Initial Analysis on the SSO and Bypass Issues

Draft Proposal to include SSO and Bypass in Future Model

CBP Wastewater Workgroup

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Summary:

SSO and Bypass are two regulated wastewater loading sources that have not been included as model inputs in the Chesapeake Bay Watershed Model. Data analysis shows that in Maryland both SSO and Bypass loads are significant and in the same magnitude as CSO loads. SSO loads and Bypass loads may not stand out among all loading sources on annual basis, but are concentrated discharges during the storm events when are the exact time periods the Bay model under estimates.

The Wastewater Workgroup recommends to include the SSO and Bypass in the future Bay models for the following two goals:

1) To improve the model performance during the wet weather events.
2) To provide modeling measurements to recognize and encourage the implementation efforts in eliminating SSO and Bypass, which will improve water quality and reduce potential health risks.

Background:

Sanitary Sewer Overflows (SSO) occur mainly when there are blockages or breaks in the sanitary sewer line and sewer defects that allow storm water and groundwater to overload the system causing wastewater to flow out of the collection system. SSO is considered as illegal discharge under the Clean Water Act and has traditionally been avoided in the Bay Models.

Bypass is permitted mainly as storm driven Bypass of partially treated wastewater, but not included in the reported DMR data for many plants.

Therefore, these two regulated wastewater loading sources (except Blue Plains 001 outfall) have not been included in and tracked by the Bay models so far.

Related Problems:

1) SSO presents not only potential health dangers, but also causes serious water quality problems.

Blue Water Baltimore, a NGO, has raised questions on how the Bay models handle the sewage spills and if the SSO elimination efforts would help in achieving the TMDL goals. Currently, Baltimore has eliminated all its Combined Sewer Overflows (CSO), and we have removed Baltimore off our active CSO list tracked by the Bay model, but the sewage overflows in Baltimore area continue as SSO, which continue to be a major issue for the Baltimore area.

Currently we can respond to such questions asked by Blue Water Baltimore only with a general answer-any non-model-input sources including SSO have been covered in the model background simulation.

However, we cannot provide any data or specifications to describe the SSO issue in the Bay watershed. Since we have not included these sources in the model, the Bay model is not currently capable to provide any measures to track the SSO pollutions and its reduction efforts or connect the local government/community plans on SSO elimination with the TMDL implementation goals.

2) Model has underestimated during storm events for many major river basins

This has been a common model simulation issue in the Bay watershed models including the phase 6 model. The following two figures, Figure 1 and Figure 2, compared the TN and TP loading values for both the phase 6 model output and observed data for the Potomac River Basin. The observed water quality data was generated from a multiple linear regression model known as Weighted Regressions on Time, Discharge, and Season (WRTDS).

