Rochester Water Reclamation Plant

2019 Facilities Plan

Technical Memorandum 1: Influent Flows and Loadings

TM 1 of 13 | J4325

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Brown AND Caldwell

Brown AND Caldwell

30 East 7th Street, Suite 2500
Saint Paul, MN 55101

T: 651.298.0710

Technical Memorandum

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To: Matt Baker, P.E. Project Manager

From: Harold Voth, P.E. Project Manager

Prepared by: ______________________________
Lloyd Winchell, P.E., Process Engineer
Minnesota License No. 48674, Expiration 6/30/20

Reviewed by: ______________________________
Donavan G. Esping, Minnesota License No. 22972, Expiration 6/30/20

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the state of Minnesota.

Signature:

Name: Lloyd Winchell

Date: July 3, 2018 License No. 48674

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List of Abbreviations

AWW	average wet weather
BC	Brown and Caldwell
cap-d	capita per day
$cBOD_5$	carbonaceous biochemical oxygen demand
City	City of Rochester
COD	chemical oxygen demand
d	day(s)
ft	foot/feet
ft^2	square foot/feet
g	gram(s)
gal	gallon(s)
GLUMRB	Great Lakes Upper Mississippi River Board
gpd	gallon(s) per day
hr	hour(s)
L	liter(s)
lb	pound(s)
m	meter(s)
mg	milligram(s)
mgd	million gallons per day
mL	milliliter(s)
MPCA	Minnesota Pollution Control Agency
PHWWF	peak hour wet weather flow
PIWWF	peak instantaneous wet weather flow
TKN	total Kjeldahl nitrogen
TM	technical memorandum
TP	total phosphorus
TSS	total suspended solids
VA	volatile acids
WRP	Water Reclamation Plant

Executive Summary

This technical memorandum (TM) presents the City of Rochester (City) Water Reclamation Plant (WRP) influent flow and loading projections that will serve as the basis of the WRP Facilities Plan evaluations. The TM presents historical plant influent flows and loadings, projected influent flows and loadings based upon historical plant data, and design influent flow and loadings projections which incorporate influent chemical oxygen demand (COD), carbonaceous biochemical oxygen demand ($cBOD_5$) and total suspended solids (TSS) adjustment factors based upon sampling and analysis efforts conducted under the influent wastewater characterization and BioWin™ process model calibration (Brown and Caldwell, 2018)

Historical plant influent flows and loadings from January 1, 2012 through December 31, 2017 were analyzed to define the existing baseline flows and loadings. Reported flows and loadings were then projected through Year 2045 based upon 1.5 percent yearly compounded growth. Several other growth projection approaches were considered but resulted in either extremely high or low projections or were not consistent with the City's growth expectations.

The historical based influent COD, $cBOD_5$ and TSS loading projections were then increased by the following multiplication factors based upon comparative sampling using the existing influent sampler and an ISCO type sampler and subsequent BioWin model calibration results. The "adjusted" loadings serve as the design influent loadings.

- Design influent $cBOD_5$ load= historically based plant influent $cBOD_5$ load* 1.15
- Design influent TSS load = historically based plant influent COD load* 1.35
- Design influent COD load = design influent $cBOD_5$ load* 1.87 where 1.87 represents the influent COD:$cBOD_5$ ratio measured during the August 2017 wastewater characterization sampling program (Brown and Caldwell 2018). Design influent COD loadings are based upon $cBOD_5$ as COD is sampled only once per week and WRP reported COD measurements during the August 2017 sampling event were consistently 35 percent greater than measured by an outside laboratory.

Continued evaluation and investigation of the plant influent loadings is recommended.

Table ES-1 presents the existing and Year 2030 and 2045 design flow and loading projections. In addition, the City identified that all new facilities shall be designed to hydraulically pass a peak flow of 60 mgd based on the design of the existing headworks. This flow rate will be incorporated into the design along with the other flows listed in Table ES-1. See Attachment C for charts of the projected design influent flow and loading projections.

Table ES-1. Rochester WRP Design Influent Flow and Loading Projections

Item	Units	Existing Baseline	Year 2030	Year 2045
Flows				
Annual Average	mgd	12.9	15.9	19.9
Average Dry Weather	mgd	10.6	12.9	16.2
Average Wet Weather	mgd	15.7	19.0	23.8
Peak Hour Wet Weather Flow	mgd	34.0	40.8	50.8
Peak Instantaneous Wet Weather Flow	mgd	38.9	45.6	55.6[c]
Carbonaceous Biochemical Oxygen Demand[d]				
Annual Average	lb/d	44,100	53,600	67,200
Maximum Month	lb/d	53,400	64,900	81,300
Maximum Week	lb/d	62,400	75,800	94,900
Maximum Day	lb/d	66,800	81,200	101,700
Chemical Oxygen Demand[a,d]				
Annual Average	lb/d	82,500	100,300	125,600
Maximum Month	lb/d	99,900	121,500	152,100
Maximum Week	lb/d	116,600	141,700	177,500
Maximum Day	lb/d	124,900	151,800	190,200
Total Suspended Solids[d]				
Annual Average	lb/d	32,200	39,100	49,000
Maximum Month	lb/d	38,500	46,700	58,400
Maximum Week	lb/d	42,700	51,800	64,900
Maximum Day	lb/d	48,300	58,700	73,600
Ammonia				
Annual Average	lb-N/d	2,600	3,200	4,000
Maximum Month	lb-N/d	3,200	3,900	4,800
Maximum Week	lb-N/d	3,400	4,100	5,100
Maximum Day	lb-N/d	4,300	5,200	6,500
Total Kjeldahl Nitrogen[b]				
Annual Average	lb/d	4,900	6,000	7,500
Maximum Month	lb/d	6,000	7,300	9,100
Maximum Week	lb/d	6,300	7,700	9,600
Maximum Day	lb/d	8,100	9,800	12,300
Total Phosphorus				
Annual Average	lb/d	740	900	1,130
Maximum Month	lb/d	880	1,070	1,330
Maximum Week	lb/d	1,030	1,250	1,570
Maximum Day	lb/d	1,210	1,470	1,840

[a] *COD based on COD:cBOD$_5$ ratio observed during wastewater characterization (August 23-31, 2017) of 1.87.*

[b] *TKN based on historical ammonia:TKN ratio observed during wastewater characterization (August 23-31, 2017) of 0.53.*

[c] *Peak instantaneous flow of 60 mgd to be used in planning.*

[d] *Influent cBOD$_5$, COD, and TSS include a 1.15, 1.15, and 1.35 adjustment factor, respectively, based on special sampling and BioWin model calibration.*

Section 1: Historical Influent Flows and Loadings

This section provides an overview of the historical influent flows and loadings. The City provided plant influent data from January 1, 2012, through December 31, 2017. The data set included reported daily values for the following influent parameters:

- Flow (daily)
- Temperature (daily)
- $cBOD_5$ (3 samples per week)
- TSS (5 samples per week)
- Ammonia (3 samples per week)
- Total phosphorus (TP, 3 samples per week)
- Total organic carbon (TOC, 5 samples per week)
- Soluble $cBOD_5$ ($scBOD_5$, 1 sample per week starting January 6, 2015)
- COD (1 sample per week starting February 12, 2015)
- Soluble COD (sCOD, 1 sample per week starting February 12, 2015)
- Volatile suspended solids (VSS, 1 sample per week starting January 5, 2015)
- Total Kjeldahl nitrogen (TKN, 1 sample per month)
- Volatile acids (VA, 1 sample per week starting February 12, 2015)

The City began routine analysis for COD, sCOD, $scBOD_5$, VSS, and VA in 2015 to further understand the plant influent wastewater characteristics.

This section focuses on establishing baseline conditions for the annual average, maximum month, maximum week and maximum day flows and loadings for the first six parameters (flow, temperature, $cBOD_5$, TSS, ammonia, and TP). If the number of data points available was half or less of the averaging period (e.g. only 15 reported data points in a 30-day averaging period) a percentile was used where the maximum month and maximum week are represented by the 92nd and 98thpercentile.

1.1 Influent Flows

Table 1-1 summarizes the historical influent flows. Average dry weather flow relates to the lowest 30-day running average during the year. Annual average represents the daily average flow during the year. The average wet weather (AWW) and maximum week flows are the highest 30-day and 7-day running averages during the year, respectively. Finally, maximum day represents the highest single daily flow in the given year.

Plant staff noted that prior to 2014 the influent flow meter was believed to be reading high by about 7 percent. Influent flow data from January 1, 2012 through December 31, 2013 was multiplied by a factor of 0.93 to correct for this flow discrepancy. Also, unless noted otherwise the maximum value observed for each flow condition over the five plus years will be used as the “Existing Baseline” condition for projecting future flows.

The Rochester WRP influent flow averaged 12.6 mgd over the last five plus years. The highest annual average flow was observed in 2014 and 2017 at 12.9 mgd. The 12.9 mgd flow rate will serve as the “Existing Baseline” annual average condition used for establishing the future projected flow rates.

Table 1-1. Rochester WRP Historical Influent Flows (mgd)

Flow	2012	2013	2014	2015	2016	2017	Existing Baseline[a]	Peaking Factor
Average Dry Weather	11.2	10.9	10.9	10.6	10.7	10.6	10.6	0.8
Annual Average	12.3	12.8	12.9	11.9	12.1	12.9	12.9	--
Average Wet Weather	13.3	17.9	14.9	14.2	13.6	15.7	15.7	1.2
Maximum Week	13.8	21.5	17.0	15.2	16.3	16.3	21.5	1.7
Maximum Day	15.9	25.5	19.4	16.8	22.8	18.2	25.5	2.0
Peak Hour Wet Weather	--	--	--	--	--	--	34.0	2.6
Peak Instantaneous Wet Weather	--	--	--	--	--	--	38.9	3.0

[a] *Historical baseline to be used in design flow projections.*

Year 2013 contains the highest AWW, maximum week and maximum day flows. The reported maximum day flow of 25.5 mgd occurred on May 5, 2013 which saw steady rainfall for four days prior. The range for AWW maximum week flows both include the maximum day flow. The AWW for 2017 was used as the existing baseline because flow metering data was believed to be more accurate and correlated better with the AWW flows from the other years. The historical data is captured in Figure 1-1 and includes plant influent flow and precipitation recorded at the Rochester International Airport.

The peak hour wet weather flow (PHWWF) of 34.0 mgd and peak instantaneous wet weather flow (PIWWF) of 38.9 mgd were determined using MPCA flow determination guidelines. MPCA defines the PHWWF as the resultant peak hour flow from a 5-year one-hour storm event when groundwater is high and the PIWWF as the resultant peak hour flow from a 25-year one-hour storm event when groundwater is high. The PHWWF is typically used in process analysis such as maximum clarifier surface over flow rates, or chlorine contact detention times. The PIWWF is used to define the hydraulic flow capacity which the plant must pass. Attachment A contains the MPCA flow determination worksheet calculations.

The calculated PHWWF matches the predicted peak hour flow from a 5-year storm event of 33 to 36 mgd using the sanitary sewer system hydraulic model (HDR, 2017) under existing and potential no flow limitation scenarios respectively. Conversely, the PIWWF of roughly 38.9 mgd is significantly lower than the sanitary sewer system hydraulic model predicted flows of 65 to 70 mgd. The sanitary sewer hydraulic model PIWWF peaking factor of 5.0 or greater is excessively high given the PHWWF peaking factor is 2.63. See Attachment B for the sanitary sewer system hydraulic model flow hydrographs.

Table 1-1 also includes the influent flow peaking factors. The peaking factors are typical of municipal facilities.

