Appendix

D

LOADING ANALYSIS INFORMATION
SALT CREEK WATERSHED

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D1 Analysis Methods

Aquatic life use was fully supported in the Salt Creek watershed (Muskingum River basin) according to Ohio EPA's 2008 field survey (Ohio EPA 2010). Recreation use, however, was not supported in multiple assessment units in which at least one site's geometric mean did not attain the water quality standards criteria. Twenty-three sites were sampled to determine recreation use support.

A study was carried out to develop an *E. coli* total maximum daily load (TMDL) as required by Section 303(d) of the Clean Water Act. The TMDL report defines in-stream bacterial conditions, potential sources, bacteria targets and needed reductions and recommends implementation strategies. This appendix gives details about the loading analysis that was completed.

Of the 20 sites found to be in recreation use non-attainment during the summer of 2008, a subset of nine representative sampling locations was established on six different streams within the watershed, and these sites were used for further study of the causes of recreation use non-attainment. These nine sites included four sites on the mainstem of Salt Creek and five sites on the tributaries showing impairment that have the largest flow contribution to Salt Creek.

D1.1 Justification of Method

In order to determine the magnitude of bacteria impairment and differentiate between types of bacteria sources contributing to impairment, load duration curves (LDCs) were calculated for analyzed sites following the methods described in U.S. EPA's *An Approach for Using Load Duration Curves in the Development of TMDLs* (U.S. EPA 2007). See Figure D-1 and Table D-1 for examples.

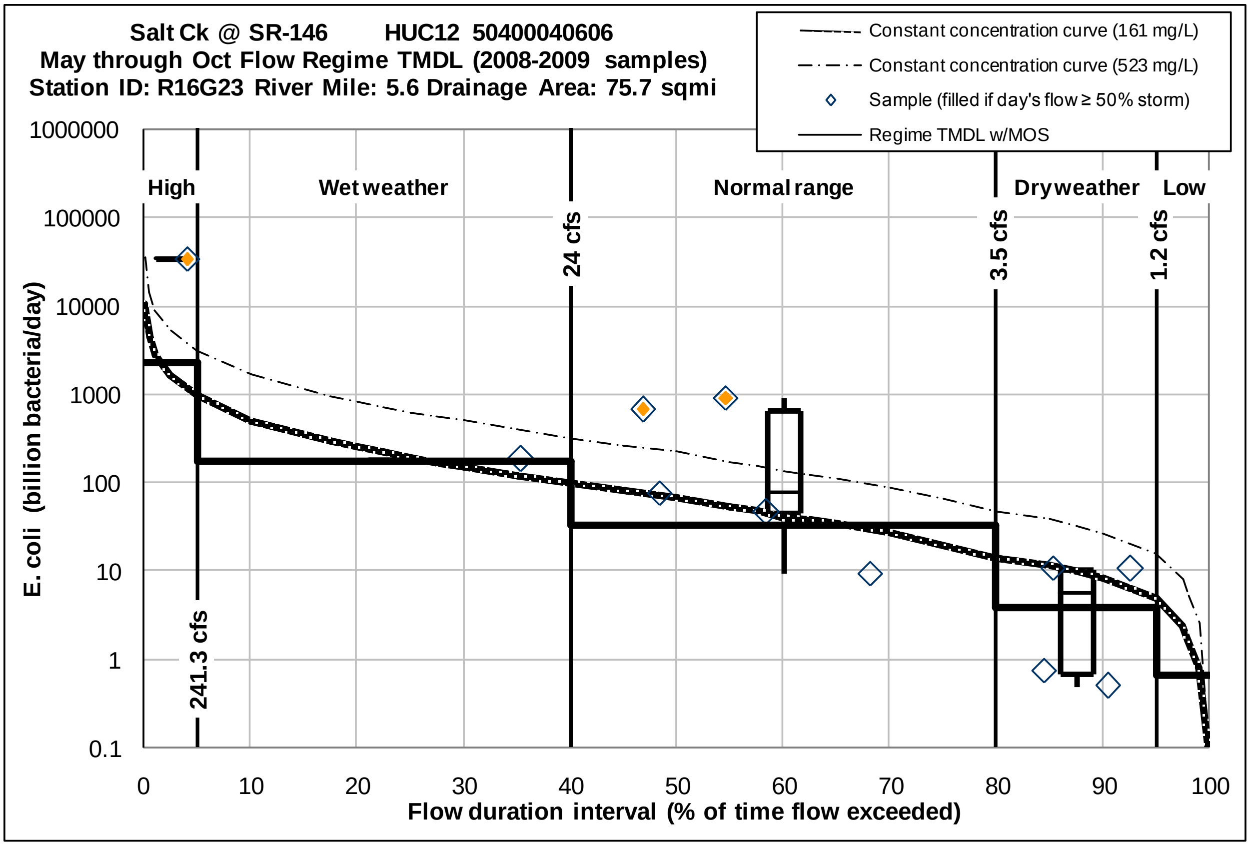

Figure D-1. Example load duration curve.

Table D-1. Example TMDL table from load duration curve calculations.

Flow regime TMDL analysis *E. coli* (billion bacteria/day)	**High**	**Wet weather**	**Normal range**	**Dry weather**	**Low**
Duration interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	1	1	5	4	N/A
Median sample load	33,209	179	75	5.54	N/A
TMDL	2,735.221	214.071	40.063	4.731	0.791
WLA: total	0.221	0.071	0.063	0.061	0.061
WLA: Zanesville MS4	0.16	0.01	0.002	0	0
WLA: ODOT Rest Area 5-20	0.061	0.061	0.061	0.061	0.061
LA	2,079	162	30	3.53	0.54
MOS: 20%	547	43	8	0.95	0.16
AFG: 4%	109	9	2	0.19	0.03
Nonpoint (LA) % load reduction required	**92%**	**0%**	**47%**	**15%**	N/A

Values were adjusted for rounding.

D1.2 Load Duration Curves

Load duration curves (LDCs) can assist in distinguishing between point and nonpoint sources that contribute to *E. coli* loading by highlighting the flow conditions under which impairment occurs. Load duration curves plot the concentration of a given pollutant according to the flow at which the sample was collected. The acceptable load, based on water quality standards, varies according to flow. Hence, exceedances of the allowable load at any particular flow indicate times at which excessive loads are entering the stream. Because of this relationship to flow, load duration curves can assist in distinguishing between sources of load exceedances. For example, at lower flows when there is little precipitation creating runoff, there is little to no in-stream flow to dilute *E. coli* entering the stream from external sources. Because of this, any *E. coli* contributions to the stream during low flows are likely from point sources. Examples of bacteria point sources include combined sewer overflows (CSOs), municipal separate storm sewer systems (MS4s) or wastewater treatment plants. High bacteria levels under low flow conditions may also indicate direct nonpoint sources, such as concentrated cattle grazing in the stream channel, leaking sewer lines, or failing home sewage treatment systems.

Under higher flow conditions, point sources are typically diluted by in-stream flow. Therefore, high *E. coli* loading is likely caused by precipitation washoff or erosion of contaminated land surfaces. Some typical nonpoint sources of *E. coli* include manure spreading, stream bank erosion, and washoff from livestock feeding operations.

