REAL TIME CONTROL OF COMBINED SEWER OVERFLOW IN EDMONTON

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Abstract: CSO (Combined Sewer Overflow) has negative impacts on the environment due to the pollutants contained in the diluted sanitary flow carried to the river. CSO to the river may have acute effects for the river downstream of the discharge point. About 80% of the annual CSO discharge from the City of Edmonton is from the Rat Creek CSO. The City of Edmonton's Drainage Services has developed a long-term capital works implementation plan to reduce the environmental impacts of the City's combined sewer system. The CSO Control Strategy will mitigate the environmental impacts of Edmonton's combined sewer system. The CSO control plan includes an early action plan and a long term control plan. The main component of the Early Action Control Plan (EACP) involves the mobilization of in-line system storage through the "RTC - Real Time Control" of moveable gates/dams. Two real time control gates, RTC4&6, were built in 2002 and 2004, respectively. Another real time control gate, RTC3 has just been built and currently under operation. Since RTC4&6 were built, a total of 3,995,000 m^3 flow has been prevented from CSO at Rat Creek. The CSO at Rat Creek will be reduced even more significantly with RTC3's operation.

1 INTRODUCTION

Real Time Control (RTC) facilities RTC3, RTC4 and RTC6 were constructed under the Early Action Control Plan (EACP), portion of Edmonton's CSO Control Strategy. The purpose of RTC is to reduce combined sewer overflows by storing flow and reducing the peak flow rate in downstream tunnels during rainstorms and spring snowmelt. Figure 1 shows the RTC4 Trunk Storage Profile. In small storms and snowmelt events, the very large sewers carrying the flow are mostly empty, and these facilities employ gates to store flows in this empty space.

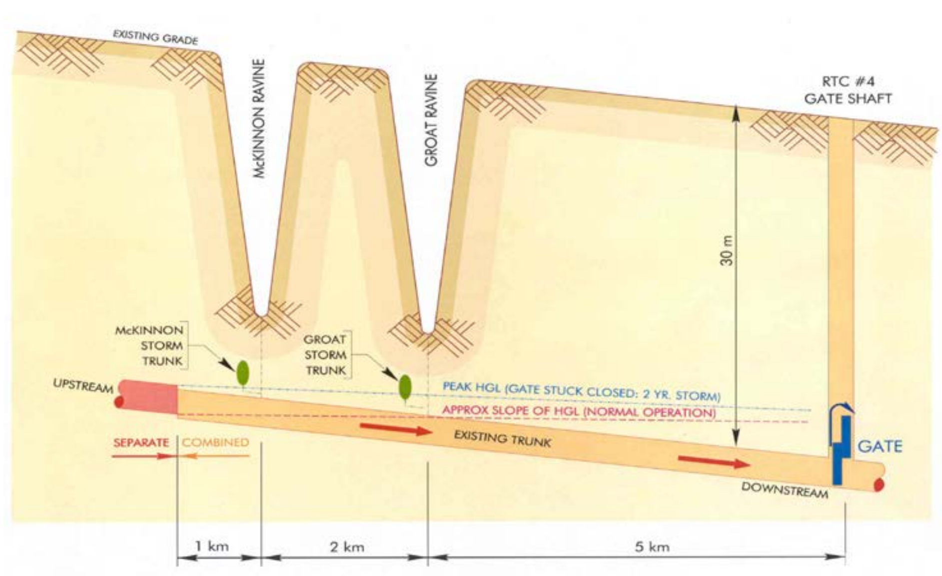

Figure 1: RTC4 Trunk Storage Profile

Conceptual, preliminary, and detailed design of RTC4 was carried out by Infrastructure Systems Ltd. (ISL). Preliminary and detailed design of RTC6 was completed by Edmonton Drainage Design and Construction, with electrical and instrumentation design by Techna West. Both facilities were constructed by the City of Edmonton's Drainage Services, Design and Construction section.

RTC4 is located on a 1.95 meter diameter tunnel, 30 meters below ground level, at 95 Street and 108 Avenue in Edmonton. RTC6 is located on a 2.4 meter diameter tunnel, 20 meters below ground, at 114 Avenue and 101 Street. RTC3 is located on a 3.15 meter diameter tunnel, 35 meters below ground level, at 85 street and Jasper Avenue and was constructed by the City of Edmonton's Drainage Services, Design and Construction section. The locations for RTCs can be seen from Figure 2.

