NACWA
A Clear Commitment to America's Waters

April 9, 2009

Leif Hockstad
U.S. Environmental Protection Agency
Climate Change Division (6207J)
1200 Pennsylvania Ave, NW
Washington, DC 20460
Via Email: Hockstad.Leif@epa.gov

Re: NACWA Comments on Wastewater Treatment Emissions Estimates in EPA's Draft *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007*

Dear Mr. Hockstad:

The National Association of Clean Water Agencies (NACWA) has reviewed Section 8.2, *Wastewater Treatment*, of the U.S. Environmental Protection Agency's (EPA) draft *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007* (*Draft Inventory*). NACWA represents the interests of nearly 300 publicly owned wastewater treatment agencies nationwide, serving the majority of the sewered population in the U.S. NACWA members are very much aware of the growing importance of global climate change and are already engaged in efforts to reduce greenhouse gas (GHG) emissions. As more state-wide and national efforts are launched to curb levels of greenhouse gases, EPA's *Inventory* will certainly take on added significance. The wastewater treatment category of the *Inventory* consistently ranks in the top categories for nitrous oxide and methane emissions in the U.S., although the emissions are much smaller in magnitude than for the highest ranked categories. The wastewater category is broad, including municipal wastewater treatment, septic systems, and industrial wastewater treatment. Our review focused on the portion of the wastewater treatment emissions from municipal facilities, which are a fraction of the total wastewater treatment emissions.

NACWA submitted comments on the two previous *Inventories*, and these comments outlined how we believed that EPA's methodology resulted in over-estimation of the methane and nitrous oxide emissions from centralized wastewater treatment facilities, or publicly owned treatment works (POTWs). We suggested alternative values for many of the factors used in the calculations, and recommended a data-based approach, rather than theoretical assumptions, be used for estimating nitrous oxide emissions. We appreciate EPA's response to our previous comments and the Agency's willingness to work with NACWA to refine the greenhouse gas emissions estimates for POTWs. Although EPA's general methodology has not changed in the current *Draft Inventory*, several values used in the calculations of

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nitrous oxide emissions have been adjusted, resulting in lower emissions estimates for POTWs. NACWA is pleased with these adjustments, and has recommendations for further adjustments that may lead to more accurate estimates of both nitrous oxide and methane emissions.

In the comments below, we present a general recommendation for reporting the greenhouse gas emissions estimates for wastewater treatment and justification for further revising the nitrous oxide emissions estimates, based on previous NACWA comments and the discussions we had with EPA in April 2008 and April 2009 about these comments. At EPA's request, we are providing more information about the nitrogen loading data we collected from U.S. POTWs, values of nitrogen loading rates published in literature, and a discussion of how protein consumption data may be reconciled with the data collected by NACWA. We also discuss our suggestions for improving the methane emissions estimates.

Wastewater Treatment Emissions Summary

Tables 8-6 and 8-7 in the *Draft Inventory* provide a summary of methane and nitrous oxide emissions, showing total emissions as well as the separate contributions from domestic and industrial wastewater treatment. NACWA recommends that the domestic emissions for methane be broken down into emissions from septic systems and from centralized systems, given the significant difference in the amount of emissions from these two types of treatment systems.

Domestic Wastewater Nitrous Oxide Emission Estimates

The *Draft Inventory* calculates nitrous oxide emissions from POTWs using estimated nitrogen loadings to wastewater that are based on reported annual protein consumption. This is the methodology used in the Intergovernmental Panel on Climate Change (IPCC) protocol document[1] (*IPCC Guidelines*). Expressed as nitrogen (N), the estimated nitrogen loading rate to POTWs for domestic sources is:

(32.2 kg consumed protein/capita-year) x (0.16 kg N/kg protein) x (1.4 factor for non-consumed protein)
= 7.21 kg N/capita-year

Changing the units of this value to grams of nitrogen on a daily basis results in:

(7.21 kg N/capita-year) x (1000 g/kg) x (1 year/365 days)
= 19.8 g N/capita-day

This value has decreased compared to the values used in past *Inventories*, since the calculation now uses the actual per capita protein consumption, 32.2 kg/year, rather than all protein theoretically available for consumption per capita, 41.9 kg/year. This is an important refinement of the calculation, and NACWA supports this change for nitrous oxide estimates based on protein consumption.

As in previous *Inventories*, the nitrogen loading rate is further increased by a factor of 1.25 to account for industrial and commercial contributions, as follows:

[1] IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Prepared by the National 18 Greenhouse Gas Inventories Programme, Eggleston H.S., Buenida L., Miwa K., Ngara T., and Tanabe K. (eds.) 19 Published: IGES, Japan, 2006.

1.25 x (19.75 g N/capita-year)
= 24.7 g N/capita-day

Both of the above loading rates are higher than rates presented in standard references such as Metcalf & Eddy[2], as NACWA has pointed out in previous comments on the *Inventory*. Metcalf & Eddy report per capita nitrogen loading rates to wastewater of 15 g N/capita-day, a value usually considered the "industry standard" by POTWs. These values are supported by a wealth of data and have been widely confirmed in U.S. practice. The type of data used in Metcalf & Eddy represents all domestic sources of nitrogen, including meal production and consumption, the use of other nitrogen containing compounds, and both residential and commercial sources.

NACWA conducted a literature review to find other nitrogen loading rates, and the results are shown in Table 1. These published values average 13.3 g N/capita-day, which is even less than the value reported by Metcalf & Eddy. The nitrogen loading rate used in the *Draft Inventory* is higher than most of the values found in the literature, but it does fall within the ranges reported by two references. The 1993 EPA manual reports a range of 8.16 to 22.7 g N/capita-day for raw influent wastewater, and the 4th edition of Metcalf & Eddy reports a range of 8 to 22 g N/capita-day for typical wastewater. The value used in the *Draft Inventory* of 19.8 g N/capita-day for domestic sources only falls in the upper part of these ranges, while the value of 24.7 g N/capita-day for all sources is above these ranges. Other EPA publications cite lower values, such as 11.2 and 12 g N/capita-day for the domestic contribution to nitrogen loading, which is much lower than the *Draft Inventory* value. NACWA believes that the value used in the *Inventory* should be closer to the average nitrogen loading value from the available literature, rather than in the upper part of a range of values.