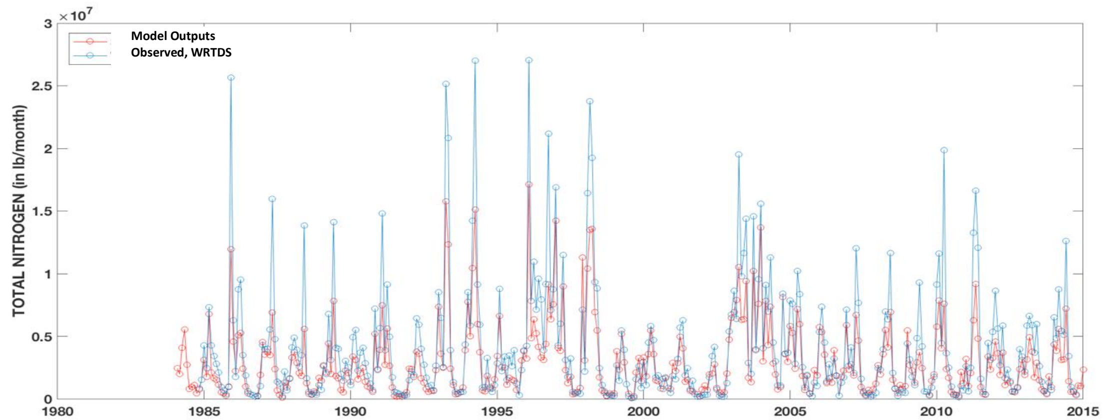

Figure 1 Potomac River TN Loads– phase 6 model output vs observed

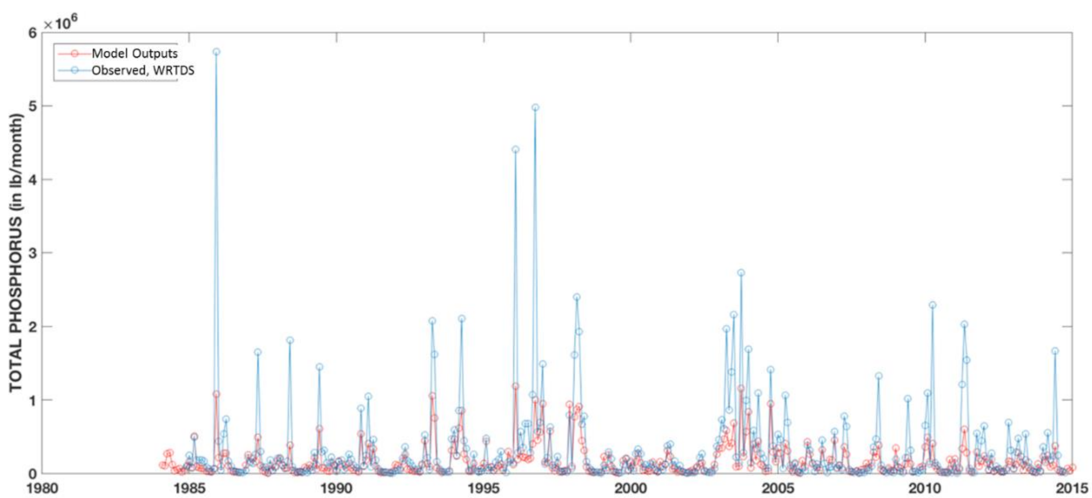

Figure 2 Potomac River TP Loads– phase 6 model output vs observed

As these two graphs show, the observed values (in light blue color) during the weather events are significantly greater than the model outputs (in red color).

The underestimation could be caused by many factors. One of the major factors could be low model input caused by underestimated or missing loading contributions from different sources during the storm events, such as urban runoff, agriculture land runoff, CSO, SSO, Bypass, and etc. Further research may be needed to study the details of causes to correct this problem and improve the model. However, as the workgroup in charge of the wastewater related model inputs, we know that SSO and Bypass are two missing loading sources in the model, which could bear at least partial blame for the model underestimation problem. But, how significant are these two sources? Do they provide meaningful load contributions compared with the loading sources we have currently tracked, such as CSO?

Data Study:

Data Source:

By regulations, all CSO, SSO and Bypass that reach surface waters are required to be reported. These data exists in all Bay jurisdictions, but in different forms. Some jurisdictions have their data published through online database while others have the data in other formats varying from paper report to excel spreadsheet.

Following is a screen shot from the Maryland website hosting their Reported Sewer Overflow Database that includes data of Bypasses, SSOs and CSOs reported to the MDE from January 2005 to the most recent update.
http://www.mde.state.md.us/programs/Water/Compliance/Pages/ReportedSewerOverflow.aspx