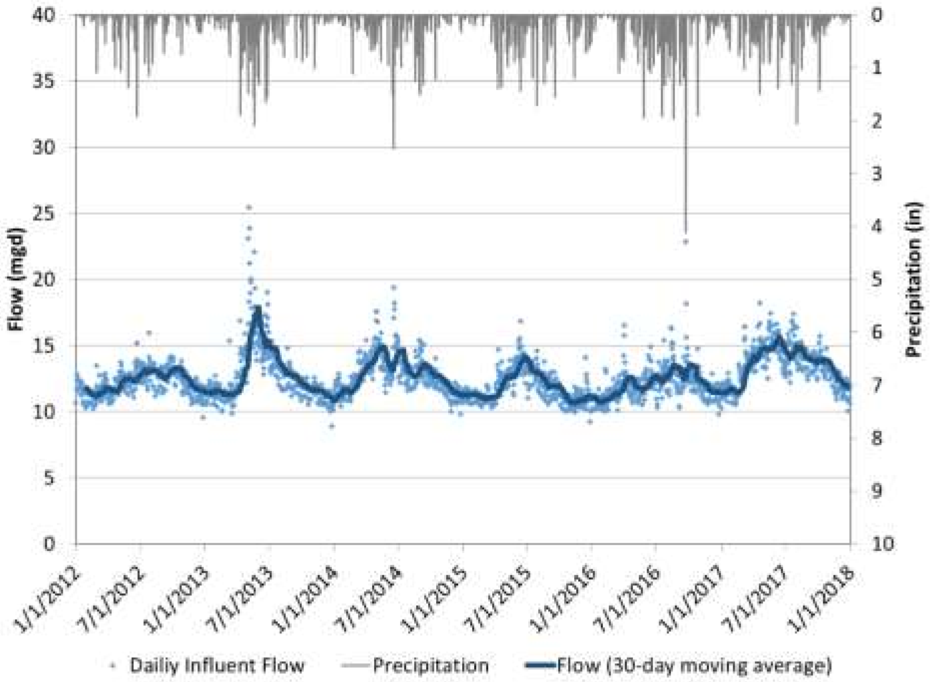

Figure 1-1. Rochester WRP daily influent flow and precipitation

1.2 Raw Influent Loadings

Table 1-2 summarizes the raw influent loadings for the last five plus years (loadings prior to 2014 have been adjusted with the flow correction factor discussed above). The reported loadings of each parameter/loading condition have generally remained constant over the six-year period. Figures 1-3 through 1-6 show the loadings over time. Variations do occur from year to year. Figure 1-2 illustrates the variation in annual loading over the last six years by normalizing annual average loadings to the selected baseline loading identified in Table 1-2. Year 2014 and 2017 loadings are typical of the selected baseline loading conditions.

Figures 1-3 through 1-6 show the historical daily data (blue dots) and a 30-day moving average (blue line). Note in limited instances the 30-day moving average may not correlate exactly with the values in Table 1-2 because a percentile approach was used to overcome insufficient data points available for the moving average (e.g. the 92nd percentile, 100th percentile less 1/12, was used for maximum month).

The peaking factors listed in Table 1-2 are typical. The 1.2 peaking factor for maximum month calculated for all parameters is typical of other municipal facilities. Maximum day peaking factors for the WRP are also in line with other facilities. Brown and Caldwell experience is a 1.6 maximum day peaking factor for ammonia is typical of municipal facilities.

1.2.1 Carbonaceous Biochemical Oxygen Demand (cBOD$_5$)

The existing baseline annual average cBOD$_5$ loading is 38,400 lb/d. This was the observed value in 2014 and is about 2,500 lb/d higher than the average of the six annual averages from the provided data. In general, the influent cBOD$_5$ loadings have been relatively constant as shown in Figure 1-3 with seasonal and annual variations. The highest maximum month (46,500 lb/d) occurred in November of 2012 while the maximum day value (58,100 lb/d) occurred on October 5, 2017. The maximum week value for 2015 only contained one data point so the 98th percentile was used to calculate this year's value.

1.2.2 Total Suspended Solids

Figure 1-4 shows the historical TSS loading over the six-year period analyzed. The existing baseline annual average loading of 23,800 lb/d was recorded in 2017 and the variation from year to year was less than 7 percent as shown in Figure 1-2. The maximum month (28,400 lb/d) and maximum day (35,800 lb/d) both occurred in October of 2017with the maximum day value (October 5, 2017) being part of the 30-day moving average used to establish the maximum month value.

1.2.3 Ammonia

The historical ammonia loadings are shown in Figure 1-5. The existing baseline annual average loading of 2,600 lb/d, was reported in 2014 and 2017. This value was lower than the earlier year's annual averages (2,900 and 2,700 lb/d for 2012 and 2013 respectively), but were considered more representative of the plants influent. This decision was made with the City staff during a flow and loading workshop on September 21, 2017. From 2014 through 2017 the loadings have been relatively level. The maximum month (3,200 lb/d) and maximum day (4.300 lb/d) were also taken from 2014 (highest values in the 2014 through 2017). The maximum month value represented the 92nd percentile of 2014 since the highest 30-day moving average for that year only contained 12 data points.

1.2.4 Total Phosphorus

The existing baseline annual average TP loading of 740 lb/d occurred in 2017. Figure 1-6 shows the TP loading has been relatively constant over the six years analyzed. 2017 also contained the maximum month (860 lb/d) and maximum day (1,210 lb/d) TP loadings, the former occurring in mid-September and the latter on the 31st of July.

Table 1-2. Rochester WRP Historical Raw Influent Loadings (lb/d)

Item	2012	2013	2014	2015	2016	2017	Existing Baseline	Peaking Factor	MOP 8 Peaking Factor[b]
Carbonaceous Biochemical Oxygen Demand									
Annual Average	36,900	34,200	38,400	35,600	33,200	37,100	38,400	--	--
Maximum Month	46,500	39,300	42,700	39,500	37,900	45,200	46,500	1.2	1.25
Maximum Week	54,200	45,600	50,700	50,200	49,900	51,500	54,200	1.4	--
Maximum Day	57,400	53,400	57,000	55,700	55,800	58,100	58,100	1.5	1.5
Total Suspended Solids									
Annual Average	21,800	21,300	23,700	22,100	21,200	23,800	23,800	--	--
Maximum Month	27,200	23,300	26,600	24,600	24,500	28,500	28,500	1.2	1.25
Maximum Week	30,500	26,100	29,400	26,500	25,600	31,600	31,600	1.3	--
Maximum Day	34,700	30,600	34,000	34,900	34,400	35,800	35,800	1.5	1.6
Ammonia-Nitrogen									
Annual Average	2,900	2,700	2,600	2,400	2,300	2,600	2,600[a]	--	--
Maximum Month	3,700	3,000	3,200	2,800	2,600	2,900	3,200[a]	1.2	1.15
Maximum Week	4,300	3,500	3,400	3,000	2,800	3,100	3,400[a]	1.3	--
Maximum Day	5,100	4,200	4,300	3,700	3,100	3,600	4,300[a]	1.6	1.25
Total Phosphorus									
Annual Average	730	680	720	660	640	740	740	--	--
Maximum Month	860	770	820	720	700	860	860	1.2	--
Maximum Week	910	860	890	820	780	1,030	1,030	1.4	--
Maximum Day	1,040	1,070	1,060	870	900	1,210	1,210	1.6	--

[a] *During a flow and loading workshop on September 21, 2017 the City decided to use the 2014 data for ammonia-nitrogen for existing baseline loadings.*

[b] *WEF, 2010.*

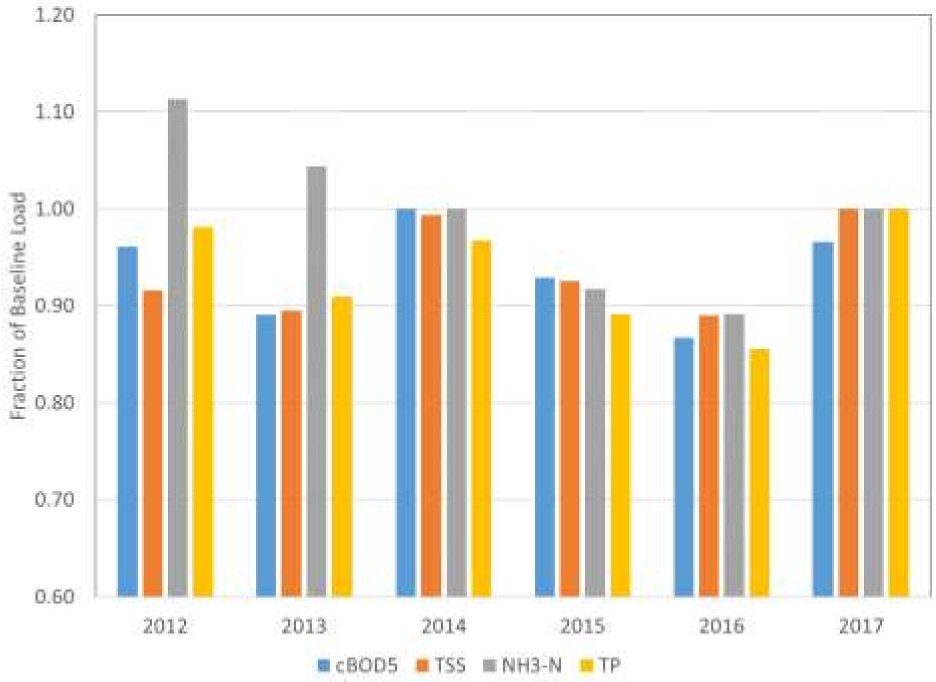

Figure 1-2. Rochester WRP annual average loadings normalized to existing baseline loading

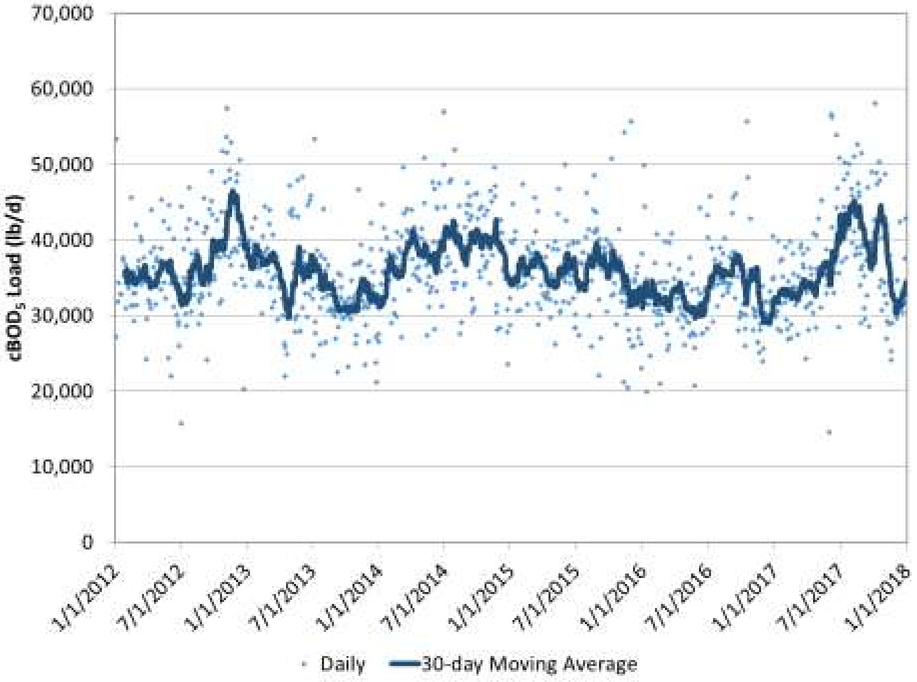

Figure 1-3. Rochester WRP historical cBOD$_5$ loadings (January 1, 2012 – December 31, 2017)

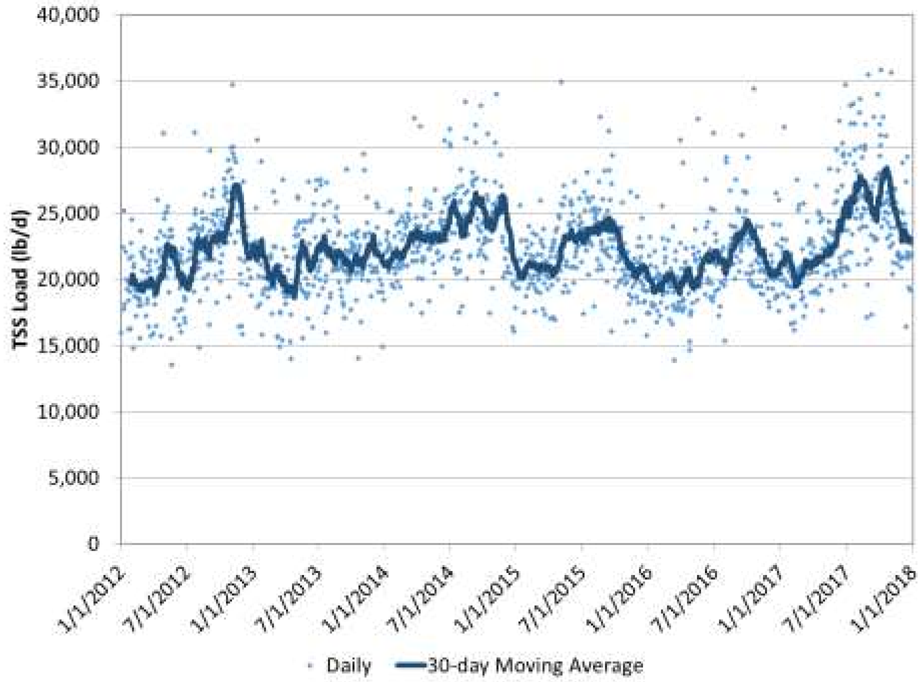

Figure 1-4. Rochester WRP historical TSS loadings (January 1, 2012 – December 31, 2017)

