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Practical Measures for the Prevention of Basement Flooding Due to Municipal Sewer Surcharge

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Basement flooding due to municipal sewer surcharge is a recurring reality in many Canadian municipalities that exposes occupants to health risks and devaluation of property. Advances in our understanding of the causes and the development of appropriate technologies have now rendered this problem practically avoidable.

Executive Summary

This report is based on a project funded by the Canada Mortgage and Housing Corporation External Research Program. The project was motivated by concerns for providing adequate levels of protection about unwanted sources of moisture in residential basements that may cause property damage and/or adversely affect the health and safety of the occupants. Requirements in building codes and standards are intended to assure minimum levels of health and safety for aspects such as structural integrity, indoor air quality and fire protection. Evidence indicates that minimum levels of protection against basement flooding due to municipal sewer surcharge are not being uniformly achieved across Canada. In the same way that the probability of structural failure has been set to a societally acceptable threshold within building codes and design standards, measures for the prevention of basement flooding should offer a fairly consistent degree of protection in all buildings. Basement flooding due to municipal sewer surcharge continues to represent a weak link in a system of housing technology and regulation that, otherwise, makes Canada an envied world leader.

Widely referred to as the "bible" of the construction industry, the *National Building Code of Canada (NBC)* is designed to ensure that buildings are structurally sound, safe from fire, free of health hazards, and accessible.

Source: http://irc.nrc-cnrc.gc.ca/pubs/codes/nrcc38726_e.html

Basement flooding problems continue to occur in many Canadian municipalities and challenge government, industry and academia for effective mitigation measures. Basement flooding cannot be addressed in isolation because it often represents one symptom among many that stem from municipal drainage systems that are not sustainable. Environmental impacts from current approaches to sanitary waste and stormwater management are significant, affecting groundwater, surface water bodies, and the ecosystems they vitally support. Economic impacts associated with municipal infrastructure in Canada, much of which is rapidly deteriorating, are burdensome. Preventing basement flooding involves a deeper understanding of ecosystems, watersheds, municipal infrastructure systems and the diversity of building connection types to these systems. The background needed to understand and appreciate this larger context goes beyond the scope of this research project, however, related sources of information have been referenced for interested readers.

The causes of basement flooding range from existing municipal infrastructure that did not benefit from contemporary urban drainage design strategies, to individual buildings with inadequate sanitary, foundation and/or lot drainage. At the large system scale, some municipalities have inherited infrastructure demanding improvements that will consume considerable time and investment due to the scale and complexity of the causes underlying their basement flooding problems. At the individual house scale, ineffective site grading and poor design, construction and/or maintenance of the drainage connections further contribute to the potential of basement flooding. In older, inner city neighbourhoods with small lot sizes, illegal connections of the foundation drainage to the sanitary sewer system are often tolerated, as there are no safe and effective means of discharging sumps onto frozen yards. Due to this diversity, there is no single, simple solution to the problem of basement flooding. Instead, a series of related measures are needed to effectively deal with a particular type of basement flooding problem. For simple cases, individual house measures may prove successful. In more complicated cases, these measures must be coordinated with modifications to the minor drainage system. For the most complex cases, the major drainage system design must be addressed along with some combination of intermediate and individual building measures. The various strategies, techniques and technologies needed to practically eliminate basement flooding within a particular context are not widely shared, and often difficult to access. The findings of this research project reinforce those of previous related studies that lament the low level of knowledge base contributions and technology transfer initiatives in the area of basement flooding mitigation and prevention. This report provides a framework for improving basement flooding prevention and protection.

Findings

Key findings of this research project indicate that many of the issues, identified as long as two decades ago, have yet to be effectively addressed.

1. Inadvertently, past practices for the design of Canadian municipal sanitary sewer and stormwater drainage systems often created an off-line storage network for surcharges called basements.
2. Most municipalities in Canada experience basement flooding problems due to municipal sewer surcharge, and the majority of causes for these flooding problems are systemic.
3. Basement flooding related insurance claims in Canada are estimated to be in the order of $140 million per year based on a multi-year average. This represents an average of approximately 30,000 to 40,000 incidents per year, with an average cost of damages per flooding incident between $3,000 and $5,000.
4. Mounting evidence points to significant health risks linking basement flooding with the potential for the growth of molds that cause allergic reactions, asthma episodes and other respiratory problems. Economic impacts related to health care and productivity have yet to be assessed.
5. Canadian municipalities have developed and implemented a number of successful approaches to protection of basements against flooding. Three major aspects of protection measures were identified: i) the individual dwelling; ii) the minor system (the neighbourhood or sub-division, as defined by its local drainage system); and iii) the major system (municipal or regional level). Integrating protection measures across all three levels is key to a successful basement flooding protection program.
6. There is still no central repository of basement flooding protection knowledge and precedents currently available to urban drainage system designers, and no established forum for the exchange of information was identified during this research project.
7. The trend in basement flooding prevention programs is very encouraging among the municipalities surveyed, and most municipalities in Canada have implemented, or are soon initiating, formal prevention programs that include various media for public education/information.
8. Advances in backflow prevention devices (backwater valves) and sump pump technologies offer homeowner’s effective and reliable levels of protection against basement flooding, however codes and standards for their performance and installation are lagging.
9. Lack of applied research, inadequate technology transfer, gaps in codes and standards, and municipal accounting practices represent the primary barriers to progress in the mitigation of basement flooding problems.

In summary, despite the lack of a coordinated program among Canadian municipalities and government bodies for basement flooding protection due to municipal sewer surcharge, significant improvements have been achieved by individual municipalities. Further progress hinges on additional funding for both infrastructure improvements and support of programs for exchanging knowledge, coordinating research and development efforts, and addressing gaps in codes and standards.

Recommendations

The following recommendations are submitted for consideration by all stakeholders concerned about basement flooding issues.

1. Federal, provincial, municipal and consumer stakeholders should actively pursue the development of criteria and requirements to be integrated within existing national codes and standards that address basement flooding protection measures. In particular, requirements for site and foundation drainage in the National Building Code of Canada (NBC), and sanitary and stormwater provisions in the National Plumbing Code of Canada (NPC) should be examined and amended as required, in order to reasonably "*ensure that buildings are free of health hazards*".
2. Public sector funding aimed at assembling and maintaining the basement flooding prevention and mitigation knowledge base, and institutionalizing a forum for the exchange of experiences and ideas, is vital. It is recommended that the Federation of Canadian Municipalities confer with other public sector stakeholders to obtain funding and coordinate a national basement flooding protection program.
3. To further the effectiveness of the basement flooding protection program outlined above, public sector funding for strategic research should be provided to develop and disseminate standards and best practices for the design (computer simulation, modeling, monitoring) of urban drainage systems and for the performance and proper installation of basement flood protection measures (backflow valves, sump pumps, etc.).
4. Research and development of innovative technologies for sustainable urban infrastructure should be encouraged through government funding and tax incentives. This initiative should include empirical studies, similar to those conducted in the U.S., to establish the effectiveness of "*landscape as infrastructure development*" techniques and low impact development models on sanitary and stormwater management. Results from this R&D process should be made available in a format that is suitable to designers (parametric computer simulation) and regulatory authorities to eliminate technical and regulatory barriers to innovation.
5. Consumer protection against the risk of property damage and exposure to health hazards must be significantly improved beyond present levels. Homebuyers and rental tenants must be able to reliably and conveniently determine the flooding history and level of basement flooding risk for any property in a timely fashion. It is unacceptable that a household should be vulnerable to a different level of protection for structural failure or electrical shock than for basement flooding, without its knowledge. The idea of health warnings on packages of cigarettes should be extended to basements in flood prone areas.
6. Stakeholders, such as CMHC, Federation of Canadian Municipalities, Insurance Bureau of Canada, Consumers Council of Canada, etc., are urged to help establish a reliable means of reporting and monitoring the status of basement flooding events and mitigation measures across Canada, and advocate necessary improvements through appropriate research and development initiatives.

Just as it was once acceptable to smoke in public buildings (hospitals included), basement flooding continues to be accepted by a Canadian public that is largely unaware of its health implications. Sufficient evidence exists to strongly support the obligation by all levels of government to reasonably respond to this problem, and develop effective programs aimed at the practical elimination of basement flooding within a threshold of probability that is congruent with those applied to other health and safety measures in housing and buildings.

Civic progress through sewer and water construction (circa 1898) was oblivious to the risks of basement flooding being passed on to inheriting generations.

Research Project Overview

The impetus for this research project stems from a broadly based stakeholder consortium project, *Performance Guidelines for Basement Envelope Systems and Materials*, co-ordinated by the Institute for Research in Construction, National Research Council Canada (IRC/NRC) and Canada Mortgage and Housing Corporation (CMHC). [Note: For further information on this project, refer to http://irc.nrc-cnrc.gc.ca/pubs/rr/rr199/index_e.html.] These guidelines for design and evaluation of basement envelope systems and materials are being developed under the guidance and review of a steering committee formed by representatives of industry associations and government agencies. The guidelines focus on the performance requirements of residential basements and address the following general questions: what does the system have to do, and what do the materials within that system have to do to ensure that the following loads and transfer mechanisms are controlled as intended: heat loss; air leakage and soil gas entry; and moisture from the outside air, from the ground, from the inside air, as well as that introduced during construction; and rain water and ground water?

During the guidelines development process, it became apparent that the level of moisture protection afforded by various basement systems was in certain cases determined not by the selection and arrangement of materials, but by the level of risk associated with municipal sewer surcharges that were largely beyond the control of the basement system designer and builder. Despite all of the advances in basement technology, a 21st century basement could be flooded by a 19th or 20th century municipal sewer system. In view of this weak link in the basement system performance knowledge base, the research presented in this report was proposed and subsequently awarded by CMHC.

This research project was funded under CMHC's External Research Program. Work commenced in May 2001 and was substantially completed by December 2002. Research methods employed in this project consisted of a literature review and muncipal surveys. The literature review was conducted using the University of Toronto's library services (electronic database search facilities), in parallel with an electronic search of CISTI. Searches of Internet resources followed once a base of key words and terminology was culled from the literature review. A review of product literature in the areas of backflow prevention devices and sump pumps was also conducted to identify available mitigation products and technologies.

Surveys were developed and forwarded to a number of Canadian municipalities that were identified via prior letters of interest and subsequent telephone contacts. Municipalities and key contacts were identified through the Federation of Canadian Municipalities database. All surveys were subsequently followed-up with telephone interviews. The surveying was initiated in the summer of 2001 and results continued to be received up to the end of September 2002.

Field investigations originally planned to be conducted with selected municipalities have not proven possible due to financial limitations, however, several municipalities provided non-confidential field evidence for inclusion in the final report.

Scope and Objectives

This project was limited to residential basements in Canada that have sanitary and/or storm connections to municipal infrastructure that are prone to surcharge during extreme rainfall and/or snow melt events. The work focused on practical measures currently available to existing homeowners experiencing basement flooding problems, and builders constructing new homes within sewer surcharge-prone areas. Contributing factors influencing the severity of this problem were also investigated for aspects pertaining to the dwelling and immediate surrounding property (grading, conveyance, storage, and inflow/infiltration). Successful and cost-effective measures undertaken by municipalities in regard to modifications to existing municipal drainage systems were also surveyed.

The objectives of this project included:

1. Up-to-date literature review of basement flooding problems due to sewer surcharge, including any evidence of remedial or preventive mitigation measures.
2. Illustrated and/or photographed, technical documentation of sewer surcharge mitigation measures which have been successfully deployed in Canada, or elsewhere, and which are available to existing homeowners and builders.
3. Documentation of successfully deployed mitigation measures at the municipal infrastructure level.
4. Identification of technical and/or regulatory barriers associated with these mitigation measures.
5. Publication of a project report documenting all previous items.
6. Development of a documentation package distilled from the project that can be readily transformed into a CMHC "*About Your House*" publication, which renders the results of the research immediately useful to individual homeowners.

Development of a CMHC "*About Your House*" publication is scheduled for completion after release of the final report. In order to conserve printing resources, this report provides numerous links to Internet resources that are only available online. These sources proved invaluable in assembling this report and readers are urged to visit the Web sites containing information relevant to basement flooding issues.

The next section of this report provides a background to basement flooding problems and mitigation measures that is based on a review of what are considered significant studies related to this issue.

Background to Basement Flooding

The history of basement flooding in Canada is not well documented. Earlier studies of basement construction and moisture control measures indicate that parging and dampproofing of basement walls, along with the installation of weeping tile around their perimeter, started to appear in the 1920s, and by 1944 these measures had become a requirement in the NHA Housing Standard.[1] Up to this point in time, it is reasonable to assume that basement flooding did not concern occupants and regulatory authorities simply because basements were viewed more as damp cellars and less as livable spaces connected to the above-grade areas of dwellings.

Figure 1. The effects of basement flooding, revealed above after removing a section of wall board, are often hidden by cosmetic repairs to interior finishes, leaving occupants susceptible to long term exposure to molds, often unaware of associated health risks.

Even when the construction of basements to accommodate future finishing and furnishing became prevalent from the 1950s onwards, historical statistics for basement flooding were not systematically collected. It remains difficult to estimate whether basement flooding is more or less common today than 50 years ago. However, basement flooding remains a commonly experienced problem in most parts of Canada and this section reviews previous studies in order to provide a background to the issues related to this report.

[1] Timusk, J., *Insulation Retrofit of Masonry Basements*, Ontario Ministry of Municipal Affairs and Housing, October 1981.

Evaluation of Urban Drainage Methods for Basement Flood Proofing (1984)

In 1984, Paul Wisner and Martin Hawdur prepared a report for CMHC titled *Evaluation of Urban Drainage Methods for Basement Flood Proofing*.[2] This report was based on a study conducted under the External Research Program and focused on issues that had become widely recognized by federal agencies, municipalities, practitioners and researchers.

The key findings and recommendations from this study have been extracted and are summarized below.

- *Despite many recent advances in storm water management and urban hydrology, the design of new drainage systems within subdivisions and that of relief sewers is still conducted on a traditional basis developed many years ago when the main function of drainage was traffic convenience and basement flooding was not a major concern.*
- *Storm sewers were typically sized using the Rational Method and a design storm frequency ranging between 2 and 10 years to provide a uniform frequency of surcharge within a municipality, however, the relation between surcharge and the risk of basement flooding is a function of differences in elevation, and vary significantly within a system, often depending on factors such as location of inlets. These criteria and practices assume that flooding is unavoidable.*
- *Based on reports from various municipalities regarding system performance following large storms, it was difficult to compare the real performance of the system with that considered in the design. Basement flooding may be due to several causes not directly related to the capacity of storm sewers and consequently its flood proofing requires complex measures, including the control of overland flow and of inflow in sanitary sewers.*
- *A review of different studies on basement flood proofing examined new alternatives such as roof disconnections, street ponding and inlet control, backwater valve-sump pump (BV-SP) systems and storage. The implementation of these alternatives was considered difficult since it required the cooperation of homeowners, and their effectiveness, reliability and public acceptance remains unknown. Most studies recommended traditional relief sewer schemes as opposed to options such as street ponding because it was viewed that a suitable model to support quantitative analysis was lacking.*
- *A survey of 34 municipal engineering departments found that in a majority of them, basement flooding was considered a high-priority problem. Relief works and their implementation required very high annual expenses and years to complete. Approximately one third of the areas with flooding problems had systems that were 5 to 25 years old, while the rest had older systems, and about two-thirds of the areas had separated storm sewers. Some areas reported what was considered "rare" - the occurrence of flooding 2 to 3 times in a period of 5 to 10 years, while other areas reported more frequent occurrences.*
- *Surveys also indicated that increased attention was being given to alternative relief and mitigation methods with just over half of the respondents reporting the application of computer simulation for relief studies. Municipal engineers reported that decision-makers and the public were not well informed on the nature of drainage problems and many decisions were not taken on a technical basis.*
- *A limited public survey conducted with homeowners in streets with different densities of flooded homes yielded answers mostly from areas with flooding problems. It was found that the value of furnishings in basements and the damages resulting from flooding vary significantly. The average damage was reported as $3,000 and 30% of the flooded homes in areas with storm sewers had structural damages. Homeowners did not seem to be adequately informed about mitigation measures indicated a general desire for increased protection and a willingness to contribute in order to reduce significantly the risk of flooding.*

[2] Wisner, Paul and Martin J. Hawdur, *Evaluation of Urban Drainage for Basement Flood Proofing,* for Canada Mortgage and Housing Corporation, March 1984.

- *A review of strategies for the selection of flood proofing alternatives indicated the choices are to a large extent influenced by the expected performance of a system and the acceptance of responsibility by homeowners. The study proposed that there should be new strategies for updating existing systems and for improved design of new systems. For existing systems, they consist of comparing not only the cost of various relief solutions for the same storm as in the criteria for new developments, but also the examination of alternatives for the recurrence interval of these storms, trade-offs between basement flooding and inconvenience due to ponding, and pilot tests with new solutions. It is recommended that more emphasis be put on public education and incentives for local solutions.*
- *In new developments, this study proposed a strategy based on the experience of several provinces and advocated the elimination of sewer surcharge not only for frequent, but also for rare storms. This can be achieved by means of combined inlet control with adequate street grading and provision of overflows at low points in parks. This should be combined with local measures such as backwater valves for sanitary sewers, elimination of roof inflow in foundation drains, sealing of manhole covers, etc. Flooding in the proposed drainage system will not only be less frequent but also less sensitive to small changes in conduit size, storm intensity and even increased imperviousness. This performance is also not related to probabilistic concepts and is therefore easier to understand.*
- *A greater sophistication in urban hydrological modeling techniques is required to most effectively implement appropriate mitigation strategies. Based on their studies to mitigate basement flooding, Canadian municipalities have gained considerable experience with specific methods, however, there is a limited exchange of experience and a considerable variation in design and improvement practices across Canada.*

In summary, this major study identified key issues, barriers and opportunities facing Canadian municipalities during the early 1980s. Most notable in the study's recommendations was the call for national standards, programs and conferences to improve and exchange mitigation policies, regulations and technologies.

Protection of Basements Against Flooding: Trends and Impacts of Drainage Regulations (1990)

The previous study was followed by further research presented in 1990 by Paul Wisner in a CMHC External Research Program project, *Protection of Basements Against Flooding: Trends and Impacts of Drainage Regulations*.[3] This research report attempted to present a holistic assessment of the basement flooding problem and all the technologies then currently available for its identification, prevention and mitigation.

The main findings of this study are as follows:

- *Because of the lack of national and even provincial guidelines based on state-of-the-art techniques for the protection of basements against flooding, there are considerable differences between the level of implementation of various solutions, type of models, monitoring standards, etc.*
- *Studies conducted in Canada for the reduction of basement flooding did not consider the economic benefits resulting from the reduction in treatment plant loading. A cost-benefit analysis is frequently lacking or vague, and the proposed level of servicing varies from one municipality to another.*
- *Canadian studies and solutions focus on improvements to the municipal part of the system. Recent USA experience shows that private system connections, with in-house service, may be a major component of the infiltration/inflow contribution.* [Note: Private system connections and in-house service are defined as those parts of the plumbing services and stormwater system located on private property and within the building, upstream from the connection to municipal infrastructure.]

Based on his research, Wisner submitted the following recommendations:

- *CMHC efforts to improve the use of basements for dwelling purposes should recognize that to achieve the required level of protection, the improvement of the general drainage and sewerage policies would require a very lengthy and complex process. Hence it is considered that focusing attention on the private part of the system may be more beneficial in terms of immediate returns, for aspects such as:*
  - *improvement procedures for the selection of basement protection devices such as very safe sump pump and backflow valve designs;*
  - *review of designs and procedures for the testing of the connection between internal services and the sanitary sewer. This includes the review of plumbing codes, and mainly testing and inspection procedures;*
  - *development of a methodology and implementation procedures for the improvement of the private part of the system in areas with substantial infiltration/inflow.*

- *There is a need for coordination of efforts for the abatement of infiltration/inflow for relief of basement flooding, as well as for increased treatment costs. Frequently recommended solutions to basement flooding, which are based on improved conveyance in sanitary sewers or storage, do not lead to savings in the cost of treatment. Federal or provincial funding is not available for flooding relief but can be obtained for pollution abatement in a period of growing national concern over the improvement of the environment. This leads to the following recommendations:*
  - *Federal or provincial standards for infiltration/inflow studies, including monitoring and modelling, should be developed.*

[3] Wisner, Paul, *Protection of Basements Against Flooding: Trends and Impacts of Drainage Regulations*, for Canada Mortgage and Housing Corporation, May 1990.

  - *Present standards for sanitary sewer design have very small allowances for infiltration and no allowance for inflow. While modern construction techniques are better than those for older systems where high infiltration/inflow values have been monitored, a safety factor against surcharge, which does not exist at present, should be considered to account for aging effects, problems with private connections, faulty maintenance, etc. Since it is obvious that pollution control agencies want to discourage potential infiltration/inflow sources, policing of systems can be assured by monitoring even if pipe sizes are somewhat greater and can probably convey additional flows.*
  - *Acceptance of very rare overflows from sanitary systems to storm sewers could be considered. Municipalities, which have many overflows from combined sewers and pollution problems caused by frequent storm runoff, could probably accept a sanitary overflow once in 10 or 25 years.*

- *Since a significant effort is presently being invested in monitoring and modeling, it would be useful to consider research which may lead to national policies for monitoring and modeling procedures. Several areas are:*
  - *hydraulic laboratory and field tests for different types of equipment and national guidelines for monitoring similar to those used in the UK and the State of Massachusetts;*
  - *establish a database of the most reliable data obtained, so far, from measurements and use them for the comparison of models, and to develop recommendations for modeling; and*
  - *selection of a modelling package.*

- *Since the cost of the various efforts described above is very high and funds are increasingly difficult to obtain, there is a need for a comprehensive analysis of economic aspects related to this problem.*

This study considerably furthered a Canadian understanding of the basement flooding problem by identifying some of the economic, social and political dimensions of the problem. From an economic perspective, the costs associated with basement flooding go beyond the damage suffered by the individual households. Inflow/infiltration to sanitary systems also place an economic burden on treatment sewage treatment facilities, and the environmental impacts may also be significant, though difficult to monetize. In terms of social policy, basement flooding may be viewed as a health and safety issue that has failed to be addressed in codes and standards. Taxpayers assume equal access to municipal services such as garbage collection and potable water, yet they do not receive equal protection against basement flooding from engineered systems. Politically, it is difficult to advocate improvements to the private portion of the systems contributing to basement flooding because this requires educating taxpayers and admitting that they are not receiving equal service. Hence, the financial focus on municipal system improvements that may not be more cost effective, but appear to benefit everyone. In summary, it is fair to conclude that by 1990 the state of knowledge to address basement flooding problems was clearly identified, sufficiently developed and accessible.

Stormwater Control to Prevent Basement Flooding (1992)

Shortly following the previous study, CMHC released another study in 1992 based on research conducted by CH2M Hill Engineering Ltd., *Stormwater Control to Prevent Basement Flooding*.[4] The study was motivated by a concern that during storm events, many Canadian cities continued to experience varying degrees of basement flooding despite increasing knowledge available to urban drainage system designers. The report presents an overview of stormwater management practices across Canada and evaluates these practices in relation to the problem of basement flooding. The purpose of this study was to review the current Canadian design practices in order to identify areas where they may be inadequate or to identify stormwater management trends, developed by some municipalities, that may help other municipalities/agencies with their design criteria.

The key findings of this study have been summarized as follows:

- *The study found that basement flooding is common across Canada and that the lack of understanding on the part of urban drainage system designers on the total response of their systems to wet weather conditions is a serious impediment to successful resolution of problems. Deficiencies that have historically occurred at different stages in the design of urban stormwater drainage systems have resulted in inadequate sewer systems. These deficiencies have led to some basement flooding.*
- *Short duration, high intensity storm events can cause street flooding and result in high infiltration/inflow (I/I) to the sanitary sewer systems. I/I to sewer systems occurs through manhole covers, cracked or open barrel joints in manholes, sewer system cross-connections, broken pipes or cleanouts, cracked and open pipe joints, structural failure of pipelines, and defective lateral connections. The quantity of I/I can be serious enough to have a major influence on sewer system performance. Basement flooding occurs when that influence is severe enough to overload the sewer system and cause residential service connections to back up.*
- *Communities that have experienced extreme basement flooding appear to have studied the situation and in the process have become knowledgeable on most of the factors that influence sewer system flows in their area. This typically entails understanding stormwater drainage patterns, identifying all the I/I sources, and developing an ongoing program to eliminate the most serious contributors. However, these municipalities have no obligation to, and seldom do, transfer their successfully developed methodologies to other municipalities.*
- *Jurisdictional issues can lead to or exacerbate the problem of basement flooding. The on-lot parties (builder, owner) generally do not realize that deficient drainage designs and practices can cause significant stress on the sewer systems and result in basement flooding in their own properties and that of their neighbours. Conflicts can develop over the maintenance of stormwater control facilities, from the homeowners' responsibilities on-lot, to the municipal versus regional responsibilities for sewer system design and maintenance. The age of the sewer infrastructure and its drainage patterns can contribute to the problems.*
- *Municipal systems that operate within the confines of a regional drainage system must fit into the capacity of that regional system. Basement flooding could result from inadequate drainage practices outside of the municipality. Regional facilities may be inadequate and poorly planned, resulting from a merging of municipal plans rather than the use of a masterplan that incorporates, to the fullest extent, the regional drainage area impacts.*
- *A greater understanding of the roles of developer, owner, and municipal authority is evolving and the development process in many municipalities is beginning to reflect more equitably the responsibilities of each stakeholder. This will undoubtedly lead to more effective urban drainage systems, particularly in newly developed areas.*

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[4] *Stormwater Control to Prevent Basement Flooding*, CH2M Hill Engineering Ltd. (Tom Field, P.Eng.) for Canada Mortgage and Housing Corporation, March 1992.

