Technical Memorandum

Date:	Monday, February 06, 2017
Project:	MOA MS4 Monitoring Program
To:	Kristi Bischofberger, Municipality of Anchorage Watershed Management Services
From:	Audrey Russo, HDR Molly Reeves, HDR
Subject:	Municipal Separate Storm Sewer System Water Quality Program Monitoring Program Performance Evaluation

The Municipality of Anchorage's (MOA) and Alaska Department of Transportation (ADOT) Municipal Separate Storm Sewer System (MS4) permit (AK52558) requires the MOA to evaluate the results of the monitoring programs to date and submit the results with the Annual Report.

Section 4.1.8 of the MS4 permit requires that:

> *[w]ithin one year and four years of the effective date of the permit, evaluate the results of the monitoring program to date and submit the results in the Annual Report. In the evaluation, discuss the effectiveness of street sweeping to reduce turbidity in the outfall, street sweeping and public education to reduce fecal coliform bacteria in the outfall, and other trends or characteristics that may appear as a result of monitoring.*

This evaluation will consist of a review of the Stormwater Outfall Monitoring (SWO) program water quality data collected during the 2011-2015 permit cycle and 2016 sampling season and a qualitative interpretation of the MOA street sweeping program effectiveness on removing turbidity and fecal coliform bacteria in stormwater runoff.

Street sweeping occurs three to four times a year in Anchorage and is performed by both the ADOT and the MOA, following the sweep schedule presented in Table 1 of the MS4 permit requirements in Section 4.0. The MOA has at least one sweeper operating after the completion of the spring sweep. In fall, after September 15, crews sweep until freezeup. The MOA uses mechanical broom sweepers, mechanical broom sweepers with vacuum assist, and vacuum sweepers. Mechanical broom sweeper collect dirt with one or more brooms that direct swept dirt onto conveyors that is then deposited into a hopper. Mechanical broom sweepers are best suited for sweeping heavy dirt loads and streets with rough surfaces under damp to slightly wet conditions. They can also be used to loosen compacted dirt but do not perform well on lower dirt loads.

Table 1. Permit Required Sweeping Schedule

Period in the Year	Residential	Arterial and all other	Public Parking Lots[1]
April 1 – June 15	1 tandem[2]	2 tandem	1 vacuum[3]
June 15 – Sept 15	1 tandem	1 tandem	-
After Sept 15	1 tandem	1 tandem	1 vacuum

Notes:

1. A vacuum sweeper sucks up loosened street particles with a vacuum and sends the directly to a hopper
2. "Tandem" means one mechanical sweeper preceding one vacuum sweeper during the same sweeping event (on the same day). This is equivalent to two sweepers sweeping the same surface; a mechanical sweeper uses a conveyor belt to carry the collected debris to a hopper. Tandem method is relevant for curb and gutter configured streets. Methods may vary for ditched roads as indicated in the Street Sweeping Operations Plan.
3. Threshold size for public parking lots to be swept will be determined as permittees update their street sweeping plan(s).

Mechanical broom sweepers with vacuum assist function like those without but also have an air intake plenum to create a vacuum. These sweepers are more efficient than the sweepers without the vacuum assist at removing fine particles but do not perform as well under heavy loading or rough road surfaces that can cause vacuum breaks. Best performance is found under damp conditions.

A regenerative air vacuum sweeper is utilized and is preceded by a water truck for dust suppression. The regenerative air vacuums recycle exhaust air through an intake plenum that reduces dust. These sweepers are known to be effective at removing fine particles. The capital and maintenance costs are high and they don't perform well under heavy street dirt loading or rough road surfaces.

In the spring the MOA sends 14 mechanical sweepers followed by four vacuum sweepers on arterial roads. In the summer and fall, eight mechanical sweepers followed by two vacuum sweepers are sent on arterial roads. In spring, summer, and fall five mechanical sweepers followed by two vacuum sweepers are sent on residential roads.

Data collected that is potentially relevant to addressing the effectiveness of street sweeping includes the volume of sediment collected annually, particle size distribution of the sediment collected, and water quality data collected from MOA stormwater outfall monitoring. The sum volume totals for each of the last 5 years (2015-2011) are provided in Table 2. These volume totals include all reported swept volumes summed together for both MOA and DOT operators for both arterial and residential road categories. Also included is a calculated estimate of total weight swept.