When high *E. coli* loads exist under mid-range flow conditions, or high loads occur under all conditions, they can be attributed to a mixture of point and nonpoint sources. Site investigation using digital mapping, aerial photography or an on-the-ground visit can help conservation staff develop priorities for implementation based on the LDC evidence for either point or nonpoint sources of *E. coli*.

It is important to note that the load duration curve method does not enable one to attribute impairment to any one particular source; instead it is a tool used to determine the flow conditions under which impairment occurs and the probable types of sources contributing to that impairment.

An outline of LDC development specific to the Salt Creek watershed is as follows:

1. An historical daily flow record was obtained for the USGS Gage 03149500 “Salt Creek near Chandlersville, OH” for the period of record containing November 1, 2000 through March 31, 2009. Dates outside of the recreation season (May 1 through October 31) were excluded from the record. This flow record was then ordered and ranked to determine, for each daily flow, the percentage of the period of record when that flow was equaled or exceeded. This flow exceedance range constitutes the x-axis in a graphical LDC plot.
2. In-stream bacteria loads were determined for each sampling event using stream sample bacteria concentration in conjunction with calculated instantaneous flow data for each sampling location. At the appropriate flow exceedance, the corresponding *E. coli* concentration for a stream sample was plotted as a point on the y-axis of the LDC. In order to determine instantaneous flow at the time of each sampling event, the following steps were taken:
    a. Hourly flow data for each sampling date were obtained from USGS 03149500 “Salt Creek near Chandlersville, OH”.
    b. Sampling locations with larger drainage areas, similar to the USGS gage site, were assigned scaled hourly flows based on the ratio of each sampling location’s drainage area compared to that of the gage site.
    c. Six flow measurements were made at a smaller, tributary sampling location (*Buffalo Fork at Okey Rd.*) and plotted in a regression against the corresponding USGS gage flow. This relationship was used to generate hourly flows at *Buffalo Fork at Okey Rd*.
    d. Sampling locations with smaller drainage areas were assigned scaled hourly flows based on the ratio of each sampling location’s drainage area compared to that of *Buffalo Fork at Okey Rd*.

3. Target *E. coli* loads were calculated by applying the applicable *E. coli* WQS concentration value at each flow exceedance value for the entire flow duration interval.
4. A margin of safety was calculated to account for unknown variability.
5. An allowance for future growth, based upon population growth projections, was factored into any needed load reductions.
6. The LDCs were divided into five hydrologic regimes and within each regime the total required nonpoint load reduction percentage is calculated by incorporating the margin of safety and allowance for future growth into the target load and determining the difference between this target and the existing load in each flow regime.

A "TMDL table" is associated with each LDC, detailing the information that is graphically presented in the LDC figure. Each table contains the following information for each hydrologic regime:

- number of samples
- median sample *E. coli* load
- total maximum daily load (TMDL)
- total wasteload allocation (WLA) and individual WLAs, including MS4
- nonpoint source load allocation (LA)
- margin of safety (MOS) load
- allowance for future growth (AFG) load
- nonpoint source (%) load reduction required.

Target and Existing Deviation

For a given impaired site, each hydrologic condition (high flows, moist conditions, mid-range conditions, dry conditions or low flows) was assigned a target bacteria loading rate (cfu/day) by multiplying the class B *E. coli* water quality standard, 161 cfu/100 ml, by the median flow of each hydrologic class at that site and a constant, used to convert cubic feet per second to milliliters per day: $T = Q_m * S * C$; where T = target bacteria load, Q_m = median flow for a specific hydrologic class, S = water quality standard, 161 cfu/100 ml and C = a unit conversion constant (cubic feet per second to milliliters per day). Median observed bacteria loads in each hydrologic condition were compared to the median target value in that condition, after incorporating a margin of safety and allowance for future growth, in order to quantify needed reductions.

To use a hypothetical example, assume the median flow under 'dry weather' at the site *Green River at Horse Camp,* a class B river*,* is 50 cfs, the margin of safety is 40% and the allowance for future growth is 4%. The target bacteria load would be determined as follows:

(i) 50 (cfs) * (1 – (0.4 + 0.04) *161 (cfu/100 ml) * C = 1.26×10^{11} (cfu/day)

The actual bacteria load would then be calculated by substituting the target concentration with the median observed concentration over the same hydrologic range. In this case let it be 200 (cfu/100 ml).

(ii) 50 (cfs) * 200 (cfu/100 ml) * C = 2.45×10^{11} (cfu/day)

Finally, if the observed load is larger than the target load, the total nonpoint load reduction is expressed as a percentage:

(iii) (2.45×10^{11} (cfu/day) – 1.26×10^{11} (cfu/day)) / 2.45×10^{11} (cfu/day)* 100%
= 49% total nonpoint load reduction

Downstream Class A Recreation Use Protection

In order to protect downstream class A recreation use attainment, any facilities within 5 river miles upstream of a class A receiving water are also held to the more-protective class A WQS. Salt Creek flows into the Muskingum River south of Zanesville at the town of Philo. The entire length of the Muskingum River is designated as class A PCR in OAC Rule 3745-1-24; for class A streams 126 cfu/100 ml is the *E. coli* WQS. There are no NPDES permitted facilities within five miles of the Muskingum River.

Wasteload Allocation

There are two individual NPDES permitted sanitary dischargers in the Salt Creek basin. Each of these dischargers is assigned a wasteload allocation (WLA) based upon the design flow of the treatment facility and the water quality standard applicable to its receiving water. Because a given facility operates at most times at some fraction of its design flow, the WLA for each facility includes an amount of reserve capacity up to the design flow of the facility.

The wasteload allocation for each of these facilities is included for all nested, downstream LDCs within the watershed. For example, the ODOT Rest Stop 5-20 WLA is included in the LDC for the most immediate downstream sampling location, *Salt Creek at US-40 (RM 12.91)*, as well as the two other downstream sampling locations, *Salt Creek at SR-146 (RM 5.6)* and *Salt Creek adjacent Manns Fork Road (RM 1.1)*.

<u>Blue Rock State Park</u> (Ohio EPA Permit # 0PP00088*AD)
Located at 7924 Cutler Lake Road, the facilities consist of two primitive campground areas as well as a beach house facility located near Cutler Lake with full restroom facilities. The sanitary wastewater generated at the beach house receives treatment from an extended aeration wastewater treatment plant with an average daily design flow of 3,000 gallons per day (0.003 MGD). The treated effluent undergoes primary settling and secondary treatment prior to being disinfected and discharged to Manns Fork downstream of the lake spillway.

<u>ODOT Rest Stop Facility 5-20</u> (Ohio EPA Permit # 0PP00052*CD)
Located along the westbound lane of Interstate 70 approximately four miles west of Norwich, the rest stop consists of two full service restrooms which discharge sanitary wastewater to an extended aeration package plant with an average daily design flow of 10,000 gallons per day (0.01 MGD). The sanitary waste receives primary, secondary and tertiary treatment through an initial trash trap, aeration basins with clarifiers and surface sand filters. Following the tertiary treatment from the sand filters the treated effluent is disinfected in the months of May through October with ultraviolet radiation and discharged to Frog Run.