The report offers the following conclusions:

- *The division of responsibilities for the design, construction, and ongoing operation of on-lot and sewer system drainage contributes significantly to the problem of basement flooding. The construction and maintenance of house service connections appear to be difficult to control due to the large number of parties involved, from the land development stage to the final house completion. Codes and standards for work carried out on the lot (including the National Building Code) need to include and emphasize on-lot drainage considerations. Those responsible for design and operation of the sewer systems should have a clearer understanding of the effect of on-lot stormwater contributions to their systems and how these contributions can cause systems to surcharge and overload. The key to public involvement in improving drainage and reducing basement flooding is better coordination between urban planners, developers, and municipal officials.*
- *There is a need for municipalities to develop master drainage plans that incorporate all their drainage components into one plan. In this way the limitations of that system will be clearly identified following the results of a thorough investigation of all local conditions, including: local soil types, climate, topography, historical system development, and future planning data.*
- *Maintenance of sewer systems is identified as a necessity in stormwater management control and a municipality should establish a program that will ensure proper operating conditions for the municipality and for the homeowner. This is supported through studies in the U.S. that identify the need for maintenance responsibilities to be clearly defined.*
- *There is a need to educate homeowners with respect to the effect of poor lot grading and roof leader extensions on urban stormwater drainage systems, as local surface drainage due to poor lot grading and roof leader extensions can be significant. These contributions might be reduced by educating homeowners.*
- *Code approved backflow valves and sump pumps have failed in some instances but it is generally recognized that the failure is due to improper installation, lack of maintenance, or poor sump pump sizing or selection. These problems could be reduced by establishing installation procedures and standards for plumbers, by training building inspectors, and by educating homeowners.*
- *In planning and designing residential redevelopments in existing urban areas, particularly those involving densification, the impact on the stormwater drainage system should be analyzed by the developer and reported to the municipality. The report should address local surface drainage, sewer system flow, and overland flow implications. The above analyses will provide a basis for determining the risks associated with providing below-grade accommodation in a redevelopment project.*
- *To solve the problem of basement flooding, it will take a great deal of cooperation among the major players, namely, the homeowners, the developers, the builders, and the policy makers, to provide a system that will allocate clear responsibilities and full accountability.*
- *This 1992 CMHC report concludes that, due to the long-term health impacts of basement flooding, inspection requirements for on-lot drainage, including roof leader extensions, lot grading, and foundation drain discharges, should be on an equal footing with electrical and plumbing components for building construction and be so reflected in the appropriate codes and standards.*

In summary, this study provided a more in-depth view on some of the areas identified in Paul Wisner's 1990 report and clearly reinforced the need for municipalities to avail themselves of the regulatory and technical tools needed to systematically address basement flooding. By this time, it is fair to say that Canadian municipalities knew or ought to have known how to proceed.

Management and Maintenance Practices of Storm and Sanitary Sewers in Canadian Municipalities (2002)

The most recent research contribution to our understanding of basement flooding problems was published in 2002 by Allouche and Freure,[5] The study examines a number of issues that are not directly related to basement flooding, but relevant to all stakeholders in municipal infrastructure.

Basement flooding is associated with health hazards, negative physiological impacts, and economical losses. The first two issues are of significant importance but lay outside the scope of this report. As for economical losses, basement flooding claims are a major item for Canadian insurance companies. This is commonly attributed to the fact that Canadians are 'living in their basements'. In many Canadian households a significant portion of the high value possessions are kept in basement areas (e.g. TVs, DVDs, PCs, entertainment centres). As a result, the average claim value for basement flooding across Canada ranges between $3000 and $5000, depending on the province, and is rising. In terms of value per claim, water damage is second only to fire and roof collapse (IICC, 1999a; IICC, 1999b). According to statistics collected by the Insurance Information Centre of Canada (IICC) water damage related insurance claims across Canada between 1995 and 1999 totalled approximately $1.2B. While IICC statistical data does not distinguish between basements flooding and other water related damage claims, discussions with industry experts suggests that a conservative allocation to basement flooding will be in the order of 60%. Thus, basement flooding related insurance claims in Canada are in the order of $140 million per year based on a multi-year average.

Based on the above excerpt from the report, the direct cost of basement flooding in Canada is significant. Indirect costs associated with impaired health, loss of productivity (disruption to household routines and homeowners having to take out time to deal with flooding consequences), impacts on occupant health, increase in refuse and debris deposited in landfill sites, and environmental impacts associated with flushing of disinfectants and germicides into the sewer system during clean-up, as well as the resource depletion and greenhouse gas emissions associated with manufacturing replacement household goods damaged by flooding – none of these impacts are accounted for in the study.

Perhaps most significant to property owners is the discounting of property values in areas prone to basement flooding. Assuming the introduction of legislation for disclosure, similar to that enacted for urea formaldehyde insulation placed in homes, requiring property owners to report the frequency of past occurrences and risk of basement flooding to prospective purchasers, the cost of devaluation could easily dwarf the direct costs associated with basement flooding. Canadian municipalities are potentially exposed to a high degree of risk because it remains unlikely they can deflect liability to any other agencies or stakeholders. To further complicate the situation, most Canadian municipalities do not enjoy foreseeable revenues that enable them to deal unilaterally with basement flooding problems in the short term. Allocating funding from other social and environmental priorities to deal with basement flooding problems affecting what is often a minority of the tax base entails not only political risks, but may also impact initiatives needed to sustain the economic viability of the whole community. Looking back at the past two decades through the perspective of the earlier studies, and comparing their findings to the present situation reported by municipalities and insurance statistics, opportunities to invest in basement flooding mitigation measures during more affluent periods may not have been sufficiently capitalized. Urban intensification and suburban sprawl have further exacerbated the situation such that fostering the former while discouraging the latter implies a user pay structure that may well discourage both forms of development. Municipalities with major basement flooding problems have dubious futures compared to their "high and dry" counterparts.

[5] Allouche, E.N. and P. Freure, *Management and Maintenance Practices of Storm and Sanitary Sewers in Canadian Municipalities*, Institute for Catastrophic Loss Reduction (ICLR) Research Paper Series – No. 18, University of Western Ontario, Geotechnical Research Centre, Department of Civil and Environmental Engineering, April 2002.

The ICLR study concludes with some sobering insights on Canada's municipal infrastructure:

- *While most levels of government agree that there is an urgent need for the renewal of Canada's municipal infrastructure, sources for the needed capital, estimated to be as much as $45 billion, are less apparent.*
- *Some of the needed capital can be generated through greater efficiency and advanced technology. In particular, optimizing the management and maintenance of municipal assets, the development and adoption of more cost effective inspection and rehabilitation technologies, a greater degree of integration among various construction activities and the development of alternative income sources (e.g., reclaimed wastewater) and water conservation programs.*
- *To fully realize these potential savings the three key issues need to be addressed: a) training and continuing education at all levels must be given a stronger emphasis; b) a unified system is needed for approval of offshore technologies as well as for evaluating the suitability of competing rehabilitation construction methods; and, c) decision-making processes must be streamlined in term of setting priorities according to a standard cost-benefit procedure within an integrated asset management strategy.*
- *Canadian municipalities spend approximately $19.2 per capita per annum on the replacement and rehabilitation of existing municipal sewer networks, an amount slightly higher than that reported for the 1996-97 construction season of $18.21 per capita.*
- *Only 10% of rehabilitation budgets are spent on condition assessment programs (approximately $1.5 per capita per year).*
- *Closed Circuit Television (CCTV) systems and smoke testing are the most common methods utilized by Canadian municipalities for the inspection of municipal sewer networks. Newer technologies such as sonar and ground penetrating radar have not been widely accepted to date in this market.*
- *The utilization of trenchless technologies by Canadian municipalities is on the rise, with 82% of municipalities using one or more pipe lining techniques in the year 2000 compared with only 66% in 1996 and 32% in 1991.*
- *Comparison of the composition of sewer networks in Canada and the USA has shown significant differences in terms of the relative weight of various pipe materials. The most common pipe material in Canadian sewers is concrete (41%) while vitrified clay is most commonly used in the USA (56%). Canadian sewers also contain larger quantities of plastic pipes (PVC/HDPE). These findings imply that research and development efforts in the USA might not fully address the needs of Canada's municipal sewer systems.*
- *The return period for inspection and assessment of sanitary and storm sewers in Canadian municipalities is between 25 and 30 years, which is nearly equal to the design life of many of these facilities.*

[Note: The full report is available under the Publications link at the ICLR Web site (http://iclr.org/).]

Present Perspective on Basement Flooding

Where basement flooding was once viewed as an almost natural phenomenon that affected what were mostly damp, leaking basements, our societal perspective has changed considerably since the 1950s and has recently taken into account impacts on human health and safety. In Canada, consumers now commonly expect basements to potentially perform as livable spaces, offering the same quality environment as the rest of the dwelling. The trend in the value of basement contents continues to edge upward as so many leisure and entertainment appliances find their way into basements that are typically finished and furnished. Basement flooding is now considered more than simply annoying or costly – it is also being increasingly recognized as a primary cause of health and safety concerns. The following excerpt is one example among a growing body of evidence that may dramatically alter our perspectives on basement flooding.

PULMONARY HEMORRHAGE AND HEMOSIDEROSIS IN INFANTS

published by Rainbow Babies and Childrens Hospital and Case Western Reserve University (http://www.case.edu/pubs/cnews/1998/2-5/fungus.htm)

Over the past several years, there have been a number of young infants (most under 6 months old), in the eastern neighborhoods of Cleveland, who have been coughing up blood due to bleeding in their lungs. Some infants have died and more infants continue to get ill. This bleeding, a disorder called Pulmonary Hemorrhage appears to be caused by something in their home environments, most likely toxins produced by an unusual fungus called *Stachybotrys chartarum* or similar fungi.

What is Pulmonary Hemosiderosis?

Bleeding in the lungs.

What are the Symptoms?

Severe bleeding can cause coughing up blood or nose bleeds. This is particularly concerning in infants under 6 months old. Chronic, low grade bleeding can cause chronic cough and congestion with anemia.

What Causes the Bleeding?

Most likely, toxins made by an unusual fungus or mold *Stachybotrys*. When infants breathe in the toxins, the blood vessels in their lungs may become fragile. The weak vessels may be bothered by cigarette smoke or stresses from other illnesses and start to bleed. You cannot see the toxins in the air rather they are carried in the microscopic fungal spores.

How Do I Know if the Fungus or Mold is in My House?

This fungus or mold grows only on wood or paper that have gotten very wet for more than a few days or so. (It does NOT grow on plastic, vinyl, concrete products, or ceramic tiles). If the wood/paper gets wet and is not cleaned up and dried, the fungus may grow and spread. The fungus is black and slimy when wet. It is NOT found in the green mold on bread or the black mold on the shower tiles (but the shower tiles should be kept clean too). If you have had plumbing leaks, roof leaks, **flooding in the basement** (even if you don't use the basement), or **sewer backup** in the past year, look for mold or a musty odor.

Common Areas for this Mold Growth:

Water soaked wood, ceiling tiles, wall paneling, unpainted plaster board surfaces, cotton items, cardboard boxes, and stacks of newspapers. If these areas have been very wet, usually for longer than one week, check for mold. After the area dries, the fungus will not continue to grow, but the black dust caused by the fungus can be sucked up by the furnace blower and spread throughout the house. Be sure and check your basement for the black mold. If you do not have access to the basement, ask your landlord for assistance. Note: not all black mold is *Stachybotrys*, but moldy homes are not healthy homes.

Inadvertently, past practices for the design of Canadian municipal sanitary sewer and stormwater drainage systems often created an off-line storage network for surcharges called basements. Basement flooding may not have been foreseeable but this does not lessen contemporary concerns for all of its known and suspected impacts. Given the present state of knowledge and technology, basement flooding in neither unavoidable nor acceptable, except for extreme events that fall outside normative levels of risk (i.e., > 1:100 year events).

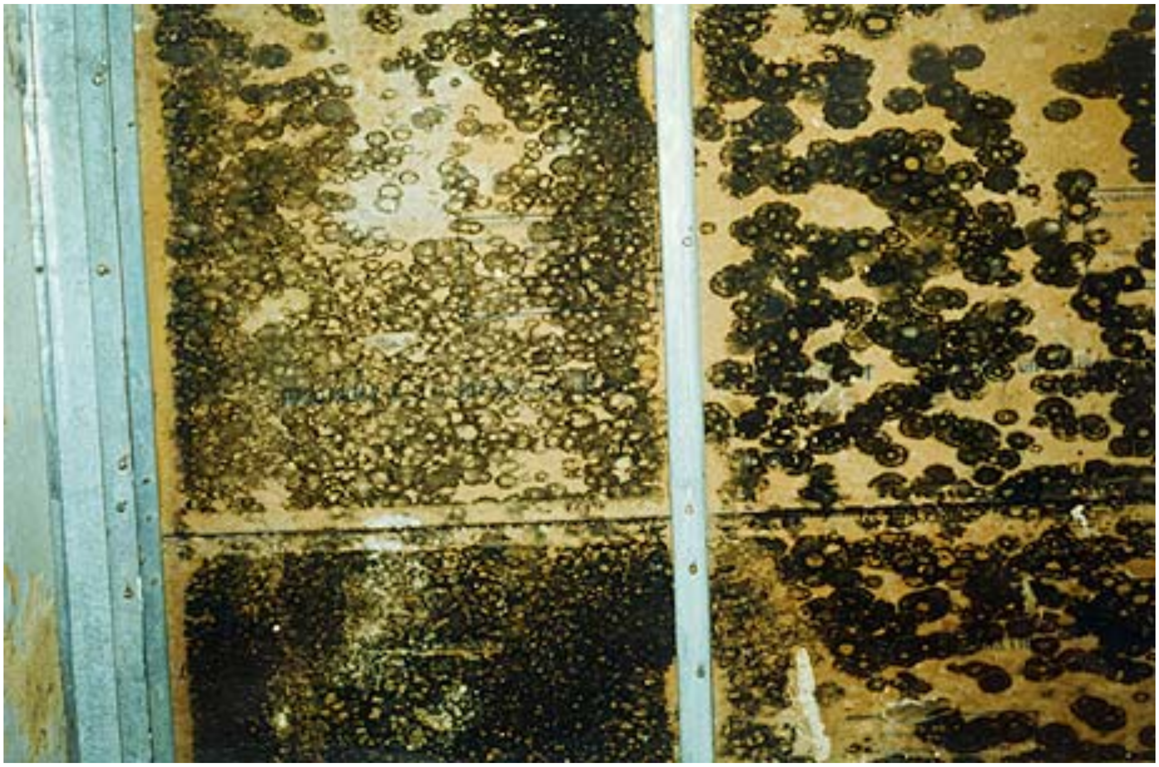

Figure 2. Heavy growth of *S. chartarum* and some other fungi on gypsum wall board in a flooded school basement. This growth occurred about one week after the flood. It was removed before remodeling. Source: Professor Berlin D. Nelson, *Stachybotrys chartarum*: The Toxic Indoor Mold, Nov. 2001. http://www.apsnet.org/online/feature/stachybotrys/

It may be reasonably expected that basement flooding prevention and mitigation measures will gain importance as epidemiological data are more broadly disseminated to consumers who are increasingly suspicious of the institutions their tax dollars fund to protect their health and safety. Within the post-Walkerton world, effective means of reducing the risks of basement flooding may soon be sought and eventually demanded by many affected Canadians.

The next section of this report discusses the results of the 2001 municipal surveys. It is important to note that the completed surveys remain confidential, however, selected data were extracted and reproduced in this report based on normative research criteria and practices.

Survey Results

The survey of 24 Canadian municipalities provided numerous perspectives on basement flooding issues and mitigation measures. It is important to note that the surveys were carried out under agreements that do not permit publication of confidential information volunteered in the surveys, with exception to information that is readily available from publicly accessible sources such as municipal Web sites. The survey questionnaire is reproduced in Appendix A, the survey respondents are listed in Appendix B, and some of the results discussed in this section of the report are briefly summarized in Appendix C.

General Data and Trends *(Part 1)*

A comparison between the 24 municipalities responding to this survey indicates some changes since a previous, similar survey was conducted by CH2M Hill Ltd. in 1991. However, this longitudinal comparison is only possible among 6 municipalities that are common to both surveys: Vancouver, Calgary, Edmonton, Regina, Winnipeg and Laval. It should be noted that due to incomplete survey responses, a complete analysis of the survey data was not possible, but sufficient information was obtained to provide a meaningful comparison among a representative cross-section of Canadian municipalities.

All of the municipalities responding to the population question in Part 1 of the survey (18 of 24) have experienced population growth in the past decade, ranging from approximately 0.9% to 34%, and forecast growth rates over the next decade ranging from 1% to 26%. It was not possible to determine what proportion of this growth involved urban intensification and redevelopment of existing areas. In some cases, the reported drainage areas were much lower than those listed in the 1991 survey and it remains unclear if this was due to reporting error or changes in municipal boundaries. There were also instances of municipalities experiencing a decrease in population, and presumably a reduced tax base for supporting infrastructure.

Since 1991 there are some notable changes with respect to the proportion of combined versus separated sewers in some municipalities. Vancouver reported a 50% combined to 50% separated sewer ratio, compared to a 60% to 40% ratio, respectively, in 1991, representing a 20% reduction of combined sewers in its older residential areas. Regina eliminated the last 10% of its combined sewers in the early 1990s and now has a 100% separated sewer system. In some municipalities, such as Laval, the reduction in percentage of combined sewers resulted by virtue of new separated sewer construction, rather than the separation of existing combined sewers. Virtually all of the municipalities reported some improvements to their sanitary and storm sewer infrastructure, the most common alternative to separating combined sewers being the installation of interceptors and relief sewers.

Design Criteria *(Part 2)*

The design criteria employed for sanitary and storm sewers have not changed for 5 of the 6 municipalities common to this survey and the 1991 survey noted earlier. In Edmonton, design values were decreased from 350 to 300 L/cap/day, presumably due to monitoring. It is interesting to note the wide range of values for residential sanitary design flows reported across Canada – a high of 455 in Vancouver and a low of 50 in Dawson. Excluding Dawson from the comparison, the difference between Vancouver and Winnipeg is still 180 L/cap/day. It was not possible to determine the empirical basis for these values and it remains questionable whether or not these reflect actual differences among the Canadian population.

Infiltration and inflow (I/I) allowances generally indicate the condition and quality of the sanitary sewer system, and were found to range from a low of 0.02 litres per second per hectare (L/s/ha) in Regina (based on empirical data) to 0.4 used in some parts of St. Catharines. A significant trend emerging from the survey responses is that I/I allowances were generally lower in municipalities where these flows were actually monitored, although this practice may have led to improved I/I control measures being implemented thus resulting in lower allowances.

In terms of stormwater management, virtually all municipalities employ a major/minor system strategy with design of the major system based on a 100 year storm using computer simulation, and design of the minor system based on a 2 – 10 year storm, with a 5 year storm return period being most commonly employed. The use of computer simulation, albeit with varying degrees of sophistication, is now a common practice in all of the major municipalities recently surveyed. This indicates that since the time of the first CMHC funded survey on basement flooding problems in 1984, the diffusion of computer technologies for simulating urban hydrology and pipe networks is practically complete. In some cases, municipalities such as Calgary clearly specify guidelines for the deployment of computer simulations by consultants and design professionals. Extrapolating this trend, it is foreseeable that a convergance of geographical information systems (GIS) and simulation software will take place in most Canadian municipalities within the next several decades.

Basement Flooding History, Damages and Liability *(Parts 3 & 9)*

Despite considerable investments in various mitigation measures, significant advances in analysis and design capabilities available to municipal works engineers, and almost two decades of objective information regarding these issues, chronic basement flooding problems continue to plague almost all of the municipalities surveyed. Incidents of basement flooding range from an average of several per year, to several dozen or several hundreds annually, with extreme incidents corresponding to severe storms causing several thousand basements to flood within a matter of one or several days.

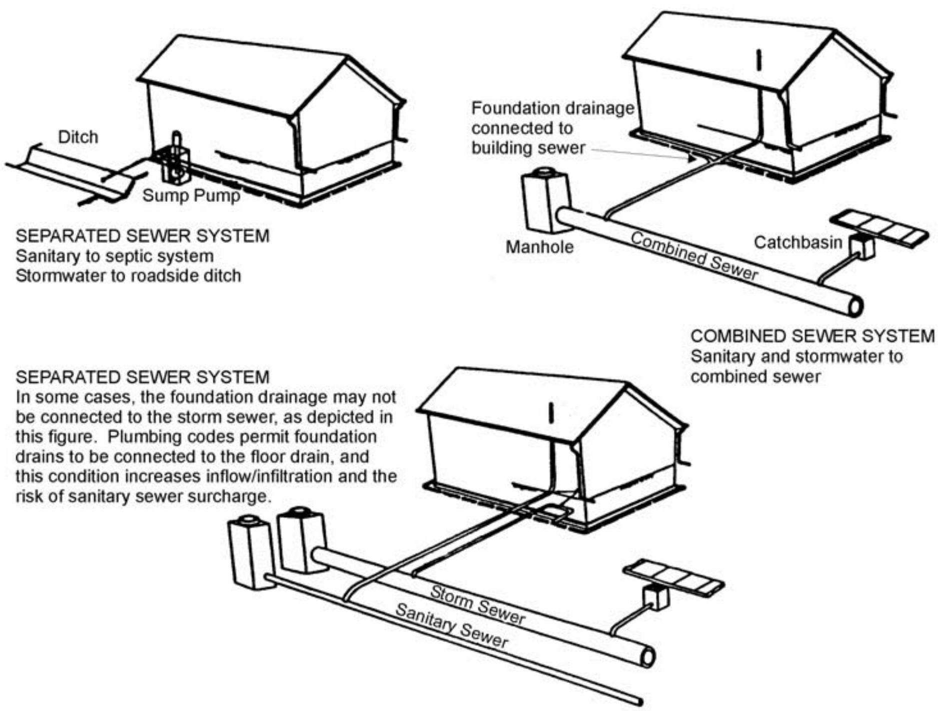

Figure 3. The risk of sewer backup is associated with the type of municipal infrastructure and sewer connection(s) serving the building. (Adapted from Wisner and Hawdur,1984)

It was not possible to extract a precise breakdown of the causes for the reported histories of basement flooding from the survey data, but some trends were notable. First, major basement flooding incidents were usually associated with the inadequate response of the major system, and/or the interface between the major and minor systems. Second, non-major system related basement flooding incidents are highly correlated to storm events that exceed the design storm return period. Typically, 1 in 25 year storms are almost certain to cause flooding in susceptible areas. Third, the plugging of sewers and lateral connections to sewers account for a significant proportion of random basement flooding incidents where the design storm intensity is not exceeded. Fourth, some incidents of basement flooding have nothing to do with municipal infrastructure, rather these are caused by poor lot grading and/or foundation drainage practices. These findings suggest incidents of basement flooding are not completely avoidable from a municipal infrastructure perspective, if for no other reason than the statistical probability of an actual storm event exceeding the return period of the major and/or minor systems. However, where best engineering practices have been applied to major/minor system design, where by-laws regulating grading practices, backflow devices, sump pumps, future developments, etc., are effectively enforced, and where municipal infrastructure is properly maintained and repaired, basement flooding may be practically eliminated to a highly acceptable threshold of probability, similar to that enjoyed by the limit states design of building structures.