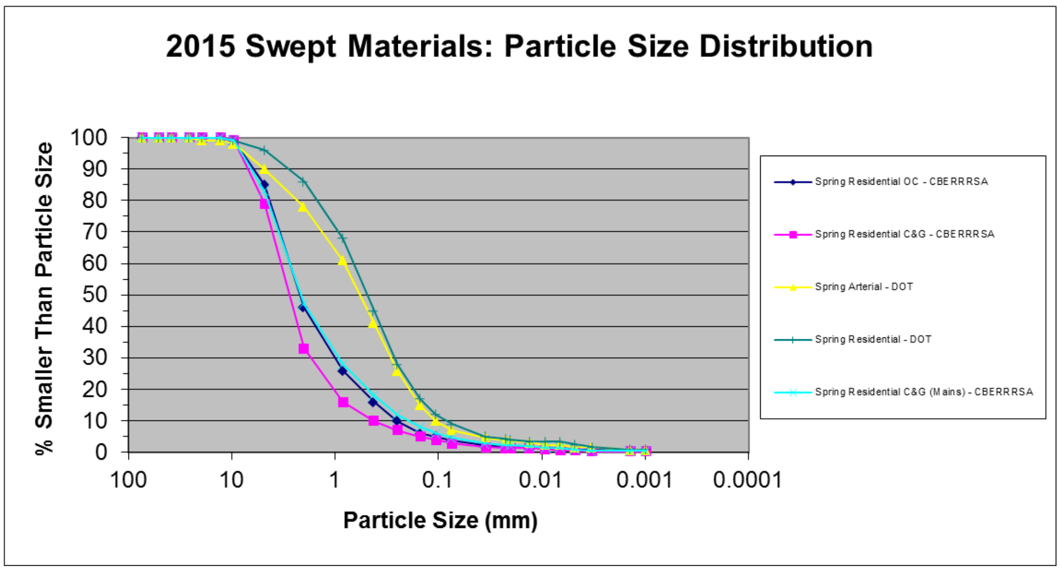
Table 2. Annual volume of sediment swept.

Year	Total Volume Swept (cubic yards)	Total Weight Swept (lbs) calculated*
2015	28,095.3	93,524,350
2014	25,997.2	86,540,236
2013	32,955.6	109,703,585
2012	32,817.2	109,242,709
2011	31,127.3	103,617,323
Avg	30,198.5	100,525,640

Formula: (cyds)(27ft3/cyd)*(2.67spec.gravity)*(0.74porostiy factor)*(62.4lbs/ft3) = lbs

Particle size distribution of sediment collected during street sweeping is analyzed annually. Figure 1 displays the data from 2015. Data from prior years is similar and is available upon request.

Figure 1. Particle size distribution from sediment collected during street sweeping in 2015.



Several studies have demonstrated that particles less than 50 micrometers (µm) (0.05 millimeters (mm)) make up more than 70% of the suspended sediment load carried by stormwater runoff (Andral et al. 1999 and Furumai et al. 2002). Figure 1 displays that particle sizes collected during Anchorage street sweeping are primarily much larger in size than this 0.05 mm fraction that make up the largest typical suspended sediment load in runoff, that also accounts for the majority of sediment impacting turbidity in runoff water quality.

The MOA stormwater outfall monitoring occurs during storm events between June and October each year. Data discussed herein is from 2011 through 2016. Between 2011 and 2016, no outfall sample events occurred during the first sweep period in Table 1 (no stormwater samples collected before June 15). Four storm events were sampled each year between 2011 and 2016, and sample collection events occurred in summer and fall, with the earliest sample collection event on June 21 and the latest sample collection event on October 16. An evaluation of the outfall monitoring is provided in the Stormwater Outfall Monitoring Report; however the turbidity and fecal coliform data from these events is discussed herein for the purpose of evaluating street sweeping performance to comply with Section 4.1.8 of the MS4 permit.

Ten outfall locations are monitored for stormwater pollution and the effectiveness of best management practices such as street sweeping. Sites SWM01, SWM03, SWM04, and SWM06 serviced residential areas; sites SWM02, SWM05, SWM07, and SWM09 serviced industrial areas; and sites SWM08 and SWM10 serviced mixed residential and industrial areas (Table 3). Locations of the outfall stations and catchment areas are displayed on Figure 2.

