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REDUCING URBAN FLOOD RISK IN CANADA THROUGH CODE INTERPRETATION

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ABSTRACT: While it has been previously reported that resolution of building code enforcement issues may result in reduced vulnerability to extreme natural events, issues surrounding code interpretation have not previously been studied. Among other topics, this study investigated interpretation of code wordings that relate to installation of backwater valves to protect homes from sewer backup—a significant cause of basement flooding associated with extreme precipitation events and urban flooding in Canada. Despite consistent application of code wordings related to backwater valves across the regions of Canada represented in this study, it was found that there are differing interpretations of code wordings, which resulted in differing reported frequencies of installation of backwater valves on both sanitary/combined and storm sewer service connections.

Key Words: Urban Flood, Inflow and Infiltration, Sewer Backup, Canada, Building Code, Plumbing Code

1. INTRODUCTION

Urban flooding resulting from extreme precipitation events is a significant issue for residents, municipalities and insurers across Canada. Several recent events have exemplified the substantial impact of these events. In July, 2013, an extreme rainfall event flooded thousands of homes in the Greater Toronto Area region of southern Ontario—the most populous urbanized region of Canada—resulting in $940 million in insured losses for Canadian property and casualty insurers. A significant event also occurred in southern Alberta in June, 2013 resulting in over $5 billion in losses to governments and $1.7 billion in insured losses. Though the majority of these losses were associated with riverine flooding, it was reported that a significant portion of the insured losses experienced during this event were associated with urban flooding—specifically, sewer backup (Government of Alberta, 2014; PCS Canada, 2014).

Many other Canadian communities, including Montreal, Thunder Bay, Hamilton, Toronto, Mississauga, Edmonton and Moncton, have all been affected with individual or multiple urban flood events that have resulted din $10s or $100s of millions in insured losses over the past decade (Sandink, 2013). In 2012, the Insurance Bureau of Canada estimated that an average of $1.7 billion is paid out to homeowners every year for water damage losses—much of which are associated with urban flooding. Reports indicate that many home insurers have been increasing home insurance rates or reducing coverage as a result of the significant losses they have experienced as a result of water damage and urban flooding over the past few years (Carrick, 2012; CBC, 2014; Smith, 2014; Smolkin, 2013; Tait, 2013).

This paper investigated the application of an article of the 2010 Canadian National Plumbing Code that relates to the protection of homes from a particular component of urban flood risk (sewer backflow/backup), which has been driving the majority of insured losses from urban flooding events. The study revealed that the same wording of the code, though applied consistently across Canada, is interpreted differently at the local level, resulting in differences in the reported frequency of installation of backflow protection devices. The author argues that the wording of this section of the code be clarified with the intent of reducing risk of sewer backup for Canadian homeowners, municipalities and insurers.

1.1 Building Codes and Disaster Risk Reduction

The application and enforcement of building codes has been advanced by several researchers as a long-term, sustainable hazard mitigation strategy (Burby & May, 1999; Burby, 2006; Burton *et al*., 1993; Dean, 1995; Mileti, 1999; Simonovic, 2011; Tobin & Montz, 1997; Wisner *et al*., 2004). Codes are an important component in disaster resilience as they affect the construction and design of buildings, and specify "...not only structural design but also construction methods and materials" (Tobin & Montz, 1997: 212). Illustrating the role of codes in disaster risk reduction, Theckethil (2006) identified several functions of building codes, including reduction of death, property damage and reduction in the need for aid following disaster events (Table 1).

Table 1: Functions of building codes

Reduce death, property damage, disruption to employment in institutions and businesses and need for aid following a disaster
Contribute to the durability of buildings and help maintain quality of life and property values
Ensure the protection of consumers especially homebuyers from purchasing substandard or dangerous housing
Offer a predictable playing field for designers, builders and suppliers
Allow economies of scale in the production of building materials and construction of buildings

Source: Theckethil, 2006: 97

The National Research Council oversees the production of Canada's national model codes, which include the National Building Code, the National Plumbing Code, the National Fire Code and the National Energy Code for Buildings (NRC, 2012a). National model codes are adapted and adopted by provincial governments, and most provinces adopt the National Building and Plumbing Codes with minor amendments (NRC, 2012b). Implementation and enforcement of provincial codes is undertaken at the local level, and it is the local authority (often municipal government) that is "responsible for creating the organizational structure for...code enforcement" (Simonovic, 2011: 35). The resources allocated to the enforcement of codes at the local level may be affected by the relative importance placed on construction and building inspections in comparison to other priorities of local government (Simonovic, 2011).

