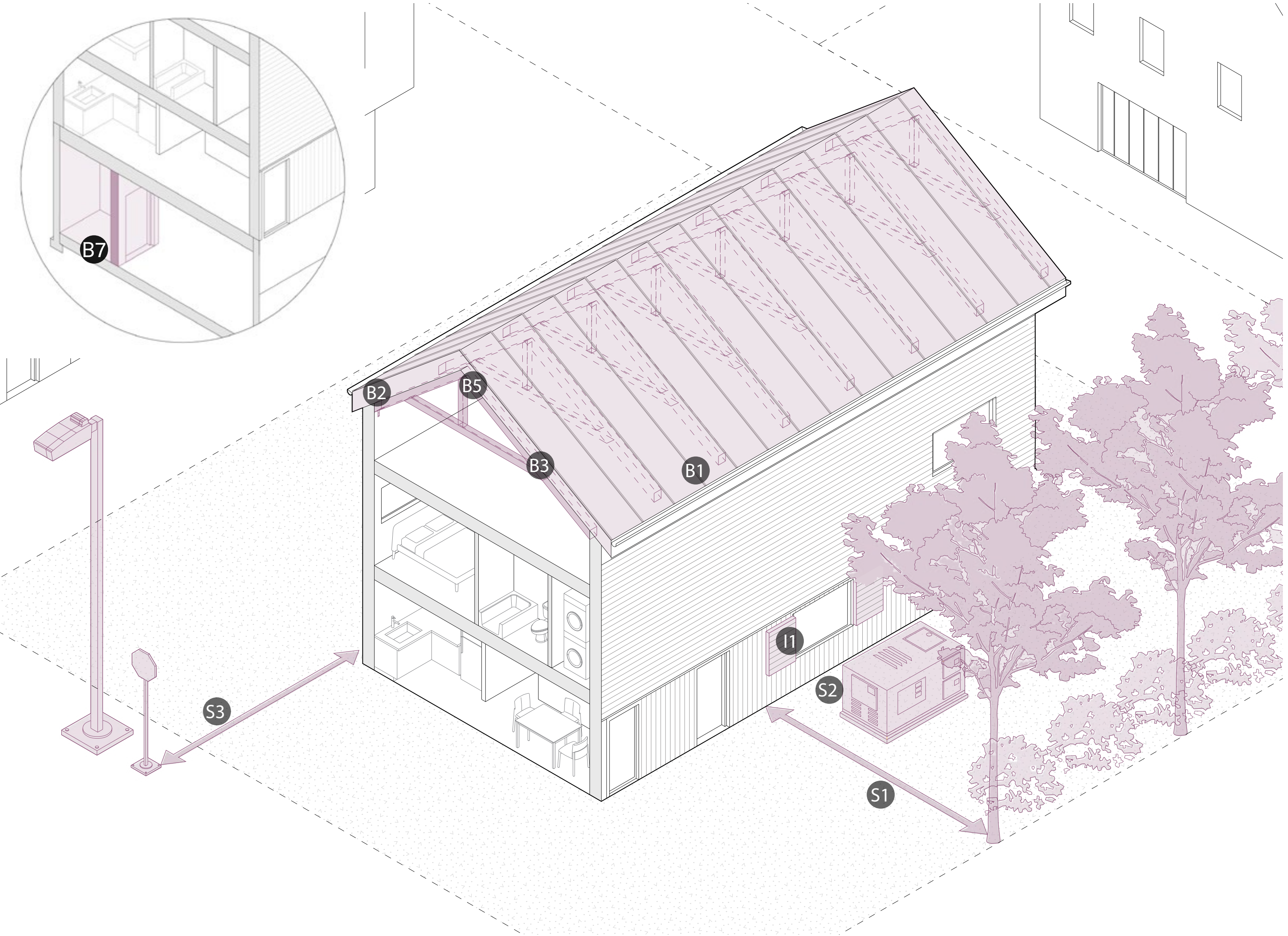


*Image of prototype Catalogue House with strategies to address tornadoes, hurricanes, and storms. See following page for detailed descriptions of design strategies.*

Structural design for high winds
Consult a structural engineer to ensure framing, connections, and anchorage are designed for high wind loads

+++ *high impact* ++ *moderate impact* + *low impact*

### Building

| | | |
|---|---|---|
| B1 | Weather-resistant roofing material<br>Choose materials like metal, clay, or slate that withstand high winds and heavy precipitation during storms | +++ |
| B2 | Waterproofed roof deck (included in all base roof designs)<br>Install a waterproof membrane layer beneath roof covering to prevent water intrusion during winds or heavy rain | ++ |
| B3 | Roof sheathing, fasteners, and fastener spacing<br>Use thicker sheathing, stronger fasteners, closer spacing, and hurricane ties to reinforce roof against wind uplift | ++ |
| B4 | Roof vents (not pictured)<br>Install roof vents rated for high winds | ++ |
| B5 | Structural design for high winds<br>Consult a structural engineer to ensure framing, connections, and anchorage are designed for high wind loads | +++ |
| B6 | Garage doors rated for high wind (if applicable, not pictured)<br>Install wind-rated garage doors to prevent structural breaches and internal pressurization during storms | ++ |
| B7 | Safe room with concrete walls<br>Construct an reinforced safe room to provide refuge during storms or tornadoes (possibly below ground) | ++ |

### Interiors & Systems

| | | |
|---|---|---|
| I1 | Protective shutters<br>Install operable or fixed shutters to shield windows and glazed doors from windborne debris and pressure changes | ++ |
| I2 | Hail guards on roof-mounted equipment (not pictured)<br>Use hail-resistant covers or mesh to protect HVAC units and other rooftop systems from impact damage | + |

*Also refer to the Interiors & Systems strategies in the Flooding section of this guide—such as elevated mechanical systems, sump pump backups, and autonomous power supply—as these measures are also critical in storm-prone areas and during periods of extreme precipitation.*

### Site

| | | |
|---|---|---|
| S1 | Natural windbreaks and thoughtful ventilation strategies<br>Plant trees and shrubs at safe distances to reduce wind pressure and prevent storm damage from falling limbs | +++ |
| S2 | Alternative or onsite power supply<br>Integrate backup power systems like solar panels or generators to maintain functionality during outages | ++ |
| S3 | Secure site elements<br>Ensure a safe distance from light poles, shading elements, and signage | + |
| S4 | Underground power and telecommunication lines (not pictured)<br>Relocate power and communication lines underground to protect them from wind damage | + |

# Appendix

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