<u>Municipal Separate Storm Sewer System</u>
Allocations for the one Phase II MS4 in the Salt Creek watershed were determined based on the area of the MS4 draining to each assessment location. Townships, municipalities, and urbanized areas as documented in geographic information system (GIS) files within the Salt Creek watershed were used to determine the total regulated area for each MS4. These areas were then used to estimate WLAs based on the proportion of the upstream drainage area located within the MS4 boundaries. Storm water runoff was assumed to occur only during high flows, wet weather and normal flow conditions.

Load Allocation

The load duration curve method was selected to assign in-stream bacteria loads at a given site to one or several potential bacteria sources (see U.S. EPA 2007). In a load duration curve, patterns of bacteria impairment can be examined and addressed relative to the flow conditions under which they occur which allows a set of potential bacteria sources specific to a given site to be highlighted. Under the highest flow conditions, point sources are likely to be masked by in-stream dilution; therefore high bacteria measurements in these conditions are associated with precipitation washoff or erosion of contaminated land surfaces. Impairments under mid-range flows can be caused by a mixture of point and nonpoint sources. Under the lowest flow conditions, recreation use impairments are generally attributable to sources not associated with runoff events, such as a failing HSTS or in-stream livestock.

Each sampling location was visited under a range of different flow conditions approximately 11 different times during the recreation seasons of 2008 and 2009. Additionally, during sampling events in the watershed, Ohio EPA made observations regarding the land use (i.e., housing density and location of livestock farms) proximal to each sampling location to outline potential sources of bacteria.

Daily loading of bacteria was calculated for each site utilizing *E. coli* stream sample data. Existing in-stream loads, target loads and load duration curves were calculated from the collected data. Using these data and notes about land use, recommendations regarding sources and potential implementation were developed.

Margin of Safety

The Clean Water Act requires that a TMDL include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality. U.S. EPA guidance explains that the MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as loadings set aside for the MOS).

An implicit MOS is incorporated in various ways, including in the derivation of the *E. coli* water quality criterion and in not considering the die-off of pathogens as part of the TMDL calculations. The implicit MOS is also enhanced by the use of the geometric mean target (which is a seasonal target) to calculate daily loads. In addition, an explicit MOS has been applied as part of all of the bacteria TMDLs by reserving 20% of the allowable load because of the broad fluctuation of *E. coli* concentrations that occurs in nature and the relatively low numbers of data points available for this analysis. The explicit MOS in each allocation is shown in the TMDL allocation tables throughout Section 5.

Critical Conditions

Critical conditions for in-stream bacteria vary by source and can occur across the hydrograph, from washoff of land-deposited bacteria under moist conditions to in-stream livestock and failing home sewage treatment systems (HSTSs) in low flow conditions. Nonpoint sources to which bacteria loads are allocated in the Salt Creek basin include livestock, both manure washoff and in-stream animals, and failing HSTSs.

Allowance for Future Growth

The population of Muskingum County, which contains the entire Salt Creek watershed, is projected to grow by 4% from 2010 to 2020 (ODD 2003). In order to ensure recreation use attainment over the next ten years of population growth, an allowance for future growth (AFG) of 4% of the assimilative capacity was reserved from each TMDL.

D2 Results

In the sequence of figures and tables below, the load duration curve for each site (Figures D-2 through D-10) is shown, followed by the TMDL table for that site (Tables D-2 through D-10).

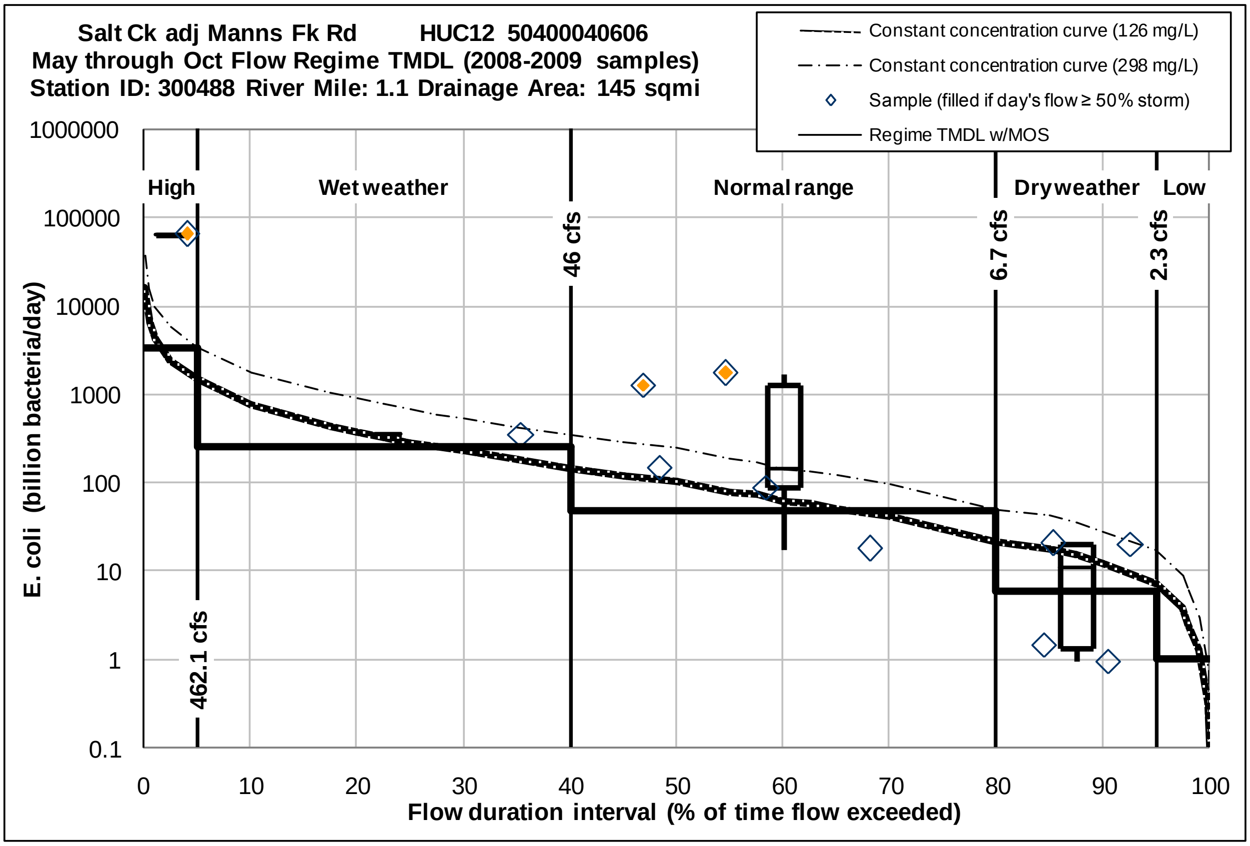

Figure D-2. Load duration curve for site on Salt Creek adjacent to Manns Fork Road.

Table D-2. TMDL table for site on Salt Creek adjacent to Manns Fork Road.