Much of the research on the role of codes in disaster risk reduction in North America has been conducted in the US (Burby & May, 1999; Mileti, 1999; Theckethil, 2006; Tobin & Montz, 1997). This research has identified issues related to code enforcement for damage reduction from extreme natural events. For example, while the South Florida Building Code was identified as a successful approach at incorporating protection from hurricane winds in new construction, lack of adequate enforcement reduced its effectiveness in curbing damages from Hurricane Andrew in 1992 (Burby, 2006; Tobin & Montz, 1997). Indeed, Platt (1998) and Burby (2006) reported that approximately 25% of the damage that was experienced in Florida during Hurricane Andrew resulted from faulty construction and poor code enforcement—specifically, $4 billion in damages were attributed to code enforcement failures in Dade County, Florida during Hurricane Andrew.

A 1995 survey of local building administrators in southeastern US revealed that half of respondents felt that their departments were not adequately staffed to perform necessary inspections or handle necessary plan review responsibilities (Insurance Research Council and Insurance Institute for Property Loss Reduction, 1995 cited in Mileti, 1999). Burby (2006) further identified significantly higher levels of per-capita US National Flood Insurance Program payouts for states and regions that did not require building code enforcement in comparison to regions where code enforcement programs were in place. Mileti (1999) summarized the shortcoming of building codes as a tool for the reduction of natural disaster losses in the US, and stated that

> ...building codes are for life safety and do not provide for property protection or functionality after a disaster; many local jurisdictions do not have a building official or department, many states allow local jurisdictions to petition wavers from the state-required building code, and; state-mandated codes are often reserved only for certain types of buildings and not for most commercial or residential structures (Mileti, 1999: 165-166).

Aside from enforcement, the content of codes can also affect their ability to limit disaster risk, and building code application in Canada and the US has been criticised for lack of adequate consideration of extreme natural events. For example, in both the US and in Canada, building codes establish the minimum acceptable standards for the preservation of public safety, health and welfare and for the protection of property and the built environment, rather than disaster risk reduction (Mileti, 1999; Simonovic, 2011; Tobin & Montz, 1997). The utility of building codes for reduced disaster risk is also affected by the fact that they apply only to new or proposed construction, and only affect existing buildings if major renovations are conducted (Simonovic, 2011). However, while building codes may apply only to new construction, the expected lifespan for housing ranges from 60 to 100 years with major alterations occurring every 10 to 20 years (Auld *et al*., 2007). Thus, incorporation of disaster risk reduction in new buildings can serve to reduce disaster vulnerability over several decades.

It has also been revealed that it is difficult to encourage property owners to incorporate disaster risk reduction measures in existing buildings on a voluntary basis. A substantial body of research on public behaviour related to natural hazard risk reduction has shown that, before and after disaster events, there is often limited individual willingness to participate in disaster risk reduction (Burton *et al*., 1993; Mileti, 1999). Kunreuther (2006) describes the “natural disaster syndrome,” a central feature of which is the lack of voluntary adoption of disaster mitigation measures by individuals exposed to disaster risk. Kunreuther (2006) posits that it is difficult for homeowners to understand and adapt to high-consequence, low-probability events, and individuals tend to adopt the perception that natural disasters “will not happen to [them],” thus reducing their propensity to expend resources (time, money) on risk reduction measures (Kunreuther, 2006: 209).

A lack of voluntary mitigation action has been specifically identified for earthquake (Lindell & Perry, 2000; Palm, 1990), flooding (Laska, 1990; Shrubsole *et al*., 1995; Siegrist & Gutshcer, 2006; Yoshida & Deyle, 2005), and wildland fire (Brenkert-Smith *et al.*, 2006; McCaffrey, 2004; McGee, 2007; Winter & Fried, 2000). Previous research has also revealed that few homeowners who have been exposed to urban flooding or who live in areas considered vulnerable to urban flooding adopt risk reduction measures including installation of backflow protection devices (Sandink, 2011; 2007), though a willingness to pay for increasing capacity of municipal infrastructure to reduce urban flood risk has been previously identified (Arthur, 2009). Thus, requirement of disaster mitigation measures in new homes may serve as a more effective alternative to voluntary adoption in existing homes.

2. PRIVATE-SIDE (HOMEOWNER-LEVEL) URBAN FLOOD RISK REDUCTION

During intense rainfall events in urban areas, homes may be affected by overland flooding, infiltration flooding and/or sewer backup. Overland flooding occurs when extreme precipitation events exceed the capacity of urban stormwater management infrastructure, including underground storm or combined sewer systems and overland flow systems, resulting in uncontrolled flows of stormwater that can enter homes through windows, doors or other openings close to the surface of the ground. In Canada, underground stormwater management infrastructure is often designed for 1 in 5 year peak flows and overland flow routes are often designed to handle 1 in 100 year events. When precipitation events exceed these standards, overland flooding can occur. However, in older subdivisions, infrastructure capacity may be designed to a lower standard. Further, overland flow routes were not commonly incorporated into subdivision design until the 1970s in Canada (Hulley *et al*., 2008), resulting in higher overland flood risk in older urban subdivisions. This type of flooding is not insurable for the majority of Canadian homeowners outside of Quebec (IBC, 2009a,b).