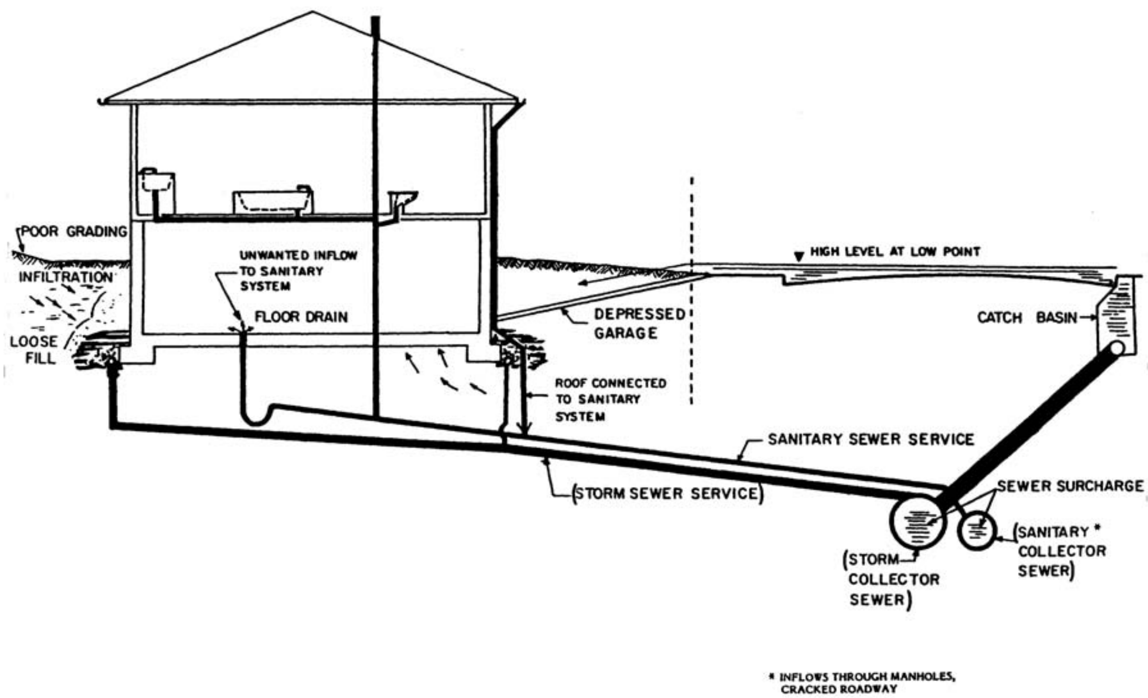

Figure 4. Typical causes of basement flooding in separated sewer systems. (Source: Wisner and Hawdur,1984)

The costs of damages due to basement flooding also vary widely. Respondents to the survey reported that claims ranged from several hundred dollars to a high of $40,000 where a large, expensively finished and furnished basement was involved. Average costs of damages reported in the survey are as follows: St. John $4,270; Winnipeg $2,400; and Regina $5,000 (based on a 1983 event). This corroborates the $3,000 to $5,000 range reported by Allouche and Freure from the Institute for Catastrophic Loss Reduction. One aspect of basement flooding that was overlooked in this survey deals with the impact of recurring claims on the cost and availability of homeowner insurance. It was anecdotally reported that some houses could no longer obtain basement flooding insurance coverage, and in houses where molds developed after the flooding, insurers cancelled their policies altogether. In cities like Toronto, homeowners have addressed this issue by finishing their basements with impervious surfaces (ceramic tile, terrazzo, etc.) and selecting furniture with tall legs so that damages are minimized and cleaning is made easier.

Sharing of costs associated with damages is relatively consistent across Canada with most municipalities rejecting claims unless they are liable. Liability is not rigorously defined, but essentially includes any form of sewer backup except that occurring within the private property portion of the lateral sewer connection. The growth of roots within sewer laterals is a common occurrence in many parts of Canada that can sufficiently plug the pipe during more extreme storm events to induce backup problems. Some municipalities accept liability for trees growing on city property that plug any portion of the lateral, but these issues were not fully addressed in the survey responses.

It is worthwhile noting that basement flooding history is not a mandatory disclosure item for house sellers anywhere in Canada. Based on a limited number of queries directed to provincial real estate councils and real estate boards in major Canadian cities, none have provided a field within their listing databases (e.g., MLS), such as those listing urea formaldehyde insulation or cost of heating, to indicate the susceptibility of basements to flooding.[6] Similarly, landlords' disclosure of the risk of basement flooding to prospective tenants is not mandatory anywhere in Canada, hence appropriate insurance coverage may not be knowledgeably elected, leaving tenants inadequately protected. A missing component of this survey deserving future attention involves the perspectives of homeowners and tenants who have experienced basement flooding problems.

Preventive Measures – Individual House *(Part 4)*

In view of the common occurrence of basement flooding due to sewer surcharge, a number of preventive measures have been adopted by Canadian municipalities. These are presented in greater detail in the next section of this report, but are summarized here based on the survey responses.

For individual properties, including residential buildings, the following preventive measures have been widely adopted:

- Improved grading practices controlled through by-laws and enforced by inspections;
- Eavestrough/downspout disconnection from the municipal system, and conveyance of runoff overland to the minor system;
- Backflow valves are mandatory in many municipalities to protect basement plumbing fixtures from surcharges.
- Sump pumps are required by some municipalities to convey foundation drainage to the ground surface, rather than permitting connections to the municipal system.
- Disconnection of illegal laterals has been adopted in some municipalities where these illegal connections have caused surcharges in combined sewers. This measure is often combined with the installation of a sump pump.

Most individual house measures are derived from programs aimed at existing dwellings in flood prone areas, and are now being applied with confidence to redevelopment and infill projects.

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[6] Strictly speaking, most real estate board and/or council code of ethics require that a vendor property information statement is appended to a listing, however, this may not afford reasonable protection to the purchaser as in the case where the vendor deliberately avoids disclosure and basement flooding occurs several years after purchase. The purchaser must provide proof that basement flooding occurred during the vendor's tenancy, but this requires the cooperation of the municipality and/or vendor's insurer.

Preventive Measures – Major/Minor System *(Part 6)*

The extent and diversity of measures for dealing with basement flooding problems caused by the major/minor systems ranges considerably across Canada. Before outlining preventive measures reported in the surveys, the definitions of minor and major systems are presented below.

The Minor System

The minor system consists of carefully designed closed and open conduits and their appurtenances, with the capacity to handle runoff from a storm expected to occur once within a one-year to five-year period and in a way that will cause relatively minor public inconvenience. The criteria recommended for this system are as follows:

a) Level of Service – One- or two-year rainfall intensity for normal residential areas, increasing up to five or ten years for major traffic arteries and commercial districts.
b) Design to recognize surcharging to road surfaces, permitting the hydraulic gradient to follow roadways, resulting in a more economic system.
c) No connections other than to catchbasins and other inlet structures.
d) Foundation drains must not be connected by gravity to storm sewers, except where the sewers are sufficiently deep or large to prevent hydrostatic pressure in basements during surcharge conditions.
e) Minimum depth of cover to be a function of external loading, but the springline must always be below frost depth.
f) Downspouts should, wherever possible, be discharged to the ground, utilizing suitable splash pads.

The Major System

The major system is the route followed by runoff waters when the minor system is inoperable or inadequate. It is usually expensive to eliminate any need for a major system. By careful attention from the initial planning stage, a major system can usually be incorporated at no additional cost and will often result in substantial savings in the minor system as well, i.e., greater protection at less cost. The criteria recommended for this system are as follows:

a) Level of Protection–100-year frequency desirable, 25-year minimum.
b) Continuous road grades or overflow easements to open watercourses.
c) No damage may be caused to private structures due to flooding.
d) Surface flows on streets to be kept within reasonable limits.

(Source: *Modern Sewer Design*, Fourth Edition 1999, American Iron and Steel Institute)

The most significant preventive measure reported by progressive municipalities is the use of computer modeling and simulation to formulate and assess various mitigation strategies. This is normally combined with monitoring of storm events and pipe flows to accurately calibrate the models. These strategies, which are further discussed in the following section, mainly consist of sewer separation, inlet control devices and relief or interceptor sewers for the minor systems, and various forms of retention/storage for the major system. It is worthwhile noting that while more sophisticated strategies exist, a lack of experience and/or confidence with the simulation of low impact development technologies, such as porous pavements and green roofs, tends to drive designers towards more conventional solutions that have been successfully demonstrated in other jurisdictions.

Prevention Programs/Public Information *(Parts 5 & 8)*

The trend in basement flooding prevention programs is very encouraging among the municipalities surveyed, with 17 of the 24 respondents indicating a formal prevention program was either well established or recently initiated. Of the 7 municipalities without formal programs, 5 of these inform their citizens through a variety of media about basement flooding prevention measures. In 2 of the municipalities, basement flooding was simply too rare an occurrence to justify a formal program.

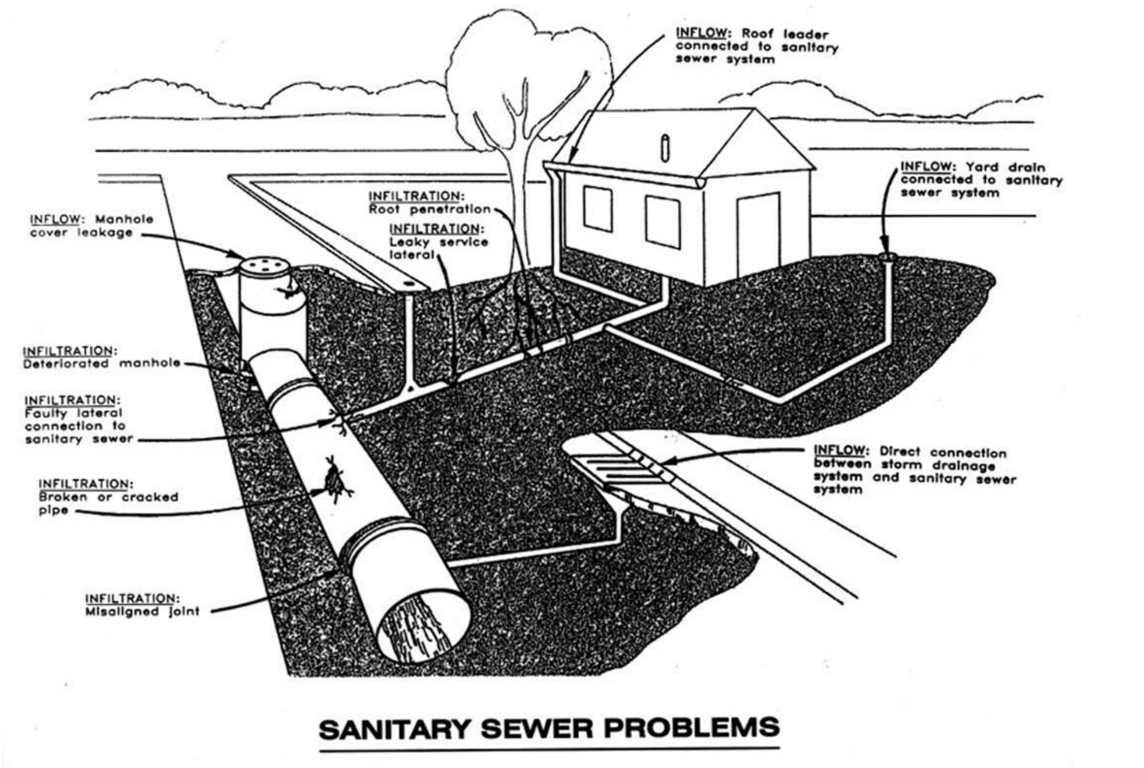


Figure 5. Example of public education illustration explaining infrastructure problems.

Public education programs are essential for explaining the complexities of urban infrastructure problems. Most members of the public have little appreciation for why their basements flood and what can be done about it – this also holds true for many of the elected politicians who must be patiently educated by staff and their consultants.

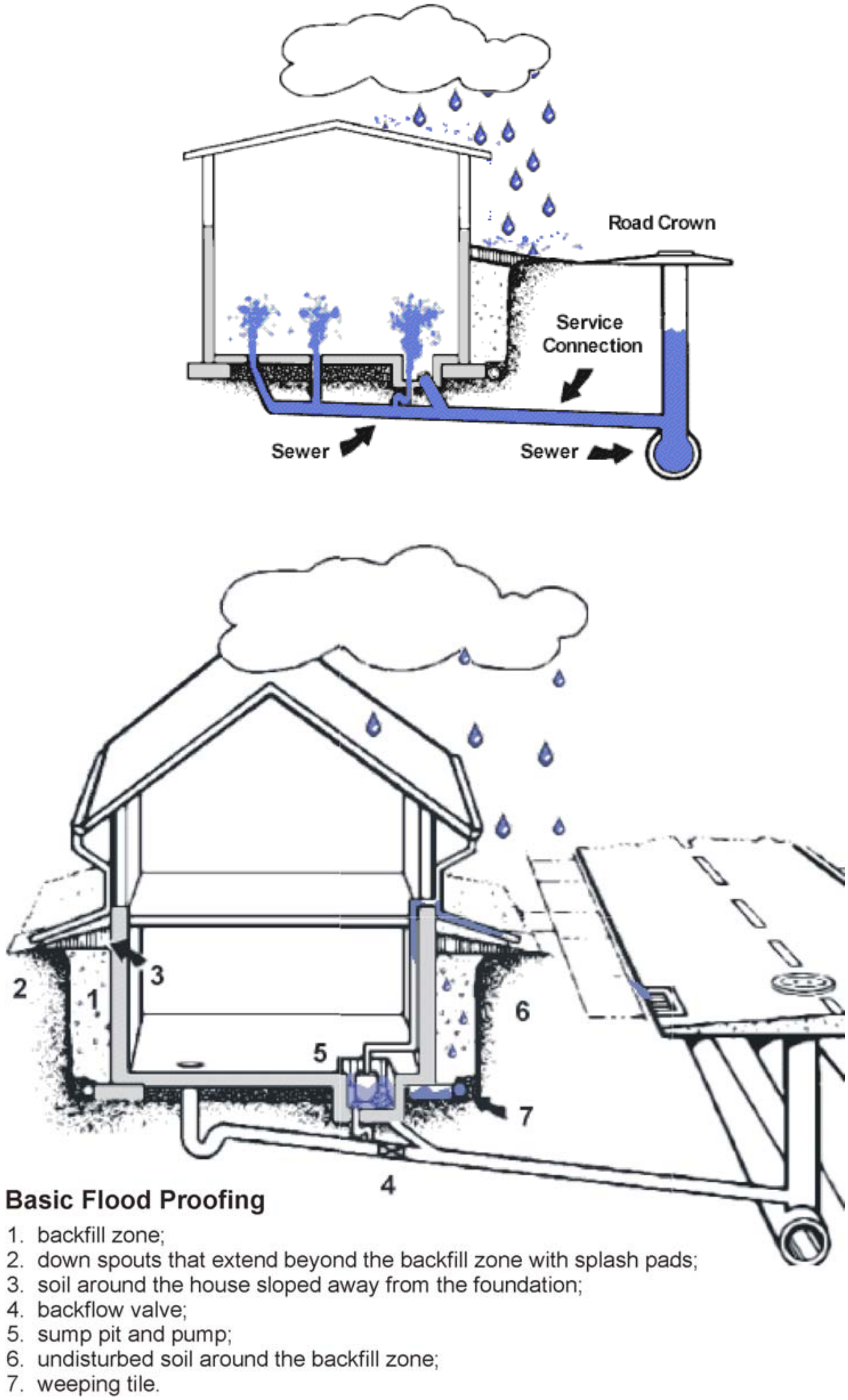


Figure 6. City of Regina's flood proofing Web site provides animated explanations of basement flooding phenomena and preventive measures.

Infill Housing and Redevelopment (Part 7)

One of the interesting questions arising from the Basement Guidelines consortium project involved the construction of new, infill housing in areas where the municipal infrastructure was prone to sewer surcharge. The intent of the National Building Code of Canada is to provide a minimum level of health and safety, however, the connection of basements to infrastructure and acceptable levels of risk against flooding is not directly addressed by any of Canada's model codes.

Most municipalities have addressed infill housing through by-laws enforced at the building permit stage where one or more of the preventive measures for individual houses, or buildings, must be provided. These measures are subsequently inspected and approved to ensure compliance. In progressive municipalities, developers are required to harmonize minor system design with the master plan and may elect among a large number of measures whose performance may be reliably predicted by computer modeling and simulation.

Redevelopment, as it pertains to intensification in established urban areas, is now being studied in larger municipalities to determine potential impacts on the existing infrastructure. This is causing developers to seek technologies that reduce stormwater flow into combined sewer systems, and this has been reported to cause concern for city officials who do not have confidence in the effectiveness of alternate technologies and the accuracy and reliability of how they are modeled in computer simulations. This situation is compounded by suburban sprawl that in some cases places additional loads on severely strained downstream systems, leading to confrontations over which form of growth is actually being advocated by the municipal administration. Compared to its technical aspects, the political dimensions of urban infrastructure remain far more complex and difficult to resolve.

Jurisdictional Issues *(Part 10)*

The most significant jurisdictional issue reported in the surveys is related to private versus public (municipal) components of the sanitary and stormwater systems. Homeowners are seldom aware that they are responsible for the portion of the connections to municipal infrastructure that are located on their property. As a result, homeowners seldom perform routine checks and required maintenance.

In some isolated cases, regional municipalities reported jurisdictional issues between the regional government and the individual municipalities. Moncton reported that jurisdictional issues arise between the Greater Moncton Sewerage Commission and Riverview, Dieppe and Moncton. Many municipalities noted that interior plumbing is provincially regulated while exterior piping is municipally regulated, on occasion causing conflicts between local by-laws and plumbing code enforcement.

Overall, the few jurisdictional issues reported were described as representing minor, negotiable barriers to the implementation of basement flooding protection measures.

The following section of this report deals with practical mitigation measures for the prevention of basement flooding.

Practical Mitigation Measures

Mitigation measures for basement flooding can range significantly in cost and sophistication. Measures appropriate to one municipality may not be appropriate to another due to factors such as climate, geography, topography, the nature of the existing municipal infrastructure and the characteristics of the building stock. In older urban areas, combined sewers coupled to the roof drainage (eavestroughs/downspouts) and foundation drainage (weeping tiles) often experience combined sewer overflow (CSO) problems. In such cases, practical mitigation measures differ from a situation where newer buildings serviced by a separated sewer system experience basement flooding. The review of practical mitigation measures that follows focuses on two major aspects of basement flooding protection: municipal policy, planning and regulation; and the implementation of appropriate mitigation technologies.

Municipal Policy, Planning and Regulation

Based on the survey responses, the overwhelming success stories involve integrated policies, planning and regulation. This may be taken for granted in some municipalities, but an examination of regional government systems indicates that considerable effort is required.

Unfortunately, case studies of successful integrated processes are not well documented, and even if they were, the political dimensions of municipal policy, planning and regulation may not be easily shared among municipalities. One of the biggest obstacles to achieving effective, sustainable urban drainage system reported in the surveys was the influence of developers on changes to master plans. These plans for drainage systems often involve years of effort and a considerable investment on the part of the municipality, including public participation. As an example, consider the following:

The former Municipality of Metropolitan Toronto began the development of the Wet Weather Flow Management Master Plan in 1997. It is being developed in a staged manner under the Class Environmental Assessment process.

*The focus in **Step 1**, completed in December 1998, was on collecting data on environmental conditions and developing a vision, goal and objectives to guide the Master Plan process.*

↓

***Step 2** (now underway) of the Master Plan process will culminate with the development of a Wet Weather Flow Management Strategy for the City. It will include by-laws, policies, projects, programs, a monitoring plan, an implementation plan and funding mechanisms.*

↓

***Step 3** will focus on implementing the Master Plan and*

↓

***Step 4** will monitor the Plan's effectiveness and update it where and when needed.*

(Source: City of Toronto's Wet Weather Flow Management Master Plan http://www.city.toronto.on.ca/wes/techservices/involved/wws/wwfmmp/index.htm)

Political influences over technical and environmental aspects of urban drainage system design are not likely to disappear, however, public education and vigilance are required to maintain the integrity of these vital planning processes.

Mitigation Technologies

A wide range of mitigation technologies is now available to homeowners, builders and municipalities. In order to have readers appreciate the difficulty associated with obtaining information about these technologies, this section has restricted all figures and images to those available through either the Internet or as provided by the survey respondents. What follows represents the extent of the collective knowledge base in Canada that is readily available for understanding and applying mitigation technologies. This is not intended as a criticism, rather it should be viewed as an opportunity to pursue improved technology transfer initiatives.

Grading and Site Drainage

Many basements are flooded by runoff that is directed toward the basement instead of being conveyed away to the minor system. Most municipalities control lot grading and site drainage through by-laws, however, it is only possible to ensure compliance within the framework of construction inspections. Later, after soil settlement and the maturing of planted vegetation, it is common to find that grading and drainage no longer comply with municipal requirements. New approaches are depicted below, and it is important to recognize how controversial and influential lot grading and site drainage are with respect to urban drainage system design and operation.

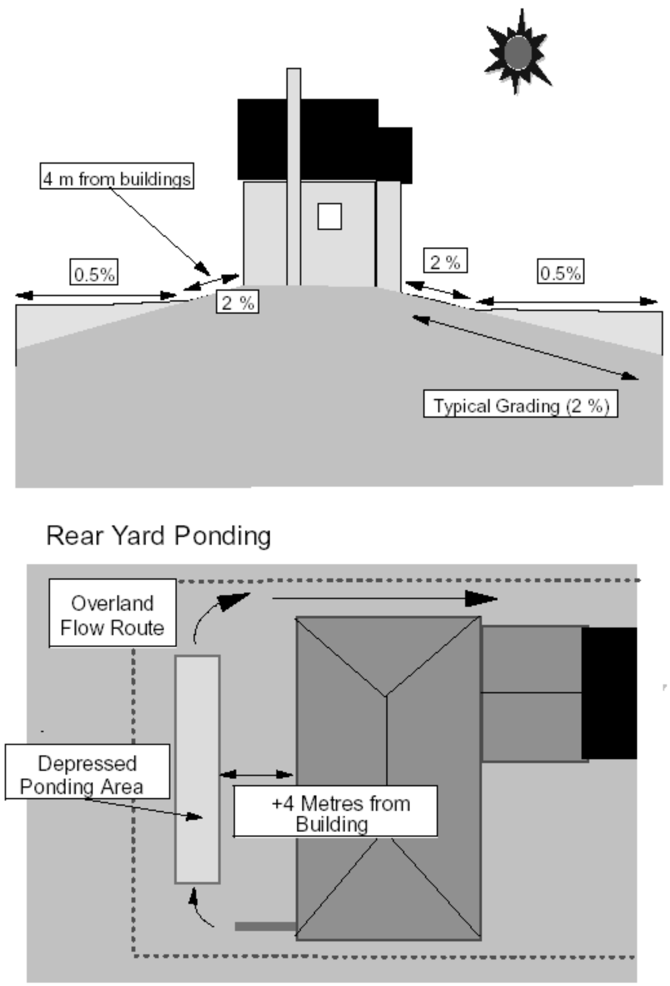


Figure 7. Recommended guidelines for lot grading and conveyance of runoff around houses. (Source: *Stormwater Management Planning and Design Manual*, Ontario Ministry of the Environment, Draft Final Report, November 1999.)

The lot grading guidelines depicted in Figure 7 do not reflect conventional approaches to landscaping where gardens and shrubs are planted in the proximity of the building perimeter. In developments with small lot sizes, such as townhouses or row houses, it may not be practical to locate a ponding area (which may also serve as a garden or planted area) 4 or more metres away from the building.

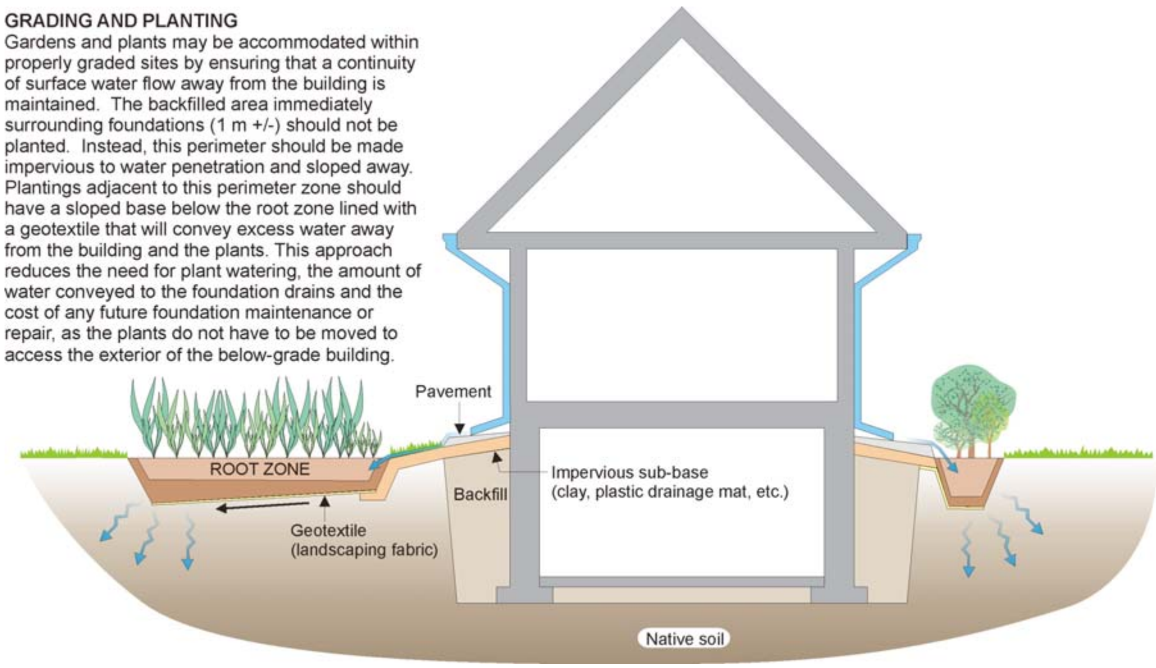


Figure 8. The use of impervious layers and geotextiles permit a more traditional approach to landscaping around buildings.

Disconnection of Downspouts

Disconnecting downspouts can prevent basement flooding and help reduce sewage pollution in receiving waters. Some downspouts discharge water onto the ground but many are connected directly to the sewer system. Downspout disconnection involves disconnecting a downspout from the place where it discharges to the sewer system and redirecting the water flow onto the ground or into a rain barrel. Allowing stormwater to infiltrate in urban residential areas is one way of managing runoff at-source, and by doing so, preventing a wide variety of downstream effects, in particular, basement flooding. Vancouver and Toronto, along with other municipalities, have successfully deployed disconnection programs and in the process extended the treatment capability of the combined stormwater/sanitary sewage system while helping to restore the hydrological cycle in urban areas.

