Centre for International
Governance Innovation

Policy Brief No. 141 — October 2018

Flood Risk Mapping in Canada: Moving Forward on a National Priority

Daniel Henstra and Jason Thistlethwaite

Key Points

- To improve public awareness of flood risk and meet its commitment to the United Nations Sendai Framework on Disaster Risk Reduction, Canada must develop up-to-date flood risk maps and make them publicly available.
- Effective flood maps improve risk perception, ensure information is accessible and stimulate risk reduction. Good flood maps provide: information to personalize the experience of flooding; local and historical context; a legend; legible flood extents; definitions of scientific and technical terminology; transparency on uncertainty and limitations; data on all forms of flooding; and risk reduction advice.
- Until a more coordinated map development process can occur, the Government of Canada should create a national online repository where existing maps are collected and made publicly accessible.

Introduction

Flooding is a major global problem that affects millions of people annually. Floods have become more frequent and severe over the past few decades (Berghuijs et al. 2017) and models project increased future flooding along rivers, in coastal zones and in urban areas (Kundzewicz et al. 2014; Vitousek et al. 2017; Winsemius et al. 2016). Countering this threat requires a strategy of disaster risk reduction, meaning a concerted effort to "reduce the damage caused by natural hazards…through an ethic of prevention" (United Nations Office for Disaster Risk Reduction 2018).

Flood risk maps — cartographic depictions of potential flooding and its possible impacts on property and assets — are a potentially valuable tool to support disaster risk reduction. Good quality, current flood risk maps can, for instance, inform land-use planning decisions to prevent new development in high-risk areas, motivate people living in these areas to take protective action, and legitimate contentious decisions around disaster risk reduction, such as relocating households out of harm's way (Dransch, Rotzoll and Poser 2010; Kellens et al. 2009).

Flooding is Canada's most common and costly natural hazard and reducing the risk of flood-related disasters is an explicit policy priority (Canadian Underwriter 2016). However, Canadians in most parts of the country lack access to high-quality, current flood risk maps. A recent national assessment commissioned by the Government of

About the Authors

Daniel Henstra is a CIGI senior fellow and associate professor of political science at the University of Waterloo. At CIGI, Daniel's research centres on the multi-level governance of complex policy areas, such as climate change adaptation and flood risk management, where he focuses on the networked relationships among elected officials, public servants, stakeholders and the public. Daniel's research has been supported by grants from the Social Sciences and Humanities Research Council, as well as from the Marine Environmental Observation Prediction and Response Network. In addition to his academic work, he has substantial experience in applied policy analysis, including contract research with government departments such as Infrastructure Canada, Natural Resources Canada and Public Safety Canada. Daniel holds a Ph.D. in political science from the University of Western Ontario (2007).

Jason Thistlethwaite is a CIGI senior fellow, as well as assistant professor in the School of Environment, Enterprise and Development in the Faculty of Environment at the University of Waterloo. At CIGI, Jason's research focuses on the global governance of disaster and climate change risk. His research will dive deeper into Canada's current approach to hazard disclosure in real estate markets, flood risk mapping and the moral hazard surrounding disaster assistance. To inform this research, Jason works directly with business and government leaders in the insurance, banking, real estate, building and investment industries. His research has been published in a number of academic and industry journals, and he is a frequent speaker and media contributor on Canada's growing vulnerability to extreme weather. Jason holds a Ph.D. in global governance from the Balsillie School of International Affairs.

Canada, for instance, indicated that the availability of flood maps is grossly uneven across the 10 provinces and most flood maps are outdated, with a median age of 18 years (MMM Group Limited 2014).

In the wake of major flooding in recent years, governments and other stakeholders have shown a renewed interest in flood risk mapping (see, for example, Natural Resources Canada and Public Safety Canada 2017; Office of the Auditor General of Canada 2016). Moreover, a survey of Canadians living in high-risk areas indicated that 92 percent want up-to-date flood maps to be publicly available (Thistlethwaite et al. 2017). As governments in Canada consider options for an expanded use of flood risk maps to support disaster risk reduction, it is valuable to consider key characteristics that experts associate with effective flood risk maps and to explore the approaches of other states in the international community. This policy brief provides information on these topics and offers several recommendations on how flood maps could be used effectively to improve disaster risk reduction in Canada.