Infiltration flooding occurs as a result of rising groundwater levels or infiltration of water into the backfill zone surrounding the exterior of below-grade foundation walls. This water can enter basements through cracks in foundation walls and basement floors or where the basement floor joins the foundation wall. Foundation drainage systems, also referred to as weeping tiles, are incorporated into homes to reduce the risk of infiltration flooding, however infiltration flooding can occur when foundation drainage systems fail due to blockages or pipe collapse. Further, older Canadian homes (for example, those built before the 1950s) may not have foundation drainage systems, increasing their risk of experiencing infiltration flooding. This type of flooding is also not insurable for the majority of Canadian homeowners outside of Quebec (see IBC, 2009a,b; 2001; 1994).

Sewer backup occurs as a result of surcharging or overloading of municipal underground sewer systems. When excess water enters sanitary sewers, surcharging can occur, which results in the reversal of flow of sewage into homes through underground sewer connections. Sanitary surcharge is related to inflow and infiltration (I/I), where excess water enters municipal sanitary sewer systems through cracks and loose joints (infiltration), or through cross-connections between sanitary and stormwater infrastructure (inflow). Sewer backup can also occur when homes are serviced by storm sewer connections, frequently incorporated into newer homes to service foundation drainage and eaves trough systems. Sewer backup is the only widely available homeowner flood coverage in Canada (IBC, 2009a,b; 2001; 1994), and as discussed above, this type of flooding has been a major driver for home insurance claims over the past few years in Canada.

Table 2 summarizes measures that can be retrofitted into private, ground-related homes to reduce urban flood risk and whether these measures are addressed in the Canadian National Building or Plumbing Code. Sealing cracks in foundation walls and floors reduces infiltration flood risk for individual homes. Homeowners can also decrease their risk of experiencing flooding from stormwater overland flows through lot-grading that directs water away form foundations and through installation of window wells. While providing limited protection for individual homes, disconnection of downspouts and foundation drainage from municipal sanitary sewer systems can significantly reduce I/I, thus reducing sewer backup risk at a regional level. Backwater valves, maintenance and repair of sewer laterals and sewage ejector systems serve to reduce the risk of sewer backup for individual homes.

As displayed in Table 2, many effective private-site urban flood risk reduction measures are not addressed in the 2010 National Building or Plumbing Codes. Several of these measures are home-maintenance issues, and thus are not relevant for new home construction. The focus of this study is on the article of the National Plumbing Code (NPC) that relates to the installation of backwater valves in new homes—one of the most effective and widely recommended private-side measures for reducing sewer backup risk (see Sandink, 2011). As discussed in the following section, the wording of the sentence of the National Plumbing Code that relates to backflow protection device installation is unclear and prone to different interpretations across the country.

Table 2: Private-side urban flood risk reduction measures and code references

Measure	Function	Notes on Code References
Seal cracks in foundation walls, basement floors	Reduces infiltration flood risk by limiting the risk of water entering the home through below-grade foundation walls and basement floors.	NBC section 9.13 provides guidance on foundation wall damp-proofing and waterproofing. However, this is typically a maintenance issues and is thus not directly addressed in building or plumbing codes.
Extension of downspouts/splash pads	Reduces infiltration flood risk by limiting the amount of water that enters “backfill zone,” and decreases amount of water that enters the municipal sewer system through possible foundation drain connections.	NBC 9.26.18.2 requires that, when downspouts drain onto a yard, measures be taken to limit erosion at the discharge point (e.g., splash pad). The article also requires that extensions be used to carry rainwater away from the building, but extension length is not specified.
Lot grading/backfilling/swales	Reduces infiltration flood risk by directing water away from backfill zones, decreases amount of water that enters the municipal sewer system through possible foundation drain connections, and reduces overland/stormwater flow flood risk by directing surface water away from the home.	NBC subsections 9.12.3 and 9.14.6 provide general advice on grading of foundation excavation backfill and site surface drainage, and requires that the building site shall be graded so that water will not accumulate near the building.
Backflow protection devices (i.e., backwater valve(s))	Reduces sewer backup risk by protecting the home from the backflowing of surcharged sewer systems into homes through underground sewer connections.	NPC article 2.4.6.4. (3) refers to requirements for backwater valves in new construction.
Sewage ejector system/overhead sewer system	Same as above.	NPC Sentence 2.4.6.3. (1) requires gravity drainage to building sewers where possible, prohibiting use of this type of device (depending on local interpretation of codes).
Maintenance, repair of sewer laterals	Reduces sewer backup risk by removing blockages in home’s sewer connection, reduces private-side contributions of infiltration into municipal sewer system.	Maintenance issue—does not apply to new construction.
Window wells/well covers	Reduces overland/stormwater flow flood risk by limiting risk of water entering basement windows, and facilitation of appropriate lot grading.	Related to site drainage and backfill (NBC 9.12.3 and 9.14.6).
Downspout disconnection from municipal sanitary/combined sewer	Disconnection reduces sewer backup risk by decreasing inflow into municipal sewer system. Extensions and splash pads limit infiltration flood risk by directing roof drainage away from foundation walls.	NPC article 2.4.6.1 states that sanitary and storm systems should remain separate, thus prohibiting connection of downspouts to sanitary systems.
Foundation drain disconnection, sump installation, sump backup systems	Reduces sewer backup risk by limiting private-side contributions to municipal inflow/infiltration. Sump pump backup systems limit risk of flooding of homes by sump pump failure.	NBC subsections 9.14.2 and 9.14.5 refer to foundation drainage and disposal of foundation drainage. Sentence NBC Sentence 9.14.5.1.(1) allows foundation drainage to drain the sanitary sewer connections, which may increase flood risk. There is no requirement in the NBC for backup systems for sump pumps.

