Rowlett Creek Watershed Characterization Project: Modeling Report

Developed by The Rowlett Creek Watershed Protection Partnership

Assessment Units: 0820A and 0820B

On the cover:

Rowlett Creek right before it flows into

Lake Ray Hubbard, Garland, TX

Rowlett Creek Watershed Characterization Project

Modeling Report

Developed by

The Rowlett Creek Watershed Protection Partnership

Funded by

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Investigating Entity

Texas A&M AgriLife Extension

Prepared by

Fouad Jaber and Therese Mehta – Texas A&M AgriLife Extension

With Contributions from

Heather Firn – Texas River Authority of Texas

Wenjie Sun – St. Cloud State University (Formerly Southern Methodist University)

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Introduction

Rowlett Creek flows through the Dallas-Fort Worth (DFW) Metroplex cities of Plano, Richardson, Garland, McKinney, Frisco, Allen, Murphy, and Rowlett, which constitute a highly urbanized watershed. The creek also flows to a major water supply reservoir owned by the City of Dallas. The majority of the creek is within the city limits of Plano. The City of Plano is the ninth most populous city in the state of Texas (2020 United States Census). Land uses in the watershed area consist of developed land (84.36%), green, agricultural, and open spaces (15.25%), wetlands (0.22%) and open water (0.17%).

Rowlett Creek was first placed on the Texas 303(d) list in 2014 for bacterial impairment. Rowlett Creek is also listed as having a concern for nitrate. The water quality problems to be addressed are bacteria impairment and concern for nitrate, as well as any other parameters stakeholders select. This project is part of the Texas Commission on Environmental Quality (TCEQ) 303(d) Visioning Project in the Upper Trinity River Basin.

Rowlett Creek, Segment 0820B and its tributaries, make up a significant portion of the East Fork Trinity River drainage and Lake Ray Hubbard watershed. With continuous growth in the region, Rowlett Creek is exposed to water quality and habitat degradation caused from human activity, urban runoff, and erosion.

Rowlett Creek and its tributaries make up a significant portion of the Rowlett Creek basin that drains into the East Fork Trinity River and Lake Ray Hubbard. The Cities of Allen and Frisco make up the head waters of the Rowlett Creek basin. The majority of the creek runs through Plano eventually flowing downstream through other cities including Richardson, Garland, and Rowlett. Tributaries of the Creek also run through McKinney, Allen and Murphy. The land surfaces making up the Rowlett Creek drainage are mostly impervious, including roadways, alleys, buildings, parking lots, driveways, and sidewalks. Due to the lack of pervious surfaces and natural buffers in this drainage, over 90% of the precipitation that falls here flows to the stream, rather than being absorbed by the historical natural prairie habitat. Because of this Rowlett Creek is exposed to water quality and habitat degradation caused from human activity, urban runoff, and erosion.

The Rowlett Creek Watershed Characterization project aims at identifying sources and locations of pollutants in the stream using a combination of existing data and collected data.

In this report, flow and water quality data collected through this project and historical data obtained from various sources are used to develop an understanding of the extent and sources of contaminants in Rowlett Creek. The analysis is done at several locations in the creek in order to understand the causes as well as the geographical sources of the contaminants. The modeling is divided into two sections:

1- Hydrological modeling that allows us to estimate the flows at the outflow of each of the subwatersheds (where a monitoring station) is located from the lone United States Geological Survey (USGS) station located in the watershed (Station # 08061540). This modeling was done using historical flow data and the model was calibrated and validated using goodness-of-fit statistical measures to accept the calibration results.
2- Load duration curves (LDC) development where the loads of various water quality constituents are calculated for each monitoring sampling event (both historical and monitored data) and plotted against the flow exceedance percentage. The LDCs are then compared to allowable maximum load geomean.

Rowlett Creek Watershed

The Rowlett Creek watershed is located within the East Fork Trinity River, subwatershed of the Trinity River watershed, as presented in Figure 1. For the purpose of this study, the watershed was divided into five subwatersheds that include two tributaries and three sections of the main creek. The subwatersheds are identified in Figure 1. The outlets of the five sites were selected as monitoring locations and based on the collected data and historical data collected in these subwatersheds, LDC were developed for each of the subwatersheds for constituents of interest.

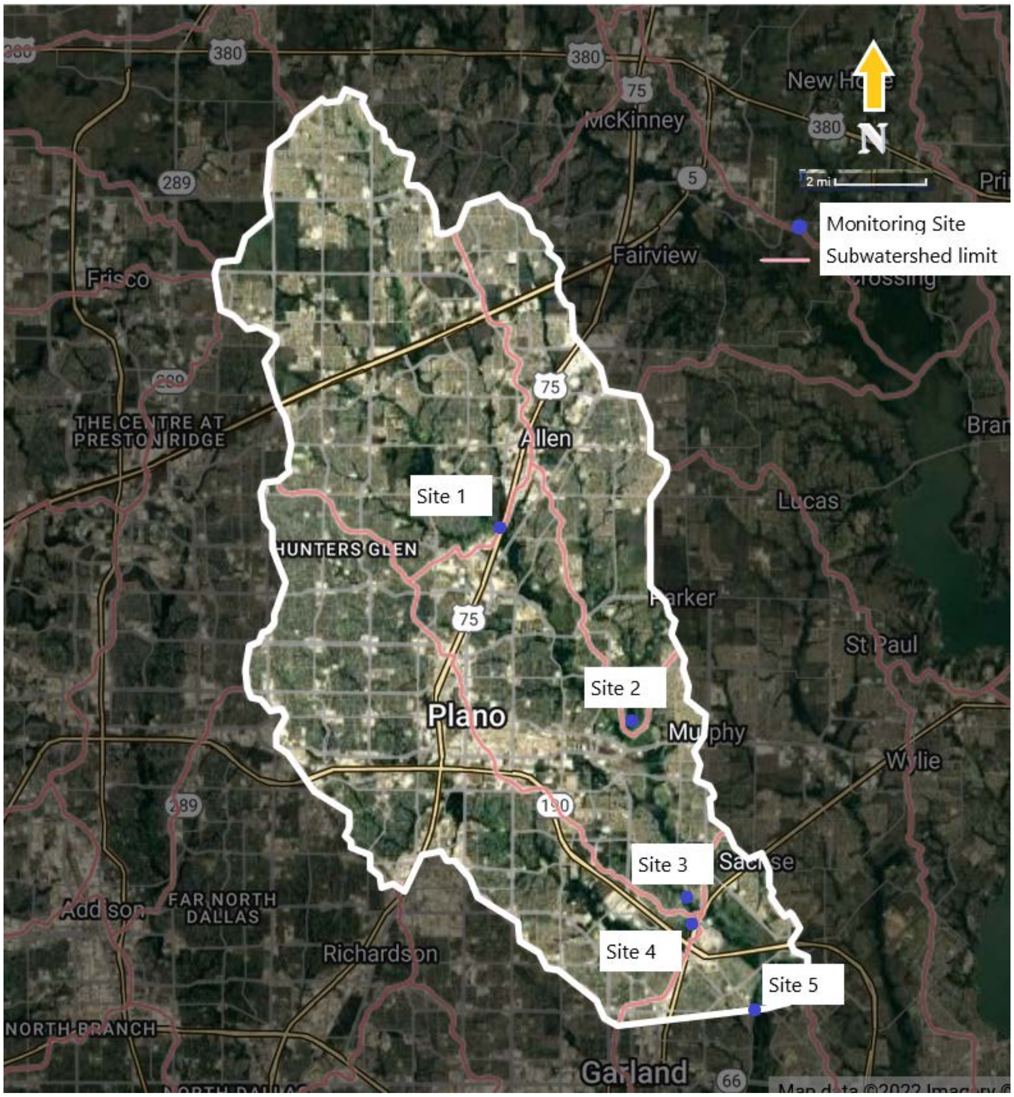

Figure 1. Rowlett Creek watershed showing subwatershed and monitoring sites locations.

Water Quality Parameters

This study conducted water quality sampling and analysis for a large variety of water quality parameters (particularly for *E. coli*, NO_3^-(nitrate)/NO_2^- (nitrite) (as N(nitrogen)), TKN (Total Kjeldahl Nitrogen), NH_3^-N (ammonia nitrogen), TP (total phosphorus), and TSS(total suspended solids)) in order to determine the technical information needed to ascertain impairment and build the subsequent Rowlett Creek Watershed Protection Plan (WPP) in the future. Field parameters collected and analyzed included pH, DO (dissolved oxygen), conductivity, temperature, and flow using TCEQ SOP V1 (TCEQ, 2008). A detailed description of the analyses can be found in Table 1. Parameters were subsequently used to develop load duration curves and compared to Surface Water Quality Standards and Nutrient Screening Levels as outlined by TCEQ, as described in Tables 2 and 3.

Table 1. NTMWD (North Texas Municipal Water District) Measurement Performance Specifications for Characterization of Rowlett Creek Monitoring, Parameters in Water

Parameters in Water											
Parameter	Units	Matrix	Method	Parameter Code	TCEQ AWRL	LOQ	LOQ Check Sample %Rec	Precision (RPD of LCS/LCSD)	Bias %Rec. of LCS	Lab	Completeness
Field Parameters											
pH (standard units), Field determined	s.u.	water	EPA 150.1 and TCEQ SOP, V1	00400	NA	NA	NA	NA	NA	Field	90
Oxygen, dissolved (mg/L) (Field determined, actual reading from instrument)	mg/L	water	SM4500 O-G and TCEQ SOP, V1	00300	NA	NA	NA	NA	NA	Field	90
Specific conductance, Field (us/cm @ 25C)	uS/cm	water	EPA 120.1 and TCEQ SOP, V1	00094	NA	NA	NA	NA	NA	Field	90
Temperature, Water Field determined, (Degrees Centigrade)	deg. C	water	SM2550B and TCEQ SOP, V1	00010	NA	NA	NA	NA	NA	Field	90
Flow volume for duration of storm event	gallons	water	TCEQ SOP, V1	50052	NA	NA	NA	NA	NA	Field	90
Total water depth	m	water	TCEQ SOP, V1	82903	NA	NA	NA	NA	NA	Field	90
Flow (CFS)	CFS	water	TCEQ SOP, V1	00061	NA	NA	NA	NA	NA	Field	90
Conventional Parameters											
E.coli, Colilert, IDEXX , Holding time,	hours	water	NA	31704	NA	NA	NA	NA	NA	NTMWD**	90
Residue, Total Nonfiltrable (mg/L)	mg/L	water	SM 2540D	00530	5	1*	NA	NA	NA	NTMWD**	90
Nitrite plus nitrate, Total one lab determined value (mg/L as N)	mg/L	water	EPA 353.2	00630	.05	.05	70-130	20	80-120	NTMWD **	90
Phosphorus, total, wet method (mg/L as P)	mg/L	water	EPA 365.3	00665	.06	.05	70-130	20	80-120	NTMWD**	90
E.coli, Colilert, IDEXX Method, MPN/100ml	mpn / 100ml	water	Colilert Quanti-Tray	31699	1	1	NA	0.5***	NA	NTMWD**	90

Nitrogen, Kjeldahl, Total (mg/L as N)	mg/L	water	EPA 351.2	00625	0.2	0.2	70-130	20	80-120	NTMWD**	90
Nitrogen, Ammonia, Total (mg/L as N)	mg/L	water	EPA 350.1	00610	0.1	0.1	70-130	20	80-120	NTMWD**	90

*TSS LOQ is based on the volume of sample used.

**The lab is TNI-accredited for the total nonfiltrable residue, *E.coli*, nitrate and phosphorous procedures.

References:

United States Environmental Protection Agency (USEPA) Methods for Chemical Analysis of Water and Wastes, Manual #EPA-600/4-79-020

American Public Health Association (APHA), American Water Works Association (AWWA), and Water Environment Federation (WEF), Standard Methods for the Examination of Water and Wastewater, 20th Edition, 1998. (Note: The 21st edition may be cited if it becomes available.)

TCEQ SOP, V1 - TCEQ Surface Water Quality Monitoring Procedures, Volume 1: Physical and Chemical Monitoring Methods, 2012 (RG-415).

TCEQ SOP, V2 - TCEQ Surface Water Quality Monitoring Procedures, Volume 2: Methods for Collecting and Analyzing Biological Assemblage and Habitat Data, 2014 (RG-416).

*** *E.coli* samples analyzed by IDEXX Colilert Quanti-Tray should always be processed as soon as possible and within 8 hours. When transport conditions necessitate delays in delivery longer than 6 hours, the holding time may be extended and samples must be processed as soon as possible and within 30 hours. This value is not expressed as a relative percent difference. It represents the maximum allowable difference between the logarithm of the sample result and the logarithm of the duplicate result. See section B5.

Table 2. Surface Water Quality Standards for Rowlett Creek Assessment Unit (AU) 0820B (Source TCEQ)

Parameter	Criteria	Segment ID 0820B	Corresponding Designated Use
DO (mg/L)	Grab minimum	3	Aquatic life
DO (mg/L)	Grab screening level	4	
pH range		6.5-9.0	
E. coli (MPN/100 ml)	Geomean	126	Contact recreation
Temperature (°F, °C)		95 /35	

Table 3. Nutrient Screening Levels for Rowlett Creek AU 0820B

Parameter	TCEQ screening Levels		EPA Reference Criteria			
	Lake/Reservoir	Stream	Lake/Reservoir		Stream	
TKN (mg/L)	-	-	0.38[a]	0.41[b]	0.3[a]	0.4[b]
NO_3-N + NO_2-N (mg/L)	0.37	1.95	0.017[a]	0.01[b]	0.125[a]	0.078[b]
TP (mg/L)	0.2	0.69	0.02[a]	0.019[b]	0.037[a]	0.038[b]
NH3 (mg/L)	0.11	0.33	-	-	-	-

(a) reference conditions for aggregate Ecoregion IX waterbodies, upper 25th percentile of data from all seasons, 1990-1999.

(b) reference conditions for level III Ecoregion 29 waterbodies, upper 25th percentile of data from all seasons

Field Parameters

Water Temperature

Water temperature as a water quality parameter is an important indicator of health in an aquatic ecosystem. The temperature of water is directly associated with aquatic organisms' physiological processes. DO decreases in the water column as the temperature increases. This results in an increased oxygen demand by the aquatic community and subsequent stress on higher-level organisms. Further, rapid variations in water temperature are more detrimental to aquatic species, especially for organisms that may lack the biological advantages of adapting quickly to the change.

Dissolved Oxygen

DO is a physiological requirement of aquatic communities. DO is influenced by both temperature and nutrient concentrations, albeit indirectly. The amount of DO in the water column is also impacted by decomposition processes and primary productivity.

Specific Conductance

Specific conductance is best described as the effectivity of a liquid conducting electricity and a standard temperature of 25°C. Conductivity increases in a waterbody when ionic dissolved solids levels increase. Nutrients and salts make up ionic dissolved solids. Reduced water quality occurs when ionic dissolved solids, specifically nutrients, increase and DO subsequently decreases.

Potential Hydrogen (pH)

A healthy aquatic waterbody falls within a pH range of 6.5 to 9.0 and is considered neutral if the pH is 7.0. Values less than 7.0 would classify the body as acidic whereas values greater than 7.0 would classify the waterbody as alkaline.

Laboratory parameters

E. Coli

E. coli is a bacterium found in the intestines of humans and warm-blooded animals and humans. If the waste is excreted in the open, during a rain event it can be picked up by stormwater runoff and be either channeled into surface water and/or ground water or directly deposited into the waterbody. If *E. coli* is found at high concentration in waterbodies it could indicate, for example, the presence of wildlife and livestock in the watershed, illicit wastewater connections and subsequent discharges, and/or improperly treated wastewater. Depending on the strain, toxins may be produced and could cause illness if ingested. Waterbodies are defined by their ability to host recreational activities and are based on levels of *E. coli*. The U.S. EPA has designated a standard *E. coli* concentration based on the geometric mean of a certain number of samples because the concentration can vary by orders of magnitude. The method for detection of *E. coli* is used as a proxy for the possibility of human illness when humans are recreating in water. The higher the concentration of *E. coli* the greater the possibility that there will be more toxic *E. coli* strains, other bacteria, or viruses ingested while swimming, wading or boating in waterbodies.

Solids

Total suspended solids (TSS) are suspended particles in a water column that, when sampled, are not capable of passing through a specific pore sized filter. Solids are made up of organic matter that can include algal, bacterial cells or organisms as well as inorganic matter that includes soil sediments due to erosion.

Nutrients

Nitrogen and phosphorus are limiting nutrients in the aquatic environment. They are essential but can also cause detrimental effects in riverine and reservoir ecosystems if found in overabundance. Stormwater runoff carries residential and agricultural fertilizers that are full of nutrients. Runoff can also carry animal waste and pollutants from sanitary sewer overflows. Further, Wastewater Treatment Plants (WWTP) effluent could be a source of nutrients in some waterbodies. Total nitrogen is composed of nitrate, nitrite and total Kjeldahl nitrogen (TKN). Nitrate is very abundant as an inorganic, oxidized form of nitrogen and nitrite is not as common as an inorganic, oxidized form of nitrogen. TKN contains organic nitrogen and ammonia, the inorganic form of nitrogen. Total phosphorus (TP) is a parameter used to analyze a water sample for all forms of phosphorus. Forms of phosphorus include organic and inorganic forms as well as dissolved and particulate forms.

Rowlett Creek Watershed Data and Modeling

Existing Data

Existing data were compiled from the databases created by the City of Plano (CoP), North Central Texas Council of Governments (NCTCOG), and Trinity River Authority Clean Rivers Program (TRA CRP). All the data were reviewed and performed for quality checked to satisfy the data and information needed for this project. The collection and qualification of the TRA CRP data and the CoP data were addressed in the Quality Assurance Project Plan (QAPP)- Trinity River Authority; Kilpatrick, 2021). The collection and qualification of the NCTCOG data were addressed in the Regional Stormwater Monitoring Program: Monitoring Program and Quality Assurance Project Plan for Wet Weather Equipment Deployment and Sampling Protocol 2011-2016 approved by TCEQ (Atkins, 2016). The sources of monitoring data were summarized in Table 4.

Table 4 Existing Data Sources.