Figure 9. Downspout disconnected from municipal sewer system discharges to a rain barrel connected to a soak pit. Savings in potable water use for irrigation along with reductions in pollution and sewage treatment costs are benefits that extend beyond basement flooding protection.

Figure 10. Cistern (1,500 gallon capacity) installed in Portland, Oregon and approved in 1998 for potable water use after treatment indicates the future of downspout disconnection.

Installation of Backflow Prevention Devices
Backflow valves have been successfully deployed across most municipalities in Canada, and represent an effective, low cost basement flooding measure, as described below.

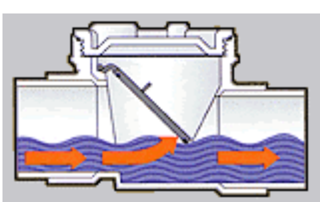
Many individuals and families who have experienced sewage backups have indicated the great inconvenience and mental stress they have gone through. Some degree of mental stress also remains with them just knowing that another major storm could flood their homes again. In addition, insurance companies will typically increase premiums and deductibles for sewer backup coverage should the homeowner have multiple flooding claims. Furthermore, if it appears that flooding could occur repeatedly, insurance companies will generally cancel their sewer backup coverage altogether

While the City is responsible for many of the initiatives to reduce flooding potential, homeowners can take their own measures to provide greater flood protection for themselves. One of the most effective measures is to install pumping systems. With a properly installed and operating pump in place, backups from the City system can be prevented. These systems, however, are often quite costly to retrofit into existing homes.

Some citizens have requested that they be allowed to install simple backflow prevention devices. Conventional backflow valves are prone to clogging by solids if used on sanitary lines. As a result, they have only been used on stormwater systems in the past. However, a new backflow prevention device has recently been developed which is much less prone to failure on sanitary or combined systems. Several hundred of these devices have been installed in homes in Edmonton over the past year and have worked well in minimizing basement flooding from their combined systems.

The Permits & Licences Department are now allowing these new backflow preventors to be installed on sanitary and combined lines where flooding is a concern. This provides homeowners with a less costly method of dealing with backups from the City system. It should be noted that these devices are not as effective as pumped systems because the household plumbing generally cannot be used during a major storm event. The duration of backups, however, is relatively short thus minimizing the inconvenience of not being able to use their plumbing fixtures. This makes the backflow prevention option a much more cost-effective method, if installed and maintained correctly, to prevent sewage and stormwater from backing up into homes.
By installing these devices in homes that have been flooded, the mental stress to homeowners regarding future flooding would diminish considerably. In light of the recent increase in storm events, and with this new low cost backflow prevention option available, Engineering Services is proposing to contact all homeowners who have experienced flooding in the past ten years to inform them of this new option.

Source: *Storm Flooding Update and Proposed Assistance Program*, General Manager of Engineering Services, City of Vancouver, November 28, 1997.
http://www.city.vancouver.bc.ca/ctyclerk/cclerk/971209/a14.htm



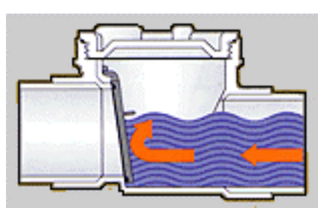


Figure 11. Backflow valves permit waste water to run through the valve assembly to the sewer, but prevent backflows from entering the building.

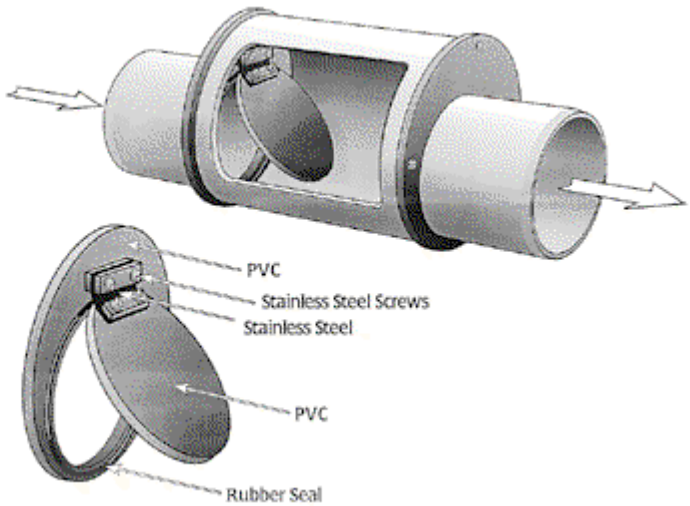


Figure 12. Normally closed backflow valves violate venting requirements in many plumbing codes, and certain designs, such as this older model, are prone to plugging by trapped solids.

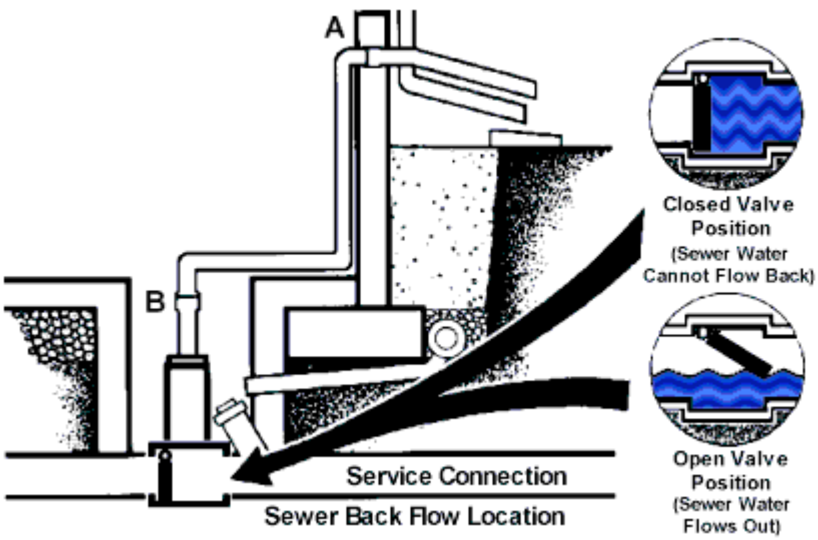


Figure 13. City of Regina recommended location for backflow valve. It is essential that backflow valves can be accessed for inspection and maintenance.

Standards for backflow valves and the harmonization of plumbing codes with municipal practices for basement flooding prevention are long overdue in Canada. It is interesting to note that throughout this study, it was not possible to conveniently access a list of approved backflow valves and municipally recommended installation instructions.

Installation of Sump Pumps

Sump pumps are normally installed when foundation drainage is disconnected from the municipal sewer system and gravity drainage to a ditch or drywell is not available. A sump pump is a highly effective basement flooding protection measure, however, there are currently no standards in Canada governing minimum performance and reliability levels. Proper installation is also not fully addressed in current plumbing codes (for example, the depth of the sump needed to maintain sufficient draw down to keep the basement dry is not referenced in any codes or standards, and is largely a trial and error process until successful local precedents evolve). As a result of this gap in the regulation of sump pumps, it is important to consider back-up systems that are interconnected with an alarm system to notify occupants of the primary sump pump failure.

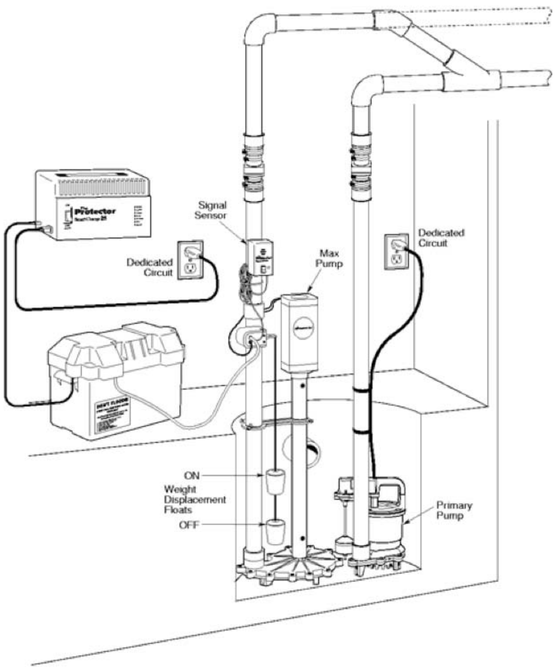


Figure 14. Sump pump with battery powered backup sump pump - most power failures coincide with severe storm events.

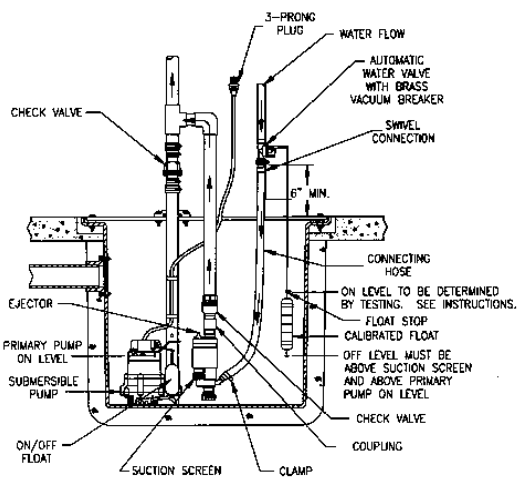


Figure 15. Water powered back-up sump pump uses potable water supply to automatically drive pump impeller during periods of main sump pump failure or electrical power outages.

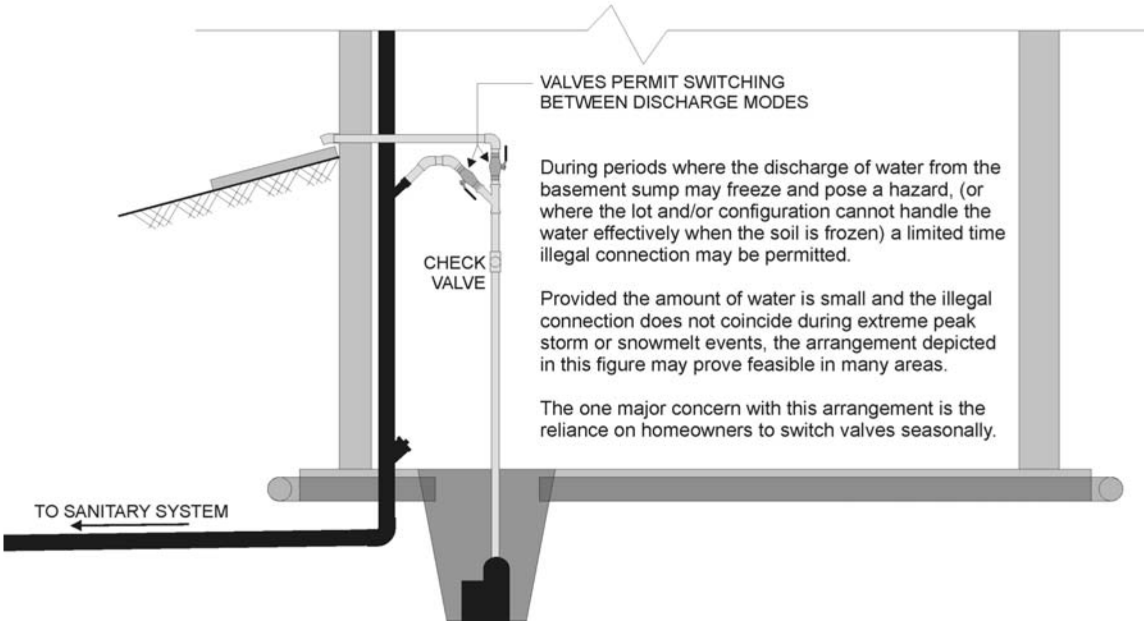


Figure 16. Accommodating instances where discharging sump water to the lot surface is impractical translates into permitting temporary illegal connections under suitable conditions.

Disconnection of Illegal Connections

Illegal connections are normally due to existing, non-conforming conditions in older parts of municipalities where connection practices were not well specified and/or controlled. The following excerpt from the City of Elmhurst Web site provides a clear explanation of this measure. (http://www.elmhurst.org/elmhurst/publicworks/sumppump.asp)

What is an illegal connection?

An illegal connection is a connection that permits extraneous storm-related water (water from sources other than sanitary fixtures and floor drains) to enter the sanitary sewer system. The extraneous storm-related water is water that should be going to the storm sewer or allowed to soak into the ground without entering the sanitary sewer.

What are the different types of illegal connections?

Illegal connections include connections of downspouts, sump pumps and area drains to the house sewer lines. In addition, defective house sewer lines cause extraneous water to enter the sanitary sewers and thus they are also illegal connections.

Where should storm drainage from downspouts, sump pump, and / or other drain appurtenances be directed if it can't be discharged to the sanitary sewer?

Modern subdivision construction standards generally call for water from sump pump, area drains and the like to be diverted to the storm sewers, front or back yards or above ground drainage ditches.

Why is it important for everyone to remove illegal connections?

Removal of illegal connections will significantly reduce the flow of extraneous storm-related water in the sanitary sewer system. This stormwater ends up at the wastewater treatment plant and is treated along with sanitary flow. The cost of treating this clean water could be reduced by reducing the quantity of water from the sanitary sewer.

How can surcharged sanitary sewers cause basement flooding?
A surcharged sewer flows at a level greater than the "normal" level. If the home has sanitary fixtures or floor drains at an elevation below the surcharge level, basement flooding can occur. The sanitary sewers have been designed to transfer sanitary waste only. Extraneous storm water flow added to the normal sanitary flow can exceed the capacity of the sanitary sewer resulting in a situation where the sanitary sewer is "surcharged." Basically, surcharging occurs when the amount of flow trying to get through a pipe exceeds the maximum capacity of the pipe thus building up pressure in the pipe. When pressure builds up it seeks to relieve itself through any means possible, one of which is by backing up private sanitary services and filling basements and crawlspaces. Reducing the extraneous flow will reduce the surcharging and sewer back-ups.

Do illegal connections really contribute large amounts of extraneous water to the sanitary sewer system?
Yes. For example, an eight-inch sanitary sewer can handle domestic waterflow from up to 465 homes; however, it takes only twelve sump pumps operating at full capacity to overload an eight-inch sanitary sewer.

How does the City of Elmhurst identify illegal connections?
The City has completed engineering studies conducted by an independent consultant for the purpose of identifying illegal connections to the sanitary sewer lines. Such studies included smoke and dye testing of the sewers and house lines and house inspections. Also, you are required to call for an inspection when you are selling your home.

If I have an illegal connection what do I do to correct it?
It is suggested that you consult a licensed plumber to determine the most appropriate methods of removing a specific illegal connection.

The following are some possible solutions:

- *The sump pipe could be run overland to a ditch or swale that could drain to another location. Also, a long flexible tube that can be moved around the yard to avoid discharge in only one portion of the yard could be used.*
- *The sump pump can be run underground through a 4" or 6" diameter perforated PVC pipe, with holes at the bottom and backfilled with washed gravel. An overflow tube should be placed at the opposite end to allow the water to escape in the event that the volume of the pipe is exceeded. This pipe tube is located at a convenient area of the yard such as a garden. Another option could be to run it to a drywell.*
- *Route the sump pump to a City storm sewer via a 6" pipe and tie into the back of an inlet or the crown of the mainline pipe by way of a core hole. No breaking out of the concrete pipe is allowed. If the homeowner is doing the work the City will make the tap. If the homeowner hires a contractor, the contractor is required to do all the work. In both cases, a permit and street deposit (if done by a contractor) will be required with proper inspections made by the Engineering Division.*
- *Install a 6" diameter PVC storm sewer with drainage inlets to serve as a community backyard drain for a cluster of homes with sump pump connections. The City has an annual program to assist in this type of installation. It is a cost-sharing program with resident participation. Please contact the Elmhurst Department of Public Works for information. Connection to the City storm sewer may by made as outlined above.*

***Note**- Caution must always be taken to prevent freezing in pipes. This could be done by placing a tee where the pipe exits the building. One branch could go underground and the other could be capped off or valved to pump into the yard during the winter. Another option is to have the 2" diameter sump pump tie into the larger 4" or 6" pipe at the house allowing for expansion and overflow. Pipes flowing overland should be kept no farther than 10 feet from the house in winter to avoid icy sidewalks.*

I've never had basement flooding due to surcharged sewer. Why should I remove my illegal connections?

You may not have basement flooding due to surcharged sewers. But if your plumbing pumps or drains storm-related water into the sanitary sewer, it may well be the cause of flooding in your neighbor's basement.

The greatest barrier to the removal of illegal connections is funding. While very effective in reducing inflows to sewer system, illegal connection removal programs require extensive inspection and monitoring. Many municipalities address illegal connections when they undertake major rebuilding of roads and services in existing neighbourhoods.

Inlet Control Devices

Controlling the amount of stormwater flowing into the municipal drainage system is an effective control measure for basement flooding protection.

According to U.S. Environmental Protection Agency, Combined Sewer Overflow Management Fact Sheet, *Inflow Reduction*, September 1999
http://www.epa.gov/owm/mtb/inflwred.pdf

Flow restriction and flow slipping methods utilize roadways and overland flow routes to temporarily store storm water on the surface, or to convey storm water away from the combined sewer system (CSS). Flow restriction is accomplished by installing static flow or "braking" devices in catch basins to limit the rate at which surface runoff can enter the CSS. Excess storm flow is retained on the surface and enters the system at a controlled rate, eliminating or reducing the chance that the system will be hydraulically overloaded and overflow. The volume of on-street storage is governed by the capacity of the static flow device, or orifice, used for restriction, as well as surface drainage patterns.

As opposed to flow restriction, where flow rates into the CSS are reduced but all storm flow eventually flows into the storm sewer system, flow slipping refers to the intentional blocking of storm water from entering the CSS at catch basins for the purpose of routing, or "slipping", it elsewhere. Flow slipping is accomplished by partially or completely blocking the entry of surface runoff at catch basin inlets and letting the runoff follow overland flow routes.

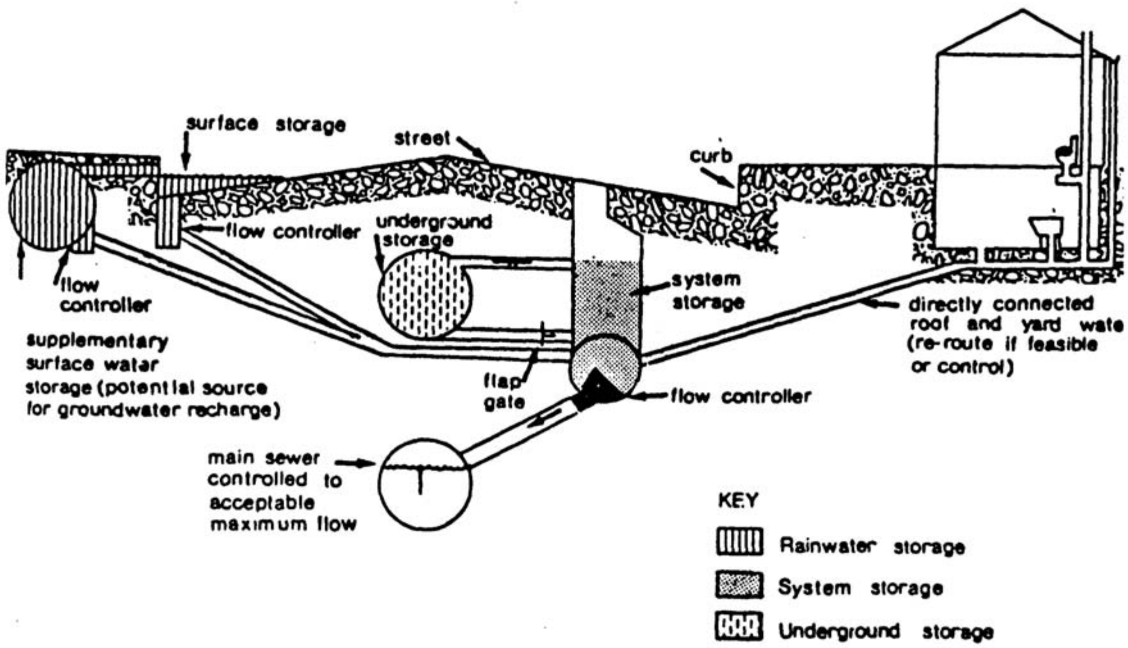


Figure 17. Principles of application of inlet control devices in storm sewer rehabilitation. (Source: Wisner, 1990)

Flow restriction and flow slipping can effectively reduce inflow during peak runoff periods and can decrease combined sewer overflow (CSO) volume. Use of these methods must be carefully planned to ensure that sufficient surface storage or overland throughput capacity exists in the drainage area. These methods are almost always used in conjunction with other practices, such as roof drain and basement sump pump redirection.

Flow restriction works best in relatively flat areas where temporary ponding and detention of water on streets is acceptable. Extensive public education and testing are required to build support and address concerns that residents and elected officials may initially have regarding on-street storage. Flow slipping is an option where opportunities for on-street storage are not available. The "slipped" flow can be diverted along natural drainage routes to separate receiving waters, separate storm sewer systems, or even to more optimal locations within the CSS.

The use of flow restriction and flow slipping requires a detailed evaluation of the collection system and catch basins. The community must assess the potential for unsafe travel conditions, flood damage, and damage to roadways. Pilot studies and monitoring are recommended to identify impacts and confirm performance.

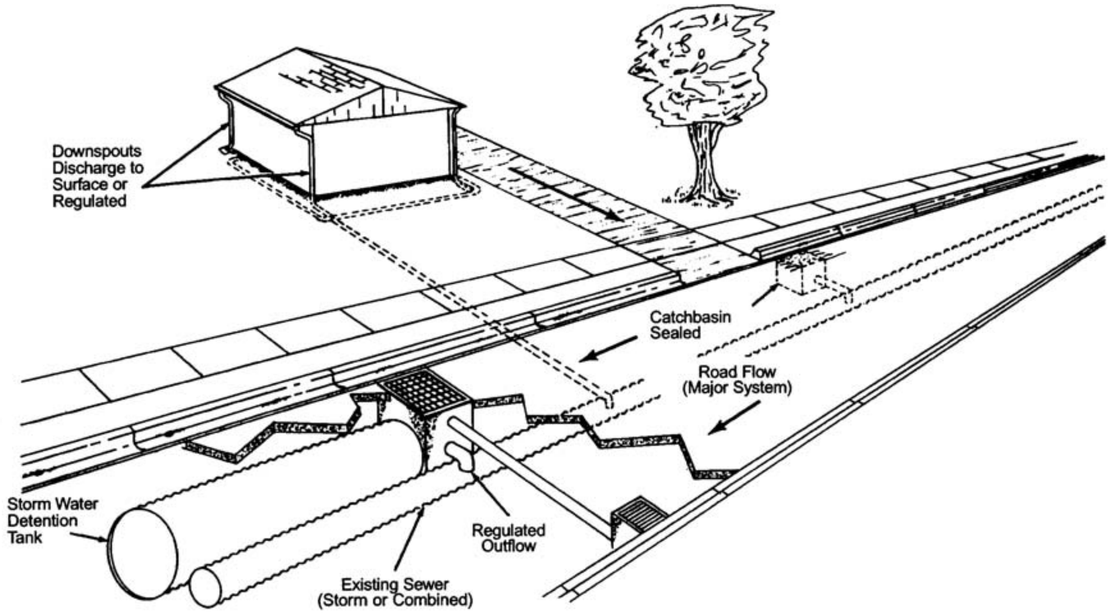
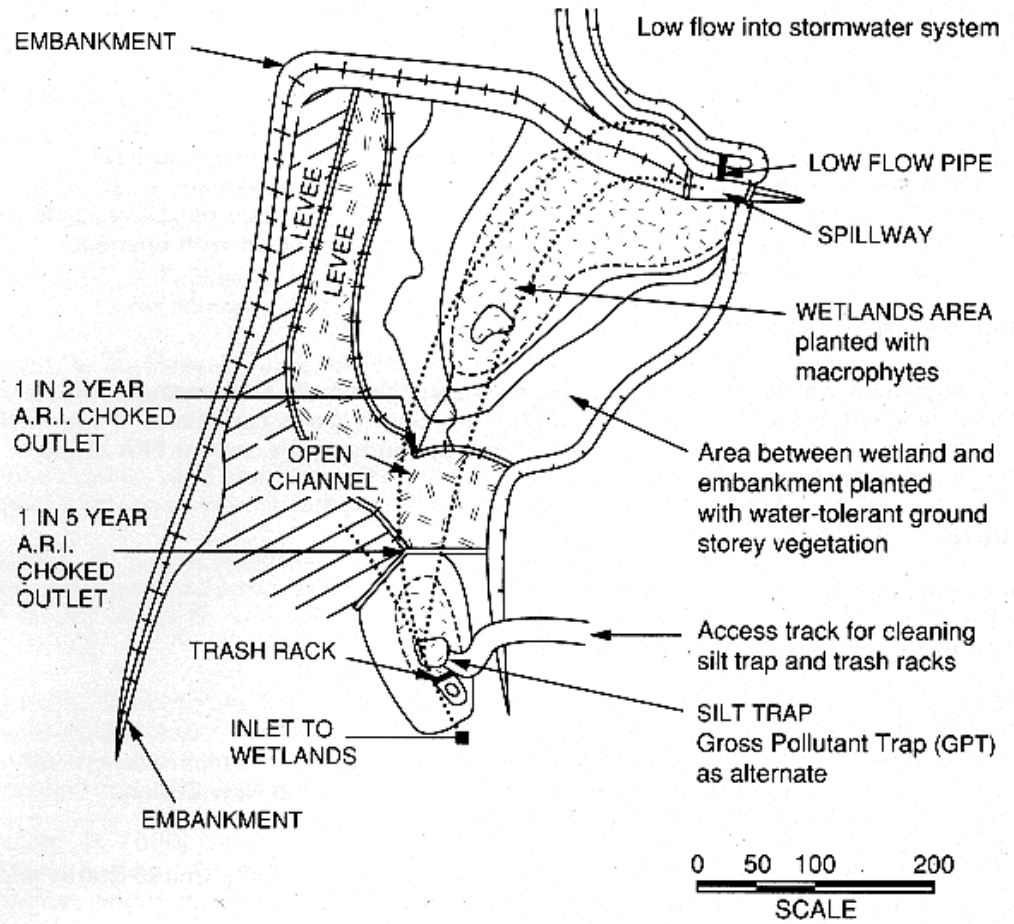


Figure 18. Example of an inlet control system. (Source: *Modern Sewer Design*, Fourth Edition 1999, American Iron and Steel Institute)

The effective deployment of inlet control devices normally requires sophisticated computer simulation combined with reliable monitoring data of storm events and drainage system flows. Most importantly, public consultation and education are needed to deal with concerns and misconceptions while explaining how the short term storage of stormwater that appears inconvenient to pedestrians and motorists is promoting dry basements and reduced pollution.