Source: NRC, 2010a,b; Sandink, 2011; 2009

2.1 The National Plumbing Code and Sewer Backflow Protection

The key sentence in the NPC that relates to the frequency of installation of backwater valves in new homes is sentence 2.4.6.4.(3), which states "…where a *building drain*[i] or *branch*[ii] may be subject to *backflow*[iii], a gate valve or *backwater valve*[iv] shall be installed on every *fixture drain*[v] connected to them…." Referring to "protection from backflow caused by surcharge," Division B Appendix A of the NPC states that "these requirements are intended to apply when in the opinion of the authority having jurisdiction there is danger of backup from a public sewer" (NRC, 2010a: A-22, Division B). Thus, interpretation of this article as it relates to the requirement for the installation of backwater valves depends on the interpretation of the word "may" in sentence (3) of the article. Sentence 2.4.6.4(3) and its intent as stated in the NPC are provided in Table 3.

Table 3: Sentence 2.4.6.4.(3) in the NPC of Canada (2010) and it's intent

Code Sentence	Intent
3) Except as provided in Sentences (4), (5) and (6), where a building drain or a branch may be subject to backflow, a gate valve or a backwater valve shall be installed on every fixture drain connected to them when the fixture is located below the level of the adjoining street.	Sanitation: To limit the probability that a backup of public sewers will lead to backflow into building drainage systems, which could lead to unsanitary conditions, which could lead to harm to persons.

It was hypothesized that this sentence of the NPC may be interpreted in one of two ways by local officials. One manner of interpretation of this sentence would result in the installation of backwater valves only in specific circumstances. In these cases, only some homes "may" be subject to backflow, where, for example, local officials interpret this part of the code to mean that only homes in subdivisions constructed in areas that have had histories of sewer surcharging are required to have backwater valves. These areas might include infill development in older subdivisions, or newer subdivisions that are connected into older sewer systems that have had histories of surcharging causing sewer backup

A further manner of interpretation would result in the installation of backwater valves in most or all new homes built in a municipality. In these cases, any home "may" be subject to backflow, as municipalities may consider all homes that are connected to the sanitary sewer system as potentially at risk of sewer backup. For example, the municipalities of Windsor, Toronto and Ottawa, among several others in Ontario, have adopted by-laws or code interpretations that require the installation of sanitary backwater valves in all or most new home construction because there is the potential for sewer backup on any home connected to an underground public sewer system (City of Ottawa, 2011; City of Toronto, 2008; City of Windsor, 2011).

3. METHODS

A survey targeting local officials responsible for code interpretation and implementation was administered over a four month period starting in June and ending in October, 2012 using an online survey tool. The questionnaire was designed to solicit feedback on the wording of NPC 2.4.6.4.(3) and how it affected frequency of installation of backwater valves in new, ground-related homes in communities across Canada.

