D2. Wastewater Point Source Nitrogen Loads

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Introduction

Nitrogen, in its various forms, functions as both a nutrient with the potential to contribute to eutrophication (i.e. in coastal waters), and as a toxic pollutant with the potential to affect aquatic life and human health. In circumstances where excess nitrogen (N) loading may preclude the attainment of designated uses, loading from point sources is of particular importance because it can be controlled with nutrient removal technology through permit limits. This chapter provides estimates of N loading from municipal and industrial point source dischargers with National Pollution Discharge Elimination System (NPDES) permits; hereafter referred to as point sources. Load sources not covered in this chapter include: permitted industrial or municipal stormwater, concentrated animal feeding operations, large subsurface treatment systems, individual subsurface treatment systems, spray irrigation facilities where measured drain tile flow data are unavailable, and the land application of wastewater treatment biosolids. Significant sources from this list are generally covered in other chapters. Loads from individual point sources are aggregated and presented by basin and major watershed. Seasonal patterns, yield per unit area, yield per capita, and the distribution of load between municipal and industrial sources are examined in greater detail. Although this chapter primarily focuses on total nitrogen (TN), estimates of ammonia (NHx), total kjeldahl nitrogen (TKN), and nitrite and nitrate nitrogen (NOx) are also presented in various tables and appendices.

Project results are presented first, followed by a discussion of the methods used to determine the estimated point source loads.

Statewide totals

Currently, Minnesota has over 900 wastewater point sources that actively discharge to surface waters. Of these point sources, 64% are domestic wastewater treatment plants (WWTPs) and 36% are industrial facilities (Appendix D2-1). In total, it is estimated that wastewater point sources discharge an average annual TN load of 28,671,429 pounds statewide (Table 1). Most of this load is from municipal dischargers (24,929,970 pounds/year TN, 87%); the remainder is from industrial facilities (3,741,459 pounds/year TN, 13%). Within most basins, municipal facilities account for over 90% of the point source load (Table 1). The few exceptions include basins like the Rainy River and St. Croix River which have large, water-using industrial facilities.

Despite the large number of individual permits in Minnesota, the majority of wastewater point source TN loading comes from a small number of large facilities. The 10 largest point sources, as measured by average annual TN load, collectively amount to 67% of the point source TN load. The single largest facility is the Metropolitan Council Environmental Service (MCES) Metro WWTP which discharges an annual average TN load of 10,363,151 pounds/year. The Metro WWTP, by itself, amounts to 36% of the overall point source TN load. The remaining MCES facilities within the top 10 include the Blue Lake, Seneca and Empire WWTPs which collectively discharge 12% of the point source TN load. Other notable large municipal TN load sources include the Western Lake Sewer and Sanitary District (WLSSD) WWTP in Duluth, Rochester WWTP and St. Cloud, which are estimated to discharge 7%, 3%, and 2% of the overall municipal TN load, respectively. Following the 10 largest dischargers, no single facility amounts to over 1% of the state wide point source TN load. It should be noted that the industrial load only includes estimates from industrial facilities that have individual NPDES permit and not facilities considered significant industrial users (SIUs), which discharge to municipal WWTPs for further treatment. Insufficient data are available from which to estimate SIU flow and loading to municipal WWTPs statewide.

Table 1. Estimated wastewater point source TN loading per basin from industrial and municipal dischargers (2005-2009).

	Industrial		Municipal		Total
Basin	**Load (lbs/yr)**	**%**	**Load (lbs/yr)**	**%**	**Load (lbs/yr)**
Upper Mississippi River	1,132,842	8%	13,609,734	92%	14,742,576
Minnesota River	273,539	6%	4,443,605	94%	4,717,144
Lake Superior	256,035	9%	2,614,346	91%	2,870,381
Lower Mississippi River	257,372	10%	2,386,378	90%	2,643,750
Rainy River	1,576,132	93%	113,388	7%	1,689,520
Cedar River	14,219	2%	621,129	98%	635,348
Red River of the North	63,066	10%	554,806	90%	617,872
St. Croix River	84,148	23%	287,900	77%	372,049
Des Moines River	84,062	30%	200,291	70%	284,353
Missouri River	44	0%	98,392	100%	98,436
Total	**3,741,459**	**13%**	**24,929,970**	**87%**	**28,671,429**

Major basin wastewater point source loads

Upper Mississippi River Basin

On average, more TN is discharged annually by wastewater point sources in the Upper Mississippi River Basin (UMR) than in all other basins state-wide (14,742,576 pounds/year, 51%, Figures 1 and 3). Although there are numerous domestic and industrial dischargers within this basin, (142 and 118, respectively) the majority of the flow and loading is discharged by a few large municipal sources in the Twin Cities Metropolitan Area (TCMA). Industrial point source loading is generally estimated to be small (8%) as compared to municipal (92%). The few exceptions include high protein industries like food, rendering, and paper, the latter of which adds nutrients to feed bacteria and thereby reduce biological oxygen demand (BOD). Within the UMR, the two highest loading major watersheds are the Mississippi River Twin Cities and St. Cloud which generate annual TN loads of 10,972,760 and 864,231 pounds, respectively (Figure 2, 4, Appendix D2-2). Municipal wastewater accounts for the majority of point source loading within these watersheds (Figure 3).

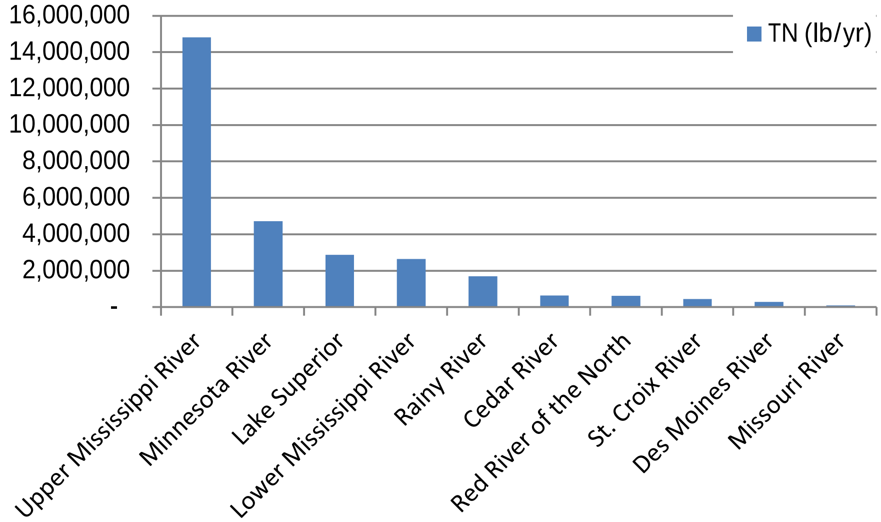

Figure 1. Comparison of watershed basin annual TN load estimates from permitted point sources.

Minnesota River Basin

The Minnesota River Basin (MRB) is estimated to have the second highest annual wastewater point source TN load (4,717,144 pounds). This equates to 16% of the total statewide point source TN load. Unlike the UMR, loading in the MRB is more evenly distributed among its 155 municipal and 81 industrial facilities in most sub basins. The Minnesota River (Shakopee) has the highest point source TN load within the MRB (3,170,968 pounds/year) and is the second highest loading major watershed in the state. Point source TN loading in the MRB Shakopee primarily comes from larger municipal facilities.

Lake Superior, Lower Mississippi, and Rainy River Basins

The Lake Superior, Lower Mississippi River, and Rainy River Basins have the third, fourth, and fifth highest annual wastewater point source TN loads at 2,870,381 pounds, 2,643,750 pounds, and 1,689,520 pounds, respectively. Like other basins, the point source TN loading in the Lake Superior and Lower Mississippi River Basins is primarily from municipal sources. Point source TN in the Rainy River, however, is estimated to be mostly from one large paper manufacturer. Industrial TN loading is estimated to be 93% of the total point source load. Paper facilities typically have a carbon rich pulp influent which requires that nutrients (i.e. phosphorus and N) be added to feed bacteria and thereby reduce BOD. Given the tremendous flow from the paper industry, moderate to high effluent TN concentrations can result in large loads.