Data Type	Monitoring Project/Program	Collecting Entity	Dates of Collection	QA Information	Data Use(s)
Bacteria (E.coli)	TCEQ SWQM Program	TCEQ	11/8/2006 – 07/25/2017 at station numbers 17845 10765 21478 10753	TCEQ SWQM QAPP; SWQMIS database	summary statistics, trend analysis
Monitoring Data (Field measurements: Temperature, dissolved oxygen, pH, etc.)	TCEQ SWQM Program	TCEQ	12/27/1984 10/1/1995 and 6/31/1996 - 05/15/2018 at station numbers 20378 22144 10757 10771 21478	TCEQ SWQM QAPP; SWQMIS database	summary statistics, trend analysis
Flow Data	United States Geological Survey (USGS)	USGS and TCEQ	For the period of record collected by the USGS at	USGS QAPP; USGA	Flow duration curves,

	flow data and TCEQ SWQM Program		station no. 08061540 and TCEQ station numbers 20378 22144 10757 10771 21478	database; TCEQ SWQM QAPP; SWQMIS database	Loading calculations; summary statistics, trend analysis
Precipitation Data	National Weather Service (NWS)	NWS	Most up-to-date precipitation data will be downloaded from the NWS website following storm events.	NWS Website	Loading calculations and extrapolation analysis
Precipitation Data	City of Plano	City of Plano	Up-to-date data will be provided by the City of Plano	Plano database	Loading calculations and extrapolation analysis

SWAT Modeling

Soil and Water Assessment Tool (SWAT), the most widely used hydrological model in the world, was used to simulate flows and watershed total pollution loadings under various scenarios. SWAT is a physically based, deterministic, continuous, watershed-scale simulation model developed by U.S. Department of Agriculture (USDA) Agricultural Research Service (Arnold et al., 1998) and tested for a wide range of regions, conditions, practices, and time scales (Gassman et al., 2007). SWAT model subdivides a basin/watershed into subwatersheds connected by a stream network, and further delineates hydrologic response units (HRUs) consisting of unique combinations of land cover and soils in each subbasin. The HRU is the smallest landscape component of SWAT used for simulating hydrologic processes. Hydrological processes are divided into two phases - land phase and channel/floodplain phase. The land phase calculates the upland loadings of flow, sediment, nutrients, and pesticides from each HRU, which are then area-weighted to subwatershed level. The channel/floodplain phase calculates the routing from the upland loadings from each subwatershed through the channel/stream and dam/reservoirs network.

The SWAT model requires spatial (e.g., digital elevation model, land use, soil) and temporal (e.g., weather and streamflow) data to simulate various biophysical processes in the watershed that generate streamflow. Land management and dam characteristics/operation data are also important for capturing the impacts of various management interventions. The outputs from the SWAT model provided flow information to develop Flow and Load Duration Curves (FDCs and LDCs) for current and load reduction strategies. In order to obtain flows at the outlet of each of the five subwatersheds in Rowlett Creek (see Figure 1), the model was calibrated using the Lone USGS station in the watershed. Results from the outlet of each subwatershed were subsequently obtained using model results.

Calibration and validation

As listed in Table 4, data from USGS station 08061540 were used to model flow in the Rowlett Creek Watershed using SWAT. In order to parametrize SWAT, several model runs were done using the daily flow data from 1/1/2009 until 12/31/2013. Several parameters were continuously modified to obtain satisfactory results as defined by a set of goodness-of-fit criteria. The parameters modified included Curve number, Manning's roughness, slope, groundwater flow, available water content, and other

SWAT specific parameters. These were selected after a sensitivity analysis showed that these parameters have the highest impact on model results.

Goodness-of-Fit

Quantitative acceptance criteria were expressed in relative, rather than absolute form. That is, relevant calibration outputs will be ranked on a scale ranging from "unsatisfactory" to "very good." Calibration strives to obtain the best fit possible. The level of uncertainty determined in calibration will be documented to aid decision makers in interpretation of results. Measures, sometimes referred to as calibration criteria, that will be used include:

1) Percent bias (PBIAS): PBIAS measures the average tendency of the simulated data to be larger or smaller than their observed counterparts (Moriasi et al., 2007). The optimal value of PBIAS is 0.0, with low-magnitude values indicating accurate model simulation. Positive values indicate model underestimation bias, and negative values indicate model overestimation bias (Moriasi et al., 2007). PBIAS is calculated with the equation below where PBIAS is the deviation of data being evaluated, expressed as a percentage.

$$\text{PBIAS} = \frac{\left[\sum_{i=1}^{n}\left(Y_i^{obs} - Y_i^{sim}\right) * (100)\right]}{\sum_{i=1}^{n}\left(Y_i^{obs}\right)}$$

Where:

Y_i^{obs} is the ith observation for the constituent being evaluated,

Y_i^{sim} is the ith simulated value for the constituent being evaluated,

and n is the total number of observations.

General calibration/validation targets for PBIAS consistent with current best modeling practices are shown in Table 5.

Table 5. General percent error calibration/validation targets for watershed models applicable to monthly, annual, and cumulative values.

	Relative Percent Error		
	Very Good	**Good**	**Fair**
Hydrology/Flow	<10	10-15	15-25
Sediment	< ± 15	± 15 to ± 30	± 30 to ± 55
Nutrients (TP & TN)	< ± 25	± 25 to ± 40	± 40 to ± 70

(Donigian, 2000, Moriasi et al., 2007)

2) Nash-Sutcliffe efficiency (NSE): The NSE is a normalized statistic that determines the relative magnitude of the residual variance ("noise") compared to the measured data variance ("information") (Nash and Sutcliffe, 1970). NSE indicates how well the plot of observed versus simulated data fits the 1:1 line. NSE is computed as shown below:

$$\text{NSE} = 1 - \left[\frac{\sum_{i=1}^{n}\left(Y_i^{obs} - Y_i^{sim}\right)^2}{\sum_{i=1}^{n}\left(Y_i^{obs} - Y_i^{mean}\right)^2}\right]$$

Where:

Y_i^{obs} is the i^{th} observation for the constituent being evaluated,

Y_i^{sim} is the i^{th} simulated value for the constituent being evaluated

Y^{mean} is the mean of observed data for the constituent being evaluated

n is the total number of observations.

NSE ranges between negative infinity and 1.0, with 1.0 being the optimal value (a perfect model fit) and values <0.0 indicating that the mean observed value is a better predictor than the simulated value, thereby demonstrating unacceptable model performance. Good performance is indicated by values >0.5 and acceptable performance by values between 0.0 and 0.5 (Moriasi et al., 2007). More specifically, NSE > 0.75 is considered very good, NSE between 0.6 to 0.75 is considered good and NSE between 0.4 to 0.6 is considered satisfactory. This is applicable to flow, sediments, and nutrients (Moriasi et al., 2007). NSE is known to be greatly influenced by larger deviations (Legates and McCabe 1999, Krause et al. 2005). Thus, in comparing modeled flows for example, NSE is a better measure simulating peak flows rather than baseflows. Nonetheless, NSE remains highly recommended (Legates and McCabe, 1999) and widely used, providing extensive information on reported values.

3) Root Means Squared Error (RMSE)

RMSE is the standard deviation of the residuals. It is a measure of how far from a regression line data points are. RMSE is defined as:

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{N}\left(x_i - \hat{x}_i\right)^2}{N}}$$

Acceptable values of NSE and RMSE are shown in Table 6.

Table 6.Satisfactory values for goodness-of-fit measures based on Moriasi et al. 2007

	Very Good	Good	Satisfactory	Unsatisfactory
Nash-Sutcliffe Efficiency (NSE)	0.75<NSE≤1.00	0.65<NSE≤0.75	0.50<NSE≤0.65	NSE≤0. 50
Root Mean Square-Observations Standard Deviation (RSR)	0.00≤RSR≤0.50	0.50<RSR≤0.60	0.60<RSR≤0.70	RSR>0.70

AgriLife anticipates that generating the performance metrics that are described above will satisfy the study objectives.

FDC and LDC Development

Flow duration curves (FDC) and load duration curves (LDC) are not specific models, but data calculators. The calculation of flow and load duration curve graphs have been shown to be an effective method for determining load reductions (Cleland, 2003). A duration curve is a graph that displays a given parameter's value that has been met or exceeded related to the percent of time. Percent of time is scaled ranging between 0 and 100. Pollutant loadings, point sources or non-point sources, for example are displayed to enable the determination of patterns depending on the conditions of stream flow. Best Management Practices (BMPs) and implementation strategies can be determined based on the observed pattern in order to direct focus on a specific pollutant source. For example, exceedances of allowable loads at low flows and thus could allow focus on point sources. In addition, LDCs can be used as a method to evaluate current impairments in order to narrow the focus to non-point source or point source pollution.

FDC demonstrate the flows of streams and rivers by predicting the frequency with which flows of various sizes will occur. They are also necessary in the development of load duration curves, which can effectively demonstrate the relative loadings of constituents from different tributaries (Cleland, 2003). The first step in developing FDCs and LDCs is to estimate continuous daily streamflows spanning multiple years at tributary sites in Rowlett Creek Watershed. Estimates of streamflow data for all tributary locations were derived using an existing USGS record from USGS 08061540 Rowlett Creek near Sachse, TX near Site 5. The records from this gauge were then modeled to adjust for upstream flows for the contributing subwatershed to Site 5. FDCs indicate the percentage of time during which a certain value of flow is equaled or exceeded. The estimated streamflows span years January 1980 to December 2022. A flow exceedance of less than 10% typically indicates that the stream flows are directly impacted by storm runoff events (Cleland, 2003). Daily average discharge rates are downloaded from the nearest the USGS station and sorted from highest cubic feet per second (cfs) to lowest cfs. The percentage or flow duration interval is determined by associating zero with the highest stream discharge and 100 with the lowest stream discharge. Three zones are then established on the graph identifying high flows as 0-10%, mid-range flows as 10-80%, and low flows as 80-100%.

Research Results and Discussion

SWAT Calibration Results

Figure 2. shows the final results of the calibration of the Rowlett Creek Watershed at the USGS Station location.

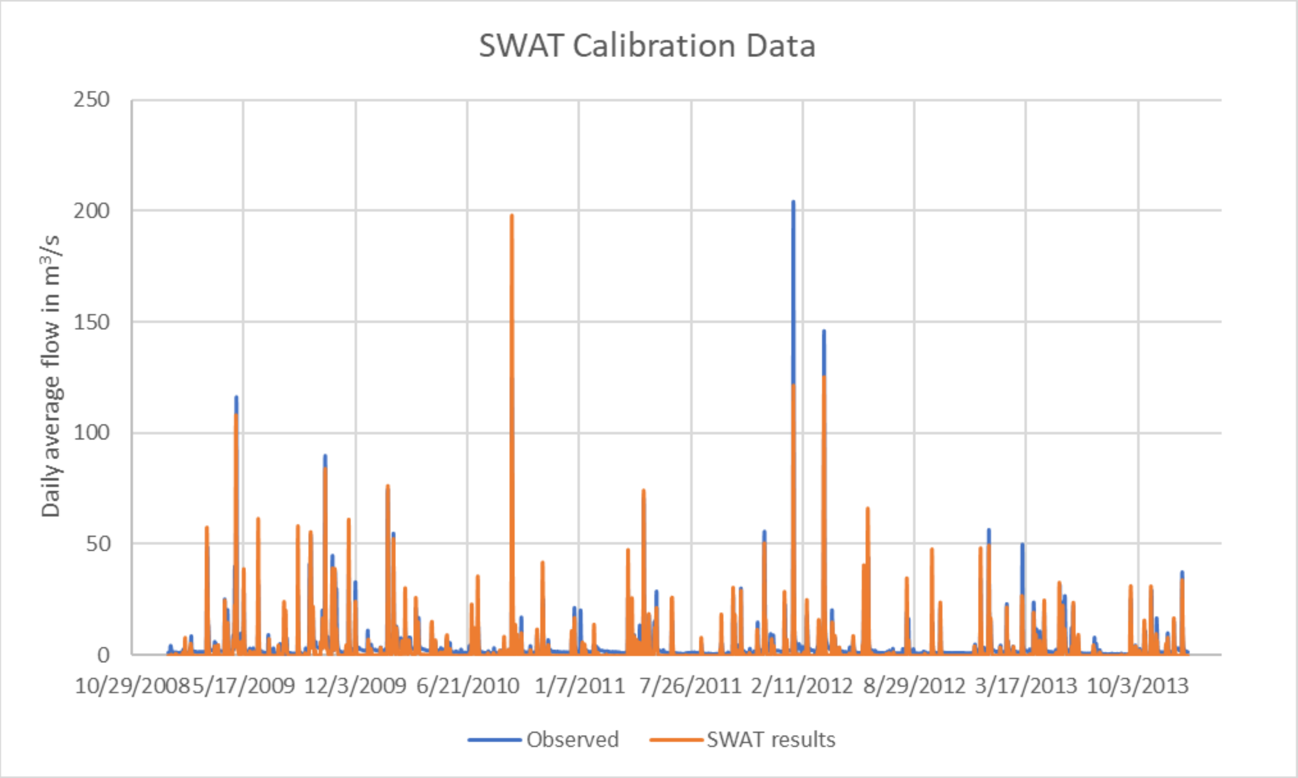

Figure 2. SWAT Model results compared with observed data at the Rowlett Creek USGS Station.

The results show good match with the observed data. The goodness-of-fit measures results (Table 7), show, Good rating for the RSR and NSE and satisfactory for the PBIAS. These results allow us to use the SWAT model to extract flow time series for the outlets of the five subwatersheds studied.

Table 7. Goodness-of-fit results for final calibration of the SWAT model

RSR	**0.60**
NSE	**0.65**
PBIAS	**15.97**

Flow Duration Curve

Using the calibrated SWAT Model, flow time series for the time when water quality data was available were modeled and obtained for each subwatershed. Flow data for a particular sampling location were then sorted in order and then ranked from highest to lowest to determine the frequency of a particular flow in the stream. Flow data collected as part of routine water quality monitoring were used to develop FDCs for subbasins 1, 2, 3, 4, and 5 of Rowlett Creek. These results are used to create graphs of flow volume versus frequency, which produces a flow duration curve for each waterbody (Figures 3-6).

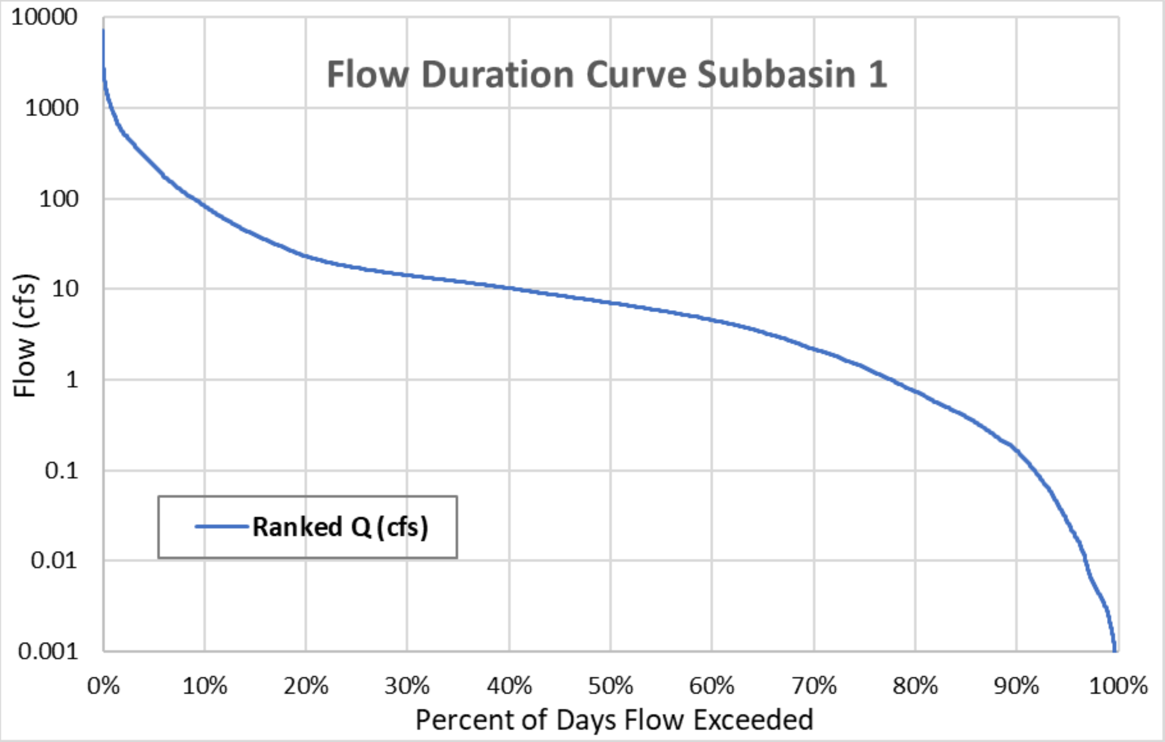

Figure 3. Flow duration curve at site 1.

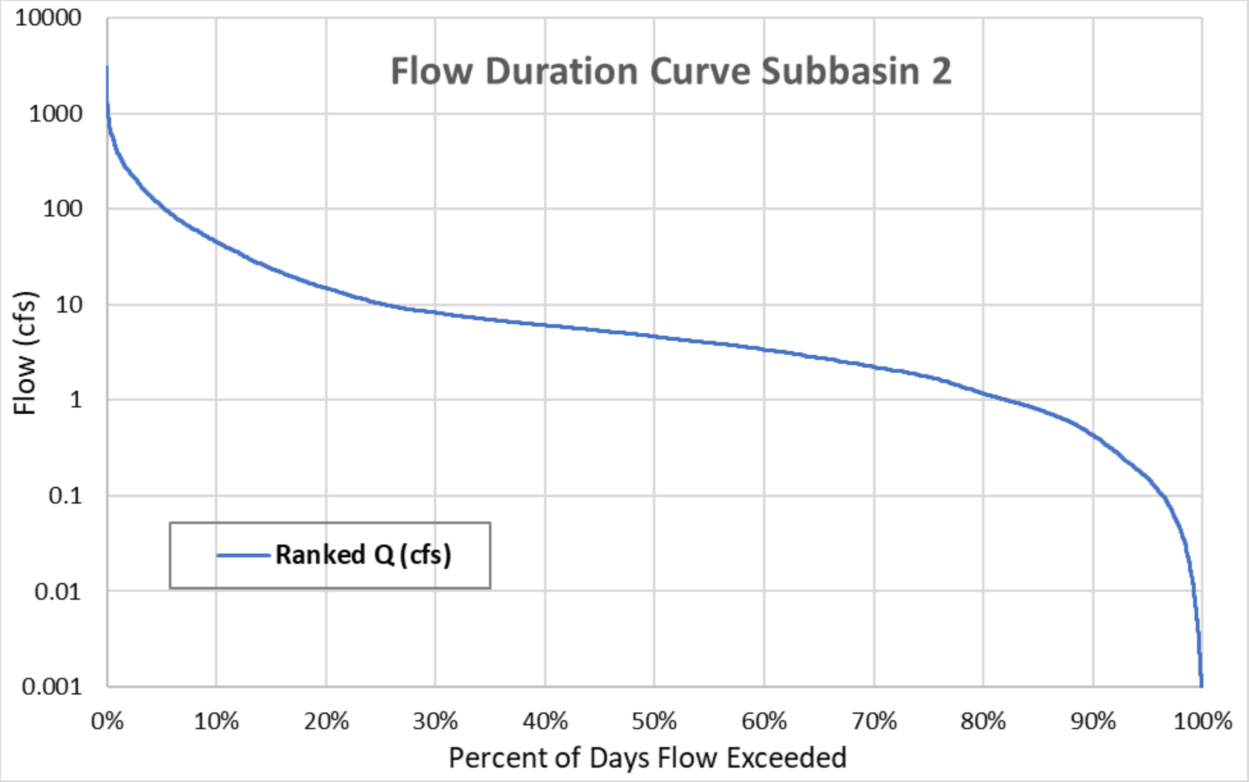

Figure 4. Flow duration curve at site 2.

