City Discharges to the North Saskatchewan River

Addressing the Challenge

By: Drainage Services Branch, Asset Management & Public Works, City of Edmonton

About the Authors

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Introduction

Huge strides have been made in the last 50 years to reduce the impact from City discharges on the North Saskatchewan River (NSR). Advanced wastewater treatment facilities and infrastructure works to convey more combined sewer flows for treatment have reduced nutrient discharges by as much as 70% and 30% for phosphorus and nitrogen, respectively. But with the continued development of more greenfield into urbanized lands, stormwater runoff is becoming an ever more significant source for

pollutants discharged to the river. For substances like suspended solids, which have attached to them other pollutants like metals and bacteria, over 80% of its annual mass loading to the river comes from rainwater washing off City streets and discharged to the river through stormwater outfalls. Current land development practices result in more "hard" or impervious surfaces that generate 5 to 10 times more runoff from rainfall events than was the case when the land was greenfield - a field or a tree stand. Neighbourhood ponds have been built in new neighbourhoods since the 1980's to temporarily store this increased volume of runoff to avoid local street flooding. These wet ponds or constructed wetlands also provide some settling and biological treatment of pollutants – but not enough to offset an additional incremental pollutant load from the new development.

With stormwater loadings to the river trending higher, the City needs to find innovative ways to better manage its stormwater loadings if the City is to ensure "*no further degradation in water quality*" – the principle basis for the Water Management Framework and Integrated Watershed Management Plan for the NSR. For the City, this means more end-of-pipe treatments for stormwater like the FCM-award winning Kennedale wetland facility in Hermitage Park. But that's only the beginning of the story. End-of-pipe treatments only help to mitigate existing loads from developed lands. A more sustainable approach to land development needs to be implemented that does not create more pollutant loadings to the watershed from the 300-400 hectares of land that is urbanized in the City each year. Low Impact Development (LID) designs that include green roofs, rain gardens, bioswales, and other water-absorbent landscape features are being looked to, to soak away more of the rainwater that falls on urban lands and thereby reduce pollutant loadings to the river. To protect river water quality, the City will need to change its servicing standards and reposition itself to better integrate more "green" infrastructure into the developed urban landscape, i.e. build it right the first time.

Background

For undeveloped lands the natural hydrologic cycle governs the patterns of rainfall and evaporation, the amount of shallow infiltration and aquifer recharge, soil column moisture, and vegetative land cover. A small portion of the rainfall stays on the surface and overland flows through vegetation before entering creeks and the river. Most rainfall gets soaked up by the "spongy" landscape and is earth-media filtered before eventually being transported via groundwater to flow into creeks and the river.

With land development in urban areas, this natural cycle is broken because the soil layer is scrapped away, replaced with "hard surfaces" like buildings and roadways, and even

the grassed areas are usually graded to have only a thin (100 cm) soil depth. It's not surprising then that rainfall events can generate 5 to 10 times the volume of runoff (with much higher pollutant transport) with the built-out urban footprint. And with no earth-media filtration to treat the runoff, this means creeks and the river get heavy loads of pollutants from urbanized areas like parking lots and roadways. The higher volume of runoff itself also causes accelerated rates of erosion in creeks.

Edmonton's Drainage System

The total land area of the City of Edmonton is 71,000 hectares (ha), with about 34,000 ha of urban footprint. On average about 400 ha of greenfield lands are being developed each year in Edmonton. The older parts of the City built prior to the 1960's were serviced using only a single pipe in the ground to convey sanitary flows and street runoff drained away using catchbasins in roadway gutters, hence the term "combined sewer". Edmonton's combined sewer area is about 4,300 ha in size and is the source of combined sewer overflows (CSOs) to the NSR and Mill Creek. Rainfall that is drained to this single pipe can fill it up, overloading its flow capacity, and then the rainwater/raw sewage mixture overflows to the river at engineered outfall locations. Edmonton has a total of 18 CSO outfalls – all of which are located downstream of EPCOR's drinking water intakes on the NSR, i.e. the CSOs do not pose a threat to our drinking water.