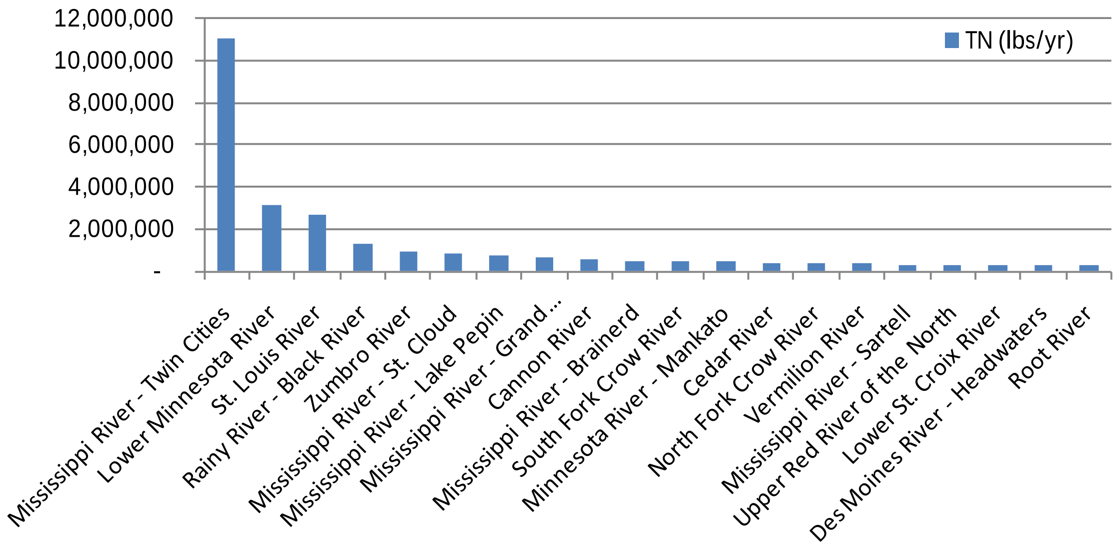

Figure 2. Annual N load estimates from permitted point source dischargers within the top 20 major watersheds in Minnesota.

Cedar, Red, St. Croix, Des Moines, and Missouri River Basins

The remaining basins of the state, including the Cedar River, Red River, St. Croix River, Des Moines River, and Missouri River, are estimated to collectively generate less than 7% of the wastewater point source TN load. The major watersheds within these basins generate annual TN point source loads in the range of less than 100 pounds to roughly 400,000 pounds.

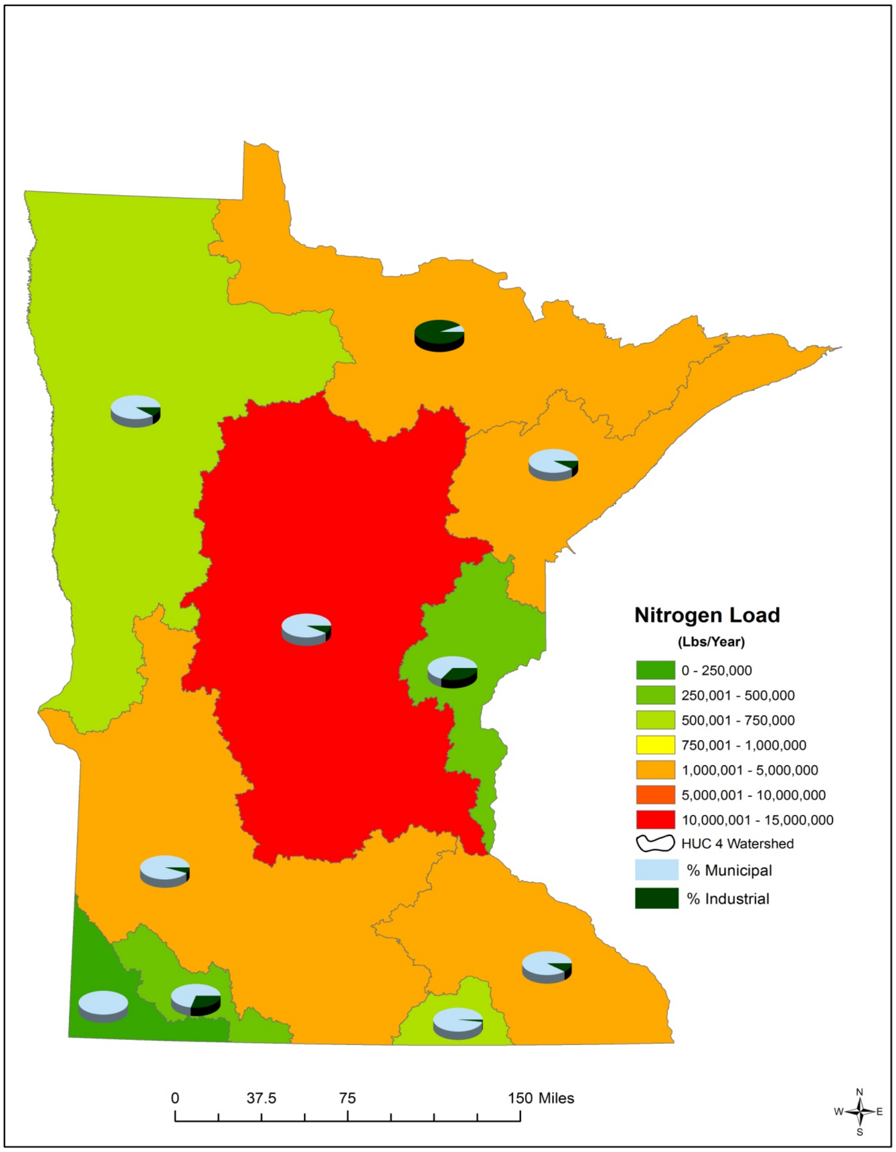

Figure 3. Total nitrogen load by basin from municipal and industrial NPDES point sources (2005-2009). Pie charts represent the percent load distribution among municipal and industrial facilities within each basin.

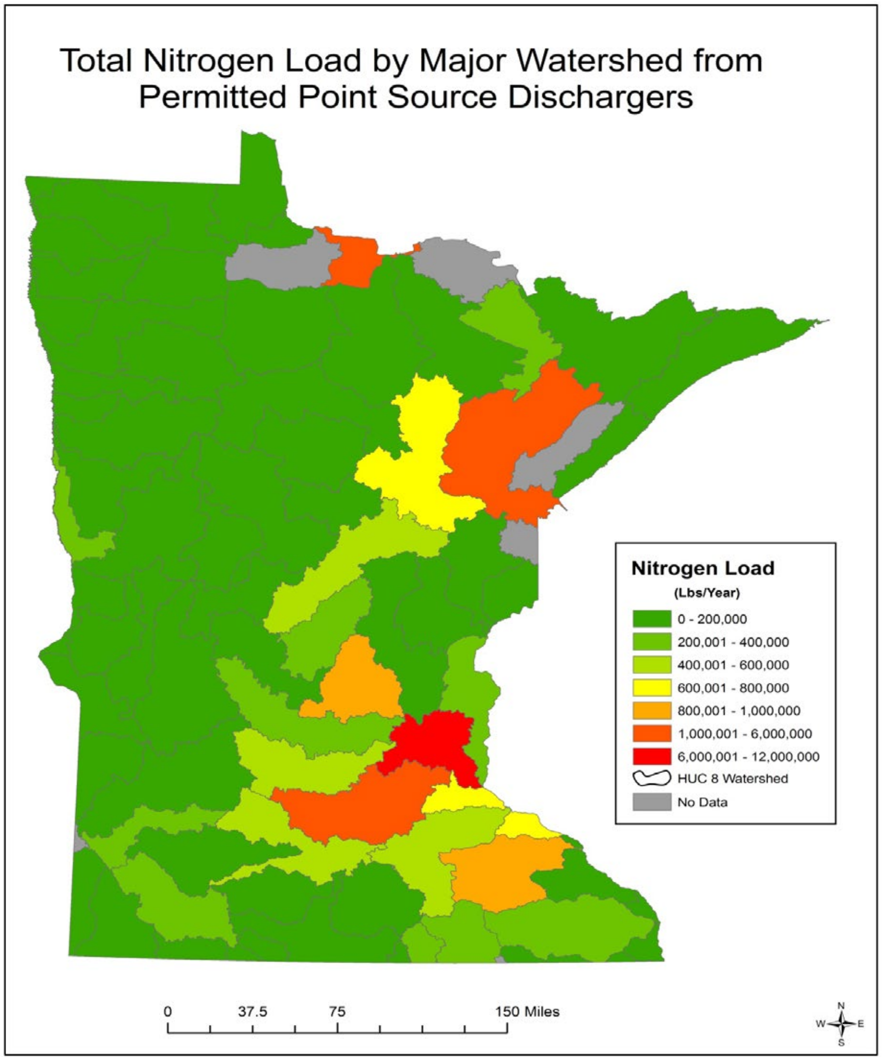

Figure 4: Total nitrogen annual load by major watershed from municipal and industrial NPDES point sources (2005-2009).