On-Line and Off-Line Storage

In older communities, where combined sewer systems are still common, storm water flows often exceed the sewer system's hydraulic capacity. Redevelopment of urban areas can also increase the impervious areas served by the sewer system, which, in turn, increases storm water flows to combined sewers. An alternative solution to this problem is the introduction of on-line and off-line storage.



Flood Retarding Basin Plan incorporating a Wetland for Treating Urban Runoff. Most constructed wetlands for treating urban stormwater will be simpler, but will include elements of this general design.

Adapted from Breen et al (1992)

Figure 19. Example of an off-line storage basin that retards peak flows within manageable thresholds.

Near-surface storage in open or covered basins is the most common method of combined sewer overflow retention. Retention basins may be placed on-line or off-line from the combined sewer. Online retention basins are connected in series to the combined sewer and retain excess flows when the inlet flow surpasses the outlet capacity. Off-line retention basins are connected in parallel to the combined sewer and receive flows only during wet weather periods.

Figure 20. Retention basins of the kind shown in this figure are becoming less popular due to concerns for mosquito breeding grounds that may spread the West Nile virus.

In addition to the knowledge and experience needed to successfully deploy storage/retention systems, consideration for public safety (water depth vs drowning hazard) and issues such as aesthetics and odour often cause municipal engineering departments to consider less visible alternatives. Basements continue to represent the most common off-line storage system for municipal sewer surcharges.

Third Pipe Systems
There are cases where basement flooding is due to surcharged storm sewers, and some municipalities have reported the successful implementation of third pipe systems, also referred to as foundation drain collectors. Third pipe systems typically convey water collected from foundation drainage systems to nearby water bodies. The water is normally very clean and may be introduced to receiving waters without violating environmental protection guidelines.

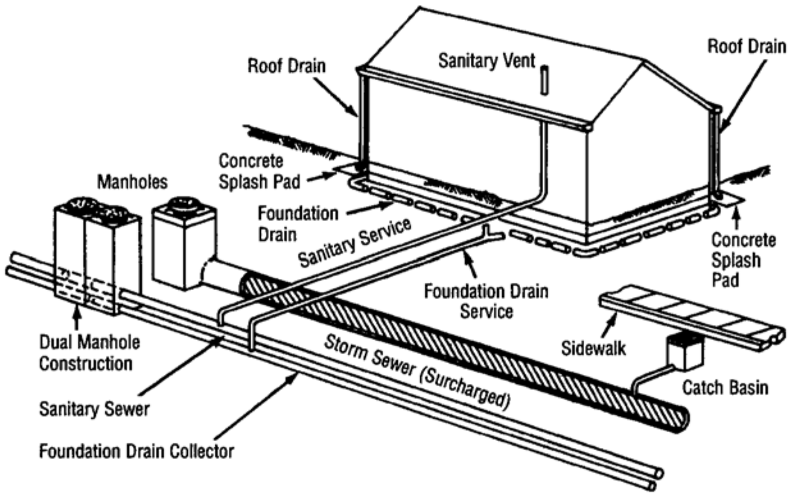


Figure 21. Example of third pipe system dedicated to collection of foundation drainage. (Source: *Modern Sewer Design*, Fourth Edition 1999, American Iron and Steel Institute)

Third pipe systems have proven cost effective since the introduction of trenchless technologies that enable reduce the need for costly and disruptive excavation. In general, third pipe systems are a viable alternative in areas where improvements to the minor system are difficult and costly, and their effectiveness requires careful interpretation of computer simulation data.

Separation of Combined Sewer Systems
Where combined sewer systems frequently surcharge and cause basement flooding, or their overflows pollute receiving waters, many municipalities have elected to separate sanitary waste from stormwater flows. Sewer separation is the practice of separating the combined, single pipe system into separate sewers for sanitary and storm water flows. In a separate system, storm water is conveyed to a storm water outfall for discharge directly into the receiving water. Based on a comprehensive review of a community's sewer system, separating part or all of its combined systems into distinct storm and sanitary sewer systems may be feasible. Communities that elect for partial separation typically use other combined sewer overflow (CSO) control measures.

According to U.S. Environmental Protection Agency, Combined Sewer Overflow Management Fact Sheet, *Sewer Separation*, September 1999 (http://www.epa.gov/owm/mtb/sepa.pdf),

Sewer separation can be considered wherever there is a combined sewer system, however an evaluation of the most appropriate CSO control should be performed prior to selecting sewer separation or any other measure. Sewer separation has often been the appropriate technology in areas where one or more of the following conditions exist:

- *Most sewers are already separated;*
- *Siting constraints and costs prohibit the use of other structural measures; and*
- *The uses and the assimilative capacities of receiving waters prohibit the use of other combined sewer overflow control measures.*

An example of how sewer separation is combined with other measures is reported in *Wastewater Separation for Basement Flood Relief in the City of Winnipeg*, by Gordon Steiss, CET, Wardrop Engineering and W.D. Watters, P.Eng, City of Winnipeg, Water and Wastewater Department, July 2002.

The City of Winnipeg has developed a sewer upgrading program in response to extensive property damage from basement flooding as a result of intense summer rainstorms. The objective of the program is to upgrade all of the City's 42 combined sewer districts to a minimum 5-year level of basement flood protection. Implementation of relief works is prioritized on the basis of a benefit cost analysis comparing the cost of the relief works to the reduction in damages over the life cycle of the relief works.

The Marion and Despins Combined Sewer Districts were identified as districts where high benefits could be realized by implementing relief works to reduce basement flooding damages. Studies concluded that the most cost-effective relief works would be a combination of:

- *Stormwater Separation – installing new land drainage sewers to separate stormwater from the combined sewer system;*
- *Storm relief sewers – parallel combined sewer relief piping to augment the capacity of the existing sewer system; and,*
- *Wastewater Separation – installing new wastewater sewers to connect to the individual service connections* and isolate the buildings/residences from the combined sewer system.

The adjacent Marion and Despins Districts comprise 260 hectares and 160 hectares of primarily residential area, respectively. A major topographic feature of the two districts is an ancient Red River oxbow. Over time the oxbow has been filled for development; however, the land around the oxbow is two to three metres lower than the surrounding area. The low area, coupled with the relatively shallow sewers in the area, precluded conventional relief measures for basement flood protection. Conceptual design studies indicated that wastewater separation was the least-cost solution to the basement flooding problem.

Wastewater separation entails the connection of the existing building service connections to new wastewater sewers. The existing combined sewers are used to convey stormwater from the area, as well as dry weather flow from other portions of the district. Since the combined sewers are no longer connected to the buildings, they are allowed to surcharge above basement levels in the separated area. The wastewater is collected and conveyed to a lift station where it is pumped back to the combined sewer system, and ultimately conveyed to the treatment plant.

The detailed design of the wastewater separation system was the first such design carried out in the City of Winnipeg. The first step was to determine a suitable location for the lift station, in what was primarily a fully developed residential neighbourhood. The initial design considered placing the station under a large traffic island; however this site required a dependable overflow (to the combined sewer system) in the event of service disruption. As the levels in the combined sewer would be above basement elevations during significant wet weather flow events, it was determined that a gravity overflow could not be counted on to prevent basement flooding. Accordingly, it was established that the lift station would require a standby power source. This led to another review of the area to find a location suitable for a building to house the standby power generator.

A suitable location was found on a City-owned vacant lot. Using this site required a conditional use variance to the property to permit the establishment of the wastewater pumping station. The City's Board of Adjustment subsequently approved the conditional use application. The approval was due, in large part, to the City's public notification program to advise the residents on details of the planned facility as well as the corresponding increase in the level of basement flood *protection. A conveyance system routing was then designed to collect the wastewater and convey it to the pumping station.*

The detailed design of the system included an analysis of dry weather and wet weather flows. Dry weather flow estimates were calculated based on the following typical design values used in the City of Winnipeg:

- *occupancy – 3.5 persons per residential unit, 2 persons per multi-family unit;*
- *per capita water consumption – 270 l per capita; and,*
- *groundwater infiltration – 2,200 litres per hectare per day.*

This analysis resulted in an average dry weather flow of 11.3 Litres per second. This value compared favourably, on an area basis, to the City's dry weather flow monitoring data and was selected as the design value. Rainfall dependent infiltration and inflow to the wastewater sewer system consisted of manhole inflow and weeping tile contributions. Manhole inflow was calculated based on the City's design value of 12 litres per manhole per minute. The estimate of weeping tile flow required more careful consideration.

An earlier study had developed design hydrographs for weeping tile flow corresponding to lot grading, ranging from good to unsatisfactory conditions. A field investigation was carried out to characterize lot grading at each of the 350 buildings in the service area. Weeping tile flows were derived for each reach of sewer based on the various design hydrographs multiplied by the number of buildings with each lot grading type. Composite flow hydrographs were then developed for individual service areas and included dry weather flow, manhole inflow and weeping tile flow components.

A computer model (Stormwater Management Model – SWMM) of the proposed wastewater collection and pumping system was developed to size the individual components. The design flows were routed through the model, with successive computer simulations used to optimize the piping system and pumping facilities. The recommended piping system ranges in size from 250 mm to 450 mm in diameter, with a peak wet weather flow of 85 litres per second to the pumping station.

The wastewater collection system consists of more than 4,000 metres of main-line piping. The pumping station features a cast-in-place concrete structure with standby power and a firm pumping capacity of 85 litres per second. The work was tendered in three contracts in November 2001 – January 2002. Construction is underway. The intent of the project is to complete the works in time to provide basement flood protection for the area for the 2002 wet weather season.

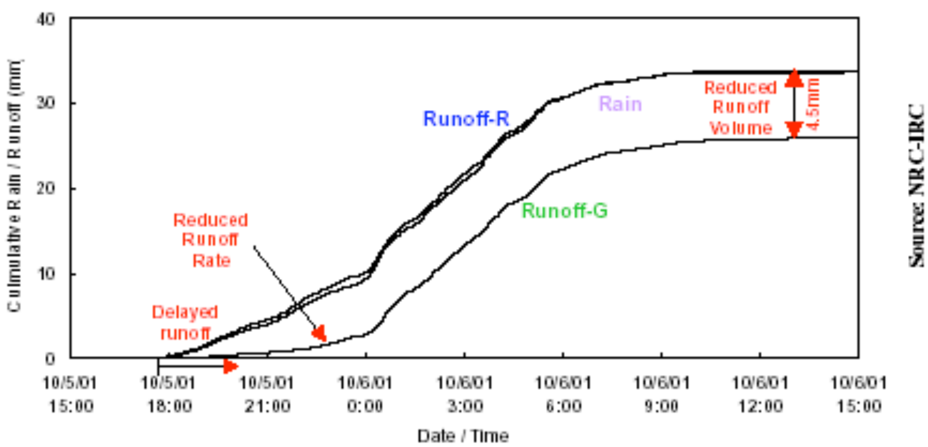
Sewer separation, often in combination with other control measures, represents an effective means of preventing basement flooding. But it is costly and highly disruptive during construction. As noted in the Winnipeg project cited above, numerous, sophisticated analyses are needed to refine concepts, and many of the associated logistics require careful planning and consideration.

Landscape as Infrastructure Development (Low Impact Development)
Before the time of human settlements, the landscape provided a natural infrastructure for supporting native ecosystems. Landscape as infrastructure development (LID), also known as low impact development (LID), is an innovative stormwater management approach with a basic principle that is modeled after nature: manage rainfall at the source using appropriately distributed, decentralized controls. The goal of this approach is to mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source. Techniques are based on the premise that stormwater management should not be seen as stormwater disposal. Instead of conveying and managing / treating stormwater in large, costly end-of-pipe facilities located at the bottom of drainage areas, LID addresses stormwater through small, cost-effective landscape features located at the lot level. These landscape features, known as Integrated Management Practices (IMPs), are the building blocks of LID. Almost all components of the urban environment have the potential to serve as an IMP. This includes not only open space, but also rooftops, streetscapes, parking lots, sidewalks, and medians. LID is a versatile approach that can be applied equally well to new development, urban retrofits, and redevelopment / revitalization projects. Unlike conventional approaches to stormwater management, LID is not hidden from public view, instead providing visual and recreational benefits that enhance a community's quality of life. Some of these approaches are described and illustrated below.

Green Roofs
A major contributor to stormwater management problems is runoff from roofs. The deployment of green roof technology is aimed at addressing runoff rates and volumes, while providing numerous additional benefits such as: lower heating and cooling loads; extended service life of roofing membranes; and reduction in urban heat island effects. Green roof installations in Canada are increasing and at this point appear to be delivering their expected performance. A major barrier to implementing green roof technologies, aside from making the connection between roof runoff and basement flooding, is the lack of economic incentives available to building owners. When owners implement water or energy conservation measures, they realize savings in their water and energy bills. Municipalities may consider appropriate incentives, such as interest free loans or property tax credits, in order to foster the implementation of green roof technology.

Figure 22. Green roof demonstration project at Toronto City Hall transforms dull concrete into a verdant landscape while reducing cooling loads and stormwater runoff.

Figure 23. Green roofing technology improves energy efficiency and extends the life roofing membranes by protecting them from exposure to sunlight and temperature extremes. These benefits more than offset the initial cost premium associated with green roofs.



This graph records the cumulative rainfall and runoff from the Green Roof and the Reference Roof during a 34mm rain event over a 15h period in October 2001. The green roof delayed runoff and reduced runoff rate and volume.

Figure 24. This graph depicts the attenuation of runoff rate and the reduction of runoff volume associated comparing between a green roof system (Runoff-G) and a regular roofing system (Runoff-R). This testing conducted by the Institute for Research in Construction, National Research Council of Canada will enable designers to integrate green roof effects into stormwater models, and hopefully represents the beginning of further field verification of the performance of LID technologies.

Detention Basins
The main reasons for use of dry detention basins are reducing peak stormwater discharges, controlling floods and preventing downstream channel scouring. It is also possible for this approach to remove a limited amount of pollutants, and generally represents the lowest cost alternative for large runoff volumes.

Detention basins are an impoundment or excavated basin for the short term detention of stormwater runoff from a completed development area followed by controlled release from the structure at downstream, pre-development flow rates. There are several types of detention devices, the most common being the dry detention basin and the extended dry detention basin. These are structures which hold a certain amount of water from a storm and which release the water through a controlled outlet over a specified time period based on design criteria. The extended detention basin drains more slowly or may retain a permanent pool of water.

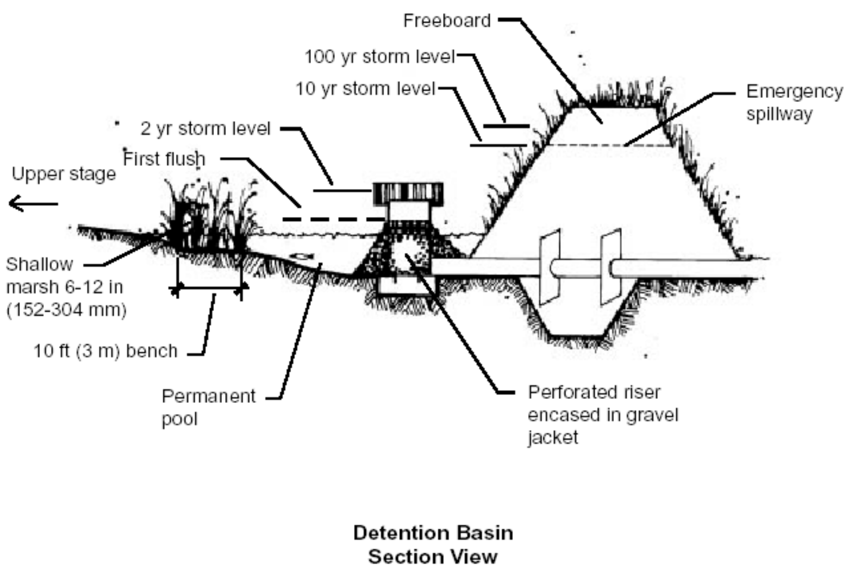


Figure 25. Basic design and construction considerations for detention basins. [Source: NRCS Planning and Design Manual, NRCS.]

Figure 26. A newly constructed detention basin that will eventually mature into a tree filled meadow.

Figure 27. Rock rip-rap for erosion control is used at the inlets to the detention basin. Note the pre-cast concrete overflow control structure.

Figure 28. Flood tolerant tree species must be selected for use in detention basins. Local varieties that thrive along lake shores and stream beds are reliable choices.

Figure 29. Water accumulations normally subside within hours of a storm's passage, and in rare instances may have a duration of one or several days.

Bioretention Cells

One of the primary objectives of LID site design is to minimize, detain, and retain post development runoff uniformly throughout a site so as to mimic the site's predevelopment hydrologic functions. Originally designed for providing an element of water quality control, bioretention cells can also achieve runoff volume control. By infiltrating and temporarily storing runoff water, bioretention cells reduce a site's overall runoff volume and help to maintain the predevelopment peak discharge rate and timing. The volume of runoff that needs to be controlled in order to replicate natural watershed conditions changes with each site based on the development's impact on the site.

A bioretention facility consists of a porous soil covered with a thin layer of mulch. A stand of various grasses, shrubs, and small trees is established to promote evapotranspiration, maintain soil porosity, encourage biological activity, and promote uptake of some pollutants. Runoff from an impervious area is directed into the bioretention facility. The water infiltrates through the plant/mulch/soil environment, providing the treatment.

Typically, bioretention practices are integrated throughout a land development project and are strategically placed to intercept runoff near the source. Originally designed to provide an element of water quality control, recent studies have shown that quantity control can be achieved as well. Bioretention systems function similar to infiltration/filtration practices with the added advantage of aesthetically pleasing landscaping in the form of a dense vegetative cover.

Bioretention systems can be designed to mimic natural hydrologic processes that occur in vegetated areas to absorb and filter water through evapotranspiration and soil filtering mechanisms. Through wastewater treatment experiences and literature research, it has long been recognized that soils and plant materials can successfully filter pollutants from water.

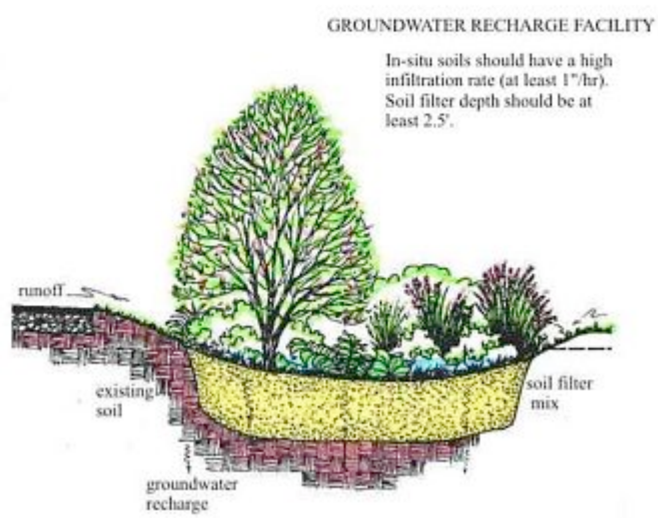


Figure 30. Where the runoff volume is manageable, a groundwater recharge application of bioretention cells is preferable, and generally less costly.

In some cases, bioretention cells can be used to capture and re-direct runoff through underdrains. The use of underdrains can make the bioretention cell act more like a filter that discharges treated water to the storm drain system than an infiltration device. However, the ponding capability of the cell will still reduce the immediate volume load on the storm drain system and reduce the peak discharge rate. Where the infiltration rate of native soils is high enough to preclude the use of underdrains (at least 25 mm or 1"/hour), increased groundwater recharge also results from the use of the bioretention cell. If used for this purpose, care should be taken to consider the pollutant load entering the system, as well as the nature of the recharge area.

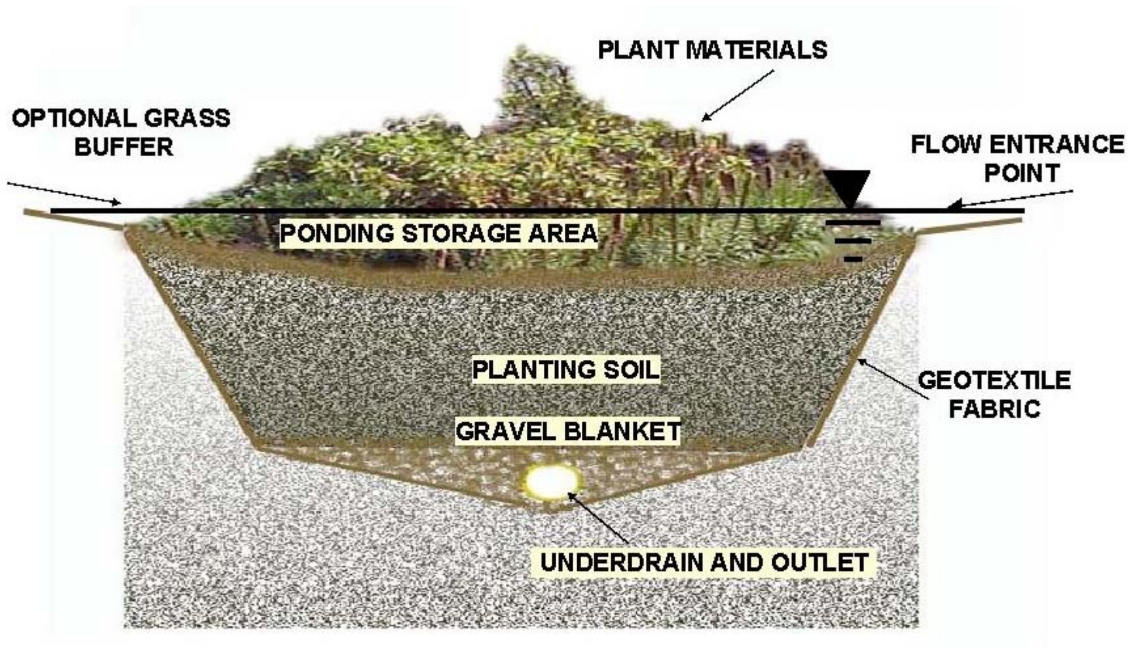


Figure 31. A section of a hybrid bioretention cell that serves both as a stormwater infiltration and filtering device.

Bioretention systems are modeled after the biological and physical characteristics of an upland terrestrial forest or meadow ecosystem. These systems use vegetation, such as trees, shrubs, and grasses, to remove pollutants from stormwater runoff. Sources of runoff are diverted into bioretention systems directly as overland flow or through a stormwater drainage system. Alternatively, a bioretention system can be constructed directly in a drainage channel or swale.

Bioretention cells are dynamic, living, micro-ecological systems. They demonstrate how the landscape can be used to protect ecosystem integrity. The design of bioretention cells involves, among other things, the hydrologic cycle, non-point pollutant treatment, resource conservation, habitat creation, nutrient cycles, soil chemistry, horticulture, landscape architecture, and ecology. A bioretention cell necessarily demonstrates a multitude of benefits. Beyond its use for stormwater control, the bioretention cell provides attractive landscaping and a natural habitat for birds and butterflies. The increased soil moisture, evapotranspiration, and vegetation coverage creates a more comfortable local climate. Bioretention cells can also be used to reduce problems with on-site erosion and high levels of flow energy. All of these benefits are attainable by designing green space to perform more than its visually pleasing function.

Bioretention is usually best used upland from inlets that receive sheet flow from graded areas and at areas that will be excavated. The site must be graded in a manner that minimizes erosive conditions as sheet flow is conveyed to the treatment area, maximizing treatment effectiveness. Construction of bioretention areas is best suited to sites where grading or excavation will occur in any case so that the bioretention area can be readily incorporated into the site plan without further environmental damage. Bioretention should be used in stabilized drainage areas to minimize sediment loading in the treatment area. A maintenance plan is required to maintain the long term performance of this storwater management measure.