Flood Mapping in Canada

The most concerted flood mapping effort in Canada occurred under the Flood Damage Reduction Program (FDRP). This intergovernmental initiative, which operated between 1975 and 1999, aimed to identify and map areas at high risk of flooding (Bruce 1976; Watt 1995). Based on the "100-year flood" — a flood that statistically has a one percent chance of occurring in any given year — a total of 957 "designated flood risk areas" were identified, meaning those lands that are subject to recurrent and severe flooding (Environment Canada 2013).

The FDRP produced hundreds of flood hazard maps, which indicated geographic areas, typically along waterways and coasts, that could be inundated by a 100-year flood. Some of these maps also included additional information, such as the type of flood, flood extent, water depths and flow velocity (Paine and Watt 1992). Flood hazard maps are typically used to support planning and engineering functions, such as setting zoning regulations, enforcing development standards and prioritizing mitigation measures (Porter and Demeritt 2012).

In Ontario, for example, flood hazard maps are created by conservation authorities — regional watershed management agencies empowered by provincial legislation — and are used to regulate development in flood-prone areas along waterways.

Although they provide a rational basis for public policies and administrative decisions, flood hazard maps typically contain highly technical data, lack information on potential adverse consequences associated with flooding and fail to distinguish between different flood sources. These characteristics limit their utility for strengthening public understanding of flood risk. Flood risk maps, by contrast, include information about assets at risk and potential adverse consequences associated with floods, typically denoted in terms of households affected, the likely impact on economic activity and so on (Stevens and Hanschka 2014, 909). They are intended to support policy dialogue, promote public risk awareness and inform decisions about strategic interventions to mitigate flood risk.

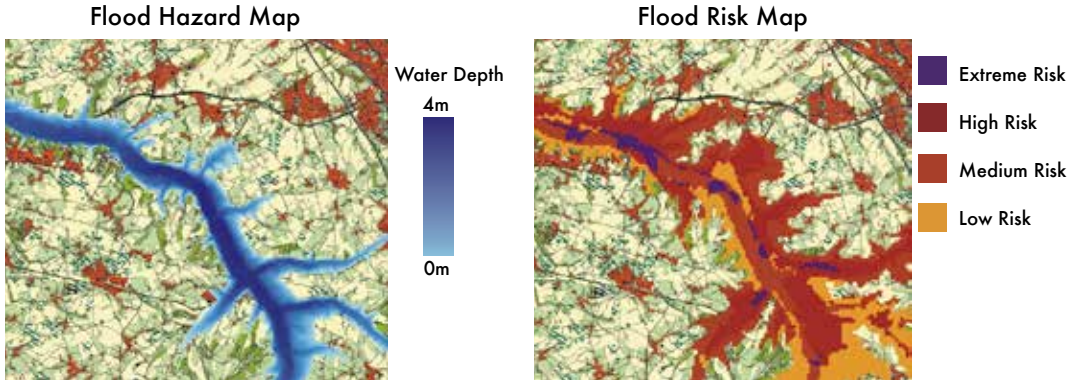
Flood risk maps offer a number of important benefits to different user groups (Van Alphen et al. 2009; Van Kerkvoorde et al. 2018). Land use planners can use flood risk maps to identify flood-prone areas and potential inundation zones in order to make decisions about locating new development and infrastructure. Flood risk maps provide crucial intelligence for emergency management professionals about the location and concentration of vulnerable populations and threats to evacuation routes. Managers of critical infrastructure networks (for example, electricity, gas, water) find value in flood risk maps to assess potential disruptions to service continuity. Insurers are interested in flood risk maps to estimate potential damage to residential and commercial properties and to price premiums accordingly. Perhaps most importantly, flood risk maps inform citizens about the likelihood and potential impacts of flooding on their property, which can encourage them to protect themselves (for example, by buying insurance).

Characteristics of Effective Flood Risk Maps

In recent years, governments in Canada have shown renewed interest in updating existing flood maps and producing new maps to support disaster risk reduction. In 2017, for instance, a Flood Mapping Committee comprising six federal departments, which was advised by a working group that included representatives from provincial governments, industry and academia, released a Federal Floodplain Mapping Framework. Its core objective is to "facilitate a common national best practice and increase the sharing and use of flood hazard information" that will generate a "comprehensive understanding of hazard exposure in order to inform mitigation and preventative measures" (Natural Resources Canada and Public Safety Canada 2017, 10).