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[i] Defined in the NPC as "...the lowest horizontal piping, including any vertical offset, that conducts sewage, clear-water waste or stormwater by gravity to a building sewer..." (NRC, 2010: Division A 1-3)
[ii] Defined in the NPC as "...a soil-or-waste pipe connected at its upstream end to the junction of 2 or more soil-or-waste pipes or to a soil-or-waste stack, and connected at its downstream end to another branch, a sump, a soil-or-waste stack or a building drain" (NRC, 2010: Division A 1-3)
[iii] Defined in the NPC as "...a flowing back or reversal of the normal direction of flow" NRC, 2010: Division A 1-3)
[iv] Defined in the NPC as "...a check valve designed for use in a gravity drainage system." (NRC, 2010: Division A 1-3)
[v] Defined in the NPC as "...the pipe that connects a trap serving a fixture to another part of a drainage system" (NRC, 2010: Division A 1-5)

A total of 243 respondents participated in the survey. Respondents consisted of local and municipal officials directly responsible for implementation and interpretation of provincial plumbing and building codes. Where there were multiple responses from individual municipalities, if available, only the responses from the most senior respondent from the municipality (including, for example, responses from the Chief Plumbing or Building Official) were included in the analysis. In some instances, several respondents replied to the survey from the same municipality, but did not leave contact or title information. In these cases, responses were left out of the analysis, and only respondents who clearly indicated that they were associated with the municipality were incorporated into the analysis.

The respondent filtering process described above resulted in the identification of 160 valid responses from individuals representing local authorities responsible for code interpretation and implementation in the Yukon, British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, New Brunswick and Nova Scotia. Respondents from all regions except Saskatchewan worked for municipal governments or local municipal authorities. The majority of Saskatchewan respondents (6 of 7) responded from the perspective of Regional Health Authorities, which are responsible for plumbing code interpretation and implementation for all but three Saskatchewan municipalities. A summary of total and valid responses for each province represented in the survey is provided in Table 4. The combined populations of local authorities and municipalities represented in the survey are also provided in Table 4. Responses from New Brunswick and Nova Scotia were combined to simplify the analysis.

Table 4: Response summaries

Province/Region	**Responses**		**Combined Population of Valid Response Municipalities/Local Authorities**[1]	**% of Prov./Reg. Pop.**[1]
	Total	**Valid**		
British Columbia	69	41	1,882,665	44%
Alberta	42	21	2,150,714	65%
Saskatchewan	8*	7*	>430,466[†]	>44%[†]
Manitoba	37	25	766,016	67%
Ontario	82	58	6,261,979	51%
New Brunswick and Nova Scotia	8	7	675,191	41%

*6 Regional Health Authorities, representing 9 cities and 107 towns, and hundreds of additional municipalities and includes one municipal respondent

[†]Includes population only for 116 cities and towns under the jurisdiction of Regional Health Authority respondents and the individual municipality that replied to the survey

[1]2006 figures. Sources: BC Stats, 2011; Saskatchewan Ministry of Municipal Affairs, 2012; Statistics Canada, 2011

4. RESULTS AND DISCUSSION

Simonovic (2011: 35) stated that “any code is only as good as the enforcement that goes along with it.” The results of this study indicate that, in addition to enforcement, interpretation is also important when considering the effectiveness of codes for reducing disaster losses. This study revealed that code interpretation differs between many local authorities responsible for code implementation within the case study provinces of BC, Alberta, Saskatchewan, Manitoba, Ontario, New Brunswick and Nova Scotia. Differences in interpretation existed despite consistent wording across the country.

As presented in Table 5, a considerable proportion of respondents from all provinces represented in the survey indicated that the code would be interpreted in a way that would require backwater valves in all or most new homes. Specifically, the majority of respondents from Alberta, Saskatchewan, Manitoba, and New Brunswick/Nova Scotia indicated that the code was interpreted in a way that would require sanitary backflow protection for all or most new homes. However, the majority of Ontario and British Columbia respondents reported that NPC sentences 2.4.6.4.(3) would be interpreted in a way that would require backwater valves only in “rare, specific circumstances.”

Table 5: Responses to the question "In your (municipality/health region), this part of the code would be interpreted to mean that backwater valves shall be installed in..."

Response	**Province/Region**					
	BC[1]	**AB[2]**	**SK[3]**	**MB[4]**	**ON[5]**	**NB/NS[6]**
	%	**%**	**%**	**%**	**%**	**%**
All new homes	7	52	43	52	14	29
Most new homes	12	29	43	20	12	29
Rare, specific circumstances	66	19	-	28	60	14
Code does not require BWVs in any circumstance	7	-	-	-	3	-
Not sure how this part of the code would be interpreted in my municipality	2	-	-	-	3	-
No response	6	-	14	-	8	28

[1]British Columbia (n=41), [2]Alberta (n=21), [3]Saskatchewan (n=7), [4]n=25, [5]n=58, [6]n=7

Code interpretation in the province of Alberta was more consistent than in other provinces. While the Government of Alberta does not require local authorities to interpret this article of the code in a specific way, guidance on interpretation issues is provided through the Alberta Safety Codes Council. The Council offers several mechanisms, including the training of Safety Codes Officers and interpretation support, including an inspector phone-line that is staffed by a plumbing officer that can provide advice on code interpretation issues. Twice-yearly meetings of a professional association which include Safety Codes Officer discussion on code interpretation issues also aids in consistent interpretation of code wordings in the province (Pers. Comm., S. Manning, Chief Plumbing and Gas Administrator, Alberta Municipal Affairs, Aug. 2, 2012).