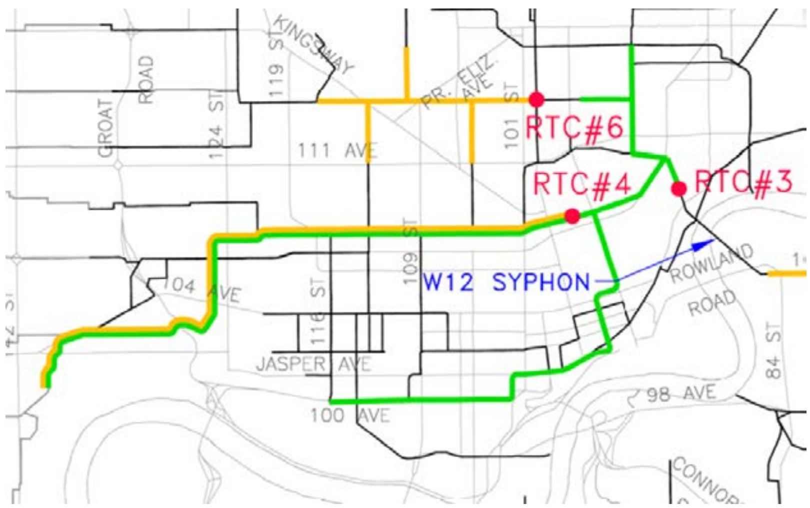

Figure 2: Locations of RTC3, 4, and 6

RTC4 and RTC6 are similar in configuration, having the same physical components and operational concept. Both RTCs utilize 2 set points for control: upstream and downstream. The upstream set point is normally set to the maximum desired storage level (i.e. doesn't cause basement flooding or manhole surcharge in the upstream areas). The downstream set point is normally set to the peak dry weather flow level. CSO is estimated to begin when downstream level is above this set point and this is confirmed by sensors at overflow points as well as occasional visual confirmation during events. When the upstream water level is lower than the upstream set point, the downstream water level controls gate operation; and when the upstream water level is equal to or higher than the upstream set point, the upstream water level controls gate operation. RTC3, a new facility, is controlled by two PID (proportional integral derivative) loops, for upstream and downstream control, and the syphon gate is controlled by one PID loop for upstream control. The RTC3 gate operates similar to RTC4 and 6, but when flows rise beyond its storage capacity they are diverted via the W12 siphon to a high rate treatment system at the Gold Bar Wastewater Treatment Plant.

RTC4 and RTC6 are most effective during small and medium sized rainstorms and snowmelt events, but have limited effect during long duration or heavy rainfall events. RTC3 and the W12 siphon were operational in 2014. The W12 tunnel will divert the flow that is more than RTC3 storage capacity to Gold Bar Wastewater Treatment Plant for treatment. RTC3 and the W12 tunnel will reduce the CSO at Rat creek significantly.

2 METHODS

The storage rating curves were developed by ISL Engineering for storage analysis and were used for storage analysis and to calculate the volumes of flow prevented from entering the river.

Based on the most conservative stage-storage curve, the formula of $Y=-6.0797x^5+109.85x^4-740.28x^3+2473.7x^2-1799.1x+614.3$ was used for RTC4 (figure 3). The maximum storage from this curve is 15,600 m^3 when the storage depth is about 6.5m. Here Y is the storage volume in cubic meters (m^3), and x is the flow depth measured in front of the gate shaft (upstream level).

For RTC6, the storage rating curve is $Y=1.0551x^5-17.649x^4 +56.729x^3 +324.78x^2-378.23x$ (figure 4) with a maximum storage of 10,600 m^3 when the storage depth is about 9.0 m. Here Y is the storage volume in cubic meters (m^3), and x is the flow depth measured in front of the gate shaft (upstream level).

For RTC3, the storage rating curve is Y= 1843.2 x- 1154840.3 (Figure 5) with a maximum storage of 25,000 m^3 when the storage depth is about 10m. Here Y is the storage volume in cubic neters (m^3), and x is the flow depth measured in front of the gate shaft (upstream level).

A loading analysis for RTC4&6 was also conducted in order to estimate how much pollution was discharged to the North Saskatchewan River and how much was reduced due to operations of RTC4&6.