Wastewater point source yield

Nonpoint pollutant load sources are commonly assessed by a yield or per unit area basis. For means of comparison, TN point source yield values were also calculated for basins (Appendix D2-1), major watersheds (Figure 5, Appendix D2-1(B)), and in a few select cases by the land area contributing to a specific wastewater treatment facility (sewershed) (Figure 6, Table 2). Wastewater point source yields are intended to represent the TN loading potential from low to high density residential landcover. Basin and watershed yields might best be used to rank or compare watersheds or basins with each other. In contrast, sewershed yields are a more direct measure of urban point source load potential because the land area directly represents the extent of the collection system area. Yield on a per capita basis was also examined for a few select urban watersheds where sufficient user data were available (Table 2). Note that the nature of yields from wastewater point sources is different than yields from nonpoint sources, since all of the load from point source contributing areas is released at specific points in the rivers, instead of being a more diffuse discharge occurring over a larger geographic area. Yield comparisons between point and nonpoint sources are more appropriate for assessing the relative effects on downstream waters. However, the localized effects from point and nonpoint source discharges can potentially be different from similarly N yielding areas.

Basins and major watersheds

The Mississippi River Twin Cities major watershed has, by far, the highest wastewater point source TN yield (17.0 pounds/acre, Figure 5, Appendix D2-1(B)). Other major watersheds with notable yields include the Rainy River – Manitou (3.8 pounds/acre), the Minnesota River – Shakopee (2.7 pounds/acre) and the Mississippi River – Lake Pepin (1.9 pounds/acre). High point source yields typically result from a large volume of wastewater discharged within a given area. However, in some cases like the Cedar River Basin, the comparatively high point source yield is the result of a small overall basin area. Major watershed yields, especially in the Metro Area, may be distorted due to sewersheds that overlap defined watershed boundaries (Figure 6). For Example, the Metro WWTP receives wastewater from developments within the Lower Minnesota River; this amplifies the overall yield within the Mississippi River - Twin Cities watershed. Conversely, the Blue Lake WWTP serves developments within the Mississippi River – Twin Cities watershed. It is difficult to predict the difference in volume and pollutant loading received from sewersheds that extend beyond the watersheds that they discharge within.

Sewersheds

Sewershed yield was examined for seven metro area WWTPs to better understand the range in sewershed nitrogen yield. The Twin Cities metro area was selected for yield analysis because of the good availability of wastewater data, its dominance statewide in wastewater treatment volume, and the wide range of population densities within the sewersheds. Three primary aspects were analyzed; 1) point source yield per sewershed area, 2) sewershed population density, and 3) yield per capita (Table 2). Sewersheds are defined as the estimated perimeter surrounding a collection system of interest (Figure 6). It should be noted that sewersheds inevitably contain features such as parks, wetlands, and lakes which may not be characteristic of urban land cover or significantly contribute to TN loading. Area-based yields were calculated in consideration of both municipal and industrial point source loading. Industrial yield contributions included those industries with outfalls either located within or directly adjacent to sewershed boundaries. Finally, population density, yield per capita, and their relationship to area-based yield were also examined.

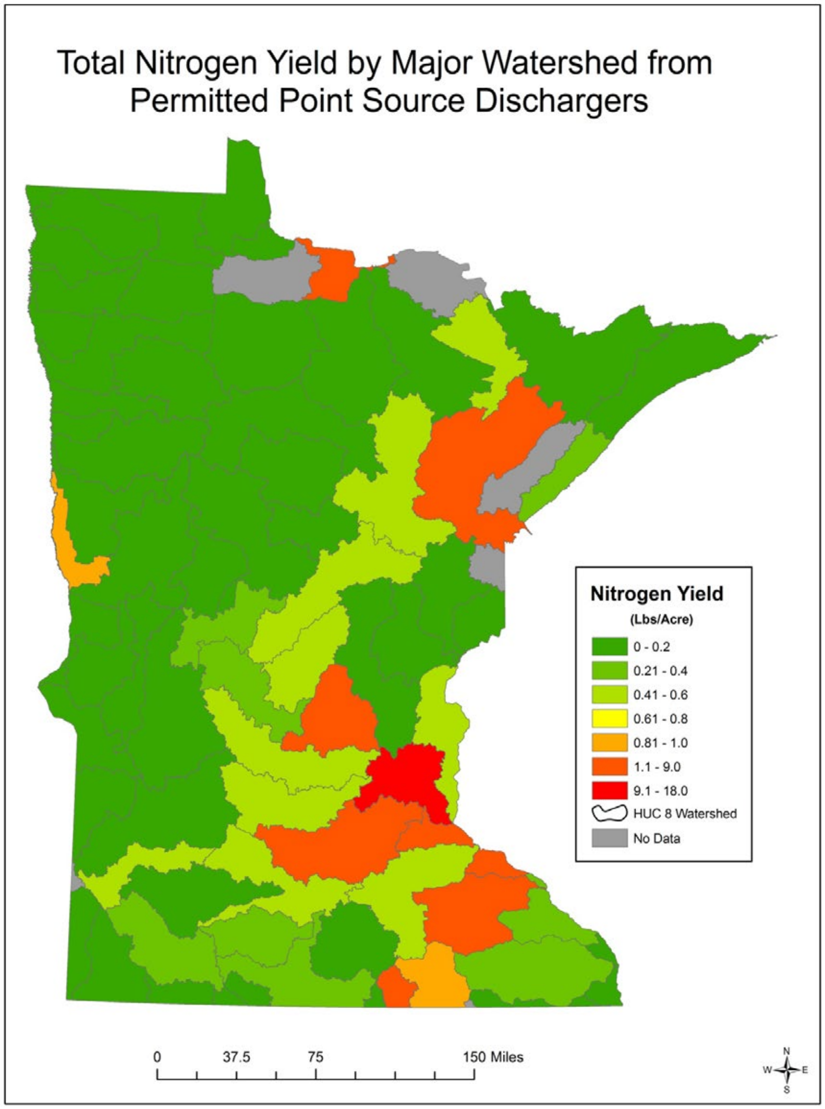

Figure 5. Total nitrogen yield by major watershed from municipal and industrial NPDES point sources (2005-2009).