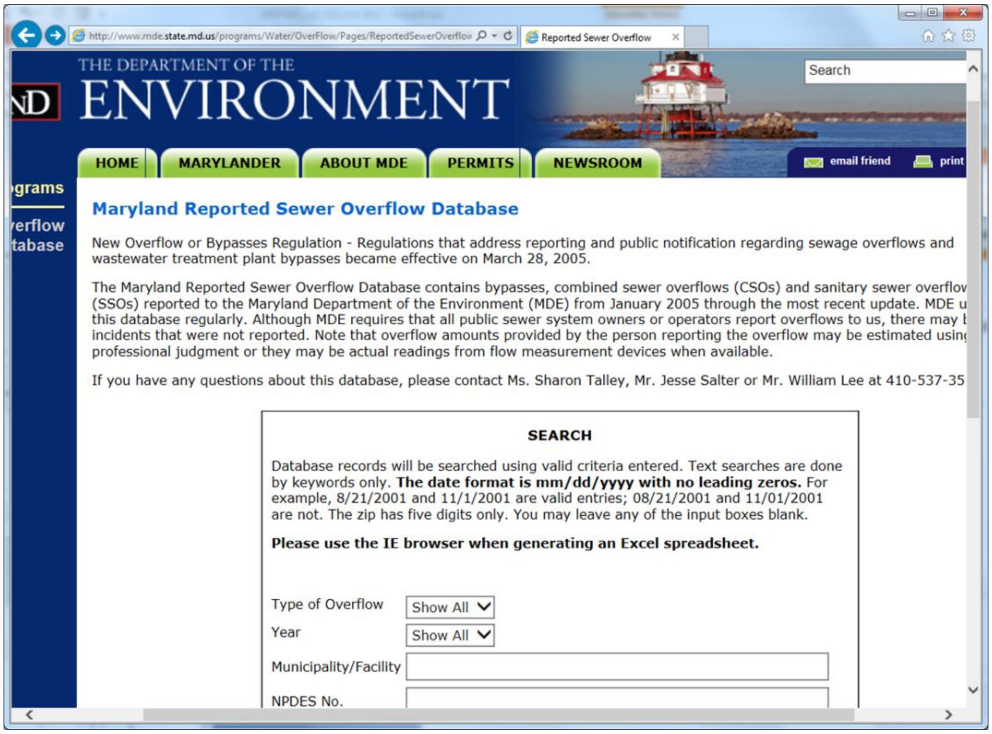

Figure 3 MDE online database for CSO, SSO and Bypass

The newly revised Maryland CSO data was based on this database and used to replace the Tetra Tech CSO estimates in the phase 6 Bay model calibration.

The SSO and Bypass data used in this analysis was also downloaded for this site.

Flow Data Analysis:

Maryland SSO and Bypass flow data (2005-2016) are summarized by year in annual total volumes, annual average volumes per event and number of events per year, which were then compared with related MD CSO data to show the relative levels of SSO and Bypass contributions.

Figure 4 compares the total annual flow volumes for CSO, SSO and Bypass in Maryland between 2005 and 2016. On this chart, SSO and Bypass annual total volumes are comparable with CSO volumes, but CSO volumes are comparatively greater. On average, SSO volume is about 1/3 of CSO volume on annual basis.

