

CHAPTER 4: ELEMENT B-ESTIMATING LOADS AND REDUCTIONS NEEDED

4.1 BASELINE POLLUTANT LOADING AND REDUCTIONS NEEDED FOR PRIMARY POLLUTANTS OF CONCERN

The primary pollutants of concern that this Deer Creek Watershed Management Plan addresses are *E. coli* and Chloride. Deer Creek and its tributary, Black Creek, are identified as impaired for chloride on the 2020 303(d) list. Twomile Creek is identified as impaired to *E. coli* on that list too. A Total Maximum Daily Load (TMDL) report for *E. coli* for Deer Creek and Black Creek was approved by the U. S. Environmental Protection Agency (EPA) in 2019. See Appendix 2-A Bacterial TMDL. A TMDL for chloride for Deer Creek and Black Creek is being prioritized as high and is identified on the 2020 303(d) List as being scheduled for 2025. A TMDL for *E. coli* for Twomile Creek is being prioritized as medium and is scheduled for 2026-2030 on that list too.

4.11 E. COLI LOADING

The Missouri Department of Natural Resources (MoDNR) provided estimates of existing *E. coli* loading and concentrations for Deer Creek Water Body ID (WBID) 3826 and Black Creek Water Body ID (WBID) 3825. The existing mean concentration is 6,628 counts/100mL for Deer Creek and 9,161 counts/100mL for Black Creek. These concentrations were used along with stream flow to calculate load reductions needed for BMP implementation in the Deer Creek and Black Creek subwatersheds, as appropriate. Tables 4-1, 4-2, and 4-3 present estimated *E. coli* reductions needed for each water body to attain water quality standards, which were calculated using the load duration curve and available water quality data collected from the water body. The load duration curves for Black Creek and Deer Creek can be found in the Bacteria TMDL¹ and presents *E. coli* sample data and the corresponding stream flow at the time sampling occurred. The load duration curve (Figure 1) and estimate of the *E. coli* reduction needed for Twomile Creek (WBID) 4079 were prepared to support this plan and are not part of a total maximum daily load study. A TMDL for *E. coli* for Twomile Creek is being prioritized as medium and is scheduled for 2026-2030. **Average reduction in *E. coli* loading needed is 83% reduction in Black Creek, 70% reduction in Deer Creek, and 57% reduction in Twomile Creek.**

Table 4-1. Average *E. coli* loading and reductions needed at various stream flow conditions in Black Creek

Flow Condition	Percent of Time Flow is Met or Exceeded	Flow (cfs)	TMDL (counts/day)	TMDL Target (counts/100 mL)	Estimated Existing Load (counts/day)	Existing concentration (counts/100mL)	Reduction Needed (%)
Low Flow	95%	0.43	2.16E+09	206	4.00E+09	380	46
Dry Conditions	75%	0.88	4.46E+09	206	2.39E+10	1,110	81
Mid Range	50%	1.64	8.29E+09	206	8.71E+10	2,171	90
Moist Conditions	25%	4.37	2.20E+10	206	8.70E+11	8,137	97

¹ Appendix 2-A Bacterial TMDL pgs. 23-24

High Flows	10%	18.31	9.23E+10	206	1.13E+13	25,225	99
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Average Existing load and concentration = 2.46E+12 counts/day or 9,161 counts/100mL

Average reduction needed = 83%

Black Creek Flows

Flow Condition	Range of Expected Flows (cfs)
Low Flow	0 cfs to 0.56
Dry Conditions	>0.56 to 1.21
Mid Range	>1.21 to 2.07
Moist Conditions	>2.07 to 16.3
High Flows	>16.3

Table 4-2. Average *E. coli* loading and reductions needed at various stream flow conditions in Deer Creek