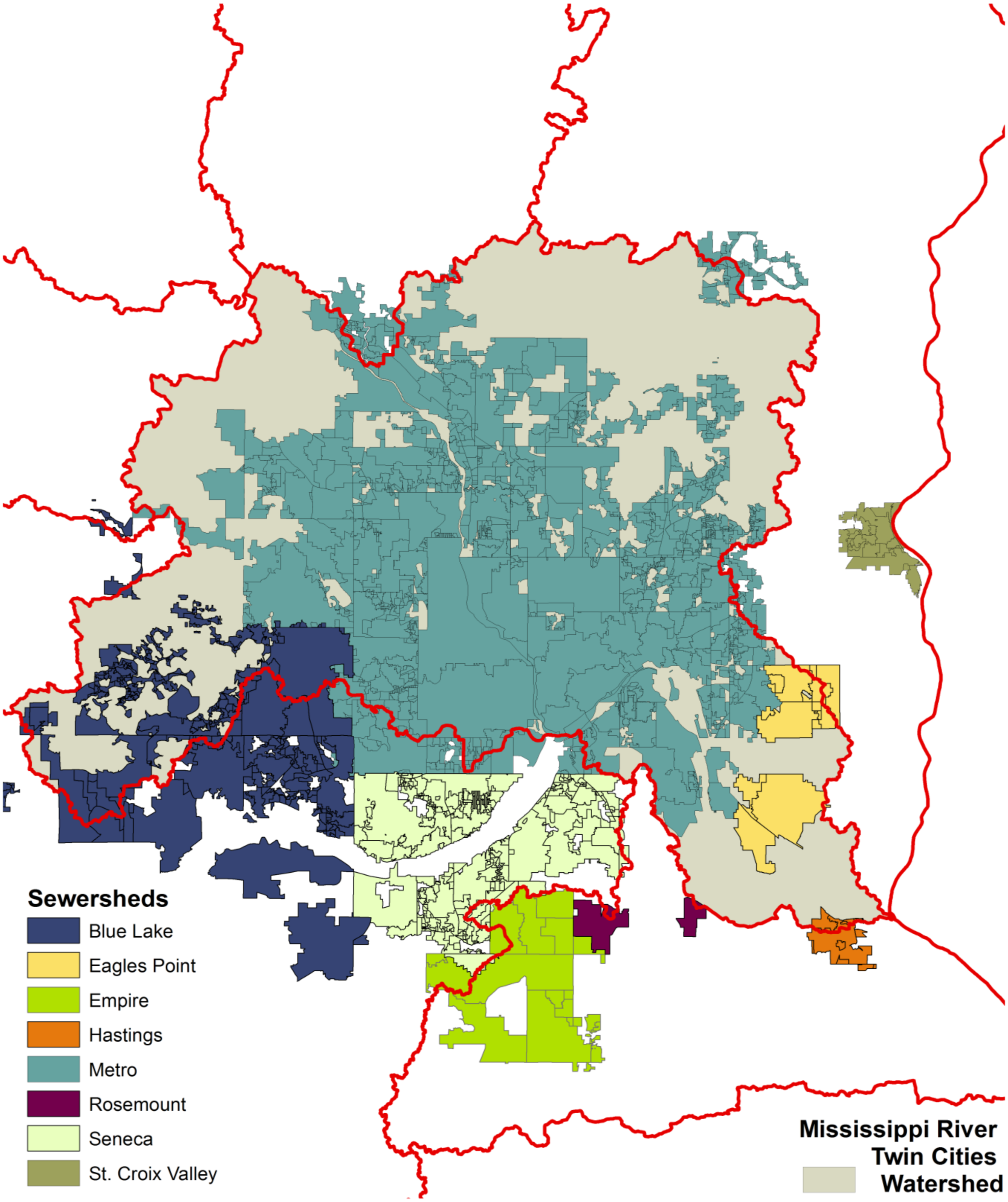

Figure 6. Municipal sewer drainage areas (sewersheds) within the TCMA in relationship with major watershed boundaries. It should be noted that effluent discharged in one watershed may contain drainage from adjacent watersheds given that sewershed and watershed boundaries overlap.

Table 2. Total nitrogen wastewater point source yield data from seven sewersheds (2005-2009).

	Area and Population			Average Annual Load			Average Annual Yield			
Sewershed	Area[1] acres	Population[2]	Population Density persons/ acre	Municipal pounds/ year	Industrial pounds/ year	Total pounds/ year	Municipal pounds/ acre	Industrial pounds/ acre	Total pounds/ acre	Per Capita pounds/ person
Metro	512,941	1,846,185	3.6	9,971,974	115,180	10,087,154	19.4	0.2	19.7	5.5
Blue Lake	174,126	285,162	1.6	1,308,553	50,248	1,358,801	7.5	0.3	7.8	4.8
Seneca	79,569	244,996	3.1	1,270,979	42,828	1,313,807	16.0	0.5	16.5	5.4
Empire	95,999	149,509	1.6	656,614	101	656,715	6.8	0.0	6.8	4.4
Eagles Point	25,140	71,741	2.9	270,448		270,448	10.8	0.0	10.8	3.8
Stillwater	13,070	27,787	2.1	164,470	33,331	197,801	12.6	2.6	15.1	7.1
Hastings	5,079	20,572	4.1	103,254		103,254	20.3	0.0	20.3	5.0
Average	129,418	377,993	2.7	1,963,756	48,338	1,998,283	13.3	0.5	13.9	5.1

[1]WWTP service areas are derived from the Metropolitan Council sewersheds GIS layer.
[2]Population data derived from the Metropolitan Council Research Group's draft 2010 population data, which is based on 2010 census data.
Note: Sewershed area and population data provided by Metropolitan Council (pers. comm. K. Jensen, E. Resseger, 3/16/2012)

The estimated sewershed area ranges from 5,079 acres (Hastings) to 512,941 acres (Metro) and averages 129,418 acres (Table 2). Overall, sewershed population ranges from 20,572 to 1,846,185 people. The population density of these sewersheds ranges from 1.6 (Blue Lake and Seneca) to 3.6 capita per acre. Of note, the smallest sewershed, Hastings, had the second highest population density. As such, sewershed size does not correlate well with population density.

Wastewater point source TN loading in select sewersheds ranged from approximately 100,000 pounds/year to nearly 10,000,000 pounds/year, most of which was estimated to be from municipal sources (Table 2). The range of loading closely relates to both the size and population of a given sewershed. Total sewershed yield per unit area ranged from 6.8 to 20.3 pounds/acre with an average of 13.9. In most sewersheds the industrial component was minor (0-4%). However, in Stillwater, estimated TN loading from a power plant amounted to 17% of the total area-based sewershed load. Given that the power users extend far beyond the boundaries of the Stillwater sewershed, addition of this industrial load results in an elevated area-based yield that may not accurately depict the urban activity of that particular sewershed area. Nonetheless, the average municipal area-based yield (13.3 pounds/acre) closely resembles that of the average total area-based yield (13.9 pounds/acre), which includes individually permitted industrial dischargers.

Sewershed per capita yield and population density are also important components to consider. TN yield per capita ranges from a minimum of 3.8 pounds/capita (Eagles Point) to a maximum of 7.1 pounds/capita (Stillwater) with an average of 5.1 pounds/capita (Table 2). There were no strong relationships between per capita yield and either total area-based yield (R^2 = 0.21, Figure 7) or municipal area-based yield. This is due, in some part, to Stillwater's high per-capita yield yet moderate area-based yield. In contrast, strong relationships were observed between population density and both total area-based yield (R^2 = 0.80, Figure 8) and municipal area-based yield (R^2 = 0.89, Figure 9).

Sewershed areas may not be readily available for many urban communities, and yet population density data often is. One may estimate municipal area-based yield with population density data of the desired scale. The linear relationship between population density and municipal area-based yield is defined below (Figure 9):

Equation 1:

$$y = 5.3164x - 1.0084$$

Where:
y = municipal point source average annual TN yield (pounds/acre), and
x = population density (capita/acre)

For example, if a community served by a municipal wastewater treatment plant had a population density of 1.9 capita/acre (roughly equivalent to that of the state of New Jersey; U.S. Census Bureau, 2010), the estimated municipal point source annual TN yield equates to 8.9 pounds/acre (Equation 1). Additional industrial load, not serviced by the WWTP could be included as a yield if the total population of concern were known. It is important that the user carefully evaluate the scale of the sewered population that one wishes to represent.

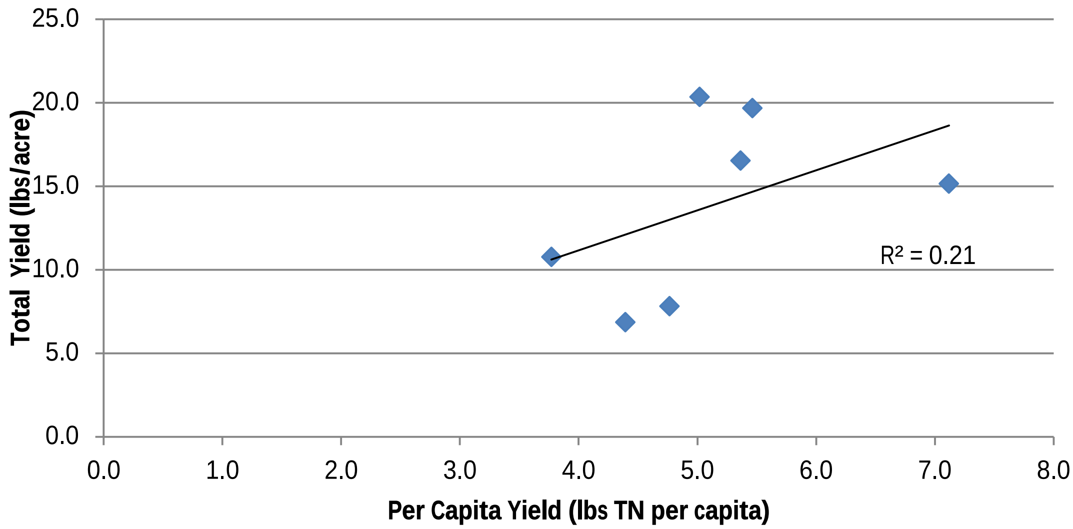

Figure 7. Sewershed point source TN per capita yield versus total area based yield. The total yield includes estimates of both municipal and industrial point source yields calculated from estimated discharges.

