# APPENDIX A

CSO & SSO Pollutant Concentrations for Purposes of Watercourse Modeling,
Technical Memorandum, December 13, 2004

# Draft Technical Memorandum

| | | | |
|---|---|---|---|
| **Project Name:** | MMSD – 2020 Facilities Plan | **MMSD Contract No:** | M03002P01 |
| **DMS Folder Name:** | Water Quality Analysis | **MMSD File Code:** | M009PE000.P5580.P01 |
| **Document Name:** | CSO and SSO Pollutant Concentrations | **HNTB Charge No:** | 34568-PL-620-104 |

**Date:** December 13, 2004
**To:** Bill Krill, HNTB
**From:** Mary Recktenwalt & Jeremy Nitka/Triad Engineering
**Subject:** CSO and SSO concentrations for Purposes of Watercourse Modeling; MMSD Planning Area
**CC** Robert Biebel, SEWRPC

## 1. INTRODUCTION - PURPOSE

The 2020 Team was tasked with providing a summary of combined sewer overflow (CSO) and sanitary sewer overflow (SSO) concentration data to be used in calculating point source loadings for input into the model. The purpose of this memo is to document the sources of data and methodologies used to develop recommended CSO and SSO pollutant concentrations to be used in calculating the point source loadings for CSOs and SSOs.

The development of recommended pollutant concentrations was a collaborative effort of the 2020 Team that involved a series of memos and communications between Triad Engineering Incorporated (Triad) and the Southeastern Wisconsin Regional Planning Commission (SEWRPC). Memos prepared by SEWRPC (Appendices D and E) provide a summary of the correspondence and analyses that support the recommended concentrations. The following discussion provides background and further details regarding the analyses performed.

### 1.1. 2. MMSD SANITARY SEWER OVERFLOWS (SSOs)

The 2020 Team obtained SSO sampling data from MMSD for the period 1994 to 1999. There is no sampling data available after 1999 because after that year, the MMSD was no longer required by WDNR (Wisconsin Department of Natural Resources) to sample SSOs.

The following analyses were performed on the data:

1. Raw MMSD SSO sample data (received electronically) was quality checked with MMSD staff to confirm or dispute what appeared to be outlier data.
2. The 2020 Team calculated the means using the detection limit in place of the samples with reported non-detects and ½ the detection limit in place of non-detects. There was little difference between the calculated means. The 2020 Team used the ½ detection limit data in order to be consistent with our recommended approach for treating all such data.
3. The concentration data for each parameter was tested for normality and it was determined that all parameters are log normally distributed.

4. The 2020 Team observed that two of the MMSD SSO sample locations (#030 N. Richards Street and #044 N. Lydell and Lancaster) exhibited BOD and TSS concentrations significantly higher than the other sites. The 2020 Team met with MMSD personnel to evaluate these sample locations and determined that the site #044 at N. Lydell and Lancaster previously experienced surcharging that may cause the BOD and TSS concentrations at this location to be out of range of typical SSOs. Under the direction of SEWRPC, the four samples from this site were removed from the analysis.

During 1994 to 1999, MMSD took 33 samples of SSOs to the Milwaukee River (representing 14 separate sampling dates) but only one each of the Menomonee and Kinnickinnic Rivers (note: one overflow event may be represented by several sampling dates.) The 2020 Team recommends using one set of concentrations to represent SSOs for all watersheds in the modeling because there is insufficient data to develop separate representative concentrations for SSOs that discharge to the Menomonee and Kinnickinnic Rivers.

Under direction from SEWRPC, the 2020 Team desired to use one set of pollutant concentrations to represent SSOs from MMSD and other municipal discharges within Wisconsin. The 2020 Team obtained SSO sampling data from WDNR that represented recent sampling from 11 Wisconsin communities. This community data was obtained to ensure that the SSO pollutant concentrations being used for modeling were representative of both the MMSD and local communities. The 2020 Team performed a quality assurance review of the sampling methods and data and eliminated results from samples that were not representative of SSOs based on the communities' descriptions of the samples. In addition, sample results of fecal coliform were eliminated if the laboratory reporting levels were too low (e.g. > 6,000 #/100 mL was reported by the laboratory instead of an actual number). In concert with the recommendations by the Technical Advisory Team (TAT) and SEWRPC, the 2020 Team added BOD, TSS and total phosphorus data from six of the communities to the MMSD data set prior to performing the statistical analysis.