Bioretention typically treats storm water that has run over impervious surfaces at commercial, residential, and industrial areas. For example, bioretention is an ideal storm water management BMP for median strips, parking lot islands, and swales. These areas can be designed or modified so that runoff is either diverted directly into the bioretention area or conveyed into the bioretention area by a curb and gutter collection system.

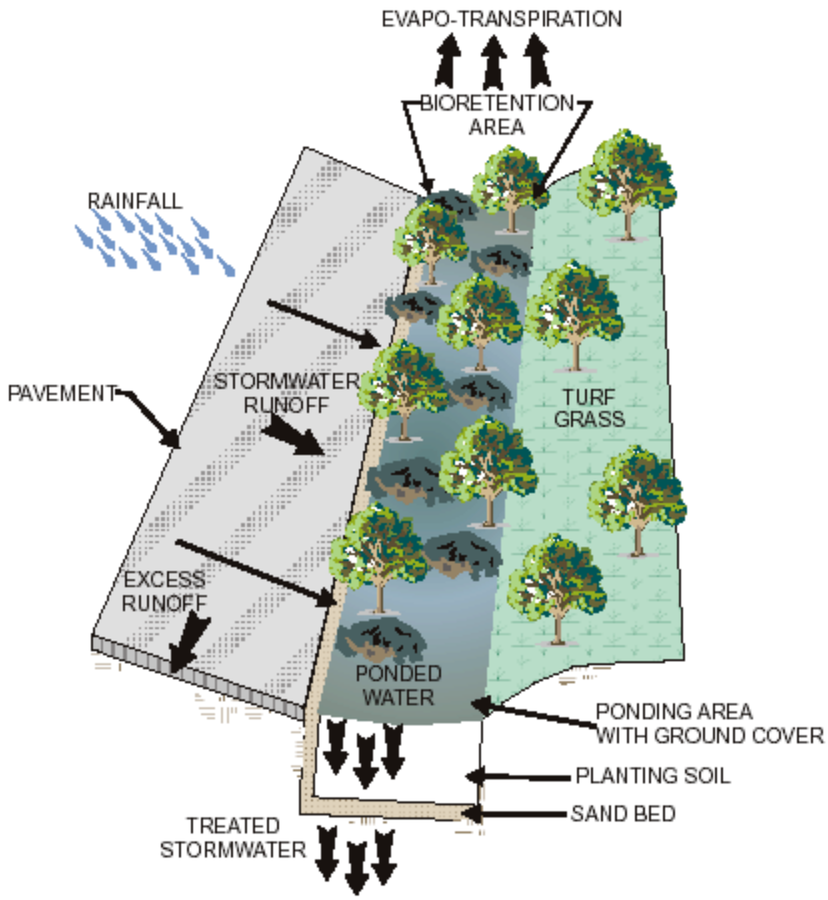


Figure 32. Components of a typical bioretention area. [Source: Ten Towns Great Swamp Watershed Management Committee, Cedar Knolls, NJ]

Figure 33. Bioretention cells may be cost effectively incorporated into existing developments when these are being re-paved or improved.

Figure 34. Courtyards and perimeter yards may be used to advantage, directing runoff from roofs and paved surfaces to bioretention cells that incorporate plantings.

Figure 35. Bioretention cell accepts runoff from roadway for temporary storage and filtration during storm events.

Figure 36. Bioretention strips may be integrated within parking lots to reduce runoff and effectively filter road de-icing salts. Note the incorporation of a catchbasin to capture extreme weather flows and avoid local water accumulations.

Figure 37. An example of a bioretention cell integrated within an existing parking lot.

Figure 38. Inlets to bioretention cells may support beautiful plant growth that enhances the visual quality of parking lots.

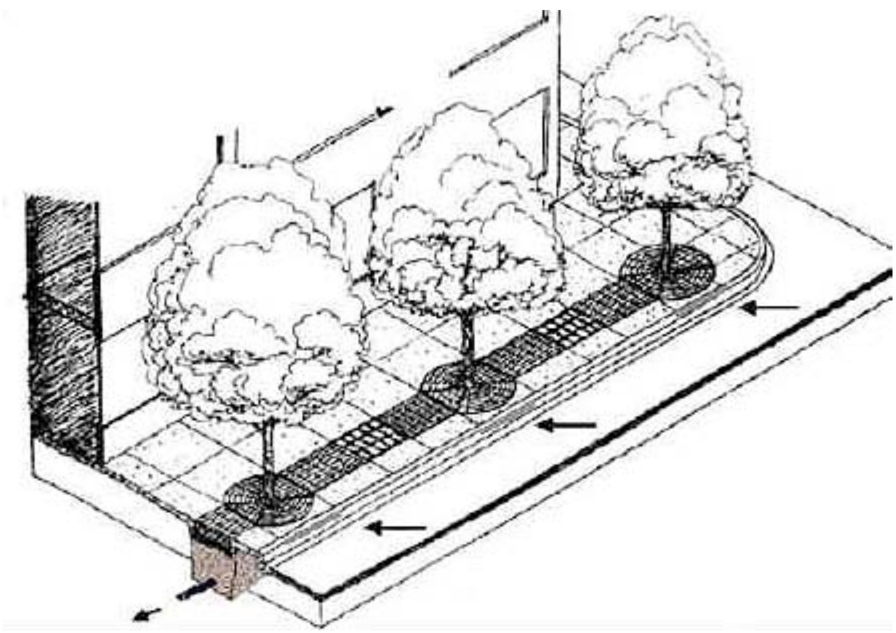


Figure 39. Another form of bioretention cell is a tree filter box. This technology is available from a growing number of North American manufacturers, and is proving effective in filtering stormwater from urban streets. (Source: Virginia DCR Stormwater Management Program.)

Permeable Pavement
A permeable pavement is either porous or has gaps that allow passage of stormwater from the surface to the underlying soil. Under the pavement is an excavation filled with gravel to allow the storage of water. Underneath the gravel is a sand layer to provide filtration of the draining water. The whole underground system is wrapped in a geofabric to keep the soil from mixing with the gravel causing reduced storage space. An overflow pipe is installed to drain excess water away from the excavation.

Porous pavement allows rainfall to infiltrate through it. It may consist of materials having regularly interspersed void areas which are filled with pervious materials, or it may have the appearance of conventional pavement but be formulated to have greater porosity. Its primary purpose is to reduce water pollution from low volume traffic areas by providing a bearing surface to accommodate vehicles while allowing infiltration of surface water and filtration of pollutants. The system should be able to receive and infiltrate a 25 mm (1.0 inch) rainfall with little or no runoff. A firm sub-base is necessary for the successful deployment of permeable pavements. A 75 to 150 mm (3 to 6 inch) layer of compacted sand below the pavement is advisable.

Field evaluations indicate that porous pavements may attenuate runoff volumes, approaching anywhere from one-third to one-sixth the flow volumes occurring from impervious asphalt pavements (see http://www.epa.gov/owow/nps/pavements.pdf for recent research results).

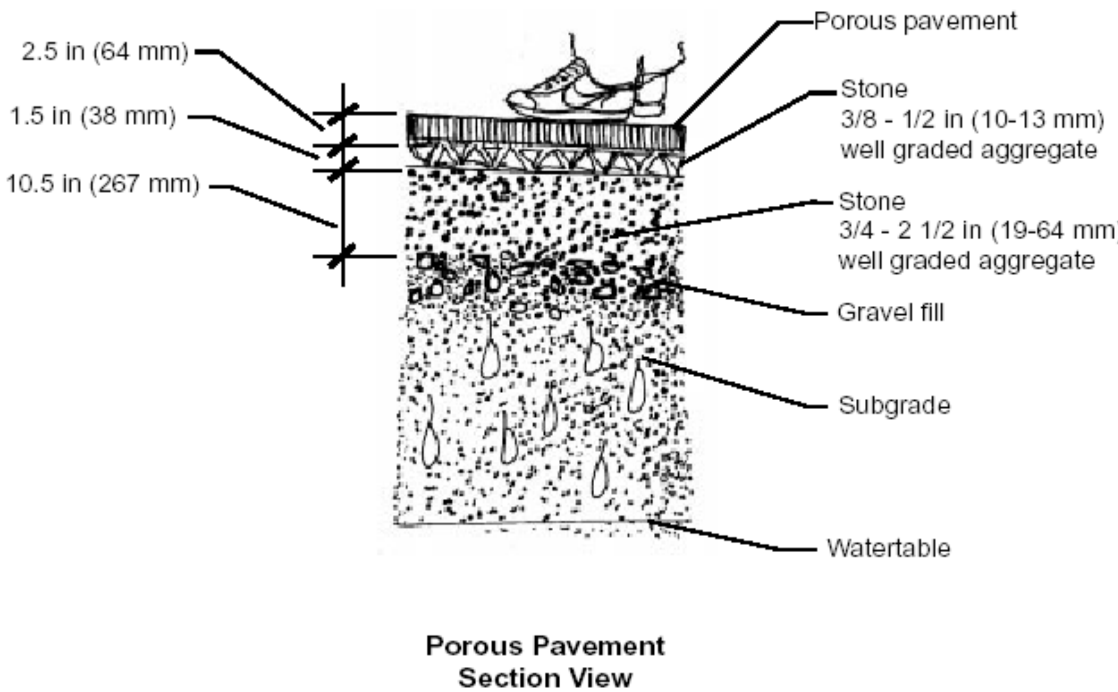


Figure 40. This section through a porous or permeable pavement installation is suitable to free draining sub-soils. More sophisticated geotechnical engineering, design and construction may be required for sites with cohesive soils.

Low Impact Development Strategies

Suburban sprawl based on conventional development standards is beginning to induce major stresses on municipal infrastructure. These effects have become more widely recognized in areas of Canada where the amalgamation of municipalities into a greater metropolitan governance (e.g., Toronto) has revealed the lack of fit between individual municipal approaches that were never properly integrated within a larger model. The examples depicted below represent alternative development strategies that attempt to reduce stormwater management stresses of centralized infrastructure systems, while improving the quality and quantity of groundwater recharge.

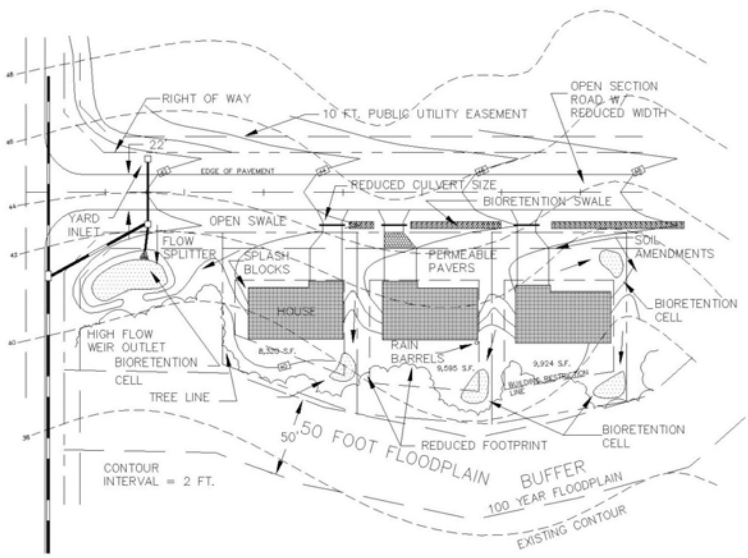


Figure 41. Low impact development strategies for single family housing. [Source: Low Impact Development Center Inc.]

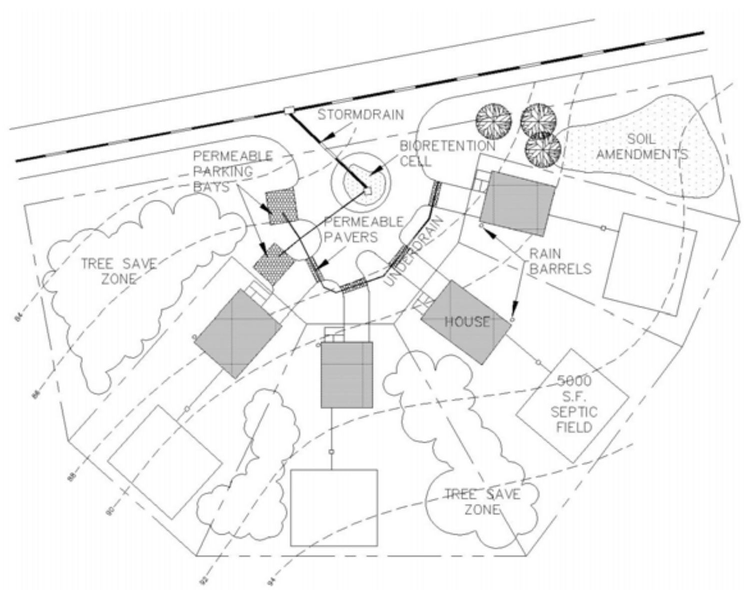


Figure 42. Zero lot line subdivision for single family housing employing low impact development strategies. [Source: Low Impact Development Center Inc.]

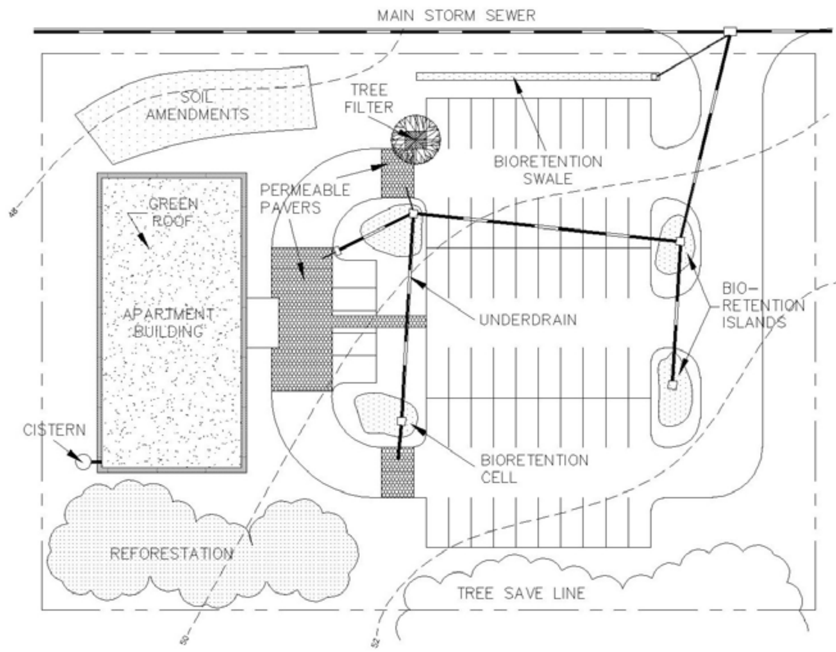


Figure 43. Low impact development strategies for multi-unit housing. [Source: Low Impact Development Center Inc.]

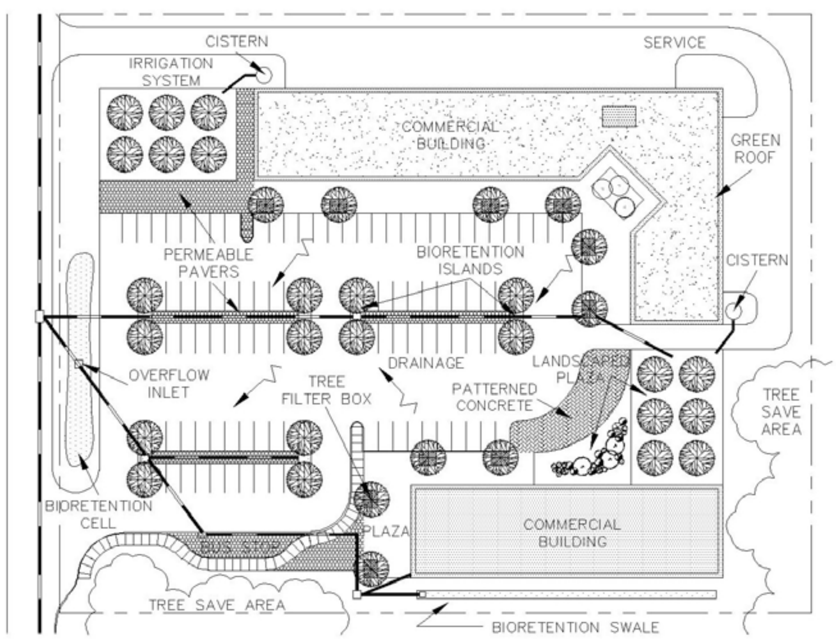


Figure 44. Commercial strip mall employing low impact development strategies. [Source: Low Impact Development Center Inc.]

Infrastructure Maintenance
Research into infrastructure maintenance has determined that it is an effective prevention and mitigation measure for basement flooding. Some of the municipalities surveyed have embarked on rodding programs intended to reduce sewer blockage leading to backup and basement flooding. They have all indicated success with this and other forms of maintenance.

A major component of the previously noted study, *Management and Maintenance Practices of Storm and Sanitary Sewers in Canadian Municipalities*, by Allouche and Freure from the Institute for Catastrophic Loss Reduction, dealt with the correlation between preventative maintenance and reduction of basement flooding. Key findings and conclusions are excerpted below:

The results of a survey of preventative maintenance practices currently used by Canadian municipalities in managing their buried sanitary and storm sewer networks are presented. Survey results were collected from 26 municipalities of various sizes and in different geographical locations across Canada. Analysis of the data collected reveals that Canadian municipalities spend approximately $20.00 per capita per annum on the inspection, replacement and rehabilitation of existing municipal sewer networks, an amount slightly higher than that reported for the 1996-97 construction season of $18.21 per capita (Ariaratnam et al., 1999). From this amount approximately 90% is spent on construction activities and 10% on condition assessment and evaluation. The data reveal a significant increase in expenditure for rehabilitation of buried infrastructure for mid-size and large municipalities in comparison to the 1996 levels. While most levels of government agree that there is an urgent need for the renewal of Canada's municipal infrastructure, sources for the needed capital, estimated to be as much as $45 billion, are less apparent.

Closed Circuit Television (CCTV) systems and smoke testing are by far the most common methods utilized by Canadian municipalities for the inspection of municipal sewer networks. Newer technologies such as sonar and ground penetrating radar have not been widely accepted in this market. The utilization of trenchless technologies by Canadian municipalities is on the rise, with 82% of municipalities using one or more pipe lining techniques in the year 2000 compared with only 66% in 1996 and 32% in 1991. Comparison of the composition of sewer networks in Canada and the USA has shown significant differences in terms of the relative weight of various pipe materials. The most common pipe material in Canadian sewers is concrete (41%) while vitrified clay is most commonly used in the USA (56%). Canadian sewers also contain larger quantities of plastic and plastic pipes (PVC/HDPE). These findings imply that research and development efforts in the USA might not fully address the needs of Canada's municipal sewer systems.

The return period for inspection and assessment of sanitary and storm sewers in Canadian municipalities is between 25 and 30 years, which is nearly equal to the design life of many of these facilities. Computerized data management and record keeping systems are commonly used in Canadian municipalities, with 78% of respondents indicating the utilization of such systems compared to 71% in the USA. Forty-one percent of all municipalities use automated data management systems/GIS, compared with 44% in the USA. A pipe defect classification system developed by the Water Research Centre (WRc), a U.K. research organization, is commonly used by Canadian municipalities. Sixty-eight percent of all respondents use it exclusively or in combination with an internally developed system.

Basement flooding is a common event in Canadian municipalities with 42% of respondents indicating that storm surges and basement flooding occur several times each year in their jurisdictions. As for post-disaster management and recovery, only 15% of the municipalities with populations of less than 250,000 have guidelines in place for conducting post-disaster inspection of their buried municipal services. Forty-one percent of the municipalities indicated that such a post-disaster inspection would likely take more than 18 months, with only 23% being confident in *their ability to accurately determine the damage inflicted on their buried networks in the aftermath of such an inspection.*

The more advanced the inspection technologies and data management system that a municipality uses the greater is its appreciation of the complexity associated with a post-disaster inspection of its linear networks. When an aggregate measure of the municipality's level of sophistication was contrasted with its anticipated level of performance, it was found that the more sophisticated the municipality the longer the anticipated post-disaster inspection is expected to take, and the higher is the predictable percentage of determinable damage caused by the natural disaster. Additionally, municipalities possessing more sophisticated data management systems are more likely to have developed guidelines for post-disaster inspection of their storm and sewer networks.

No clear correlation was observed between the frequency of basement flooding and the average annual precipitation, implying that infiltration and inflow (I/I) contributions are more significant than the base flow with respect to the creation of overflow conditions. Direct correlation was observed between the level of investment in the inspection and management of the storm and wastewater collection system and the frequency of basement flooding.

The study goes on to make the following recommendations:

1. *Liability in terms of basement flooding frequency might be considered as an external factor in the overall assessment of the urgency of the action needed to repair/upgrade sewer systems, as it is a key performance parameter.*
2. *Among the costs associated with the upgrading of a municipality's data management system, the most significant one is the bridging of the "data gap" between the available data and the quality and quantity of data believed to be necessary to effectively operate the new system. It is recommended to develop a methodology for determining the expected cost of bridging this gap and the most cost effective manner for doing so.*
3. *The condition assessment market in Canada for linear sewer system is approximately $50M per year, an amount believed to be insufficient for supporting a coast-to-coast specialized private sector that own and operate advanced condition assessment technologies. It is recommended to investigate various mechanisms, policies and incentives that will make advanced inspection and assessment technologies more readily available to medium size Canadian municipalities.*
4. *The relationship between the return period for inspection and assessment of buried pipe systems and the life cycle costs of such systems is currently ill-defined. There is a need to further research this area to determine the optimum return period for inspection that will minimize the life cycle costs of the system.*
5. *Additional research is needed to support the establishment of national standards and guidelines for post-disaster inspection of linear lifeline networks. Additionally, an educational effort should be made across the municipal engineering community to raise awareness of the importance of a comprehensive and properly documented lifelines emergency response strategy (LERS).*
6. *It is the accumulative effect of responses to immediate and short-term needs (e.g., basement flooding) that enhances the resilience of a municipal system to potentially catastrophic, but infrequent, events such as natural disasters. It is suggested to study the relationships between localized improvements of lifeline management and maintenance practices and the overall resilience of the system to natural disasters, in order to maximize the benefits of the latter from the former.*

Technical and Regulatory Barriers

This section of the report deals with the various technical and regulatory barriers impacting basement flooding mitigation measures. The topics presented below have been identified and are briefly discussed, with the understanding a more in-depth study of these barriers remains beyond the scope of this study.

Lack of Applied Research

A review of applied engineering journals indicates that basement flooding due to municipal sewer surcharge is not a widely pursued research topic. All manner of research on stormwater management simulation techniques continues to enjoy considerable funding, but the specific application of these techniques for reducing the risk of basement flooding remains relatively minimal. The same relationship holds true for a number of related areas ranging from sump pump design and performance, through to the effectiveness of various measures and strategies for managing stormwater (e.g., green roofs, bioretention cells, etc.). As a result, designers and policy makers are reluctant to consider approaches that cannot be modeled and assessed through some form of risk and cost/benefit analysis. Based on municipal surveys and a review of earlier studies, it is interesting to note that a great deal of empirical research has actually been conducted within individual municipalities, but there are no formal mechanisms for accessing this knowledge and experience.

Inadequate Technology Transfer

Technology transfer between researchers and practitioners appears to be highly limited in Canada for the mitigation of basement flooding. There are few, if any, regular forums for exchanging knowledge and expertise in this area among municipalities, engineering consultants and researchers. Aside from the research projects sponsored by CMHC since the mid-1980s, there have been no other notable national studies on the mitigation of basement flooding. This finding was continually reinforced in the process of conducting this study. The depth and quality of information available through conventional publications available in libraries, electronic journals and the Internet proved to be marginal in the area of basement flooding mitigation. In general, various U.S. government agencies provided better information to assist designers than is available from Canadian sources.

Gaps in Codes and Standards

Codes and standards for plumbing systems and equipment such as sump pumps and backflow prevention devices contain numerous gaps. Permitted methods for foundation drainage and plumbing arrangements found in building codes (provincial jurisdiction) may conflict with municipal requirements for connections to infrastructure. An example of this situation is the case where the foundation drains are connected to the basement floor drain, making it extremely difficult and expensive to address what is considered in most municipalities to be an illegal connection. Another critical gap is where the sizing of sump pumps and the depth of sump pits is not addressed within building codes. Presently, local experience and/or trial-and-error approaches are used to address these parameters. A more reliable approach would be to research the relationship between soil types, the rate of pumping, and the depth of extraction in order to determine sufficient draw down over the entire foundation area to keep the basement dry. Other notable gaps include an absence of guidelines for the construction of dry wells and French drains, and more innovative forms of conveyance and detention, such as bioretention cells. This issue of gaps in codes and standards was identified nearly two decades ago, however, the causes of the inertia holding back progress in this area could not be specifically identified in this study. It should be noted that the codes and standards process in Canada remains open to input from any stakeholder and that these gaps and inconsistencies are fully addressable through publicly accountable processes.

Municipal Accounting Practices

A significant barrier to the mitigation of basement flooding stems from the accounting practices adopted by municipalities and public sector organizations. The information needed to make informed decisions about investments in maintenance, repair, replacement and expansion of infrastructure has not been integrated effectively according to the Canadian Institute of Chartered Accountants.