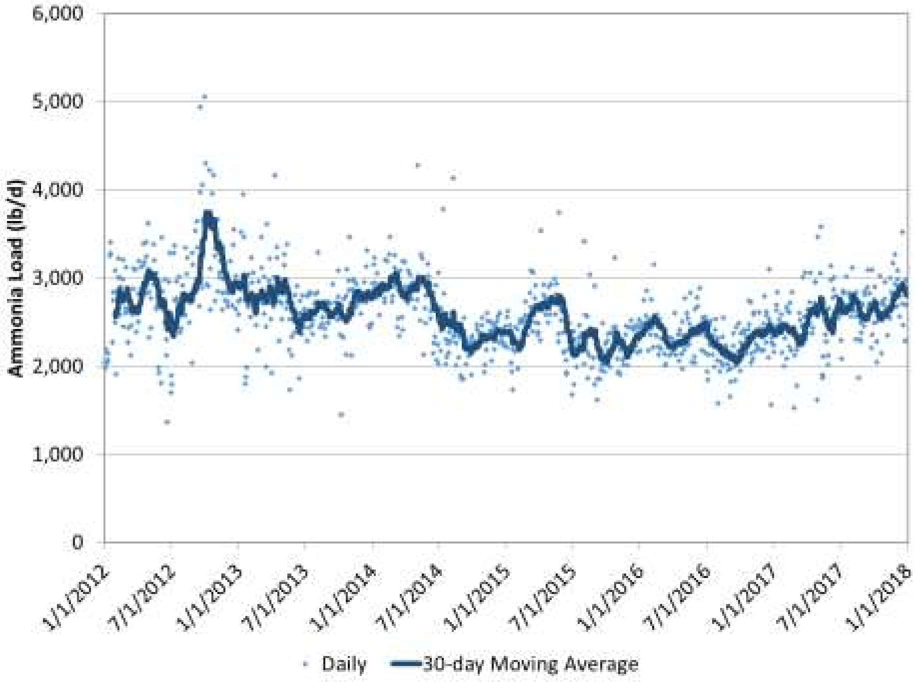

Figure 1-5. Rochester WRP historical ammonia loadings (January 1, 2012 – December 31, 2017)

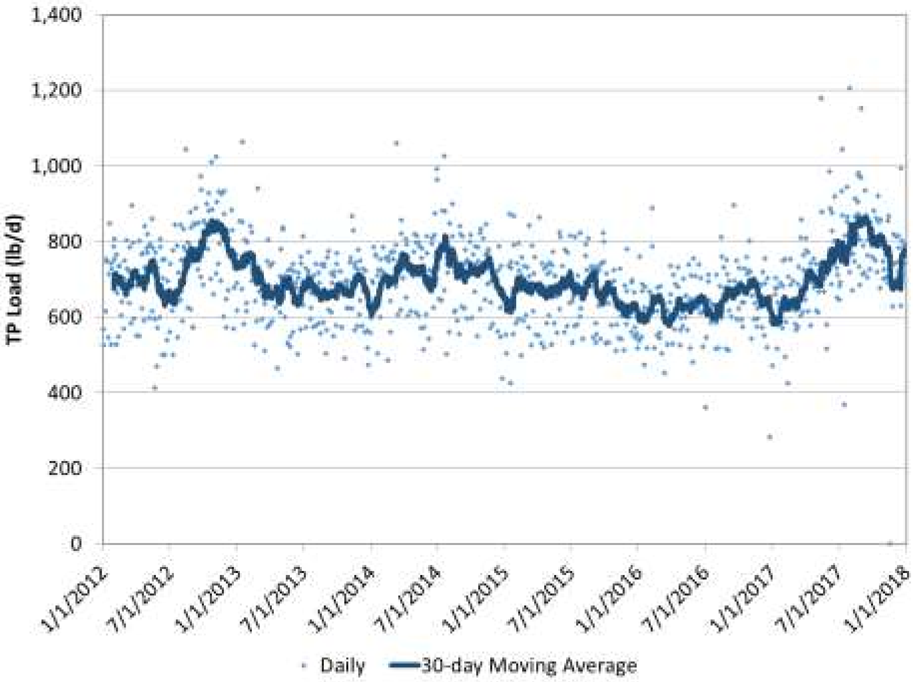

Figure 1-6. Rochester WRP historical TP loadings (January 1, 2012 – December 31, 2017)

1.3 Raw Influent Temperature

The historical influent temperature data is presented in Figure 1-7 below. The seasonal pattern is clear with monthly temperatures ranging from 12 to 20 degrees Celsius (°C) on a 30-day rolling average basis. March and April are the coldest periods of the year while August and September are the warmest. The average temperature over the five-year period is 16 °C.

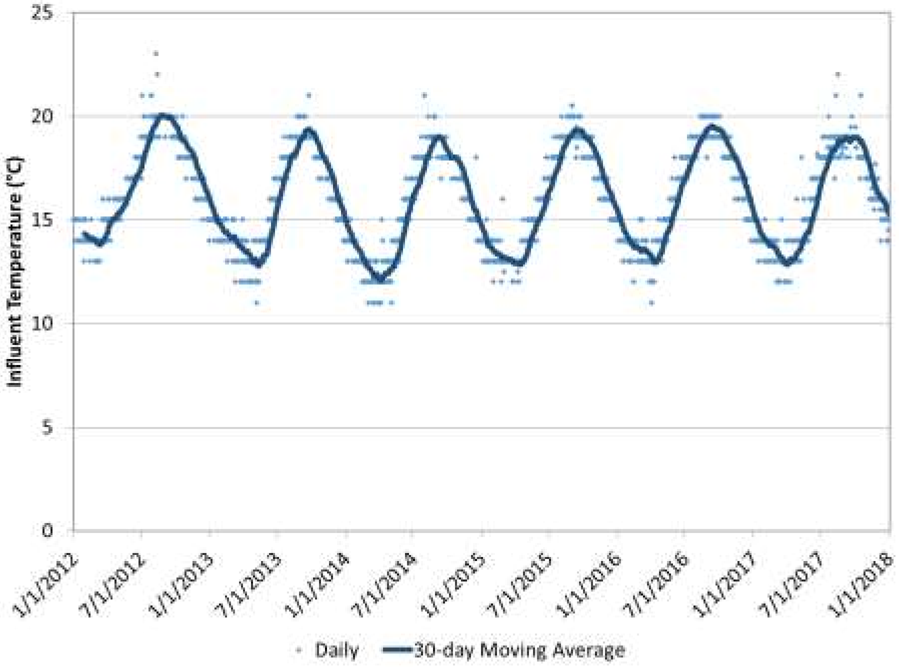

Figure 1-7. Rochester WRP historical influent temperature (Jan. 1, 2012 – Dec. 31, 2017)

Section 2: Projected Flows and Loadings

This section presents the projected influent flows and loadings based upon the historical plant influent data. **The final design COD, cBOD$_5$, and TSS loading projections are updated in Section 4.**

2.1 Projected Growth

Six different approaches were considered for estimating the future growth within the Rochester WRP sewerage system and are presented below. These approaches were presented to the City on September 11, 2017 and compare the annual average flows and loadings using 2016 as the base year for flow and loading projections unless noted otherwise.

2.1.1 Approach 1 – 1996 Master Plan

The 1996 Master Plan (Black and Veatch, 1996) provided annual average flow and loading projections up to the Year 2045. The projections were based on 23 percent population growth rate data (1990-2015) provided by the Rochester Olmsted Consolidated Planning Department. Residential, commercial, and industrial flow and loadings were reportedly projected at the same rate. Table 2-1 summarizes the projections which do not adhere to a linear or exponential growth model and the Master Plan is silent on the precise projection methods.

Table 2-1. Influent Flow and Loading Projections Approach 1
1996 Master Plan Projections (Annual Average)

Item	Units	1995	2005	2015	2045
Flow	mgd	12.7	13.7	14.2	17.4
Biochemical Oxygen Demand,	lb/d	30,600	33,200	34,200	41,900
Carbonaceous Biochemical Oxygen Demand[1]	lb/d	26,400	28,600	29,500	36,100
Total Suspended Solids	lb/d	23,100	25,000	25,800	31,600
Ammonia	lb-N/d	1,890	2,050	2,110	2,580
Total Phosphorus	lb/d	1,140	910	930	1,140

[1] *Carbonaceous biochemical oxygen demand estimated using a cBOD$_5$:BOD$_5$ ratio of 0.862 (median observation at ten municipal wastewater treatment facilities)*

2.1.2 Approach 2 – Compounded Growth

A typical approach for estimating future growth uses a compounded yearly model. This approach was based on the recommended annual average growth rate (1.5 percent compounded annually) used by the Destination Medical Center for projecting the City's growth over the next 30 years. The 1.5 percent compounded growth rate was applied to both influent flow and load assuming the same relative contributions from residential, commercial, and industrial sources.

In general, the baseline annual average flow or loading was projected using the following growth equation and the 1.5 percent growth rate cited above.

$$X(t) = X_0 e^{rt}$$

Where,

X(t) = flow or loading at time t

X_0 = initial flow or loading

r = growth rate (1.5 percent)

t = number of years beyond base year

Table 2-2 summarizes the annual average flow and loading projections for Year 2030 and 2045 resulting from the exponential growth model.

Table 2-2. Influent Flow and Loading Projections Approach 2 – Compounded Annual Growth (Annual Average)

Item	Units	Existing Baseline	Year 2030	Year 2045
Flow	mgd	12.9	15.9	19.9
Carbonaceous Biochemical Oxygen Demand	lb/d	38,400	47,300	59,300
Total Suspended Solids	lb/d	23,800	29,400	36,800
Ammonia	lb-N/d	2,600	3,200	4,000
Total Phosphorus	lb/d	730	900	1,130

2.1.3 Approach 3 - Linear Growth

Approach 3 uses a linear growth model based upon an annual growth increase of 1.5 percent of the baseline condition. Like Approach 2, the growth rate was applied to the baseline influent flow and loading condition assuming the same percentage of contributions from residential, commercial, and industrial sources.

In general, the baseline annual average flow or loading was projected using the following growth equation and the 1.5 percent rate cited above.

$$X(t) = X_0(1 + rt)$$

Where,

X(t) = flow or loading at time t

X_0 = initial flow or loading

r = growth rate (1.5 percent)

t = number of years beyond base year

Table 2-3 summarizes the annual average flow and loading projections for Year 2030 and 2045 resulting from the linear growth model.

Table 2-3. Influent Flow and Loading Projections Approach 3 – Linear Growth (Annual Average)

Item	Units	Existing Baseline	Year 2030	Year 2045
Flow	mgd	12.9	15.6	18.5
Carbonaceous Biochemical Oxygen Demand	lb/d	38,400	46,400	55,100
Total Suspended Solids	lb/d	23,800	28,800	34,200
Ammonia	lb-N/d	2,600	3,100	3,700
Total Phosphorus	lb/d	730	880	1,050

2.1.4 Approach 4 – Municipal Growth Only

Given industrial flow and loadings do not necessarily track with domestic flow and loadings, this approach looked at keeping industrial contributions static while increasing the domestic contributions (i.e. residential and commercial) using a 1.5 percent compounded growth rate.

This approach assumes a WRP sewerage area population of 111,907 in 2015 (Minnesota State Demographic Center). The population was projected to increase at the 1.5 percent compounded growth rate discussed above. The following flow and loading criteria were applied to the projected population increase.

- Flow – 100 gallons per capita per day (gal/cap-d, GLUMRB, 2014)
- $cBOD_5$ – 0.19 pound per capita per day (lb/cap-d, BOD_5 rate of 0.22 from GLUMRB * 0.862 for typical $cBOD_5$:BOD_5 ratio observed at other facilities)
- TSS – 0.25 lb/cap-d (GLUMRB, 2014)
- Ammonia – 0.024 lb/cap-d (TKN of 0.046 lb/cap-d from GLUMRB * 0.53 ammonia:TKN ratio observed during 2017 wastewater sampling event)
- TP – 0.0059 lb/cap-d

Table 2-4 summarizes the annual average flow and loading projections resulting from the exponential model application to domestic flows and loadings with a static industrial contribution.

Table 2-4. Influent Flow and Loading Projections Approach 4 – Municipal Growth Only (Annual Average)

Item	Units	Existing Baseline	Year 2030	Year 2045
Population	capita	113,600	140,100	175,500
Flow	mgd	12.9	15.5	19.1
Carbonaceous Biochemical Oxygen Demand	lb/d	38,400	43,400	50,100
Total Suspended Solids	lb/d	23,800	30,500	39,300
Ammonia	lb-N/d	2,600	3,200	4,100
Total Phosphorus	lb/d	730	885	1,090

2.1.5 Approach 5 – 2003 Master Plan Amendment

The 1996 Master Plan influent flow and loading projections were updated for the 2007 plant expansion in the Amendment to Rochester Wastewater Master Plan (Howard R. Green and CH2M Hill, 2003). The updated flows and loadings were projected to Year 2025 and 2050 using a similar 1.5 percent compounded growth rate and population basis. The flows and loadings were calculated for Year 2030 and Year 2045 using the Amendment to Rochester Wastewater Master Plan Year 2025 as a basis for the projections. The Amendment to Rochester Wastewater Master Plan also reported values for design Year 2015, but Year 2025 was selected to fall within range currently being analyzed (2016-2045). Table 2-5 summarizes the updated flow and loading projections. Note the Amendment to the Rochester Wastewater Master Plan used BOD_5 which was converted into $cBOD_5$ for comparison to other approaches.