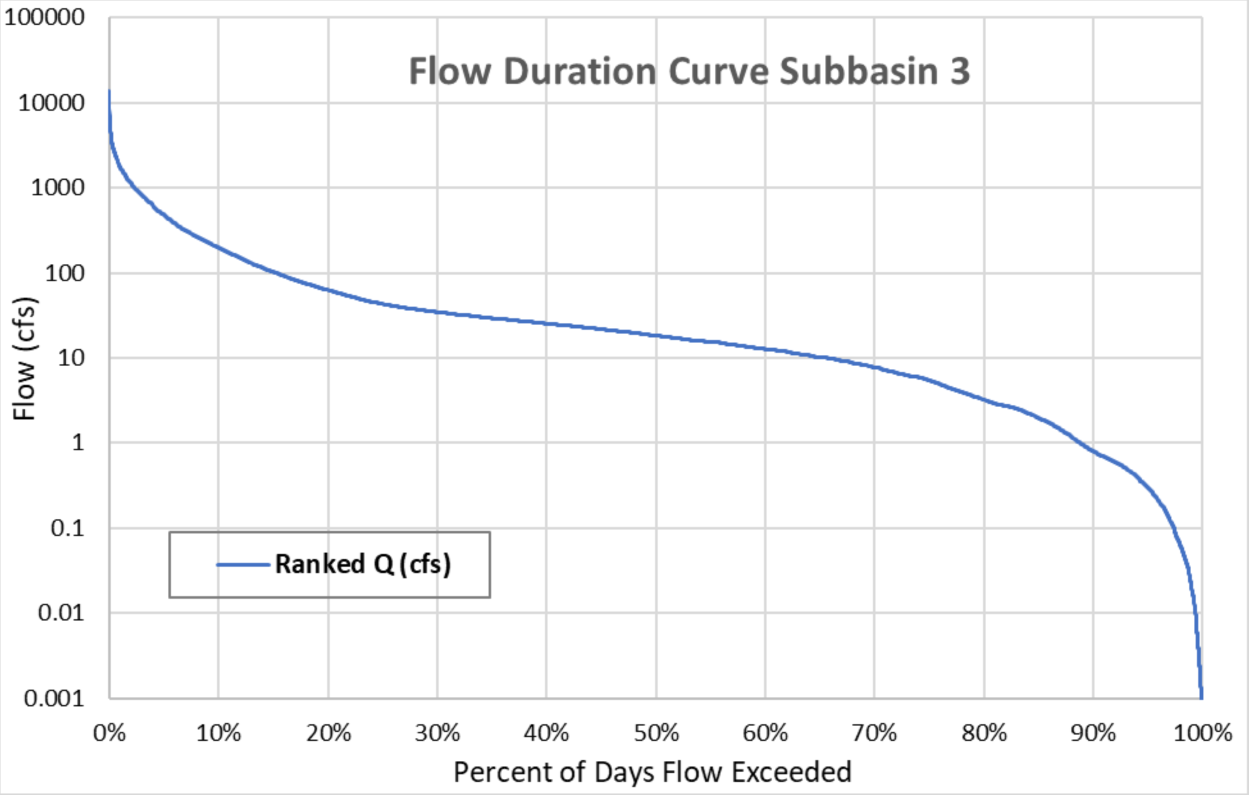

Figure 5. Flow duration curve at site 3.

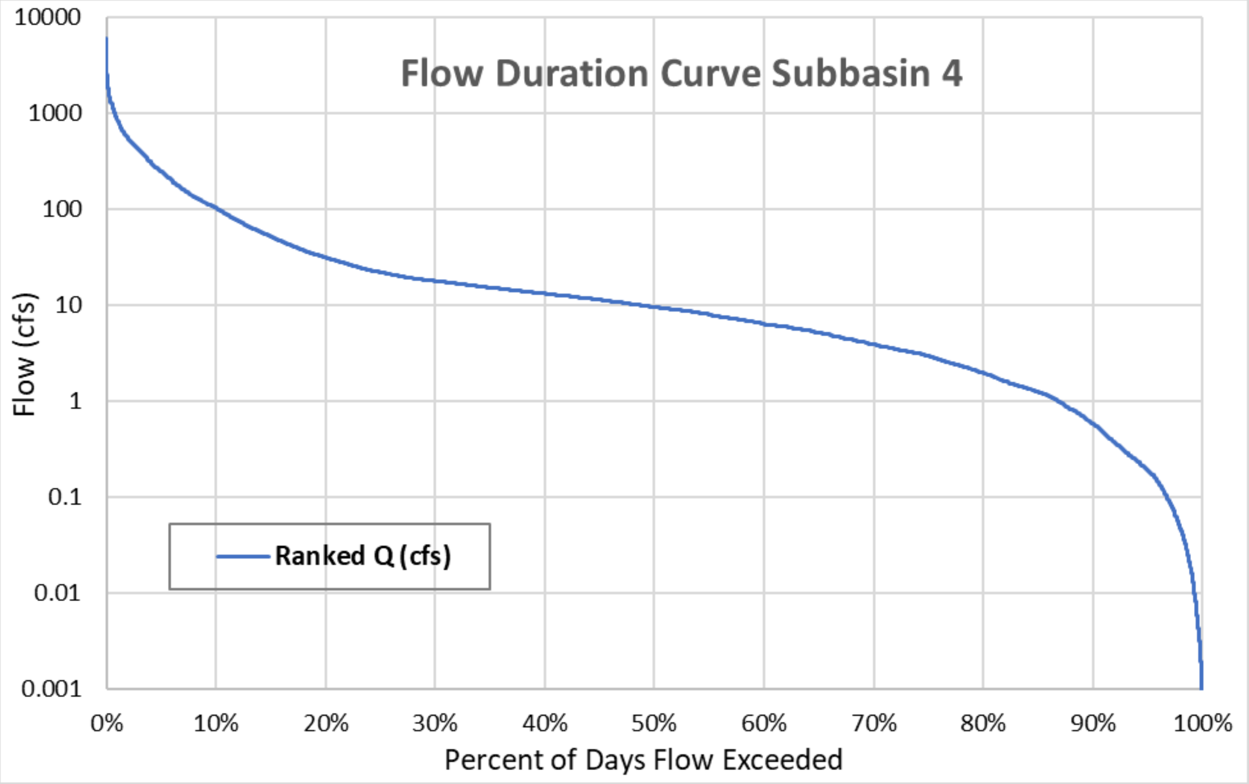

Figure 6. Flow duration curve at site 4

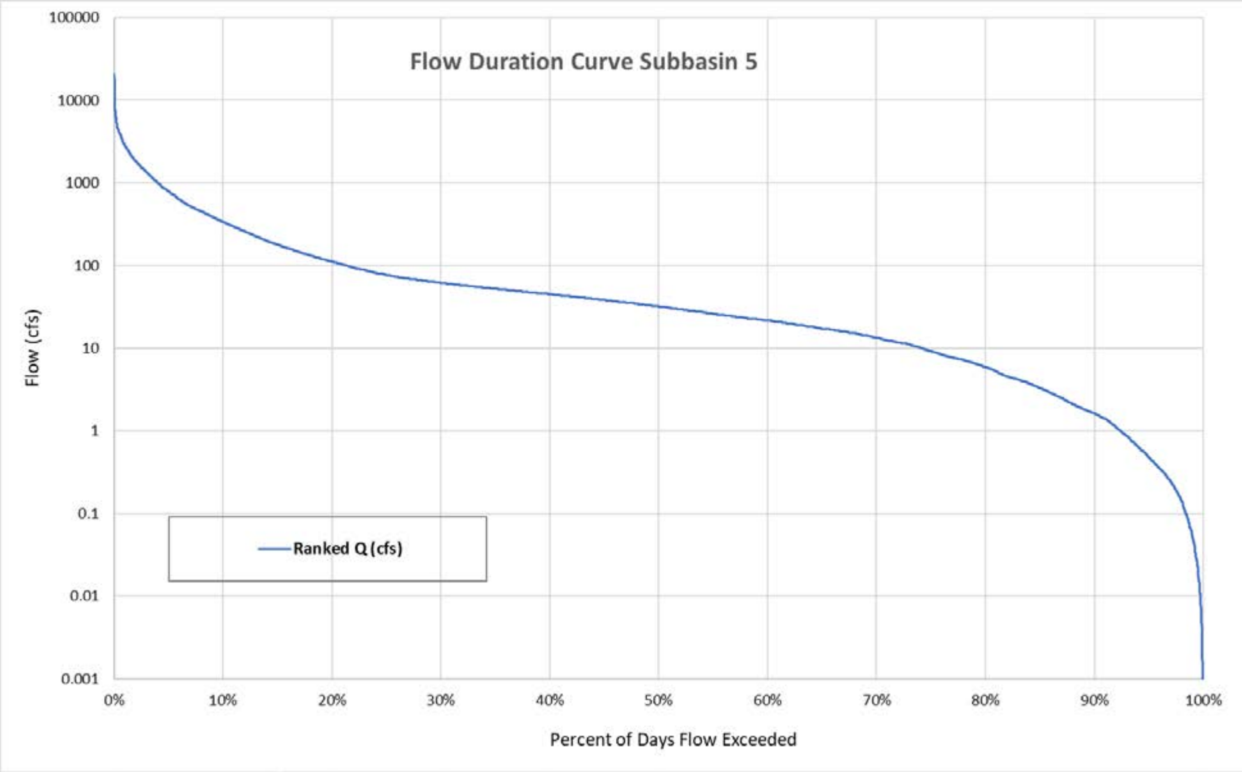

Figure 7. Flow duration curve at site 5.

The graphs show that sites 1, 2 and 4 are small watersheds with flows exceeded 20% of the time are around 22, 15 and 31 cfs. Sites 3, which subbasin includes sites 1 and 2, has a flow of 61 cfs exceeded 20% of the time and Site 5, which subbasin includes all the other 4 sites, has a 20-percentile flow of 109 cfs.

Load Duration Curve Analysis

A widely accepted approach for analyzing water quality is the use of a Load Duration Curve (LDC). A LDC allows for a visual determination of how stream flow may or may not impact water quality, in regard to a specific parameter. The first step in developing an LDC is the construction of a Flow Duration Curve (FDC) (See figures 3-6 above).

Next, data from the flow duration curve are multiplied by the concentration of the water quality standard for the pollutant to produce the allowable LDC. This curve shows the maximum load (amount per unit time; e.g., for bacteria CFU/day) a stream can carry across the range of flow conditions (low flow to high flow) without exceeding the water quality standard. Typically, a margin of safety (MOS) is applied to the threshold pollutant concentrations to account for possible variations in loading from potential sources, stream flow, effectiveness of management measures, and other sources of uncertainty. A 10% MOS for bacteria was selected for this plan.

Stream monitoring data for a pollutant also can be plotted on the curve to show frequency and magnitude of exceedances. Typically, flow regimes are identified as areas of the LDC where the slope of the curve changes because that correlates with a significant change in flow. In the LDCs for the Rowlett Creek watershed, there are three flow regimes: high (0-10th percentile flow), midrange (11th – 80th percentile flow), and low flows (81th -100th percentile flow). These regimes reflect where a change in the slope of the LDC line is detected. Pollutant data plotted on the LDCs for the Rowlett Creek Watershed in this report covered data collected from 1981 to 2022.

In the below figures, the red line indicates the maximum acceptable stream load for pollutants and the squares, triangles, and circles represent water quality monitoring data collected under high, mid-range and low flow conditions, respectively. Where the monitoring samples are above the red line, the actual stream load has exceeded the water quality standard, and a violation of the standard has occurred. Points located on or below the red line are in compliance with the water quality standard. In order to analyze the entire range of monitoring data, regression analysis is conducted using the monitored samples to calculate the “line of best fit” (blue line). Where the blue line is on or below the red line, monitoring data at that flow percentile is in compliance with the water quality standard. Where the blue line is above the red line, monitoring data indicate that the water quality standard is not being met at that flow percentile. Regression analysis also enables calculation of the estimated percent reduction needed to achieve acceptable pollutant loads. The green line indicates the 10% margin of safety agreed on for this project.

E. coli

E. coli is a bacterium found in the intestines of humans and warm-blooded animals and humans. If the waste is excreted in the open then, during a rain event, it can be picked up by stormwater runoff and be either channeled into surface water and/or ground water or directly deposited into the waterbody. If *E. coli* is found at high concentration in waterbodies it could indicate, for example, the presence of wildlife and livestock in the watershed, illicit wastewater connections and subsequent discharges, and improperly treated wastewater for example sanitary sewer overflows and poorly maintained onsite sewage facilities (septic). Depending on the strain, toxins may be produced and can cause illness if ingested. Waterbodies are defined by their ability to host recreational activities and are based on levels of *E. coli*. The U.S. EPA has designated a standard *E. coli* concentration based on the geometric mean of a certain number of samples because the concentration can vary by orders of magnitude. The method for detection of *E. coli* is used as a proxy for the possibility of human illness when humans are recreating in water. The higher the concentration of *E. coli* the greater the possibility that there will be more toxic *E. coli* strains, other bacteria or viruses that can be ingested while swimming, wading or boating in waterbodies. Concentrations of *E. Coli* samples often exceeded the maximum value able to be tested by the lab. There is, therefore, an artificial ceiling on values reported. For contact recreation in Texas, the geomean of *E. coli* must be below 126 cfu/100 mL. Thus, the threshold concentration used in the LDC analysis was 113 cfu/100mL for bacteria.

Figures 8 to 12 show the LDCs for sites 1 to 5, respectively for *E. Coli.* All sites exceeded the allowable load in one or more of the ranges. Site one slightly exceeded the allowable load for high and mid-range flows and to a lesser extent for low flows. Site 2 had a similar pattern to site one, with low flows being less (or not) above the allowable limit. Sites 3 and four were consistently above the allowable limit for all flows indicating while site 5 was only above the allowable limits for the high and mid flows.

