Revised
PW9.13

TORONTO

STAFF REPORT
ACTION REQUIRED

Street Sweeper Evaluation Results and Operational Considerations

Date:	October 21, 2015
To:	Public Works and Infrastructure Committee
From:	General Manager, Transportation Services
Wards:	All Wards
Reference Number:	P:\2015\ClusterB\TRA\TIM\pw15008tim.docx

SUMMARY

The purpose of this report is to respond to a request from the City Council to review the City's existing street sweeper fleet and assess its effectiveness in improving the ambient air quality on city roads through the removal of fine road dust, the tonnage of street debris collected, equipment maintenance costs and downtime.

In addition, the report identifies some of the current challenges Transportation Services has been experiencing due to the fact that the fleet complement is limited to a single technology which cannot meet some of the operational conditions encountered on City roads. To address these concerns, the report provides details on a replacement plan and seeks City Council approval to have a mixed fleet of sweeper technology. A mixed fleet of sweepers is essential in order to ensure the maximum effectiveness under various operational conditions, especially in handling debris removal during spring clean-up, leaf collection season, post storm event clean-up and expressway cleaning.

RECOMMENDATION

The General Manager, Transportation Services recommends that:

1. City Council approve that Transportation Services' complement of street sweepers be comprised of a mixed fleet of sweeping technology, including regenerative-air, mechanical and other types of technology to ensure that both environmental and operational requirements can be met, and that the environmental (PM_{10} and $PM_{2.5}$ efficiency) and operational performance of any procured sweeper be third party verified under Environment Canada's Environmental Technology Verification Program (ETV).

Financial Impact

Transportation Services will begin the replacement of its aging fleet of street sweepers in 2016. Approximately ten (10) regenerative-air or other type of technology (i.e., non-mechanical) street sweepers will be procured in 2016 and approximately fourteen (14) mechanical-type street sweepers in 2017. The cost to replace the non-mechanical and mechanical street sweepers in 2016 and 2017 is approximately $5.8 million spread over the two years and will be funded through the division's 'Transportation Vehicle Reserve Account', number XQ1015.

The Deputy City Manager and Chief Financial Officer has reviewed this report and agrees with the financial impact information.

DECISION HISTORY

City Council, at its meeting of July 19, 20, 21 and 26, 2005, adopted a staff report entitled, "PM_{10} and $PM_{2.5}$ Efficient Street Sweepers for the City of Toronto" (Works Committee Report 7, Clause 4). http://www.toronto.ca/legdocs/2005/agendas/committees/wks/wks050629/it009.pdf

In addition, the following motion was adopted requesting,

"That the Acting General Manager, Transportation Services, be requested to report to the Works Committee, six months after the street sweepers have been in place, on the effectiveness of such sweepers."

City Council at its meeting of July 7, 8 and 9, 2015 received for information a staff report entitled, "Auditor General's Office - Forensic Unit Status Report on Outstanding Recommendations" (AU3.13). Within Appendix 1(Recommendations Not Fully Implemented) of this report, the Auditor General highlighted the following outstanding recommendation http://www.toronto.ca/legdocs/mmis/2015/au/bgrd/backgroundfile-81321.pdf:

"City Council request the Chief Corporate Officer, in consultation with the General Manager, Transportation Services Division, to review the City's street sweeping performance measurement processes and where applicable develop appropriate measures. Such a process be developed in order to measure the ongoing effectiveness of the City's street sweeping services as well as identify areas which require attention. Areas which should be addressed would include, but not limited to, air quality, tonnage of debris collected and equipment downtime information. Such an evaluation be reported to City Council as required in 2006."

ISSUE BACKGROUND

The Transportation Services Division has, until very recently, been deploying a mixed fleet of street sweepers in order to mirror operational needs and manage the very diverse operational conditions. The regenerative-air street sweepers have contributed to the removal of a significant amount of fine

particulate matter from the City of Toronto's paved roads year-round and have benefits to the community, including:

- reduced airborne particulate matter which contributes to GHG emissions;
- improved local air quality and benefits to the general health of City's residents, workers and visitors, by reducing acute and chronic exposure of fine particulates;
- removal of toxic loads from City streets thereby improving storm water quality and reducing the cost of storm water treatment; and
- year-round sweeping including on Smog Days.