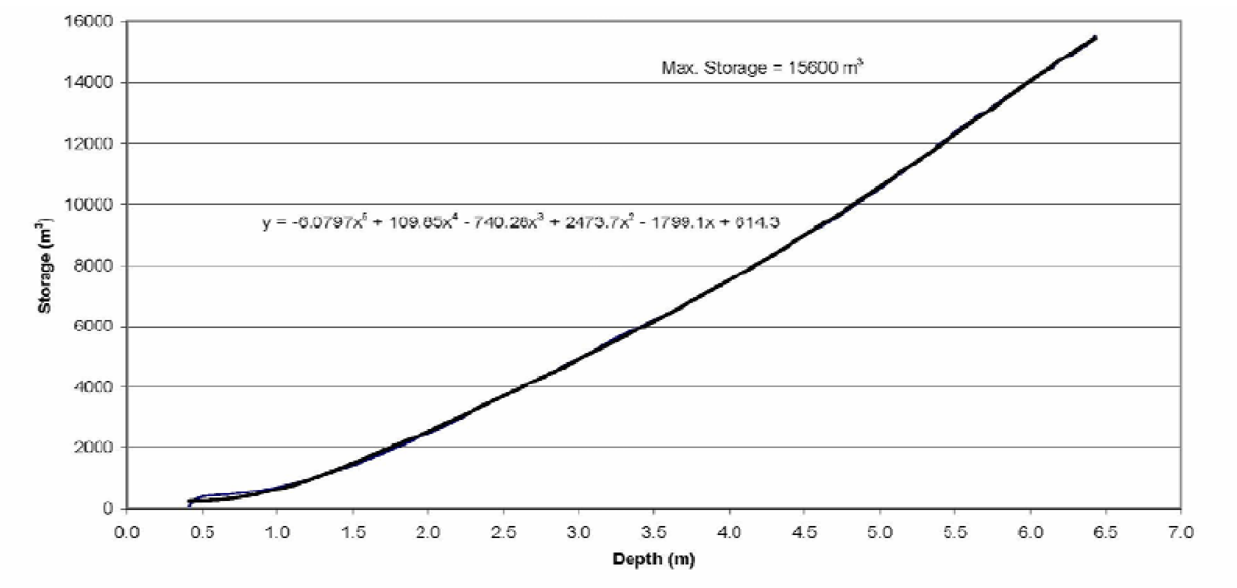

Figure 3: Storage Rating Curve for RTC4

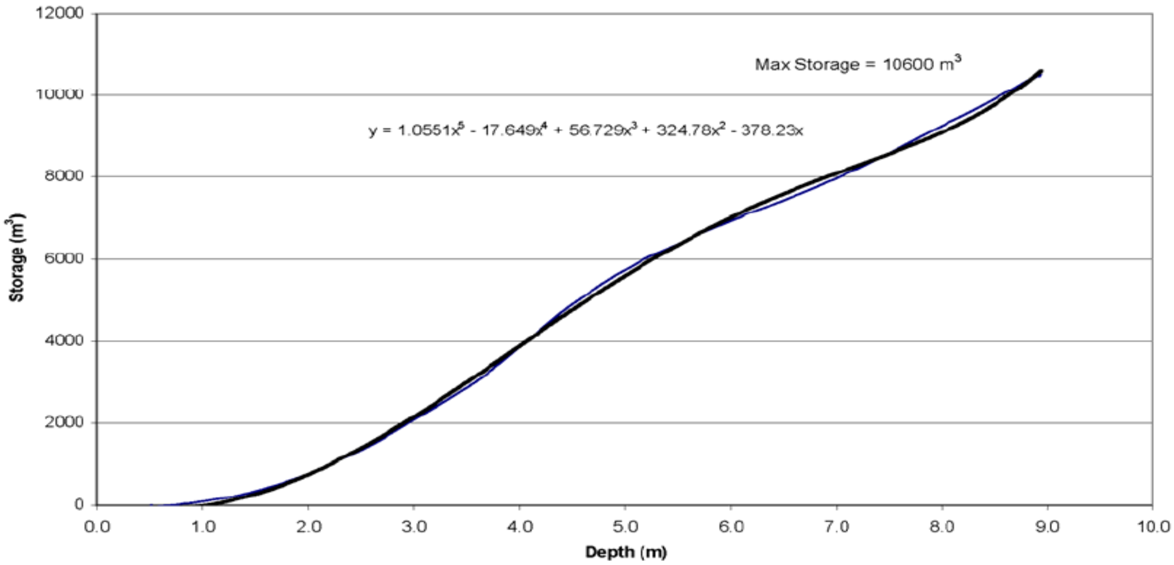

Figure 4: Storage Rating Curve for RTC6

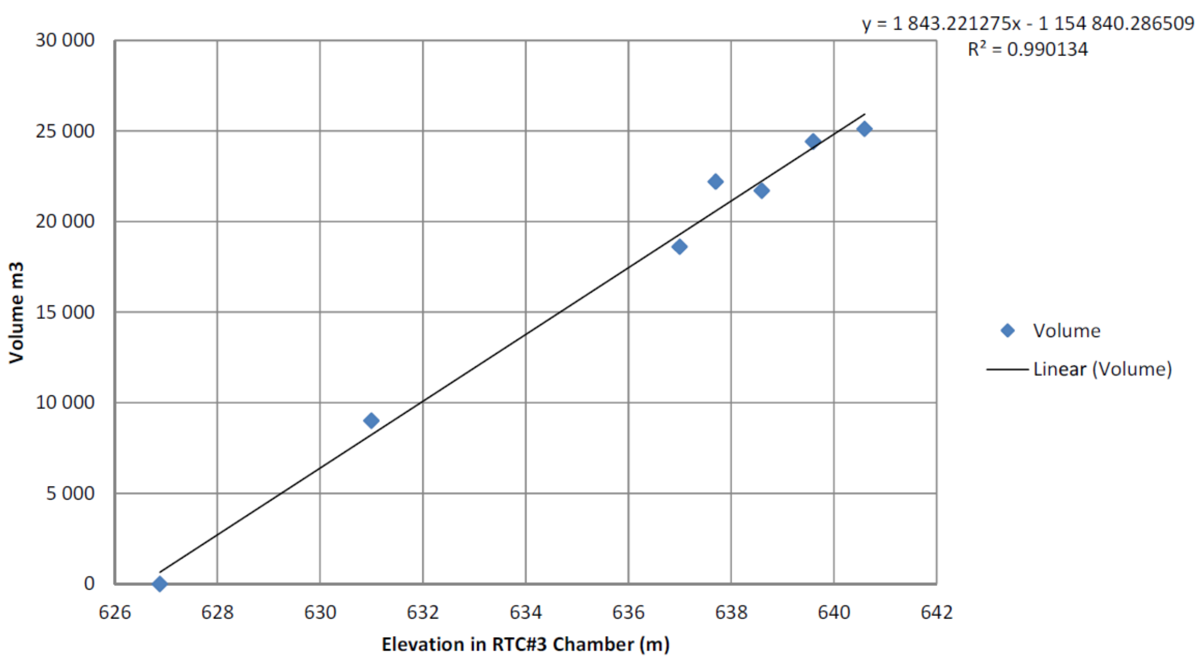

Figure 5: Storage Rating Curve for RTC3

The data for analysis was collected from:

- Rain Gauge(RG) data, for the rainfall events (mm) was taken from WISKI (a software for the city's Flow and Rainfall monitoring). RG#18 (located in downtown Edmonton) was used for the study.
- WISKI program for RCT4: site 361 and RTC6: site 435, obtained upstream levels (m).
- WISKI program for RCT4: site 362 and RTC6: site 425, obtained downstream levels (m).
- WISKI program for Rat Creek CSO volumes (Site#118).
- 2012 Rat Creek CSO quality annual report to the City of Edmonton By Golder Associates.
- SCADA program: obtained gate positions for RTC4 and RTC6.

- Data collection for RTC3 started later 2014 and was not included in this paper as there is no storage activity during dry weather.

3 PERFORMANCE

3.1 RTCs for Snowmelt

As Edmonton is a cold climate city, snowmelt has significant impact on its CSO. Snowmelt usually happens from March to April in spring season. RTCs can have a higher CSO reduction rate for snowmelt than summer rainfall events since snowmelt is a slow process. This process is similar to the RTCs responding for small rainfall events.

Figure 6 is the comparison to previous years (2008-2014) of spring CSO volume and CSO reduction at Rat Creek. The winter precipitation values (November - April) were obtained from Environment Canada. The blue bars show the volume of CSO prevented from entering the river.