As part of Safety Codes Officer training in Alberta, the province issues information bulletins to assist in code and building inspection issues. The bulletin related to protection of building drainage systems provides advice on interpretation of the Alberta provincial plumbing code sentence 2.4.6.4.(3). Specifically, the bulletin advises that "a backwater valve or gate valve shall be installed on drains to every fixture that is installed below the adjoining street and, therefore, subject to backflow" (Safety Codes Council, 2007). The interpretation provided by the Safety Codes Council removes uncertainty associated with the term "may" in NPC sentence 2.4.6.4.(3), advising that code officials consider any home connected to a sewer systems as vulnerable to sewer backup.

4.1 Service Connection Affected by Code Wordings

To better understand how NPC article 2.4.6.4 was being interpreted by local authorities, respondents were asked if the article referred to storm, sanitary/combined, or all types of home service connections. The NPC defines building drains as "...the lowest horizontal piping, including any vertical offset, that conducts sewage, clear-water waste or storm water by gravity to a building sewer" (NRC, 2010: 1-3), indicating a reference to both sanitary and storm sewer systems. Thus, the code intends for this section to refer to both sanitary and storm connections. However, the survey revealed further inconsistency regarding interpretation of this aspect of the NPC. In general, the majority of respondents from each region represented in survey responses interpreted the code article to refer only to sanitary and combined sewer service connections, but a portion of respondents from each region, ranging from 12% in Manitoba to 36% in Ontario, indicated that the code article referred to storm as well as sanitary/combined connections. Further, 7%, 8% and 5% of BC, Manitoba and Ontario respondents respectively indicated that this article of the code referred only to storm sewer service connections (See Table 6).

Table 6: Service connection type referred to in article 2.4.6.4.

Response	Province/Region					
	BC[1]	**AB[2]**	**SK[3]**	**MB[4]**	**ON[5]**	**NB/NS[6]**
	%	**%**	**%**	**%**	**%**	**%**
Sanitary and combined	56	71	86	76	50	86
Storm	7	-	-	8	5	-
All of the above	27	24	14[7]	12	36	14
Don't know	-	-	-	-	2	-
No response	10	5	-	4	7	-

[1]n=41, [2]n=21, [3]n=7, [4]n=25, [5]n=58, [6]n=7; [7]Saskatchewan municipal respondent

Interpretation of the type of service connection that is referred to in NPC 2.4.6.4(3) is important because there is a need for backwater valves on both sanitary laterals and storm laterals when foundation drainage is gravity fed into storm sewer service connections. Storm backwater valves have been required or recommended in municipalities to reduce the risk of storm sewer backup entering foundation drainage or entering basements through sump pits when foundation drains are gravity fed to storm sewer connections (City of Ottawa, 2011; City of Moncton, n.d.).

4.2 Reported Frequencies of Valve Installation (Sanitary and Storm)

Respondents were asked to estimate the number of ground-related homes in their jurisdictions that were equipped with sanitary (Table 7) and storm (Table 8) backwater valves. Higher reported frequencies of sanitary valve installations were reported in Alberta and Saskatchewan. In these two provinces, respondents indicated that the majority (i.e., over 96%) of ground-related homes in their jurisdictions built since 2005 were equipped with sanitary backwater valves. Fewer respondents reported high rates of installation of storm backwater valves when compared to sanitary backwater valves.

It was hypothesized that, due to the interpretation of which homes "may" be subject to backflow, backwater valves would be required for homes located in infill subdivisions located in older areas with histories of sewer backup, or for new subdivisions that were to be connected into municipal sanitary systems with sewer backup histories. While respondents reported that these factors were motivators for the installation of backwater valves in a minority of homes built since 2005, a number of other motivating factors were identified by respondents through open-ended responses. For example, several respondents reported that backwater valves had been incorporated into new homes due to specific owner and builder preferences as well as requests made by insurers. This finding warrants further investigation into motivators for installing backwater valves in "rare, specific circumstances" in new homes. For example, future research might explore why specific individuals or developers have requested installation of backwater valves in new homes when valves are not required through municipal by-laws or code interpretations.