The Transportation Services Division, in collaboration with other divisions, developed and implemented the Clean Roads to Clean Air Program (CRCA) in 2005. The program helped to develop procedures and standards to evaluate the operational and environmental (PM_{10} and $PM_{2.5}$ efficiency) performance levels of various street sweeper technologies, and created a framework for continual assessment and improvement of sweeping practices. A significant outcome of the program was the development of two sweeper testing protocols; "Operational On-Street" and "PM_{10} and $PM_{2.5}$ Street Sweeper Efficiency" and respective performance criteria. These two testing protocols were adopted by Environment Canada's Environmental Technology Verification Program (ETV), which provides third party verification services.

In a staff report in 2005 titled, 'PM_{10} and $PM_{2.5}$ Efficient Street Sweepers for the City of Toronto (All Wards)', the CRCA program was detailed and a street sweeper replacement plan was presented including identifying for Council the need to have a mixed fleet of street sweeper technology in order to provide an optimal street sweeping solution to not only reduce the accumulation of fine particulate matter ($PM_{10,}$ and $PM_{2.5}$) from the City's roads, but also to effectively handle the removal of significant amounts of road debris during spring clean-up, leaf collection season and expressway cleaning. However, City Council at its meeting on July 16, 17, 18 and 19, 2007, while considering the report entitled, "Climate Change, Clean Air and Sustainable Energy Action Plan: Moving from Framework to Action"(EX10.3), adopted, among many other motions, motion number 9 that directed, "…the General Manager of Transportation Services to include in the 2008 Capital Budget submission an allocation (estimated at $7 million) to move the entire street sweeper fleet to new technology, based upon the success of the Clean Roads to Clean Air program…..", which limited replacement of sweepers to only regenerative-air type sweepers and therefore precluded any remaining serviceable mechanical sweepers from being replaced with new mechanical sweepers.

In 2007 and 2008 Transportation Services replaced its complement of aging street sweepers with $PM_{10,}$ and $PM_{2.5}$ compliant regenerative-air street sweepers, which were third party verified under the ETV program. These sweepers are approaching the end of their service life and need to be replaced over the next few years.

COMMENTS

City Council requested that the Transportation Services Division report back on the effectiveness of its existing street sweeper fleet. The information that will be discussed in greater detail in the following sections will include impacts on air quality, tonnage of debris removed from city roads and equipment maintenance cost and downtime.

Street Sweeper Ambient Air Quality Monitoring Study

In 2014, an ambient air quality monitoring study (Study) was undertaken to assess the effectiveness of regenerative-air street sweepers in improving the ambient air quality through the reduction of PM_{10} and $PM_{2.5}$ concentration levels on City streets. This Study is the monitoring component of the CRCA Program that was initiated back in 2003. As part of the Study, ambient air quality testing was undertaken to measure the performance of both a mechanical and regenerative-air street sweeper to obtain the following results:

- Ambient air quality concentrations, measured at nose-level, pre- and post-street sweeping;
- Dust concentration levels during sweeping operation; and
- Silt loading removal from the paved road surface pre- and post-sweeping.

The test was conducted on Markham Road, between McNicoll and Turbina Avenues. Stationary monitors were used to measure the ambient air quality continuously for 48 hours each week for three consecutive weeks. Air quality monitors were set at three different height levels (1.5 metres, 3 metres and 4. 5 metres) measuring both PM_{10} and $PM_{2.5}$ concentrations every 3 seconds. This monitoring sequence was done for both the mechanical and regenerative-air sweepers and a comparative analysis was undertaken of the data collected.

The testing attempted to replicate the silt loading conditions on the paved surface of the road pre-and post-deployment of the regenerative-air street sweeper in order to determine the effectiveness of the sweeper technology as a mitigating measure on ambient air quality. The testing measured the air quality in a real world environment, recognizing that many environmental conditions could not be controlled. This testing differs from the one that would be done under the City of Toronto's PM_{10} and $PM_{2.5}$ Street Sweeper Efficiency Test protocol, which was developed to control as many environmental factors using a systematic, quantifiable and objective approach to evaluate and ultimately determine the most efficient PM_{10} and $PM_{2.5}$ street sweeper technology for procurement purposes.