Table 2-5. Influent Flow and Loading Projections Approach 5 –Master Plan Amendment (Annual Average)

Item	Units	Year 2025	Year 2030	Year 2045
Flow	mgd	20.3	21.9	27.4
Carbonaceous Biochemical Oxygen Demand	lb/d	43,800	47,200	59,100
Total Suspended Solids	lb/d	33,800	36,400	45,600
Ammonia	lb-N/d	3,100	3,300	4,100
Total Phosphorus	lb/d	1,350	1,460	1,820

[1] Carbonaceous biochemical oxygen demand estimated using a $cBOD_5$:BOD_5 ratio of 0.862 (median observation at ten municipal wastewater treatment facilities)

2.1.6 Approach 6 – Rate Study

The final projection approach investigated uses the Rate Study (Municipal Financial Services, 2015) projections. The Rate Study looked at recorded data from 1998 through 2014 to develop projections for Years 2016 to 2021. The projections generally followed a linear model with some variability due to water conservation expectations.

Table 2-6 summarizes the flow and loading projections for the Rate Study. The Year 2030 and 2045 projections were estimated using a straight-line approximation from the Years 2016 through 2021 projections. Note the Rate Study stated BOD_5 data, so for comparison to the other projection approaches in this TM the BOD_5 data was converted into $cBOD_5$ data.

Table 2-6. Influent Flow and Loading Projections Approach 6 – Rate Study (Annual Average)

Item	Units	Existing Baseline	Year 2030	Year 2045
Flow	mgd	12.9	13.3	13.7
Carbonaceous Biochemical Oxygen Demand	lb/d	38,400	37,200	41,000
Total Suspended Solids	lb/d	23,700	29,700	34,200
Ammonia	lb-N/d	2,600	3,100	3,200
Total Phosphorus	lb/d	730	860	920

[1] Carbonaceous biochemical oxygen demand estimated using a $cBOD_5$:BOD_5 ratio of 0.862 (median observation at ten municipal wastewater treatment facilities)

2.1.7 Projection Approach Evaluation

Figures 2-1 through 2-5 compare the different annual average flow and loading projection approaches. Also included are historical data (green dots). As discussed above, City staff noted prior to 2014 the influent flow meter reading is believed to be incorrect and has been adjusted by a correction factor of 0.926. The flow corrected historical data are shown in the figures as grey dots. Lastly, the lone yellow dot in each figure placed at Year 2025 indicates the facility capacity as listed in the City's presentation delivered during the project solicitation phase (City of Rochester, 2017).

2.1.7.1 Influent Flow

Annual average flow projections were similar for Approaches 2, 3, and 4 with 2045 projected flows of 17 to 20 mgd as shown in Figure 2-1. Approach 5 resulted in exceptionally high annual flows compared to the other approaches reaching roughly 27 mgd in 2045. Approach 1 and 6 exhibited relatively slow growth rates though Approach 1 reached over 17 mgd in Year 2045.

2.1.7.2 Raw Influent Loadings

The annual average $cBOD_5$ loading projection trends differ from the influent flow projection observations as shown in Figure 2-2. Approach 2 (1.5 percent compounded growth) and Approach 5 (2003 Master Plan Update) resulted in the highest $cBOD_5$ loading projection of roughly 59,300 lb/d by Year 2045 followed closely by Approach 3 (55,100 lb/d). Approach 4 which assumes industrial loadings remain at current levels has a projected $cBOD_5$ loading of 50,100 lb/d by Year 2045. Approaches 1 and 6 both exhibited a similar, relatively slow, growth rate and both approaches projected significantly lower loadings compared to the other approaches.

The projected annual average TSS loadings shown in Figure 2-2 were relatively tightly grouped by Year 2045, ranging from roughly 32,000 to 38,000 lb/d. Approach 5 was the exception reaching over 45,000 lb/d by 2045. Approaches 1 and 6 again utilized the slowest growth rates overall.

The average annual ammonia projected loadings ranged from 2,500 to 4,100 lb/d in Year 2045. In similar form, Approaches 1 and 6 exhibited the slowest growth rates and achieve the lowest loadings by Year 2045. Approach 5 resulted in the highest loading by Year 2045, but was nearly identical to Approach 4. Approach 4 reported the fastest overall loading increase.

The projected annual average TP loadings ranged from just over 900 lb/d to over 1,800 lb/d for Year 2045 projections. Approaches 1 and 6 again used the lowest growth rates though Approach 6 projected the lowest Year 2045 TP loading and Approach 1 was the fourth lowest. Approaches 2, 3, and 4 resulted in roughly the same TP projection of 1,100 lb/d in Year 2045. Approach 5 TP projections were again exceptionally higher than the other approaches.

Given the tendency for Approaches 1, 5, and 6 to yield very low or high projections they were eliminated from consideration. The linear growth assumed with Approach 3 is not consistent with the City's growth expectation and was similarly eliminated from consideration. The 1.5 percent compounded growth rate utilized in Approach 2 allows for some industrial growth where Approach 4 does not. A follow up progress meeting was held with the City on September 21, 2017 which selected Approach 2 to be used for developing flow and loading projections. This approach provides a slight conservativeness compared to Approach 4 while maintaining the 1.5 percent compounded growth rate used by the Destination Medical Center.