Table 3. Stormwater Outfall Sample Locations and Contributing Area Characteristics

Station ID	Subbasin ID	Outfall/Node ID	Watershed	Contributing Land Use	Outfall Diameter	Drainage Acreage	Percent Impervious
SWM01	1040b	1040-3	L. Campbell	Residential	18	91.38	35.52
SWM02	1210	847-1	L. Campbell	Industrial	18	37.17	81.53
SWM03	1224a	1224-1	Campbell	Residential	36	99.99	70.05
SWM04	1224b	1224-2	Campbell	Residential	18	20.10	31.78
SWM05	805	207-1	Campbell	Industrial	24	58.34	75.41
SWM06	219	314-22	Chester	Residential	26	33.81	37.26
SWM07	507	484-1	Chester	Industrial	24	50.17	87.68
SWM08	549	86-1	Chester	Mixed	42	354.62	68.94
SWM09	132	499-1	Chester	Industrial	24	40.04	53.65
SWM10	554	525-2	Chester	Mixed	24	47.51	74.62

Turbidity

The turbidity concentrations at each outfall sample location were reviewed from 2011 through 2016. The mean annual turbidity concentration for each outfall location is shown in Figure 3. The mean turbidity concentration for each outfall sample event by contributing area land use type is provided in Figure 4. The turbidity and fecal coliform data from outfall monitoring is provided in Attachment 1. Specific dates of street sweeping are not available to compare with the dates of outfall sampling.

The residential outfall catchment areas (average of the four residential sites is 61 acres) are generally larger than the industrial outfall catchment areas (average 46 acres) (Table 2). On the other hand, the industrial outfall catchment areas have generally higher percent of impervious surface (average 75 percent) than residential locations (average 44 percent); therefore the average acreage of impervious surface is relatively similar between residential (30 acres) and industrial (35 acres) type catchment areas. Given that arterial roads are swept an additional time over residential roads, a comparison between industrial catchment area land use types and residential land use types is presented; however, the specific industrial catchment area outfall sample sites may not include the arterial roads that are swept twice between April 15 and June 15. A detailed street sweeping schedule would be required to confirm.

Residential areas tend to have lower turbidity levels than industrial areas, excluding outfall monitoring location SWM02 (Industrial), which had exceptionally low turbidity throughout monitoring (Figure 3 and 4). Between 2011 and 2016 the annual mean turbidity concentration in stormwater for all residential outfall sites was 62.3 NTU, and the annual mean concentration for all industrial outfall sites was 90.2 NTU. The mean turbidity for all sampling dates at SWM02 was 9.5 NTU.