Test Results

An analysis was done on the collected data to compare the ambient air quality concentration levels prior to, during and after street sweeping for both the mechanical and regenerative-air street sweepers. In addition, silt loading data was collected prior to and after street sweeping to determine the removal efficiency of each sweeper. Tables 1 to 3 in Appendix 1, show the results of the tests for the respective street sweepers. The measured concentration levels and removal efficiency quantities were averaged for all three days of testing for each street sweeper. The final results clearly demonstrate that the regenerative-air street sweeper:

- has a removal efficiency that is 2.5 times higher when compared to the mechanical sweeper (i.e., 66% versus 26% - further detailed in Tables 1 and 2 of Appendix 1).;
- when compared to the mechanical sweeper has higher average entrainment efficiency levels for both PM_{10} and $PM_{2.5}$ (90% and 89%, respectively), during the actual sweeping process (refer to Table 3 in Appendix 1); and

- has Maximum PM_{10} and $PM_{2.5}$ ambient air concentrations measured pre-and post-street sweeping that were four to five times better than for the mechanical street sweeper (see Tables 1 and 2, Appendix 1).

These regenerative-air street sweepers have allowed for a significant amount of fine particulate matter to be removed from the City of Toronto's paved roads year-round. *The results of the 2014 Study demonstrated that the regenerative-air street sweeper can reduce airborne fine particulate matter, at street level, by at least 27% (this figure arrived at by taking the average difference in efficiency criteria between the regenerative-air and mechanical sweepers summarized in Tables 1 & 2, Appendix 1).*

Performance of Existing Fleet of Sweepers

Street Sweeping Tonnage and Kilometres Swept

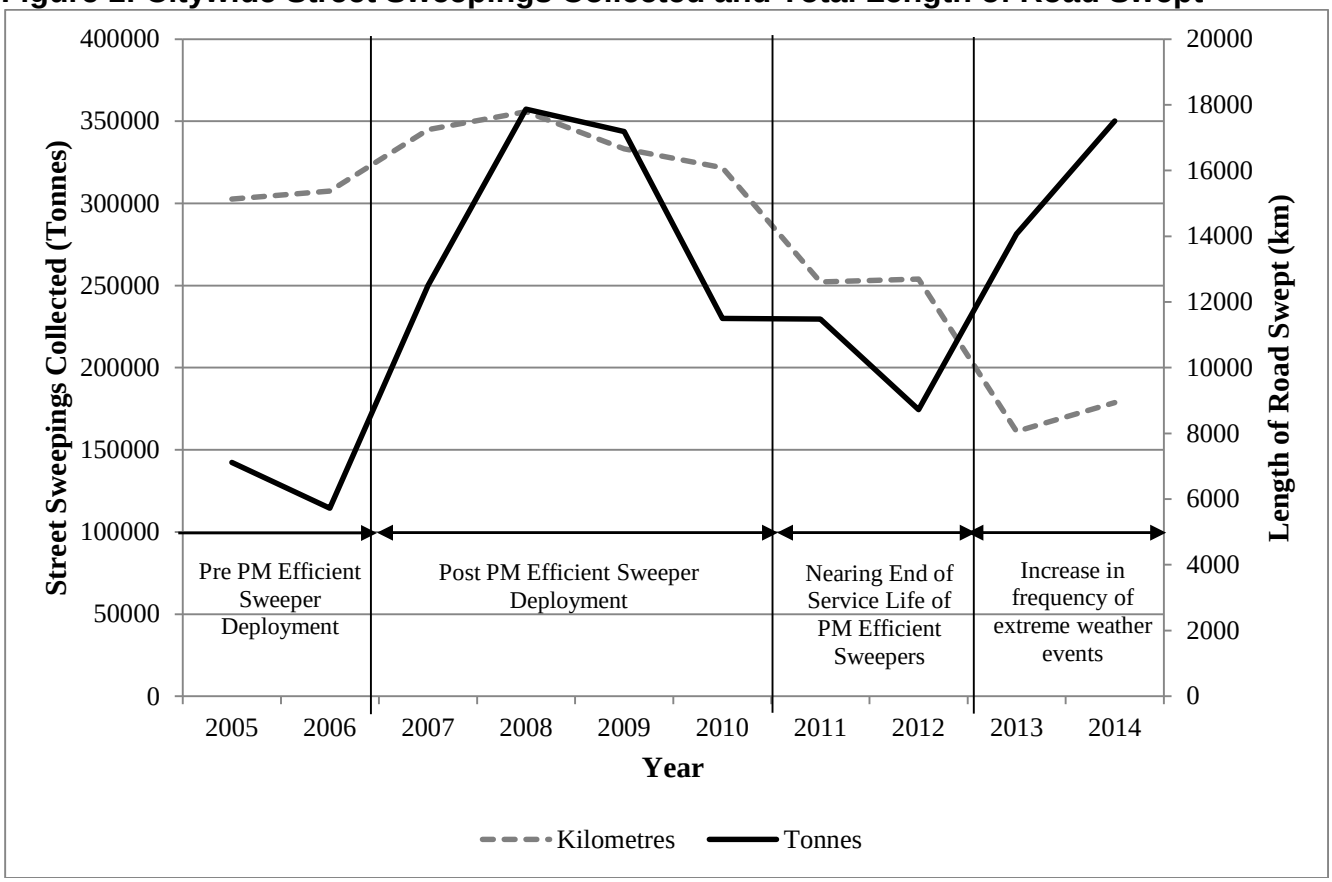
The majority of the City's street sweepers were replaced over a two year period in 2007 and 2008 with 50 new regenerative-air street sweepers, with the exception of 14 mechanical sweepers greater than ten years old which were retained as part of the fleet. The new sweepers resulted in a significant increase in street sweeping material being removed from the City's paved road surface. The actual tonnage of street sweepings is summarized in Table 1 below and shows that the average tonnage for the period 2005 to 2006 (pre-new sweepers) to the period 2007 to 2009, the percentage change in sweeping material removed increased by 247% . This spike is attributed to the effectiveness of the new technology. The amount of material removed has decreased since due to the efficient removal of silt loadings and less accumulation of fine road dust, a decrease in street sweeper service levels and an aging fleet. There was a spike in material removal in 2013/14 due to a number of significant rain events and an ice storm. In addition, a number of regenerative-air sweepers were rebuilt which helped improve their performance.