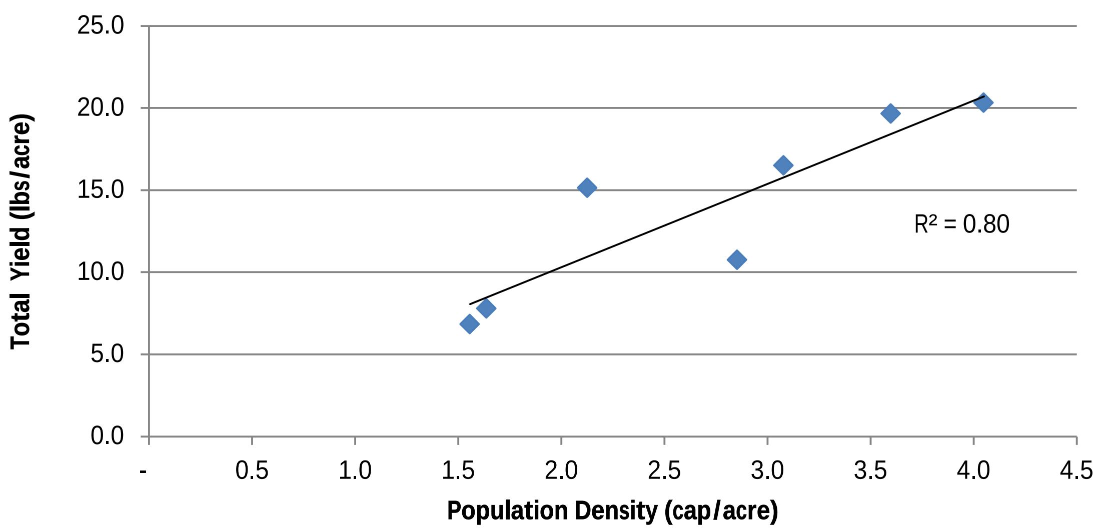

Figure 8. Sewershed population density (cap/acre) versus point source TN area based yield. Total yield includes values from individually permitted municipal and industrial point sources.

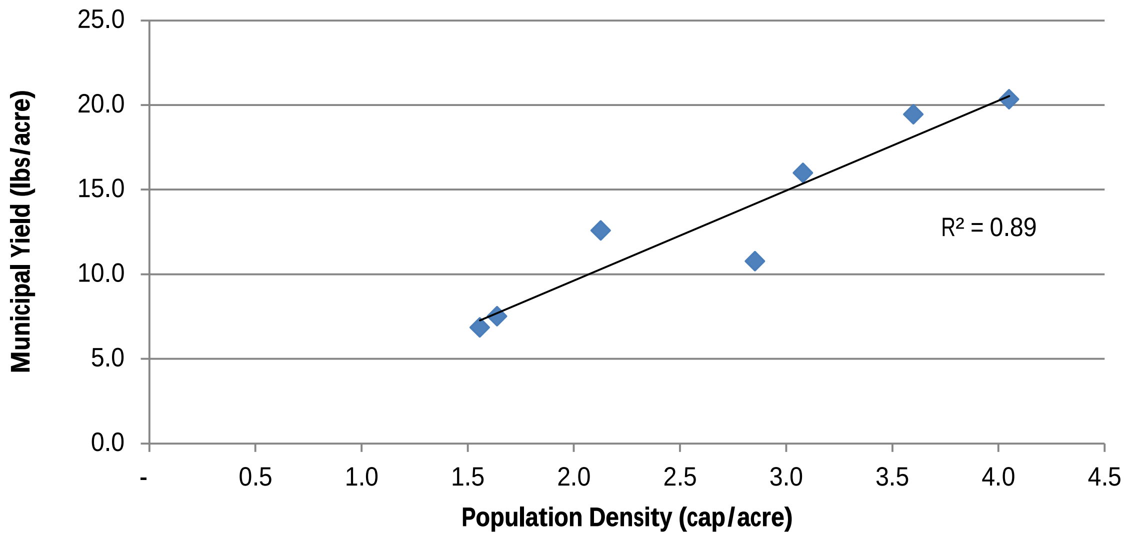

Figure 9. Sewershed population density (cap/acre) versus municipal point source TN area based yield. Municipal yield does not contain values from individually permitted industrial point sources.

Seasonal patterns

Pollutant loading from wastewater point sources is typically assumed to be constant as compared to nonpoint sources. In this section, seasonal patterns of point source TN loading within the Minnesota River Basin (MRB) are examined in greater detail. Although the MRB has a large number of small individual facilities, the mix of facility type and size makes these patterns suitable to be applied to other basins.

In total there are 236 active point sources within the MRB. This equates to 26% of all active dischargers statewide. Together, they discharge an average annual TN load of 4,717,144 pounds/year. Within the MRB 66% (155) of point sources are domestic and 34% (81) are industrial; primarily cooling water discharges. Furthermore, 37% (87) of all active point sources are municipal stabilization ponds. Ponds are often used by smaller communities. Unlike other treatment systems, ponds do not discharge continuously, but rather, store wastewater for extended periods of time and discharge for a few days to weeks within a regulated time slot. In southern Minnesota, including all of the MRB, the acceptable discharge period is in the spring from March 1 through June 15 and in the fall from September 15th to December 31st. In the north, acceptable discharge periods are less restrictive and range from March 1 through June 30 in the spring and September 1 through December 31 in the fall.

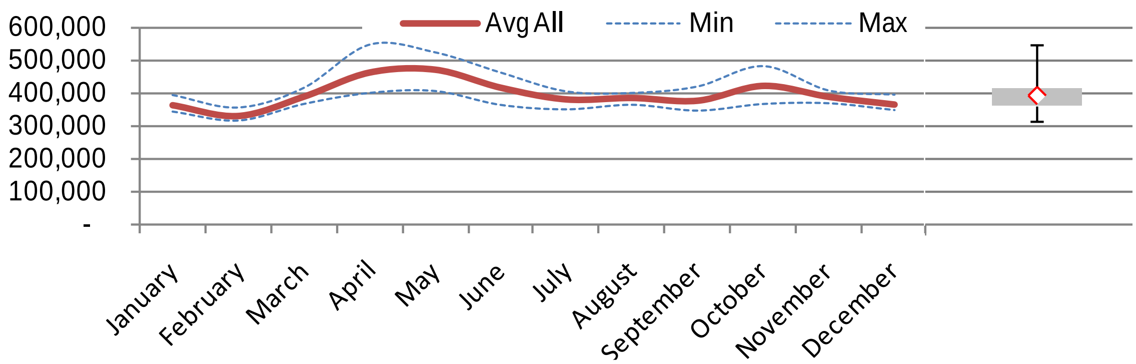

Figure 10. Monthly average point source TN effluent load (lbs) in the Minnesota River Basin (2005-2009). The adjacent box and whisker plot shows the distribution of all monthly values. The grey box indicates the 25th and 75th percentile range. The red diamond represents the mean value; whiskers represent minimum and maximum values.

Five years of monthly average TN data from all active point sources demonstrates a slight seasonal swell in mean loading and an increase in variability (Figures 10 and 11). The median monthly load is 382,265 pounds with a 12% coefficient of variation (Figure 10). The discernible rise in spring (April, May) and fall (October, November) loading coincides with annual precipitation patterns and the pond discharge window. Despite the fact that 37% of point source permits in the MRB are ponds, they only account for 3% of the annual load (Figure 11).