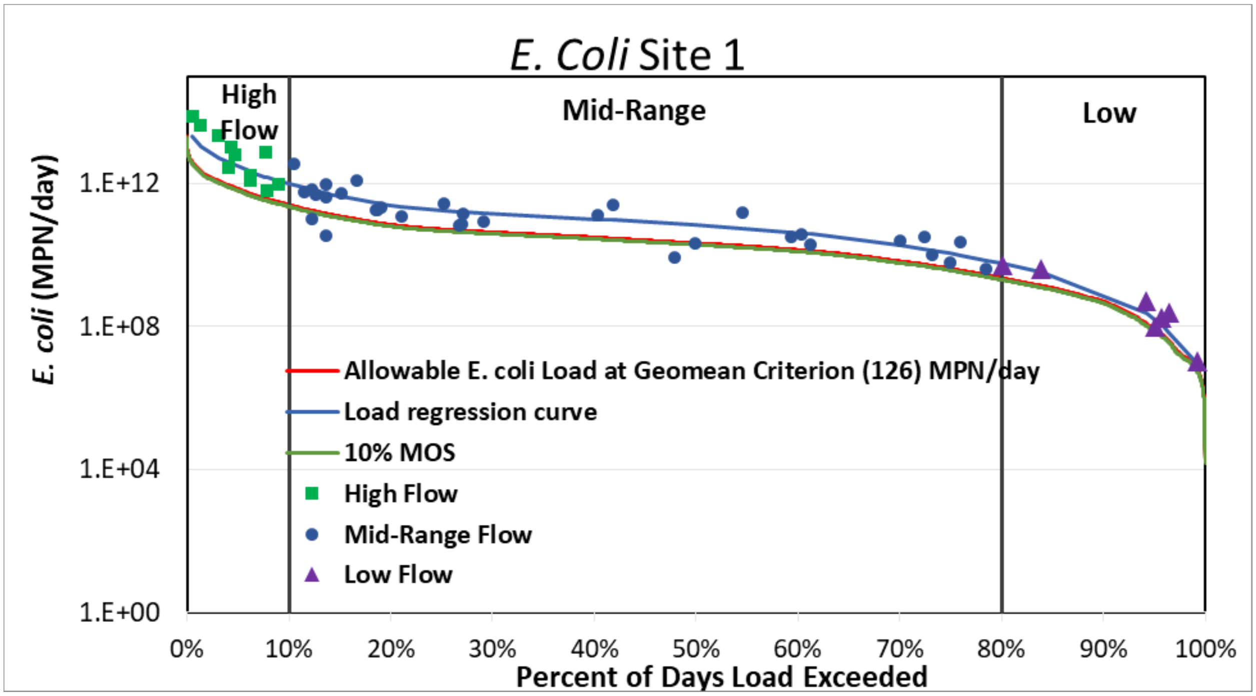

Figure 8. Load duration curve for E. Coli *at site 1.*

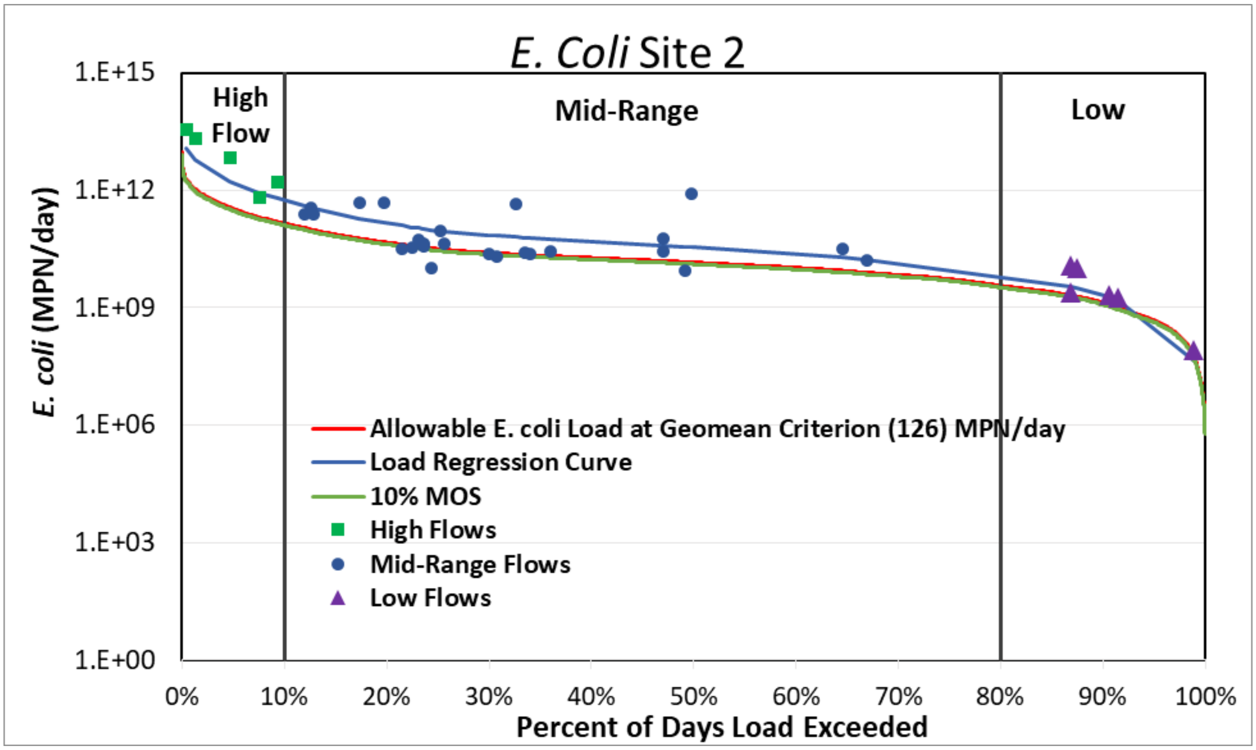

Figure 9. Load duration curve for E. Coli *for site 2.*

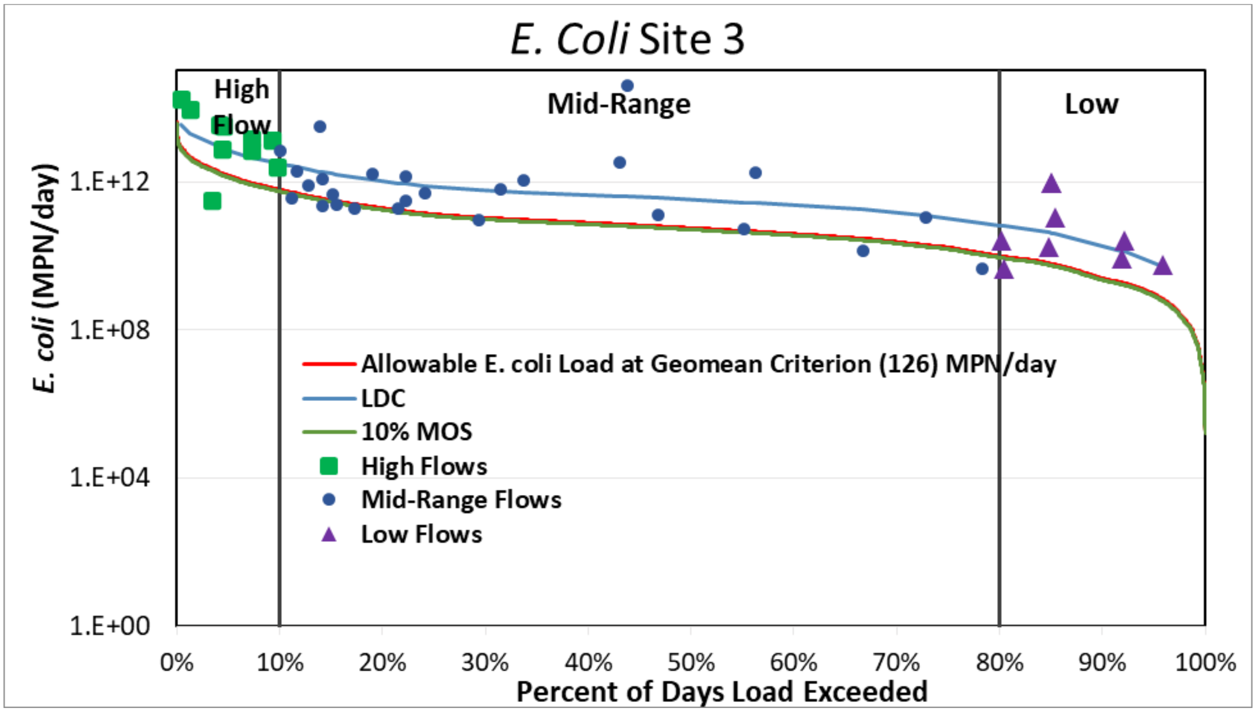

Figure 10. Load duration curve for E. Coli *for site 3*

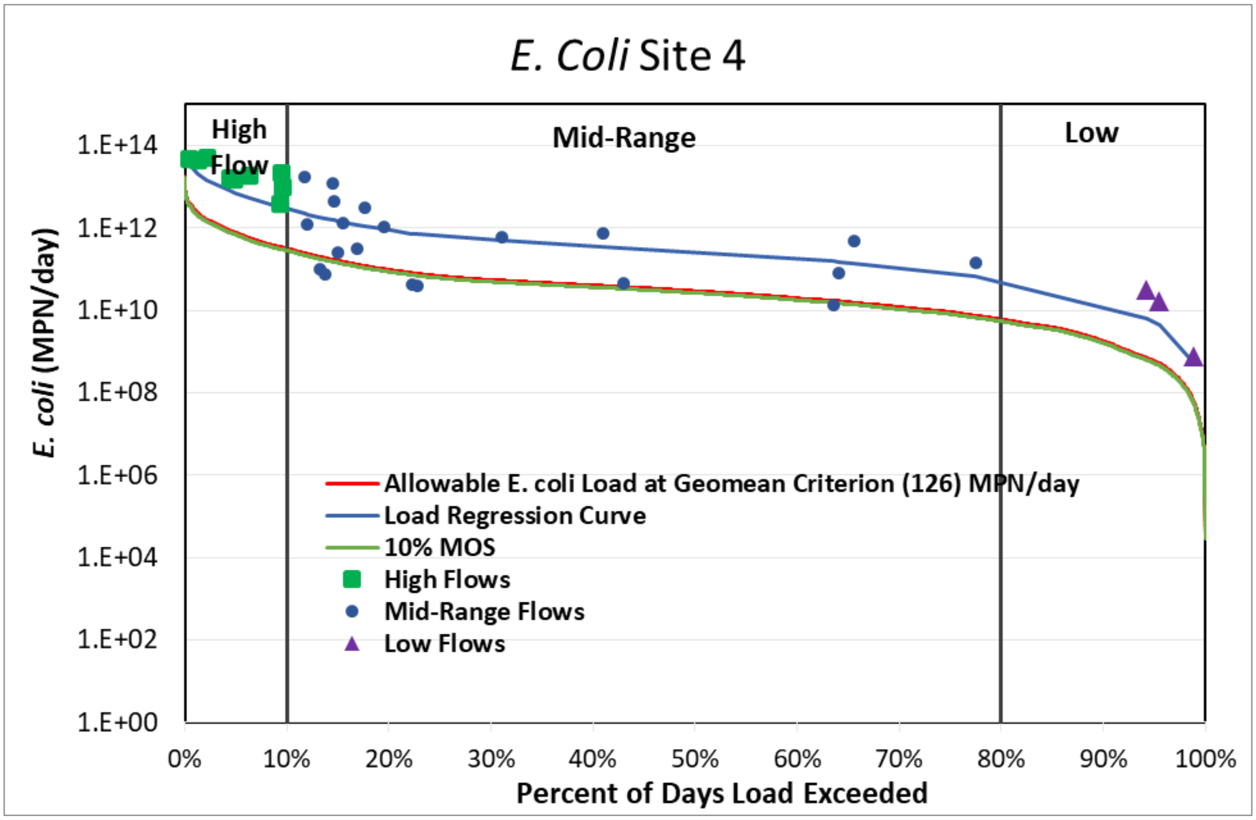

Figure 11. Load duration curve for E. Coli *for Site 4.*

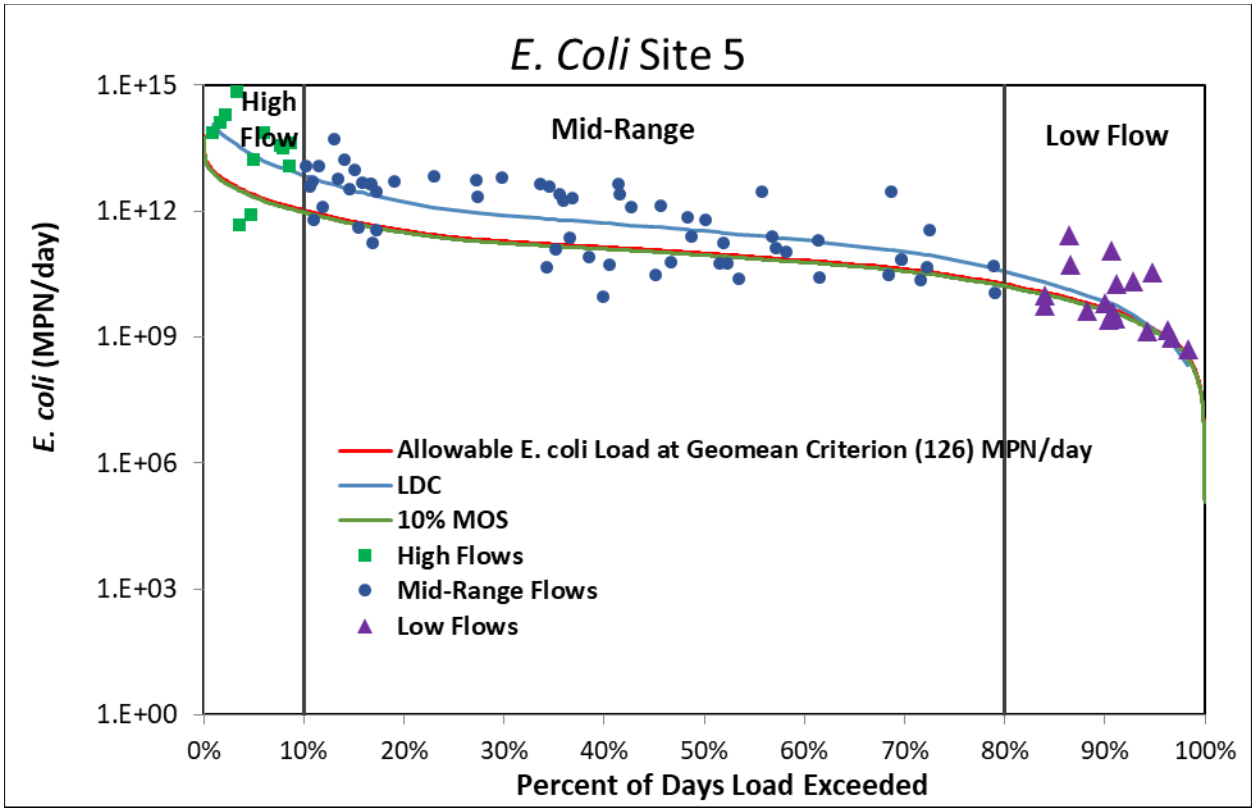

Figure 12. Load duration curve for E. Coli *for site 5.*

Nitrate-Nitrite Nitrogen

Nitrogen in the forms of nitrite and nitrate measures inorganic nitrogen in the stream. Nitrate is very abundant as an inorganic, oxidized form of nitrogen and nitrite is not as common as an inorganic, oxidized form of nitrogen. Levels of inorganic nitrogen appear to be slightly increasing over time during routine sampling. Nitrate level were at or below 10% MOS for all sites except low flows at site 5. That could be influenced by backflow from the Lake. Sites 3 and 4 are nearly at 10% MOS indicating a potential concern for nitrate at those subwatersheds.

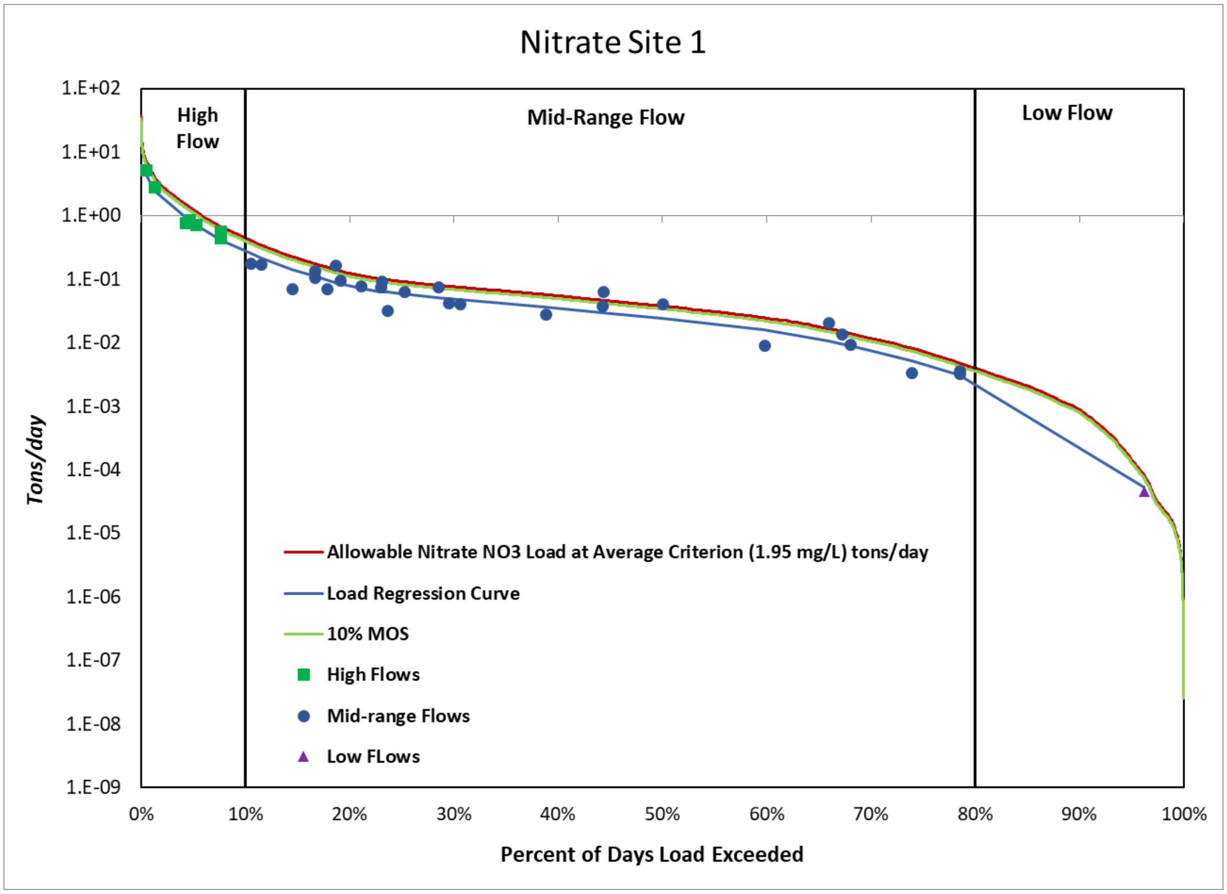

Figure 13. Nitrate/nitrite load duration curve at site 1 showing the allowable load and the 10% MOS.

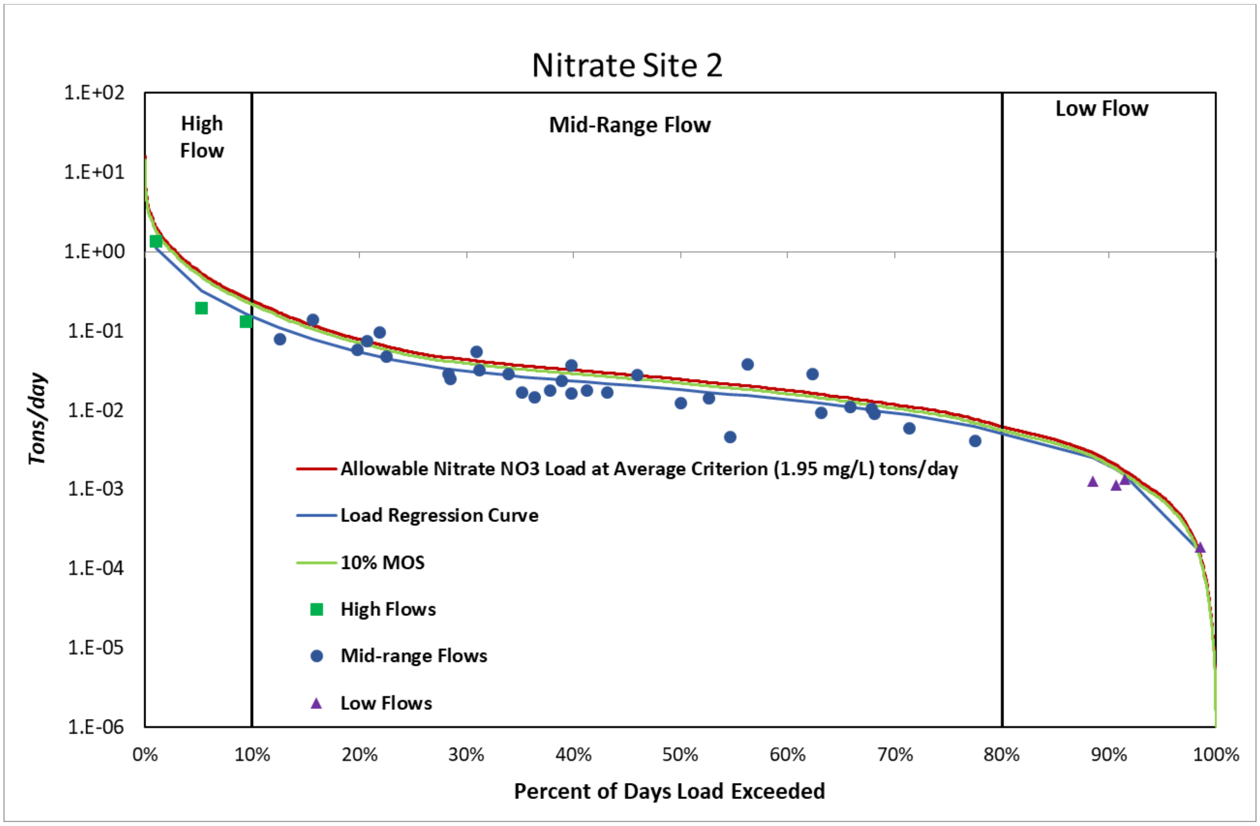

Figure 14. Nitrate/nitrite load duration curve at site 2 showing the allowable load and the 10% MOS.