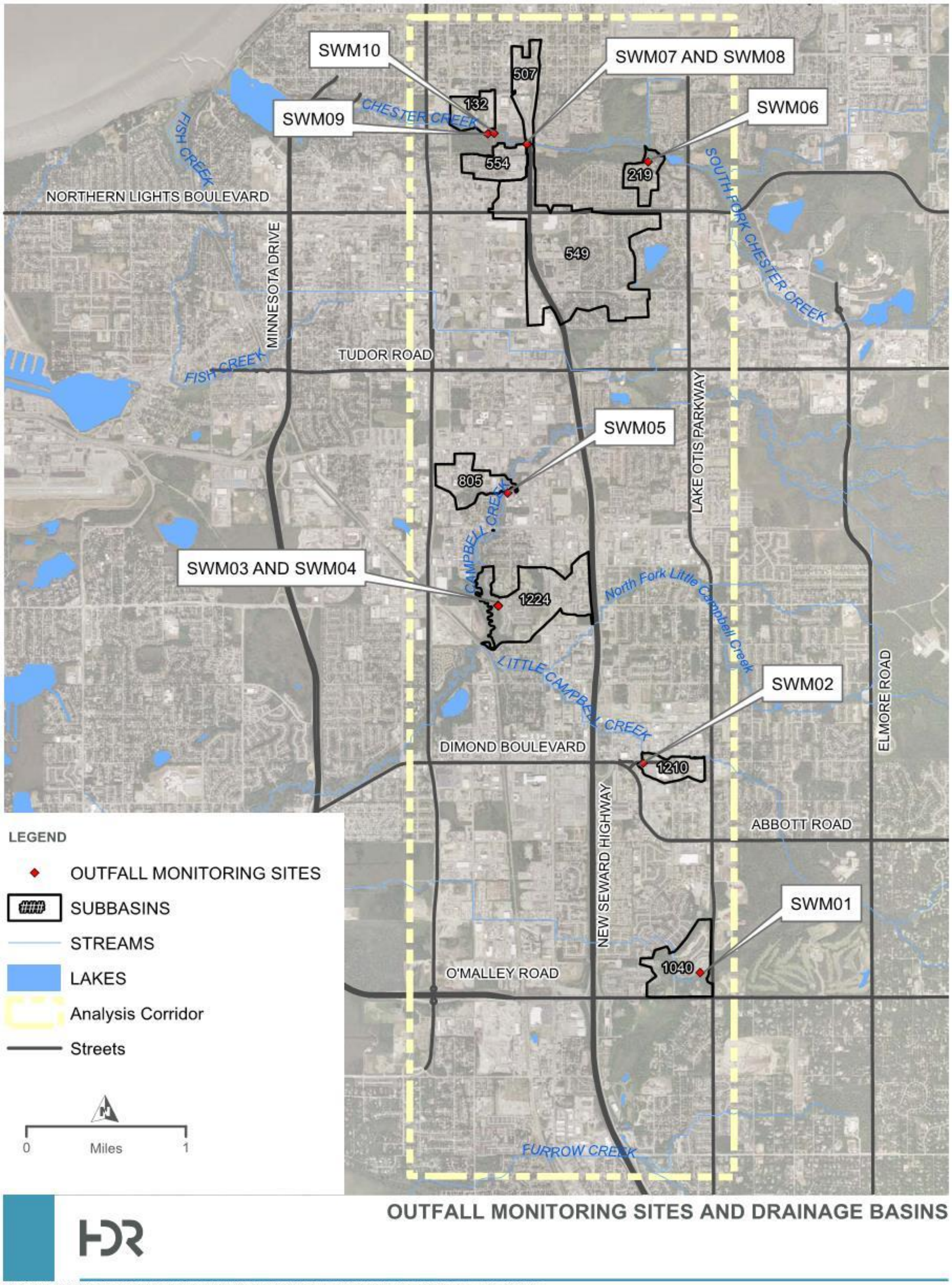


Figure 2. Outfall Monitoring Sites and Contributing Drainage Areas

Residential site SWM03 was lower than all other residential sites monitored except in 2011, when it had elevated turbidity levels. Construction occurred near SWM03 in 2011 that is suspected to have been the source of elevated turbidity levels during that year. When the two anomalous outfall sample events in 2011 for site SWM03 were removed, the annual mean residential turbidity decreases to 27.5 NTU. The annual mean for residential site SWM01 (28.1 NTU) was lower than all industrial sites except site SWM09 in 2013. According to the 2015 Annual Monitoring Report, Construction activities were also suspected to be the cause of elevated turbidity at SWM09 in 2015. Turbidity levels for residential site SWM04 were lower than all industrial sites every year of monitoring.

Figure 4 displays the mean turbidity concentration from all industrial catchment area outfalls for each sample event. Industrial outfalls have higher turbidity than residential and mixed use outfall catchments in 2011 to 2013. In 2014, 2015, and 2016 the industrial outfall turbidity concentrations more closely resemble the residential and mixed use outfall concentrations of turbidity. The cause for the change in 2014, 2015, and 2016 is unknown. If the industrial outfall sample sites do in fact contain arterial roads that are swept more than the residential roads, there is no apparent benefit in turbidity concentrations at industrial outfalls that could be accounted for by the additional sweep of those roads (Figure 4). However, the sample collection timing within the storm hydrograph has a significant impact on the stormwater turbidity concentration; therefore, without an analysis of the data collection within each storm event and paired with street sweeping events, the stormwater turbidity data is of limited use in evaluating street sweeping effectiveness.

SWM07 consistently had the highest turbidity and fecal coliform levels. SWM07 drains the area between north and south-bound lane of Seward Highway near 15th Avenue (Figure 2).

There does not appear to be a trend of turbidity in stormwater during each sample season (e.g. higher turbidity earlier in the sample season).