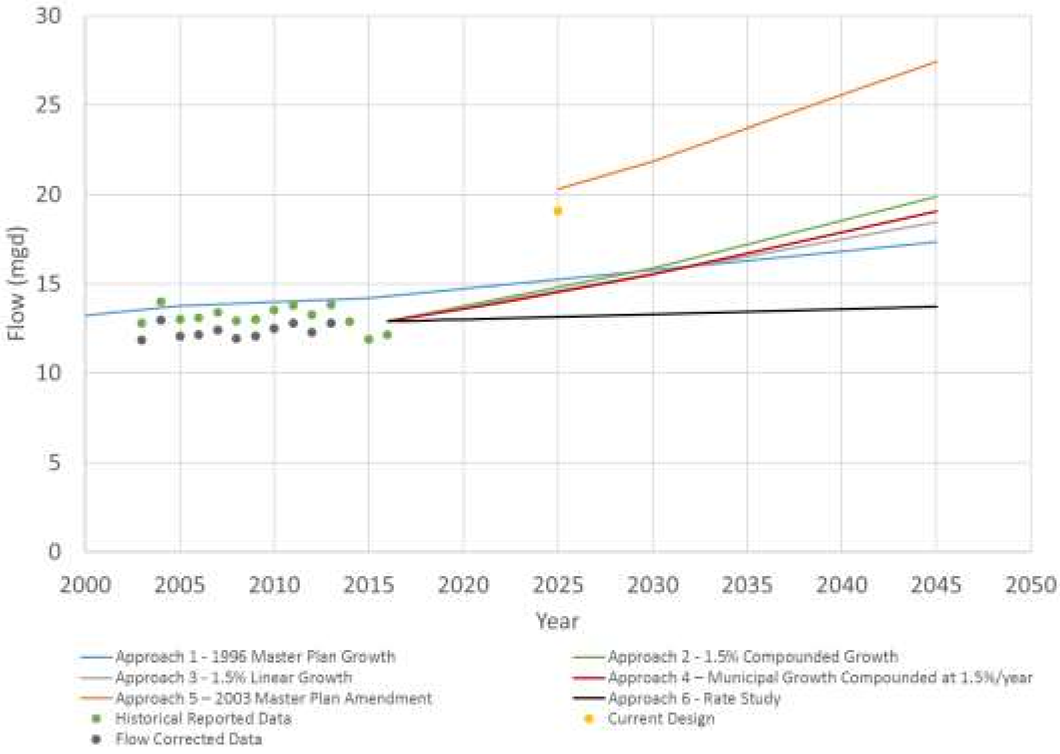

Figure 2-1. Historical and projected annual average influent flows

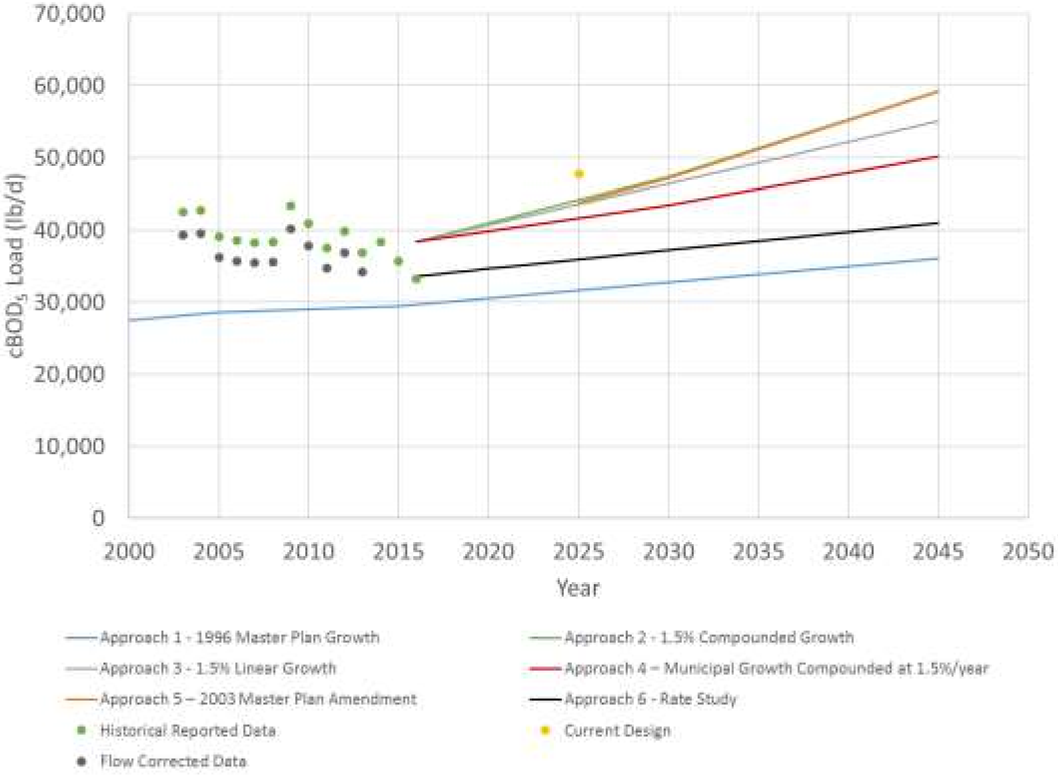

Figure 2-2. Historical and projected annual average influent $cBOD_5$ loadings

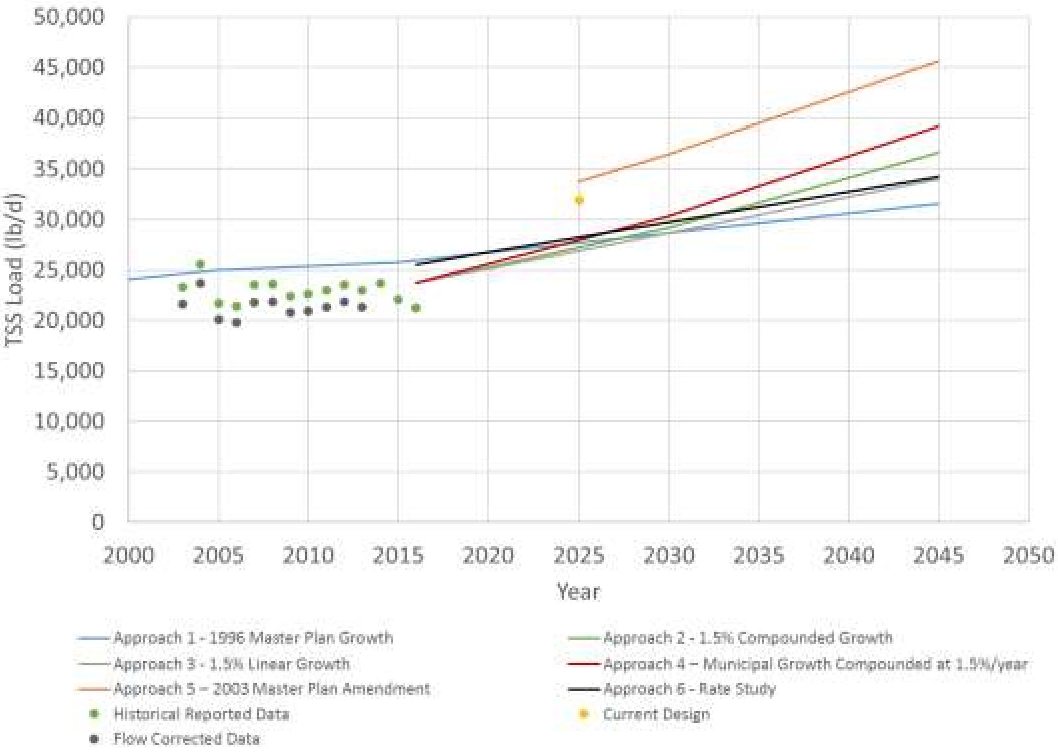

Figure 2-3. Historical and projected annual average influent TSS loadings

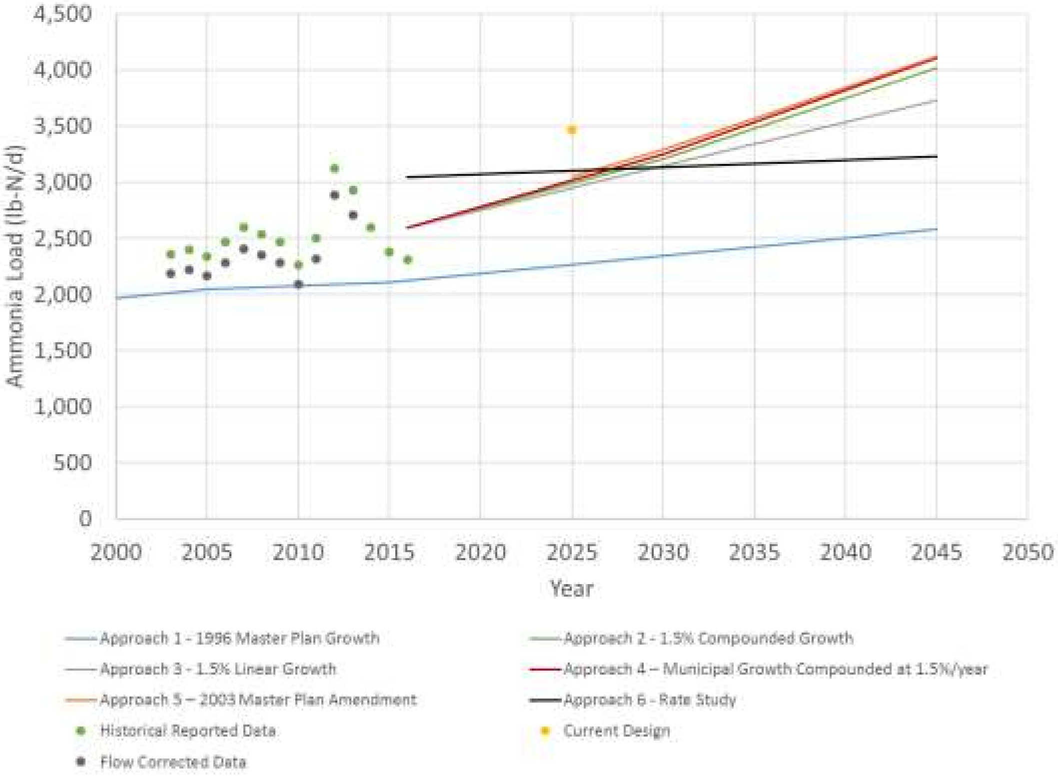

Figure 2-4. Historical and projected annual average influent ammonia loadings

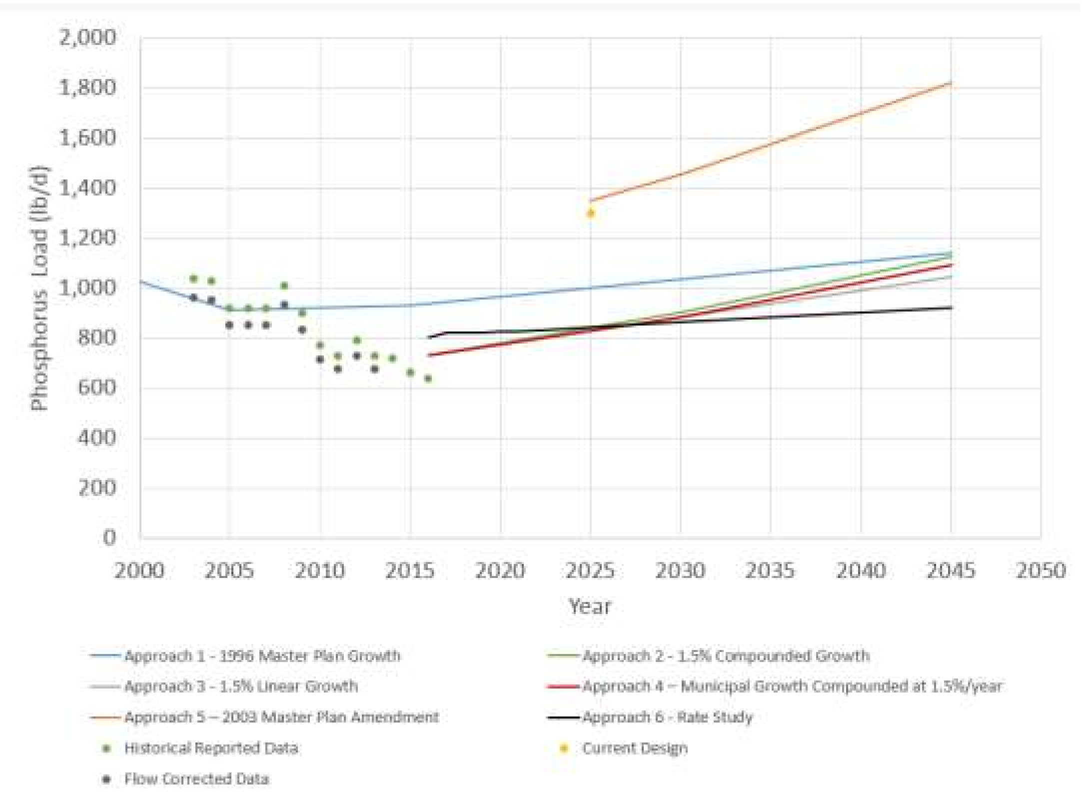

Figure 2-5. Historical and projected annual average influent TP loadings

2.2 Projected Influent Flows and Loadings

Table 2-7 summarizes the projected flows and loadings using a 1.5 percent compounded growth rate. The projected PHWW and PIWW flows are calculated using the MPCA flow determination guidelines included in Attachment A. The City requested any new facilities have capacity to pass a peak flow of 60 mgd based on the capacity of the headworks system (progress meeting between the City and Brown and Caldwell on September 21, 2017). The project team also established a planning horizon Year of 2045 and use 2017 as the base year for projections.

As noted earlier, the WRP has started measuring influent COD in 2015 about once per week and influent TKN monthly since at least 2012. These two parameters are required inputs in the BioWin™ simulator which will be used for facility process evaluation. Given the City's limited influent COD database and that the City reported COD values were consistently higher than an outside lab reported results during the 2017 wastewater characterization sampling program, the influent COD loadings are calculated by multiplying the influent cBOD$_5$ loading by the COD:cBOD$_5$ ratio of 1.87 measured during the 2017 wastewater characterization sampling event. Similarly, the influent TKN loading is calculated by dividing the projected ammonia loading by the ammonia:TKN ratio of 0.53 observed during the same period.

Table 2-7. Rochester WRP Projected Influent Flows and Loadings Base Upon Reported Data
(see Table 3-2 for Final Influent Design Flows and Loadings)

Item	Units	Existing Baseline	Year 2030	Year 2045
Flows				
Annual Average	mgd	12.9	15.6	19.6
Average Dry Weather	mgd	10.6	12.9	16.2
Average Wet Weather	mgd	15.7	19.0	23.8
Peak Hour Wet Weather	mgd	34.0	40.8	50.8
Peak Instantaneous Wet Weather	mgd	38.9	45.6	55.6
Carbonaceous Biochemical Oxygen Demand				
Annual Average	lb/d	38,400	46,600	58,400
Maximum Month	lb/d	46,500	56,500	70,700
Maximum Week	lb/d	54,200	65,900	82,500
Maximum Day	lb/d	58,100	70,600	88,400
Chemical Oxygen Demand[a]				
Annual Average	lb/d	71,800	87,200	109,200
Maximum Month	lb/d	86,900	105,600	132,300
Maximum Week	lb/d	101,400	123,200	154,300
Maximum Day	lb/d	108,600	132,000	165,400
Total Suspended Solids				
Annual Average	lb/d	23,800	29,000	36,300
Maximum Month	lb/d	28,400	34,600	43,300
Maximum Week	lb/d	31,600	38,400	48,100
Maximum Day	lb/d	35,800	43,500	54,500
Ammonia				
Annual Average	lb-N/d	2,600	3,200	4,000
Maximum Month	lb-N/d	3,200	3,900	4,800
Maximum Week	lb-N/d	3,400	4,100	5,100
Maximum Day	lb-N/d	4,300	5,200	6,500
Total Kjeldahl Nitrogen[b]				
Annual Average	lb/d	4,900	6,000	7,500
Maximum Month	lb/d	6,000	7,300	9,100
Maximum Week	lb/d	6,300	7,700	9,600
Maximum Day	lb/d	8,100	9,800	12,300
Total Phosphorus				
Annual Average	lb/d	740	900	1,130
Maximum Month	lb/d	880	1,070	1,330
Maximum Week	lb/d	1,030	1,250	1,570
Maximum Day	lb/d	1,210	1,470	1,840

[a] *COD based on COD:cBOD$_5$ ratio observed during wastewater characterization (August 23-31, 2017) of 1.87.*

[b] *TKN based on historical ammonia:TKN ratio observed during wastewater characterization (August 23-31, 2017) of 0.53.*

Section 3: Design Influent Flows and Loadings

The Rochester WRP reported plant loadings and operating data showed several anomalies related to high overall sludge production and secondary treatment system volatile suspended solids yields. A series of “sleuthing” investigations were completed to uncover these data anomalies. A summary of the investigations is included in the Wastewater Characterization and BioWin Calibration TM. (Brown and Caldwell, 2018)

Based upon these sleuthing investigations and BioWin wastewater treatment plant model calibration, adjustment factors to the Rochester raw influent COD, cBOD5, and TSS loadings were developed as shown in Table 3-1.

Table 3-1. Rochester WRP Raw Influent Adjustment Factors

Parameter	Adjustment Factor
TSS	1.35
$cBOD_5$	1.15
COD	1.15
TKN	1.0
Ammonia	1.0
TP	1.0

Table 3-2 summarizes the final design flows and loadings projections. The City should continue investigations to modify its existing sampling system to obtain representative samples and investigate sample degradation in sample collection/transport.

Table 3-2. Rochester WRP Design Influent Flows and Loadings.

Item	Units	Existing Baseline	Year 2030	Year 2045
Flows				
Annual Average	mgd	12.9	15.9	19.9
Average Dry Weather	mgd	10.6	12.9	16.2
Average Wet Weather	mgd	15.7	19.0	23.8
Peak Hour Wet Weather	mgd	34.0	40.8	50.8
Peak Instantaneous Wet Weather	mgd	38.9	45.6	55.6[c]
Carbonaceous Biochemical Oxygen Demand[d]				
Annual Average	lb/d	44,100	53,600	67,200
Maximum Month	lb/d	53,400	64,900	81,300
Maximum Week	lb/d	62,400	75,800	94,900
Maximum Day	lb/d	66,800	81,200	101,700
Chemical Oxygen Demand[a,d]				
Annual Average	lb/d	82,500	100,300	125,600
Maximum Month	lb/d	99,900	121,500	152,100
Maximum Week	lb/d	116,600	141,700	177,500
Maximum Day	lb/d	124,900	151,800	190,200
Total Suspended Solids[d]				

Table 3-2. Rochester WRP Design Influent Flows and Loadings.