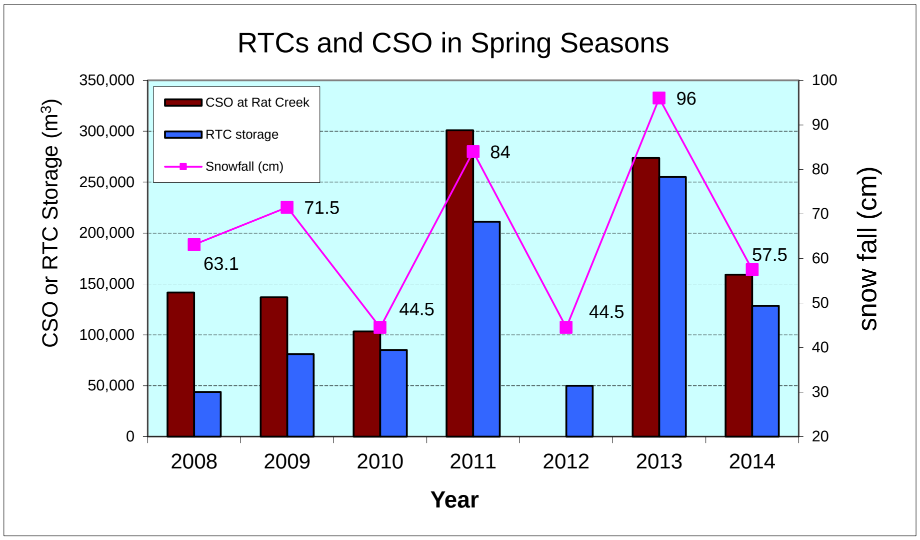

Figure 6: RTCs and CSO in Spring Season

3.2 RTCs for rainfall events

RTC storage for rainfall counts about 80% of the total storage. However the reduction rate for rainfall was lower than the reduction rate during snowmelt as the peak flows from rainfall are greater than from snowmelt. A typical storage event can be seen from figure 7. The large blue bulge in the figure is the increase in level as flows are being stored.

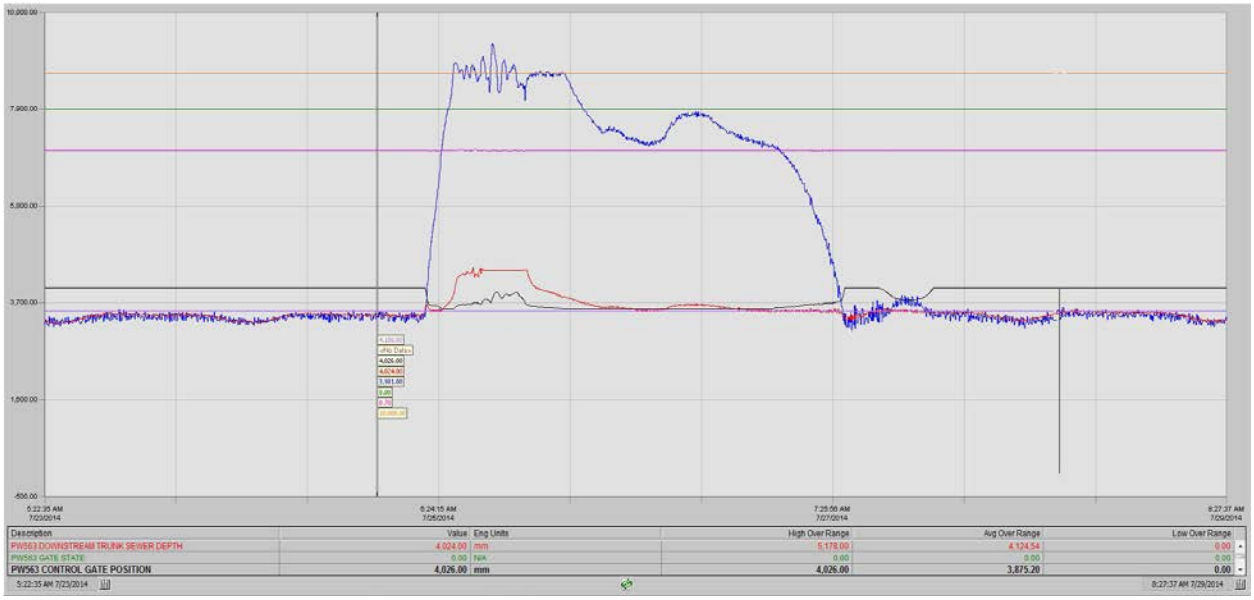

Figure 7: A typical Storage for RTCs

4 TOTAL STORAGE FOR RTC4&6

Table 1 summarizes the RTC4&6's performance from 2004 to 2014. The total annual storage for RTC4 and RTC6 was 3,995,229 m^3. The total CSO at Rat Creek was 19,124,455 m^3. The average CSO reduction rate from 2004- 2014 was 17.3%. Note that RTC6 was constructed and started work in 2006. RTC3 started work in later 2014.