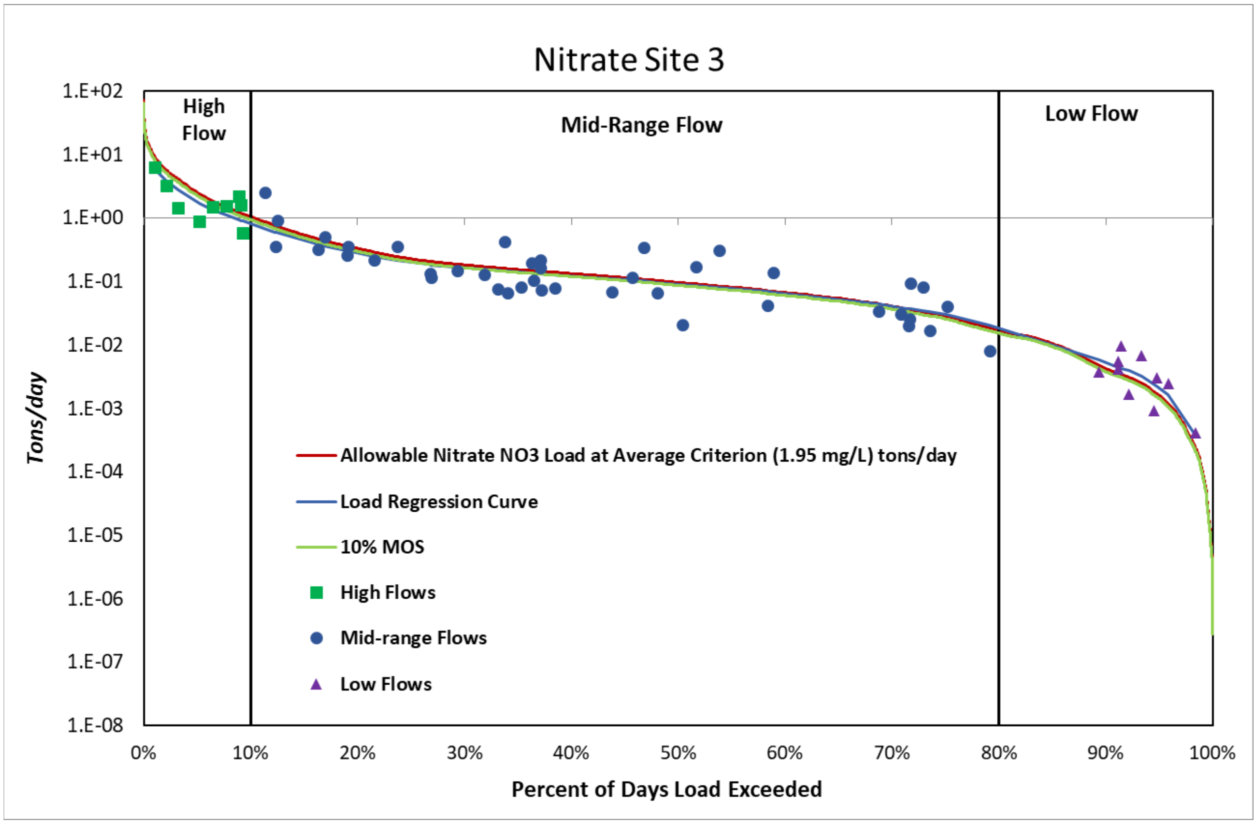

Figure 15. Nitrate/nitrite load duration curve at site 3 showing the allowable load and the 10% MOS.

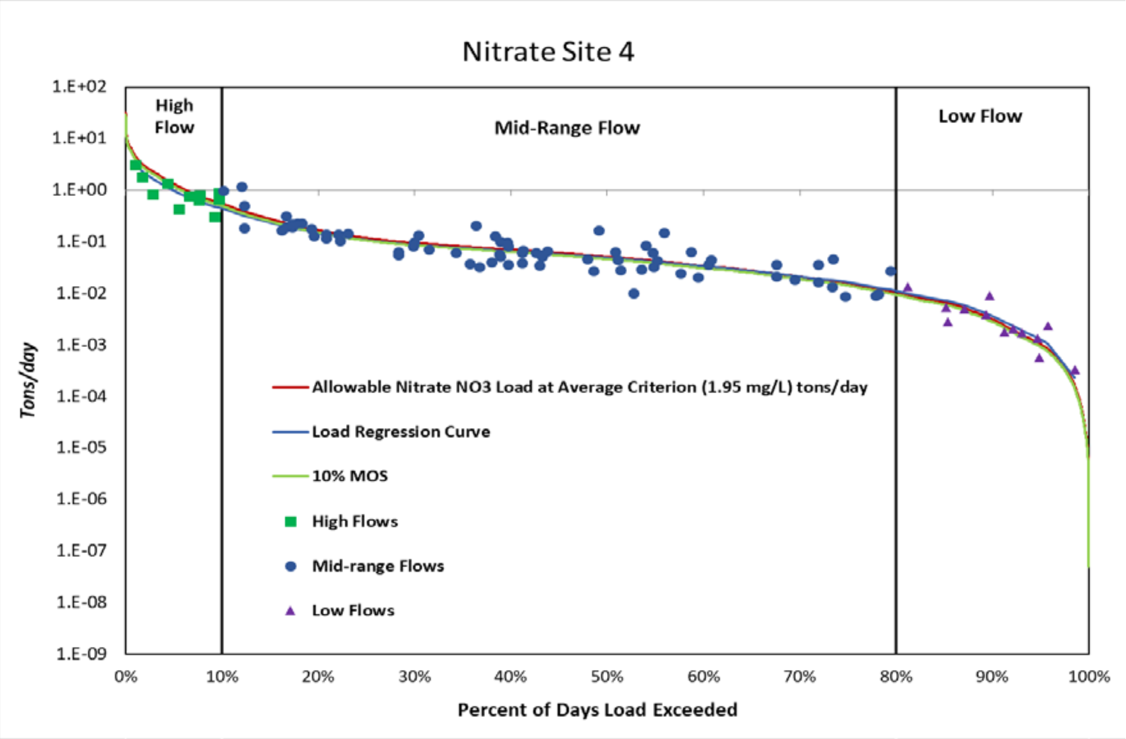

Figure 16. Nitrate/nitrite load duration curve at site 4 showing the allowable load and the 10% MOS.

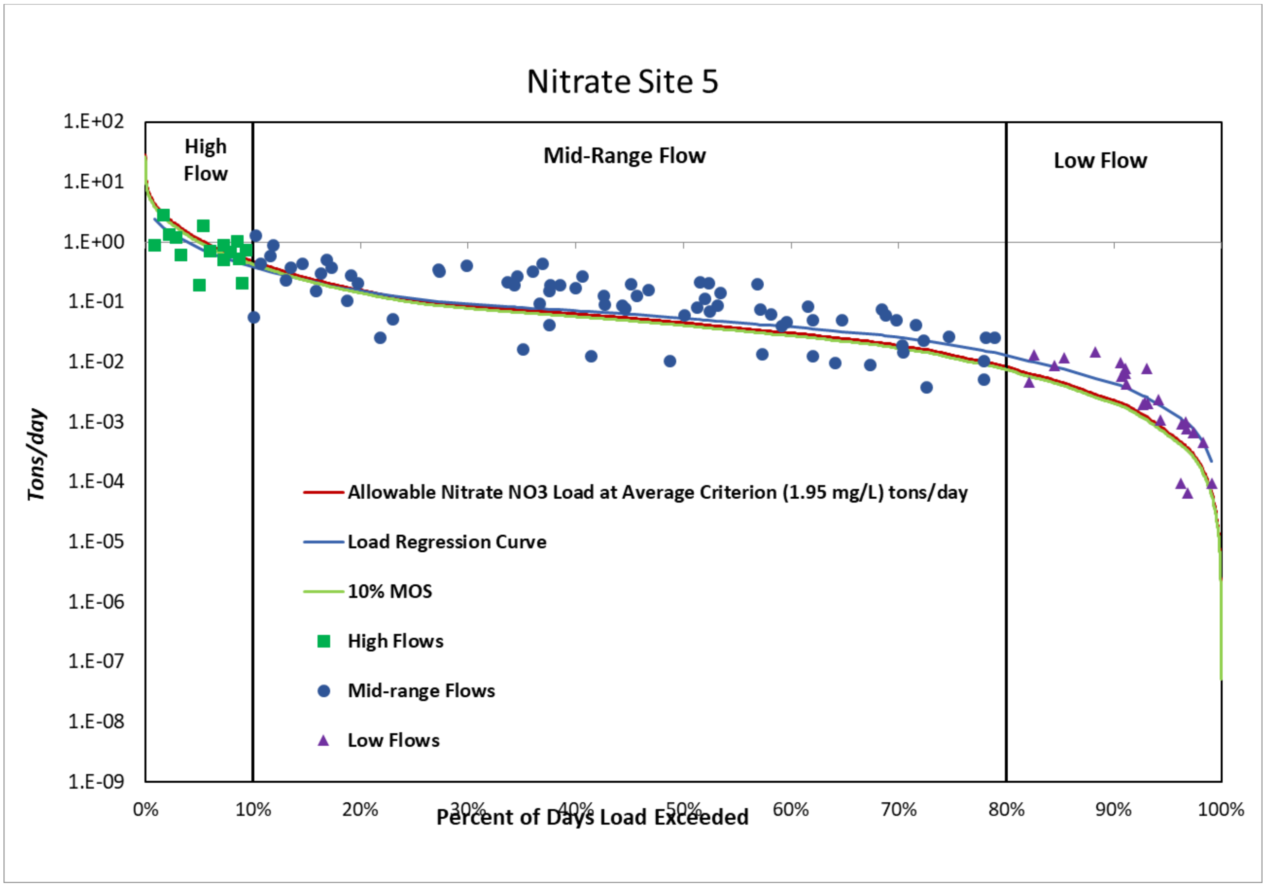

Figure 17. Nitrate/nitrite load duration curve at site 5 showing the allowable load and the 10% MOS.

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is the measure of organic nitrogen plus ammonia nitrogen in a sample. TKN exceeded the allowable load for all sites with sites 2, 3 and 4 noticeably higher than the limit.

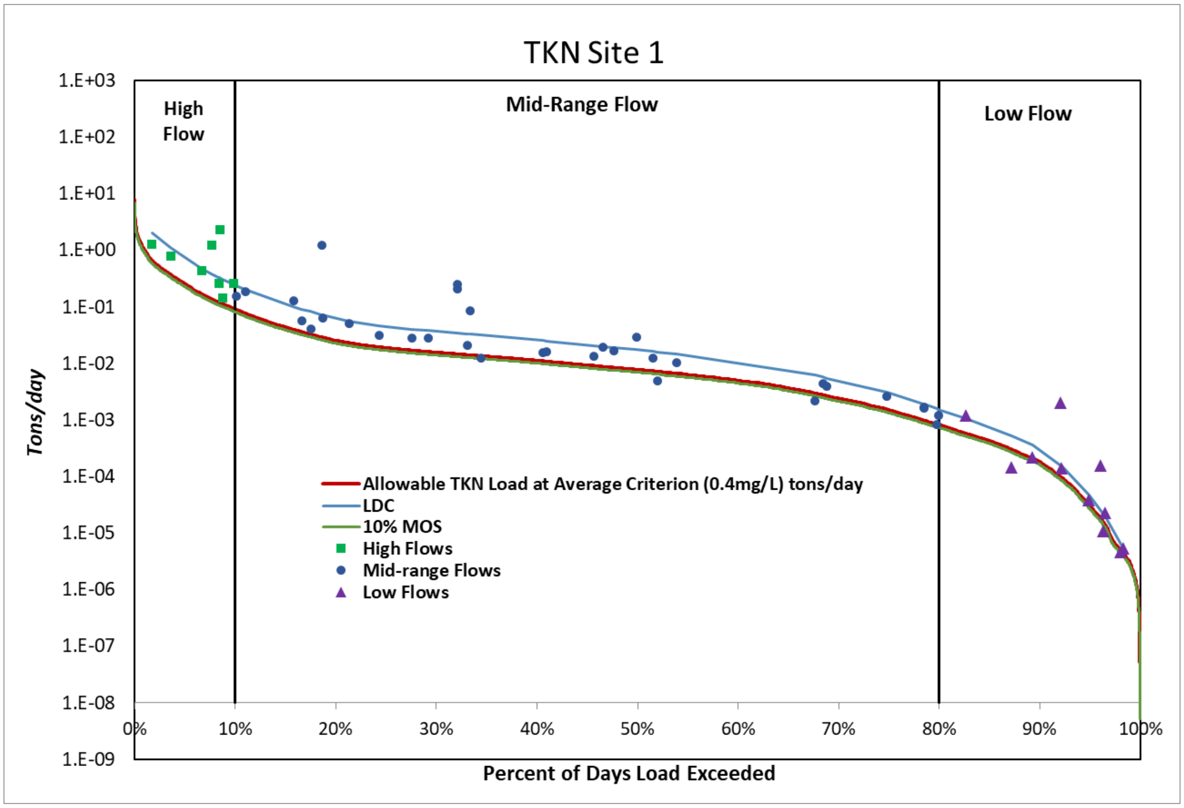

Figure 18. TKN load duration curve at site 1 showing the allowable load and the 10% MOS.

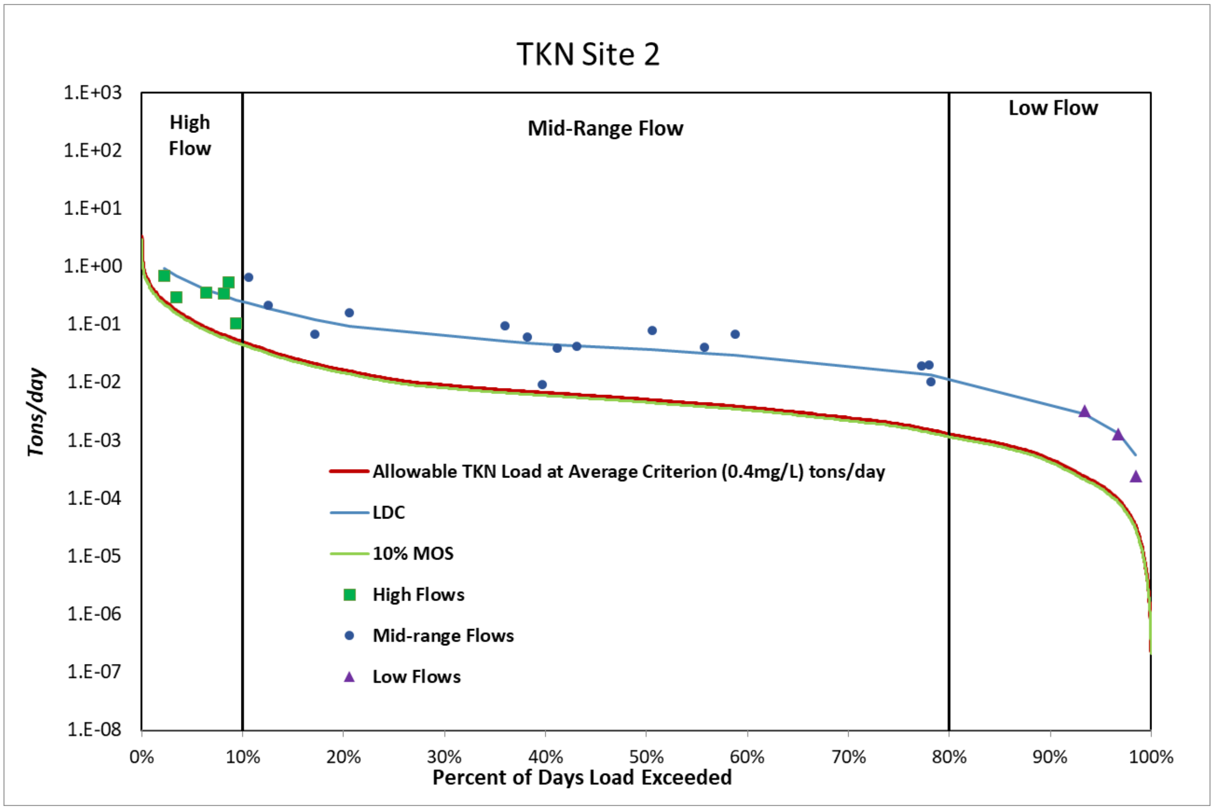

Figure 19. TKN load duration curve at site 2 showing the allowable load and the 10% MOS.

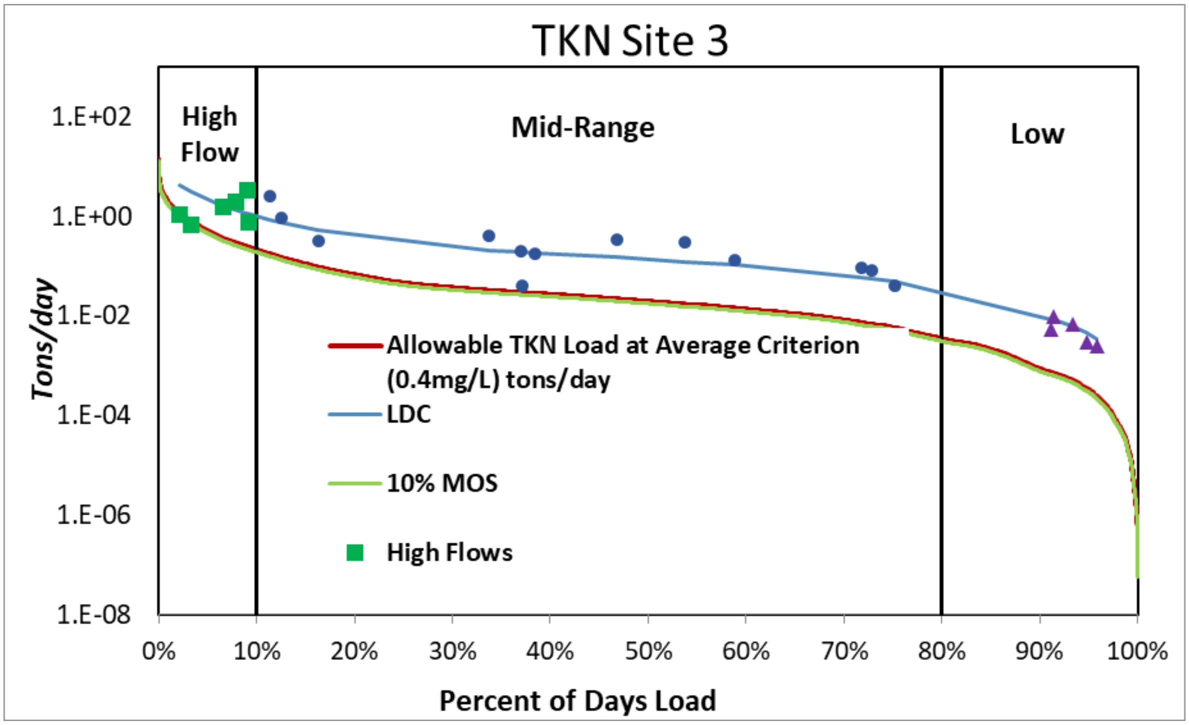

Figure 20. TKN load duration curve at site 3 showing the allowable load and the 10% MOS.