Various reports that analyse the state of Canada's existing infrastructure have been published. For example, the 1994 Report of the Auditor General of Canada noted that the Department of National Defence's infrastructure is ageing, and that approximately $1.7 billion in maintenance has been deferred. According to the 1997 National Highway System Condition and Needs Update, the net present value of the required resources to upgrade the national highway system was estimated at $13.1 billion. And a 1996 study of the Federation of Canadian Municipalities indicated that more than $40 billion is required to repair municipal infrastructure systems to an acceptable level. These amounts reflect the culmination of a lack of available resources for maintenance and renewals of infrastructure, commonly referred to as the "infrastructure deficit."

Although a number of studies have indicated that an infrastructure deficit exists, the methodology of measuring such a deficit does not appear to be consistent. Many engineering systems can estimate the costs associated with ongoing maintenance, but the systems are not integrated. A pavement management system, for example, operates in isolation of a sewage pipe-condition system. As yet, there is no corporate-wide system available to establish and collect consistent financial data on such systems.

[Source: CAmagazine, June/July 2000, p. 37, "*The Infrastructure Web*" by Tim Beauchamp.] http://www.camagazine.com/index.cfm/ci_id/6169/la_id/1

A recently completed research report goes on to explain:

When the cost of using infrastructure is not reported, the cost cannot be taken into account and governments cannot adequately exercise the stewardship responsibilities assigned to them. Further, without understanding the future maintenance and replacement costs associated with having infrastructure, governments cannot easily assess whether they can afford to maintain existing programs or expand both the type and quality of programs.

[Source: *Accounting for Infrastructure*, A Research Report prepared by the Canadian Institute of Chartered Accountants.] http://www.cica.ca/index.cfm/ci_id/11051/la_id/1.htm

It is important to recognize that current public sector accounting practices represent a formidable barrier to the mitigation of basement flooding. When this fundamental barrier is combined with a lack of applied research, inadequate technology transfer, and gaps in codes and standards, it is understandable that basement flooding mitigation has not managed to enter the 21st century.

Conclusions and Recommendations

This report concludes with the following summary of key findings. It is important to recognize that many of the issues, identified as long as two decades ago, have yet to be fully and consistently addressed.

1. Inadvertently, past practices for the design of Canadian municipal sanitary sewer and stormwater drainage systems often created an off-line storage network for surcharges called basements.
2. Most municipalities in Canada experience basement flooding problems due to municipal sewer surcharge, and the majority of causes for these flooding problems are systemic.
3. Basement flooding related insurance claims in Canada are estimated to be in the order of $140 million per year based on a multi-year average. This represents an average of approximately 30,000 to 40,000 incidents per year, with an average cost of damages per flooding incident between $3,000 and $5,000.
4. Mounting evidence points to significant health risks linking basement flooding with the potential for the growth of molds that cause allergic reactions, asthma episodes and other respiratory problems. Economic impacts related to health care and productivity have yet to be assessed.
5. Canadian municipalities have developed and implemented a number of successful approaches to protection of basements against flooding. Three major aspects of protection measures were identified: i) the individual dwelling; ii) the minor system (the neighbourhood or sub-division, as defined by its local drainage system); and iii) the major system (municipal or regional level). Integrating protection measures across all three levels is key to a successful basement flooding protection program.
6. There is still no central repository of basement flooding protection knowledge and precedents currently available to urban drainage system designers, and no established forum for the exchange of information was identified during this research project.
7. The trend in basement flooding prevention programs is very encouraging among the municipalities surveyed, and most municipalities in Canada have implemented, or are soon initiating, formal prevention programs that include various media for public education/information.
8. Advances in backflow prevention devices (backwater valves) and sump pump technologies offer homeowner’s effective and reliable levels of protection against basement flooding, however codes and standards for their performance and installation are lagging.
9. Lack of applied research, inadequate technology transfer, gaps in codes and standards, and municipal accounting practices represent the primary barriers to progress in the mitigation of basement flooding problems.

In summary, despite the lack of a coordinated program among Canadian municipalities and government bodies for basement flooding protection due to municipal sewer surcharge, significant improvements have been achieved by individual municipalities. Further progress hinges on additional funding for both infrastructure improvements and support of programs for exchanging knowledge, coordinating research and development efforts, and addressing gaps in codes and standards.

Recommendations

The following recommendations are submitted for consideration by all stakeholders concerned about basement flooding issues.

1. Federal, provincial, municipal and consumer stakeholders should actively pursue the development of criteria and requirements to be integrated within existing national codes and standards that address basement flooding protection measures. In particular, requirements for site and foundation drainage in the National Building Code of Canada (NBC), and sanitary and stormwater provisions in the National Plumbing Code of Canada (NPC) should be examined and amended as required, in order to reasonably "*ensure that buildings are free of health hazards*".
2. Public sector funding aimed at assembling and maintaining the basement flooding prevention and mitigation knowledge base, and institutionalizing a forum for the exchange of experiences and ideas, is vital. It is recommended that the Federation of Canadian Municipalities confer with other public sector stakeholders to obtain funding and coordinate a national basement flooding protection program.
3. To further the effectiveness of the basement flooding protection program outlined above, public sector funding for strategic research should be provided to develop and disseminate standards and best practices for the design (computer simulation, modeling, monitoring) of urban drainage systems and for the performance and proper installation of basement flood protection measures (backflow valves, sump pumps, etc.).
4. Research and development of innovative technologies for sustainable urban infrastructure should be encouraged through government funding and tax incentives. This initiative should include empirical studies, similar to those conducted in the U.S., to establish the effectiveness of "*landscape as infrastructure development*" techniques and low impact development models on sanitary and stormwater management. Results from this R&D process should be made available in a format that is suitable to designers (parametric computer simulation) and regulatory authorities to eliminate technical and regulatory barriers to innovation.
5. Consumer protection against the risk of property damage and exposure to health hazards must be significantly improved beyond present levels. Homebuyers and rental tenants must be able to reliably and conveniently determine the flooding history and level of basement flooding risk for any property in a timely fashion. It is unacceptable that a household should be vulnerable to a different level of protection for structural failure or electrical shock than for basement flooding, without its knowledge. The idea of health warnings on packages of cigarettes should be extended to basements in flood prone areas.
6. Stakeholders, such as CMHC, Federation of Canadian Municipalities, Insurance Bureau of Canada, Consumers Council of Canada, etc., are urged to help establish a reliable means of reporting and monitoring the status of basement flooding events and mitigation measures across Canada, and advocate necessary improvements through appropriate research and development initiatives.

Just as it was once acceptable to smoke in public buildings (hospitals included), basement flooding continues to be accepted by a Canadian public that is largely unaware of its health implications. Sufficient evidence exists to strongly support the obligation by all levels of government to reasonably respond to this problem, and develop effective programs aimed at the practical elimination of basement flooding within a threshold of probability that is congruent with those applied to other health and safety measures in housing and buildings.

CMHC SCHL

External Research Program Sponsored Study

Canada

Questonnaire

This questionnaire forms part of a larger study sponsored by Canada Mortgage and Housing Corporation entitled ***Practical Measures for the Prevention of Basement Flooding Due to Municipal Sewer Surcharge***. Kindly take the time to complete this questionnaire and return it in the self-addressed, postage paid envelope provided. Where space allotted in the questionnaire for additional information is insufficient, please feel free to attach additional pages and/or supplemental documentation.
Thank you for your assistance.

1. Municipality

Current Population ___________________

Please express growth rates as either a percentage of current population, or an actual number of persons.
Growth Rates (past decade) _____________________
Expected Growth (next decade) _________________

Urban Drainage System Area (m2) ________________

Breakdown of Drainage System Types
Combined _____ %
Separated _____ %
Other (please explain) ___________________________
_____ %

Additional Information necessary to describe your system (optional):

2. Design Criteria for New Developments - please attach relevant documentation from engineering department & include:

Sanitary Flows
Peaking Factors
I/I Allowances
Design Storm Data

Weeping Tile Connections to:
❒Sanitary ❒Storm ❒Sump Pump
❒Other ______________________________________
Downspouts Connected to:
❒Storm ❒Other _______________________________

Additional Information (optional)

3. Basement Flooding History (for the last decade, list number and severity of residential basement flooding events, dates, and causes)

Additional Information re: residential basement flooding events (optional):

4. Preventive Measures - Individual House

Indicate common preventive measures used at the homeowner level (e.g., backflow valves, sump pumps, etc.), the effectiveness of each measure, and whether or not each measure is approved and/or regulated.

5. Prevention Programs

Does your municipality have a formal preventive program in place, and if so:

a) What are the key elements of the program (ie. Pamphlets, videos, on-line information, etc.)?

b) Describe the protocol a homeowner would follow if experiencing a flooded basement?

c)Which municipal department oversees the program?

d) Who specifies the preventive equipment and performs the work?

e) How long has the program been in effect?

f) Are the effects of the program measureable and, if so, please describe the results.

g) What are the costs to the municipality of maintaining the program?

h) What are the costs to the homeowner?

i) Given the resources, what – if any – improvements to the program would you recommend?

j) Does your program allow for homeowner feedback and, if so, please describe the nature of the feed back to date (ie. Positive, negative, common experiences, etc.).

6. Preventive Measures - Major & Minor Systems

What other measures have been taken to reduce basement flooding and how effective have these been proven?

How were these preventive measures identified, engineered and implemented, and at what cost?

7. Infill Housing & Redevelopment in Existing Areas

How does your municipality control redevelopment?

How is storm water managed and enforced?

In areas prone to basement flooding, how is this problem being addressed at the building controls level?

What are the most common preventive measures taken for infill housing and redevelopment?

8. Public Information

Are there public information programs in place to help homeowners reduce the risks of basement flooding, and if so, please explain their nature and history?

Are plumbers and basement contractors informed of appropriate measures to consider against flooding, and if so, how is this carried out?

9. Damages and Liability

What is the scope of damages reported by residential homeowners due to flooding?

What percentage of the cost of damages does your municipality bear?

10. Jurisdictional Issues

Are there jurisdictional issues that affect effective measures for basement flooding (please explain)?

How have these been addressed?

11. Contact Person(s)

Indicate the name, title/department, telephone number and E-mail address of persons other than yourself who were involved in completing this survey.

12. Additional Information

Please provide any additional supporting information you consider relevant to this survey (e.g., homeowner communications, Web sites, important issues overlooked in this survey, etc.).

We are compiling a bibliography of useful literature/information/publications to share with research participants and homeowners. Are there any publications, web sites or other information sources that you think should be included in the bibliography? If so, please provide a list of bibliographical references and/or copies of relevant publications.

13. Further Participation

Is it possible to arrange for a visit to your municipality to review basement flooding prevention measures (indicate procedure and contact person)?

If a visit is not possible, can you provide us with photographs or other visual documentation of preventive measures and specifications available (please enclose herewith or indicate procedure and contact person)?

Name of Respondent	
Title	
Telephone and/or e-mail address	

Important Note: The information provided in this questionnaire is strictly confidential in accordance with relevant research policies and procedures established by Canada Mortgage and Housing Corporation.

Appendix B – List of Survey Respondents

Municipality	Contact	Address	Phone/e-mail
BRITISH COLUMBIA			
Vancouver	Steve McTaggart Assistant Sewers Engineer	City of Vancouver City Hall 453 West 12th Avenue Vancouver, British Columbia V5Y 1V4	(604) 873-7356 steve_mctaggart@city.vancouver.bc.ca
City of West Vancouver	Chris Leonard Utilities Superintendent		(604) 925-7111 fax: (604) 925-5988 cleonard@westvancouver.net
City of Burnaby	Barry Davis Assistant Director Engineering	Department of Public Works 4949 Canada Way Burnaby, British Columbia V5G 1M2	(604) 294-7186 fax: (604) 294-7425 davis@city.burnaby.bc.ca
ALBERTA			
Calgary	Ted Fedick Manager Systems Maintenance	City of Calgary Waste Water and Drainage P.O. Box 2100 Station M Calgary, Alberta T2P 2M5	(403) 268-4951 fax: (604) 268-3476 tfedick@gov.calgary.ab.ca
Edmonton	Derek Melmoth General Supervisor	Public Services Drainage Section 5th Floor Century Place	(780) 496-5662 Fax: (780) 496-2865 Derek.Melmoth@gov.edmonton.ab.ca
Red Deer	Greg Sikora Municipal Engineer	City of Red Deer Engineering Services Department 4914 – 48th Avenue Box 5008 Red Deer, Alberta T4N 3T4	(403) 342-8169 fax: (403) 342-8211 gregsi@city.red-deer.ab.ca
SASKATCHEWAN			
Regina	Bob Crawford Environmental Engineer	Municipal Engineering Department City of Regina P.O. Box 1790 Regina, Saskatchewan S4P 3C8	(306) 777-7437 bcrawfor@cityregina.com
Saskatoon	Cal Sexsmith Manager, Planning and Design	City of Saskatoon 222 3rd Avenue North Saskatoon, Saskatchewan S7K 0J5	(306) 975-2762 cal.sexsmith@city.saskatoon.sk.ca
MANITOBA			
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ONTARIO			
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Kitchener	Hans N. Gross, P.Eng. Manager Engineering Design & Construction	Engineering Services City Hall, P.O. Box 1118 200 King Street West Kitchener, Ontario N2G 4G7	(519) 741-2416 fax: (519) 741-2633 hans.gross@city.kitchener.on.ca
London	Karl Grabowski, P.Eng. Environmental Services Engineer	Environmental Services Department Wastewater and Drainage Eng. Div. 300 Dufferin Ave. P.O. Box 5035 London, Ontario N6A 4L9	(519) 661-5071 fax: (519) 661-2355 kgrabows@city.london.on.ca
(Region of Halton) Oakville, Burlington, Milton: - Campbellville Halton Hills: - Georgetown - Acton	Jacqueline Weston Special Studies and Research Engineer	Planning and Public Works Engineering Services Division The Regional Municipality of Halton 1151 Bronte Road Oakville, Ontario L6M 3L1	(905) 825-6030, ext. 7433 fax: (905) 847-2192 westonj@region.halton.on.ca
St. Catherines	Cindy Toth, B.Sc. Dipl.EST (IHE) Pollution Control Co-ordinator	Environmental Services Division Transportation and Environmental Services Department City of St. Catherines Lake Street Service Centre 383 Lake Street St. Catherines, Ontario L2N 4H5	(905) 688-5601, ext. 2193 fax: (905) 646-6570 ctoth@city.stcatharines.on.ca
Windsor	Jake Renaud Engineer III (Sewers Division)	Public Works, Rm.302 City Hall, P.O. Box 1607 Windsor, Ontario N9A 6S1	(519) 255-6351 fax: (519) 255-9847 jrenaud@city.windsor.on.ca

QUEBEC			
Laval	Pierre Lamarre, ing. Chargé de projets - infrastructures	Service de l'Ingénierie Ville de Laval 1333 boul Chomedey bureau 801, CP 422 Succ St-Martin Laval, Québec H7V 3Z4	(450) 978-6888, ext.2732 fax: (450) 680-2799 p.lamarre@ville.laval.qc.ca
Gatineau	Marcel Roy, ing. directeur des services techniques	Division ingenierie Services techniques 476 boul. Saint-Rene Est Edifice Eugene-Beaudoin Gatineau, Quebec J8P-8A9	(819) 243-2345, ext.4501 roym@ville.gatineau.qc.ca
NEW BRUNSWICK			
Monton	Mike Richard, CET Utilities Supervisor Engineering Department	City of Moncton Operations Centre 100 Worthington Avenue Moncton, New Brunswick E1X-9Z3	(506) 859-2638 mike.Richard@moncton.org
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PRINCE EDWARD ISLAND			
Charlottetown	Craig Walker Engineer	City of Charlottetown 199 Queen Street P.O. Box 98 Charlottetown, P.E.I. C1A-7K2	(902) 629-4014 fax: (902) 894-7094 cwalker@city.charlottetown.pe.ca
Summerside	Harry Hutchinson Supervisor	City of Summerside P.O. Box 1510 Summerside, P.E.I. C1N 4K4	(902) 432-1263 fax: (902) 436-4255
YUKON			
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Appendix C – Summary of Survey Results

Refer to questionnaire in Appendix A for full version of questions cited below.
N/R indicates no response to question, N/A indicates question is not applicable.

Municipality	Vancouver	West Vancouver	Burnaby
1. Population (2001 Census)	550,000 (545,671)	45,000 (41,421)	195,000 (193,954)
Growth rate 1991-2001	16.6%	~ 5%	~ 22%
Expected growth 2001-2011	8.2%	~ 5%	~ 22%
Urban drainage system area	114.50 km^2	N/R	N/R
Combined	50%	N/R	N/R
Separated	50%	N/R	N/R
Other		150km storm; 380 km sanitary	
2. Weeping tile connections to:	Storm	Storm, dry wells	Storm, ditch or rock pit where no storm
Downspouts connected to:	Storm	Storm, open ditch, creek	Storm, other
Sanitary Flows (L/cap/day)	455 res., 220 comm.	227	N/R
Peaking Factors	Harmon's PF*	Harmon's PF	N/R
I/I Allowance (L/s/ha)	0.13	0.13	N/R
Minor System Design Storm	5 yr. res., 10 yr. comm.	5 – 10 yr.	10 yr.
Major System Design Storm	100 yr.	N/R	N/R
3. Flooding History 1991-2001	424 total	Avg. 15 claims per year	665 total
5. Formal prevention program?	Yes	Yes	No, response is on case by case basis
5c. What dept. oversees	Engineering Dept.	Utilities	Engineering Dept.
5e. How long in effect?	Rodding and relay program 10 years + Advisory team ~3 years	25 years +	N/A
5g. Costs of program?	Rodding - $50,000/yr Relays - $850,000/yr Advisory team - $8,000/yr	$1.5 million (as per 2001 budget)	N/A
5h. Cost to Homeowner	None	Taxes	Cost of maintenance & replacement
5j. Formal feedback mechanism?	No	N/R	N/R
7. How does municipality control re-development?	Zoning, development and building by-laws	Bldg. permits for renovation or new projects	Sub-division control by-law, bldg. permits, re-zoning pre-requisites, connection by-laws
8. Public information program?	Only at time of building permit application	Only to plumbers through engineering dept.	No
9. Cost sharing of damages?	N/A	N/R	None
10. Jurisdictional issues?	No	Public/private liability	No

*Harmon's Peaking Factor = $1+\frac{14}{4+\sqrt{P}}$

where P= population in thousands

Municipality	Red Deer	Calgary	Edmonton
1. Population (2001 Census)	68,308 (67,707)	881,300 (878,866)	663,000 (666,104)
Growth rate 1991-2001	17.3%	23.8%	9.1%
Expected growth 2001-2011	15.7%	22%	3.5%
Urban drainage system area	62.1 km^2	497 km^2	320 km^2
Combined	0	0	16%
Separated	100%	100%	84%
Other		Service area includes Cochrane, Airdrie, Chestermere Lake	Sanitary system drains through the combined sewer system to get to the city's only wastewater treatment plant
2. Weeping tile connections to:	Sanitary, storm (depending on conditions)	Storm	Storm, sump pump (typical)
Downspouts connected to:	Splash pads – overland to roadways	Storm	Storm, ground surface (typical)
Sanitary Flows (L/cap/day)	320	380	300
Peaking Factors	Harmon's PF	Harmon's PF	Harmon's PF (min. 1.5)
I/I Allowance (L/s/ha)	0.20	No allowance	0.28
Minor System Design Storm	5 yr.	prior to 1952 – 2 yr. post 1952 – 5 yr. > 30 ha – Unit Area Release Rate Method	5 yr.
Major System Design Storm	100 yr.	100 yr. using computer simulation	100 yr.
3. Flooding History 1991-2001	995 from 1997-2001	864 total	2,573 total
5. Formal prevention program?	Yes, but under development	Yes	Yes
5c. What dept. oversees	Engineering services & public works	Wastewater and drainage business unit (WWD)	Asset Management and Public Works Dept., Drainage Services division
5e. How long in effect?	Just getting underway	10 yrs +	Floodproofing program since 1991
5g. Costs of program?	Printing costs and display costs	Public response group total budget $3 million	$400,000 annually $150 million to be allocated to CSO mitigation
5h. Cost to Homeowner	None	Storm Drainage Upgrade Charge $1.38/month per customer since 1994	Difference between approved re-imbursement amount and actual costs
5j. Formal feedback mechanism?	Homeowners will be given a hotline number	Yearly customer surveys with positive feedback	Yes, via regular questionnaire, and when homeowner applies for refund.
7. How does municipality control re-development?	Development agreements	Land-use zoning and development permit	Planning and Development Department via required approvals
8. Public information program?	Numerous media	Numerous media	Numerous media
9. Cost sharing of damages?	No	City covers claims for which it is liable – avg. claim $1,890 1998-2000	Damages vary on case by case basis
10. Jurisdictional issues?	No	No	N/R

Municipality	Regina	Saskatoon	Winnipeg
1. Population (2001 Census)	200,000 (178,225)	210,000 (196,811)	630,800 (619,544)
Growth rate 1991-2001	1.2%	7.5%	0.9%
Expected growth 2001-2011	N/R	8.8%	2.5%
Urban drainage system area	92 km^2	95 km^2	279 km^2
Combined	0	0	50%
Separated	100%	93%	50%
Other	Combined sewer separation completed in early 1990s	7% ditch drainage of storm	
2. Weeping tile connections to:	Junction box	Sanitary	Sump pump
Downspouts connected to:	Lawn away from house	Storm; discharge to surface for bldgs. < 3000 sq.ft.	To splash pad, away from house
Sanitary Flows (L/cap/day)	N/R (380 in 1991 survey)	0.40 L/s/ha for 35 people/ha	270
Peaking Factors	Harmon's PF	N/R	Harmon's PF
I/I Allowance (L/s/ha)	0.02 (based on empirical data)	N/R	0.27
Minor System Design Storm	5 yr.	2 yr.	5 yr.
Major System Design Storm	100 yr.	100 yr.	min. 10 yr. (varies by area)
3. Flooding History 1991-2001	1975 – 10,000 claims 1983 – 10,000 claims @ avg. $5,000 per claim	~ 100 per year reported	30,000 estimated in 1993 fewer reported in 1994, 2000, and 2001 – avg. $2,400 each
5. Formal prevention program?	Yes – Homeowners Flood Proofing program (HOFP)	No	Yes, regulatory and voluntary
5c. What dept. oversees	Engineering Department	N/A	Water and waste department
5e. How long in effect?	10 years	N/A	Annual direct mail of pamphlets since mid-80s
5g. Costs of program?	$90,000 per year for HOFP; $3-4 million/yr drainage upgrade retrofit program	N/A	Combined Sewer Flood Relief Capital budget of $7M per year; Sewer upgrade program total est. cost of $3M
5h. Cost to Homeowner	25 cents to every municipal $1	N/A	Capital cost of backwater valve and sump pit as per by-laws ($1,400)
5j. Formal feedback mechanism?	Yes, regular questionnaire, public meetings and door to door HOFP campaign.	N/A	No formal process in place
7. How does municipality control re-development?	Zoning, bldg. & plumbing codes, and servicing agreements	Zoning by-laws, bldg. Permits; sub-division approvals with conditions	Zoning and by-laws
8. Public information program?	Numerous media	No	Numerous media
9. Cost sharing of damages?	City not involved with flood damage on private property	100% of depreciated value as per provincial legislation unless damage is caused by homeowner or is covered by insurance	0%
10. Jurisdictional issues?	City has no jurisdiction to interfere with private property rights of homeowners	No	No

Municipality	Toronto	Region of Peel	Kitchener
1. Population (2001 Census)	2,500,000 (2,481,494)	985,000 (988,948)	(190,399)
Growth rate 1991-2001	8.8%	34%	6.7%
Expected growth 2001-2011	> 8.8%	20%	> 6.7%
Urban drainage system area	632 km^2	N/R	N/R
Combined	75%	0	0
Separated	25%	100%	100%
Other			
2. Weeping tile connections to:	Sump pump		Storm, sump pump
Downspouts connected to:	Surface where possible otherwise to storm sewer	Splash pads, away from house	Surface
Sanitary Flows (L/cap/day)	Not reported due to process of harmonizing requirements among amalgamated municipalities	302.8	N/R
Peaking Factors		Harmon's PF	N/R
I/I Allowance (L/s/ha)		0.2 Fdn. Drains - 0.08 L/s/FD Man Holes – 2.8 L/s/MH	N/R
Minor System Design Storm	varies	2-10 yr.	N/R
Major System Design Storm	varies	100 yr.	N/R
3. Flooding History 1991-2001	Year 2000 major events: May12-13 – 2968 June 13 – 54 June 14 – 335 July 17 - 341	April 21 & May 12, 2000 storms 386 reported	N/R
5. Formal prevention program?	Yes, pamphlets, community newspapers and website, and "Toronto Master Plan for Wet Weather Flow Management" currently in progress	Program in development to include detailed on-line info and pamphlets	In progress
5c. What dept. oversees	Water and Wastewater Division, Works and Emergency Services	Public Works, Operation and Management Section	N/R
5e. How long in effect?	Less than 1 yr.	Less than a year	N/A
5g. Costs of program?	$3 million budget for 2001	Downspout Disconnection program requires no maintenance; the Check Valve Installation program = bi-annual maintenance @ $80 per check valve	
5h. Cost to Homeowner	Costs less city subsidy	Zero cost to homeowner	N/R
5j. Formal feedback mechanism?	N/R	In progress	N/R
7. How does municipality control re-development?	Planning process and development review	Local municipalities control re-development (see by-laws)	Redevelopment controls; site plan agreements
8. Public information program?	Numerous media	No	Pamphlet
9. Cost sharing of damages?	Only in case of proven negligence on the part of the city	Last storm, Region made X-Gratia payments of deductible to homeowners who reported sewer back-up Insured costs - $119,444 Uninsured costs - $250,286	Only in case of proven negligence on the part of the city
10. Jurisdictional issues?	No	Public/private liability	No