After the 1970's, the City required land be developed with the more common 2 pipe system: separate sanitary and storm sewer pipes. There are 29,400 ha of urban footprint with this separate piped system. The "minor" drainage system consists of this separate storm sewer pipe, plus gutters and catchbasin inlets and is sized to rapidly carry away runoff from road surfaces for typical, frequent rainfall events. Starting in the 1980's, the City lowered the risk of local flooding and property damage from intense storm events by requiring neighbourhood stormwater management facilities or "wet pond" be built. This "major" drainage system protects developed lands from flooding during extreme rainfall events. In the last ten years these ponds have followed a more naturalized design concept and constructed wetlands are now recommended design features. Edmonton has about 8,800 ha of urban footprint with stormwater routed through a total of 158 wet ponds and about 16 constructed wetlands. Conversely, about 20,600 ha of urban runoff can discharge directly into creeks and the river with no treatment barriers. The City has a legacy of land drainage infrastructure using the gutter-and-pipe strategy that sought to discharge rainwater as efficiently as possible into the river via 235 stormwater outfalls.

Edmonton's sanitary system and most of the flow in the combined sewers convey wastewater (and some portion of rainwater from combined sewer areas) to EPCOR's

Gold Bar wastewater treatment plant (WWTP) located at 50th Street and south bank of the NSR. The WWTP now includes pre-treatment, primary treatment, secondary treatment that includes biological nutrient removal, and ultraviolet disinfection of final effluent. It provides a world-class, tertiary level of treatment. Dealing with the solids removed from the liquid fraction requires sludge thickening, fermentation, digestion, and disposal of biosolids through land application and composting. The average design flow rate capacity for full treatment is 310 million litres per day (ML/d), 420 ML/d for peak secondary treatment plus UV, and 910 ML/d for only solids settling in the primary treatment tanks. During rainfall events, too much flow will go to the WWTP and some portion will only receive primary treatment, i.e. "secondary bypass" to NSR. Treated wastewater (not including bypasses) discharged back to the river has to meet the following concentration limits set out in the City's 2005-2015 Approval-to-Operate (No. 632-02-07) issued by Alberta Environment:

$CBOD_5$ < 20 mg/L;
TSS < 20 mg/L;
E.coli < 200 per 100 mL;
Total Phosphorous < 1 mg/L; and
Ammonia as N < 10 mg/L (winter); and
Ammonia as N < 5 mg/L (summer).

So the three major sources for pollutant loadings to the river in Edmonton are: combined sewer overflows (Rat Creek outfall plus 17 smaller ones), stormwater outfalls (4 major basins outfalls plus 230 smaller outfalls), and flows discharged back to the river from the Gold Bar WWTP (final effluent channel and secondary bypass).

Edmonton's Water Balance

Before talking about the types of major pollutants and the total loadings discharged to the river from the urban footprint, it is important to have an overall sense of the City's volume balance. The NSR flows through the City and is the receiving watercourse for urban and rural runoff. The annual volume of the river flowing past Devon (just upstream of Edmonton) and at the Alberta-Saskatchewan border is 7.08 million ML and 7.51 million ML, respectively. This means that between Edmonton and the SK border, the annual river volume increases by about 430,000 ML. Equivalent to a 6% increase in volume in a river length of about 200 km. To put this into perspective, the average cumulative rainfall in Edmonton from May through October (2000-2008) is 244 mm. Assuming 100% impervious cover on the 34,000 ha of urban developed footprint, this gives a seasonal urban runoff volume of 81,600 ML. This gross oversimplification is not

far from reality - the actual total annual volume of stormwater runoff from the City is typically about 67,000 ML (0.9% of NSR volume flowing through the City).

So how does this compare to the other inputs and outputs from the river in Edmonton? Each year the E.L. Smith and Rossdale water treatment plants withdraw from the river a combined total of about 130,000 ML of raw water (or 1.8% of NSR volume) to produce drinking water. Compared to stormwater with 67,000 ML discharged to the river annually, the other major sources of urban pollutants to the river are:

- combined sewer overflows with 1,500 ML (0.02% NSR volume);
- Gold Bar WWTP final effluent with 94,000 ML (1.3% NSR volume); and
- Gold Bar WWTP secondary bypasses with 3,000 ML (0.04% NSR volume).