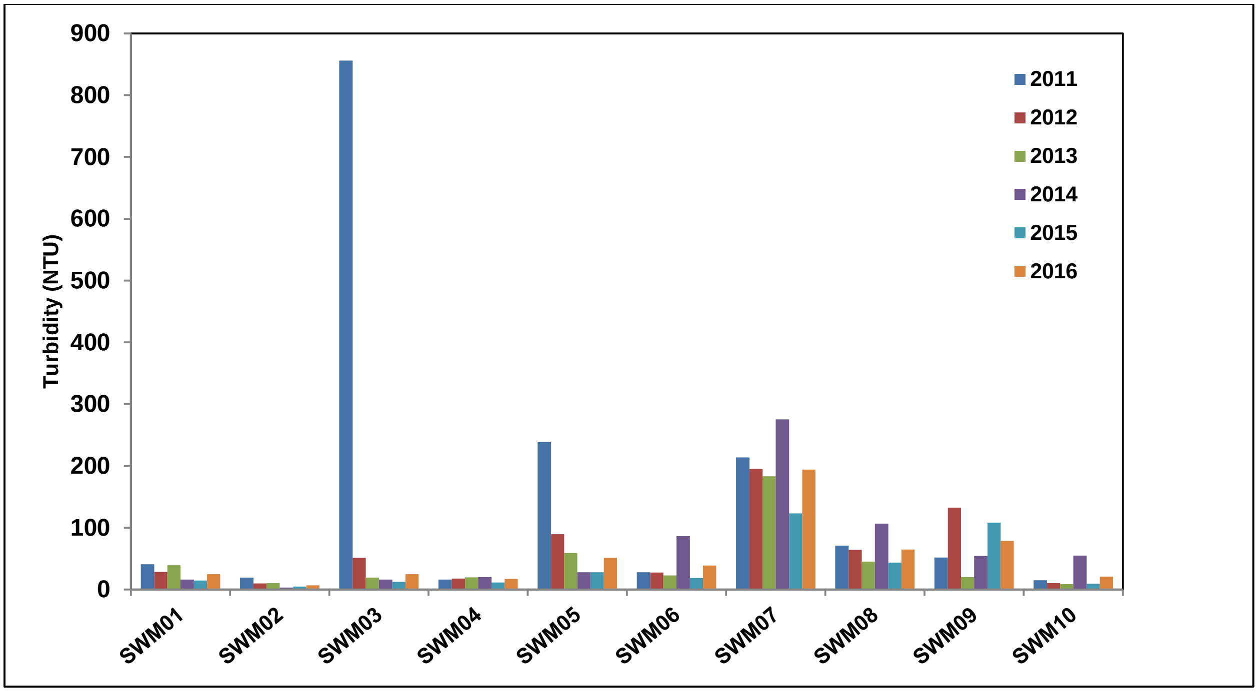


Figure 3. Mean Annual Turbidity in Stormwater at each Outfall Sample Site

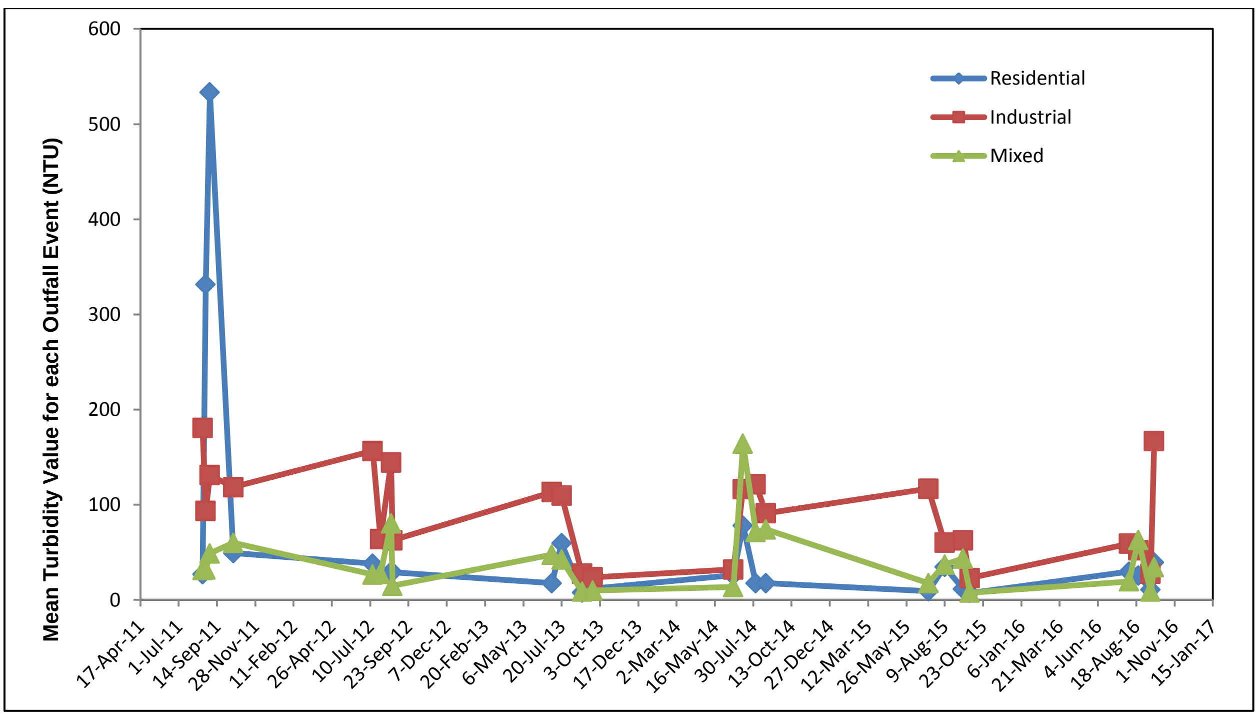


Figure 4. Mean Turbidity for each Outfall Sample Event by Contributing Area Land Use (2011-2016)

Fecal Coliform

The fecal coliform concentrations at each outfall sample location were reviewed from 2011 through 2016. The mean annual fecal coliform concentration for each outfall location is shown in Figure 5. The mean fecal coliform concentration for each outfall sample event by contributing area land use type is provided in Figure 6. The turbidity and fecal coliform data from outfall monitoring is provided in Attachment 1. Specific dates of street sweeping are not available to compare with the dates of outfall sampling.

SWM02, an industrial area, is consistently low in both fecal coliform and turbidity, as noted above in the turbidity section. The site has one of the smaller drainage areas (37.17 acres) than other outfall sample points but one of the larger percentages of impervious surfaces at 81.53 percent. The mean fecal coliform level for all sampling dates at SWM02 was 73.2 CFU/100 ml. The next lowest mean was SWM01 with 668.6 CFU/100 ml.

SWM04, a residential area, has the smallest drainage area (20.10 acres) of the ten outfall sites. Fecal coliform levels were elevated at SWM04 over the coliform concentrations at other residential outfalls. During the fourth sampling event in 2012, the fecal coliform levels reached 19,900 CFU/100 ml.