Table 1: RTC4&6 storage and CSO reduction rate

Year	RTC4 (m^3)	RTC6 (m^3)	Total (m^3)	Rat Creek CSO (m^3)	% reduction
2004	19,700	0	19,700	2,573,800	0.8%
2005	149,900	0	149,900	969,000	13.4%
2006	313,600	224,500	538,100	1,670,700	24.4%
2007	305,429	273,732	579,161	1,242,438	31.8%
2008	120,435	197,630	318,065	839,354	27.5%
2009	90,151	131,748	221,899	608,454	26.7%
2010	197,631	141,866	339,497	2,159,800	13.6%
2011	314,527	197,949	512,475	2,284,472	18.3%
2012	239,420	139,456	378,876	1,331,440	22.2%
2013	394,324	163,378	557,702	3,293,395	14.5%
2014	208,056	171,798	379,853	2,151,602	15.0%
Total	2,353,173	1,642,056	3,995,229	19,124,455	17.3%

RTC4&6 have prevented 3,995,229 m^3 from CSO at Rat Creek since 2004. This amount is equivalent to about 13 day's treatment capacity for the Gold Bar WWTP (310ML/day).

The CSO events at Rat Creek are expected to be reduced from about 50 times a year to a few times a year when RTC3 and the W12 tunnel are in used.

5 CSO REDUCTION AND THE ENVIRONMENTAL IMPACT ASSESSMENT

5.1 CSO Reduction

As shown in table 1, RTC4 and RTC 6 can significantly reduce the total annual CSO volume if they are operated correctly for the wet weather season. The total CSO reduction in 2014 was 379,853 m^3, or 15% of the total. Figure 8 demonstrates the CSO reductions from 2004-2014.

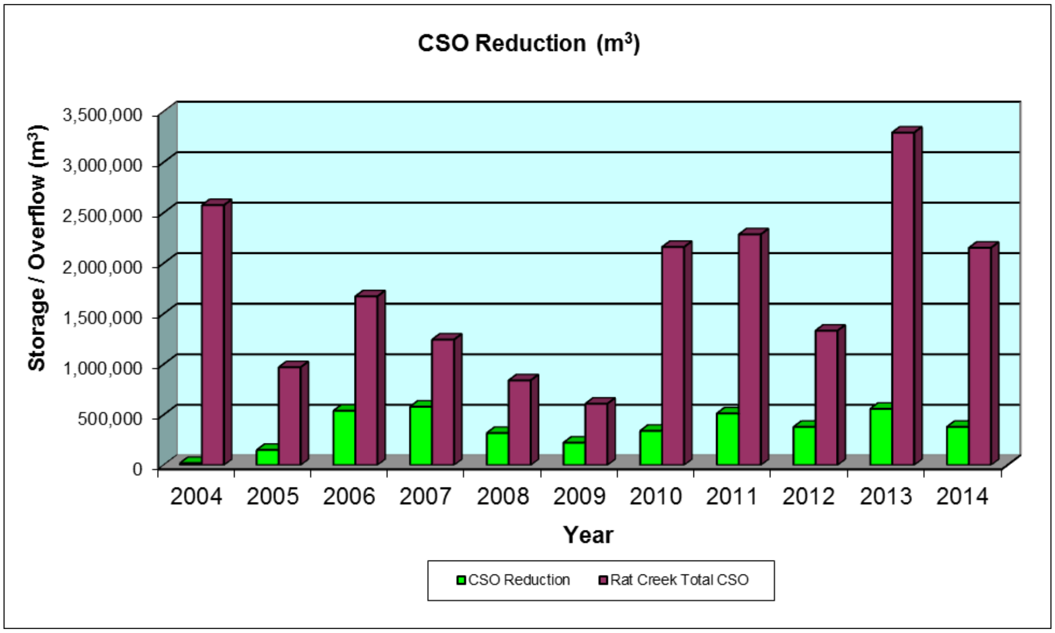

Figure 8: CSO Reductions 2004-2014

5.2 River Loading Assessment

The river loading reduction was calculated to assess RTC's positive environment impact. The loading to the river was estimated by applying average constituent concentrations for CSO at Rat Creek to the CSO reduction volumes.

The following parameters were estimated:

- Biochemical oxygen demand (BOD)
- Total suspended solids (TSS)
- Ammonia (NH_3)
- Total Kjeldahl Nitrogen (TKN)
- Nitrate and Nitrite (NO_3+NO_2)
- Total Phosphorous (TP) and
- Bacteria (*E coli.*)

As detailed in Table 2 and Figure 9-10, the loading to the North Saskatchewan River from Rat Creek CSO had been reduced because of RTC4 and RTC6. CSO concentrations at Rat Creek were obtained from the CSO quality monthly reports to the City of Edmonton completed by Golder Associates. Golder Associates is the City's contractor for CSO sampling and analysis of data. The average (Geomean) concentrations between July and August were used for the calculation.