MMSD analyzed the SSO samples for biochemical oxygen demand (BOD), total suspended solids (TSS), fecal coliform and total phosphorus. SSO concentration data was also needed for the other parameters being modeled including e-coli, ammonia, Total Kjeldahl Nitrogen (TKN), nitrate, nitrite, dissolved oxygen, chlorophyll "a", copper, zinc, and temperature. MMSD did not analyze the SSOs for theses parameters.

Municipalities typically do not sample and analyze SSOs and no data from other municipalities could be found regarding nitrogen species in SSOs. The MMSD analyzes the influent to their wastewater treatment plants for a variety of pollutants including ammonia-nitrogen. The MMSD 2020 Team also summarized the Jones Island ammonia influent data during five wet weather (CSO) events (July 20-25, 1999; May 16-21,2000; July 1-4, 2000; September 10-15, 2000; and August 11-15, 2002 – periods include one day before and one day after CSOs and SSOs occurred). One would expect that the composition of the SSOs would be similar to the influent composition during these time periods. The 2020 Team also obtained CSO sampling data from the Ohio River Valley Water Sanitation Commission (ORVWSC, also known as ORSANCO in Ohio). The ORVWSC sampled CSOs for a variety of pollutants including ammonia nitrogen and organic nitrogen.

The 2020 Team performed a regression analysis to determine if a relationship exists between BOD and ammonia nitrogen concentrations (and organic nitrogen) for both the Jones Island influent during wet weather and Louisville CSO sampling performed by the Ohio River Valley Water Sanitation Commission (ORVWSC) [Kim Mays from the ORVWSC provided sampling data on August 19, 2003]. The regression analyses showed that a statistically significant linear correlation exists between BOD and ammonia nitrogen (and organic nitrogen). The MMSD SSO BOD concentrations were applied to the regression analyses to develop recommended concentrations for ammonia nitrogen and organic nitrogen.

Details regarding the regression analysis are summarized as follows:

- Regression of BOD vs Ammonia for ORVWSC data yielded a best-fit line with equation, Ammonia=0.0264(BOD)+0.4728. The $R^2$ values for the ammonia/BOD regression statistics were 0.91 for the Jones Island Influent and 0.61 for the ORVWSC CSO data.
- That equation was applied to the MMSD SSO arithmetic and geometric means for BOD in order to obtain the corresponding means for Ammonia in SSO.
- The ORVWSC Organic Nitrogen was calculated by taking Total Kjeldahl Nitrogen and subtracting Ammonia.
- Regression of BOD vs. Organic Nitrogen for ORVWSC data yielded a best-fit line with equation, Organic Nitrogen=0.0922(BOD)+0.4313. The $R^2$ value for the regression statistic was 0.64.
- The regression equation was applied to the MMSD SSO arithmetic and geometric means for BOD in order to get the corresponding means for Organic Nitrogen in SSO.
- Graphs of the regression are located in Appendix D.

MMSD's CSO sample data was used to develop representative copper and zinc concentrations for SSOs. The regression analyses of the TSS, zinc and copper CSO data showed that a statistically significant linear relationship exists between total suspended solids (TSS) and copper (and zinc). The MMSD SSO TSS concentrations were applied to the regression analyses to develop recommended SSO concentrations for copper and zinc.

- Regression of TSS vs Zinc for the MMSD CSO data yielded a best-fit line with equation, Zinc=0.0006(TSS)+0.05. The $R^2$ value for the Zinc/TSS regression statistics was 0.66.
- That equation was applied to the MMSD SSO arithmetic and geometric means for TSS in order to obtain the corresponding means for Zinc in SSO.
- Regression of TSS vs Copper for the MMSD CSO data yielded a best-fit line with equation, Copper=0.0001(TSS)+0.0093. The $R^2$ value for the Copper/TSS regression statistics was 0.65.
- That equation was applied to the MMSD SSO arithmetic and geometric means for TSS in order to obtain the corresponding means for Copper in SSO.
- Graphs of the regression are located in Appendix E.