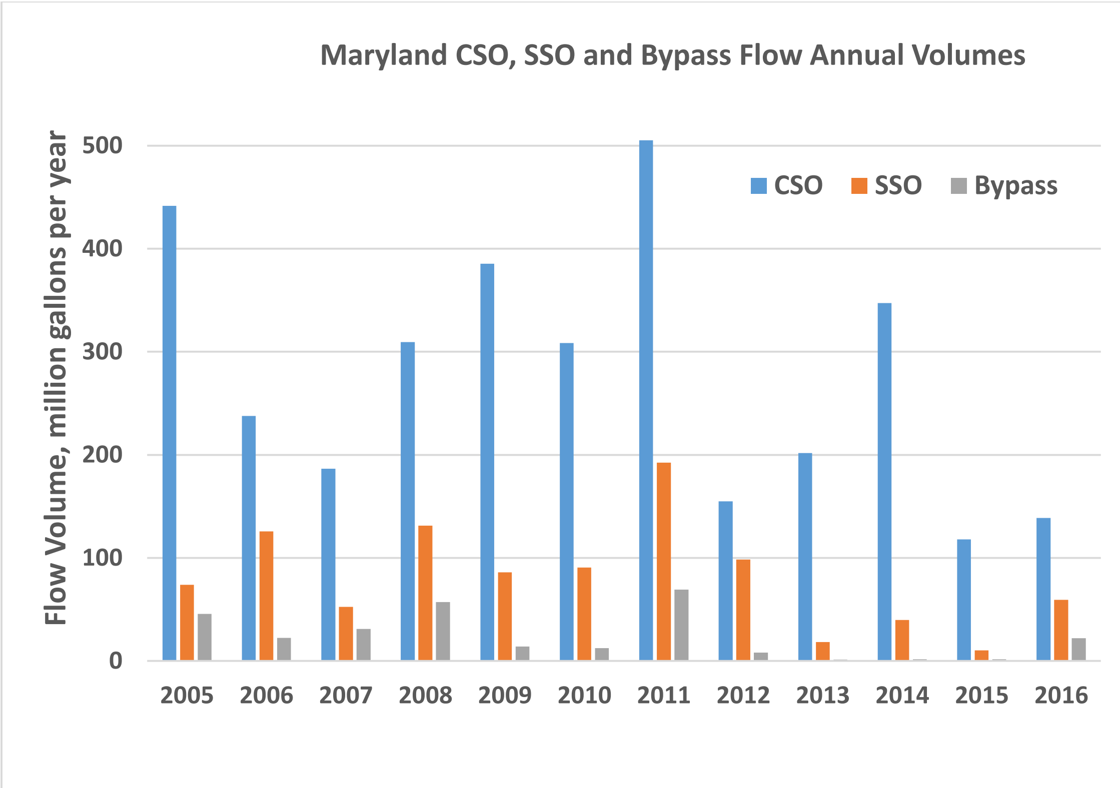

Figure 4. Comparison of CSO, SSO and Bypass annual volumes in Maryland between 2005 and 2016

That is for annual total flow volume, if we want to see how big volume on a per-event basis, we can look at the per event volume numbers. As Figure 5 shows, the per event volume numbers present different comparisons. The Bypass per event average volumes are catching up with CSO's and even greater than CSO per event volume in 2008, but the SSO average volumes per event are relatively small. So, we see that both CSO and Bypass have higher flow volumes than SSO on a per event basis. When SSO annual total volumes are greater than Bypass annual volumes, SSO must have occured more often than Bypass.