Table 1: Street Sweeping Tonnage - (2005 to 2014)

Period (Years)	Average Annual Tonnage	Percentage Change From Previous Period
2005 to 2006	6,423	-
2007 to 2009	15,854	247%
2010 to 2011	11,489	- 28%
2012	8,720	-24%
2013 to 2014	15,791	181%

Figure 1 below illustrates the chronology of events contributing to the amount of sweeping material collected from the City's paved road surface and kilometres swept over the period 2005 to 2014, which were discussed in greater detail above.

Figure 1: Citywide Street Sweepings Collected and Total Length of Road Swept



Fleet Maintenance Costs

Average maintenance costs for the fleet units varied from 2005 to 2007, but have remained fairly constant at between $44,000 and $47,000 annually since 2008 as can be seen in Table 2 below.

Table 2: Sweeper Units Annual Operating Cost

Item	Units	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total Number of Units	#	22	37	39	64	55	56	54	52	50	50
Total	**$**	**1,958,807**	**1,899,189**	**2,509,973**	**3,012,223**	**2,610,720**	**2,672,415**	**2,448,001**	**2,455,984**	**2,287,996**	**2,220,980**
Cost per Sweeper Unit	**$**	**89,037**	**51,329**	**64,358**	**47,066**	**47,468**	**47,722**	**45,333**	**47,230**	**45,760**	**44,420**

Fleet Availability

For Transportation Services to deliver adequate sweeping service on city roads it needs its full complement of street sweepers operational. Prior to 2010, the sweeper fleet complement was available for sweeping operation almost 100% of the time. However, since 2010 the annual availability of regenerative-air street sweepers has declined to around 75% of the time as they reach the end of their service life. In addition, the number of street sweepers has declined from 56 sweepers in 2010 to 50 sweepers in 2014. For 2015, the fleet consists of only 48 regenerative-air street sweepers. No mechanical street sweepers are operational.

As the regenerative-air street sweepers exceed their service life, the percentage of the fleet that will be available will decrease further.