Item	Units	Existing Baseline	Year 2030	Year 2045
Annual Average	lb/d	32,200	39,100	49,000
Maximum Month	lb/d	38,400	46,700	58,400
Maximum Week	lb/d	42,700	51,800	64,900
Maximum Day	lb/d	48,300	58,700	73,600
Ammonia				
Annual Average	lb-N/d	2,600	3,200	4,000
Maximum Month	lb-N/d	3,200	3,900	4,800
Maximum Week	lb-N/d	3,400	4,100	5,100
Maximum Day	lb-N/d	4,300	5,200	6,500
Total Kjeldahl Nitrogen[b]				
Annual Average	lb/d	4,900	6,000	7,500
Maximum Month	lb/d	6,000	7,300	9,100
Maximum Week	lb/d	6,300	7,700	9,600
Maximum Day	lb/d	8,100	9,800	12,300
Total Phosphorus				
Annual Average	lb/d	740	900	1,130
Maximum Month	lb/d	880	1,070	1,330
Maximum Week	lb/d	1,030	1,250	1,570
Maximum Day	lb/d	1,210	1,470	1,840

[a] *COD based on COD:cBOD$_5$ ratio observed during wastewater characterization (August 23-31, 2017) of 1.87*

[b] *TKN based on historical ammonia:TKN ratio observed during wastewater characterization (August 23-31, 2017) of 0.53.*

[c] *Peak instantaneous flow of 60 mgd to be used in planning.*

[d] *Influent cBOD5, COD, and TSS include a 1.15, 1.15, and 1.35 adjustment factor, respectively, based on January 2018 sampling and BioWin model calibration.*

Section 4: References

Black and Veatch. 1996. *Wastewater Master Plan – Volume II Wastewater Treatment, prepared for Rochester, MN*.

Brown and Caldwell (BC). 2018. *Water Reclamation Plant Facilities Plan Wastewater Characterization and BioWin Calibration Technical Memorandum.* In draft.

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Henningson Durham Richardson (HDR), 2017. Technical Memorandum Flow Data to Brown and Caldwell for WRP Facility Plan, December.

Howard R. Green and Cornell, Howland, Hayes & Merryfield (CH2M) Hill. 2003. *Amendment to Rochester Wastewater Master Plan, 1996*. January.

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Attachment A: MPCA Flow Determination Worksheets

Year 2017 - Baseline Conditions

Minnesota
Pollution
Control
Agency

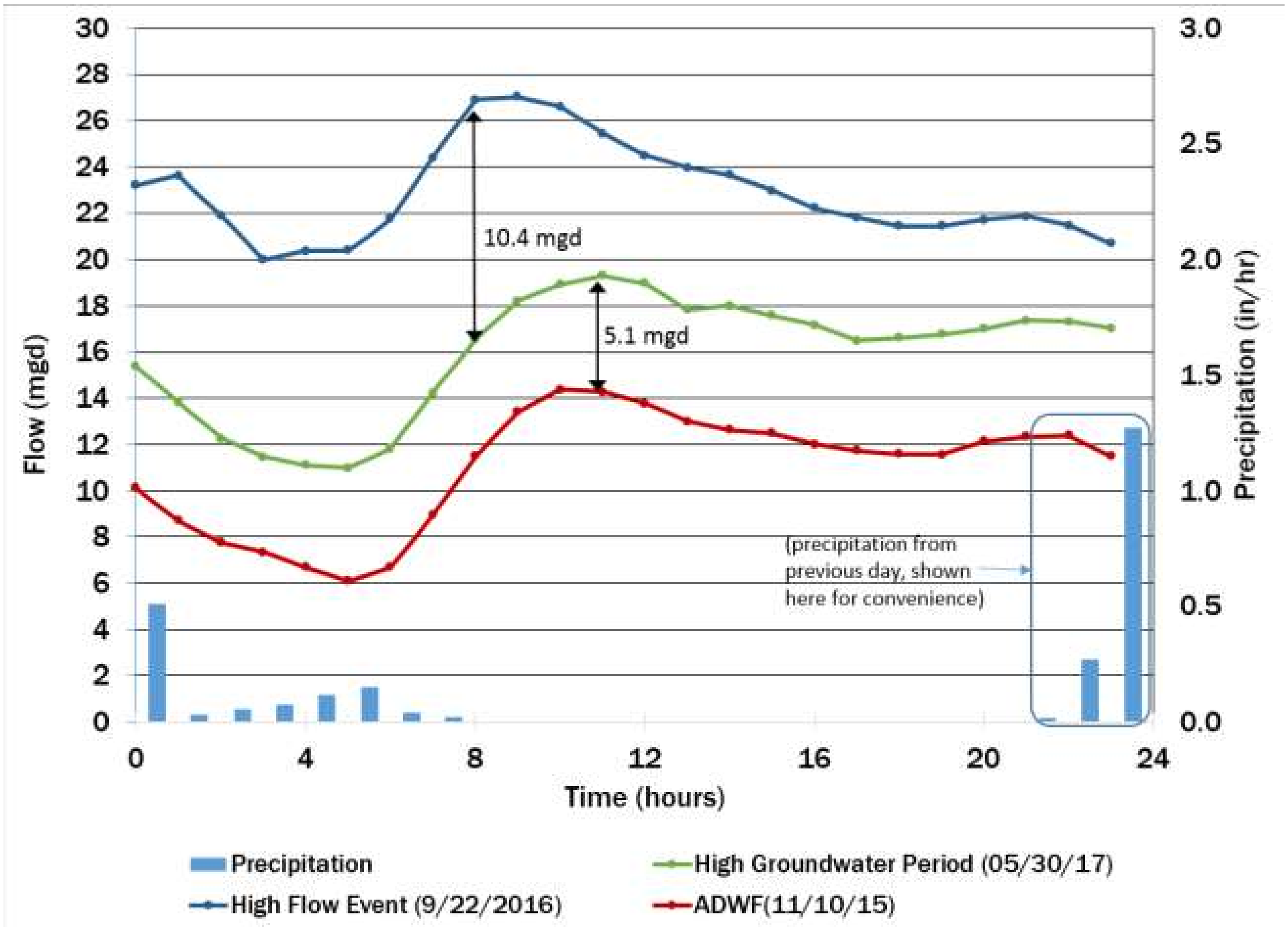
Water Quality

Wastewater
Review and
Guidance

Design Flow and Loading Determination Guidelines for Wastewater Treatment Plants

Water/Wastewater Technical Review and Guidance/#5.20, February 2002

A. Determine peak hourly wet weather design flows (PHWWF)		Flow, mgd
1	Present peak hourly dry weather flow	14.3
2	Present peak hourly flow during high ground water period (no run off)	19.3
3	Present peak hourly dry weather flow	14.3
4	Present peak hourly infiltration	5.1
5	Present peak hourly dry weather flow during high ground water period and runoff at point of greatest distance between curves Y and Z	26.9
6	Present hourly flow during high ground water (no runoff) at same time of day as (5) measurement	16.5
7	Present peak hourly inflow	10.4
8	Present peak hourly inflow adjusted for a 5-year 1-hour rainfall event	14.7
9	Present peak hourly infiltration	5.1
10	Peak hourly infiltration cost effective to eliminate	0.0
11	Peak infiltration after rehabilitation	5.1
12	Present peak hourly adjusted inflow	14.7
13	Peak hourly inflow cost effective to eliminate	0.0
14	Peak hourly inflow after rehaibilitation	14.7
15	Population increase: 6.7 mgd X 2.5	
16	Peak hourly flow from planned industrial increase	0.0
17	Estimated peak hourly flow from future unidentified industries	0.0
18	Peak hourly flow from other future increases	0.0
19	Peak hourly wet weather design flow [1+11+ sum(14...18)]	34.0
B. Determine peak instantaneous wet weather design flow (PIWWF)		
20	Peak hourly wet weather design flow [same as (19)]	34.0
21	Present peak hourly inflow adjusted for a 5-year 1-hour rainfall event [same as (8)]	14.7
22	Present peak inflow adjusted for a 25-year 1 hour rainfall event	19.6
23	Peak instantaneous wet weather design flow [20-21+22]	38.9


Flow (mgd)
Precipitation (in/hr)
Time (hours)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
4
8
12
16
20
24
10.4 mgd
5.1 mgd
(precipitation from previous day, shown here for convenience)
Precipitation
High Groundwater Period (05/30/17)
High Flow Event (9/22/2016)
ADWF(11/10/15)

Year 2030

Minnesota
Pollution
Control
Agency

Water Quality

Wastewater
Review and
Guidance

Design Flow and Loading Determination Guidelines for Wastewater Treatment Plants

Water/Wastewater Technical Review and Guidance/#5.20, February 2002

	A. Determine peak hourly wet weather design flows (PHWWF)	Flow, mgd
1	Present peak hourly dry weather flow	14.3
2	Present peak hourly flow during high ground water period (no run off)	19.3
3	Present peak hourly dry weather flow	14.3
4	Present peak hourly infiltration	5.1
5	Present peak hourly dry weather flow during high ground water period and runoff at point of greatest distance between curves Y and Z	26.9
6	Present hourly flow during high ground water (no runoff) at same time of day as (5) measurement	16.5
7	Present peak hourly inflow	10.4
8	Present peak hourly inflow adjusted for a 5-year 1-hour rainfall event	14.7
9	Present peak hourly infiltration	5.1
10	Peak hourly infiltration cost effective to eliminate	0.0
11	Peak infiltration after rehabilitation	5.1
12	Present peak hourly adjusted inflow	14.7
13	Peak hourly inflow cost effective to eliminate	0.0
14	Peak hourly inflow after rehaibilitation	14.7
15	Population increase: 2.7 mgd X 2.5	6.8
16	Peak hourly flow from planned industrial increase	0.0
17	Estimated peak hourly flow from future unidentified industries	0.0
18	Peak hourly flow from other future increases	0.0
19	Peak hourly wet weather design flow [1+11+ sum(14...18)]	40.8
	B. Determine peak instantaneous wet weather design flow (PIWWF)	
20	Peak hourly wet weather design flow [same as (19)]	40.8
21	Present peak hourly inflow adjusted for a 5-year 1-hour rainfall event [same as (8)]	14.7
22	Present peak inflow adjusted for a 25-year 1 hour rainfall event	19.6
23	Peak instantaneous wet weather design flow [20-21+22]	45.6