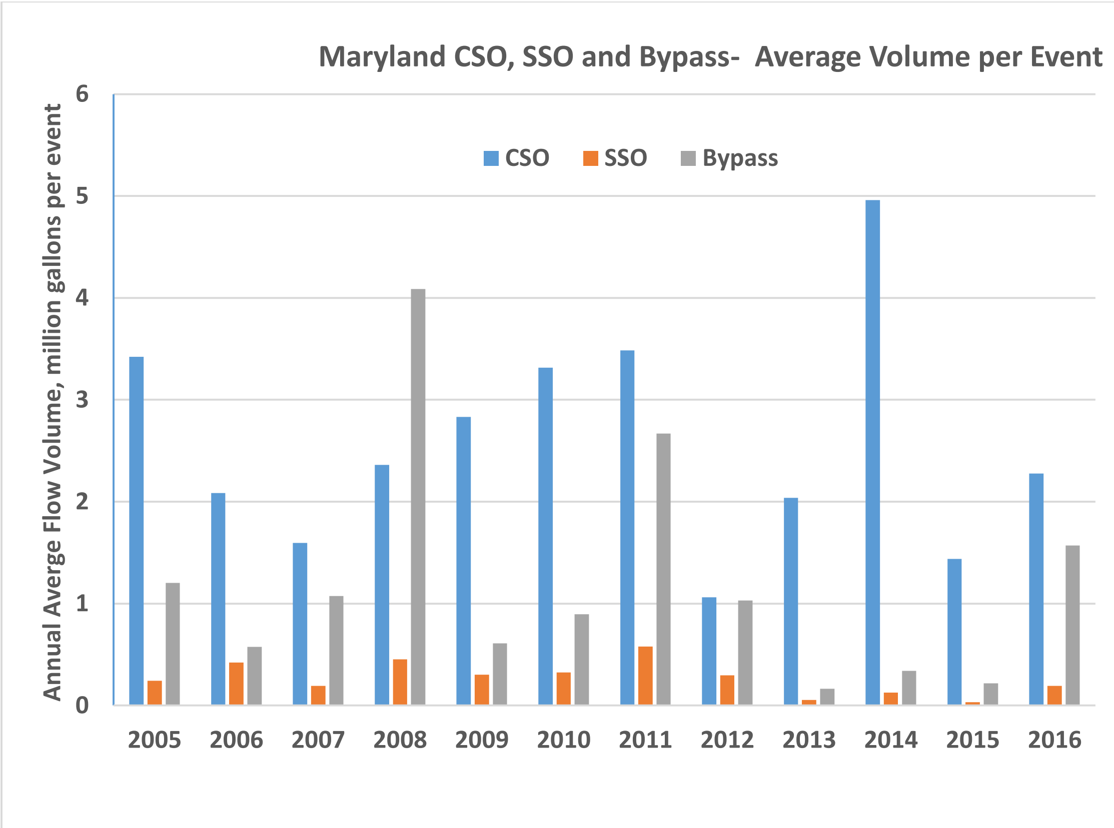

Figure 5. CSO, SSO and Bypass average volumes per event in Maryland between 2005 and 2016

Figure 6 shows us the number of events per year for Maryland CSO, SSO and Bypass, which confirms that SSO has significantly higher values in number of events per year than CSO and Bypass, though SSO's per event volume is small. We can also see that the number of CSO events has shown a down trend over the years between 2005 and 2016, but the number of SSO events stays strong year by year with a slight up trend. The CSO down trend is in line with the implementation process of CSO Long Term Control Plan (LTCP). However, the separation of combined sewer system eliminates CSO through changing the sewer systems from combined systems to separated systems, which does not means that separated system won't have the sewage overflow problem. The overflow after the separation project or elimination of CSO is no longer considered as CSO, but as SSO. Therefore, with LTCP progress, more CSO areas are converted to non-CSO areas with separated systems. The sewage overflows from these areas used to be considered as CSO now become SSO. This may explain why we see a slightly up tread for the number of SSO events while CSO is decreasing. However, due to the combined efforts in eliminating CSO and reducing SSO, the overall annual volumes of CSO, SSO and Bypass present a down trend in Figure 4.

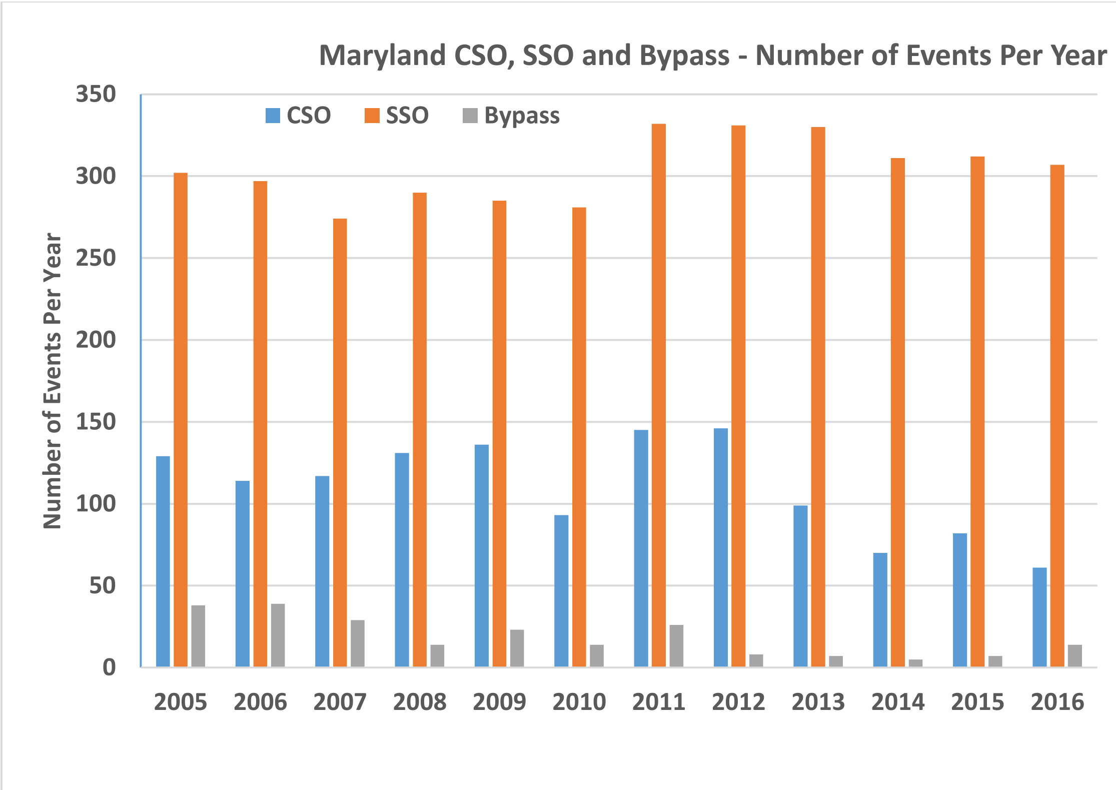

Figure 6. Annual number of events of CSO, SSO and Bypass Maryland between 2005 and 2016

Table 1 lists all the summarized data presented in the Figure 4, 5 and 6.