Table 1. References in literature for nitrogen per capita loading rates.

Reference	Value (g N/ capita-day)	Comments
U.S. EPA, *Manual: Nitrogen Control*, EPA/625/R-93/010 Office of Research and Development, Office of Water, Washington DC 20460, September 1993.	12	Residential contribution.
U.S. EPA, *Manual: Nitrogen Control*, EPA/625/R-93/010 Office of Research and Development, Office of Water, Washington DC 20460, September 1993.	8.16-22.7	Based on raw influent wastewater characteristics of per capita pollutant generation rates of 0.18-0.25 lb/capita/day (BOD). The pollutant relationship between BOD and TKN was defined as 0.1-0.2 TKN/BOD. (Table 2-2, p. 26)

[2] Tchobanoglous, G., F.L. Burton, and H.D. Stensel, *Wastewater Engineering: Treatment and Reuse, Metcalf & Eddy, Inc.* 4th Edition, McGraw-Hill, New York, 2003.

Table 1 (continued).

U.S. EPA, *Systems Manual: Onsite Wastewater Treatment*, EPA/625/R-00/008 Office of Research and Development, Office of Water, Washington DC 20460, February 2002.	6-17	Total nitrogen loading value from Table 3-7, Constituent Mass Loadings and Concentrations in Typical Residential Wastewater. This applies to typical residential households with standard water-using fixtures and appliances.
U.S. EPA, *Systems Manual: Onsite Wastewater Treatment*, EPA/625/R-00/008 Office of Research and Development, Office of Water, Washington DC 20460, February 2002.	11.2	Total nitrogen loading value contributions by source in Table 3-8. Estimates 0.6 g/person/day from the garbage disposal, 8.7 g from toilets, and 1.9 g from bathing, sinks, and appliances for the total of 11.2 g/person/day of nitrogen.
Metcalf & Eddy, Inc., *Wastewater Engineering: Treatment, Disposal, Reuse*, 2nd Edition, McGraw-Hill Book Company, NY, 1979.	15	"Normal domestic wastewater." Range of 10-18 g N/capita-day, with complete grinding of food waste.
Metcalf & Eddy, Inc., *Wastewater Engineering: Treatment, Disposal, Reuse*, 3rd Edition, McGraw-Hill Book Company, NY, 1991.	12	"Normal domestic wastewater" without contribution from ground kitchen waste. Range of 9 to 14 g N/capita-day.
Metcalf & Eddy, Inc., *Wastewater Engineering: Treatment, Disposal, Reuse*, 4th Edition, McGraw-Hill Book Company, NY, 2003.	9-22	Value for the United States was obtained from Table 3-14, p. 184 of typical wastewater constituent data for various countries.
Henze, M. and A. Ledin, "Types, Characteristics and Quantities of Classic, Combined Domestic Wastewaters," in *Decentralized Sanitation and Reuse: Concepts, Systems and Implementation*, Lens, P., G. Zeeman, and G. Lettinga Ed, IWA Publishing, London, 2001.	14	Values for Denmark and USA reported to be similar to range from 14 to 19 g N/capita-day.
Matsui, S., M. Henze, G. Ho, and R. Otterpohl, "Emerging Paradigms in Water Supply and Sanitation," in *Frontiers in Urban Water Management: Deadlock or Hope*, Maksimović, C and J. A. Tejada-Guibet Ed., IWA Publishing, 2001.	13	Household wastewater.

In addition, NACWA submitted data to EPA with our public comments on the previous *Inventory* that showed an average measured nitrogen loading rate of 15.1 g N/capita-day for 48 wastewater treatment facilities throughout the U.S., with a total service population of over 17 million people. Since these data are from measurements of nitrogen loading to the POTW, the nitrogen loading rate includes all sources (residential, commercial, and industrial) for the service communities represented. The service populations of the facilities ranged from 2,000 to over 2 million people. The collected data therefore provide a reasonable representation of the wastewater treatment nitrogen loading for different sizes of communities and treatment facilities in the U.S. The period of data collection varies, but in many cases the per capita nitrogen loading is based on many years worth of influent loading data. The table of data submitted is included in Attachment A for your reference.

We met with EPA in April 2008 to discuss our data and recommendations, and EPA requested that we provide more information to substantiate our data. Specifically, EPA asked that we provide the data collection procedures and more detailed nitrogen loading rate measurements, rather than the average over the POTW's monitoring period, for the utilities included in our database. In response to this request, we are providing this information for the Alexandria Sewage Authority (ASA), a major POTW in the Washington D.C. area, as an example that is representative of the POTWs included in the NACWA database. The data collection procedures used at ASA, which are representative of the approach used by the other utilities in the database, are included as Attachment B. Attachment C contains the detailed results of a recent analysis of the influent wastewater loadings for ASA.

It is important to note that the data collected by NACWA capture all sources of nitrogen influent to the POTW, including domestic, commercial, and industrial sources. The objective of this type of analysis is to determine the total loading to the POTW, so the facility can be properly sized to treat all influent waste load. Moreover, it is not possible to separate individual sources at the influent to a POTW, so only the total loading can be measured. This is true for all of the NACWA data, and the approach used by ASA is representative of the approach used by the individuals that provided data to NACWA.

Recommendations for Modifying EPA's Estimation Methodology

The nitrogen loading values discussed above are summarized in Table 2.