Flow regime TMDL analysis ***E. coli*** **(billion bacteria/day)**	**High**	**Wet weather**	**Normal range**	**Dry weather**	**Low**
Duration interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	1	1	5	4	N/A
Median sample load	63,611	343	143	10.60	N/A
TMDL	4,101.639	319.119	59.089	7.089	1.239
WLA: total	0.639	0.119	0.089	0.079	0.079
WLA: Zanesville MS4	0.56	0.04	0.01	0	0
WLA: ODOT Rest Area 5-20	0.061	0.061	0.061	0.061	0.061
WLA: Blue Rock State Park	0.018	0.018	0.018	0.018	0.018
LA	3,117	242	45	5.31	0.86
MOS: 20%	820	64	12	1.42	0.25
AFG: 4%	164	13	2	0.28	0.05
Nonpoint (LA) % load reduction required	**94%**	**7%**	**59%**	**33%**	N/A

Values were adjusted for rounding.

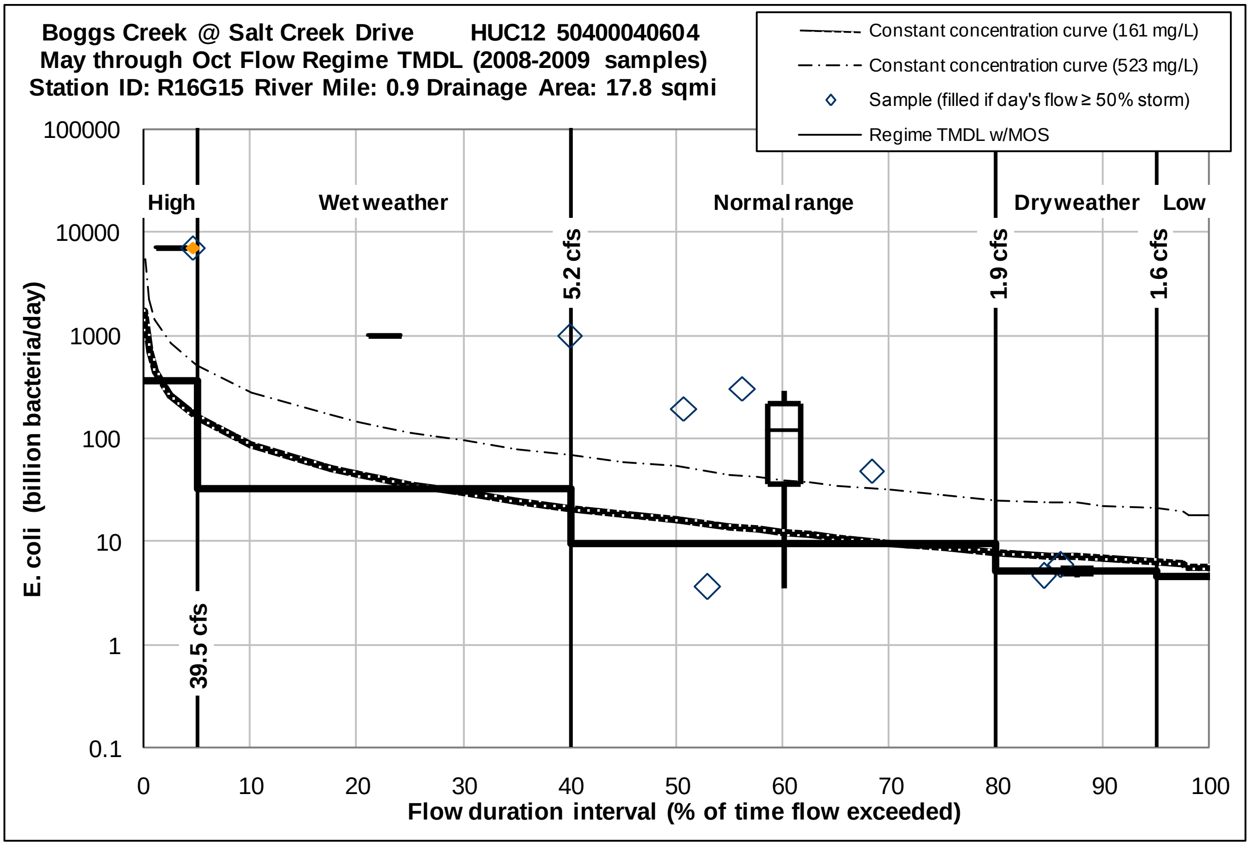

Figure D-3. Load duration curve for site on Boggs Creek at Salt Creek Drive.

Table D-3. TMDL table for site on Boggs Creek at Salt Creek Drive.

Flow regime TMDL analysis *E. coli* (billion bacteria/day)	**High**	**Wet weather**	**Normal range**	**Dry weather**	**Low**
Duration interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	1	1	4	2	N/A
Median sample load	6,980	978	118	5.16	N/A
TMDL	439.35	40.15	11.45	6.30	5.51
WLA: Zanesville MS4	35.35	3.15	0.95	0	0
LA	298	27	8	4.79	4.19
MOS: 20%	88	8	2	1.26	1.10
AFG: 4%	18	2	0.5	0.25	0.22
Nonpoint (LA) % load reduction required	**94%**	**96%**	**90%**	**0%**	N/A

Values were adjusted for rounding.