The overall flow volume from these facilities tends to be small. Limited effluent data suggests that the extended detention time in ponds facilitates denitrification. At peak, ponds are estimated to account for 8% (35,529 pounds/month) of monthly load in May and 7% (27,933 pounds/month) in October. This contribution drops to zero from January through March and July through August. In lieu of actual effluent concentration data, ponds are assumed to discharge 6 mg/L TN as compared to larger mechanical facilities which are assumed to discharge between 17 and 19 mg/L. When pond loading is removed from the total, a seasonal load swell is still observed due to increased flow and load from continuous facilities. Therefore, pond effluent only explains a fraction of the seasonal variation; the remainder can be attributed to seasonal precipitation patterns (Figure 11).

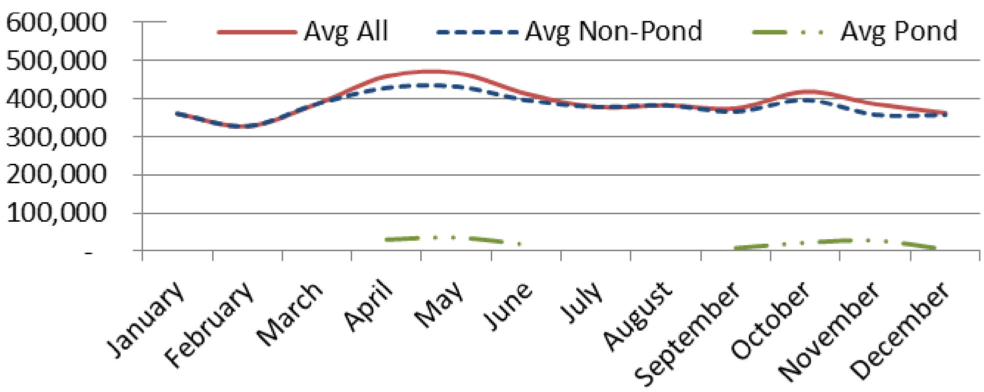

Figure 11. Monthly average point source TN effluent load (lbs) in the Minnesota River Basin (2005-2009). Municipal stabilization pond loads (green dashed), and non-pond loads (blue dashed) are disaggregated from the total monthly load (red solid).

Inflow and infiltration (I/I) of groundwater into municipal collection systems typically increases during storm events and wet seasons. Although many municipal treatment systems were built in the mid twentieth century, the collection systems often date back to the early twentieth century (MPCA 1991). Given the cost and inconvenience associated with maintenance, many of these systems are in need of repair. The remainder of the seasonal load swell, after pond loading is removed, is likely to be due to an increase in I/I. Despite the seasonal change in flow, I/I is generally assumed to have a low TN concentration, thereby resulting in a relatively constant seasonal loading rate. A review of five years of NOx data from over 350 Ohio WWTPs shows an average monthly NOx concentration change of only 3.6 mg/L (Figure 12). In spring, concentrations from all facilities averaged about 9 mg/L NOx, whereas in fall this increased to 12 mg/L. Overall, these data suggest that NOx concentrations remains relatively constant throughout the year. The Ohio data, generally, validate the constant load assumptions made for these load estimates. Effluent data currently being collected by Minnesota dischargers will better inform future analysis.

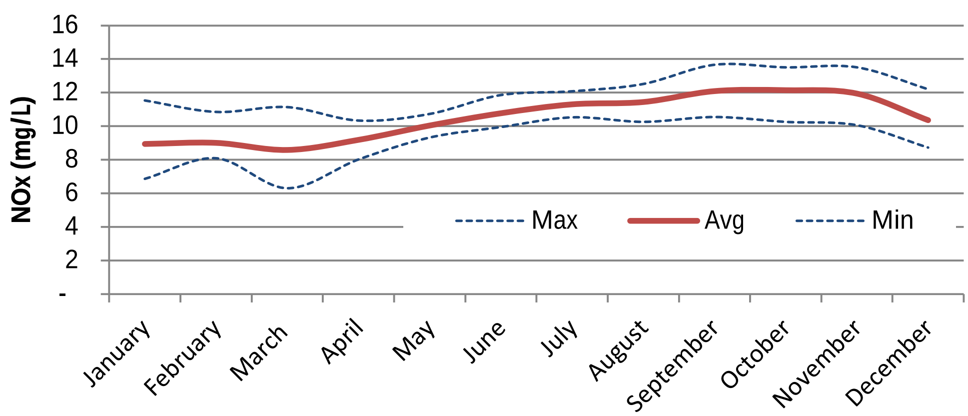

Figure 12. Monthly average NOx from over 350 Ohio WWTPs (2005-2009). Variability is greatest during spring and fall months. The average concentration rises from roughly 9 mg/L in spring to 12mg/L in fall.

Assumptions and methods

Overview

Load estimates were based on five years of discharge monitoring report (DMR) data from 2005 through 2009. At the time of analysis, only a partial year of 2010 data were available, and therefore, these data were not included. Wastewater point source N effluent data in Minnesota are somewhat sparse and coincide with the historical implementation of numeric standards. Ammonia effluent data are, by far, the most abundant. Limits and reporting requirements became more prevalent in the early 1980s. Facilities with ammonia limits generally discharge to low dilution streams or receive waste streams from high protein industries. The direct impact of ammonia from point sources is seasonal and localized. In the summer the combination of ammonia and biological oxygen demand (BOD) can cause a dissolved oxygen (DO) sag that typically occurs 2 to 5 miles downstream of a discharger in an affected stream. In winter, the DO sag typically occurs from between 20 and 30 miles downstream, at which point ammonia and BOD levels return to headwater conditions (MPCA scientist G. Rott, personal correspondence, 6/24/11).

Facilities that report TN, or NO_x either discharge upstream of a biotic life impairment, in which a form of N has been identified as a stressor, or they were found to contribute to a violation of the nitrate drinking water standard (10 mg/L NO_3). Biannual effluent monitoring for TN or NO_x is now being required for all municipal major facilities, which includes municipal point sources with average wet weather design flows (AWWDFs) greater than 1.0 million gallons per day (mgd). Future load monitoring data can be used to refine load estimates and will provide a better understanding of the variability of treatment. It is anticipated that more frequent TN and NO_x monitoring will be required if nitrate toxicity standards are developed for surface waters in Minnesota.

It would have been impractical to estimate facility loads one at a time given the large number of point sources, a five year time frame (2005-2009), and the wealth of flow, and to a lesser extent, concentration data. As such, a database system was designed to select appropriate flow and concentration records based on predetermined conditions and to calculate monthly loads (Figure 13). All DMR records for flow and the four N parameters of concern (TN, NOx, NHx, and TKN) were downloaded from the Delta database, an MCPA repository for regulatory data. No single facility is required to monitor for all four pollutant parameters of interest, so it was necessary to splice in other concentration estimates for each flow record of concern when DMR concentration data were unavailable. Concentration assumptions were either applied to specific facilities identified by permit number, or they could have been applied to a larger category of similar facilities. The success of such a system is based on two factors including: 1) database architecture, and 2) the accuracy of the concentration assumptions and actual data. Additional WWTP effluent data supplied by the Metropolitan Council Environmental Services (MCES) made it possible to test both factors.

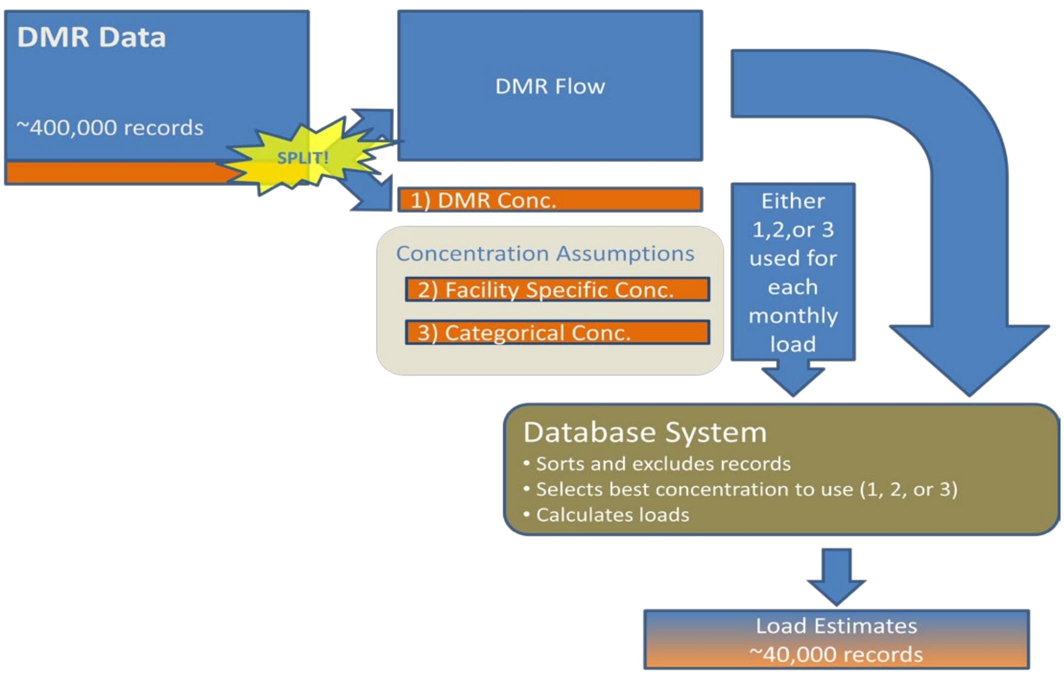

Figure 13. Overview of point source N load estimation process.