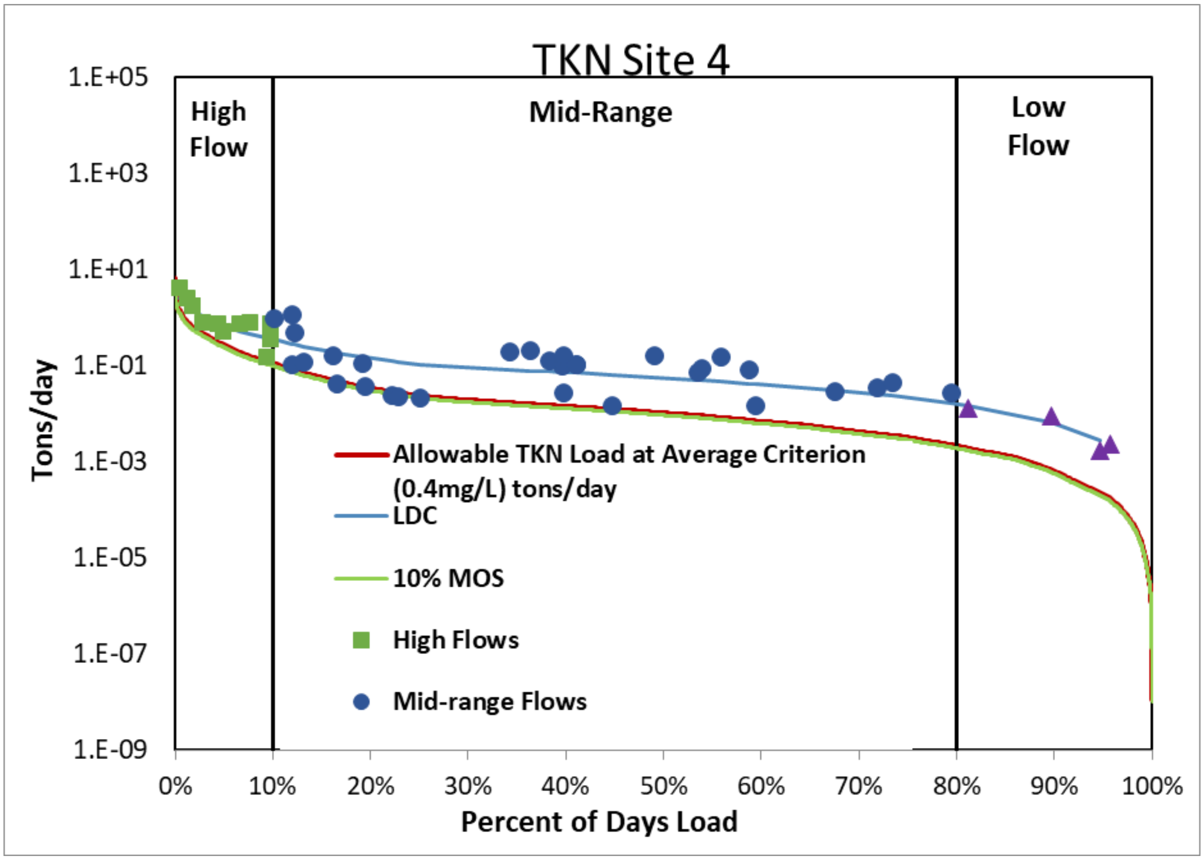

Figure 21. TKN load duration curve at site 4 showing the allowable load and the 10% MOS.

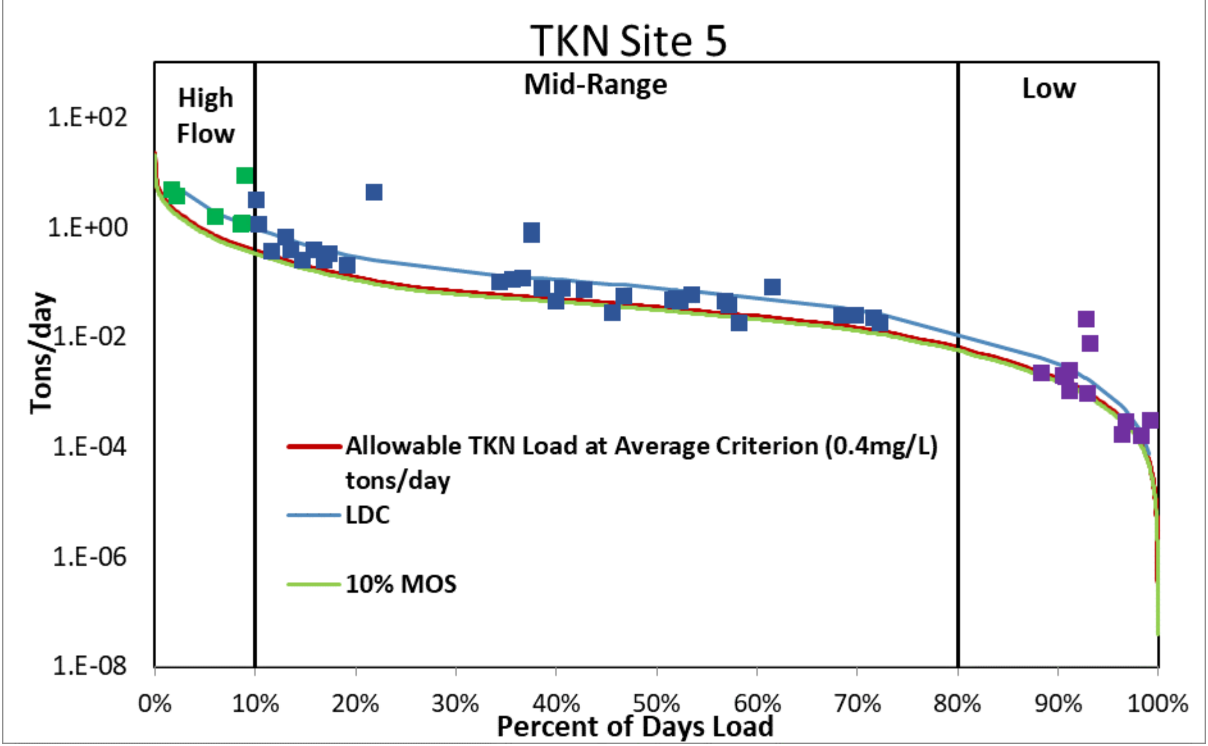

Figure 22. TKN load duration curve at site 5 showing the allowable load and the 10% MOS.

Ammonia Nitrogen

Ammonia levels in Rowlett Creek were below the allowable limit for all sites. This indicates that high TKN values shown above are mostly due to organic nitrogen. Notably, Site 4 had high ammonia loads at low flows.

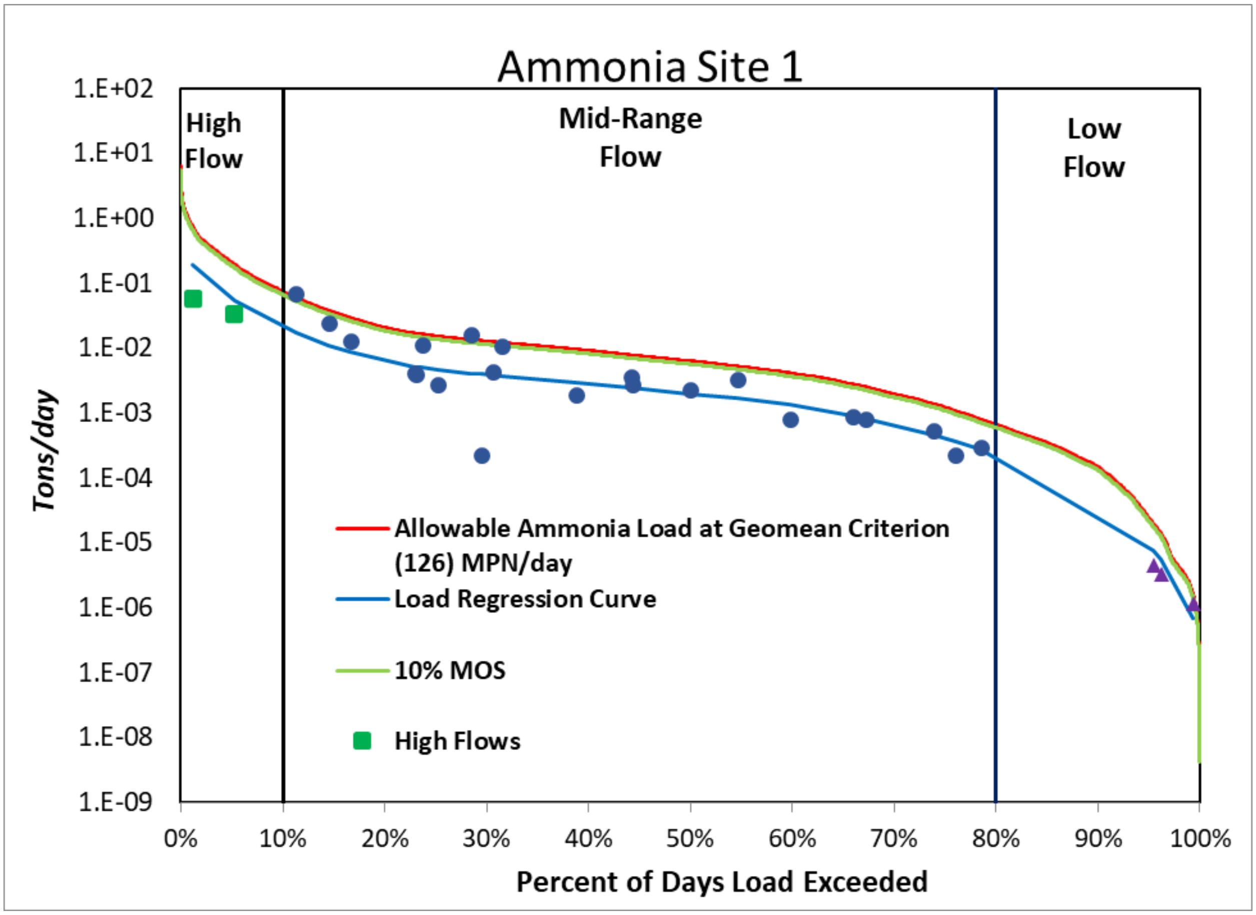

Figure 23. Ammonia load duration curve at site 1 showing the allowable load and the 10% MOS.

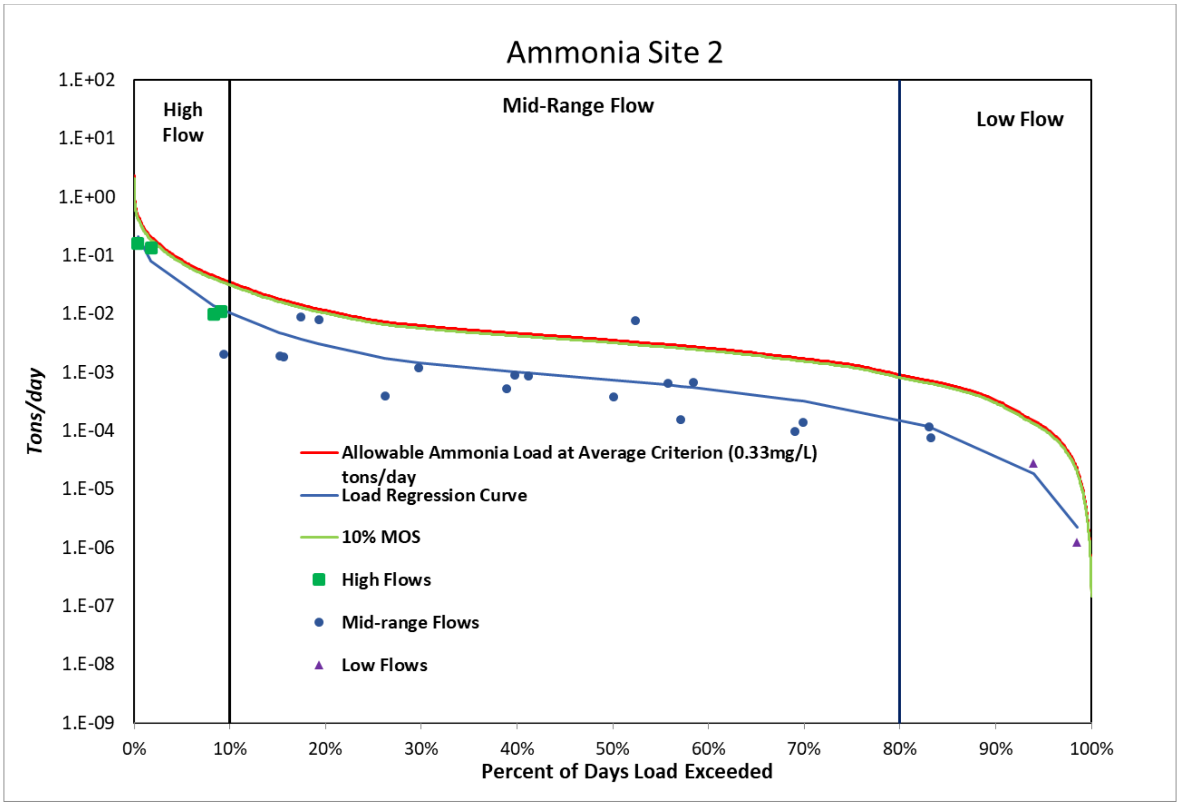

Figure 24. Ammonia load duration curve at site 2 showing the allowable load and the 10% MOS.

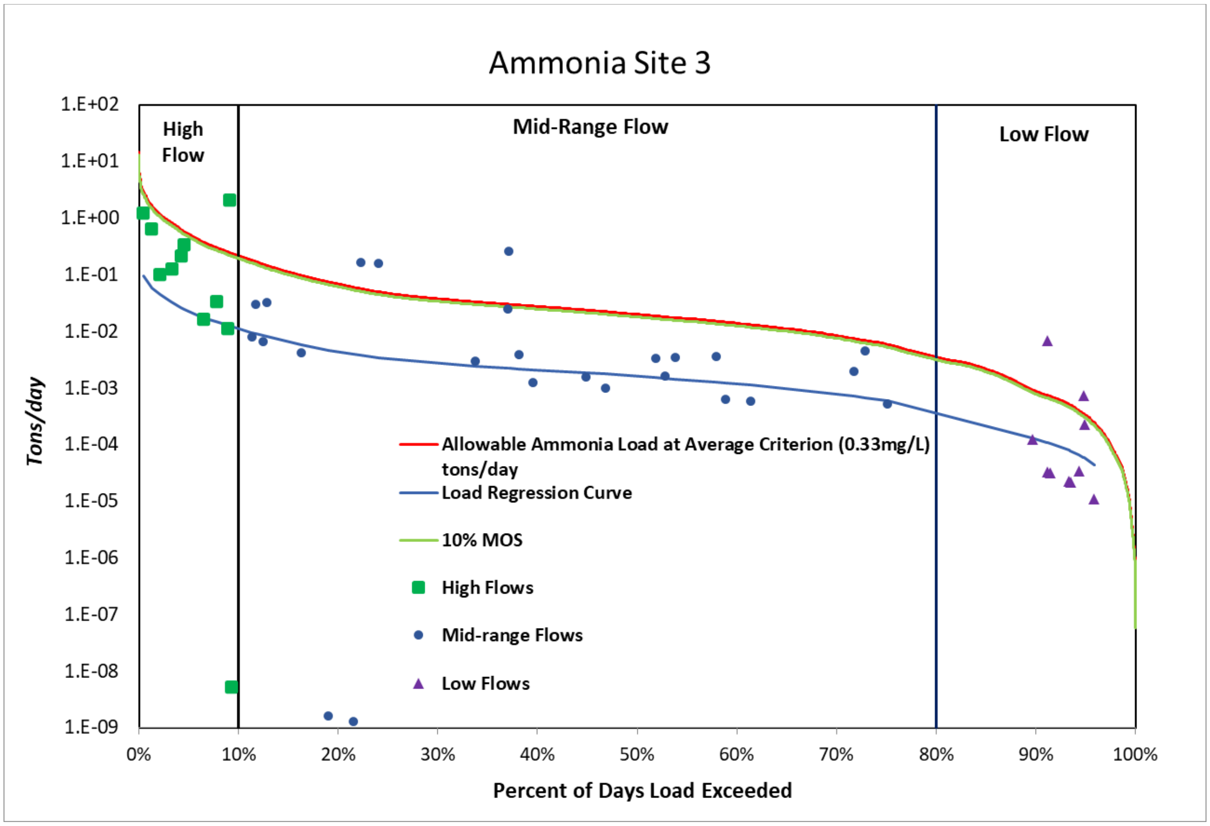

Figure 25. Ammonia load duration curve at site 3 showing the allowable load and the 10% MOS.

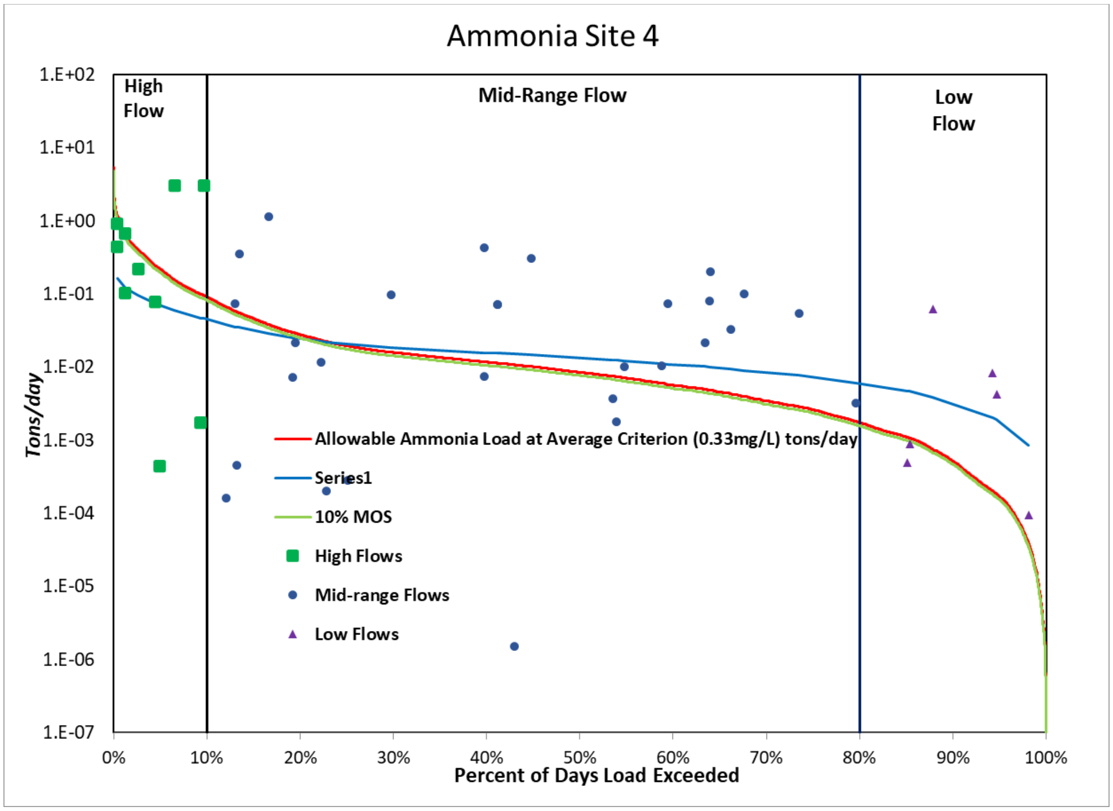

Figure 26. Ammonia load duration curve at site 4 showing the allowable load and the 10% MOS.