Operational Issues

Over the years a number of conditions have arisen that have put pressure on the aging fleet of $PM_{10,}$ and $PM_{2.5}$ efficient street sweepers, namely:

- An increase in the quantity of silt loading material due to the decrease in sweeping frequency, especially on the local road network;
- Removal of large debris, due to spring clean-up and extreme weather events. These pose operational problems and can lead to the damaging of the regenerative-air street sweepers, due to the design of their collection components;
- A decrease in the availability and reliability of the current fleet of regenerative-air street sweepers that are beyond their service life;
- There are no remaining mechanical sweepers as part of the fleet complement; and
- An increase in the number of service requests for the period 2008 to 2014 (see Table 1 and Figure 1 in Appendix 3) with almost 3 times more requests in 2014 than in 2008.

The increase in service requests has been particularly marked in the Spring (100% to 160% increase) and Fall (100% increase). The current fleet of regenerative-air street sweeper has experienced problems effectively removing the typical debris associated with these seasonal periods. The mechanical street sweeper is more effective during Spring and Fall because its components are designed to deal with large debris, compacted silt material (i.e., type of material found on the roads after a winter season) and large quantities of leaf accumulation.

Fleet Replacement Plan

Based on the City's road network length and using the current sweeping service level frequencies, a mixed fleet ratio of $PM_{10,}$ and $PM_{2.5}$ efficient street sweepers to mechanical-type sweepers should be approximately 2 to 1. The new sweepers will need to be third party verified under Environment Canada's Environmental Technology Verification Program (ETV) to ensure that the environmental (PM_{10} and $PM_{2.5}$ efficiency) and operational performance is valid.

The replacement plan will entail replacing the entire fleet. It is expected that the full fleet complement will have been replaced by the end of 2021 as illustrated in Table 4, and will consist of approximately 33 $PM_{10,}$ and $PM_{2.5}$ efficient street sweepers and 17 mechanical-type street sweepers. The procurement will follow the approved City Council process and a request for proposals (RFP) limited to street sweeper technologies that are third party verified and possess Environment Canada's Environmental Technology Verification (ETV) Certificate for both the "PM_{10} and $PM_{2.5}$ Street Sweeper Efficiency" and "Operational On-Street" Test Protocols.

The cost to replace the non-mechanical and mechanical street sweepers in 2016 and 2017 is approximately $5.8 million spread over the two years and will be funded through the division's

'Transportation Vehicle Reserve Account', number XQ1015. The remaining balance of sweepers (26) will be replaced during the period 2018 to 2020.

Table 4: Replacement Plan

Procurement Year [1]	PM_{10} & $PM_{2.5}$ Sweepers	Mechanical Sweepers	Total Sweepers
2016	10	-	10
2017	-	14	14
2018	10	-	10
2019	10	-	10
2020	3	3	6
Total	**33**	**17**	**50**

[1] – Delivery of sweepers will occur one later after procurement year

CONCLUSION

Having a mixed fleet of sweepers, which includes mechanical-type sweepers, will ensure that operational demands are met more effectively. Especially in handling debris removal during spring clean-up, leaf collection season, post storm event clean-up and expressway cleaning. In addition, the division will continue to purchase street sweepers based on best environmental and operational performance results that have been third party verified.

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ATTACHMENTS

APPENDIX 1 – 2014 Street Sweeper Ambient Air Quality Monitoring Study Results
APPENDIX 2 – Street Sweeper Tonnage and Kilometres Swept
APPENDIX 3 – Annual Service Requests Related to Sweeping

APPENDIX 1

2014 Street Sweeper Ambient Air Quality Monitoring Study Results

Table 1: Mechanical Street Sweeper Results

Efficiency Criteria	Before Street Sweeping	After Street Sweeping	Percentage Change Pre- versus Post-Sweeping
Removal Efficiency of Silt Loading (kg)	3.121	2.312	-26%
Maximum PM_{10}Concentration (mg/m^3)	0.259	0.228	-12%
Maximum $PM_{2.5}$ Concentration (mg/m^3)	0.210	0.230	10%
Average PM_{10} Concentration (mg/m^3)	0.021	0.013	-38%
Average $PM_{2.5}$ Concentration (mg/m^3)	0.020	0.013	-35%

Table 1 summarizes the percentage change in the ambient air quality and removal of silt loading from the surface of the pavement for the mechanical street sweeper - 'before street sweeping' and 'after street sweeping'. The low removal efficiency of 26% indicates an ineffective removal of silts. Also, the maximum PM_{10} and $PM_{2.5}$ concentrations levels show very little improvement from pre-to post-street sweeping. This is due to the fact that mechanical sweepers are not as effective in removing the fine particulates from the road, which results in this finer road dust being entrained into the air.