Moreover, in 2015, the Government of Canada launched the National Disaster Mitigation Program, a five-year, $200 million initiative to focus investments on significant, recurring flood risk and costs and facilitate private residential insurance for overland flooding (Public Safety Canada 2017). One

Figure 1: Two Types of Flood Maps



Source: de Moel, van Alphen and Aerts (2009, 293).

Table 1: Characteristics of Effective Flood Maps

Characteristic	Description
Personalized experience	Users can find information specific to their property (for example, searchable by postal code)
Local context	Identifiable places or landmarks that help users visualize the likely spatial extent of flooding
Historical context	Depictions of past floods (for example, photographs, victim testimonials) to help users understand potential impacts
Legend	Clear explanation of lines, symbols, colours and terminology
Legible	Easy for the user to distinguish the extent of the flood zone
Explanation of scientific and technical terminology	Meaning of terms (for example, 100-year flood zone) is understandable to a lay audience
Transparent about the limitations and uncertainty	Exposure of adjacent areas and potential expansion of inundation zone due to climate change is acknowledged
Holistic view	All forms of flooding (for example, coastal, riverine and pluvial) are depicted
Risk reduction advice	Information provided on subjects such as evacuation, property-level protection and insurance

Source: Authors

of four funding streams pertains to flood mapping, which permits provinces and territories to apply for support to develop or modernize flood maps. Flood mapping funding has recently been announced in British Columbia, New Brunswick and Ontario (Public Safety Canada 2018a; 2018b; 2018c).

Since these initiatives are in their infancy, there is an opportunity to ensure that new maps are designed to align with the principles of disaster risk reduction. A review of expert literature revealed nine key characteristics of effective flood risk maps. These characteristics can be divided into three categories: improving risk perception; ensuring good information accessibility; and stimulating risk reduction behaviour.

Improving Risk Perception

Flood maps containing concrete information and imagery that are meaningful to users are more effective in increasing an individual's understanding of flood risk (Dransch, Rotzoll and Poser 2010, 299). The first essential characteristic to achieve this objective is a personalized experience, meaning that the flood map should be detailed enough to enable users to find information specific to their property by, for example, searching their address or postal code. A second map feature to capture the user's attention is the incorporation of local context — easily identifiable places or landmarks that help an individual visualize the likely spatial extent of flooding. Third, historical context — photographs or depictions of past flood events or written testimonials of past flood victims — provides emotional cues that help users understand the potential impacts of flooding on their lives, which increases their perception of risk.

Ensuring Information Accessibility

Information accessibility is a measure of the ease and convenience of locating information, but also the level of difficulty associated with understanding information. There are five elements that contribute to the information accessibility of flood maps. First, a legend that clearly explains the meaning of lines, symbols, colours and terminology and what they represent on the map is considered a good practice for flood maps (EXCIMAP 2007, 17). Information accessibility is also enhanced if the map is legible, meaning that it is easy for the user to distinguish the extent of the flood hazard zone, since ambiguity is likely to reduce one's perception of flood risk. A

third criterion for ensuring information accessibility is whether the map includes an explanation of scientific and technical terminology, such as the meaning of the "100-year flood zone," in a way that is understandable to a lay audience (Van Alphen et al. 2009). Fourth, maps that are transparent about the limitations and uncertainty associated with flood zone delineation — such as exposure of areas adjacent to the flood lines and potential expansion of the inundation zone due to climate change — also enhance information accessibility. Finally, flood maps that provide a holistic view of flooding, meaning they depict all major forms of flooding to which a property might be exposed — coastal, riverine and stormwater — have greater information accessibility than those that include only one type of flooding.

Stimulating Risk Reduction

Assuming that the intended purpose of flood maps is, in part, to motivate individuals to contribute to disaster risk reduction, then high-quality flood maps should be expected to include some information about how users can reduce their risk of flood impacts. Therefore, the final characteristic of good flood maps is the inclusion of risk reduction advice for target audiences, which typically involves links to additional sources of information on subjects such as evacuation routes, property-level protection measures and flood insurance.