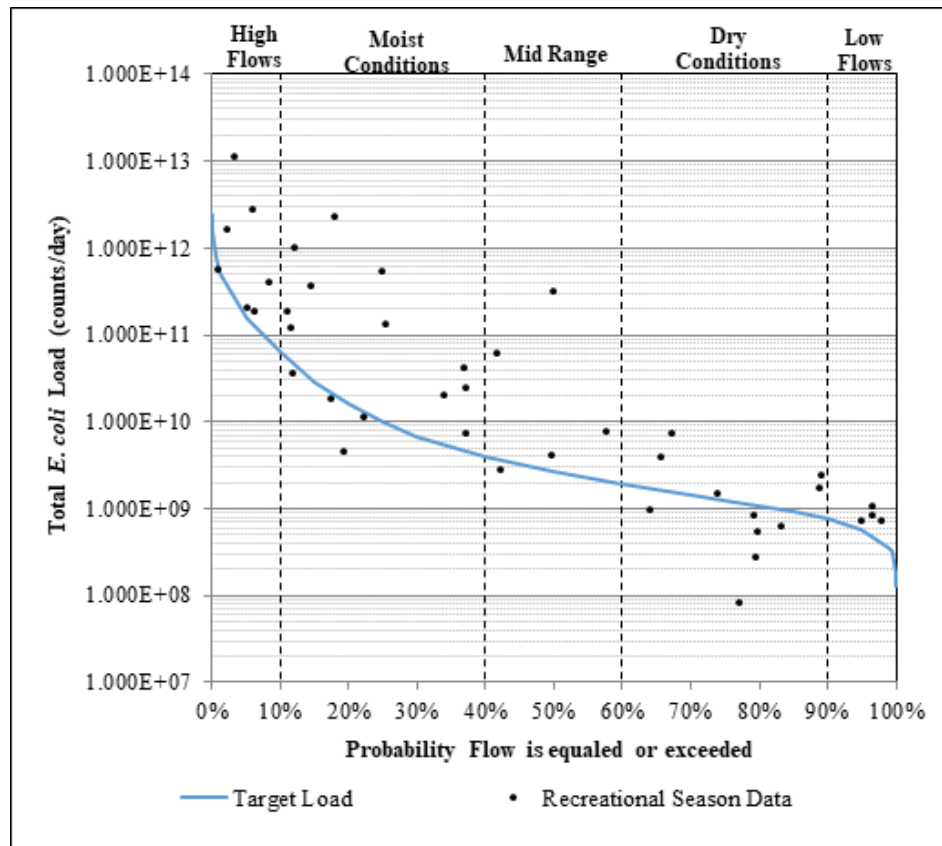
Flow Condition	Percent of Time Flow is Met or Exceeded	Flow (cfs)	TMDL (counts/day)	TMDL Target (counts/100 mL)	Estimated Existing Load (counts/day)	Existing concentration (counts/100mL)	Reduction Needed (%)
Low Flow	95%	0.58	1.80E+09	126	8.70E+08	61	0
Dry Conditions	75%	1.26	3.88E+09	126	1.21E+10	393	68
Mid Range	50%	2.78	8.58E+09	126	5.35E+10	787	84
Moist Conditions	25%	11.49	3.54E+10	126	2.65E+12	9,427	99
High Flows	10%	70.21	2.16E+11	126	3.86E+13	22,471	99

Average Existing Load and concentration = 8.26E+12 counts/day or 6,628 counts/100mL

Average reduction needed = 70%

Deer Creek Flows

Flow Condition	Range of Expected Flows (cfs)
Low Flow	0 cfs to 0.77
Dry Conditions	>0.77 to 1.84
Mid Range	>1.84 to 3.83
Moist Conditions	>3.83 to 53.69
High Flows	>53.69

Figure 4-1. Twomile Creek *E. coli* Load Duration CurveTable 4-3. Average *E. coli* loading and reductions needed at various stream flow conditions in Twomile Creek

Flow Condition	Time Flow is Exceeded	Flow (cfs)	Target Load (counts/day)	Target Concentration (counts/100mL)	Existing Load (counts/day)	Existing Concentration (counts/100mL)	Needed Reduction (counts/day)	Needed Reduction (%)
Low Flow	0.95	0.12	5.82E+08	206	8.32E+08	295	2.50E+08	30
Dry Conditions	0.75	0.24	1.23E+09	206	1.02E+09	170	0.00E+00	0
Mid Range	0.5	0.52	2.62E+09	206	1.77E+10	1,387	1.50E+10	85
Moist Conditions	0.25	2.00	1.01E+10	206	7.24E+10	1,480	6.23E+10	86
High Flows	0.05	31.05	1.56E+11	206	8.92E+11	1,175	7.36E+11	83