Table 2: Regenerative-air Street Sweeper Results

Efficiency Criteria	Before Street Sweeping	After Street Sweeping	Percentage Change Pre- versus Post-Sweeping
Removal Efficiency of Silt Loading (kg)	10.345	3.552	-66%
Maximum PM_{10}Concentration (mg/m^3)	0.319	0.156	-51%
Maximum $PM_{2.5}$ Concentration (mg/m^3)	0.331	0.177	-47%
Average PM_{10} Concentration (mg/m^3)	0.028	0.018	-36%
Average $PM_{2.5}$ Concentration (mg/m^3)	0.026	0.016	-39%

Table 2 provides similar results for the regenerative-air street sweeper. The removal efficiency of 66% demonstrates an effective removal of silts. This result is significant considering that the regenerative-air street sweeper used in the test was at the end of its service life. In addition, the water suppression system and gutter brooms malfunctioned during the street sweeper testing. Despite all these challenges experienced by the regenerative-air street sweeper, it still out-performed the mechanical sweeper. The Maximum PM_{10} and $PM_{2.5}$ concentrations show a significant improvement from pre to post street sweepings.

Table 3: Ambient Air Quality Results during Street Sweeping Test

Efficiency Criteria	During Street Sweeping Test		
	Mechanical Sweeper	Regenerative-air Sweeper	Entrainment Efficiency Improvement
Maximum PM_{10}Concentration [(mg/m^3)]/kg	0.139	0.005	96%
Maximum $PM_{2.5}$ Concentration [(mg/m^3)]/kg	0.112	0.004	96%
Total PM_{10} Concentration [(mg/m^3)]/kg	3.028	0.496	84%
Total $PM_{2.5}$ Concentration [(mg/m^3)]/kg	2.768	0.463	77%
Average PM_{10} Concentration [(mg/m^3)]/kg	0.030	0.003	90%
Average $PM_{2.5}$ Concentration [(mg/m^3)]/kg	0.027	0.003	89%

Table 3 summarizes the entrainment efficiency between the mechanical and regenerative-air street sweepers during street sweeping. The regenerative-air street sweeper demonstrated an improvement of 77% to 96% for the air quality criteria. The disturbance of road dust (silt loading material) into the air during street sweeping is significantly improved using regenerative-air street sweepers.

Appendix 2

Street Sweeper Tonnage & Kilometres Swept

Table 1: Street Sweepings Collected (metric tonnes)

Districts	Year									
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	Metric Tonnes									
Toronto and East York	2,900	1,739	5,483	7,653	6,783	5,156	5,171	3,532	5,309	7,129
Etobicoke-York	1,391	968	2,385	2,589	2,426	1,155	2,354	1,961	3,041	3,758[1]
North York	936	936	936	3,396	4,789	2,357	1,519	1,035	3,469	3,596
Scarborough	1,894	2,083	3,702	4,231	3,189	2,833	2,432	2,192	2,251	3,029
Totals	**7,120**	**5,725**	**12,507**	**17,868**	**17,187**	**11,501**	**11,476**	**8,720**	**14,070**	**17,512**

1 - Total tonnage reduced by 40% to adjust for the quantity of leaf debris that were combined with street sweepings in one of the Etobicoke -York District yards

Table 2: Length of Road Swept (km)

District	Year									
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	Kilometres									
Toronto and East York	206,824	178,657	181,747	174,147	151,985	175,327	142,318	149,941	104,897	101,243
Etobicoke-York	36,726	47,771	40,301	54,860	54,006	36,281[1]	29,298	27,519	21,114	14,935
North York	19,431	38,311	40,596	38,760	33,364	27,850	21,138	23,368	18,048	12,162
Scarborough	39,633	42,690[2]	82,304	88,020	93,888	82,359	59,429	53,190	17,135	50,352
Totals	**302,614**	**307,429**	**344,948**	**355,787**	**333,243**	**321,817**	**252,183**	**254,018**	**161,194**	**178,692**