E-coli bacteria are subset of the fecal coliform bacteria. The ratio of e-coli to fecal coliform in SSOs is expected to be within a similar range of that in sewage influent because SSOs are comprised of raw sewage and sewer inflow and infiltration. Dr. Sandra L. McLellan of the Great Lakes Water Institute (GLWI) provided a general relationship of e-coli to fecal coliform based on 102 influent samples (to Jones Island and South Shore wastewater treatment plants). Each of the fecal sample concentrations (in the MMSD's SSO data) was multiplied by this ratio (0.61) to obtain estimated e-coli values. The geometric and arithmetic mean of the estimated e-coli values were then calculated to represent e-coli concentrations in SSOs.

The 2020 Team recommends that the following values be used to represent the mean concentration data for calculating the loadings from the SSOs for modeling purposes:

**RECOMMENDED SSO MEAN CONCENTRATIONS FOR MODELING (Directly From MMSD and Wisconsin Community Sampling Data)**

| Parameter | $BOD_5$ (mg/L) | Total Suspended Solids (mg/L) | Fecal Coliform (#/100 mL) [1] | Total Phosphorus (mg/L) |
|---|---|---|---|---|
| Source of Data | MMSD sampling | MMSD sampling | MMSD sampling | MMSD sampling |
| All Watersheds (Arithmetic Means) | 51 | 193 | 1,540,000 | 3.7 |
| All Watersheds (Geometric Means) | 26 | 95 | 450,000 | 2.5 |
| Number of Values Analyzed[2] | 35 | 35 | 25 | 28 |
| Range (Min-Max) | 0.1-250 | 11-1,264 | 15,000-21,000,000 | 0.43-15.7 |
| Error of Mean [3] | 9 | 47 | 820,000 | 0.74 |

Notes: 1) The fecal coliform concentrations were rounded to two significant figures. 2) The number of values analyzed is the number of sample results evaluated for that parameter. Details of this analysis are presented in Appendix A. 3) Standard error of the arithmetic mean. 4) Includes MMSD (source MMSD) and Wisconsin Community data (source: WDNR)

**RECOMMENDED SSO MEAN CONCENTRATIONS FOR MODELING (Derived Values)**

| Parameter | Copper (mg/L) | Zinc (mg/L) | E-coli (#/100 mL) | Organic Nitrogen as N (mg/L) | Ammonia as N (mg/L) |
|---|---|---|---|---|---|
| Source of Data | MMSD Regression [1] | MMSD Regression [1] | E-coli/ Fecal Relationship-GLWI[2] | ORVWSC Sampling Regression [3] | ORVWSC Sampling Regression [3] |
| All Watersheds (Arithmetic Means) | 0.03 | 0.17 | 940,000 | 5.1 | 1.8 |
| All Watersheds (Geometric Means) | 0.02 | 0.13 | 280,000 | 3.3 | 1.4 |
| Number of Values Analyzed [4] | 35 | 35 | 25 | 35 | 35 |
| Range (Min-Max) [5] | 0.01-0.14 | 0.06-0.81 | 9,150-12,800,000 | 0.44-23.5 | 0.48-7.1 |

Notes: 1). The copper and zinc concentrations were estimated based on a regression analysis with TSS performed on CSO data from the MMSD 2) The e-coil concentrations were estimated based on a relationship between e-coil and fecal coliform in sewage influent (presented to two significant figures). 3) The nitrogen species concentrations were estimated based on a regression analysis with BOD performed on CSO data from the ORVWSC. Details of these analyses are presented in Appendix A. 4) Number of values is the number of TSS SSO sample results applied to the regression analyses. Details of this analysis are presented in Appendix A. 5) The range is the min/max of calculated values from regression analysis and relationships.