Municipality	London	Region of Halton	St. Catharines
1. Population (2001 Census)	330,000 (336,539)	330,000 (375,229)	137,000 & 17,883 (Thorold)
Growth rate 1991-2001	7.5%	24%	5%
Expected growth 2001-2011	N/R	26%	4.3%
Urban drainage system area	1,200 km sanitary sewers; 1,100 km storm sewers; 7km combined; 20 km storm + relief sewers	200 km^2	34 km^2 & 18 km^2
Combined	0.6%	0%	3.5% & 14%
Separated	99.4%	75%	96.5% & 86%
Other		25% partially separated	
2. Weeping tile connections to:	Storm, sump pump	Storm, sump pump	Sump pump
Downspouts connected to:	Surface	Storm, grassed areas or soak away pits	Surface
Sanitary Flows (L/cap/day)	295	275	320
Peaking Factors	Harmon's PF	Harmon's PF	Harmon's PF 4.5
I/I Allowance (L/s/ha)	0.1	0.28	0.28 – 0.4
Minor System Design Storm	5 yr.	varies by municipality	5 yr.
Major System Design Storm	25 yr.	varies by municipality	100 yr.
3. Flooding History 1991-2001	1,711 total	979 total	10 major events in 10 years most severe June 10, 1996 600 logged reports, actual number estimated much higher
5. Formal prevention program?	Yes	Yes, inflow and infiltration team (I/I Team) of 3 dedicated to reducing basement flooding	Yes, Flooding Alleviation Program (FLAP)
5c. What dept. oversees	Special events and approvals dept.	Engineering Planning in Engineering Services	Transportation & Environmental Services (formerly Engineering)
5e. How long in effect?	Since 1985	Since 1997	Since 1992 (10 years)
5g. Costs of program?	Total of $4.1 million since 1985 with 1,400 installations	$300,000/yr	$50,000/year budgeted $1.5 million budgeted for sewer improvements in 2002
5h. Cost to Homeowner	Zero	Capitals costs of home improvements (i.e., grading, downspout disconnection, etc.)	Any costs above the maximum $2,500 grant, plus $150 application fee. Typically, cost of work does not exceed $2,500
5j. Formal feedback mechanism?	Yes, hotline	Public information sessions	Yes, feedback phone line
7. How does municipality control re-development?	Site plan control applications	Development Control Reports	Planning Department oversees re-development; Envtl. Services becomes involved in Brownfields redevelopment
8. Public information program?	Yes, see website	No formal program beyond public information sessions to update homeowners on flood prevention measures	No
9. Cost sharing of damages?	Only if flooding is caused by city actions	Only where region is negligent	Determined on a case by case basis
10. Jurisdictional issues?	Public/private liability	Regional/municipal division of responsibilities	None

Municipality	Windsor	Laval	Gatineau
1. Population (2001 Census)	205,000 (208,402)	350,000 (343,005)	105,000 (102,898)
Growth rate 1991-2001	8.7%	15%	2.2%
Expected growth 2001-2011	~ 5%	10%	> 2.2%
Urban drainage system area	N/R	120 km^2	N/R
Combined	15.7%	25%	20%
Separated	82.0%	70%	50%
Other	2.3% interceptors, reliefs	5% septic systems	30% septic systems
2. Weeping tile connections to:	Storm, sump pump	Storm, sump pump	Storm or sanitary
Downspouts connected to:	Storm, if connected	Storm to the ground	Storm to the ground
Sanitary Flows (L/cap/day)	N/R	320	N/R
Peaking Factors	N/R	Harmon's PF ~1.7 global, 2 – 4 typical	N/R
I/I Allowance (L/s/ha)	N/R	0.07 new, 0.19 existing	N/R
Minor System Design Storm	N/R	2 – 10 yr.	N/R
Major System Design Storm	N/R	100 yr.	N/R
3. Flooding History 1991-2001	4 major events in 10 years # of floodings unspecified	Avg. 250 per year, for example 1989 – 930 1994 – 128	1994 ~ 500 (1:25 yr. event) 1996 ~ 600 (1:25 yr. event) 2000 ~ 700 (1:50 yr. event)
5. Formal prevention program?	Yes	No formal program; case by case when problem occurs	Yes
5c. What dept. oversees	Public Works Department	Engineering Dept.	Public Works
5e. How long in effect?	Approx. 20 years	Approx. 2 years	Approx. 4 years
5g. Costs of program?	$40,000 during stormy years	$2,500 per house x 60 houses = $150,000	$3,000 per house
5h. Cost to Homeowner	Capital costs of home improvements	Difference between actual costs and $2,500	Zero
5j. Formal feedback mechanism?	No formal program	No formal feedback	No
7. How does municipality control re-development?	Development agreements	N/A	By-laws
8. Public information program?	No formal program	No	Numerous media
9. Cost sharing of damages?	All claims referred back to city's insurance	Only where city is negligent	City typically pays 10% – 20%
10. Jurisdictional issues?	N/R	Developers attempt to change master plan affecting sanitary sewer and storm watershed management	No

Municipality	Moncton	Saint John	Charlottetown
1. Population (2001 Census)	63,000 (61,046)	72,000 total (69,661) 65,000 serviced	32,531(32,245)
Growth rate 1991-2001	2.9%	-3.9%, 2001 Census	1%
Expected growth 2001-2011	3.7%	N/R	1%
Urban drainage system area	66.5 km^2		42.6 km^2 (204.7 km of mains)
Combined	23%	71%	10.5%
Separated	77%	29%	89.5%
Other			
2. Weeping tile connections to:	N/R	Storm	Sanitary, storm, sump pump, and dry wells
Downspouts connected to:	N/R	Storm or surface	Storm, other, drywells
Sanitary Flows (L/cap/day)	N/R	N/R	N/R
Peaking Factors	N/R	N/R	N/R
I/I Allowance (L/s/ha)	N/R	N/R	N/R
Minor System Design Storm	N/R	N/R	N/R
Major System Design Storm	N/R	N/R	N/R
3. Flooding History 1991-2001	N/R	306 total $4,270 avg. cost of damages	No records maintained.
5. Formal prevention program?	No formal program but do distribute pamphlet and newsletters	Yes	No
5c. What dept. oversees	Utilities Division of Engineering Dept. + Plumbing Inspector of the Building Inspection Dept.	Water and Sewage Department	N/A
5e. How long in effect?	Pamphlet distribution for approx. 1 year	10+ years	N/A
5g. Costs of program?	Printing costs only	N/R	N/A
5h. Cost to Homeowner	Cost of backflow valve $200	N/R	N/A
5j. Formal feedback mechanism?	No formal feedback	N/R	N/A
7. How does municipality control re-development?	Greater Moncton Metropolitan Plan + zoning regulations	N/R	Zoning and development by-laws
8. Public information program?	Pamphlets and newsletter (see survey)	Pamphlets and newspaper advertisements	Annual notice to homeowners re: backwater valve requirements
9. Cost sharing of damages?	N/R	100% where claim is based on negligence or nuisance; 0% if problem is in lateral. Insurance responds to claims; City has $5,000 deductible per claim, including expenses	Homeowner's insurance unless city is liable
10. Jurisdictional issues?	Yes, between Greater Moncton Sewerage Commission and Riverview, Dieppe and Moncton.	N/R	Yes, interior plumbing is provincially regulated; exterior piping is municipally regulated

Municipality	Summerside	Whitehorse	Dawson
1. Population (2001 Census)	15,000 (14,654)	23,000 (21,405)	1,856 (1,251)
Growth rate 1991-2001	1.2%	-1.8% 2001 Census	6.2%
Expected growth 2001-2011	1.2%	N/R	6.3%
Urban drainage system area	N/R	N/R	3 km^2
Combined		N/R	0
Separated	75% storm system	N/R	100%
Other	25% ditched		
2. Weeping tile connections to:	Sump pump	N/R	Storm
Downspouts connected to:	Storm	N/R	Storm
Sanitary Flows (L/cap/day)	N/R	N/R	50
Peaking Factors	N/R	N/R	N/R
I/I Allowance (L/s/ha)	N/R	N/R	N/R
Minor System Design Storm	N/R	N/R	N/R
Major System Design Storm	N/R	N/R	N/R
3. Flooding History 1991-2001	N/R	6 cases where city liable	No cases reported due to very few basements in permafrost
5. Formal prevention program?	Yes, pamphlets once a year	No formal program, just what is required under Canadian plumbing code	No
5c. What dept. oversees	Water and Sewage Dept.	N/R	N/R
5e. How long in effect?	At least 12 years	N/R	N/R
5g. Costs of program?	N/R	N/R	N/R
5h. Cost to Homeowner	Cost of backwater valve	N/R	N/R
5j. Formal feedback mechanism?	No	N/R	N/R
7. How does municipality control re-development?	Since 1997, all new development must have proper drainage (no ditches)	Zoning and bldg. By-laws	Appointed planning development board
8. Public information program?	No	N/R	No
9. Cost sharing of damages?	Only where city is negligent	N/R	Only where city is negligent
10. Jurisdictional issues?	N/R	N/R	N/R

Appendix D – Literature Review

A review of basement flooding literature indicates that it appears in several categories:

1. Academic publications derived from research conducted primarily into various simulation and modeling techniques for a variety of stormwater control strategies.
2. Government publications based on funded research or actual practices, policies and regulations.
3. Private sector publications primarily in the form of product literature and marketing of goods and services aimed at the abatement of basement flooding problems.

The first and third categories have not been included in the listings that follow, with a few notable exceptions. The former category is simply too voluminous to consider, but may be readily accessed through the various journals and conference proceedings associated with stormwater management and indirectly, basement flooding. The latter category deals with proprietary products and services that were deemed inappropriate for a report of this nature.

Publications

The following books and papers related to basement flooding were identified during the literature review.

Water Resources Engineering. Ralph A. Wurbs, Prentice Hall, 2002.

Best Modeling Practices for Urban Water Systems, Monograph 10. William James (editor), Computational Hydraulics International , Guelph, Ontario, 2002.

Urban Drainage Modeling: Proceedings of the Specialty Symposium held in conjunction with the World Water and Environmental Resources Congress, May 20-24, 2001, Orlando, Florida. Robert W. Brashear (editor), American Society of Civil Engineers, 2001.

Components of a Basement Flooding Protection Plan: Sewer System Improvements. Prepared by SEMCOG, the Southeast Michigan Council of Governments, with assistance from the Basement Flooding Liability Task Force, November 2000.

Components of a Basement Flooding Protection Plan: Legislation on Liability. Prepared by SEMCOG, the Southeast Michigan Council of Governments, with assistance from the Basement Flooding Liability Task Force, June 1999 (revised, November 2000).

Inundation Simulation for Urban Drainage Basin with Storm Sewer System.
M.H. Hsu, S.H. Chen, T.J. Chang, Journal of Hydrology, 234, 21–37, 2000.

Applied Modeling of Urban Water Systems. William James (editor), Computational Hydraulics International, Guelph, Ontario, 2000.

Urban Stormwater Management Planning with Analytical Probabilistic Models. Barry J. Adams and Fabian Papa, John Wiley & Sons, 2000.

Flood Issues in Contemporary Water Management. Jiri Marsalek et al. (editors), Kluwer Academic Pub., Boston, MA 2000.

New Applications in Modeling Urban Water Systems. William James (editor), Computational Hydraulics International, Guelph, Ontario, 1999.

Advances in Modeling the Management of Stormwater Impacts. William James (editor): Computational Hydraulics International, Guelph, Ontario, 1996.

Evaluation of Urban Drainage for Basement Flood Proofing. Paul Wisner and Martin J. Hawdur for Canada Mortgage and Housing Corporation, March 1994.

A Synthesis of Technical Research and its Potential for Application in Linear Infrastructure Renewal. CH2M HILL Engineering Ltd. for Canada Mortgage and Housing Corporation, November 1994.

Stormwater Control to Prevent Basement Flooding. CH2M Hill Engineering Ltd. for Canada Mortgage and Housing Corporation, March 1992.

Protection of Basements Against Flooding: Trends and Impacts of Drainage Regulations. Paul Wisner and Associates Inc. for Canada Mortgage and Housing Corporation, May 1990.

Impact of Residential Weeping Tile Flows on Urban Drainage System Design. Field, T. and G. Bontus, Western Canada Water and Wastewater Association, 41st Annual Conference, Edmonton, Alberta, Oct. 4-6, 1989.

Guidelines for Performing Infiltration/Inflow Analyses and Sewer System Evaluation Surveys. Massachusetts Department of Environmental Protection, Division of Water Pollution Control. Boston. MA, 1989.

Modelling of Infiltration/Inflow Effects on a Large Sewerage System. Fraser, H. and K.B. Lee, Proceedings of the International Symposium on Urban Hydrology and Municipal Engineering, Markham, Ontario, June 13-15, 1988.

Case Studies of Dual Drainage Design with ICDs in Metro Toronto. Jankovic, M. and A. Lam, Proceedings of the International Symposium on Urban Hydrology and Municipal Engineering, Markham, Ontario, June 13-15, 1988.

Design of Small Storage Tanks for I/I Compensation. Lam. A., Proceedings of the International Symposium on Urban Hydrology and Municipal Engineering, Markham, Ontario, June 13-15, 1988.

The Role of Modelling in the Determination of Inflow/Infiltration Problems in Sanitary Sewers. Thompson, L.R., Proceedings of the International Symposium on Urban Hydrology and Municipal Engineering, Markham, Ontario, June 13-15, 1988.

Design Storm Pathology. Adams, B.J. and C.D.D. Howard), Canadian Water Resources Journal, 11(3), pp. 49-55, 1986.

Review of Canadian Design Practices and Comparison of Urban Hydrologic Models. James F. Maclaren Ltd., Project-No. 74-8-31, prepared for Ontario Ministry of the Environment, Pollution Control Branch, Toronto, Ontario, 1975.

Web Sites

The following web sites pertaining to basement flooding protection measures were accessed during the course of this study, and have been provided here as a source of further information to readers of this report. The listing consists of Canadian municipal web sites followed by additional web sites where basement flooding information may be accessed.

Vancouver
http://www.city.vancouver.bc.ca
http://www.city.vancouver.bc.ca/engsvcs/index.htm
http://www.city.vancouver.bc.ca/engsvcs/watersewers
http://www.city.vancouver.bc.ca/engsvcs/watersewers/floodprevention.htm
http://www.city.westvancouver.net/district_services/water_and_sewer_services.asp

Burnaby
http://www.city.burnaby.bc.ca
http://www.city.burnaby.bc.ca/engineering/works.html
http://www.city.burnaby.bc.ca/engineering/stormfaq.html

Calgary
http://www.gov.calgary.ab.ca
http://www.gov.calgary.ab.ca/living_in_calgary/water_sewage_garbage_electricity/index.html
http://www.gov.calgary.ab.ca/wwd/AboutWWD.html
http://www.gov.calgary.ab.ca/wwd/Flooding.html
http://www.gov.calgary.ab.ca/wwd/Protect.html
http://www.gov.calgary.ab.ca/wwd/Stormquestions.html

Edmonton
http://www.gov.edmonton.ab.ca
http://www.gov.edmonton.ab.ca/am_pw/drainage_services/
http://www.gov.edmonton.ab.ca/am_pw/drainage_services/flooding/index.html
http://www.gov.edmonton.ab.ca/am_pw/drainage_services/what_we_do/index.html
http://www.gov.edmonton.ab.ca/am_pw/drainage_services/flooding/brochure%201.pdf
http://www.gov.edmonton.ab.ca/am_pw/drainage_services/lot_grading/index.html
http://www.gov.edmonton.ab.ca/am_pw/drainage_services/services_for_you/index.html
http://www.gov.edmonton.ab.ca/am_pw/drainage_services/cleanriver/index.html

Red Deer
http://www.reddeercounty.ab.ca
http://www.reddeercounty.ab.ca/opsmain.htm

Regina
http://www.cityregina.com
http://www.cityregina.com/content/info_services/water_sewer/flood_control.shtml
http://www.cityregina.com/content/info_services/water_sewer/floodp/index.shtml
http://www.cityregina.com/content/info_services/water_sewer/cross_connection.shtml

Saskatoon
http://www.city.saskatoon.sk.ca/
http://www.city.saskatoon.sk.ca/org/public_works/watersewer.asp

Winnipeg
http://www.city.winnipeg.mb.ca
http://www.city.winnipeg.mb.ca/interhom/services/alpha_services.stm
http://www.city.winnipeg.mb.ca/waterandwaste/department_info.stm
http://www.city.winnipeg.mb.ca/waterandwaste/water_waste_brochures.stm

Toronto
http://www.city.toronto.on.ca
http://www.city.toronto.on.ca/sewers/index.htm
http://www.city.toronto.on.ca/sewers/basement_flooding.htm
http://www.city.toronto.on.ca/watereff/downspot.htm

Region of Peel
http://www.region.peel.on.ca
http://www.region.peel.on.ca/index.htm
http://www.region.peel.on.ca/pw/water/index.htm
http://www.region.peel.on.ca/news/2000/july/000713e.htm

Kitchener
http://www.city.kitchener.on.ca
http://www.city.kitchener.on.ca/environmental%5Fhb/part4.htm
http://www.city.kitchener.on.ca/_vti_script/search_search_our_site.htm0.idq

London
http://www.city.london.on.ca
http://www.city.london.on.ca/Cityhall/EnvServices/flooding1.htm

Region of Halton
http://www.region.halton.on.ca
http://www.region.halton.on.ca/PPW/water
http://www.region.halton.on.ca/pubworks/Crawford%20Yard/Maintenance/flooding.asp

Saint John
http://www.city.saint-john.nb.ca
http://www.city.saint-john.nb.ca/2.cfm?PageID=2-1-11
http://www.city.saint-john.nb.ca/2.cfm?PageID=6-1-2

Moncton
http://www.moncton.org
http://www.moncton.org/search/english/CITYLIVING/yourhome/plumbrequire.htm
http://www.moncton.org/search/english/CITYHALL/water/gmwap.htm
http://www.moncton.org/search/english/search.idq?
http://www.moncton.org/search/english/cityhall/citydepartments/eng/pworks.htm
http://www.moncton.org/search/english/cityhall/publications/publications.htm

Summerside
http://www.city.summerside.pe.ca
http://www.city.summerside.pe.ca/cityhall/munserv/

Territories
http://www.city.whitehorse.yk.ca
http://www.dawsoncity.org/
http://www.yukonweb.com/community/dawson/
http://www.gov.yk.ca/

Related Web Sites
The following Web sites provide further, related information regarding the mitigation of basement flooding.

General Hydrology
Hydrology Web is a site that hosts a list of links to hydrology and related resources.
http://etd.pnl.gov:2080/hydroweb.html

The Internet for Civil Engineers
http://www.icivilengineer.com/

History of Sanitary Sewers
http://www.sewerhistory.org/

Stormwater Management
CMHC - Alternative Stormwater Management Practices for Residential Projects
http://www.cmhc-schl.gc.ca/en/imquaf/himu/wacon/wacon_031_index.cfm

Environment Canada: The National Water Research Institute
http://www.cciw.ca/

Center for Watershed Protection
http://www.cwp.org/

U.S. Environmental Protection Agency, Urban Watershed Management Branch
http://www.epa.gov/ednnrmrl/

U.S Federal Emergency Management Agency
http://www.fema.gov/

Federal Insurance & Mitigation Administration (FIMA), which manages the National Flood Insurance Program and oversees FEMA's mitigation programs.
http://www.fema.gov/fima/

U.S. Environmental Protection Agency, Municipal Technologies
http://www.epa.gov/owm/mtb/

The Stormwater Manager's Resource Center
http://www.stormwatercenter.net/

Programs and Initiatives
City of Toronto's Wet Weather Flow Management Master Plan
http://www.toronto.ca/wes/techservices/involved/wws/wwfmmp/index.htm

City of Evanston, Long Range Sewer Improvement Program
http://cityofevanston.org/Departments/Water/longrange.html

City of Elmhurst Illegal Disconnection Program
http://www.elmhurst.org/elmhurst/publicworks/sumppump.asp

Design Guidelines
National Guide to Sustainable Infrastructure IRC/NRC
http://www.infraguide.gc.ca/indexe.html

Ontario Ministry of the Environment, *Stormwater Management Planning and Design Manual*
http://www.ene.gov.on.ca/envision/env_reg/er/documents/stormwatermanual/

Low Impact Development
Low Impact Development, Urban Design Tools
http://www.lid-stormwater.net/

Green Roofs for Health Cities
http://www.greenroofs.ca/grhcc/index.html

Proceedings of the Green Roof Infrastructure Workshop Held at NRC, June 25, 2001, Ottawa
http://www.greenroofs.ca/grhcc/index.html

Greenroofs.com's purpose is academic, and is not subsidized by any company or institution.
http://www.greenroofs.com/

Studies and Technical Papers
Accessing 3905 Grey-Lit Papers on Urban Drainage, William James and Kristi Rowe, School of Engineering, University of Guelph
http://www.eos.uoguelph.ca/webfiles/james/C152T07.html

Controlling Inflow and Infiltration In Wastewater Collection Systems, by Mark G. Wade, P.E.
http://www.wadeinc.com/articles/asce.htm

Modelling Sustainable Urban Drainage Structures, by M K Reeves & M Lewy,
Wallingford Software
http://www.environmental-center.com/articles/article1168/article1168.htm

Technical Papers, Associated Engineering Group, Calgary, Alberta
http://www.ae.ca/about/techpapers.html

American Rivers Report: *Paving our way to water shortages: how sprawl aggravates the effects of drought*
http://www.americanrivers.org/landuse/sprawldroughtreport.htm

The Destructive Effects of Roots in Sewers
http://www.esemag.com/0900/roots.html

The Interaction of Tree Roots and Sewers
http://www.urban-forestry.com/citytrees/v37n4a20.html

U.S. Natural Resources Defense Council, *Stormwater Strategies: Community Responses to Runoff Pollution*
http://www.nrdc.org/water/pollution/storm/stoinx.asp

City Farmer: *Evaluating Voluntary Stormwater Management Initiatives in Urban Residential Areas*
http://www.cityfarmer.org/stormwater.html

Mold, Liability and Litigation
MIT Involved in Tenants' Lawsuit Over Flooded Basement Apartments
http://www-tech.mit.edu/V117/N53/lawsuit.53n.html

Pinchin Environmental, *The Growing Liability for the Insurance and Restoration Industries Posed by Hazardous Mould in Buildings*
http://www.pinchin.net/newsletters/mouldliability.htm

Government of Manitoba, *Understanding Mould*
http://www.gov.mb.ca/gs/memo/undermold.html

Stachybotrys chartarum: *The Toxic Indoor Mold*, by Professor Berlin D. Nelson, Nov. 2001.
http://www.apsnet.org/online/feature/stachybotrys/

Pulmonary Hemorrahage and Hemosiderosis in Infants, published by Rainbow Babies and Childrens Hospital and Case Western Reserve University
http://www.case.edu/pubs/cnews/1998/2-5/fungus.htm

Associations
Water Environment Association of Ontario
http://www.weao.org/

Sump and Sewage Pump Manufacturers Association
http://www.sspma.org/

North American Society for Trenchless Technology
http://www.nastt.org/index.html

National Corrugated Steel Pipe Association
http://www.ncspa.org/

The American Concrete Pipe Association (ACPA) online resource center.
http://www.concrete-pipe.org/

Canadian Concrete Pipe Association.
http://www.ccpa.com/index1.htm

Uni-Bell PVC Pipe Association
http://www.uni-bell.org/index.htm

Innovative Products and Services
This series of links does not imply any preference or endorsement of the products and services listed. These sources are intended to provide examples of how the private sector has responded to business opportunities related to stormwater management and basement flooding.

Scientific Software Group, Storm Water Management Software
http://www.scisoftware.com/products/cat_stormwater/cat_stormwater.html

Haestad Methods' Stormwater Software
http://www.haestad.com/

Stormwater Management, Inc. of Portland, Oregon, is a progressive, innovative company whose mission is to develop stormwater treatment solutions for engineers, developers and jurisdictional authorities.
http://www.stormwaterinc.com/

Basement Flood Protector Inc., Chicago, Illinois
http://www.floodnot.com/

Mainline Backflow Products Inc.
http://www.backwatervalve.com/

Peterson Valve Company
http://www.petersonvalve.com/

Water Powered Sump Pumps
http://basementbuddy.com/

Invisible Structures Stormwater Management Products
http://www.invisiblestructures.com/

Insurance Consulting Services
Alan W. Pang
Property and Casualty Manager
Underwriting Consulting Services
CGI Business Insurance Services
(formerly the Insurers' Advisory Organization Inc.)
90 Allstate Parkway, 8th Floor
Markham, ON L3R 6H3
apang@iao.ca
http://www.iao.ca/