Flood Mapping in Other Countries

This section briefly examines flood mapping initiatives in Australia, the United Kingdom and the United States, three countries that face significant flood risk and that have committed to disaster risk reduction.

Australia

As part of a policy review following major flooding in 2011, the Australian government recognized the need to make flood risk information more publicly accessible. In 2012, it launched the Australian Flood Risk Information Portal, a web-enabled database of flood maps and studies contributed by state, territory and local governments. Once submitted, these products are standardized by Geoscience Australia, an agency of the national government that conducts research and advises on geology and geography, and are made searchable through a database.[1]

By selecting an area on a base map or entering an address, users can zoom in to identify local geographic and cultural features as points of reference, and individual property parcels are easily distinguished. The base map contains a legend and is geocoded with links to available flood studies — reports prepared by municipalities, public utility companies and consultants, which offer scenarios of possible flood impacts at specific sites throughout a community.

However, the Australian Flood Risk Information Portal is not a flood map in the conventional sense, in that the base map does not clearly identify flood hazard extents, but rather connects users to other maps and studies that contain the risk information. Moreover, although it offers a wealth of flood-related information, the portal appears to be designed primarily for use by engineers, insurers and planners, as its contents are highly technical and many of the studies require users to contact the organization that produced them, so the information is not accessible to a lay user.

United Kingdom

Flood maps in the United Kingdom are the responsibility of the Environment Agency and they are made publicly available through the National Flood Information Service.[2] By locating their property on the base map or entering their postal code, users can determine: the probability that their location will flood (reported as high, medium or low); the possible causes of flooding, with risk levels differentiated between riverine, coastal and surface water flooding; and advice on managing flood risk, including planning for emergencies, measures to improve the property's resilience and where to get help after a flood.

The base map can be scaled up to make property boundaries easily distinguishable, and users can select either a basic view (extent of flood risk area only) or a detailed view (including depth, flow and velocity for different flood types). The

1 See www.ga.gov.au/flood-study-web/.

2 See https://flood-warning-information.service.gov.uk/long-term-flood-risk.

Table 2: Comparison of Map Portals in Other Countries

Characteristic	Australia	United Kingdom	United States
Personalized experience	Y	Y	Y
Local context	Y	Y	Y
Historical context	N	N	N
Legend	Y	Y	Y
Legible	n/a	Y	Y
Explanation of scientific and technical terminology	N	Y	Y
Transparent about the limitations and uncertainty	N	Y	N
Holistic view	N	Y	N
Risk reduction advice	N	Y	Y

Source: Authors

meaning of "high risk" is transparent — greater than a 3.3 percent chance of flooding in a given year — and the maps account for flood defences that moderate flood risk in the area of interest. In addition, the mapping portal clearly explains the limitations of the flood modelling, in particular with respect to surface water flooding, which is dynamic and difficult to predict, and warns users that the maps cannot account for factors such as blocked drains or burst pipes. As such, the map includes most of the characteristics of effective flood maps outlined above. The only limitation is that the map does not contain information to help users understand the historical context of flooding at their location.

United States

The primary source of flood maps in the United States is the Federal Emergency Management Agency (FEMA), which is mandated to identify "flood hazard areas" — lands expected to be inundated by a 100-year flood (one percent annual exceedance probability event) — primarily for the purposes of determining rates under the National Flood Insurance Program. The FEMA Flood Map Service Center is the official public source of current flood hazard information and is searchable by address, community name and specific geographic coordinates (latitude and longitude).[3]

Users can zoom in to the base map to clearly identify property boundaries and recognize the topography. Area-specific maps can be downloaded by users, and they contain many of the features of good mapping practice, including recognizable local landmarks and cultural features (for example, buildings, parks), shading to demarcate the likely inundation zone of both coastal and riverine flooding, and links to information resources about how a household could mitigate its flood risk.

However, the Flood Map Service Center does not offer information on past flood events, which could help users understand the possible risks at their location, and there is no obvious consideration given to the risk facing lands adjacent to flood hazard areas or how the inundation zone might be affected by climate change. Moreover, flood maps produced by FEMA cover coastal and riverine flooding, but not stormwater flooding, so these maps do not offer a holistic view. Finally, since updating the maps often means a change in the boundaries of the flood hazard areas and consequent shifts in the cost of flood insurance, they are often received with hostility in

3 See https://msc.fema.gov/portal/home.

affected communities and sometimes spark legal challenges (Barnes 2013; Slowey 2015; Chen 2018).