The 2020 Team assumes that the concentrations of dissolved oxygen, nitrate, nitrite, and chlorophyll "a" in the SSOs are negligible. The 2020 Team does not expect SSOs to present a significant heat load to the watercourses and the temperature of SSOs should be relatively similar to the temperature of sanitary wastewater. MMSD does not measure influent wastewater temperature. According to Wastewater Engineering, Treatment, Disposal, Reuse (3rd Edition. Metcalf & Eddy, Inc, McGraw Hill, 1991, Figure 3-10), the temperature of wastewater varies from 50-70 degrees F, depending upon weather conditions and states that 60 degrees F is a representative value. Because SSOs only occur primarily in the spring and autumn, when wastewater temperature would be colder than air temperature, a representative temperature of 60 degrees F, appears reasonable.

## 2. MMSD COMBINED SEWER OVERFLOWS (CSOs)

The 2020 Team obtained CSO sampling data from MMSD for the period 1994 to 2002. The sample data for BOD, TSS, fecal coliform, and total phosphorus cover the period from 1994-2002, while the sample data for e-coli, zinc and copper cover the period from 2000-2002. The CSOs were not routinely analyzed for e-coli, zinc and copper prior to 2000 [Note: MMSD performed some sampling of CSO for zinc and copper prior to 2000, but the data is not readily available in electronic form]

During 1994 to 2002, MMSD took 332 samples of CSOs at the near-surface collectors (representing 33 separate sampling dates). Not all outfalls overflowed during every sampling date, several sampling dates may represent one storm event, and not all parameters were analyzed during every sampling date. The following samples were taken during the time period studied:

- Milwaukee River outfalls: 147 samples
- Menomonee River outfalls: 83 samples
- Kinnickinnic River outfalls: 64 samples
- Lake Michigan outfalls: 38 samples

The 2020 Team performed a series of spatial and event-based statistical analyses on the raw CSO pollutant concentration data to determine if the data could be combined for all watersheds and all events or if there are spatial or event-based data that should be considered outliers and either removed from the data set or treated separately.

While the MMSD analyzes the CSO samples for BOD, total suspended solids (TSS), fecal coliform, e-coli, copper, zinc and total phosphorus, it does not analyze CSOs for the other parameters being modeled including ammonia, Total Kjeldahl Nitrogen (TKN), nitrate, nitrite, dissolved oxygen, chlorophyll "a", and temperature. Few municipalities have sampled their CSOs for nitrogen species. Therefore, the 2020 Team used the BOD/ammonia and BOD/organic nitrogen relationships identified by the regression analyses previously mentioned to develop estimates for nitrogen species concentrations in the CSOs. The BOD concentrations in MMSD's CSOs were applied to the regression analyses to develop recommended concentrations for ammonia nitrogen and organic nitrogen.

Details of the statistical analyses performed is summarized as follows:

1. Raw MMSD CSO sample data (received electronically) was quality checked against paper copies of lab reports to confirm or dispute what appeared to be outlier data.
2. The 2020 Team calculated the means using the detection limit in place of the samples with reported non-detects and ½ the detection limit in place of non-detects. There was little difference between the calculated means. The 2020 Team used the ½ detection limit data in order to be consistent with our recommended approach for treating all such data.
3. The concentration data for each parameter was tested for normality and it was determined that all parameters are log normally distributed.