Database architecture validation

Database architecture refers to the sequence of conditional statements programmed into the database system used to select desired records and calculate loads. In total, there were nearly 400,000 flow and concentration records statewide. From this larger data dump, only approximately 40,000 records (10%) were used in this study. The remaining records were typically duplicitous and had undesired units, periods of records, or limit types (i.e. maximum, minimum etc.). Mistakes associated with faulty database architecture often result in undesired records selected, and more often, multiple loads calculated for the same time period. When errors of this sort occur, results are often distorted by a factor of two or more.

The MCES Metro facility is currently required to submit monthly average NOx concentration data as part of their DMRs which were, in turn, used to calculate loads within the database system, hereafter referred to as MPCA loads. In order to generate monthly average values, MCES collects sub-monthly NOx concentration samples. Sub-monthly values were used independently by MCES to calculate annual NOx loads, hereafter referred to as MCES loads. By comparing MPCA and MCES loads for the same facility, one can verify that the database architecture functions correctly. In this situation, long term annual average MCES and MPCA loads were only 0.1% different. Results demonstrate that the database architecture is capable of calculating loads correctly for the Metro facility, one of the largest and more complex facilities statewide. Therefore, it is reasonable to conclude that the database system is capable of deriving accurate loads for the hundreds of other point sources given the accuracy of the data and assumptions provided.

Data and assumption validation

Of the eight MCES facilities that discharged between 2005 and 2009, only Metro was required to submit NOx data. Nonetheless, MCES collected NOx samples from the remaining seven facilities for their own records and provided annual NOx loads to MPCA for this study. Long term average annual MPCA NOx loads, derived by the database from concentration assumptions, were only 5% different than MCES loads. It should be noted that these facilities are among the largest point sources in Minnesota. Results demonstrate that the concentration assumptions used in this study, and the resulting load estimates, are reasonable. In the end, MCPA loads were used in this study because they provided a finer resolution monthly estimate which could be used to analyze seasonal load patterns. In summary, point source loads were derived from actual flow and a combination of actual and assumed concentration values. Based on the comparison between MCPA and MCES loads, it is reasonable to conclude that long term average NOx and TN load estimates are within a confidence interval of 5 to 10%.

Concentration assumptions for TKN and NHx are based on a much larger body of DMR data but cannot be validated in the same manner as TN and NOx because the large majority of facilities required to report also have limits. Those without limits have the capacity to discharge at higher concentrations, the magnitude of which is somewhat difficult to estimate without effluent data.

Concentration assumptions

Categorical concentration assumptions were used to estimate most point source N loads (Table 2). Concentration assumptions were based on several sources including: limited DMR data from Minnesota and Wisconsin, additional data from MCES, and a larger database from Ohio. Following a review of available data, facilities and individual outfalls were categorized. Concentration assumptions were then used to calculate loads (Table 2). A review of over 350 WWTPs in Ohio demonstrates that seasonal concentration patterns are limited (Figure 12). Therefore, no seasonal adaptations were built into categorical concentration estimates where actual data were unavailable. The Ohio dataset also demonstrates high variability among pollutant parameters (Figure 14). With the information available, individual Ohio facilities could not be classified into categories for direct comparison with Minnesota facilities. Nonetheless, Ohio data provided another line of evidence for the evaluation concentration assumptions.

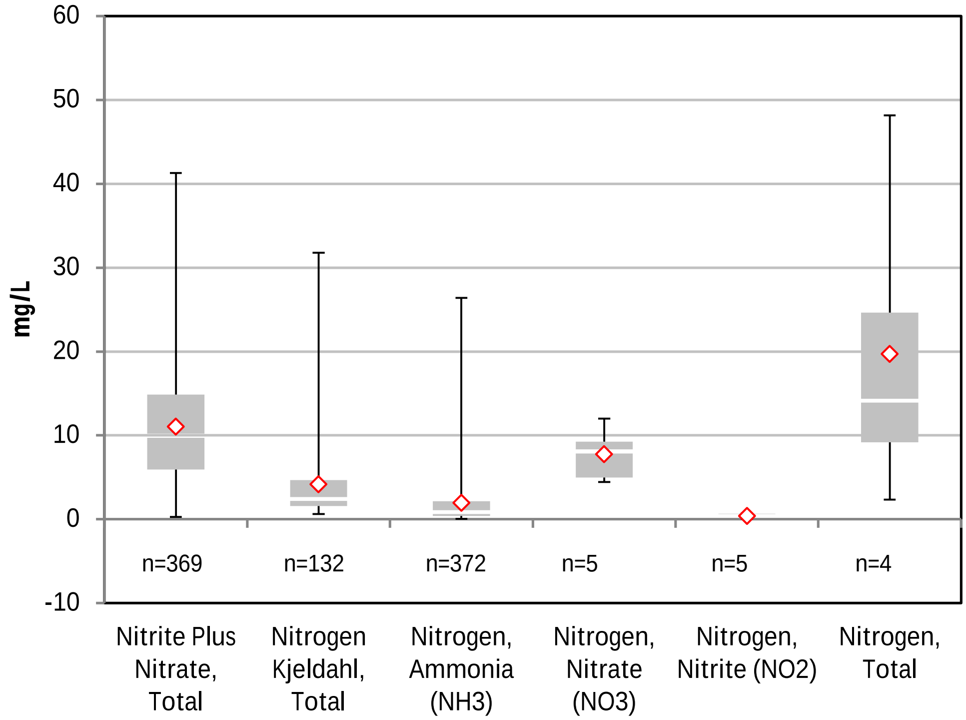

Figure 14.Distribution of effluent concentration data (2005-2009) from over 350 municipal wastewater treatment plants in Ohio. Whiskers represent minimum and maximum values. Boxes represent the interquartile range (25th to 75th percentile). Red squares and white lines represent median and mean values, respectively. Sample size (n) varies considerably among constituent.

Municipal wastewater treatment facilities were divided into four categories, A through D, which were based primarily upon design capacity and also the treatment components. Constituents like NOx have a discernible pattern among municipal categories (Figure 15). Class A larger facilities generally have higher NOx values. This may reflect a higher incidence of N-rich industrial users or possibly a lower proportion of I/I flow as a result of more recent waste collection system improvements. In contrast, smaller facilities (Class B – D) which serve incrementally smaller communities may have a higher percentage of low concentration I/I flow. In addition, most Class D and some Class C facilities are stabilization ponds which have sufficient retention time to facilitate denitrification. The available data suggests that wastewater effluent from stabilization pond dischargers often has NOx values less than 5 mg/L. Nonetheless, effluent variability from all facility classes appears to be high.