Table 7: Estimated proportion of homes built since 2005 with sanitary backwater valves

Response		Province/Region					
		BC[1]	**AB[2]**	**SK[3]**	**MB[4]**	**ON[5]**	**NB/NS[6]**
		%	**%**	**%**	**%**	**%**	**%**
0%		20	-	-	4	19	-
1-50%	1-5%	32	5	-	4	41	14
	6-20%	15	-	-	4	14	-
	21-50%	2	-	-	24	7	14
51-99%	51-75%	5	5	-	-	-	28
	76-95%	5	-	-	4	3	14
	96-99%	-	14	43	8	2	-
100%		10	62	43	20	5	28
Don't know		7	14	14	28	9	-
N/A		2	-	-	-	-	-

[1]n=41, [2]n=21, [3]n=7, [4]n=25, [5]n=58, [6]n=7

Table 8: Estimated proportion of homes built since 2005 with storm backwater valves

Response		Province/Region					
		BC[1]	**AB**[2]	**SK**[3]	**MB**[4]	**ON**[5]	**NB/NS**[6]
		%	**%**	**%**	**%**	**%**	**%**
0%		54	19	29	24	59	14
1-50%	1-5%	20	-	-	-	14	43
	6-20%	5	5	-	24	5	14
	21-50%	5	-	-	-	-	-
51-99%	51-75%	2	-	-	-	-	-
	76-95%	-	-	29	4	2	-
	96-99%	-	5	14	-	-	-
100%		-	48	-	4	10	-
Don't know		7	19	14	32	5	-
N/A		2	5	14*	8	5	14

[1]n=41, [2]n=21, [3]n=7, [4]n=25, [5]n=58, [6]n=7

*Saskatchewan municipal respondent

4.3 Relationship between Code Interpretation and Reported Backwater Valve Installation Frequencies

This study revealed a positive correlation between interpreting NPC article 2.4.6.4 in a way that required backwater valves on most or all new homes with estimated frequency of sanitary and storm backwater valve installation in homes built since 2005. Specifically, interpretation of the code to mean that "all or most" new homes are required to have backwater valves was positively correlated with increased frequency of backwater valve installation for both sanitary and storm backwater valves at a very high statistical confidence level ($p<0.001$) (see Tables 9 and 10). These findings suggest that code wording interpretation is an important component of increasing the frequency of backwater valve installation in new homes in Canada.

Table 9: Impact of code interpretation on reported frequencies of homes with sanitary backwater valves

	Approximate proportion of homes built since 2005 with sanitary BWVs	
Code requires BWVs in:	0-50% (n)	51-100% (n)
All or most new homes	14	39
Rare or no circumstances	64	3

Chi-square: 62.121, p=0.000

Table 10: Impact of code interpretation on reported frequencies of homes with storm backwater valves

	Approximate proportion of homes built since 2005 with storm BWVs	
Code requires BWVs in:	0-50%	51-100%
All or most new homes	31	16
Rare or no circumstances	61	2

Chi-square: 18.741, p=0.000

4.4 Implications for Risk Reduction through Building and Plumbing Codes

It has been argued that a drawback of building code changes to reduce disaster risk is potential increases in construction costs (Dean, 1995). However, installation of backwater valves in new homes is significantly less expensive than retrofitting valves after homes have experienced sewer backup damages. For example, several Canadian municipalities provide partial subsidy programs for homeowners affected by sewer backup for the installation of backwater valves. Subsidy rates range from

$500 to $3,000 for backwater valves, often installed in combination with other measures (e.g., foundation drain disconnection) (see Sandink, 2011). Full retrofit costs for backwater valves alone may range from $500 to $3,500. In comparison, estimates for the cost of installing mainline, open-port backwater valves in new homes range from under $100 to $250 per installation (City of Ottawa, 2011; City of Windsor, 2011; Pers. Comm., B. Plewes, Chief Building Official, Town of Collingwood, Ontario, July 18, 2013), indicating the potential economies that would be achieved by requiring backwater valves in new homes through clearer wording of NPC 2.4.6.4.(3).

The provision of protection to all homes regardless of sewer backup history is a further benefit of clarifying wording of 2.4.6.4(3) to require backwater valves. Climate change and changing development patterns present many uncertainties related to the occurrence of urban flooding, and it is not often possible to identify all areas of urban municipalities that will exposed to urban flooding during extreme rainfall events. Indeed, many municipalities have experienced regional sewer backup events in neighbourhoods that were thought to be of relatively low risk due to the existence of relatively new, separated sewer systems. I/I is also a recurrent problem for municipal separated sanitary sewer systems, which can increase sewer backup risk in modern, separated sewer systems (Capital Regional District, 2010; Genivar & Clarifica, 2008; Stantec, 2008; Region of Halton, 2012; XCG, 2008; York Region, n.d.). The potential for urban flood and sewer backup risk in any area of a municipality is reflected in the code interpretations adopted by municipalities that require backwater valves in all new homes, including the City of Toronto (City of Toronto, 2008) and the City of Windsor (City of Windsor, 2011) and the code interpretation guidance provided the Safety Codes Officers in the province of Alberta (Safety Codes Council, 2007). Thus, incorporation of backwater valves into all new homes, regardless of sewer backup history in specific neighbourhoods, would help account for the unpredictability of this risk.

