20 Years of Experience with addressing hydromodification impacts of urbanization in Calgary, Alberta, Canada

20 ans d'expérience dans la gestion des impacts de l'urbanisation sur l'hydromodification à Calgary, en Alberta, au Canada

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RÉSUMÉ

Les recommandations sur la manière de gérer les impacts de l'hydromodification sur les cours d'eau urbains ne sont disponibles que dans un nombre limité de juridictions. Dans le cas du bassin versant de Nose Creek à Calgary, en Alberta, au Canada, la combinaison d'un climat continental semi-aride et de dépôts glaciaires compacts lui confère un régime hydrologique évapotranspiratif. Le lien entre l'élargissement du cours d'eau et l'augmentation des volumes moyens annuels de ruissellement s'est traduit par des objectifs de volume de ruissellement établis par gradation dans le Plan de gestion de l'eau de 2008. Toutefois, la constatation que les débits résultants dépassaient la plage d'écoulement morphologiquement la plus sensible a conduit à l'adoption de courbes de durée d'écoulement, partant du principe que les augmentations en dehors de cette plage pourraient être considérées comme normales.

Avec le logiciel PCSWMM, l'ajustement de la courbe de durée d'écoulement cible est réalisé grâce à une approche de bilan hydrique. Premièrement, le volume total sous les courbes est « ajusté » par la mise en œuvre de pratiques de gestion intégrée des eaux pluviales (LID) intégrées aux aménagements. Ensuite, la forme de la courbe de débit résultante est affinée à l'aide d'une série de dispositifs de contrôle de débit au sein de la structure de contrôle de sortie des bassins avec retenue permanente mise en place à la sortie des réseaux. L'utilisation d'une approche à double couche proposée par le système de contrôle de la biorétention LID dans le logiciel PCSWMM permet de représenter le régime d'évapotranspiration de Calgary.

Bien que l'adoption de cette approche constitue un pas en avant dans la représentation du bilan hydrique urbain et permette ainsi de réduire considérablement les impacts sur l'hydromodification, des efforts supplémentaires sont nécessaires car les contrôles LID dans SWMM ne sont pas optimaux pour représenter l'hydrologie urbaine des prairies canadiennes.

ABSTRACT

Guidance on how to address hydromodification impacts on urban streams is only available in a limited number of jurisdictions. In the case of the Nose Creek watershed in Calgary, Alberta, Canada, the combination of its continental, semi-arid climate and tight glacial tills means that it has an evapotranspirative hydrologic regime. A relationship between the widening of the creek and the increase of the average annual runoff volumes was reflected in staged runoff volume targets in the 2008 Water Management Plan. However, the recognition that the resulting discharges exceeded the morphologically most sensitive flow window led to the adoption of flow duration curves with the premise that increases outside of the most sensitive flow window might be considered.

Using PCSWMM, matching the target flow duration curve is accomplished using a water balance approach. First, the overall volume under the curves is “matched” through the implementation of landscape-based LID practices. Next, the shape of the resulting discharge curve is finetuned using a series of flow control provisions within the outlet control structure of the end-of-pipe wet ponds. The use of a dual-layer approach offered by the Bioretention LID Control within PCSWMM allows for the representation of Calgary’s evapotranspirative regime.

While the adoption of this approach is a step forward in representing the urban water balance and thus reducing impacts on hydromodification considerably more effort is needed as the LID Controls in SWMM are not optimal for representing the urban hydrology of the Canadian prairies.

KEYWORDS

hydromodification, low energy release, modelling, planning, urban stream

1 BACKGROUND

The topic of hydromodification impacts on urban streams has slowly gained more interest in stormwater management (Bledsoe and Watson, 2001; Aquafor Beech, 2006). While the impacts of land use changes on the morphology of our urban streams have been evident for decades (Leopold, 1968); historically, most attention has been paid to flood minimization and water quality control of an often limited set of constituents. In practice, guidance on how to address hydromodification is available in only a limited number of jurisdictions, with approaches having evolved over the last couple of decades, moving from peak flow rate control to matching erosive power or matching flow duration curves (Pomeroy et al, 2008; Sacramento Region, 2018).