Brown AND Caldwell

Year 2045

Minnesota Pollution Control Agency

Water Quality

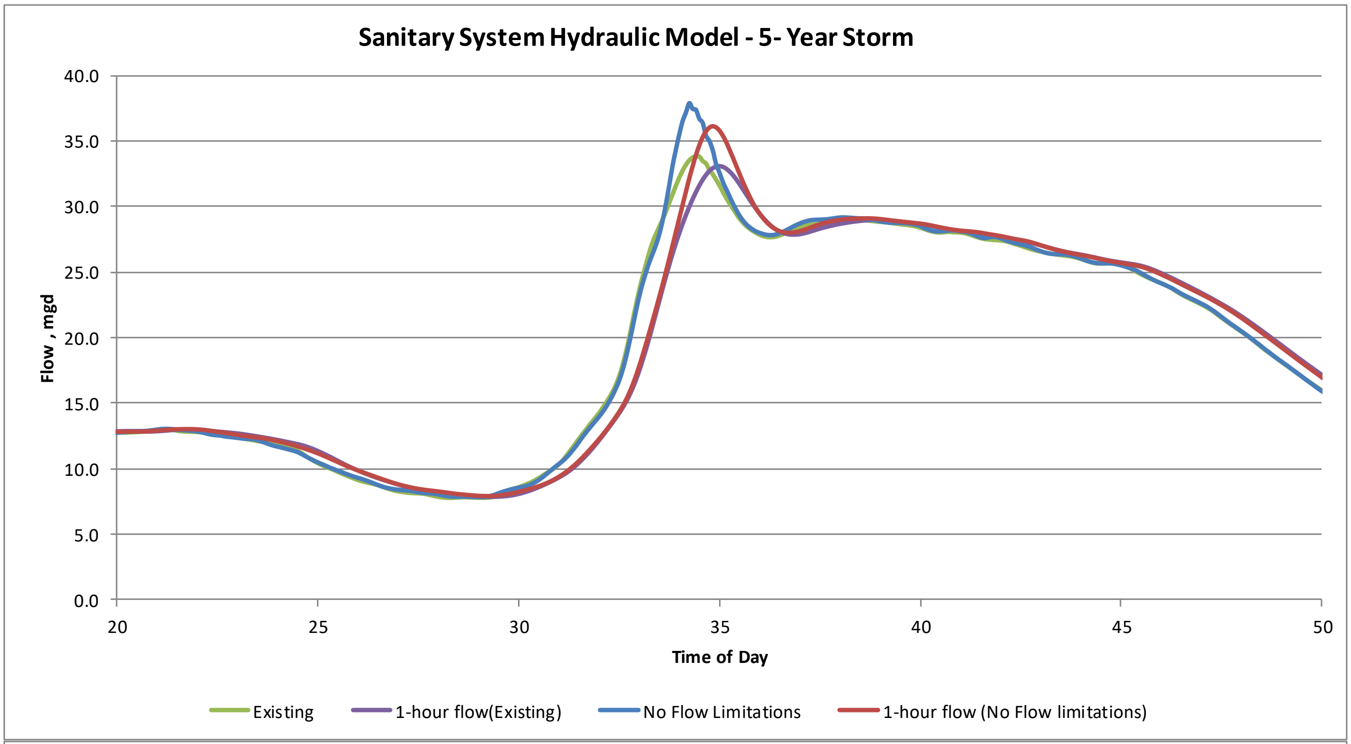
Wastewater Review and Guidance

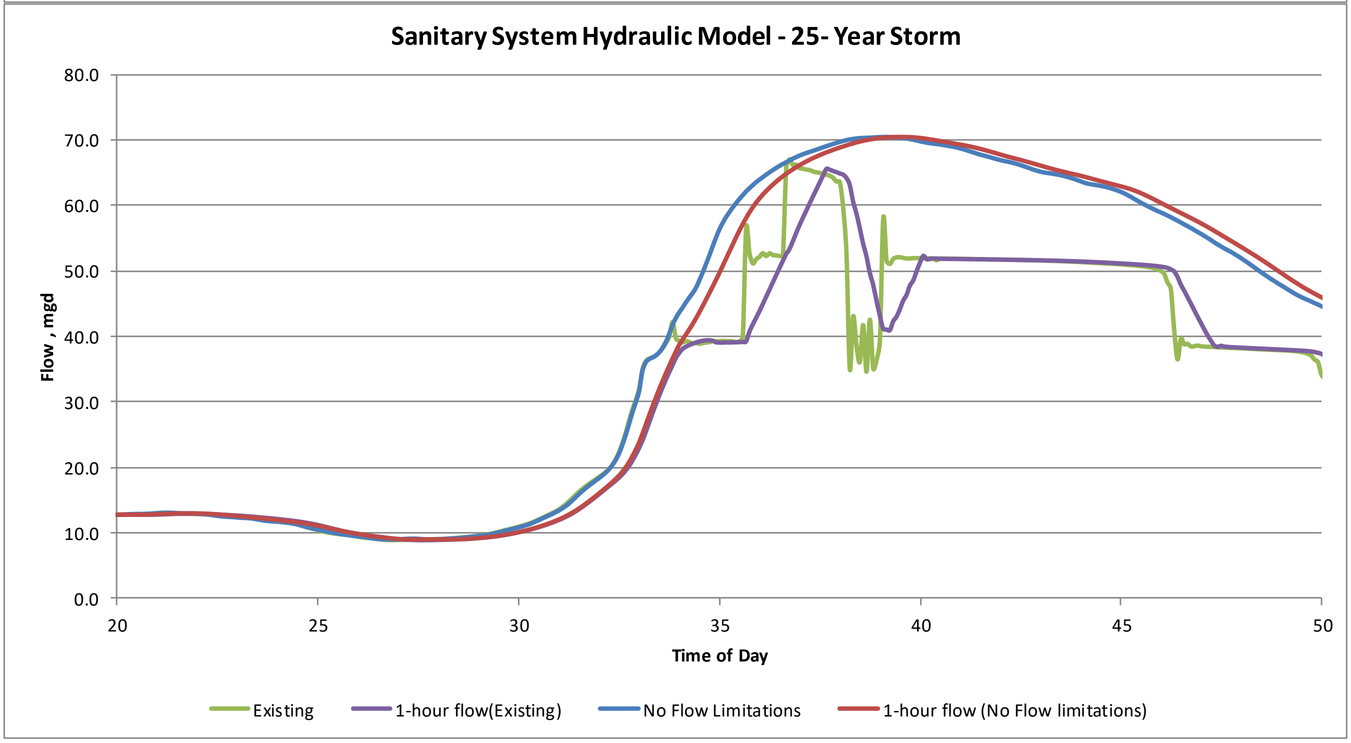
Design Flow and Loading Determination Guidelines for Wastewater Treatment Plants

Water/Wastewater Technical Review and Guidance/#5.20, February 2002

A. Determine peak hourly wet weather design flows (PHWWF)		Flow, mgd
1	Present peak hourly dry weather flow	14.3
2	Present peak hourly flow during high ground water period (no run off)	19.3
3	Present peak hourly dry weather flow	14.3
4	Present peak hourly infiltration	5.1
5	Present peak hourly dry weather flow during high ground water period and runoff at point of greatest distance between curves Y and Z	26.9
6	Present hourly flow during high ground water (no runoff) at same time of day as (5) measurement	16.5
7	Present peak hourly inflow	10.4
8	Present peak hourly inflow adjusted for a 5-year 1-hour rainfall event	14.7
9	Present peak hourly infiltration	5.1
10	Peak hourly infiltration cost effective to eliminate	0.0
11	Peak infiltration after rehabilitation	5.1
12	Present peak hourly adjusted inflow	14.7
13	Peak hourly inflow cost effective to eliminate	0.0
14	Peak hourly inflow after rehaibilitation	14.7
15	Population increase: 6.7 mgd X 2.5	16.8
16	Peak hourly flow from planned industrial increase	0.0
17	Estimated peak hourly flow from future unidentified industries	0.0
18	Peak hourly flow from other future increases	0.0
19	Peak hourly wet weather design flow [1+11+ sum(14...18)]	50.8
B. Determine peak instantaneous wet weather design flow (PIWWF)		
20	Peak hourly wet weather design flow [same as (19)]	50.8
21	Present peak hourly inflow adjusted for a 5-year 1-hour rainfall event [same as (8)]	14.7
22	Present peak inflow adjusted for a 25-year 1 hour rainfall event	19.6
23	Peak instantaneous wet weather design flow [20-21+22]	55.6

Attachment B: Sanitary System Hydraulic Model Flows


Sanitary System Hydraulic Model - 5- Year Storm
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Flow , mgd
20
25
30
35
40
45
50
Time of Day
Existing
1-hour flow(Existing)
No Flow Limitations
1-hour flow (No Flow limitations)


Sanitary System Hydraulic Model - 25- Year Storm
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Flow , mgd
20
25
30
35
40
45
50
Time of Day
Existing
1-hour flow(Existing)
No Flow Limitations
1-hour flow (No Flow limitations)