Urban Sediment Loadings

So we talked about the volumes of flow in the river and how much water is withdrawn and then returned to the river in waste flows and urban runoff from rainfall. Given the relatively small volumes withdrawn from the river and discharged back to it, the issue is *not* water quantity but rather one of ***water quality*** for the NSR. In the North Saskatchewan River basin, the largest urban footprint is the City of Edmonton which is not surprisingly the single largest source of pollutants to the river. Various river water quality monitoring programs over the last three decades have shown the long-term trend of a decline in river water quality downstream of Edmonton with respect to sediment, nutrients, organics, bacteria, and some metals. But major investments in new technology at the Gold Bar WWTP starting in 1996 have decreased nutrient loadings by as much as 70% and 30% for phosphorus and nitrogen, respectively. And UV-light disinfection of final wastewater effluent has been shown by river monitoring to have significantly decreased *E.coli* counts in the river downstream of Edmonton.

Since 1991, the City has had a program to quantify the annual mass loading of certain key pollutants discharged from the urban footprint and assess its effect on river water quality. One of the major pollutants of concern to the river is Edmonton's sediment loading. Sources of sediment to the river include land surface erosion, winter road treatment, vehicle-related debris (rust, exhaust particles, brake pad material, etc.), weathering of pavements, land development, and construction activities. Sediments can be detrimental to aquatic life by damaging sensitive gill structures and suffocating out river bottom (i.e. benthic) organisms. The City's TSS loads will differ year to year largely as a result of seasonal rainfall. But there is an upward trend in annual TSS loadings, not surprising given that land development results in a net increase in total suspended solids (TSS) loadings. For years 2000 through 2008, the annual average City

discharge of TSS to the river was about 10,500 tonnes (dividing by 365 gives a daily mass loading of 28,870 kg/d).

In the previous section we broke down the major sources of volume discharged to the river. Now let's do the same but for TSS loadings. That 67,000 ML of urban footprint annual stormwater discharged to the river contributes a TSS load of 8,600 tonnes (or 82% of the total TSS load). The other major sources of urban footprint pollutants to the river contribute TSS loadings of:

- CSOs with 760 tonnes (7% of total TSS);
- Gold Bar WWTP final effluent with 650 tonnes (6% of total TSS); and
- Gold Bar WWTP secondary bypasses with 560 tonnes (5% of total TSS).

Having already addressed TSS loadings from the wastewater system, the City is now working to better manage TSS loadings from the stormwater and combined sewer system. A *Total Loading Plan* for TSS has been developed by the City in collaboration with EPCOR and Alberta Environment. Major initiatives like end-of-pipe stormwater treatment using constructed wetlands and enhanced primary treatment (EPT) of combined sewer overflows are already underway.

Other Key Pollutants

So far we've talked about suspended solids, but there are other pollutants. Some are of emerging concern like human pharmaceuticals and agricultural chemicals for example. But the water quality parameters of most interest for river protection continue to be nutrients, organics, bacteria, and also metals.

Nutrients

Nutrients can be a mix of dissolved and organic particulates, fertilizers, sewer overflows, animal feces, and detergents. The amount and types of nutrients found in water is measured using total ammonia, total phosphorous, and Kjeldhal nitrogen. High levels of these nutrients can result in a water body becoming eutrophic – having dramatic fluctuations in dissolved oxygen levels with potential for fish kills and the growth of nuisance algae.

Ammonia is of great importance to fish health because it causes organism stress and damage to gill tissues that results in poor growth and mortality. A naturally occurring substance, ammonia readily degrades in aquatic environments and does not bio-accumulate. In water it occurs in two forms: ionized ammonia (NH_4^+) and un-ionized ammonia (NH_3) – the form more toxic to fish. Water temperature and pH affect which form of ammonia is predominant. The "toxic" level of ammonia is equivalent to about 1

mg/L total ammonia (pH 8.0, 20°C). With the biological nutrient removal (BNR) process implemented at the Gold Bar WWTP in 2002, the levels of total phosphorous and ammonia discharged to the river have dramatically been reduced. A major finding of the City's ammonia toxicity study completed in 2006 showed that there is now a very low risk of ammonia toxicity to fish in the river downstream of the Gold Bar WWTP.