Table 2. Summary of nitrogen loading values to POTWs.

Reference	Nitrogen Loading Rate (g N/capita-day)
EPA *Draft Inventory* – Domestic Sources	19.8
EPA *Draft Inventory* – Domestic, Industrial, and Commercial Sources	24.7
Metcalf & Eddy – "Industry Standard"	15
Literature Review – Range of Reported Values	6-22.7
Literature Review – Average of Reported Values	13.3
NACWA Data	15.1

As explained above, the values in the *Draft Inventory* are generally higher than from the other references. However, if the EPA methodology is used to convert only the per capita protein consumption into per capita nitrogen loading, without the additional factors to account for non-consumed protein and non-domestic sources, the result is:

(32.2 kg protein/capita-year) x (0.16 kg N/kg Protein) x (1,000 g/kg) ÷ (365.25 days/yr)
= 14.1 g N/capita-day

This value is similar in magnitude to the value found in the NACWA data and to the average value from the literature survey. EPA makes two assumptions to convert this value of protein consumption (expressed as N) into the nitrogen contribution from domestic sources:

1. All of the protein consumed is excreted.
2. The protein consumed is multiplied by the 1.4 factor for non-consumed protein to represent other sources of nitrogen in domestic wastewater.

The first assumption, that all protein consumed is excreted, is not clearly stated in the *Draft Inventory*, but it appears to be made based on the equations and values reported. EPA should clarify in the *Inventory* whether or not this assumption is made. If the assumption is not made, then the fraction of consumed protein that is excreted should be reported in the *Inventory*.

The result of these two assumptions is the loading rate of 19.8 g N/capita-day from domestic sources. Comparison of this value with the results of the NACWA survey and the literature suggest that EPA's assumptions may be overly conservative in determining the nitrogen loading rate. While protein consumption may be a reasonable "starting point" for the estimation of per capita nitrogen loading, the factors used to convert per capita protein consumption to per capita nitrogen loading may be overly conservative. The NACWA database of measured nitrogen loading rates to POTWs suggests that the actual per capita POTW influent total nitrogen value is:

1. A fraction of the reported per capita protein consumption (expressed as N), due to less protein being excreted than is consumed, with some additional nitrogen from non-consumed protein;
2. Accurately predicted by the per capita protein consumption, and the factor of 1.4 is too high for the addition of non-consumed protein to the wastewater; or
3. A combination of the two scenarios above.

It may therefore be reasonable to use per capita protein consumption as an index of potential changes in POTW influent per capita nitrogen values over the years, but the factors used to convert per capita protein consumption data into per capita POTW influent nitrogen values should be adjusted to reflect real-world data. Adjustment of these factors would likely bring agreement between NACWA's recommended data-based approach and the theoretical assumptions used by EPA. The uncertainty analysis could then consider the possibility of industrial contributions not incorporated into the standard per capita values, multiplying by the 1.25 factor currently used in the *Draft Inventory*.

Recommendations for Revisions to the Emissions Equations

NACWA recommends that two changes be made to the equations on page 8-15 used to calculate the nitrous oxide emissions from domestic wastewater. First, in the $N_2O_{WOUT\ NIT/DENIT}$ equation, the $F_{IND\text{-}COM}$ factor should be

moved outside of the square brackets. This is a typographical error rather than an error that affects the calculations.

Second, in the $N_2O_{EFFLUENT}$ equation, the US_{POP} factor should be multiplied by the WWTP factor, as it is in the $N_2O_{WOUT\ NIT/DENIT}$ equation, since septic system users should not be included in the amount of effluent discharged to aquatic environments. NACWA recommends that any contributions from septic systems be calculated in a separate equation if they are included in the *Inventory*.

Domestic Wastewater Methane Emission Estimates

The methodology used for estimating domestic wastewater methane (CH_4) emissions has not changed in the current *Draft Inventory* from the previous year, and NACWA's concerns about the emissions estimates remain the same as in our previous comments. The theoretical maximum CH_4 producing capacity for domestic wastewater, termed the B_o value, of 0.6 kg CH_4/kg BOD represents all of the CH_4 that could be produced anaerobically from the organic matter in wastewater. This value is then multiplied by a methane correction factor (MCF) that quantifies how much of the influent organic matter is actually converted to CH_4. The MCF accounts for the portion of the organic matter that is stabilized anaerobically (versus aerobically) and also for the portion that is incorporated into sludge. The MCF is 0.5 for septic systems and 0.8 for anaerobic systems.

We believe that the maximum MCF for anaerobic systems should be 2/3 or 0.67, since several well-recognized and commonly accepted references (e.g. Metcalf & Eddy and Grady, Daigger, and Lim[3]) indicate that no more than about two-thirds of the organic matter in domestic wastewater is biodegradable. NACWA recommends that EPA consider a lower MCF value that more accurately reflects the proportion of organic matter that can actually be produced through anaerobic treatment processes.

In addition, NACWA stated in previous comments that exclusive anaerobic treatment of domestic wastewater is not practiced in the U.S. Instead, the general practice is to use facultative lagoons that incorporate a combination of aerobic and anaerobic processes or natural treatment systems such as wetlands that use largely aerobic treatment mechanisms. In previous *Inventories*, central wastewater treatment systems were designated as either aerobic or anaerobic. In the current *Draft Inventory*, EPA has added acknowledgement that some systems use a combination of aerobic and anaerobic processes, stating on page 8-7 that "CH_4 emissions can arise from aerobic systems… that are designed to have periods of anaerobic activity (e.g., constructed wetlands)." NACWA supports this addition of a combined aerobic/anaerobic designation for certain treatment systems. EPA, however, still states that facultative lagoons are exclusively anaerobic systems, while NACWA believes that they should be considered combined aerobic/anaerobic systems.