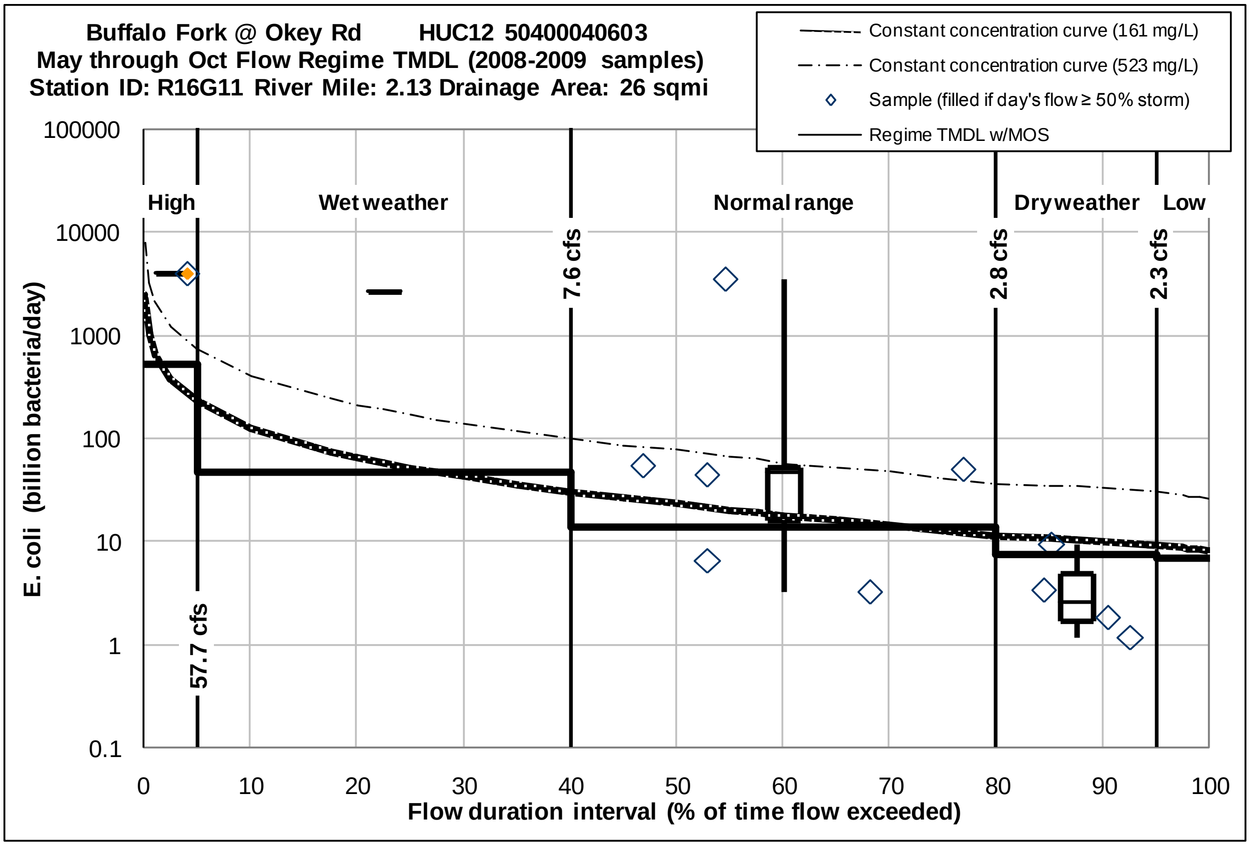

Figure D-4. Load duration curve for site on Buffalo Fork at Okey Road.

Table D-4. TMDL table for site on Buffalo Fork at Okey Road.

Flow regime TMDL analysis *E. coli* (billion bacteria/day)	**High**	**Wet weather**	**Normal range**	**Dry weather**	**Low**
Duration interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	1	1	6	4	N/A
Median sample load	3,956	2,597	47	2.56	N/A
TMDL	640	57	17	9.06	8.27
WLA	0	0	0	0	0
LA	486	44	13	6.89	6.29
MOS: 20%	128	11	3	1.81	1.65
AFG: 4%	26	2	0.7	0.36	0.33
Nonpoint (LA) % load reduction required	**84%**	**98%**	**64%**	**0%**	N/A

Values were adjusted for rounding.

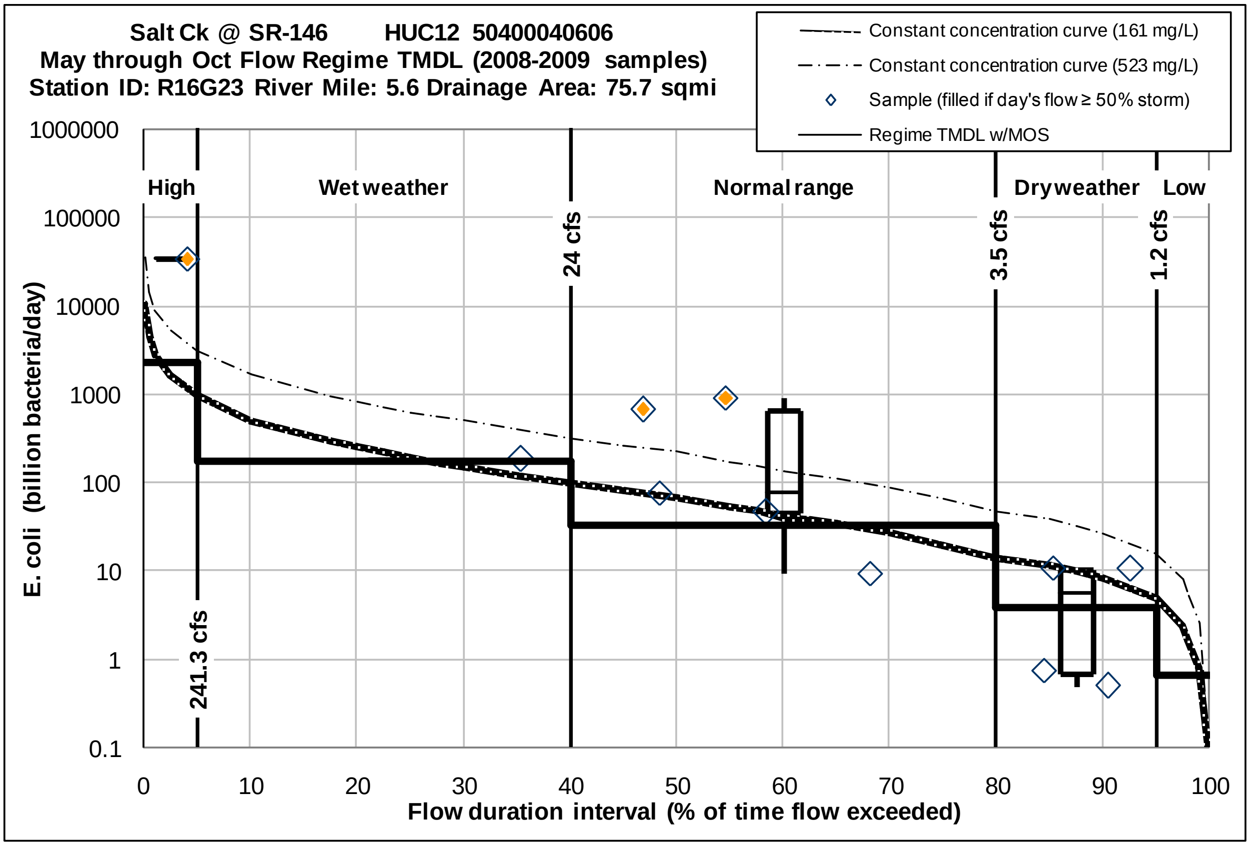

Figure D-5. Load duration curve for site on Salt Creek at State Route 146.

Table D-5. TMDL table for site on Salt Creek at State Route 146.

Flow regime TMDL analysis *E. coli* (billion bacteria/day)	High	Wet weather	Normal range	Dry weather	Low
Duration interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	1	1	5	4	N/A
Median sample load	33,209	179	75	5.54	N/A
TMDL	2,735.221	214.071	40.063	4.731	0.791
WLA: total	0.221	0.071	0.063	0.061	0.061
WLA: Zanesville MS4	0.16	0.01	0.002	0	0
WLA: ODOT Rest Area 5-20	0.061	0.061	0.061	0.061	0.061
LA	2,079	162	30	3.53	0.54
MOS: 20%	547	43	8	0.95	0.16
AFG: 4%	109	9	2	0.19	0.03
Nonpoint (LA) % load reduction required	**92%**	**0%**	**47%**	**15%**	N/A

Values were adjusted for rounding.