4. The sample data was summarized by collector, watershed, and overall for various summary statistics including arithmetic mean, geometric mean, median, minimum, maximum, standard deviation, and count.
5. Box-plots were generated for each watershed and showed a similar distribution of data per watershed based on visual inspection of box plots.
6. The 2020 Team calculated mean concentrations for each collector and for each watershed. The 2020 Team performed 1-way ANOVA test on each parameter (parameters of interest sampled by MMSD) to determine if the means for each watershed were statistically similar (P value > 0.05 denotes similar means at 95% confidence level). The ANOVA tests show that, except for total phosphorous, the means between the watersheds are statistically similar as long as the data for collector CT 5/6 (located near 25th Street and Menominee River) was removed from the calculations.
7. The ANOVA tests showed that the total phosphorous concentrations were different for each watershed. Therefore, recommend using separate representative concentrations of total phosphorous for each watershed.
8. Bonferroni's tests were also performed to confirm ANOVA results and evaluate differences between collectors. Bonferroni's test showed that the mean BOD concentration at CT 5/6 was different from each of the other sites. No other differences among sites were detected.
9. Bonferroni's test showed that mean TSS at CT 5/6 was different from that at LMS, NS10, and NS11. No other differences among sites were detected.
10. Bonferroni's test showed that mean total phosphorous at CT 5/6 was different from that at LMN, LMS, NS6, NS8, NS9, and NS12. No other differences among sites were detected.
11. Based upon ANOVA results, Bonferroni's tests and physical characteristics of the collector basins it was decided to remove the concentrations of BOD and TSS for CT5/6 from the averages and report those averages for that collector separately from the whole.
12. Regression analysis was performed for the chemistry results versus date for all parameters. This analysis showed that there are no distinct trends in the pollutant concentration data over time so combining the data from 1994-2002 appears reasonable.
13. The same regression equations used to determine ammonia and organic nitrogen in SSOs were used to estimate those parameters for the CSOs except the CSO BOD mean concentrations were used (See Appendix D for graphs and details).
14. Because there was no significant relationship between BOD and nitrate/nitrite in the ORVWSC data, the mean concentrations from the ORVWSC data were used directly to represent MMSD CSOs.

Based on the analyses performed, the 2020 Team recommends that the following values be used to represent the mean concentration data for calculating the loadings from the CSOs:

## TABLE 5
## RECOMMENDED CSO GEOMETRIC MEAN CONCENTRATIONS FOR MODELING[3] – (Directly From MMSD Sampling Data)-

| Parameter | $BOD_5$ (mg/L) | Total Suspended Solids (mg/L) | Fecal Coliform (#/100 mL)[1] | E-coli Coliform (#/100 mL)[1,2] | Total Phosphorus (mg/L) | Copper (mg/L) | Zinc (mg/L) |
|---|---|---|---|---|---|---|---|
| Source | MMSD sampling | MMSD sampling | MMSD sampling | MMSD Sampling | MMSD sampling | MMSD sampling | MMSD sampling |
| Menomonee River (all but CT 5/6) | 9 (14) | 56(88) | 160,000 (650,000) | 96,000 (130,000) | 0.64(0.83) | 0.02 (0.02) | 0.09 (0.10) |
| Menomonee River (only CT 5/6) | 54(134) | 116(172) | 160,000 (650,000) | 96,000 (130,000) | 1.07(1.46) | 0.02 (0.02) | 0.12 (0.17) |
| Kinnickinnic River | 9(14) | 56(88) | 160,000 (650,000) | 96,000 (130,000) | 0.64(0.80) | 0.02 (0.02) | 0.09 (0.10) |
| Milwaukee River | 9(14) | 56(88) | 160,000 (650,000) | 96,000 (130,000) | 0.48(0.58) | 0.02 (0.02) | 0.09 (0.10) |
| Number of Values Analyzed [4] | 332 | 331 | 78 | 28 | 304 | 136 | 136 |
| Range (Min-Max) [5] | 0.1-1,200 | 4-680 | 400-24,000,000 | 18,000- 370,000 | 0.02-8.4 | 0.0059- 0.17 | 0.029-0.7 |
| Error of Mean [6] | 0.8 (59) | 5 (36) | 340,000 | 17,800 | 0.04-0.09 (0.4) | 0.0012 | 0.005 (0.068) |

1 Bacteria concentrations were rounded to two significant figures. 2) There were an insufficient number of samples to create an e-coli mean for each watershed. 3) Arithmetic means are presented in parentheses 4) Number of values analyzed is the number of CSO sample results from all watersheds (including CSOs to Lake Michigan). 5) Range is the min-max of all CSO sample results. 6) Standard error of arithmetic mean. Error of mean of BOD, TSS and zinc for CT 5/6 in parentheses. Error of mean for phosphorus varies by watershed (because mean varies by watershed) but it ranges from 0.04 (Milwaukee River) to 0.4 (Menomonee @ CT 5/6).