Average Existing Load = 1.97E+11 counts/day

Average reduction needed = 57%

SOURCES OF *E. COLI*²

It is apparent that voluntary NPS reduction measures or implementation of BMPs suggested in this watershed based plan must be paired with other strategies to achieve load reductions goals. A 2010 USGS study about the sources of *E. coli* in metropolitan St. Louis area streams estimated that during the study over one-third of the measured in-stream *E. coli* at base flow on the upper River des Peres site originated from humans and over one-third from unknown sources. Unknown sources include *E. coli* from urban wildlife, birds except for geese, and feral cats, but also may include some percentage of human, geese, or dog samples that didn't meet the 80 percent similarity standard considered necessary to be deemed a match. Among the sites included in this study, the upper River des Peres site was determined to be the best reference site for the Deer Creek Watershed as the large river sites on the Missouri and Mississippi Rivers are not similar enough in size or origin and since the Deer Creek Watershed is a sub-watershed of the River des Peres Watershed. The study also indicated that there is a correlation between *E. coli* densities and the number of upstream combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) (USGS 2010). For these reasons, both CSOs and SSOs are considered potential contributors of *E. coli* to impaired streams in the Deer Creek Watershed. Therefore, significant *E. coli* load reductions in the watershed will be achieved through strategies outlined in the Metropolitan St. Louis Sewer District Consent Decree to address point source contributions. <https://msdprojectclear.org/about/our-organization/consent-decree/>

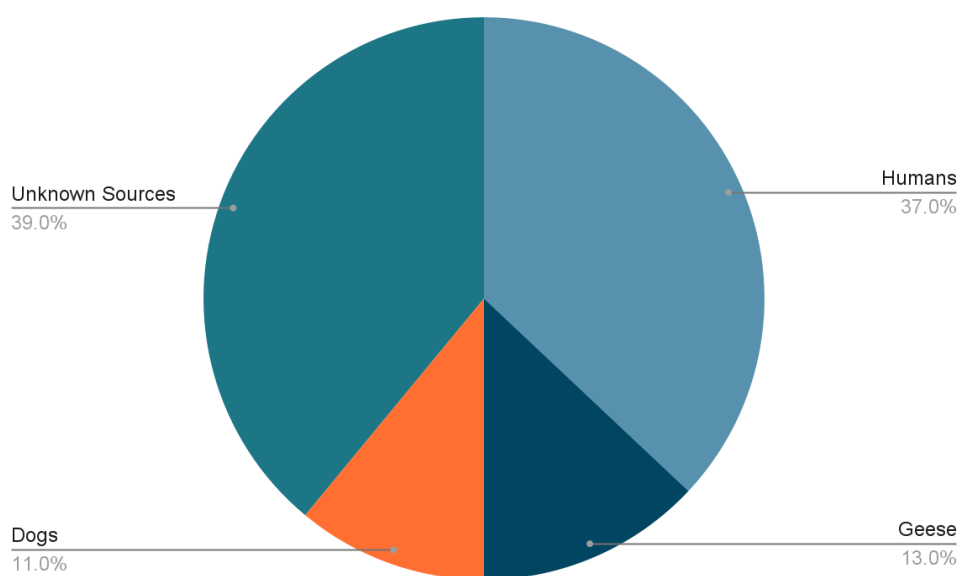


Figure 4-2. Average percentages of sources of *E. coli* at base flow on Upper River des Peres Site (USGS, 2010)

4.12 CHLORIDE LOADING

The Total Maximum Daily Load Unit at MoDNR assessed chloride loading to Deer Creek (WBID 3826) from data collected between 2001 and 2017 to support this plan. The largest exceedances were observed in the cold-weather

² Wilkison, D.H., Davis, J.V. (2010) Occurrence and sources of *Escherichia coli* in metropolitan St. Louis streams, October 2004 through September 2007: U.S. Geological Survey Scientific Investigations Report 2010–5150, 57 p <https://pubs.usgs.gov/sir/2010/5150/pdf/sir2010-5150.pdf>.

months of December through April, indicating that winter road treatment is likely the major source of chloride loading to Deer Creek (Figure 4-3). The load duration curve for Deer Creek displays observed data collected between November and April compared with data collected between May and October. The load duration curve shows the frequency of chloride concentrations above the chronic chloride criterion of 230 mg/L, which is the water quality standard for the protection of aquatic life³. Table 4-4 presents existing chloride loads (lbs/day), which represents sample data and the corresponding stream flow at the time sampling, and the estimated chloride reductions needed to attain water quality standards. **Average reduction in chloride loading needed in Deer Creek is 65% reduction.** A TMDL for chloride for Black Creek and Deer Creek has been prioritized as high.