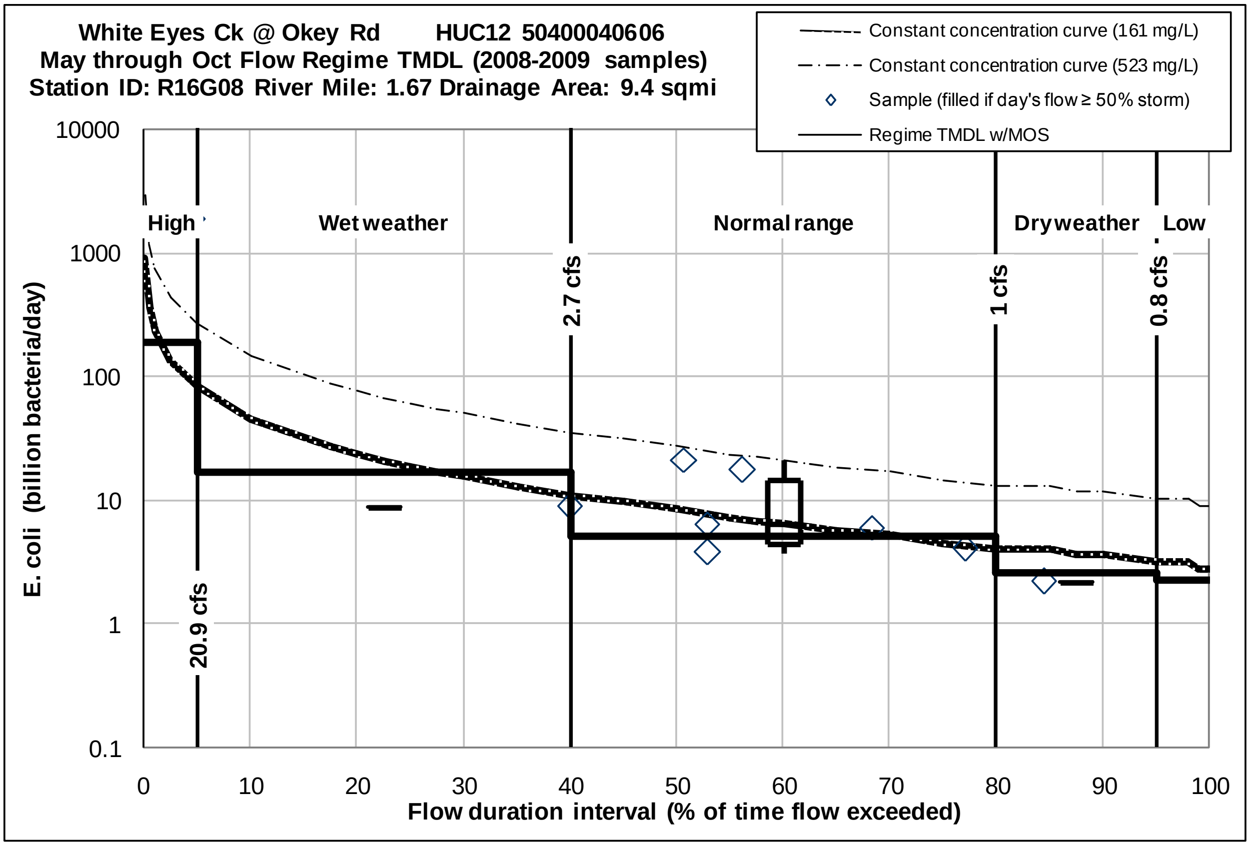

Figure D-6. Load duration curve for site on White Eyes Creek at Okey Road.

Table D-6. TMDL table for site on White Eyes Creek at Okey Road.

Flow regime TMDL analysis ***E. coli*** **(billion bacteria/day)**	**High**	**Wet weather**	**Normal range**	**Dry weather**	**Low**
Duration interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	1	1	6	1	N/A
Median sample load	1,843	9	6	2.15	N/A
TMDL	231	20	6.0	3.15	2.76
WLA	0	0	0	0	0
LA	176	15	4.4	2.39	2.10
MOS: 20%	46	4	1.3	0.63	0.55
AFG: 4%	9	1	0.3	0.13	0.11
Nonpoint (LA) % load reduction required	**87%**	**0%**	**0%**	**0%**	N/A

Values were adjusted for rounding.

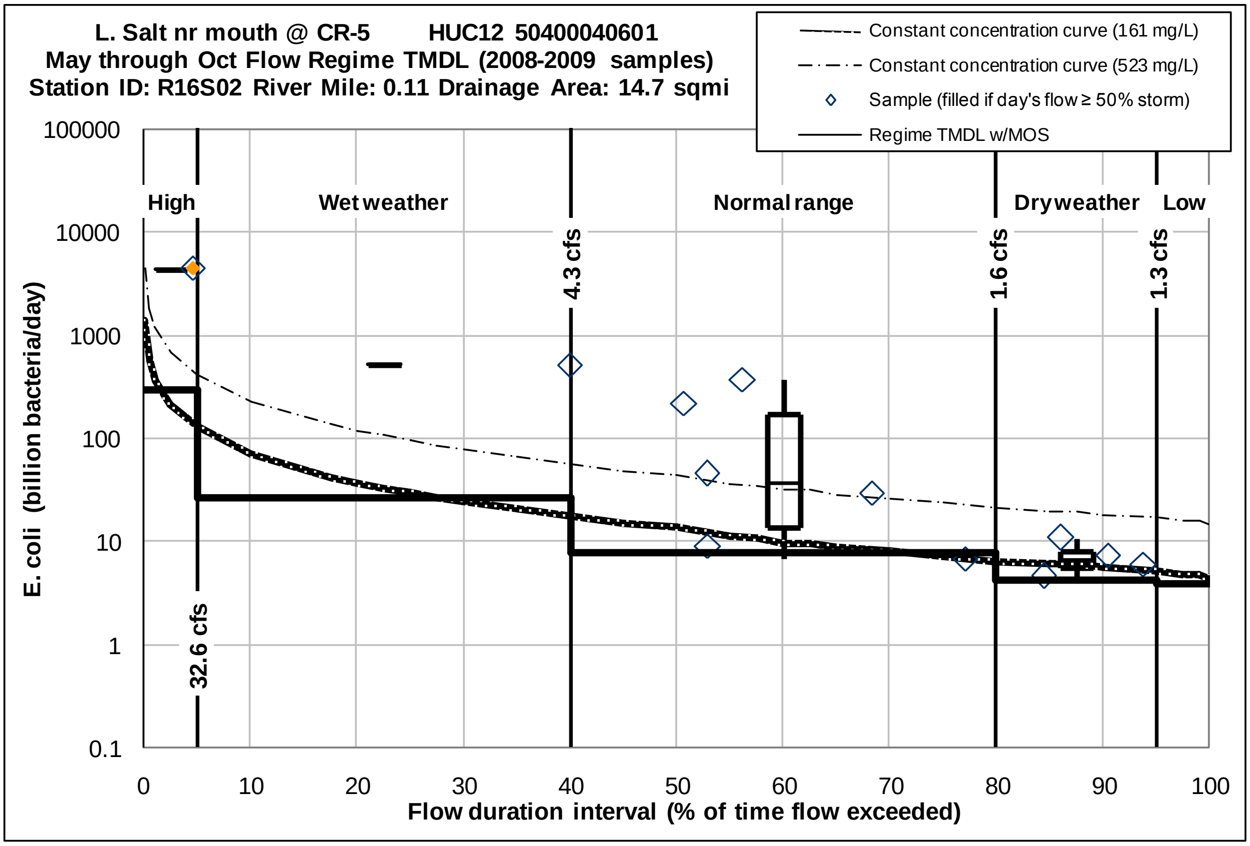

Figure D-7. Load duration curve for site on Little Salt Creek near the mouth at County Road 5.

Table D-7. TMDL table for site on Little Salt Creek near the mouth at County Road 5.