Table 2: Loading reduction at Rat Creek 2004 – 2014

Pollutants	BOD (mg/L)	TSS (mg/L)	Ammonia (mg-N/L)	NO_3+NO_2 (mg-N/L)	TKN (mg/L)	TP (mg/L)	*E Coli.* (#/100mL)
Concentrations	105	428	8.79	1.19	18.75	3.68	1.99E+06
Loading Reduction(kg)	364,373	1,438,349	27,292	3,695	58,217	12,098	72,784E+12*

Note: * most probable number (MPN) of *E coli.*

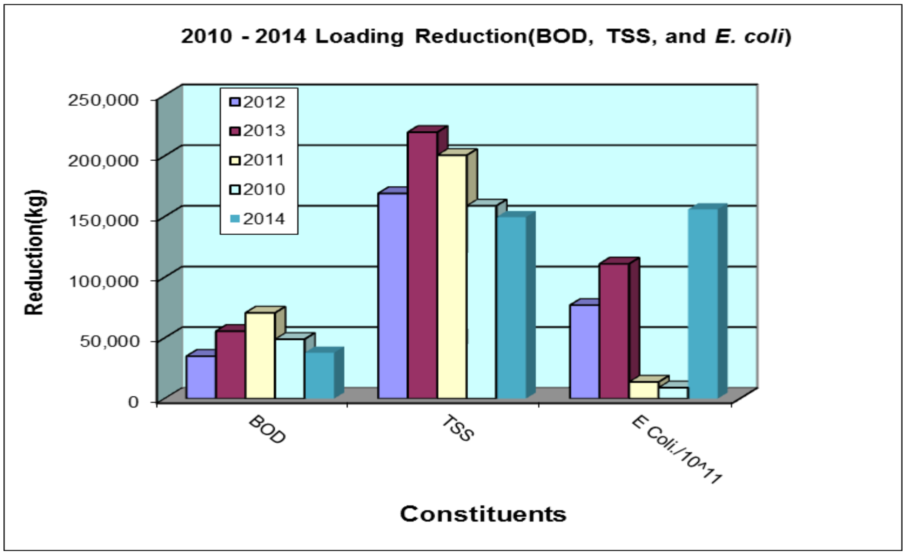

Figure 9: Loading Reduction (BOD, TSS, and *E. coli*)

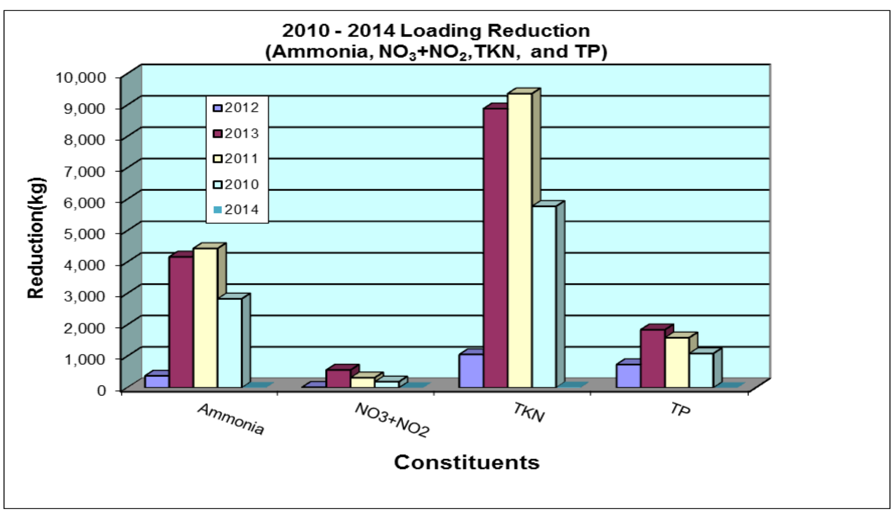

Figure 10: Loading Reduction (Ammonia, N, and TP)

6.0 SUMMARY OF CSO CONTROL AT RAT CREEK

CSO has negative impacts on the environment due to the pollutants contained in the diluted sanitary flow carried to the river. CSO to the river may have acute effects for the river downstream of the discharge point even though pollutant concentrations are about one fourth of the original concentrations from sanitary sewer (table 2). About 80% of the annual CSO discharge from the city is from the Rat Creek CSO.