Table 1. Annual reported data of CSO, SSO and Bypass in Maryland between 2005 and 2016

	CSO			SSO			Bypass		
Year	# Events	Annual Total FLOW (MG)	Avg Flow per event (MG)	# Events	Annual Total FLOW (MG)	Avg Flow per event (MG)	# Events	Annual Total FLOW (MG)	Avg Flow per event (MG)
2005	129	441.477	3.422	302	73.761	0.244	38	45.701	1.203
2006	114	237.591	2.084	297	125.669	0.423	39	22.414	0.575
2007	117	186.593	1.595	274	52.582	0.192	29	31.175	1.075
2008	131	309.496	2.363	290	131.166	0.452	14	57.210	4.086
2009	136	385.290	2.833	285	86.114	0.302	23	13.998	0.609
2010	93	308.320	3.315	281	90.783	0.323	14	12.547	0.896
2011	145	505.174	3.484	332	192.476	0.580	26	69.370	2.668
2012	146	154.902	1.061	331	98.386	0.297	8	8.248	1.031
2013	99	201.873	2.039	330	18.342	0.056	7	1.154	0.165
2014	70	347.102	4.959	311	39.649	0.127	5	1.704	0.341
2015	82	117.867	1.437	312	10.262	0.033	7	1.515	0.216
2016	61	138.818	2.276	307	59.360	0.193	14	21.984	1.570

So far, we have compared the total annual overflow volumes, average volumes per event and number of events per year among CSO, SSO and Bypass in Maryland and saw the changes in their annual volumes and event frequencies over the year. Next, we will take look at what we concern the most-their nutrient loads. Let us focus on TN load for this study.

TN Concentration Assumption

To convert the flow volumes to TN loads, we need to have the TN concentration values associated with the flows. But current CSO, SSO and Bypass reporting does not require monitoring on nutrient concentration and there are no such concentration values available in the Maryland online database. So, we have to assume some draft TN default concentrations for the calculation purpose. These draft default concentrations are picked only for testing in this analysis and not citable.

Table 2. TN draft concentrations assumed for this analysis

	Draft TN		Justification
CSO	8	mg/l	Default value recommended for CSO by Tetra Tech
Bypass	20	mg/l	Based on the flow weighted average of Blue Plains Bypass outfall TN values in 2015 and 2016.
SSO	30	mg/l	Considered with both wet and dry weather events

The current CSO default concentration used in the Bay model was recommended by Tetra Tech through an EPA funded research for CSOs that do not have their site specific default concentrations. Tetra Tech recommendations were averaged values based on their literature search and available local CSO concertation values. The Bypass TN concentration of 20 mg/l was based on the flow weighted average TN concentration of Blue Plains Bypass outfall 001 in 2015 and 2016. Since SSO could be the result of both dry and weather events, it should have higher TN concentration than Bypass during storm events. With dilution caused by higher inflow and infiltration (I&I) during storm events, SSO should have lower TN concentration than raw sewage. The typical TN concentrations of domestic sewage in sanitary sewers normally vary from 30 to 50 mg/l with an average at 40 mg/l TN. Therefore, we picked 30 mg/l as the mid-point between Bypass (20mg/l) and Raw Sewage (40mg/l) for the draft concentration of SSO (for this analysis only).

Estimated Annual TN loads from CSO, SSO and Bypass in Maryland

With the assumed draft TN concentrations listed in Table 2 and the reported annual flows in Table 1, we can come up with estimated annual TN loads for CSO, SSO and Bypass as displayed in Figure 7.