Flow regime TMDL analysis *E. coli* (billion bacteria/day)	**High**	**Wet weather**	**Normal range**	**Dry weather**	**Low**
Duration interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	1	1	6	4	N/A
Median sample load	4,364	504	37	6.50	N/A
TMDL	365	32.25	9.76	5.11	4.73
WLA: Zanesville MS4	13.96	1.25	0.36	0	0
LA	265	24	7	3.89	3.59
MOS: 20%	72	6	2	1.02	0.95
AFG: 4%	14	1	0.4	0.20	0.19
Nonpoint (LA) % load reduction required	**92%**	**94%**	**74%**	**21%**	N/A

Values were adjusted for rounding.

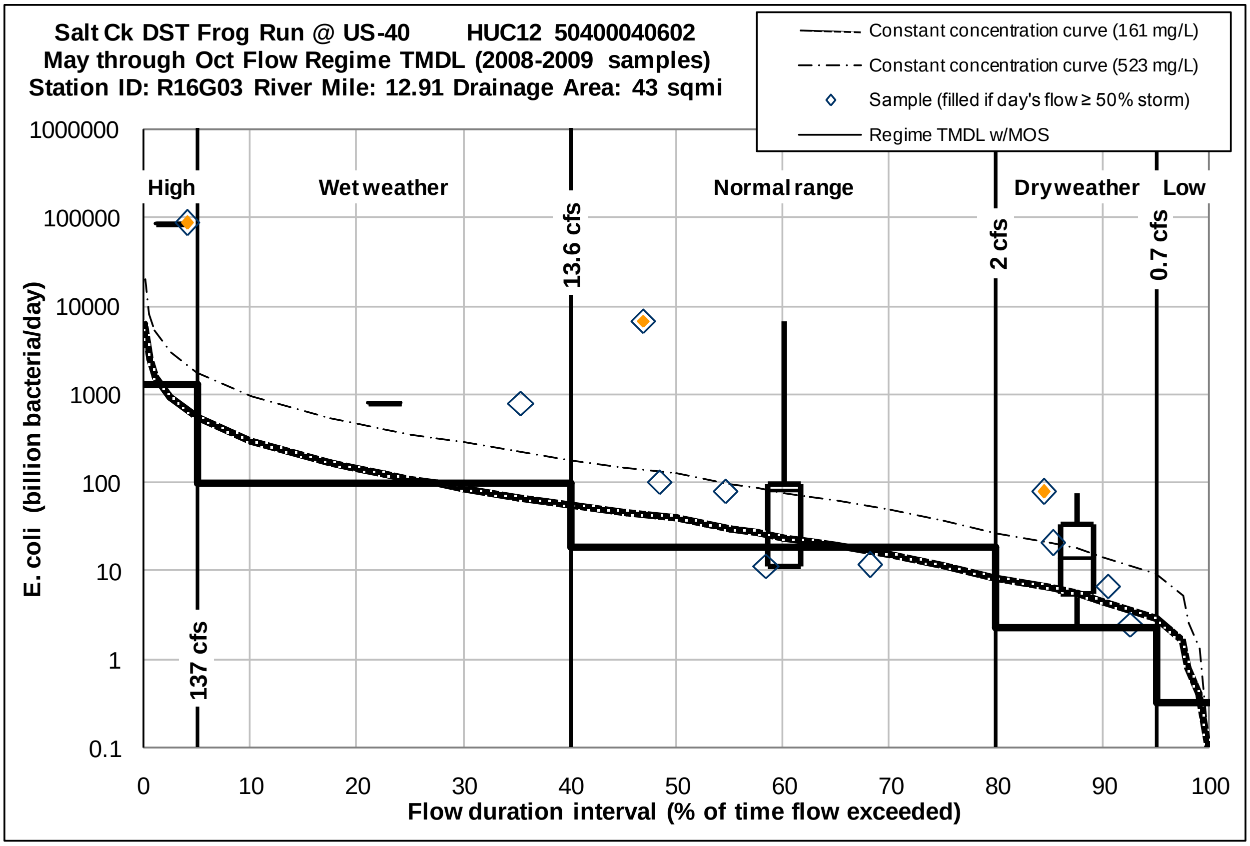

Figure D-8. Load duration curve for site on Salt Creek downstream of Frog Run at U.S. Route 40.

Table D-8. TMDL table for site on Salt Creek downstream of Frog Run at U.S. Route 40.

Flow regime TMDL analysis ***E. coli*** **(billion bacteria/day)**	**High**	**Wet weather**	**Normal range**	**Dry weather**	**Low**
Duration interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	1	1	5	4	N/A
Median sample load	84,698	773	78	13.31	N/A
TMDL	1,554.061	121.061	21.961	2.761	0.401
WLA: ODOT Rest Area 5-20	0.061	0.061	0.061	0.061	0.061
LA	1,181	92	17	2.04	0.24
MOS: 20%	311	24	4	0.55	0.08
AFG: 4%	62	5	0.9	0.11	0.02
Nonpoint (LA) % load reduction required	**98%**	**84%**	**72%**	**79%**	N/A

Values were adjusted for rounding.