Although this new aerobic/anaerobic category is defined in the *Draft Inventory*, it did not factor into the calculations for methane emissions since EPA found that "the available data are not sufficiently detailed across the time series to complete this designation." NACWA recommends that EPA continue to investigate how to differentiate between the various systems and use different MCFs for different types of systems, as EPA indicates it will do in the "Planned Improvements" section of the *Draft Inventory*. For systems that incorporate both aerobic and anaerobic treatment mechanisms, we suggest that a MCF of less than 0.67 (our recommended maximum value for anaerobic systems) is appropriate.

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[3] Grady, C. P. L., Jr., G. T. Daigger, and H. C. Lim, *Biological Wastewater Treatment*, 2nd Edition, Marcel Dekker, NY, 1999.

EPA assumes in the *Draft Inventory* that all aerobic systems are well-managed. The "Domestic Wastewater CH_4 Emission Estimates" section, however, does not clearly state this assumption, and it is only stated in the "Planned Improvements" section. We recommend pointing out this assumption clearly in the "Domestic Wastewater CH_4 Emission Estimates" section, also.

Thank you for consideration of our comments on the *Draft Inventory*. Please contact me at 202/296-9836 or *cfinley@nacwa.org* if you have any questions about NACWA's comments.

Sincerely,

Cynthia A. Finley
Director, Regulatory Affairs

Attachments

Attachment A

Nitrogen loading data from wastewater treatment facilities in the U.S. (The names, cities, and other information about the treatment facilities are not included in this table, but this information can be provided by NACWA if needed.)

State	Service Population (End of Data Period)	Nitrogen Loading (g/person-day)	Period of Data Record
CA	95,000	15.2	1995-2000
CA	80,000	11.0	1995
CA	102,000	16.6	1985-1986
CA	25,800	13.3	1993
CA	200,000	14.4	1988
CA	60,000	16.3	1994
CA	360,000	9.1	1983
CA	35,900	11.4	1995
CA	965,185	15.0	2007
CA	1,337,912	17.0	2007
CA	127,658	13.0	2006
CA	156,759	17.0	2006
CT	18,585	16.8	1998-2005
CT	5,400	20	
CT	12,980	14.1	1999-2001
CT	17,650	16.8	
CT	49,815	13.2	2002-2003
FL	187,320	15.6	1990-1999
IA	-	19.07	
IL	67,500	10.6	1999
MA	2,060,000	15	1986-1987
MA	89,589	15.4	2000
MA	6,986	11.8	2001-2006
MA	9,000	14.1	1997-2000
MN	52,150	7.0	1998
MT	139,200	14.53	2000-2005
MT	31,700	10.44	2003
MT	33,000	9.99	2004
MT	35,700	11.80	2005
NC	800,000	14.53	2007
NE	3,350	16.80	Dec. 2007
NH	17,000	20.0	2005
NJ	192,089	15.9	1999-2001

NM	-	16.8	2002-present
NV	600,000	16.80	2007
NY	26,622	22.7	1997-1999
NY	26,000	16.5	Jan. 2004- July 2007
OR	2000	19.5	2000-2004
OR	2000	15.9	1994-2000
OR	60,000	20.43	2005-2006
PA	900,000	9.7	2005
RI	139,000	19.1	1997-1998
TX	875,355	13.2	1996-2005
VA	300,818	15.9	2007
VA	273,356	15.9	July 2005 – June 2006
VA	361,582	14.5	FY 1990-2007
VA	115,000	19.1	2004-2006
VA	412,700	11.53	2001-2003
VA	82,000	18.16	2003-2006
WA	96,500	16.3	April-Oct. 2007

Attachment B

Methodology Used in NACWA Data on Per Capita Nitrogen Loading Rates

As requested by EPA, NACWA is providing additional information about the per capita nitrogen loading data provided in our previous comments. The data collected by NACWA represent the results from studies to establish future waste loads to the subject publicly owned treatment works (POTWs) and were developed in accordance with accepted engineering practice. Most of these data points represent one or more years of daily average influent nitrogen loading data to the POTW and, consequently, represent many thousands of individual data points. In order for EPA to better understand the basis for each data point, NACWA agreed to provide an example of how these values were obtained.

Attachment C is a Technical Memorandum containing the results of a recent analysis of the influent wastewater loadings for a major POTW in the Washington D.C. area, the Alexandria Sewage Authority (ASA) POTW. This work product was produced for ASA as one component of a Master Planning Study that determined how the plant would comply with the more stringent nitrogen discharge standards currently being implemented in the Chesapeake Bay region. Thus, accurate prediction of influent total nitrogen loads was quite important.

Influent nitrogen loadings were based on five years of daily influent total nitrogen mass loading rates determined in accordance with standard procedures as specified in the POTW's National Pollutant Discharge Elimination System (NPDES) discharge permit, as listed below:

1. Flow composite samples of the POTW influent were collected daily and analyzed for total nitrogen according to *Standard Methods*[4].
2. The daily average influent nitrogen concentration and the daily average influent flow (also measured and totaled as specified in ASA's NPDES permit) were then used to compute the daily average influent total nitrogen mass loading rate.
3. The daily average values for a given calendar year were averaged to compute the daily average nitrogen mass loading for the year.
4. Per capita values were then calculated for each year by dividing the yearly average influent total daily nitrogen mass loading by the estimated service population for that year, resulting in five estimates of yearly average per capita daily nitrogen loading to the plant.

The population data were obtained from the Metropolitan Washington Council of Governments (MWCOG), which runs a cooperative forecasting program to develop region-wide forecasts of employment, households, and population. As can be seen in Table 2 of the attached Technical Memorandum, the five estimates of yearly average per capita total nitrogen loading to the POTW were 0.038, 0.030, 0.031, 0.034, and 0.035 lb N/capita-day, for an average of 0.034 lb N/capita-day. Expressed in metric units, this is 15.2 g N/capita-day, with a standard deviation of 1.4 g N/capita-day. In the experience of the consulting engineer, such variation on a year-to-year basis is not unusual and probably represents natural deviations in the necessary measurements, including both influent total nitrogen loads and the service population in any year.