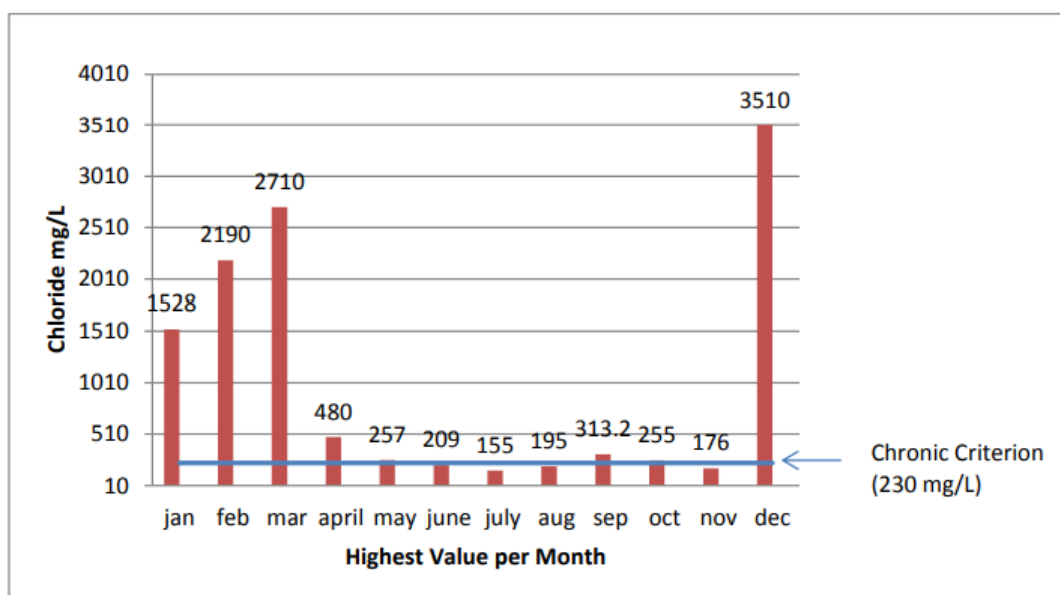


Figure 4-3. Maximum monthly chloride concentration in Deer Creek between 2001 and 2017

Table 4-4. Average Chloride loading and reductions needed at various stream flow conditions in Deer Creek

Flow Condition	Percent of time flow exceeded	Flow (cfs)	Loading Capacity (lbs/day)	Existing Load (lbs/day)	Reduction Needed (lbs/day)	Reduction Needed (%)
Low Flows	94%	0.68	842	1,040	198	19
Dry Conditions	88%	0.89	1,106	6,443	5,337	83
Midrange	50%	2.64	3,280	16,257	12,977	80
Moist Conditions	34%	5.67	7,037	107,398	100,360	91
High Flows	7%	110.42	133,209	291,826	158,616	54

Average Existing Load = 84,593 lbs/day
Average reduction needed = 65%

³ Appendix 4-A Chloride Load Duration Curve and Pollutant Reduction Estimates for Deer Creek Report, pg.4

4.2 BASELINE POLLUTANT LOADING AND REDUCTIONS NEEDED FOR SECONDARY POLLUTANTS OF CONCERN

Secondary pollutants of concern that this plan also addresses include total nitrogen (TN), total suspended solids (TSS), and total phosphorus (TP).

4.21 TN, TSS, & TP LOADING

Load duration curves and estimates of the percent reduction needed for TN, TSS, and TP for Deer Creek (WBID 3826) have been prepared by the TMDL Unit at MoDNR from water quality data collected between 2001 and 2022 to help establish present and target pollutant loads at different flow levels. These load duration curves (Figures 4-4 through 4-6) and estimates of the reduction needed for these secondary pollutants were prepared to support this plan as Missouri does not have water quality criteria for nutrients and sediment. Tables 4-5 through 4-7 present existing TN, TSS, and TP loading and estimated reductions needed at various stream flow conditions in Deer Creek.