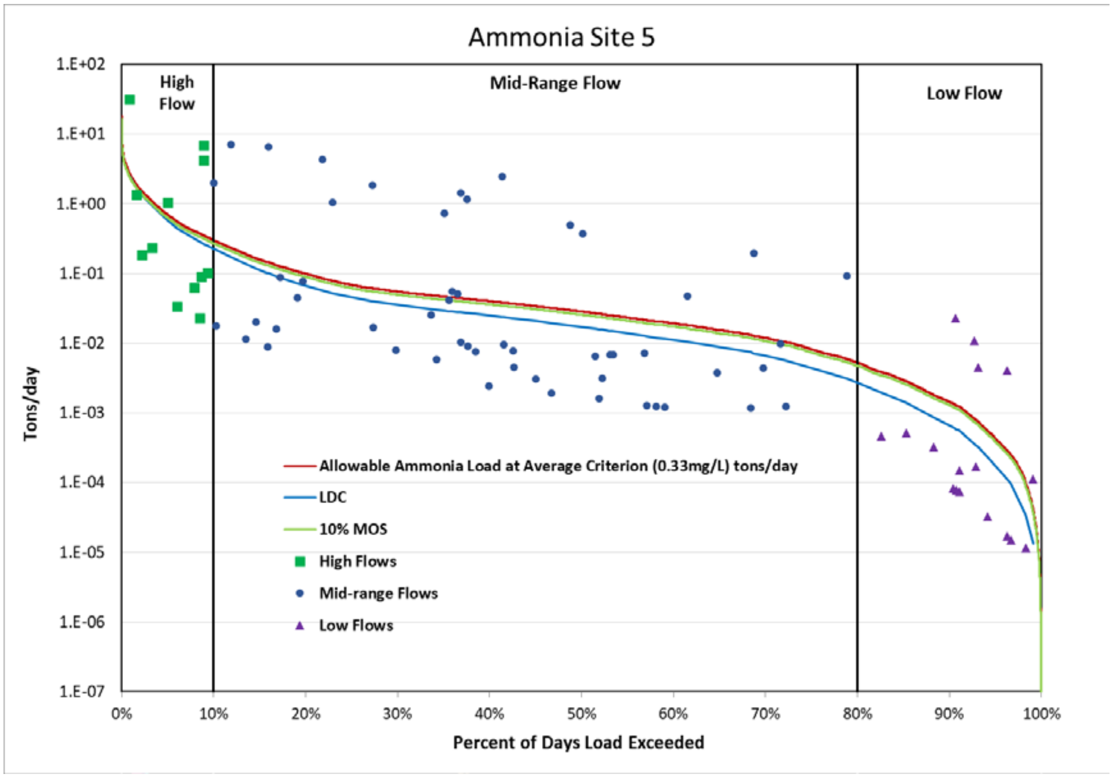

Figure 27. Ammonia load duration curve at site 5 showing the allowable load and the 10% MOS.

Total Phosphorus

Total phosphorus (TP) is a parameter used to analyze a water sample for all forms of phosphorus. Forms of phosphorus include organic and inorganic forms as well as dissolved and particulate forms. Total Phosphorus levels were in general lower than the MOS for all sites. A notable exception is high flows at site 3 and low flows at site 4.

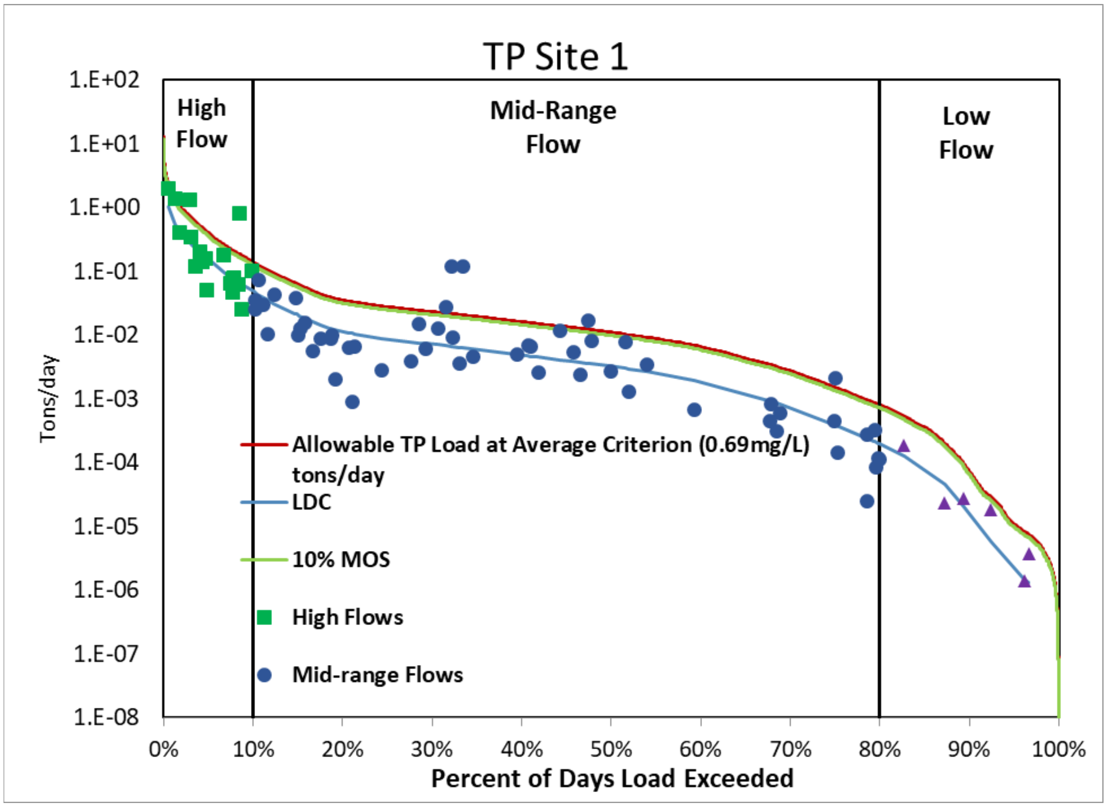

Figure 28. Total Phosphorus load duration curve at site 1 showing the allowable load and the 10% MOS.

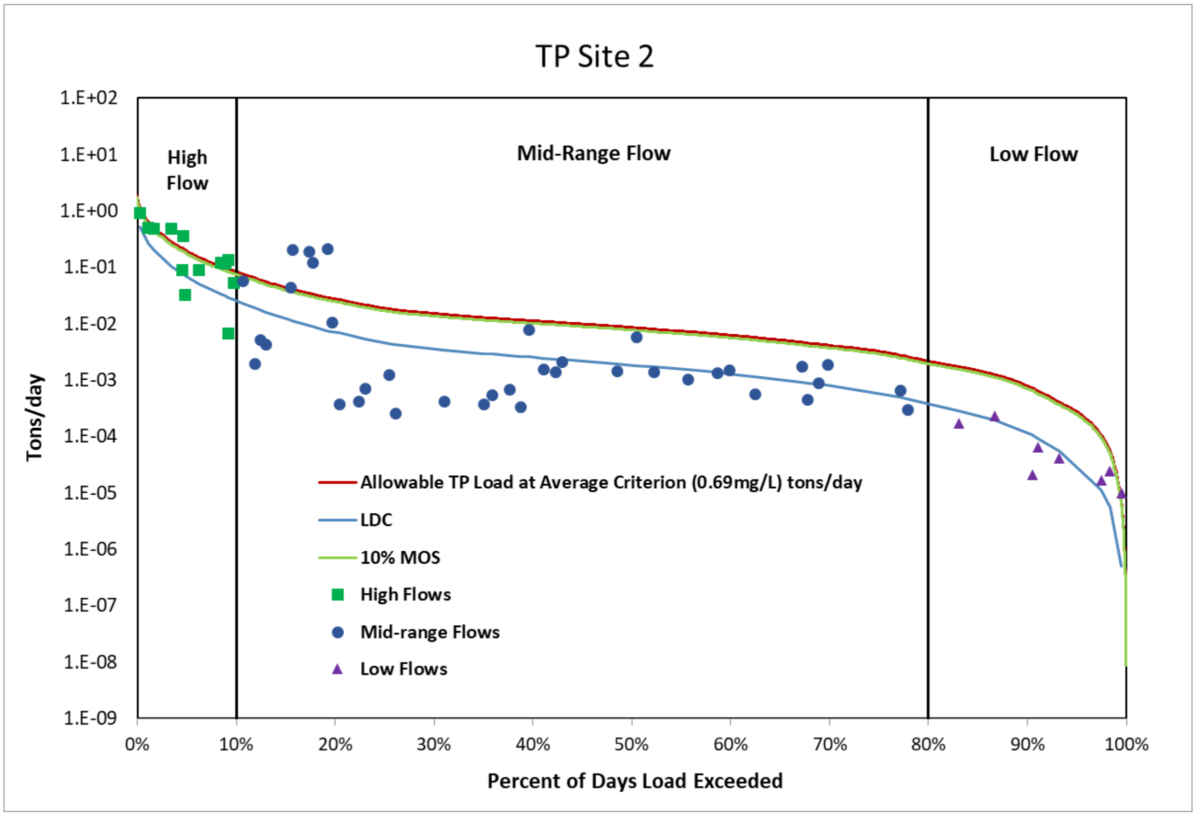

Figure 29. Total Phosphorus load duration curve at site 2 showing the allowable load and the 10% MOS.

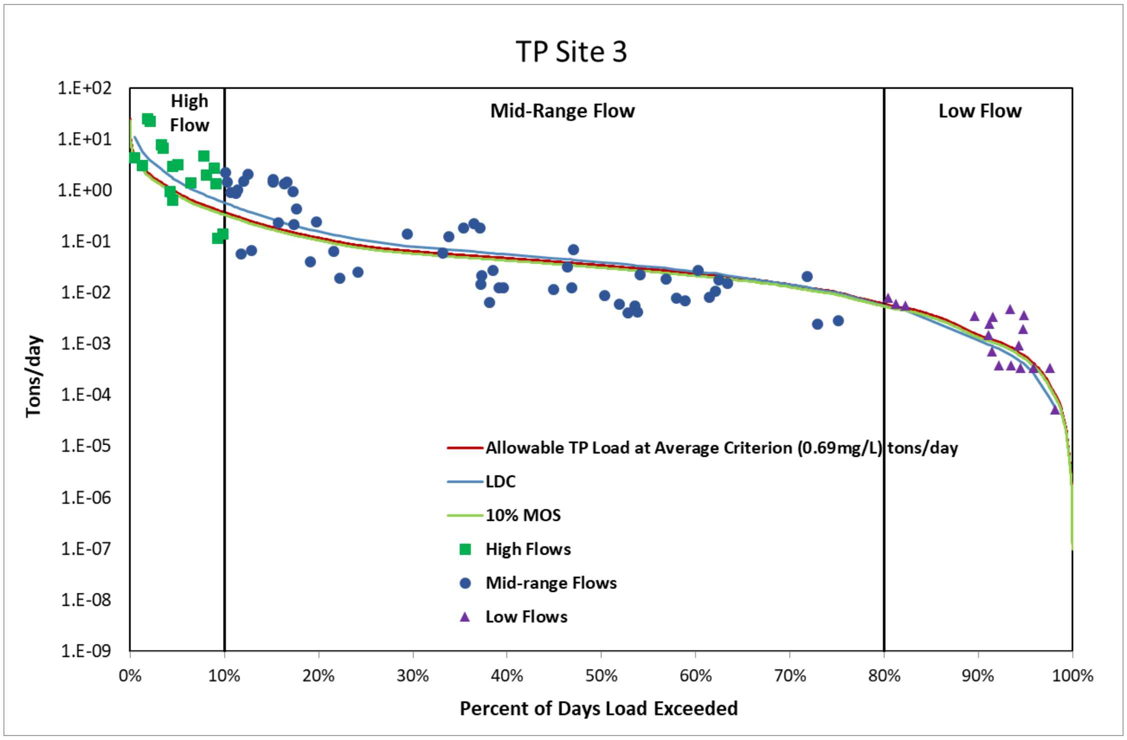

Figure 30. Total Phosphorus load duration curve at site 3 showing the allowable load and the 10% MOS.

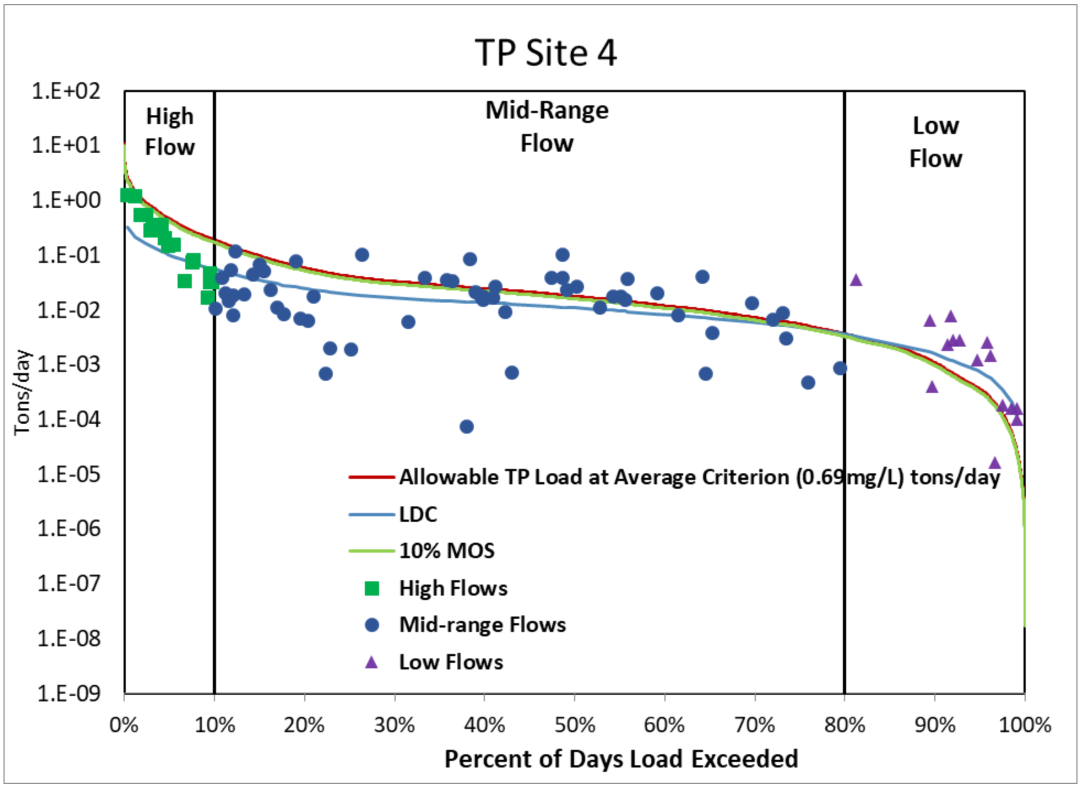

Figure 31. Total Phosphorus load duration curve at site 4 showing the allowable load and the 10% MOS.

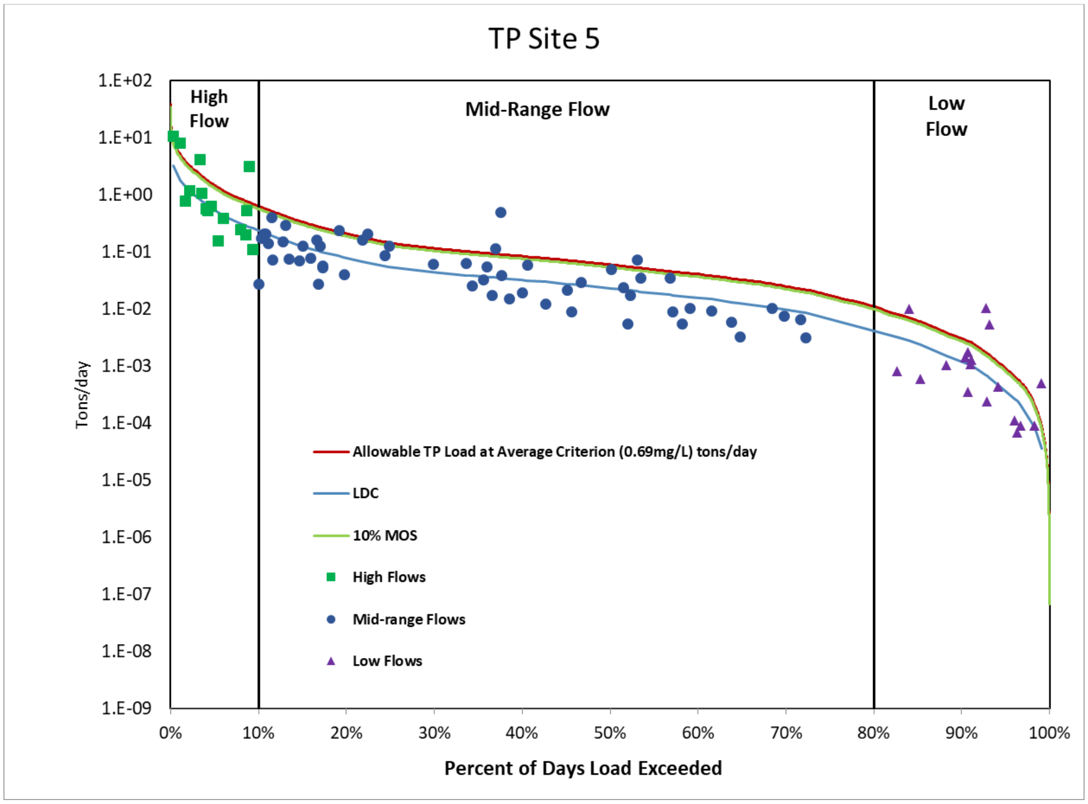

Figure 32. Total Phosphorus load duration curve at site 5 showing the allowable load and the 10% MOS.

Total Suspended Solids

Total suspended solids (TSS) are suspended particles in a water column that, when sampled, are not capable of passing through a specific pore sized filter. Solids are made up of organic matter that can include algal, bacterial cells or organisms as well as inorganic matter that includes soil sediments due to erosion. Suspended solids reduce water clarity and light penetration, slowing the growth of beneficial aquatic plant life. Fish are directly affected by sedimentation through the loss of insect prey, clogging and abrasion of gills and skin, and loss of species diversity. TSS loadings for the subwatersheds sizes were low at sites 1 and 2. These loads were significantly higher at sites 3 and to a lesser extent site 4. Site 5 was a little lower than sites 3 and 4 but the range of values was notably wider (large standard deviations). Such variability might be caused by the lake effects as Lake water levels sometimes impacted this site.