Whereas Australia has opted for a national portal that simply aggregates links to maps and studies produced by other entities, both the United Kingdom and the United States have centralized flood map production through national departments and have disseminated these maps through a searchable web interface. The former approach is efficient in that it can be operationalized relatively quickly and makes better use of existing map products, but the availability and quality of the maps vary considerably from one location to the next. The latter approach ensures greater consistency in map coverage and quality, but demands a more significant commitment of time and resources.

Implementation

Producing flood risk maps for Canada is undoubtedly a logistical and organizational challenge, due to the country's enormous geographic scale and diverse topography. Another challenge is federalism, which divides responsibility for flood risk management between two sovereign orders of government. Whereas some provinces invest heavily in flood mapping, and might therefore be hesitant to participate in a comprehensive national risk mapping initiative, others struggle to produce up-to-date maps and would welcome such an endeavour. Nevertheless, flooding is a significant problem in most parts of the country and all signs indicate more serious impacts in the years to come. As demonstrated in other states, flood risk maps are an important element of a disaster risk reduction strategy.

Furthermore, advances in technology have made a comprehensive flood risk mapping effort more sophisticated and affordable. For instance, airborne light detection and ranging, or LIDAR, allows for precise mapping of coastal areas vulnerable to flooding from storm surge, a risk that is expected to increase as sea level rises due to climate change (Webster et al. 2006). Geographic information system technology enables analysts to plot the location and concentration of vulnerable groups (for example, using census data and indicators of social vulnerability) in order to spatially visualize the potential human impacts of flooding (Armenakis and Nirupama 2014; McGrath 2017). Finally, satellite-based remote sensing technology has enhanced flood mapping by improving the capacity to forecast vulnerability to flooding of both inland and coastal areas (Klemas 2015; Olthof and Tolszczuk-Leclerc 2018). Private organizations, such as insurers and consultants, can also produce maps at less cost than governments and even offer their data for public use (Lamond and Penning-Rowsell 2014).

Although this policy brief cannot provide a full costing of a Canada-wide flood risk mapping initiative, a 2014 national assessment concluded that "the cost of updating existing mapping and creating an additional 15,300 km of mapping is approximately $365 million. The additional 15,300 km should be sufficient to ensure that mapping is available for 90–95 percent of the population in flood prone areas" (MMM Group Limited 2014, iv). It is notable that this estimate covered new mapping in riverine floodplains only, and did not include mapping for coastal or urban flooding. Nevertheless, the investment seems entirely reasonable in light of the projected costs of flooding into the future. The next section outlines several policy recommendations to improve the use of flood risk maps as a tool for disaster risk reduction.

Policy Recommendations

This policy brief has analyzed the elements of effective flood risk maps and has highlighted the approaches of various other countries to making maps publicly available. As Canada moves ahead with new efforts to produce flood maps for disaster risk reduction, governments should consider the following three recommendations:

Adopt the Australian model to make existing flood maps available, with the objective of moving to a more centralized and coordinated approach as seen in the United Kingdom and the United States. Although there are thousands of flood maps across Canada that have been produced by provincial and municipal governments, administrative agencies, consultants and academics, there is no central repository where they can be accessed by interested parties. The Government of Canada has the technical capacity to create an online database like Australia's Flood Risk

Information Portal,[4] solicit contributions from map creators and curate the collection for professional and public use. This approach, which could be implemented relatively quickly, would offer a stopgap measure until a more robust, coordinated effort to produce flood risk maps can be launched.

Screen funding applications for mapping projects based on the characteristics of effective flood maps outlined here. There is a considerable body of scholarship in Europe and North America that examines the hallmarks of good flood mapping practice, and this research should be the basis for new maps created with public funding. Specifically, new maps should be designed to improve public risk perception, ensure good information accessibility and stimulate risk reduction behaviour.