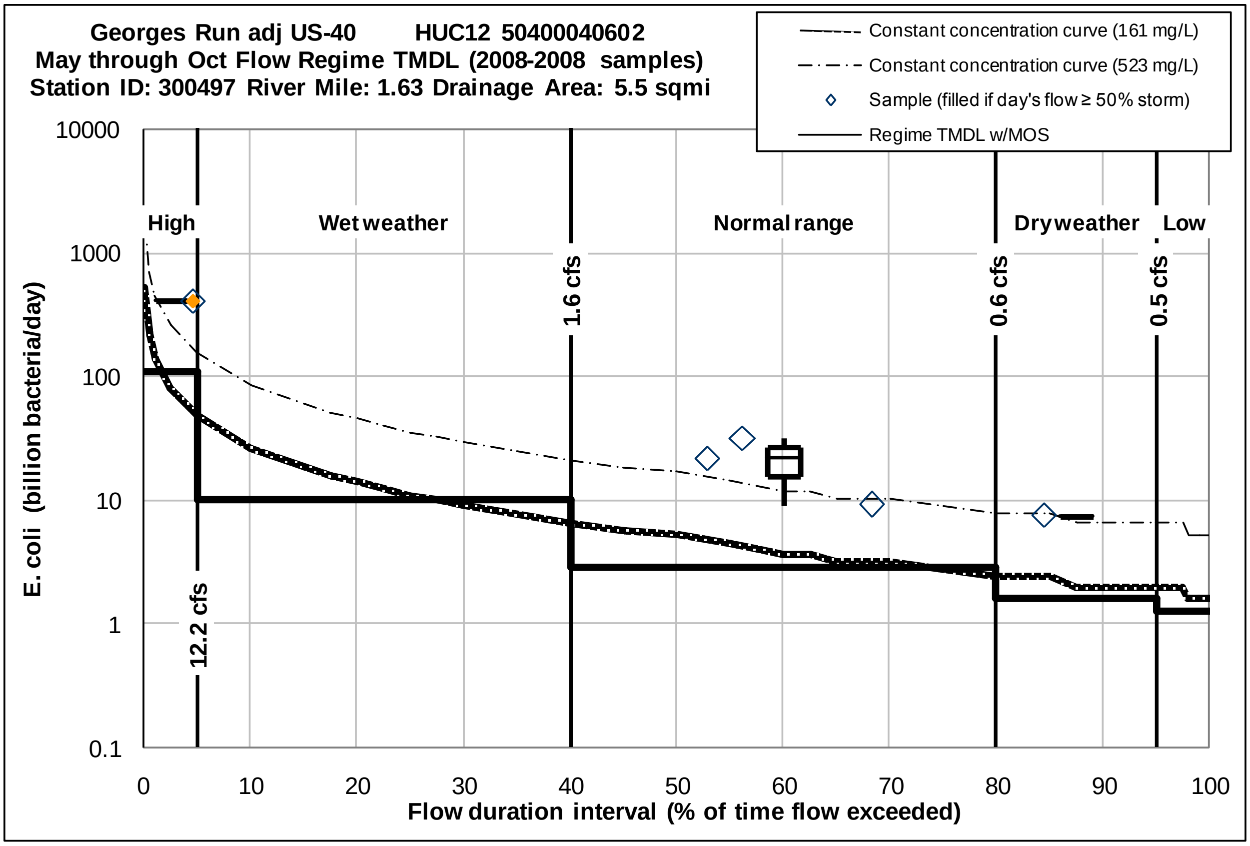

Figure D-9. Load duration curve for site on Georges Run adjacent to U.S. Route 40.

Table D-9. TMDL table for site on Georges Run adjacent to U.S. Route 40.

Flow regime TMDL analysis ***E. coli*** **(billion bacteria/day)**	**High**	**Wet weather**	**Normal range**	**Dry weather**	**Low**
Duration interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	1	N/A	3	1	N/A
Median sample load	400	N/A	22	7.42	N/A
TMDL	136	13	3.8	1.97	1.58
WLA	0	0	0	0	0
LA	104	10	3	1.50	1.20
MOS: 20%	27	2	0.7	0.39	0.32
AFG: 4%	5	0.5	0.1	0.08	0.06
Nonpoint (LA) % load reduction required	**66%**	N/A	**83%**	**73%**	N/A

Values were adjusted for rounding.

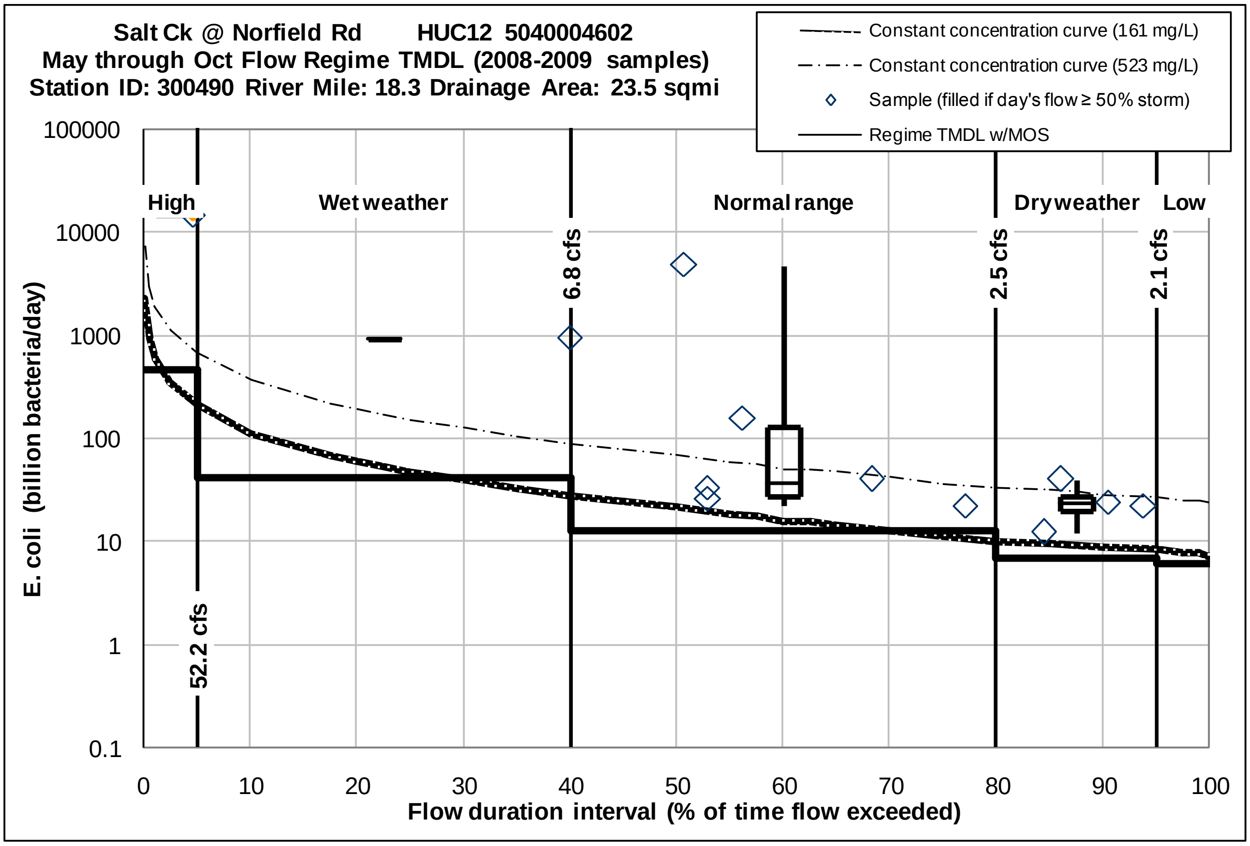

Figure D-10. Load duration curve for site on Salt Creek at Norfield Road.

Table D-10. TMDL table for site on Salt Creek at Norfield Road.

Flow regime TMDL analysis *E. coli* (billion bacteria/day)	**High**	**Wet weather**	**Normal range**	**Dry weather**	**Low**
Duration interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	1	1	6	4	N/A
Median sample load	14,480	922	36	22.61	N/A
TMDL	578	52	14.6	8.27	7.48
WLA	0	0	0	0	0
LA	439	40	11	6.29	5.68
MOS: 20%	116	10	3	1.65	1.50
AFG: 4%	23	2	0.6	0.33	0.30
Nonpoint (LA) % load reduction required	**96%**	**94%**	**59%**	**63%**	N/A

Values were adjusted for rounding.

D3 References

ODD (Ohio Department of Development – Office of Strategic Research). 2003. *Projected Population: County Totals*. Published on: http://www.development.ohio.gov/research/FILES/P200/countytotals.pdf.

Ohio EPA (Ohio Environmental Protection Agency – Division of Surface Water). 2010. *Biological and Water Quality Study of Salt Creek and Selected Tributaries (Muskingum River Basin)*. Published at: http://www.epa.ohio.gov/portals/35/documents/SaltCreek_MuskingumTSD2008.pdf.

U.S. EPA (United States Environmental Protection Agency – Office of Oceans, Wetlands and Watersheds). 2007. *An Approach for Using Load Duration Curves in the Development of TMDLs*. Published in: EPA 841-B-07-006.