Biodegradable Organics

A measure of oxygen demanding substances metabolized by bacteria in water, biological oxygen demand (or BOD) is an indicator for various substances including decaying organic matter, combined sewer overflows, and animal feces. Major improvements in wastewater treatment have resulted in a large decrease in the annual loading of BOD.

Bacteria

E.coli bacteria in the river can come from various sources including stormwater runoff, combined sewer overflows, wastewater plant bypasses, and illegal discharges. With the implementation of UV-light disinfection at the Gold Bar WWTP in 1998, there is a huge decrease in the amount *E.coli* discharged to the NSR from the sanitary system. At present, the *E. coli* loading to the river is roughly evenly split three ways between the stormwater outfalls, CSOs, and Gold Bar WWTP secondary bypasses.

Managing Water Better

The City of Edmonton's Environmental Strategic Plan already has already established some key areas of focus around managing our water resources to more efficiently use water and protect the quality of water. Corporate sustainability objectives include:

- *wastewater treatment* – ensuring sanitary and combined sewer flows are treated with the best practical technology and discharged back to the NSR such that negative impacts on downstream water quality are minimized;
- *protecting water quality* – protecting the quality of surface runoff waters entering the NSR to support a diversity of uses including local and downstream recreation and maintaining the ecological integrity of the river;
- *water use efficiency in City operations* – jointly developed by the Parks and Drainage Branch in 2009, this Strategy includes opportunities for open space landscape irrigation using City pool water harvested during annual maintenance, rainwater harvesting from City building rooftops, quantifying the usage of potable water by various City facilities, and other related initiatives; and
- *water use efficiency* – improving residential and commercial water use efficiency.

Alberta Environment plays a key role in partnering with the City to help guide development of our vision, strategies and related action plans for improving how we manage our water resources. The focal point of this partnering regulatory process is the City's Approval-to-Operate. Besides giving end-of-pipe concentration limits for fully-treated wastewater effluent, the Approval lays out a roadmap of needed strategy and action plans to help guide the City's efforts for river protection. Key milestones in the Approval for water management strategy development by the City include:

- Stormwater Quality Strategy (SWQS), completed June 2008;
- Total Loading Plan (TLP) for TSS, completed June 2009; and
- Updated CSO Control Strategy due by June 2012.

Total Loading Plan (TLP) for TSS

In 2002 the City committed itself to partner with Alberta Environment to jointly develop a total loadings framework for City cumulative pollutant discharges to the river. By 2005 this collaborative process had resulted in a loading concept that had a series of study objectives and expected outcomes, these included:

- development and calibration of a 2-D water quality model for the NSR to illustrate changes in water quality from proposed treatment improvements;
- targeting areas for further pollutant reduction;
- the decision that the 2005-2015 Approval-to-Operate reflect the total loading principle;
- that the purpose was *not* to establish an acceptable level of pollution that the river can absorb – but rather use total loadings as a tool for eliminating and/or minimizing the City's impact on the NSR.

The work done to develop the 2-D WASP river water quality model recommended that a total loading objective be first established for TSS – a key indicator for aquatic health in urban receiving watercourses. The 2005 total loading report entitled "*NSR Impact Study: Development of Total Loading Management Objectives for the City of Edmonton*" concluded that average TSS loadings from years 1994 through 2004 were not causing observable biological effects in the river. The TLP framework therefore assumes that capping City TSS discharges to current baseline levels (28,870 kg/day) is appropriate to ensure a healthy aquatic ecosystem. The TLP framework addresses load reductions from all major sources by means of:

- Stormwater Quality Strategy (SWQS) to address stormwater loadings; and
- CSO Control Strategy to address combined sewer overflows and related improvements in treatment at EPCOR's Gold Bar WWTP.