Create flood risk maps for all of Canada and make them available to the public. These maps should include information on the extent of flood hazards, assets at risk and potential adverse consequences associated with floods (for example, households affected, economic activity likely to be disrupted). Examples from other countries demonstrate that creating flood risk maps is possible and desirable. Making these maps publicly accessible contributes to productive policy dialogue, promotes risk awareness and builds legitimacy for strategic public interventions to mitigate flood risk.

Works Cited

Armenakis, Costas and N. Nirupama. 2014. "Flood Risk Mapping for the City of Toronto." *Procedia Economics and Finance*, 18: 320–26. 4th International Conference on Building Resilience, September 8–11. Salford Quays, UK. https://doi.org/10.1016/S2212-5671(14)00946-0.

Barnes, Jennette. 2013. "Flood Maps Raising Cost of Insurance." *Boston Globe*, September 1. www.bostonglobe.com/metro/regionals/south/2013/08/31/fema-address-flood-zone-worries-thousands-will-see-new-higher-flood-insurance-premiums/hduikf36GiHBCScP1oGwYK/story.html.

Berghuijs, Wouter R., Emma E. Aalbers, Joshua R. Larsen, Ralph Trancoso and Ross A. Woods. 2017. "Recent Changes in Extreme Floods across Multiple Continents." *Environmental Research Letters* 12 (11): 1–8. https://doi.org/10.1088/1748-9326/aa8847.

Bruce, James P. 1976. "The National Flood Damage Reduction Program." *Canadian Water Resources Journal* 1 (1): 5–13.

Canadian Underwriter. 2016. "Government of Canada Launches New Public Awareness Campaign on Flood Risks." *Canadian Underwriter* (blog), November 23. www.canadianunderwriter.ca/catastrophes/government-canada-launches-new-public-awareness-campaign-flood-risks-1004104321/.

Chen, David W. 2018. "In New York, Drawing Flood Maps Is a 'Game of Inches.'" *The New York Times*, January 7. www.nytimes.com/2018/01/07/nyregion/new-york-city-flood-maps-fema.html.

de Moel, H., J. van Alphen and J. C. J. H. Aerts. 2009. "Flood Maps in Europe: Methods, Availability and Use." *Natural Hazards Earth System Sciences* 9 (2): 289–301. https://doi.org/10.5194/nhess-9-289-2009.

4 For example, the Earth Sciences Sector of Natural Resources Canada houses the Canada Centre for Mapping and Earth Observation, a centre of excellence for geomatics, mapping and earth observations. See www.nrcan.gc.ca/earth-sciences.

Dransch, Doris, Henry Rotzoll and Kathrin Poser. 2010. "The Contribution of Maps to the Challenges of Risk Communication to the Public." *International Journal of Digital Earth* 3 (3): 292–311. https://doi.org/10.1080/17538941003774668.

Environment Canada. 2013. "Flood Damage Reduction Program." www.ec.gc.ca/eau-water/default.asp?lang=En&n=0365F5C2-1.

EXCIMAP. 2007. "Handbook on Good Practices for Flood Mapping in Europe." Brussels, Belgium: European Commission.

Kellens, Wim, Wouter Vanneuville, Kristien Ooms and Philippe De Maeyer. 2009. "Communicating Flood Risk to the Public by Cartography." In *The World's Geo-Spatial Solutions*, edited by William Cartwright and Pablo Gran Lopez, 1–11. Santiago, Chile.

Klemas, Victor. 2015. "Remote Sensing of Floods and Flood-Prone Areas: An Overview." *Journal of Coastal Research* 314 (4): 1005–13. https://doi.org/10.2112/JCOASTRES-D-14-00160.1.

Kundzewicz, Zbigniew W., Shinjiro Kanae, Sonia I. Seneviratne, John Handmer, Neville Nicholls, Pascal Peduzzi, Reinhard Mechler, Laurens M. Bouwer, Nigel Arnell, Katharine Mach, Robert Muir-Wood, G. Robert Brakenridge, Wolfgang Kron, Gerardo Benito, Yasushi Honda, Kiyoshi Takahashi and Boris Sherstyukov. 2014. "Flood Risk and Climate Change: Global and Regional Perspectives." *Hydrological Sciences Journal* 59 (1): 1–28. https://doi.org/10.1080/02626667.2013.857411.