[4] American Public Health Association, *Standard Methods for the Examination of Water and Wastewater*, 21st Edition, 2005 or Equivalent.

It is important to note that the data collected by NACWA represent all sources of nitrogen influent to the POTW, including domestic, commercial, and industrial sources. The objective of this type of analysis is to determine the total loading to the POTW, so the facility can be properly sized to treat all influent waste loads. Moreover, it is not possible to separate individual sources at the influent to a POTW, so only the total loading can be measured. This is true for all of the NACWA data, and the approach used by ASA is representative of the approach used by the individuals that provided data to NACWA.

TECHNICAL MEMORANDUM CH2MHILL

Alexandria Sanitation Authority Population Data and Flow and Load Projections

PREPARED FOR: Cheryl St. Amant/ASA

CC: Gayle Moomaw/ASA
Gary Weil/CH2M HILL
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DATE: May 16, 2008

Objectives

The goal of this technical memorandum (TM) is to document historical flows and loads to the Alexandria Sanitation Authority (ASA) wastewater treatment plant (WWTP) and to project flows and loads forward to year 2030 and to the design point of 54 MGD. To do this, population projections have been developed and per capita flow and loading data have been applied to estimate average flows and loads in the future. Historical data has been used to develop flow and load peaking factors which have then been applied to projected average daily values to estimate flows and loads under maximum month, maximum week, and maximum day conditions. These values are intended to be used in subsequent wastewater characterization and refinement of the process modeling to be performed upon completion of the proposed wastewater sampling program.

Source of Data

CH2M HILL completed a Wet Weather Flow Study of the influent flows to the collection system in July 2007 (Task Order 4-2005 Technical Memorandum – Wet Weather Flow Model Update and RDII Estimation, October 2007). As part of the study projected flow and population data from the City of Alexandria and from Fairfax County were compiled. The projections presented in this TM build on these same data.

City of Alexandria

ASA serves the City of Alexandria and portions of Fairfax County. The Authority has a service agreement with the County whereby the plant reserves 60% of its capacity for Fairfax County flows. Fairfax County pays ASA a fee based on the actual MGD received.

As part of the Wet Weather Flow Study, the City of Alexandria provided data from the Metropolitan Washington Council of Governments (MWCOG) which runs a cooperative forecasting program to develop region-wide forecasts of employment, households, and population. The City used data generated in the MWCOG 2005 Round 7 Estimate to calculate projected future flows to the plant based on the following equation:

Flow = 180 gpd per Household + 20 gpd per Total Employment (jobs)

The data received from the City had been adjusted to account for areas that are not served by ASA (a small portion of the City is served by the Arlington County wastewater treatment plant). Since the difference between the corrected data and the total data is very small (less than 1%), the total City of Alexandria projected household, employment and population data as provided in the MWCOG report of 2006, were used for the purposes of this study.

The data in the MWCOG report comprises the years 1990, 2000, 2005, 2010, 2015, 2020, 2025, and 2030. This data was plotted on a chart and extrapolated to obtain estimated household, employment and population data in the City of Alexandria for all the years in-between.

Fairfax County

During the Wet Weather Flow Study, Fairfax County used numbers from their planning department to estimate future flows to ASA. Using this data, which includes year-by-year historical data (1990 to 2007) and forecast data (2008 to 2030) for population connected to ASA's plant, flow and load projections were developed for contributions from the County.

Fairfax County uses an equation to calculate future flow (2008 and beyond) based on population. The equation is as follows:

$$\text{Flow (MGD)} = [85 \text{ GPD/capita} \times \text{Population} + 0.86 \text{ GPD/capita per inch of rain} \times \text{Population} \times \text{average rainfall}]/1{,}000{,}000 + 1.05 \text{ MGD}$$

The equation assumes an average annual rainfall of 45 inches for 2008 through 2030.

The 1.05 MGD added is for the City of Falls Church (County assumes a constant flow from this source in the future).

Since the only variable in this equation is the population, this results in a net equation:
Flow (MGD) = (123.6 GPD/capita × Population) /1,000,000 + 1.05 MGD

Projected Annual Average Flows

The data and equations identified above were used to project future wastewater flows from the City of Alexandria and Fairfax County (Table 1). The estimated annual average daily flow for year 2030 is 42.8 MGD for a service population of 357,500. The calculated average flow per capita is 120 gpd, which translates into a final service population of approximately 450,000 people at the design average flow of 54 MGD.

It should be noted that the Wet Weather Flow Study TM projected a 2030 average daily flow value of 44.9 mgd (see Table 11 on Page 37 of the TM). On page 36 of the TM, it states that:

> the 2005 estimates from both the County and City were compared to the 2007 flow measurements. In all cases, the measured flow was higher than the 2005 estimates. This is likely a result of several variables, including groundwater infiltration or inaccuracies in unit flow estimates. The future flow projections were, therefore, adjusted up by the increment between the 2005 estimated flow and the 2007 measured flows.

Therefore, in order to maintain consistency with the results of the Wet Weather Flow Study, 44.86 mgd will be used as the projected 2030 annual average flow.

The historical flow data was obtained from ASA's plant records (OP10 and LOIS databases). The raw influent flow used was as calculated by the plant to subtract internal recycles and used for billing.