Average reduction in TN loading needed in Deer Creek is 72% reduction, average reduction in TSS loading needed in Deer Creek is 89% reduction, and average reduction in TP loading needed in Deer Creek is 74% reduction.

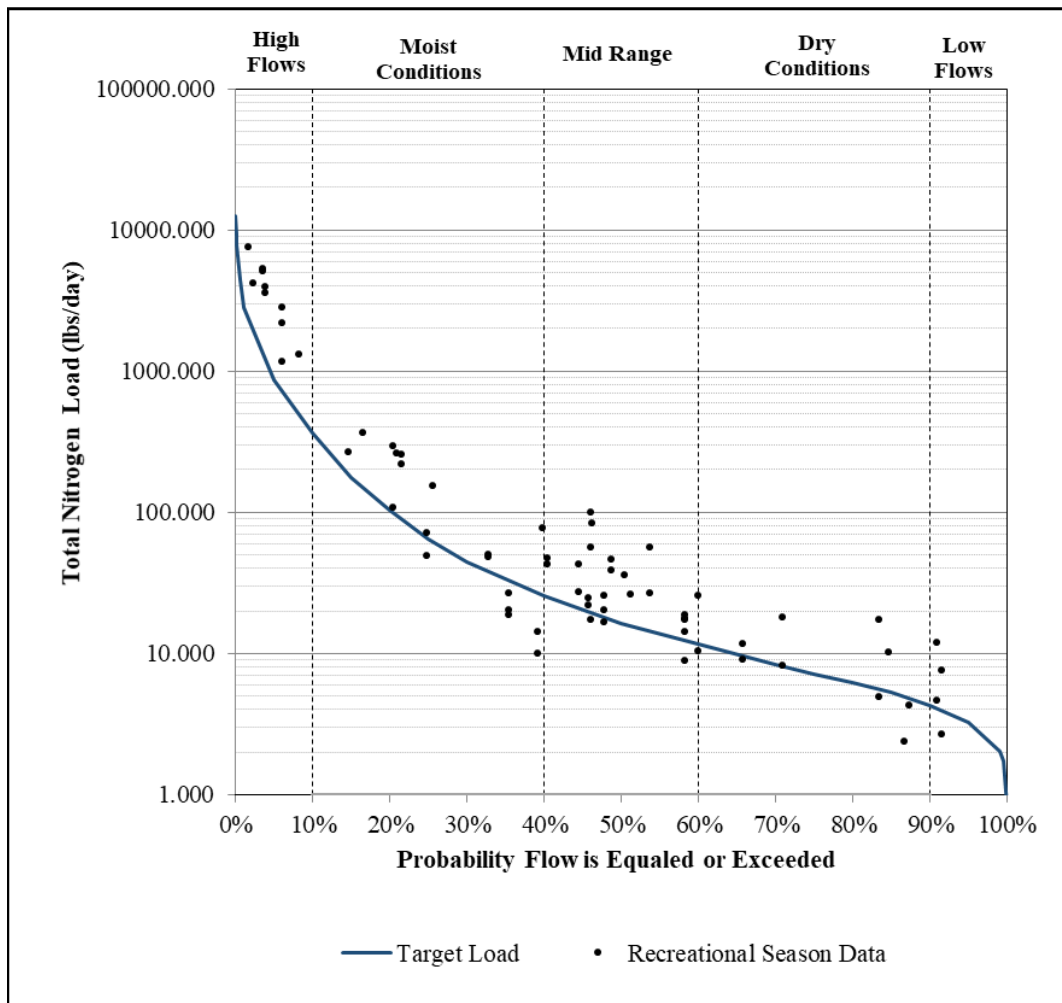


Figure 4-4. Deer Creek TN Load Duration Curve

Table 4-5. Average TN loading and reductions needed at various stream flow conditions in Deer Creek