The City of Edmonton's Drainage Services has developed a long-term capital works implementation plan to reduce the environmental impacts of the City's combined sewer system. Costing about $150 million, the CSO Control Strategy will mitigate the environmental impacts of Edmonton's combined sewer system. The CSO control plan includes an early action plan and a long term control plan. The main component of the Early Action Control Plan (EACP) involves the mobilization of in-line system storage through the "Real Time Control" of moveable gates/dams. $5 million has been spent for building RTC4&6; in addition, RTC3 was just built in 2014. Since RTC4&6 were built, a total of 3,995,229m^3 flow has been prevented from discharging into the North Saskatchewan River. RTC3 and the W12 syphon are located upstream of the Rat Creek CSO site and started operation last December. As shown in figure 11, CSO volumes at Rat Creek will be reduced significantly in the future.

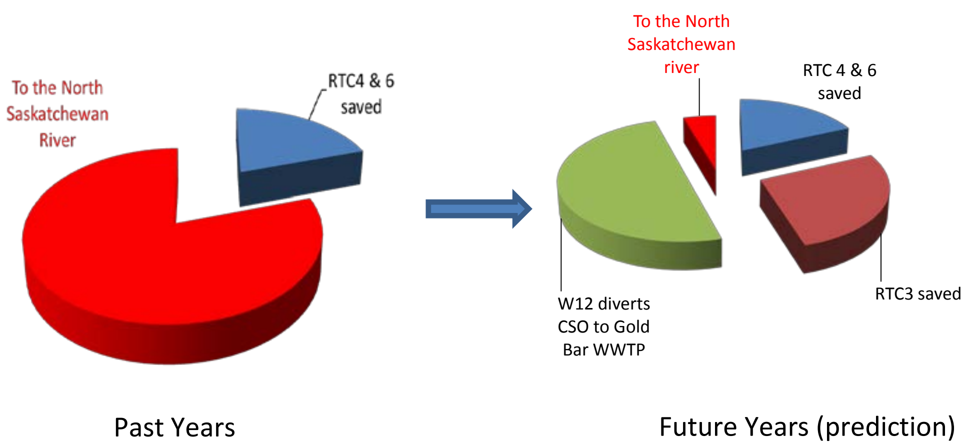

Figure 11: Future CSO volume reduction at Rat Creek

7.0 CONCLUSIONS

- The RTC4&6's performance from 2004 to 2014 was assessed in this report. About 4,000,000 m^3 of CSO have been saved since 2004 by RTC 4 and RTC6. RTC3 started to work in later 2014 and will be assessed in the future.
- RTC4 and RTC 6 can reduce the total annual CSO volume effectively if they are operated correctly for the wet weather season. The total CSO reduction rate from 2004 to 2014 was 17.3% of the total CSO at Rat Creek.
- The loading to the North Saskatchewan River from Rat Creek CSO has been reduced since 2004 because of RTC4 and RTC6. TSS, TP and BOD were reduced by 1,438 tons, 12 tons and 364 tons, respectively. Bacteria (*E Coli*.) number was reduced by 72,784E+12.
- The frequency of CSO at Rat Creek will be reduced significantly when RTC 3 and W12 tunnel are in use. The CSO frequency in normal year can be reduced from about 50 times a year to about a few times a year.

- The flow that is over RTC3 maximum storage will be diverted through W12 tunnel to Gold Bar wastewater treatment plant to have EPT (Enhanced Primary Treatment) treatment. Due to the fact that EPT is not designed for fully removing nutrients, biochemical oxygen demand, and bacteria, it is also important to further reduce the flow through the W12 tunnel to the plant and store as much flow as possible for full treatment.

- To further reduce combined sewer overflow, some other projects, such as combined sewer separation and low impact development (LID) are being implemented in Edmonton. This is a good resource control practice for CSO reduction.

- As RTC 3, RTC4, and RTC6 were built to control CSO from North Edmonton area, a new RTC site in south Edmonton may be constructed in the future to reduce CSO from the south combined sewer area.

References

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2. The Development of Operation Philosophy of RTC Gates, ISL Engineering and Land Servicers, 2010
3. 2013 Environmental Monitoring Program (EMP), Golder Associates, 2013
4. RTC4&6 assessment reports 2007-2014, Drainage Services, City of Edmonton
5. 2013 Wastewater Treatment Annual Report, EPCOR, Edmonton, 2013