TABLE 1
Historical Flows and Future Flow Projection

Year	Population	Flow[a] (mgd)	Flow per Capita[b]
1992	262,583	34.5	131.5
1993	264,615	38.4	145.3
1994	265,914	36.7	138.2
1995	267,922	33.2	123.8
1996	271,385	38.2	140.8
1997	274,207	34.9	127.3
1998	276,814	37.3	134.9
1999	278,841	35.4	126.8
2000	281,172	36.8	131.0
2001	283,904	35.3	124.5
2002	287,121	33.6	116.9
2003	290,008	42.1	145.1
2004	292,374	37.4	128.0
2005	294,164	37.4	127.1
2006	297,610	35.5	119.2
2007	300,818	33.5	111.4
2008	305,000	36.3	118.9
2010	307,500	36.9	120.1
2012	315,000	37.6	119.4
2014	320,000	38.3	119.6
2016	325,000	39.0	119.9
2018	328,000	39.7	120.9
2020	332,500	40.4	121.4
2022	337,500	40.9	121.0
2024	342,500	41.3	120.7
2026	347,500	41.8	120.4
2028	352,500	42.3	120.1
2030	357,500	42.8[c]	119.9
Design	450,000	54	120

[a] Actual, 1992 to 2007; projected, 2008 to 2030 per Fairfax County and City of Alexandria Projections
[b] Calculated. Units: Gallons per capita per day
[c] Value is prior to 2.1 mgd adjustment, per Wet Weather Flow Study TM.

Projected Annual Average Loads

Loadings to the ASA wastewater treatment plant have been quite variable throughout the years for which data is available (1992 to 2007). The general trend has been an increase in loadings to the plant, although a leveling off in recent years has been observed.

Per capita loading values for the various parameters were calculated by dividing the annual average loadings by the corresponding service population. For TSS and BOD loadings, data was used from years 2000 through 2007 since this reflects a period after automatic composite sampling was started. For TKN, ammonia, and TP loadings the period 2003 through 2007 were used since daily, as opposed to only weekly, concentration data was collected beginning in 2003.

The resulting average per capita values were compared against those found in literature. The projected future loads were then developed by multiplying the average per capita values times the future projected population. This information is summarized in Table 2.

TABLE 2
Future Load Projection

		Flow, Actual or Calculated	Per Capita Nutrient Loads (lbs/day per capita)						Flow per Capita, Calculated
Year	**Population**	**(mgd)**	**TSS**	**CBOD5-T**	**TKN**	**NH3**	**TP**	**PO4**	**(gpcd)**
2000	281,172	36.8	0.21	0.21	—	—	—	—	131.0
2001	283,904	35.3	0.24	0.21	—	—	—	—	124.5
2002	287,121	33.6	0.23	0.19	—	—	—	—	116.9
2003	290,008	42.1	0.27	0.20	0.038	0.021	0.007	0.002	145.1
2004	292,374	37.4	0.25	0.17	0.030	0.016	0.006	0.001	128.0
2005	294,164	37.4	0.23	0.17	0.031	0.018	0.005	0.002	127.1
2006	297,610	35.5	0.26	0.17	0.034	0.021	0.006	0.002	119.2
2007	300,818	33.5	0.27	0.19	0.035	0.022	0.006	0.002	111.4
Average			0.24	0.19	0.034	0.019	0.006	0.002	126
Literature Value[a]			0.25	0.22	0.029	0.019	0.008	0.003	—
2008	305,000	36.3	74,362	57,350	10,682	6,190	1,767	510	118.9
2010	307,500	36.9	74,971	57,820	10,769	6,241	1,781	514	120.1
2012	315,000	37.6	76,800	59,231	11,032	6,393	1,825	527	119.4
2014	320,000	38.3	78,019	60,171	11,207	6,494	1,854	535	119.6
2016	325,000	39.0	79,238	61,111	11,382	6,596	1,883	543	119.9
2018	328,000	39.7	79,969	61,675	11,487	6,657	1,900	548	120.9
2020	332,500	40.4	81,067	62,521	11,645	6,748	1,926	556	121.4
2022	337,500	40.9	82,286	63,461	11,820	6,849	1,955	564	121.0
2024	342,500	41.3	83,505	64,402	11,995	6,951	1,984	573	120.7
2026	347,500	41.8	84,724	65,342	12,170	7,052	2,013	581	120.4

TABLE 2
Future Load Projection

Year	Population	Flow, Actual or Calculated (mgd)	Per Capita Nutrient Loads (lbs/day per capita)						Flow per Capita, Calculated (gpcd)
			TSS	CBOD5-T	TKN	NH3	TP	PO4	
2028	352,500	42.3	85,943	66,282	12,345	7,154	2,042	589	120.1
2030	357,500	42.8[b]	87,162	67,222	12,520	7,255	2,071	598	119.9
Design	450,000	54	109,714	84,615	15,760	9,133	2,607	752	120

[a] *Wastewater Engineering—Treatment, Disposal, Reuse*. Metcalf & Eddy, Third Edition, 1991.

[b] Plus 2.1 mgd adjustment per Wet Weather Flow Study TM.

Peaking Factor Development and Projected Flows

Historical data was analyzed to determine the peaking factors that have been observed in the past for flows and loads. Because the flow peaking factors and the load peaking factors do not usually occur at the same time, the analysis looked at them separately.

Flow Peaking Factors

Maximum month, week, and day flow peaking factors (PF) are estimated in Table 3 based on historical raw influent plant flow data. The term “peak hydraulic flow” refers to the highest instantaneous flow measurement recorded by the plant’s influent flow meter.