No clear trends or patterns could be observed for fecal coliform due to the many different fluctuations between highs for each monitoring year. 2011 had two locations, 2012 had three locations, 2013 had three locations, 2014 had two locations, 2015 had two locations, and 2016 had four locations with the highest loading rate.

An analysis of fecal coliform in 2003 by MOA indicated that the highest loads would occur in August/September in association with peak runoff (MOA, 2003). Peak runoff during the 2011-2016 monitoring occurred mostly in July/August (MOA, 2012; MOA, 2013; MOA, 2014; MOA, 2015). Fecal coliform levels are typically higher in July/August in association with peak runoff and rainfall in urban areas (Figure 6).

SWM07 consistently had the highest turbidity and fecal coliform levels. The average concentration of fecal coliform at SWM07 for all storm events is 4,032.9 CFU/100 ml. The next highest average for all storm events is 2,822.7 CFU/100 ml at SWM05. SWM07 had the highest annual fecal coliform loading in five of the six years. SWM07 drains the area between north and south-bound lane of Seward Highway near 15th Avenue in Anchorage.

Other than SWM07 consistently having the highest fecal coliform levels, other sites with relatively high fecal coliform concentrations include SWM03, SWM05, SWM08, and SWM09. These sites represent residential, commercial, and mixed areas. Similarly, the lowest coliform concentrations were found at SWM01, SWM02, and SWM04, SWM06, and SWM10. These sites represent residential, commercial, and mixed areas as well. There is no apparent correlation with drainage size. As evidenced by Figure 6, there is no trend indicating a particular contributing land use has higher or lower coliform concentrations than another contributing land use.