Attachment C: Projected Design Influent Flows and Loading Charts

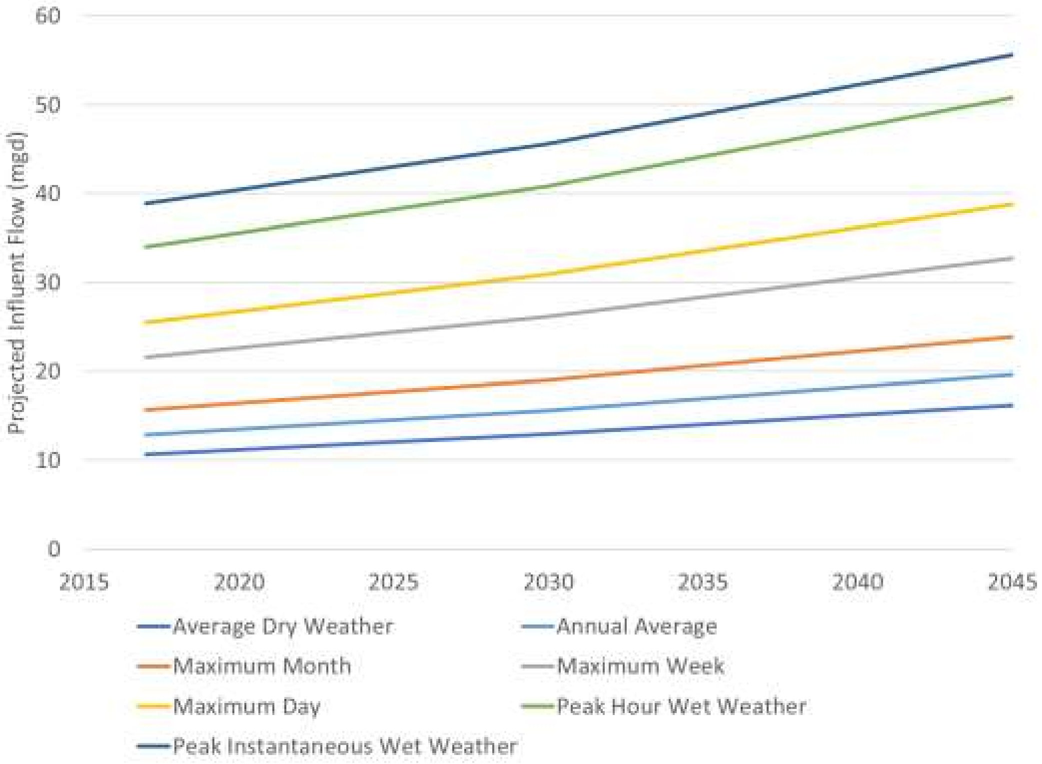


Figure C-1. Projected design influent flows

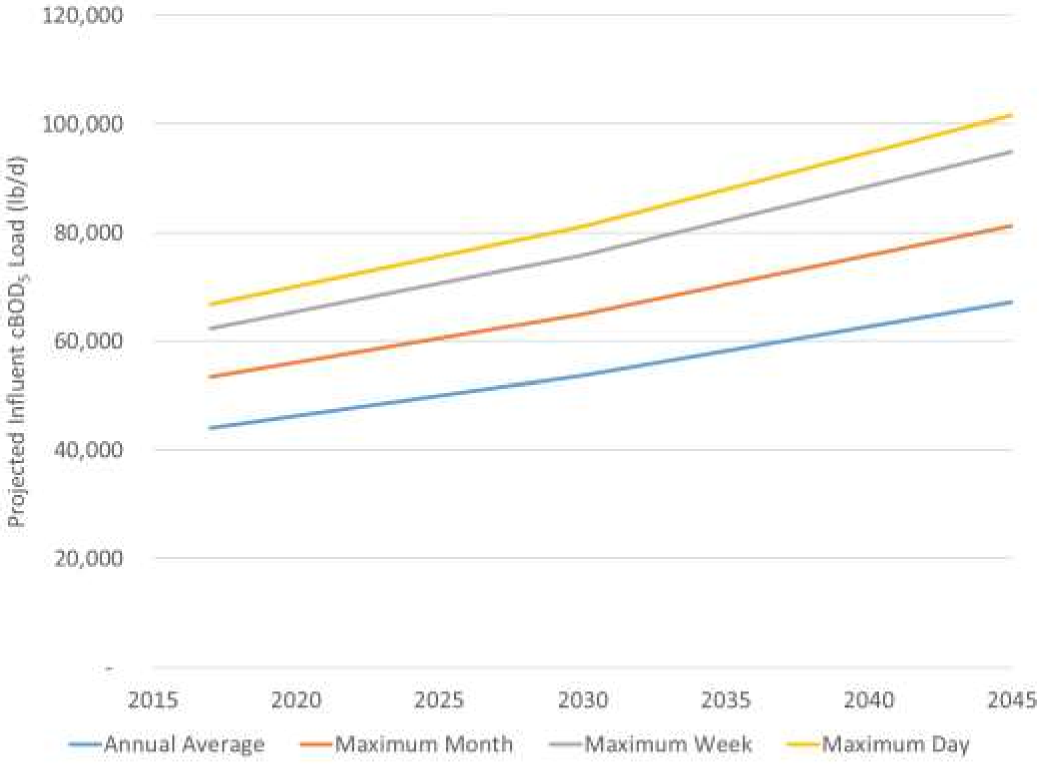


Figure C-2. Projected design influent $cBOD_5$ loads

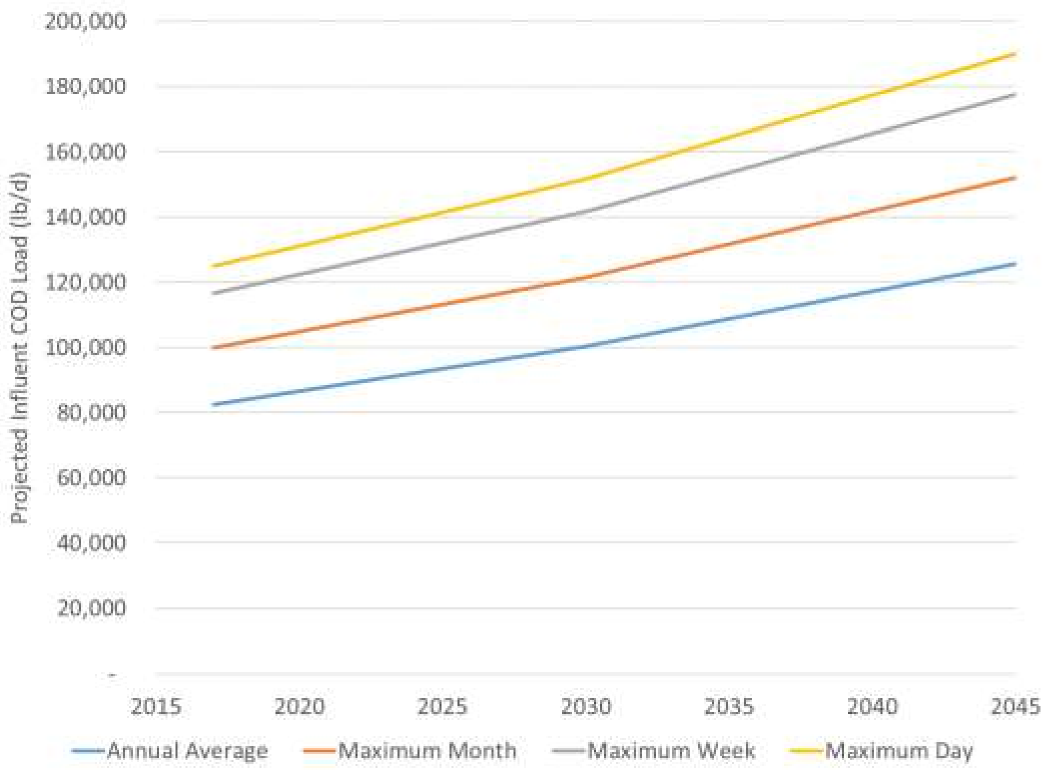


Figure C-3. Projected design influent COD loads

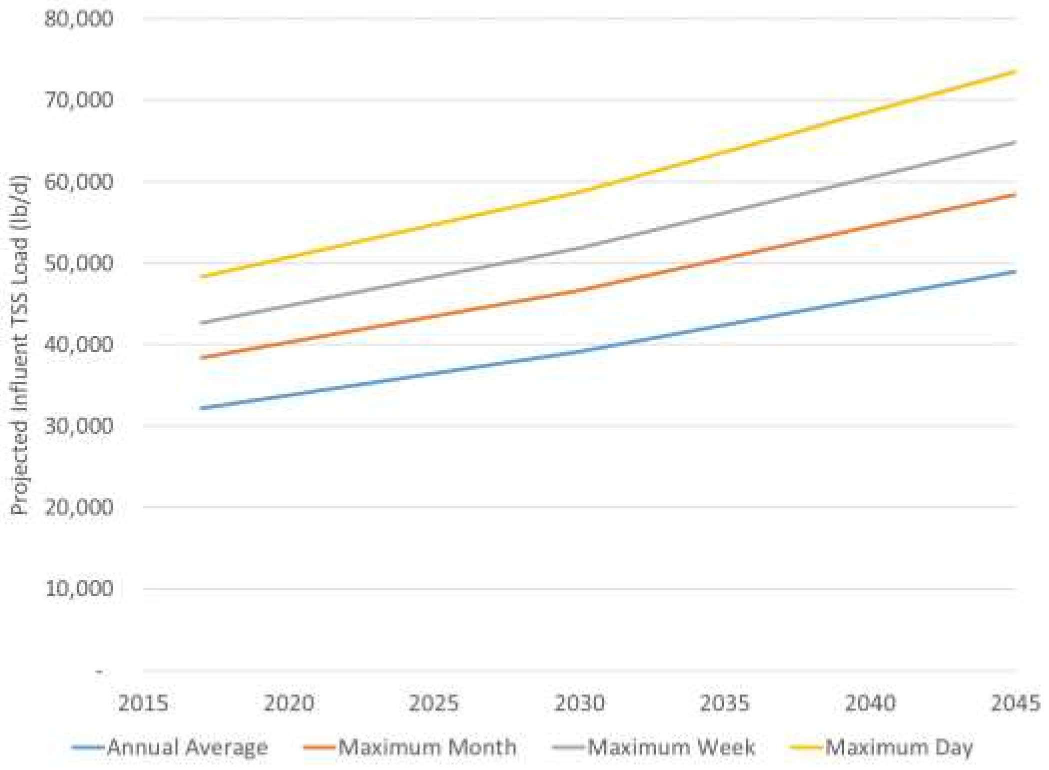


Figure C-4. Projected design influent TSS loads

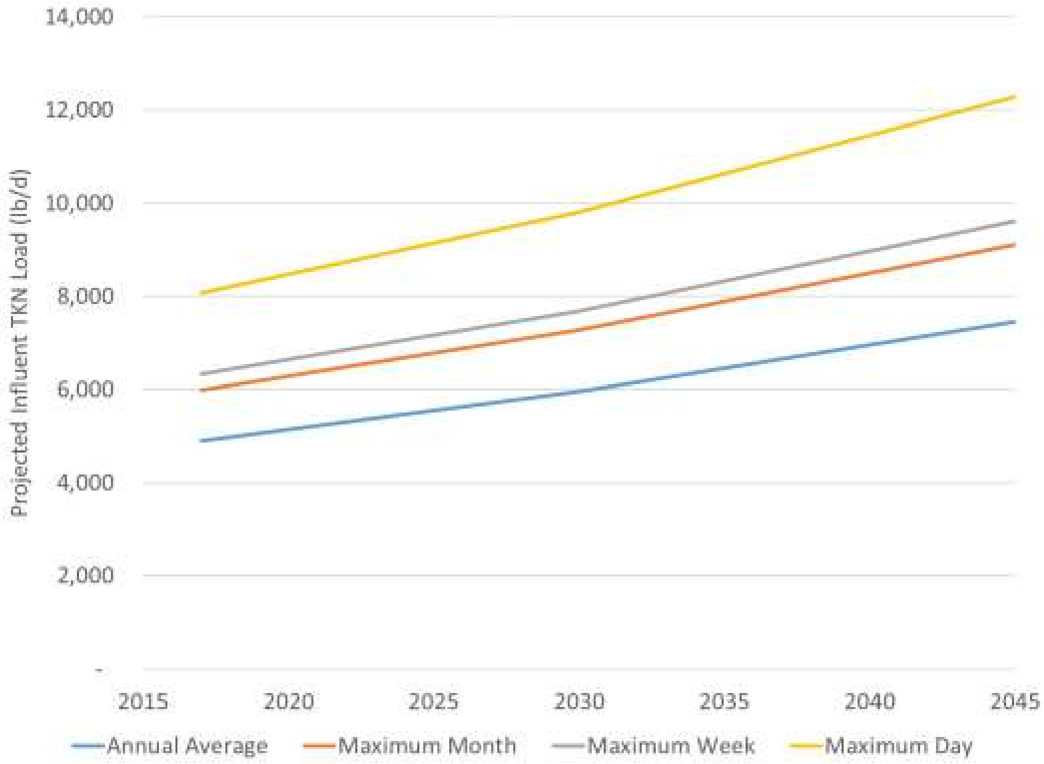


Figure C-5. Projected design influent TKN loads

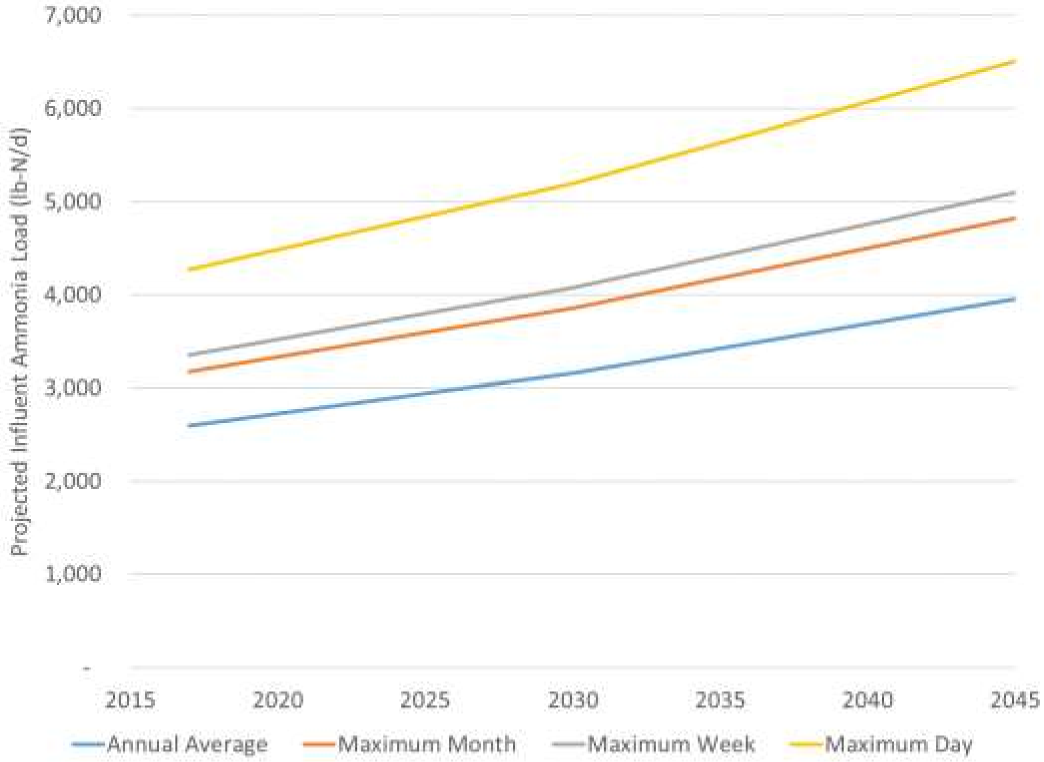


Figure C-6. Projected design influent ammonia loads

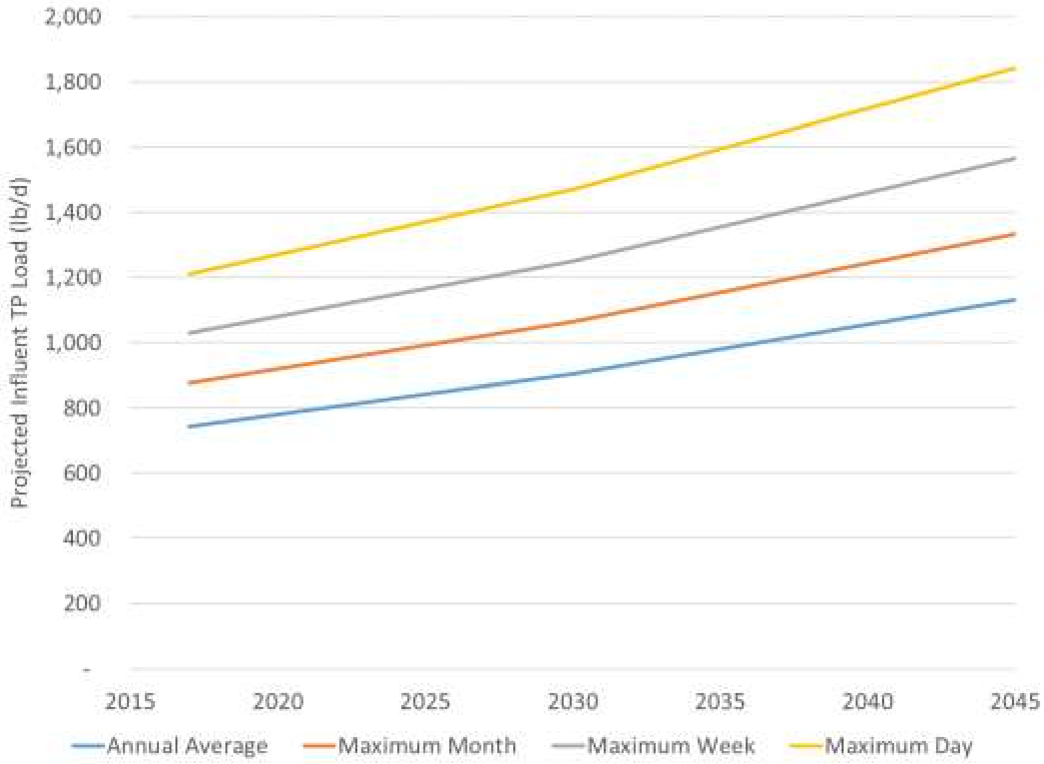


Figure C-7. Projected design influent TP loads

LOWER ENERGY // CLEAN DESIGN
DECREASED MAINTENANCE // INNOVATIVE PROCESSES

Technical Memorandum 1	Influent Flows and Loadings
Technical Memorandum 2	Wastewater Characterization and BioWin Calibration
Technical Memorandum 3	Plant Hydraulic Evaluation
Technical Memorandum 4	Primary Clarifier Computational Fluid Dynamics Modeling
Technical Memorandum 5	Final Clarifier Computational Fluid Dynamics Modeling
Technical Memorandum 6	Liquid Stream Alternative Evaluation
Technical Memorandum 7	Solids Alternative Evaluation
Technical Memorandum 8	Digester Gas Management
Technical Memorandum 9	Disinfection and Outfall Evaluation
Technical Memorandum 10	Whole Plant Evaluation
Technical Memorandum 11	Heat Recovery Loop Alternative
Technical Memorandum 12	NPDES Permitting Process
Technical Memorandum 13	Industrial Discharge Wasteloads and Practices