Percent of time flow exceeded	Flow Condition	Flow (cfs)	Target Load (lbs/day)	Target Concentration (mg/L)	Existing Load (lbs/day)	Existing Concentration (mg/L)	Reduction Needed (lbs/day)	Reduction Needed (%)
95%	Low flow	0.67	3.23	0.90	10.69	2.98	7.46	70
75%	Dry conditions	1.48	7.19	0.90	17.72	2.22	10.53	59
50%	Mid Range	3.38	16.40	0.90	56.68	3.11	40.29	71
25%	Moist Conditions	13.41	65.10	0.90	277.59	3.84	212.49	77
5%	High Flow	176.69	857.76	0.90	5,597.84	5.87	4,740.08	85

Average existing load = 1,192.10 lbs/day, average existing concentration = 3.60 mg/L

Average reduction needed = 72%

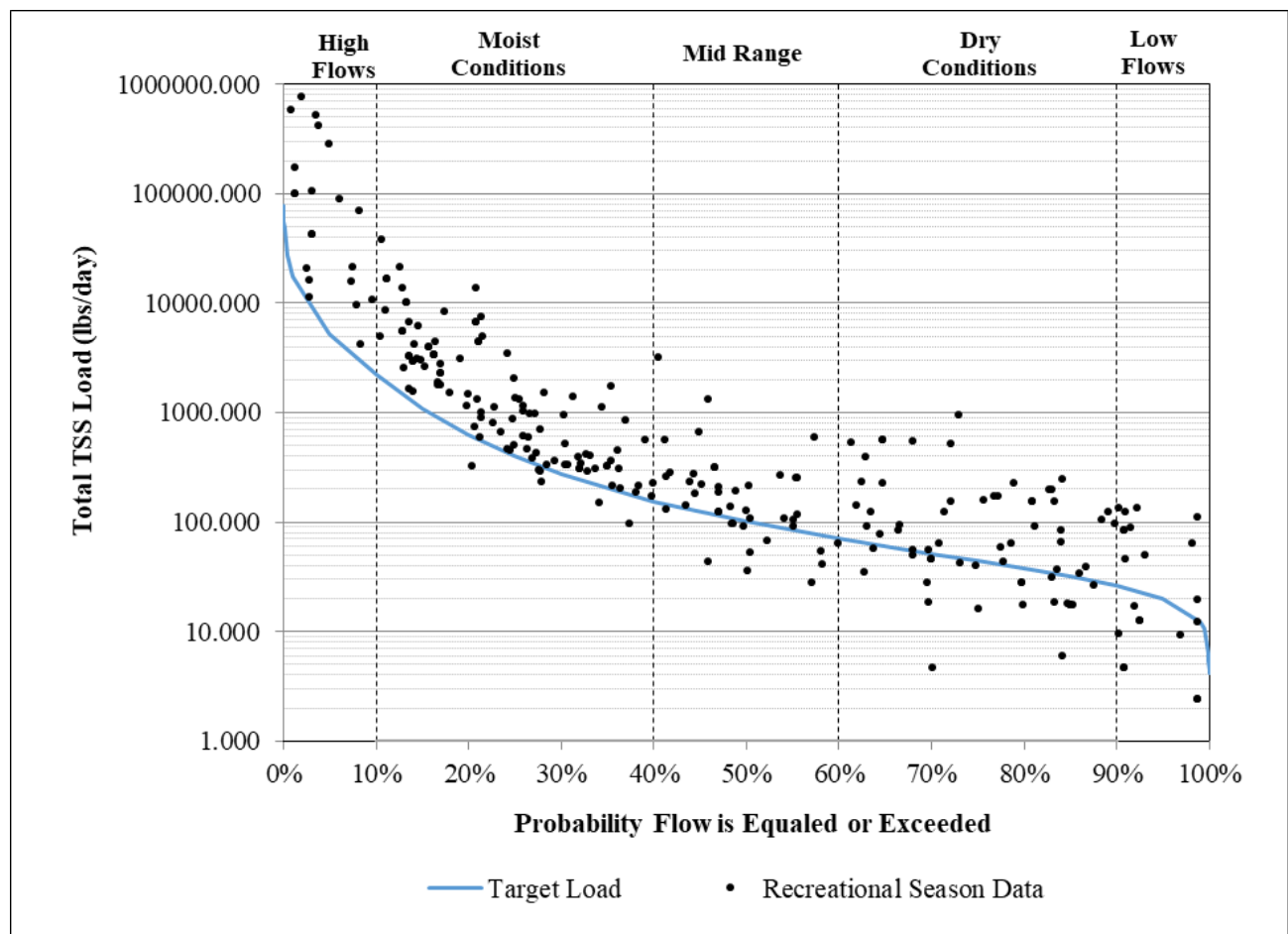
**Figure 4-5. Deer Creek TSS Load Duration Curve**