Lamond, Jessica E. and Edmund Penning-Rowsell. 2014. "The Robustness of Flood Insurance Regimes given Changing Risk Resulting from Climate Change." *Climate Risk Management* 2: 1–10.

McGrath, Heather Dana. 2017. "Web-Based Flood Risk Assessment: Rapid, User-Friendly Tools Leveraging Open Data." Fredericton, NB: University of New Brunswick.

MMM Group Limited. 2014. "National Floodplain Mapping Assessment: Final Report." Ottawa, ON: Public Safety Canada.

Natural Resources Canada and Public Safety Canada. 2017. "Federal Floodplain Mapping Framework." Ottawa, ON: Government of Canada.

Office of the Auditor General of Canada. 2016. "Mitigating the Impacts of Severe Weather." Ottawa, ON: Office of the Auditor General of Canada. www.oag-bvg.gc.ca/internet/English/parl_cesd_201605_02_e_41381.html.

Olthof, Ian and Simon Tolszczuk-Leclerc. 2018. "Comparing Landsat and RADARSAT for Current and Historical Dynamic Flood Mapping." *Remote Sensing* 10 (5): 780. https://doi.org/10.3390/rs10050780.

Paine, J. D., and W. E. Watt. 1992. "Flood Risk Mapping in Canada: 2. Compatible Mapping." *Canadian Water Resources Journal* 17 (2): 139–48. https://doi.org/10.4296/cwrj1702139.

Porter, James and David Demeritt. 2012. "Flood-Risk Management, Mapping, and Planning: The Institutional Politics of Decision Support in England." *Environment and Planning A* 44 (10): 2359–78.

Public Safety Canada. 2017. "National Disaster Mitigation Program." www.publicsafety.gc.ca/cnt/mrgnc-mngmnt/dsstr-prvntn-mtgtn/ndmp/index-en.aspx.

———. 2018a. "Federal Support for 30 British Columbia Flood Mitigation Projects." News Release, February 3. www.canada.ca/en/public-safety-canada/news/2018/02/federal_support_for30britishcolumbiafloodmitigationprojects.html.

———. 2018b. "Government of Canada Funds Flood Mitigation Project in Ontario." News Release, February 6. www.canada.ca/en/public-safety-canada/news/2018/02/government_of_canadafundsfloodmitigationprojectinontario.html.

———. 2018c. "Governments of Canada and New Brunswick Announce Funding for Flood Mitigation Projects." News Release, June 27. www.canada.ca/en/public-safety-canada/news/2018/06/governments-of-canada-and-new-brunswick-announce-funding-for-flood-mitigation-projects.html.

Slowey, Kim. 2015. "Flooded with Controversy: Developers, Owners Challenge New FEMA Floodplain Maps." Construction Dive, December 10. www.constructiondive.com/news/flooded-with-controversy-developers-owners-challenge-new-fema-floodplain/410537/.

Stevens, Mark R. and Steve Hanschka. 2014. "Municipal Flood Hazard Mapping: The Case of British Columbia, Canada." *Natural Hazards* 73 (2): 907–32.

Thistlethwaite, Jason, Daniel Henstra, Shawna Peddle and Daniel Scott. 2017. "Canadian Voices on Changing Flood Risk: Findings from a National Survey." Waterloo, ON: Interdisciplinary Centre on Climate Change and Partners for Action (P4A). https://uwaterloo.ca/climate-centre/news/canadian-voices-changing-flood-risk-findings-national-survey.

United Nations Office for Disaster Risk Reduction. 2018. "What Is Disaster Risk Reduction?" www.unisdr.org/who-we-are/what-is-drr.

Van Alphen, J., F. Martini, R. Loat, R. Slomp and R. Passchier. 2009. "Flood Risk Mapping in Europe: Experiences and Best Practices." *Journal of Flood Risk Management* 2 (4): 285–92. https://doi.org/10.1111/j.1753-318X.2009.01045.x.

Van Kerkvoorde, Maaike, Wim Kellens, Els Verfaillie and Kristien Ooms. 2018. "Evaluation of Web Maps for the Communication of Flood Risks to the Public in Europe." *International Journal of Cartography* 4 (1): 49–64. https://doi.org/10.1080/23729333.2017.1371411.