Outfall site SWM10 had high fecal coliform concentration in 2014. The storm event on August 24, 2014 had an uncharacteristically high fecal coliform level of 11,800 CFU/100ml. The Annual Report for 2014 refers to this as an anomalous event and the cause is unknown. The next two highest levels sampled for SWM10 were 4,900 CFU/100ml in 2011 and 1,600 CFU/100 ml July 10, 2014.

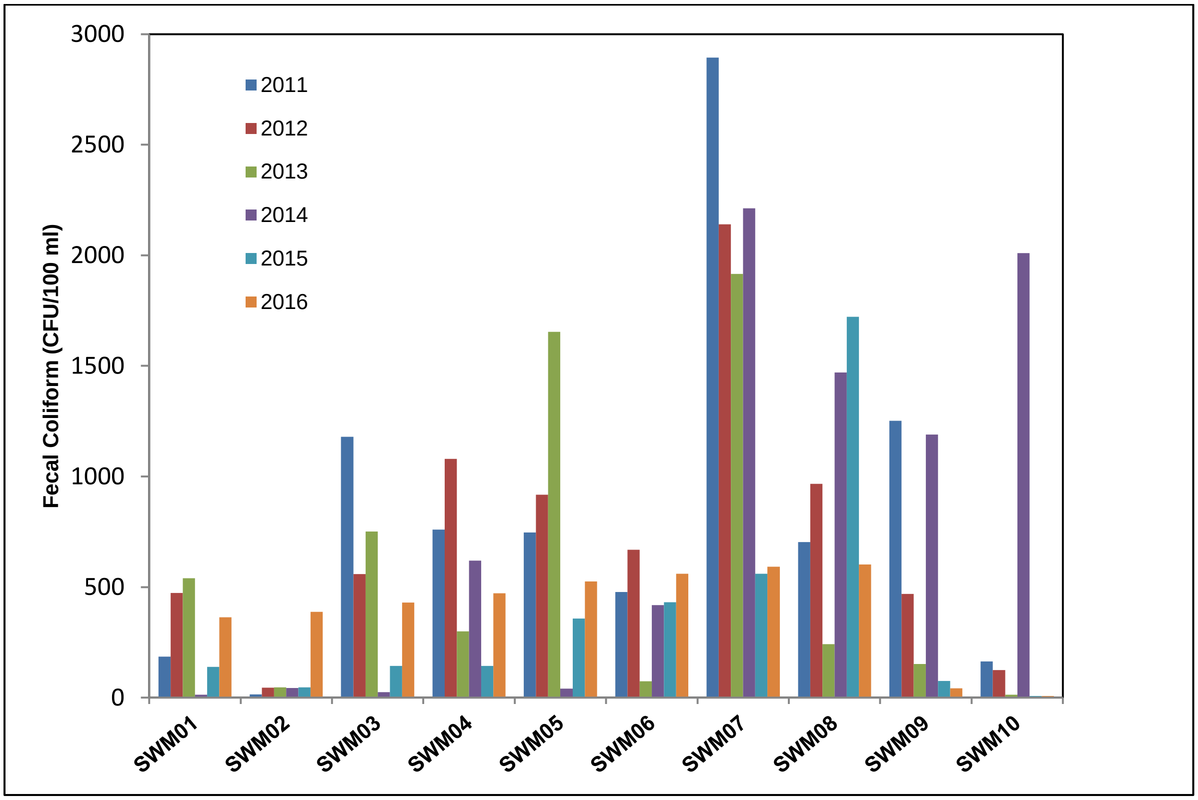


Figure 5. Mean annual concentration of fecal coliform in Stormwater at each Outfall Sample Site