1 – For 2010 the length of road swept in the Etobicoke-York District was estimated by averaging 2005 to 2009 and 2011 to 2014 data due to lack of data

2 – For 2006 the length of road swept in the Scarborough District was estimated by averaging 2004 to 2005 due to lack of data

APPENDIX 3

Annual Service Requests Related to Sweeping

Figure 1: Road Cleaning Service Requests

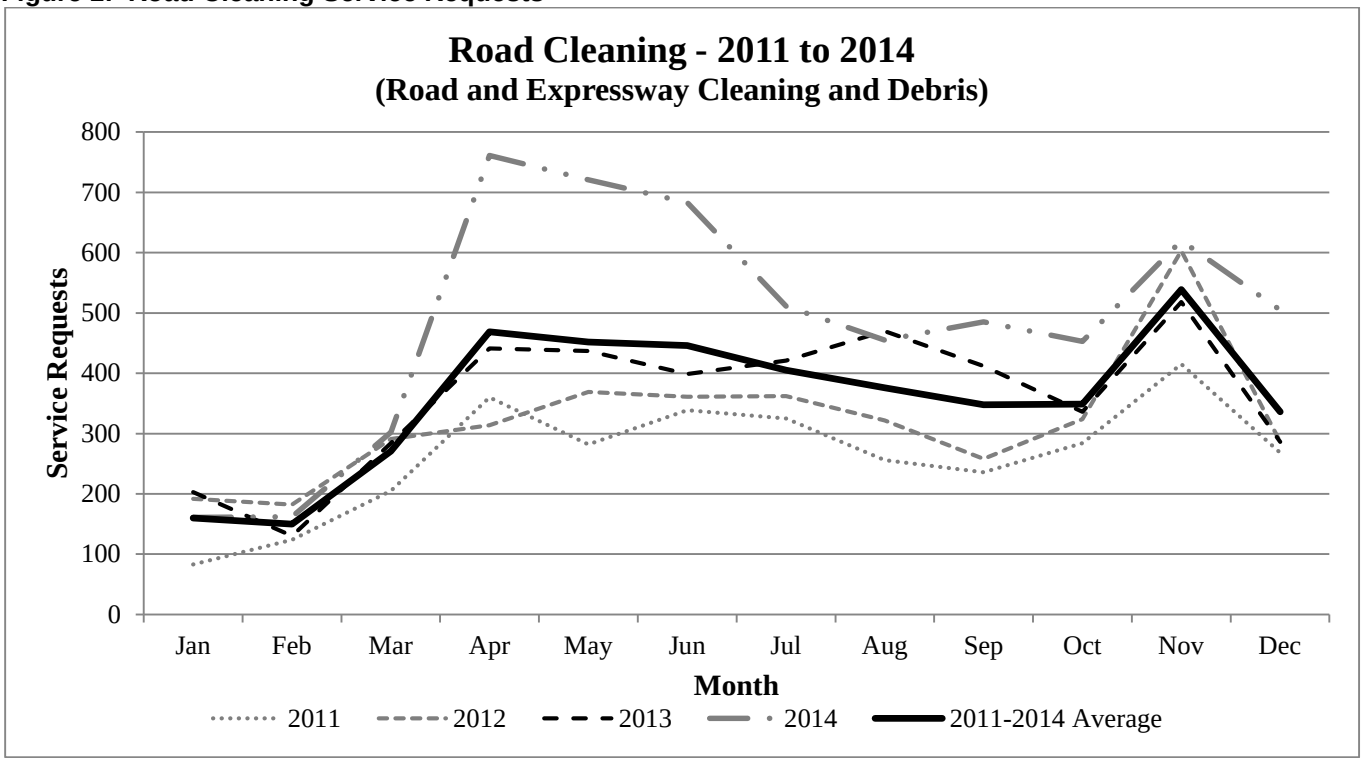

Table 1: Annual Service Request (2008-2014)

District	2008	2009	2010	2011	2012	2013	2014
Toronto and East York	474	565	979	998	1258	1232	1425
Etobicoke-York	524	486	741	971	1072	1286	1639
North York	459	376	511	594	700	775	1116
Scarborough	292	323	446	468	621	706	680
City-wide Total	**1749**	**1750**	**2677**	**3031**	**3651**	**3999**	**4860**