Vitousek, Sean, Patrick L. Barnard, Charles H. Fletcher, Neil Frazer, Li Erikson and Curt D. Storlazzi. 2017. "Doubling of Coastal Flooding Frequency within Decades Due to Sea-Level Rise." *Nature Scientific Reports* 7 (1): 1399. https://doi.org/10.1038/s41598-017-01362-7.

Watt, W. Edgar. 1995. "The National Flood Damage Reduction Program: 1976–1995." *Canadian Water Resources Journal* 20 (4): 237–47.

Webster, Tim L., Donald L. Forbes, Edward MacKinnon and Daniel Roberts. 2006. "Flood-Risk Mapping for Storm-Surge Events and Sea-Level Rise Using LIDAR for Southeast New Brunswick." *Canadian Journal of Remote Sensing* 32 (2): 194–211. https://doi.org/10.5589/m06-016.

Winsemius, Hessel C., Jeroen C. J. H. Aerts, Ludovicus P. H. van Beek, Marc F. P. Bierkens, Arno Bouwman, Brenden Jongman, Jaap C. J. Kwadijk, Willem Ligtvoet, Paul L. Lucas, Detlef P. van Vuuren and Philip J. Ward. 2016. "Global Drivers of Future River Flood Risk." *Nature Climate Change* 6 (4): 381–85. https://doi.org/10.1038/nclimate2893.

About the Global Economy Program

Addressing limitations in the ways nations tackle shared economic challenges, the Global Economy Program at CIGI strives to inform and guide policy debates through world-leading research and sustained stakeholder engagement.

With experts from academia, national agencies, international institutions and the private sector, the Global Economy Program supports research in the following areas: management of severe sovereign debt crises; central banking and international financial regulation; China's role in the global economy; governance and policies of the Bretton Woods institutions; the Group of Twenty; global, plurilateral and regional trade agreements; and financing sustainable development. Each year, the Global Economy Program hosts, co-hosts and participates in many events worldwide, working with trusted international partners, which allows the program to disseminate policy recommendations to an international audience of policy makers.

Through its research, collaboration and publications, the Global Economy Program informs decision makers, fosters dialogue and debate on policy-relevant ideas and strengthens multilateral responses to the most pressing international governance issues.

About CIGI

We are the Centre for International Governance Innovation: an independent, non-partisan think tank with an objective and uniquely global perspective. Our research, opinions and public voice make a difference in today's world by bringing clarity and innovative thinking to global policy making. By working across disciplines and in partnership with the best peers and experts, we are the benchmark for influential research and trusted analysis.

Our research programs focus on governance of the global economy, global security and politics, and international law in collaboration with a range of strategic partners and support from the Government of Canada, the Government of Ontario, as well as founder Jim Balsillie.

À propos du CIGI

Au Centre pour l'innovation dans la gouvernance internationale (CIGI), nous formons un groupe de réflexion indépendant et non partisan doté d'un point de vue objectif et unique de portée mondiale. Nos recherches, nos avis et nos interventions publiques ont des effets réels sur le monde d'aujourd'hui car ils apportent de la clarté et une réflexion novatrice pour l'élaboration des politiques à l'échelle internationale. En raison des travaux accomplis en collaboration et en partenariat avec des pairs et des spécialistes interdisciplinaires des plus compétents, nous sommes devenus une référence grâce à l'influence de nos recherches et à la fiabilité de nos analyses.

Nos programmes de recherche ont trait à la gouvernance dans les domaines suivants : l'économie mondiale, la sécurité et les politiques mondiales, et le droit international, et nous les exécutons avec la collaboration de nombreux partenaires stratégiques et le soutien des gouvernements du Canada et de l'Ontario ainsi que du fondateur du CIGI, Jim Balsillie

CIGI Masthead

Executive

Publications

For publications enquiries, please contact publications@cigionline.org.

Communications

For media enquiries, please contact communications@cigionline.org.

@cigionline

Printed in Canada on paper containing 100% post-consumer fibre and certified by the Forest Stewardship Council® and the Sustainable Forestry Initiative.

Centre for International Governance Innovation and CIGI are registered trademarks.

Centre for International Governance Innovation

67 Erb Street West
Waterloo, ON, Canada N2L 6C2
www.cigionline.org