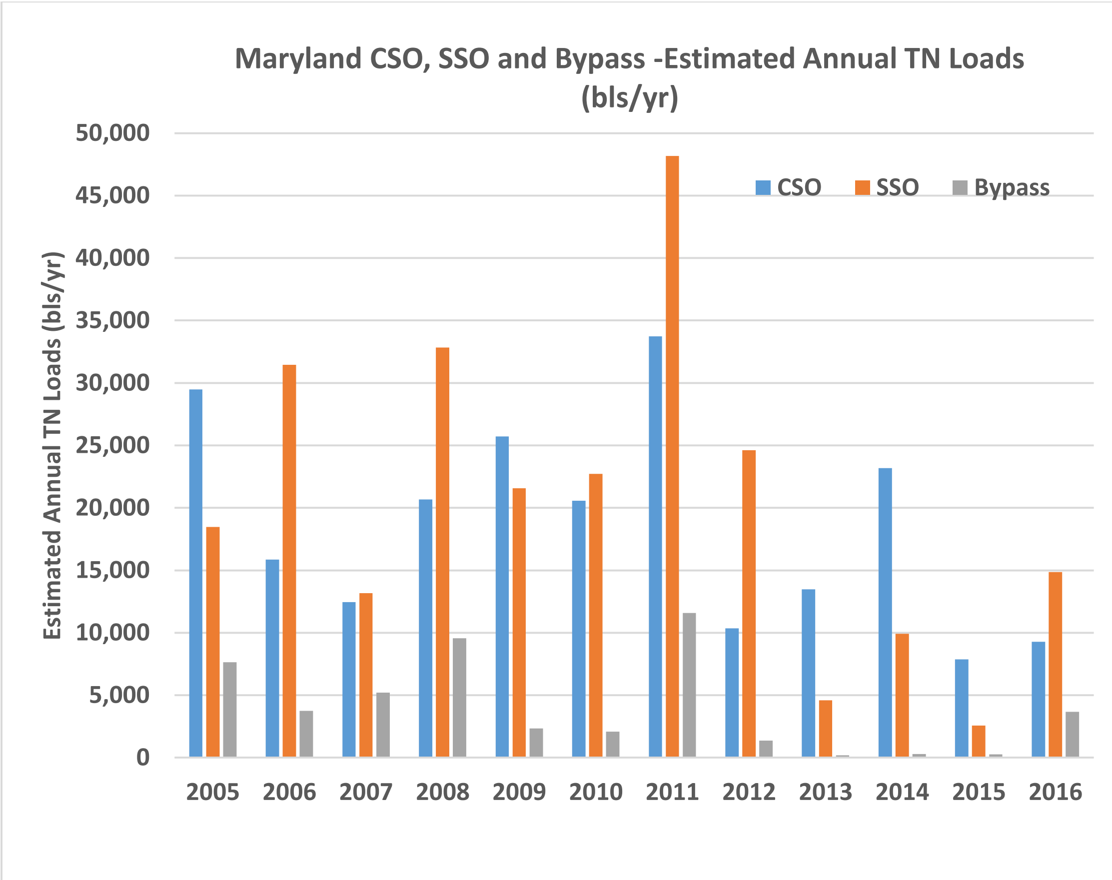

Figure 7. Estimated annual TN loads of CSO, SSO and Bypass in Maryland between 2005 and 2016

We can see from Figure 7 that (1) SSO loads could be greater than CSO loads over the years from 2005 to 2016 in Maryland and (2) the overall TN loads of CSO, SSO and Bypass are trending lower in recent years.

Figure 7 also shows that the SSO loads were around 30,000 lbs/yr TN before 2012. What this load looks like when compared with a WWTP load? A significant WWTP in the Bay watershed is normally defined as one with design flow greater than 0.5 MGD. The TN load of a 0.5 MGD significant plant with no nutrient removal process is about 30,500 lbs/yr (=0.5 mgd x 20 mg/l x 8.344x 365). Therefore, the SSO TN load in Maryland could be equivalent to the contribution from a small significant wastewater treatment plant.

In other words, compared with CSO and WWTP loads, SSO and Bypass loads are also significant and would make meaningful impact to the model if included, which will likely improve the model performance especially during storm events.