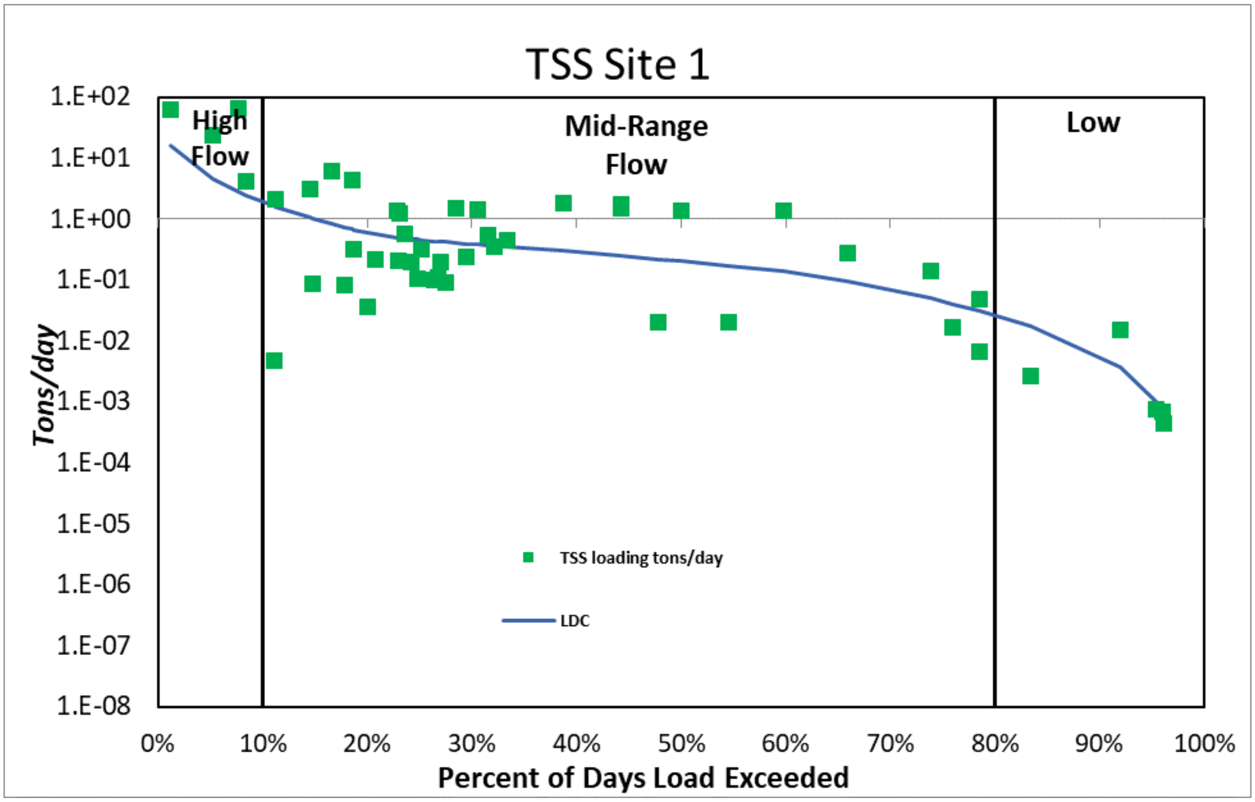

Figure 33. Total suspended solids load duration curve at site 1

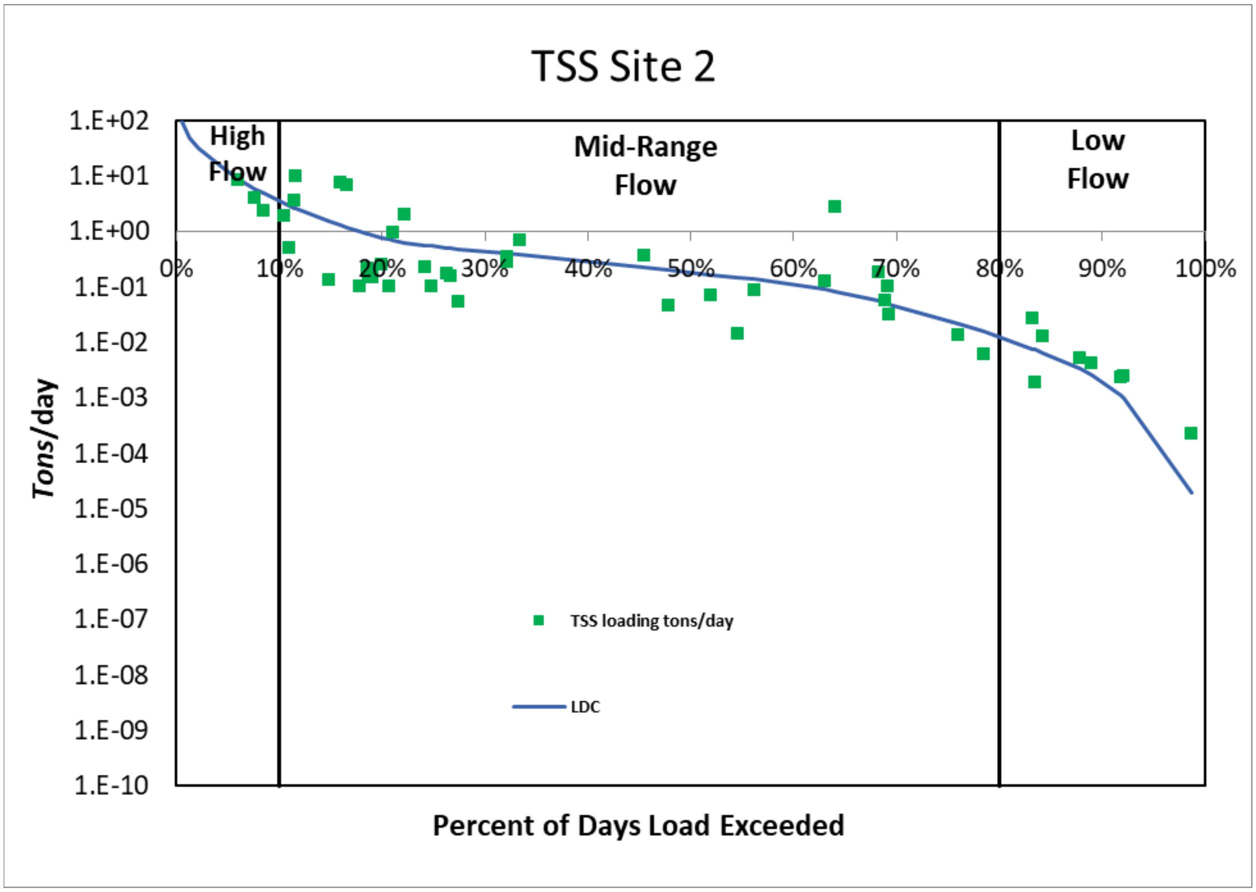

Figure 34. Total suspended solids load duration curve at site 2

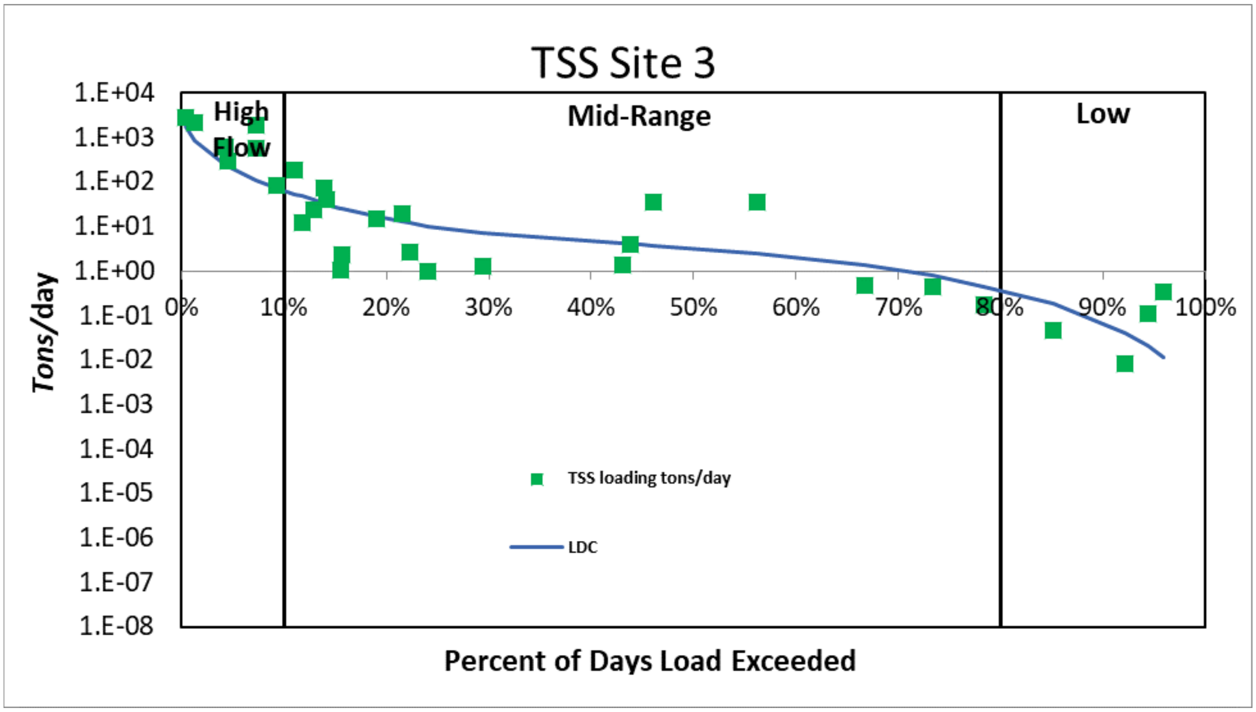

Figure 35. Total suspended solids load duration curve at site 3

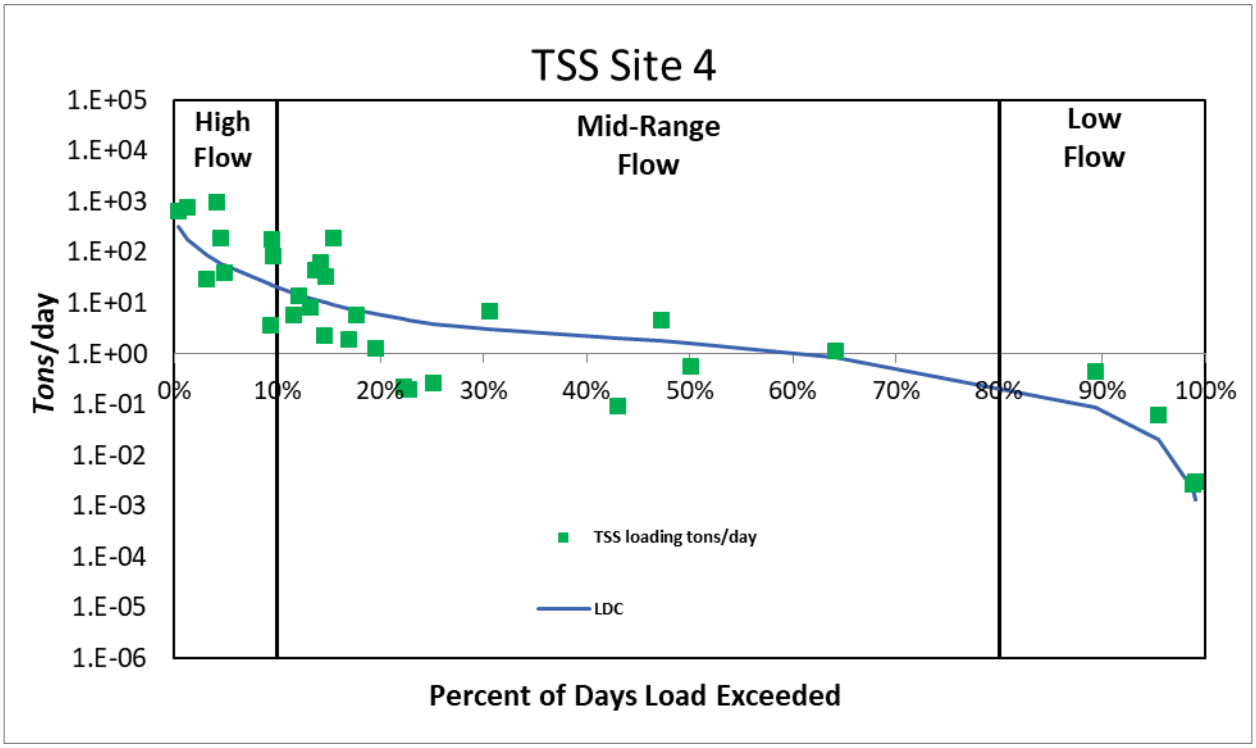

Figure 36. Total suspended solids load duration curve at site 4

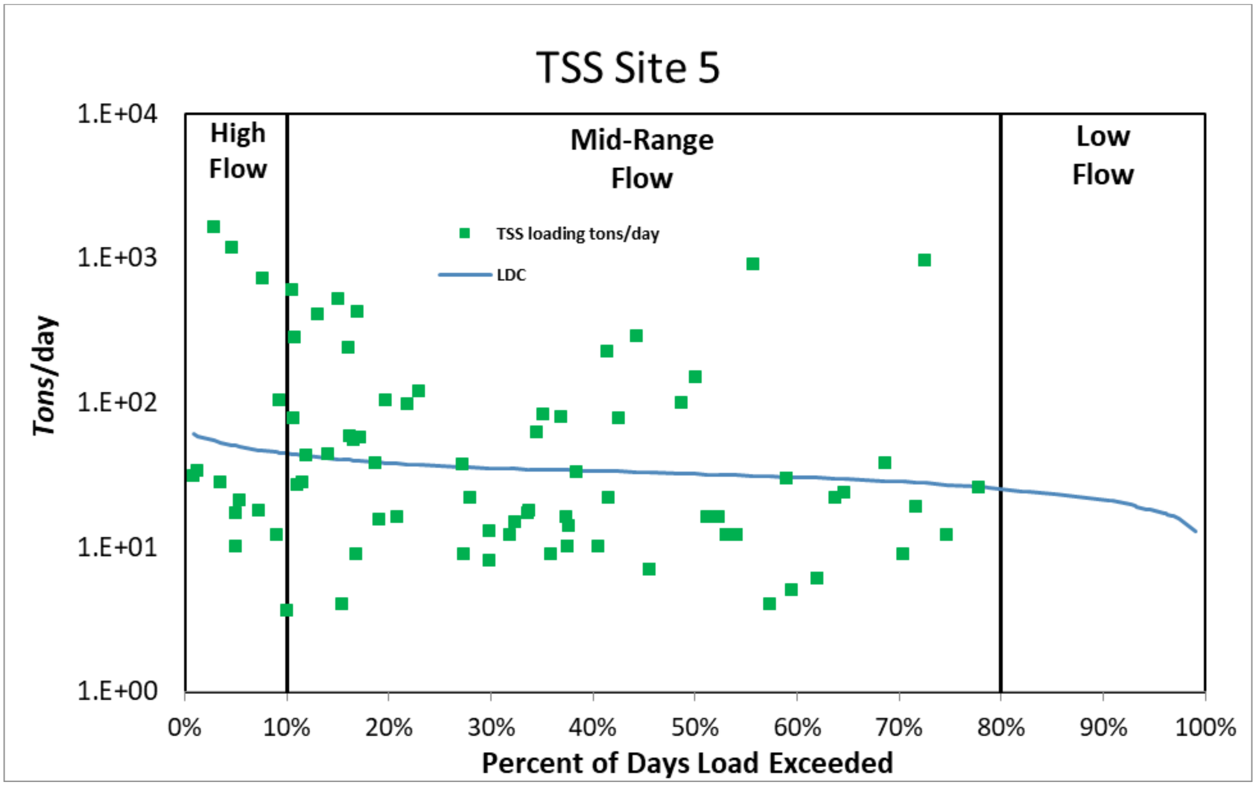

Figure 37. Total suspended solids load duration curve at site 5.

Conclusions and Follow Up

An analysis of water quality historical and collected data at five locations in Rowlett Creek was performed. The watershed was divided into five subwatersheds in order to better understand the sources and the causes of water quality impairments. Continuous long-term flow data was only available at the USGS station which matches site 5. Accordingly, a SWAT model was calibrated and validated and a flow time series for the Sites 1 to 4 were generated. Data for *E. coli,* nitrate/nitrite, Ammonia-N, Total Kjeldahl N, total phosphorus, and total suspended solids (TSS) was obtained from historical data collected by the cities and some samples collected during this project. The flow data was used to produce a flow duration curve at each of the five sites. Then water quality data from each subwatershed was used in combination with the flow duration curve to develop load duration curve (LDC) at each site. In each LDC, data was divided into high, mid-range and low flows. For each pollutant the allowable lead curve and a 10% Margin of Safety (MOS) were also plotted. For *E. coli*, the allowable limit was exceeded at all sites. At site 1, high flows and mid-range flows did exceed the allowable value much more than the low flows indicating stormwater as the main source of *E. coli* in that subwatershed. Site 2 showed a similar pattern to site one, except that the load dropped below the 10% MOS at the lower end of the low flows. Sites 3 and 4 showed a consistently large exceedance of allowable limits of *E. coli* at all flows. While site 5 has a pattern similar to sites 1 and 2, these results indicate clearly that measures to reduce load in stormwater are necessary. Further investigations will be needed to understand the higher load overall and at low flows in sites 3 and 4. Nitrate/nitrite levels are well below the allowable limit in sites 1 and 2. These levels increase to nearly equal the 10% MOS and slightly exceed it at sites 3 and 4. At site 5 the nitrate level clearly exceed the allowable limit at low flows and low mid-range flows but drops below the 10% MOS at higher flows. Ammonia is consistently lower than the 10% MOS at all sites except the low flows and the lower end of the mid-range flows in site 4. Further investigations will be done to determine sources of the exceedance at that site and determine appropriate BMPs to reduce it. TKN exceeded allowable limits at all sites for all flows. Given the low ammonia level at most sites, this is an indication of very high organic N in these streams. Organic nitrogen comes from wastewater treatments plants, animal waste and organic fertilizers. The sources and organic N and ways to reduce TKN concentrations will be investigated and presented in the WPP. Total Phosphorus was below the 10% MOS at sites 1, 2 and 5. At site 3 it was higher than the Allowable limit at high and upper mid-range flows but drops below the 10% MOS for low flows. At site 4, the trend is reversed with only the low flows exceeding the allowable limit. TSS values are hard to interpret, especially since there is no allowable limit for comparison. Nonetheless, the concentration values in sites 1 and 2 are quite low compared to concentrations in healthy watersheds. Sites 3 and 4 and to a lesser extent site 5 (which comprises the whole watershed) show some very high TSS concentrations, especially at higher flows. Since TSS can be carriers of pollutants (e.g., phosphorus and *E. coli*), measures that will reduce sediment transport in stormwater will be evaluated to reduce TSS concentrations in Rowlett Creek.

The results of this study indicate that all sites will require BMPs that will reduce *E. coli* in stormwater input. The high occurrence of organic N is also a concern that needs to be addressed. Sites 3 and 4 show higher needs for pollutant reduction for *E. coli*, nitrate, TKN and TP. A look at the land use of these two subwatersheds indicate higher urbanization and imperviousness. In addition, the Rowlett Creek WWTP is in the site 3 subwatershed. The data presented herein will provide great insight as a watershed protection plan is developed for Rowlett Creek.

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