Some key outcomes from the development of the TLP include:

- stormwater is <u>the</u> major source of TSS to the river;

- enhanced primary treatment (EPT) at the Gold Bar WWTP has the potential to reduce TSS loadings by as much as 2,200 kg/d;
- all the SWQS action plan components – 2 end-of-pipe treatment wetlands, 2 low-flow diversions, and staged LID implementation - have a combined potential TSS reduction of about 2,400 kg/d; and
- it is possible to cap TSS loadings to current baseline levels and continue to expand and grow the City's urban footprint – provided that LID practices are implemented to curb future loadings from new land development.

Stormwater Quality Strategy (SWQS)

The SWQS was developed to improve local watershed health by reducing stormwater pollutant loadings to the NSR. A review of potential stormwater quality improvement projects and a subsequent treatment concept feasibility assessment identified the Kennedale end-of-pipe treatment facility as a key project to provide the City with cost-effective TSS reduction, watershed protection benefits, and improved Hermitage Park aesthetics. Construction of the Kennedale treatment facility was completed in October 2009 – Edmonton's first wetland built exclusively for improving stormwater quality before discharge to the river. The $7 million treatment facility includes a set of oil/grit separators, park space improvements, and serves as the last barrier for treatment for urban runoff from the 7,250 ha Kennedale drainage basin. It is expected that about 1,100 kg/d (or 44%) of the suspended solids from the Kennedale trunk sewer will be removed prior to discharge to the river. With facility monitoring starting in 2010, the wetland's actual TSS load reduction performance will be assessed. Concept planning and design began in Fall 2009 on the Groat Road treatment wetland facility in Government House Park.

Constructed wetlands are examples of "green" infrastructure and are a cost-effective approach for treating stormwater. Edmonton has over a dozen constructed wetlands but these are located in upstream reaches of urban storm basins serving local neighbourhoods primarily for flood protection. But even these constructed wetlands do not address the very large increase in the volume of stormwater that comes with development, resulting in tributary stream erosion and higher pollutant loadings. The SWQS is looking at a more integrated approach for managing stormwater – one that deals with water quality and small storms in addition to the 100-year design storm event.

Low Impact Development (LID) seeks to mimic the natural hydrology of areas before development and use the landscape as a sponge to retain (not just detain) rainwater close to where it falls. This means more "green" infrastructure at the street and lot-level, and goes well beyond current servicing standards based solely on managing the

peak flow rate off a site. Continuing to provide flood protection is very important, but so is dealing with the cumulative water quality issues from the small rainfall storms that occur more frequently. The LID approach applies to all land use types, greenfield development and major infill or redevelopment. It's a long-term approach for curtailing future pollutant loads from new urban development. It employs various landscape features such as green roofs, rain gardens, and bioswales to intercept, infiltrate, detain and evapotranspire runoff. Work is currently underway to develop made in Edmonton design guidelines for LID design features that are feasible and practical for our soils and climatic conditions. These design guidelines are expected by the end of 2010 and represent a quantum leap forward in the integration of watershed protective measures into the planning and design of urban lands, and open park spaces. It is also represents a paradigm shift – rainwater *can* now become a resource for creating healthy landscapes and urban forest canopy in our neighbourhoods and Downtown. The benefits of better rainwater and stormwater management are aligned with the goals of Alberta Environment's Water for Life Strategy, the emerging Water Management Framework, and the upcoming Integrated Watershed Management Plan.

CSO Control Strategy

The CSO Control Strategy has been major initiative underway since 1995 and is expected to reduce CSO volumes, and frequency, from an average 3 million m^3 down to an expected 600,000 m^3 of combined sewer flow discharged to the river each year. This corresponds to less than 10 CSO events compared to the current 49 events expected per year. Rather than discharging these combined sewer flows to the river untreated, they will be conveyed to the Gold Bar WWTP using a new pipeline (WESS W12) to be completed in 2011 and treated using the newly built enhanced primary treatment (EPT) process. A network of "real-time control" (RTC) sites is being constructed as part of WESS W12 pipeline project to help capture these flows. As part of the CSO Control Strategy infrastructure improvements, the Gold Bar WWTP will be able to provide additional treatment capacity: upwards of 1,200 ML/d of at least primary treatment, with an additional 1,000 ML/d capacity for screening of solids and floatables. Further improvements are expected to come in 2011 with the on-site construction of Digesters #7 and #8 which are needed to manage the additional mass of solids expected from sludges in the newly built EPT facility. Besides the sanitary/combined end-of-pipe treatment improvements, the CSO Control Strategy is also based on two fundamental policies: to undertake opportunistic sewer separation as possible in combined sewer areas of the City; and that any major in-fill and/or City redevelopment be serviced such that CSOs volumes and frequency are not increased.