<u>SSO and CSO in Baltimore Metro Area</u>

Most of Maryland SSOs happen in the Baltimore metro area. Table 4 and Table 5 provide the detailed SSO and CSO information for this area. The CSO of Baltimore City was eliminated in 2007 and there is no CSO in the Baltimore County. As Table 4 shown, in the City of Baltimore, the frequency of SSO has increased after the CSO was eliminated. After elimination of CSO or separation of the combined sewer systems, the sanitary collection system becomes separated system, but overflow can still happen and will be considered as SSO, which actually increased the SSO frequency in the Baltimore area.

Table 3. City of Baltimore SSO and CSO annual volumes between 2005 and 2016

Municipality	Year	# SSO Events	Annaul SSO (Gallons)	Avg SSO (Gallons) per event	# CSO Events	CSO (Gallons)	Avg CSO (Gallons) per event
City of Baltimore	2005	84	4,749,943	56,547	4	4,885	1,221
City of Baltimore	2006	61	69,483,139	1,139,068	2	22,255	11,128
City of Baltimore	2007	61	549,564	9,009	CSO Eliminated		
City of Baltimore	2008	104	1,620,464	15,581	0	0	0
City of Baltimore	2009	152	2,167,752	14,262	0	0	0
City of Baltimore	2010	136	1,578,754	11,608	0	0	0
City of Baltimore	2011	240	10,857,511	45,240	0	0	0
City of Baltimore	2012	287	259,440	904	0	0	0
City of Baltimore	2013	279	963,690	3,454	0	0	0
City of Baltimore	2014	238	13,586,924	57,088	0	0	0
City of Baltimore	2015	260	968,168	3,724	0	0	0
City of Baltimore	2016	172	8,444,691	49,097	0	0	0

Table 5 contains only SSO data for Baltimore County because there is no CSO in this county. The SSO volumes are significant. The per-event volumes in 2011 and 2012 are about 2 mgd, which is a significant volume and equivalent to the untreated wastewater discharged from a 2 mgd significant wastewater treatment plant. In a specific river segment receiving this high SSO flow during the overflow events, the observed water quality data captured the SSO loads, but the Bay model has not included the SSO input yet. Missing such a significant input during the storm events would definitely cause the model underestimate during the events.

Table4. Baltimore County SSO annual volumes between 2005 and 2016

Municipality	Year	# SSO Evens	Annual SSO (Gallons)	Avg SSO (Gallons) per event
Baltimore County DPW	2005	73	11,450,966	156,863
Baltimore County DPW	2006	68	13,675,408	201,109
Baltimore County DPW	2007	51	3,107,394	60,929
Baltimore County DPW	2008	54	15,626,542	289,380
Baltimore County DPW	2009	40	24,064,011	601,600
Baltimore County DPW	2010	44	36,994,319	840,780
Baltimore County DPW	2011	57	120,765,533	2,118,694
Baltimore County DPW	2012	39	63,458,808	1,627,149
Baltimore County DPW	2013	46	2,908,692	63,232
Baltimore County DPW	2014	45	10,951,409	243,365
Baltimore County DPW	2015	37	1,864,382	50,389
Baltimore County DPW	2016	19	2,612,258	137,487

Like the Baltimore area, SSO is a common issue for many urban areas, especially those with aging sewer systems. We have only 64 reported CSOs in the Chesapeake Bay watershed, but SSO could happen anywhere with a sewer system. With the LTCP implementation progress, about 1/3 of the 64 CSOs have been eliminated or reduced to meet LTCP requirements. More CSO eliminations or reductions will be completed by 2025 and later years, which will convert more lands from CSO areas to SSO areas. So, the SSO issue is becoming increasingly important when we are eliminating CSO.

Conclusion:

SSO is an increasingly important issue and could happen anywhere. Bypass is a permitted practice, but not tracked by DMR data in many WWTPs. Both SSO and Bypass loads are significant during the storm events and should be included in the Bay model to improve the model performance and provide support to the SSO and Bypass reduction efforts.

The Wastewater Treatment Workgroup recommends that we should include SSO and Bypass in future model (phase 6.1 or 7?) and start to collect the SSO and Bypass data.