**RECOMMENDED CSO GEOMETRIC CONCENTRATIONS FOR MODELING- NITROGEN SPECIES[4]**
**(Derived Values) -**

| Parameter | Organic Nitrogen-as N (mg/L) | Ammonia (mg/L)-as N | Nitrate/ Nitrite (mg/L) as N |
|---|---|---|---|
| Source | ORVWSC Sampling [1] | ORVWSC Sampling [1] | ORVWSC Sampling [2] |
| Menomonee River (all but CT 5/6) | 1.3 (1.7) | 0.7 (0.8) | 1 |
| Menomonee River (only CT 5/6) | 5.4 (12.8) | 1.9 (4.0) | 1 |
| Kinnickinnic River | 1.3 (1.7) | 0.7 (0.8) | 1 |
| Milwaukee River | 1.3 (1.7) | 0.7 (0.8) | 1 |
| Number of Values Analyzed [3] | 332 | 332 | 162 |
| Range (Min-Max) [5] | 0.44-111 | 0.48-32 | 0-7 |
| Error of Mean [6] | NA | NA | 0.09 |

1) These values were calculated based on a BOD/Organic Nitrogen regression analysis performed on CSO data from the Ohio River Valley Water Sanitation Commission (ORVWSC). 2) There is no statistically significant linear relationship between BOD and nitrate/nitrite, therefore we recommend using the means directly from the ORVWSC study. Details of this analysis are presented in Appendix A. 3) Number of values for organic nitrogen and ammonia are the number of MMSD sample results (BOD concentrations) applied to the regression analysis. The number of nitrate/nitrate values is the number of nitrate/nitrate sample results provided by the ORVWSC. 4) Arithmetic means in parentheses. 5) Range is the min/max of calculated values from regression analysis. 6) Standard error of the arithmetic mean for nitrate/nitrite calculated directly from ORVWSC data. It is inappropriate to calculate arithmetic standard error of mean on the regressed data.

The 2020 Team assumes that the concentrations of dissolved oxygen and chlorophyll "a" in the CSOs are negligible. The 2020 Team expects the temperature of the CSOs to be similar to the temperature of the storm water runoff and therefore we recommend that we treat the temperature of CSOs in a similar manner as how it will be treated for the storm water runoff in modeling.

## 3. LOCAL COMMUNITY SANITARY SEWER OVERFLOWS (SSOs)

The 2020 Team contacted the WDNR for available SSO chemistry data from the twenty-eight local communities that are in MMSD's Planning Area. Local communities are not required by the Wisconsin Department of Natural Resources (WDNR) to sample SSOs. The 2020 Team obtained SSO sampling data from eleven Wisconsin communities (two within the MMSD Planning Area; the remainder outside the Planning Area). A discussion of the development of the concentrations to be used to represent local SSOs is presented in Section 1 of this memo. One set of concentrations will be used to represent SSOs from MMSD and from local communities.

**Summary of Electronic Files Supporting Recommended Values**

- Draft CSO SSO Chemistry.xls [Raw data and basic statistics- mean, geomean, min/max, median for CSO and SSO data]
- Draft CSO Collector Basin Descriptions.xls [Descriptions of size of area and population served by each near surface combined sewage collector]
- Draft CSO Metal Stats.xls [ANOVA statistics for metals by watershed and TSS/Zn and TSS/Cu regression analyses]
- Draft CSO- SSO ANOVA Stats by Watershed.xls [ANOVA statistics for conventional pollutants by watershed]
- Draft CSO SSO Boxplots and Collector Stats.xls [Box Plots by watershed and ANOVA statistics for conventional pollutants by collector]
- Draft CSO SSO Event Stats.xls [Regression analysis showing concentrations vs. time- shows time trends not significant]
- Draft CSO SSO Bacteria Stats. Xls [Evaluation of E-coli concentrations in SSOs and CSOs]
- Draft SSO-JI and ORVWSC Regression Stats.xls [Regression analysis on Jones Island Influent and ORVWSC CSO sampling to obtain nitrogen species concentrations for SSOs and CSOs).