Other Supporting Strategies

The following strategies further support the Drainage Branch's goal of advancing watershed protection.

Biosolids Management Plan

Expected in 2011, this Plan will identify new technology options and regional opportunities for beneficial uses of biosolids generated from the WWTP which are cost-effective and sustainable.

Sanitary Servicing Strategy Fund

The Sanitary Servicing Strategy is a Council approved plan used for financing major sanitary trunk construction. It includes a 75 year construction plan for four major sanitary trunk sewers in the City. As of 2010, about 20% of the planned sanitary trunk sewer construction has been completed. This Strategy helps to reduce the frequency of CSOs to the NSR and diverts these combined flows to the Gold Bar WWTP for treatment.

Wetlands Acquisition Plan

This Plan was initiated in 2009 to facilitate the acquisition of wetlands to help support flood protection and stormwater water quality goals. Phase 1 of the project involved a desktop screening of over potential 300 sites. Phase II to be completed by December 2010 is a more detailed review of these sites through field evaluations.

Challenges? … for holding the limit and/or reducing City discharges

- Population growth – increasing population results in increasing consumption of resources including water, and increasing pollutant loadings.

- Climate change – less seasonal rainfall during the summer months will result in more artificial watering to irrigate landscape and park spaces.

- Funding stormwater infrastructure – the land drainage system has been historically under funded, this gap could worsen with less municipal infrastructure funding available.

- Land zoning credit – are Municipal Reserve lands such as school fields that detain stormwater and/or retain on-site rainwater deemed a Public Utility Lot (PUL)?

- Demonstrate performance – any new LID features must be tested out and assessed for their relative performance for treatment and O&M practicality and affordability.

- Natural areas Policy C531 - outlines preservation activities when integrating the upland and the river valley with natural areas. The City's commitment to ecological considerations does not always align itself with the use of wetlands for managing stormwater runoff volumes and improving water quality.

- Alberta Water Act – under this Act is a Code of Practice for outfall structures that has the potential to encumber City applications for additional outfall structures.

- National Plumbing code and Alberta Building Code are serious legal obstacles for re-use of harvested rainwater and grey water.

- Lack of regulatory tools or provisions to promote City water re-use applications.

- City land development servicing standards are not LID friendly.

- No provincial or federal incentives to help promote implementation of LID in new urban design.

- Performance governance of LID features such as green roofs and/or BMPs like oil/grit separators on privately-owned property.

Opportunities? … for holding the limit and/or reducing City discharges

- It is expected that the Government of Alberta will endorse the draft Water Quality Objectives as set forth in the Integrated Watershed Management Plan for the NSR. If endorsed, these WQO's will require point and non-point source reductions be examined on the basis of a "no net further degradation" principle. This may raise the profile of the City's TLP for TSS and ensure funding availability for the proposed Groat Road end-of-pipe treatment wetland facility in Government House Park.

- Downtown densification and redevelopment – the renewal of the City's downtown core provides a unique opportunity to improve stormwater quality by including LID features such as green roofs, rain gardens, permeable pavers, and bioswales into the new urban footprint.

- By integrating LID principles into major redevelopment plans, a healthier landscape and improved streetscape aesthetic could make for a more socially inviting "green Downtown" that also protects the watershed and helps to alleviate the potential for local street flooding.

- The Downtown can be a showcase of LID features to demonstrate the City's vision of modern urban design that integrates green infrastructure into the urban core. Water resource management for conservation, rainwater harvesting, and stormwater capture, treatment, and re-use are fundamental components of sustainable community design.

- Integrated planning – better urban landforms should emerge by having more integrating planning/design units from across the City organization working to implement LID features in neighbourhoods and open park spaces.