1.1 Nose Creek Watershed

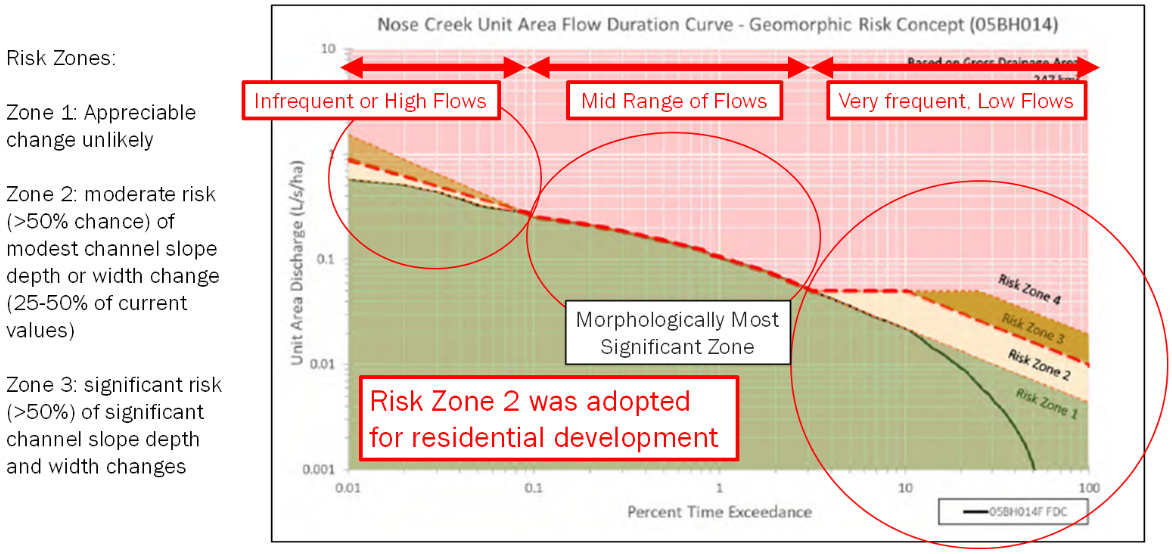
In Calgary, Alberta, Canada, efforts to address hydromodification impacts started in its Nose Creek watershed over 20 years ago, a few years after the creation of the Nose Creek Watershed Partnership, a collaboration of The City of Calgary and adjacent municipalities as well as the Calgary Airport Authority and supported by (now) Alberta Environment & Protected Areas. This watershed, which covers close to 1,000 km^2, has seen extensive urban development over the last five decades and is now (2023) home to over 400,000 people, with urbanization covering over 28% of the watershed (i.e., 17% built up and 11% disturbed), and still actively proceeding. Calgary has a continental, semi-arid climate with slightly less than 500 mm average annual precipitation. The combination of this semi-arid climate and the presence of tight glacial tills means that Calgary effectively has an evapotranspirative hydrologic regime with over 95% of the average annual precipitation returning to the atmosphere as evapotranspiration, while recharge or deep infiltration is only a few percent, and runoff about 5%. Practically, this means that urbanization leads to very significant increases in the amount of runoff as a function of the amount of hard area introduced.

1.2 Evolution of Efforts to Address Hydromodification

In spite of peak runoff rate control (for a 1:100 year condition and largely aimed at urban flood control), there was increasing evidence of stream bed and bank erosion leading to stream downcutting and widening, jeopardizing adjacent infrastructure as well as having detrimental impacts on biohabitat. The early studies highlighted the need to not only control the rate but also the volume of runoff through the implementation of low impact development practices. Given its tight glacial tills and evapotranspirative hydrologic regime this meant that specifically practices that harness the evapotranspirative power of the landscape such as the redirection of runoff from hard surfaces into adjacent landscaped areas or green roofs should be of interest, in addition to rainwater harvesting practices or the collection of stormwater in large storm ponds (often a few hectares in footprint) where runoff may be utilized for irrigation of public open space and green space.

A popular practice aimed at retaining the first say 10 or 25 mm of precipitation could not be implemented given that a largely evapotranspirative hydrologic regime means that the relevant low impact development practices would not empty sufficiently fast. As such, these practices are subject to back-to-back events, meaning that a water balance approach using continuous simulation is needed. Continuous simulation was not novel in the Calgary area since the analysis of storm ponds for flood control purposes using HYMO type models, which had been introduced over fifteen years earlier, had reflected the recognition that the low normalized, pre-development flow rates (i.e., only a few L/s/ha) meant that the sizing of these ponds has to account for back-to-back events rather than focusing solely on a say 24 hour design event analyzed with the help of single-event analysis. In the case of Nose Creek, a relationship was developed between the degree of widening and the increase of the average annual runoff volumes (van Duin and Garcia, 2008). This was reflected in staged runoff volume targets in the 2008 Nose Creek Watershed Water Management Plan (Nose Creek Watershed Partnership, 2018). The staging was a compromise to account for the reality that it would take time for the land development industry to get familiar with implementing practical and cost-effective low impact development practices.

Unfortunately, the expectation that the long-term targets could be met within one decade was overly optimistic. At the same time, it was recognized that the original 2008 runoff volume targets might have been over-conservative. First, there was a need to re-evaluate the original hydrology based on a much longer monitoring period as the original targets had been based on a relatively dry decade but there was also an increasing recognition that the creeks should be able to convey more runoff during part of the year. In the Calgary area, most of the precipitation falls in the months of June and July, with flows dropping significantly during the balance of the summer and fall. At the same time, it was also recognized that an average annual runoff volume approach overlooked the intricacies of the erosive processes in that the resulting discharges from the urban areas tended to considerably exceed the morphologically most sensitive flow window. The above led to the adoption of flow duration curves, similar to those practised in California or other US states, with the premise that increases outside of the most sensitive flow window might be considered. For instance, for the very frequent flow range, increases were deemed to be possible reflecting that historically the channel has been close to dry during part of the year. On the other end, for higher flow rates, excess energy dissipation is expected to occur when the stream accesses the overbank areas. Nevertheless, it was acknowledged that sediment movement still occurs at flow rates well below bank-full conditions given the highly erosive nature of specifically the banks of the creek. Therefore, the greater the departure from the pre-development flow duration curve, the greater the risk for wholesale morphologic change requiring extensive long-term bioengineering efforts.