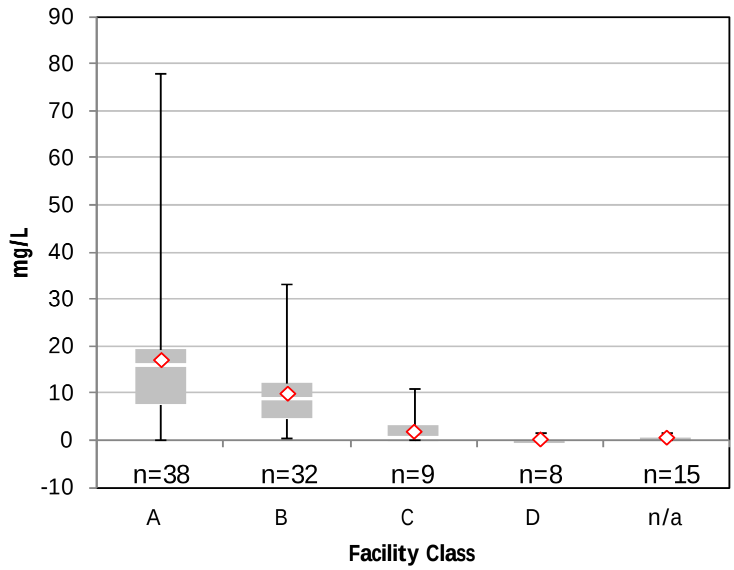

Figure 15. NOx data from municipal wastewater treatement plants in Minnesota (2005-2009). Sample size (n) varies considerably among facility classes.

Categorical concentrations for TKN and NHx were primarily derived from DMR effluent data. In addition, the difference between TN and NOx was also used to estimate TKN categorical concentrations. Class A facilities without DMR data were assumed to have TKN and NHx values of 4 and 3 mg/L, which was based upon existing data from similar classed facilities. For Class B facilities, it appeared that, on average, there was a 7 mg/L difference between TN and NOx, and therefore, it was assumed that TKN was 7 mg/L. Class B NHx was assumed to be 4 mg/L, a bit higher than other groups, due to the wide range of observed effluent data (2-70 mg/L). Class C and D municipals were assumed to have TKN of 3 mg/L and NHx of 1 mg/L. These assumptions were more closely tied to DMR data.

Industrial effluent load estimates were calculated using more facility or industry specific assumptions. As compared to municipal discharges, industrial concentrations were assumed to be moderate to low. In a few cases, two or more categories have identical concentration assumptions. In the event that future data allows for refinements of the assumptions, statewide limits can be quickly recalculated.

Industrial concentration assumptions are generally divided into two categories, high concentration and moderate to low concentration. Four categories of high concentration industrial effluents were identified; paper (P), tile lines (T), peat (PEAT), and other (O). These discharges were assumed to have TN, NOx, TKN, and NHx values of 10, 7, 3, and 2 mg/L, respectively. Paper industry assumptions were based upon data collected at one facility. Pulp rich effluent requires that nutrients, both phosphorus and N, be added to promote bacterial growth and subsequently reduce BOD. Facilities reporting tile line flow are typically draining land on which nutrient rich effluent was spray irrigated. In some cases it may be possible that these tiles are also partially draining adjacent agricultural lands. Assumptions for tile lines to surface water (T) are consistent with United States Geological Survey agricultural research in Iowa and southern Minnesota (Kalkhoff, 2000). Similarly, peat mines typically drain wetlands with the potential to be nutrient rich. As such, assumptions for PEAT were equivalent to those of tile. Assumptions for PEAT can be refined in the future when effluent data become available. The “other” category includes contact cooling water effluent with the potential for contact with N rich sources.

Table 2. Categorical concentration assumptions (mg/L)

Category	General Description	TN	NOx	TKN	NHx
A	Class A municipal - large mechanical	19	15	4	3
B	Class B municipal - medium mechanical	17	10	7	4
C	Class C municipal - small mechanical/pond mix	10	7	3	1
D	Class D municipal - mostly small ponds	6	3	3	1
O	Other - generally very low volume effluent	10	7	3	2
PEAT	Peat mining facility – pump out/drainage from peat	10	7	3	2
T	Tile Line to Surface Discharge	10	7	3	3
P	Paper industry	10	7	3	2
NCCW	Non contact cooling water	4	1	3	2
POWER	Power Industry	4	1	3	2
WTP	Water treatment plant	4	3	1	1
GRAV	Gravel mining wash water	2	1	1	1
GW	Industrial facilities, primarily private ground water well	0.25	0.25	0	0
MN00xxxx	Other individual facility assumptions based on limited data and applied per NPDES preferred ID number	Na	Na	Na	Na

Industrial categories with moderate effluent concentrations include non-contact cooling water, and the power industry (POWER). Both were assumed to use ammonia based additives, and therefore, were assigned categorical TN and NHx values of 4 and 3 mg/L respectively. There are additional challenges when estimating the load from the power industry. Most of the water used is collected from a lake or river, passed through a cooling system once without additional additives, and discharged back to the receiving water resulting in no net load increase. Most facilities use a small amount of groundwater, to which they apply ammonia-containing additives. In order to not overestimate POWER loading, categorical concentrations were only applied to a fraction of total effluent flow corresponding to the volume of groundwater which receives additives, typically 1% of total effluent flow (J. Bodensteiner at Xcel Energy, personal communication, February 3, 2011).

Industrial categories with low effluent concentrations include mine pump out and gravel mine wash water (GRAV) and industrial facilities that primarily use private well water (GW). A review of private well data determined that 75% of commercial industrial wells contained nitrate concentrations of 0.5 mg/L or lower (Kroening, 2011). Only 10% of these wells contained nitrate N concentrations greater than 2.4 mg/L.

Concentration assumptions for a short list of individual facilities, including four fish hatcheries and one small industrial facility, were based upon short-term data collected and stored outside of the MPCA Delta database. The aforementioned industry manufactures explosives, presumably with ammonium nitrate, resulting in NHx concentrations in excess of 40 mg/L. Mining activities that use explosives containing ammonium nitrate may contribute higher TN loads than what was assumed in this study (Environment Canada, 2003). Unfortunately, N effluent data and more detailed information regarding specific mining activities were not available for this study but may be a consideration for future load estimate refinements.

In summary, there is a high degree of confidence in municipal Class A load estimates. Class A facilities have the largest pool of actual concentration data for direct load calculations and from which to base concentration assumptions. In addition, Class A municipals discharge more water than all other groups

(49%, Figure 16). Loads from other categories, particularly industrials, have a lower degree of confidence. However, these lesser categories also typically discharge lower volumes of water, resulting in somewhat insignificant estimated loads on a statewide basis (Figure 16, 17). As more N concentration data become available, load estimates will be more accurate. However, given that we currently have the highest confidence in the largest point source group, additional data in the near future is not likely to significantly change either the magnitude or degree of confidence in load estimates statewide.

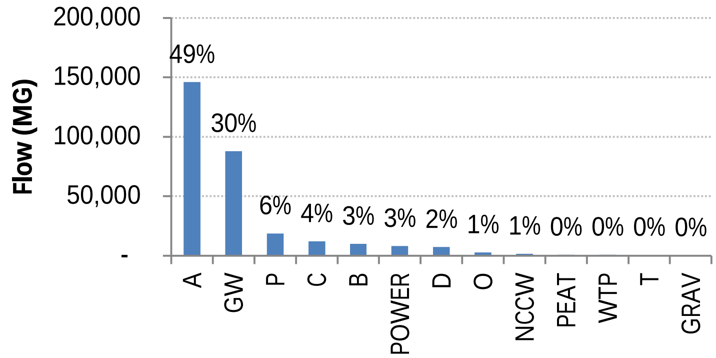

Figure 16. Flow in million gallons (MG) from various groups of point source dischargers statewide.

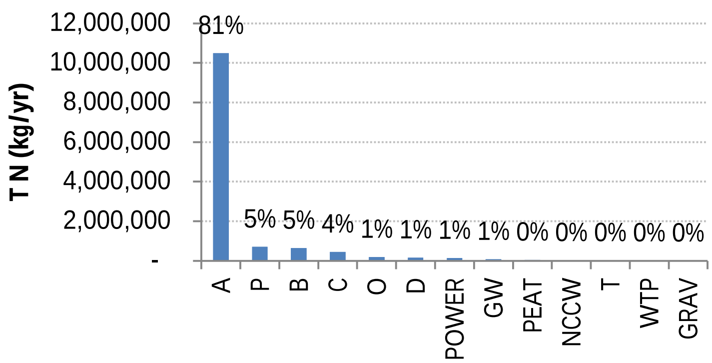

Figure 17. Total nitrogen (TN) loading in kilograms per year (kg/yr) from various groups of point source dischargers statewide.

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