TABLE 3
Historical Flow Peaking Factors

Year	Actual Avg. (mgd)	Calculated Avg.[a] (mgd)	Actual Max. Month (mgd)	Max. Month PF	Actual Max Week (mgd)	Max. Week PF	Actual Max. Day (mgd)	Max. Day PF	Actual Peak Hyd. (MGD)	Peak Hyd. PF
2000	36.83	33.74	45.26	1.34	52.12	1.54	70.08	2.08	102	3.02
2001	35.33	34.07	42.00	1.23	45.07	1.32	70.53	2.07	98	2.88
2002	33.58	34.45	39.07	1.13	48.31	1.40	73.52	2.13	—	—
2003	42.08	34.80	53.84	1.55	66.69	1.92	96.32	2.77	133.5	3.84
2004	37.43	35.08	46.92	1.34	54.35	1.55	78.02	2.22	123.4	3.52
2005	37.38	35.30	46.91	1.33	60.60	1.72	97.61	2.77	128.7	3.65
2006	35.48	35.71	45.12	1.26	66.22	1.85	103.84	2.91	125.0	3.50
2007	33.49	36.10	43.67	1.21	51.14	1.42	84.70	2.35	114.4	3.17
Avg.	**36.45**	**34.91**	**45.35**	**1.30**	—	**1.59**	—	**2.41**	—	**3.53[b]**
Max.	—	—	—	**1.55**	—	**1.92**	—	**2.91**	**133.5**	**3.84**

[a] Based on applying 120 gpcd flow to the annual population.
b Averages for period of 2003-2007, after plant upgrade completed and hydraulic bottlenecks reduced

The methodology used to develop the peaking factors in Table 3 is based on the assumption that “actual” annual average flows contain a variable base flow amount which is affected by whether the system is experiencing a “dry,” “wet,” or “typical” year. This can be seen by comparing the columns for “Actual Average” (which are direct system measurements) and “Calculated Average” which is derived by multiplying the system population by the design per capita flow rate of 120 gpcd. The data presented in Tables 1 and 2 show, for example that 2002 could be classified as a “dry” year (per capita flow of 116.9 gpcd) while 2003 could be classified as a “wet” year (per capita flow of 145.1 gpcd). By comparison, 2006 was a “typical” year with per capita flows near the 120 gpcd value.

The peaking factors are then developed by dividing the actual maximum month, week and day flows by the calculated average value. This method is also consistent with how flows and loads are projected into the future. From the data in Table 2, wet weather per capita flow are estimated at 145 gpcd while dry weather per capita flow can be estimated as 115 gpcd. The design value of 120 gpcd is taken as the average base value. From the data in Table 2, the calculated peaking factors in Table 3, and by defining the seasonal per capita flow conditions which may occur, we can define an envelope of flows which could occur for both the year 2030 case as well as the 54 mgd annual average flow case. The resulting flow peaking factors are summarized in Table 4.

TABLE 4
Per Capita Conditions and Flow Peaking Factors

Condition	Per Capita Flow (gpcd)	Max Month PF	Max Week PF	Max Day PF	Peak Hyd. PF
Typical	120	1.30	1.60	2.60	3.5
Wet	145	1.55	1.90	2.90	3.8
Dry	115	1.15	1.30	2.30	3.2

By applying the various flow conditions and peaking factors in Table 4 to the projected year 2030 annual average flow of 44.9 mgd, a seasonal matrix of flow rates can be calculated as summarized in Table 5.

TABLE 5
Year 2030 Projected Flow Rates

Condition	Average (MGD)	Max. Month (MGD)	Max. Week (MGD)	Max. Day (MGD)	Peak Hyd. (MGD)
Typical	44.9	58.3	71.8	117	157
Wet	54.2	69.5	85.3	130	171
Dry	43.0	51.6	58.4	103	144

Similarly, the values in Table 4 can be applied to the annual average design flow of 54 mgd to create a matrix of seasonal flows at the design condition as summarized in Table 6.

TABLE 6
54-mgd Projected Flow Rates

Condition	Average (MGD)	Max. Month (MGD)	Max. Week (MGD)	Max. Day (MGD)	Peak Hyd (MGD)
Typical	54.0	70.2	86.4	140	189
Wet	65.3	83.7	103	157	205
Dry	51.8	62.1	70.2	124	173

The flow rates presented in Tables 5 and 6 then frame the range of projected flow conditions which could occur based on seasonal variability. Even though a specific year might have annual average flows that fall within the typical range (around 120 gpcd), it might still experience a heavy flow event. Such was the case in 2006 for example, a typical flow year, which included one event of heavy sustained rains for about 3 days that resulted in record maximum day flows at the plant. The sewer collection system that feeds the ASA plant is partly a combined sewer system which accounts for the high variability in flows to the plant. This indicates the need to use the wet condition as a projection parameter since a heavy rain event can occur anytime in the mid-Atlantic region.

These projections are based on the assumption that current peaking factors will translate into future flows. However there are some reasons why this might not be the case:

The first is that high flow storm events add to the base flow as Infiltration and Inflow (I&I) but are not necessarily going to increase proportionally to population. The future increase in storm flow is difficult to predict as it depends on many factors such as aging of the infrastructure (which will increase flows) but also efforts by Fairfax County and the City of Alexandria to reduce I&I by replacing and lining the sewer system.

The second is that the plant is physically limited in the amount of flow it can pass and treat. During high flow events, the plant is currently at capacity even though it is below capacity on an annual average basis. As a design parameter, ASA has to determine what the peak hydraulic flow to the plant will be in the future based on the agreements and obligations it has to treat these peak flows. Currently ASA does not plan on expanding the hydraulic capacity of the plant and is not obligated to do so based on current jurisdictional agreements.

Load Peaking Factors

Historical maximum month, week, and day load peaking factors are summarized in Tables 7, 8 and 9.