A substantial body of literature has revealed that it is difficult to encourage private property owners to implement disaster mitigation measures before or after the occurrence of disaster events (see Brenkert-Smith *et al.*, 2006; Laska, 1990; Lindell & Perry, 2000; McCaffrey, 2004; McGee, 2007; Mileti, 1999; Palm, 1990; Shrubsole *et al*., 1995; Siegrist & Gutshcer, 2006; Winter & Fried, 2000; Yoshida & Deyle, 2005). Recent studies on homeowner urban flood mitigation behaviour have also revealed limited adoption of urban flood risk reduction measures in Canadian municipalities. For example, a 2007 study revealed that only 18% and 35% of homeowners in Toronto and Edmonton respectively who had histories of sewer backup had installed backwater valves (Sandink, 2007). A study of 674 homeowners in London, Ontario in 2010 in a neighbourhood that experienced a severe urban flooding event revealed that only 13% had installed a backwater valve, despite the existence of a municipal basement flood reduction subsidy program and 32% of respondents in the same study could not indicate whether or not they had a backwater valve. The same study revealed that only 2% of respondents offered a municipal subsidy to install basement flood risk reducing measures chose to participate in the subsidy program (Sandink, 2011). Thus, reliance on individual, voluntary action to install risk reduction measures after an urban flood event should not be considered a reliable risk reduction approach, and further illustrates the need to incorporate risk reduction measures at the time of construction of new homes.

The shifting of responsibility or liability for the cost of installation of backwater valves away from municipalities serves as an additional benefit for installation of backwater valves in new homes. As discussed above, several Canadian municipalities provide subsidies up to $3,000 for the retrofit of backwater valves into existing homes. Through incorporation of valves into new homes, the responsibility for the cost of valve installation—a cost that is much lower for new installations in comparison to retrofits—is shifted to developers and homeowners and away from municipalities.

There are many alternatives to the reduction of urban flood risk both at the municipal- and private-sides of new and existing development, and decision makers should not consider only one approach for risk reduction. It is also important that requirements for backwater valves do not displace other potentially more effective measures where they are appropriate. Indeed, there are multiple opportunities to incorporate urban flood risk reduction measures in new development, notably, inflow and infiltration reduction, adjusting design criteria to account for increasing frequency of extreme rainfall events, source control measures and Low Impact Development, which can limit peak stormwater flows during rainfall events (Bolivar-Phillips, 2013; FCM & NRC, 2003; Hood *et al*., 2007; Kerr Wood Leidal Associates Ltd., 2008). However, clearer wording and interpretation of code articles that relate to backwater valves should be viewed as a “low hanging fruit” for urban flood risk reduction and is a measure that has been applied with a great deal of precedent across the country.

5. CONCLUSION

While it has been previously reported that resolution of code enforcement issues may result in reduced vulnerability to extreme natural events, issues surrounding code interpretation have not previously been studied. This study investigated interpretation NPC article 2.4.6.4, which relates to installation of backwater valves to protect homes from sewer backup. Despite consistent application of NPC wording related to backwater valves across the regions of Canada represented in this study, it was found that there are differing interpretations of code wordings, which result in differing reported frequencies of installation of backwater valves on both sanitary/combined and storm sewer service connections.

The primary recommendation of this report is that sentences in the NPC and provincial building and/or plumbing codes that relate to installation of backwater valves to protect against sewer backflow be reworded or clarified. Considering recurring and escalating the costs borne by the insurance industry for sewer backup damages, uncertainties created by climate change, aging infrastructure and I/I, and considering the significant hardship that is caused to homeowners who experience basement flood events and the health risks created by sewer backup, it is recommended that codes be worded in a way that requires installation of backwater valves on sanitary connections on all homes with fixtures below the adjoining street and/or when below the nearest upstream manhole cover. Further, it is also considerably less expensive to incorporate backwater valves into new homes when compared to retrofitting after basement flood events have occurred.

The provision of advice on interpretation of the code in a manner that would require backwater valves on most or all new homes, as applied in Alberta, could also be considered as an approach to achieve the same goal. Alternatively, municipalities may adopt code interpretations that require backwater valves in all new homes through acknowledging that any drain below upstream manhole covers or below grade may be subject to backflow under severe rainfall or I/I conditions.

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