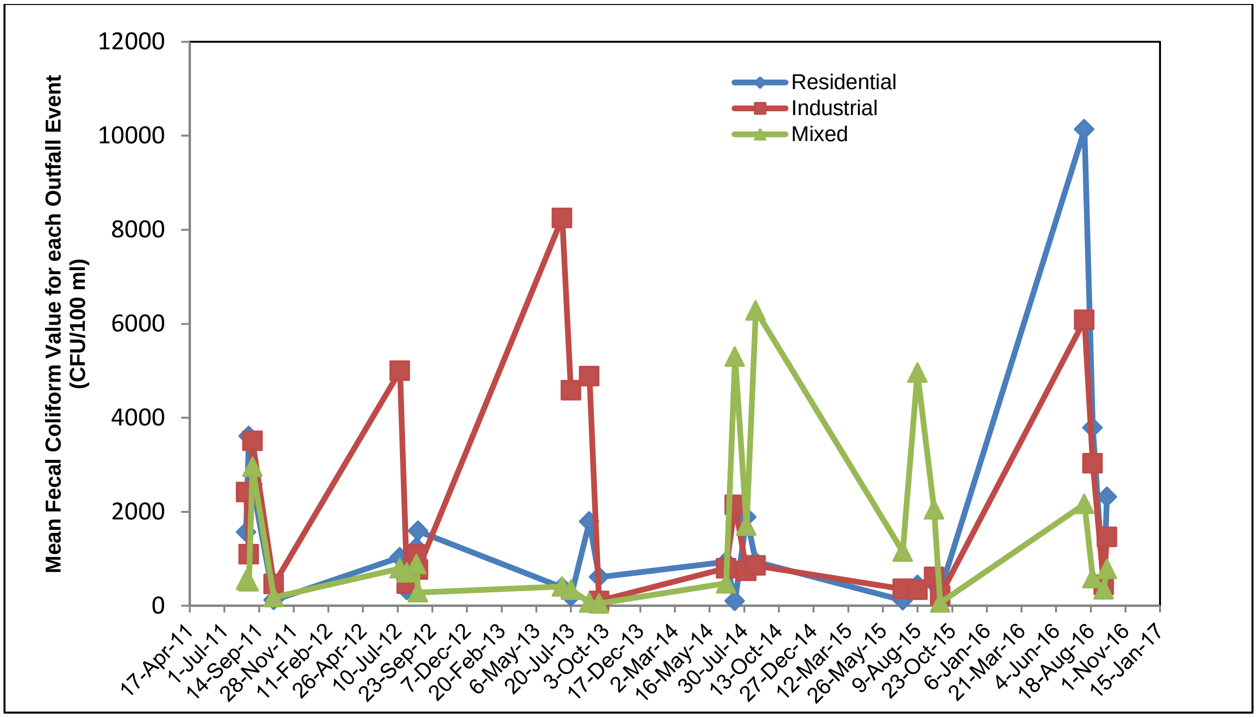


Figure 6. Mean Fecal Coliform for each Outfall Sample Event by Contributing Area Land Use (2011-2016)

Conclusions

It is well documented that correlations between stormwater outfall data and street sweeping are difficult to correlate (Selbig and Bannerman, 2007). Results of existing studies show there is little probability that street sweeping, regardless of street-sweeper type, had measurable affect on the quality of runoff. Measuring the performance of street sweeping as a stormwater quality management tool appears to be limited by the extreme variability in stormwater quality loads. It is extremely difficult to isolate changes in stormwater quality as a result of street sweeping because other factors may be affecting the movement and supply of constituents (including turbidity and fecal coliform) in catchment areas. Examples of factors that might contribute to the high variability include the amount of sediment delivered from other source areas such as lawns and driveways, the efficiency of sediment delivery in the storm sewer system, and the changes in the amount of gravel applied to enhance vehicle traction each winter. In addition, the stormwater outfall sample collection timing during the storm event hydrograph is not consistent between events, or amongst the outfall stations. There is insufficient data available regarding sweeping schedule to pair sample collection events with street sweeping events; however existing studies have concluded that a much larger number of water samples would have to be collected in order to detect any significant change due to street sweeping. For example, a U.S. Geological Survey (USGS) study of 40 paired stormwater-quality samples estimated that 200 paired stormwater-quality samples would have been required to detect a significant change (Selbig and Bannerman, 2007).

Street sweeping collected in excess of 500 million pounds of sediment between 2011 and 2015, which provides an evident account of the effectiveness of sweeping on the water quality entering the waterbodies of Anchorage. While correlating this sediment collection to specific turbidity and coliform concentrations in runoff is difficult, the sweeping treatment is understood to improve runoff water quality.

References

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