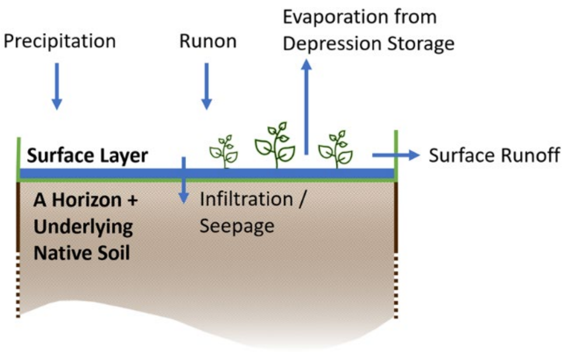
Normalized Flow Duration Curve adopted for Nose Creek (adapted from Matrix, 2021)

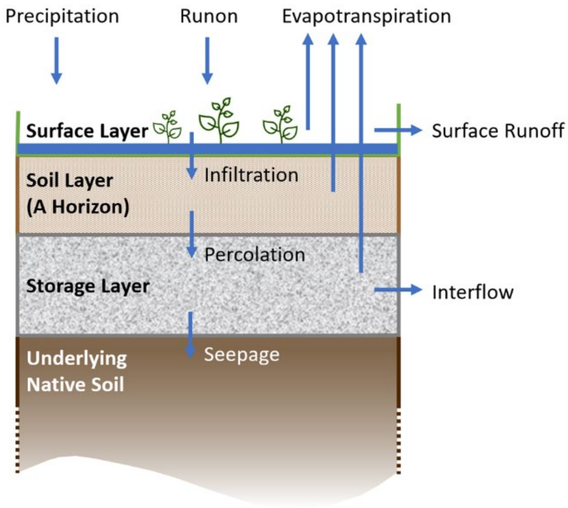
2 STORMWATER MANAGEMENT ANALYSIS APPROACH

Stormwater management analysis in the Calgary area is nowadays typically conducted with the proprietary PCSWMM version of the US EPA SWMM. The original HYMO based packages used in the 1990s and early 2000s did not include provisions to represent LID practices and were therefore phased out. The LID Controls included in SWMM allow the representation of landscape-based practices such as the redirection of runoff from hard areas into landscapes areas with deeper topsoil including rain gardens, green roofs, and blue roofs. Even the capture of runoff in large storm ponds for irrigation purposes is being represented. A custom Irrigation Design Estimation Tool was developed to represent the actual hydrologic phenomena of irrigation practices --- typical irrigation design practice focuses on supplying enough moisture to all areas to be irrigated during the peak summer season; however, it overlooks the actual water balance of the area to be irrigated, for instance, ignoring overspray or losses of irrigation water to evaporation.

About five years ago, a review of about 20 stormwater management reports prepared for projects conducted within the Nose Creek watershed concluded that over 80% were problematic. One of the main challenges was associated with the application of the default single layer infiltration approach within SWMM. This approach does not properly represent the evapotranspirative regime and allows ‘creative’ modellers to make moisture ‘disappear’ from the water balance. This challenge is being overcome by moving to the dual layer approach offered by the Bioretention LID Control within SWMM. This approach allows one to represent both the high infiltration capacity upper layer or A horizon, and the typically highly compacted, low seepage rate lower layers. It also allows keeping track of evapotranspiration and using the subdrain feature to represent interflow phenomena, such as the movement of moisture to weeping tiles or through utility trenches, which ultimately makes its way to the creeks after all.

Typical Residential Subdivision - No LID		
	Single Layer	Dual Layer
ET	26%	59%
Seepage	32%	9%
Interflow	N/A	6%
Runoff	42%	26%





Single-Layer vs Dual Layer Infiltration Modelling in PCSWMM (courtesy of Kerr Wood Leidal)

In practice, "matching" the target flow duration curve is accomplished in two steps. First, the overall volume under the flow duration curves is "matched" through the implementation of LID practices. Next, the shape of the resulting discharge curve is finetuned through the implementation of a series of flow control provisions within the outlet control structure of the end-of-pipe wet ponds (e.g., typical orifices, vortex control devices, weirs, pumps, etc.).

Unfortunately, this approach is yet far from perfect as the representation of LID in the SWMM environment is still rudimentary and needs improvement. For instance, with respect to LID controls, SWMM is not able to represent the winter and freeze-thaw conditions of the Canadian prairies necessitating the representation of sublimation and snow melt phenomena as part of the precipitation database. In addition, the representation of evaporation and evapotranspiration in an urban environment is lacking. On top of this, the reality is that other processes within our urban communities are often still overlooked or excluded for lack of credible data. Examples include irrigation of private land, leaking potable water mains and irrigation systems, or inflow & irrigation into the sanitary system all of which impact the overall water balance. While the adoption of this approach is a step forward in representing the urban water balance and thus reducing impacts on hydromodification considerably more effort is needed.

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