TABLE 7
Maximum Month Load Peaking Factors

Year	TSS	CBOD5-T	TKN	NH3	TP	OP
2000	1.08	1.07	1.15	1.32	1.08	1.45
2001	1.26	1.17	—	—	—	—
2002	1.31	1.23	—	—	—	—
2003	1.91	1.55	1.42	1.14	1.94	1.33
2004	1.55	1.77	1.33	1.24	1.49	—
2005	1.22	1.22	1.27	1.08	1.21	—
2006	1.25	1.17	1.13	1.09	1.37	1.30

TABLE 7
Maximum Month Load Peaking Factors

Year	TSS	CBOD5-T	TKN	NH3	TP	OP
2000	1.08	1.07	1.15	1.32	1.08	1.45
2007	1.51	1.27	1.18	1.08	1.17	1.21
Average	1.39	1.31	1.25	1.16	1.38	1.32

TABLE 8
Maximum Week Load Peaking Factors

Year	TSS	CBOD5-T	TKN	NH3	TP	OP
2000	1.24	1.21	—	—	1.19	—
2001	1.66	1.22	—	—	—	—
2002	2.08	1.42	—	—	—	—
2003	3.43	2.27	—	—	3.18	—
2004	3.32	2.90	1.75	1.61	2.70	—
2005	1.45	1.41	1.59	1.18	1.27	—
2006	1.96	1.43	1.30	1.18	1.73	—
2007	1.97	1.52	1.23	1.12	1.29	1.22
Average	2.14	1.67	1.47	1.27	1.89	1.22

TABLE 9
Maximum-Day Load Peaking Factors

Year	TSS	CBOD5-T	TKN	NH3	TP	OP
2000	1.77	1.60	1.70	1.62	1.49	1.88
2001	2.43	1.74	1.23	1.56	1.51	2.09
2002	2.83	1.89	1.20	1.16	1.33	1.15
2003	4.35	4.07	7.12	1.89	7.39	2.18
2004	7.09	6.05	3.18	2.12	6.77	1.79
2005	2.41	2.15	1.86	1.84	2.46	1.22
2006	3.30	1.79	1.97	1.52	3.38	2.01
2007	3.77	2.19	1.64	1.34	1.58	1.27
Average	3.49	2.68	2.49	1.63	3.24	1.70

Based on the data from Tables 7-9, the recommended load peaking factors for design are summarized in Table 10. Experience (empirical data reviews at similar facilities) was used to select the recommended peaking factors from the available data set. Since the TSS peaking factors are greater than those for CBOD, the peaking factors for TKN and TP should be greater than those for NH3 and OP since particulate portions may track closer to TSS values while soluble components (NH3 and OP) should track more closely with CBOD.

TABLE 10
Recommended Design Load Peaking Factors

Condition	TSS	CBOD5-T	TKN	NH3	TP	OP
Max. Month	1.40	1.30	1.20	1.10	1.40	1.30
Max. Week	2.00	1.50	1.40	1.20	1.50	1.50
Max. Day	3.50	2.00	2.00	1.60	2.00	2.00

Proposed Design Flows and Loads

The current plant was designed for a peak instantaneous flow of 108 MGD and it is hydraulically limited to pass about 120 MGD including any recycles routed to the head of the plant. Jurisdictional agreements dictate how much flow ASA has to take from the different sewer service areas that feed the plant. When a high flow event occurs, ASA will run their influent pump station to take as much flow as it can and the rest of the flow will surcharge in the collection system. This results in a “capping” of the amount of flow that comes into the plant. As a design parameter, ASA has to determine what the peak hydraulic flow to the plant will be in the future based on the agreements and obligations it has to treat these peak flows. Currently ASA does not plan on expanding the hydraulic capacity of the plant so the recommended design flows are based on the current plant sizing. However, the design flows will assume that even though the instantaneous flow might be capped, the high flow events are likely to be of longer duration and therefore the system will be sized to handle these high flows for periods of up to 1 week.

Table 11 presents recommended design flow rates for both the projected 2030 and 54 mgd design cases and are based on the previous flow developments. Also presented, for comparison, are the design flow values which were previously defined as 2005 design parameters. In selecting projected flow values for Table 11, average flows were taken as presented in the Wet Weather Study for year 2030 and as had been previously defined for the 54 mgd case.

TABLE 11
Summary – Design Flow Rates

Condition	Average (MGD)	Max. Month (MGD)	Max. Week (MGD)	Max. Day (MGD)	Peak Hyd (MGD)
Year 2030	44.9	69.5	85.3	108	108
54 mgd Design	54.0	83.7	108	108	108
2005 Design	54.0	70.0	80	90	108

Recommended design loads for year 2030 and the 54 mgd design cases are presented in Tables 12 and 13, respectively. 2005 design load values are presented in Table 14 for comparison purposes.

TABLE 12
Year 2030 Design Loads

Condition	TSS	CBOD5	TKN	NH3	TP	OP
Annual Average	87,200	67,200	12,500	7,300	2,100	600
Maximum Month	122,000	87,400	15,000	8,030	2,730	780
Maximum Week	174,000	100,000	17,500	8,760	3,150	900
Maximum Day	305,000	134,000	25,000	11,700	4,200	1,200

Units in pounds per day.

TABLE 13
54-mgd Design Loads

Condition	TSS	CBOD5	TKN	NH3	TP	OP
Annual Average	110,000	84,600	15,800	9,130	2,600	752
Maximum Month	154,000	110,000	19,000	10,000	3,640	978
Maximum Week	220,000	127,000	22,100	11,000	3,900	1,130
Maximum Day	385,000	169,000	31,600	14,600	5,200	1,500

Units in pounds per day.

TABLE 14
2005 Design Loads

Condition	TSS	CBOD5	TKN	NH3	TP	OP
Annual Average	100,400	73,400	14,400	--	2,500	--
Maximum Month	140,600	102,800	18,900	--	3,500	--
Maximum Week	170,700	110,100	23,000	--	4,250	--
Maximum Day	--	--	--	--	--	--

Units in pounds per day.

The projected 54 mgd design loads are higher than those defined under the 2005 design. This is consistent with the historical data which showed that loading concentrations are increasing at a greater rate than flow. So this trend translates into increasing loading rates while flows show only modest increases.