Table 4-6. Average TSS loading and reductions needed at various stream flow conditions in Deer Creek

Percent of time flow exceeded	Flow Condition	Flow (cfs)	Target Load (lbs/day)	Target Concentration (mg/L)	Existing Load (lbs/day)	Existing Concentration (mg/L)	Reduction Needed (lbs/day)	Reduction Needed (%)
95%	Low flow	0.67	19.74	5.50	124.81	34.77	105.07	84
75%	Dry conditions	1.48	43.97	5.50	352.53	44.10	308.56	88
50%	Mid Range	3.38	100.20	5.50	538.38	29.55	438.18	81
25%	Moist Conditions	13.41	397.81	5.50	6,787.04	93.83	6,389.23	94
5%	High Flow	176.69	5,241.87	5.50	500,010.24	524.63	494,768.37	99

Average existing load = 101,562.60 lbs/day, average existing concentration = 145.38 mg/L

Average reduction needed = 89%

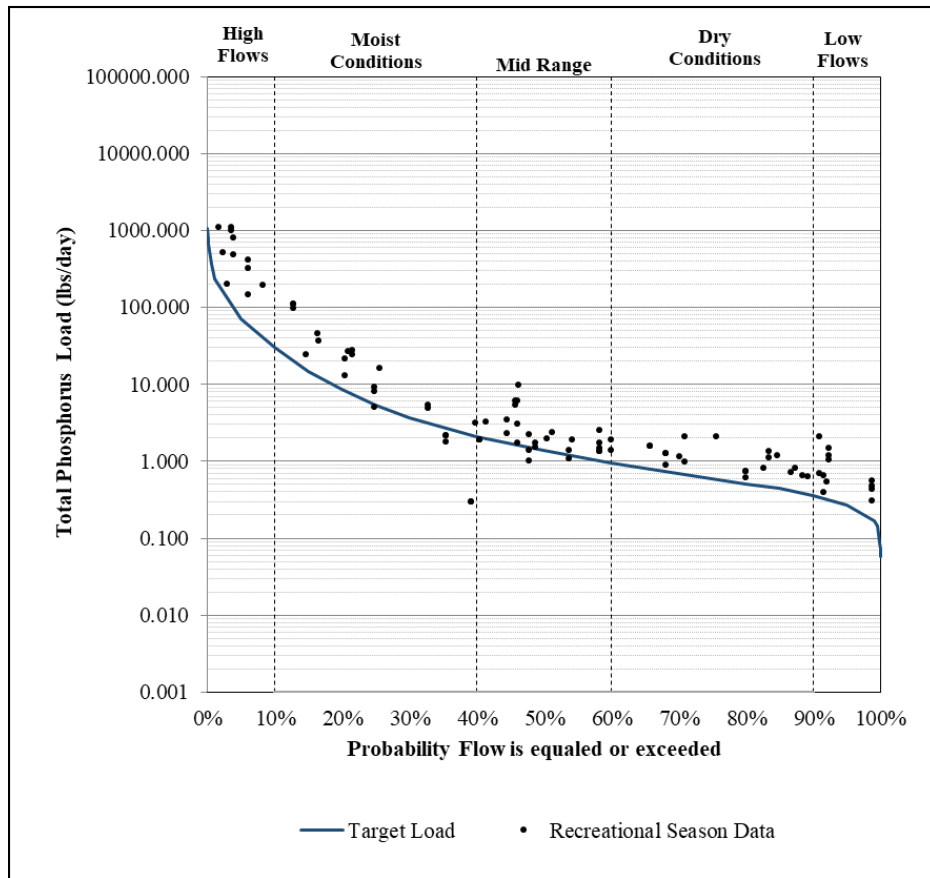


Figure 4-6. Deer Creek TP Load Duration Curve

Table 4-7. Average TP loading and reductions needed at various stream flow conditions in Deer Creek

Percent of time flow exceeded	Flow Condition	Flow (cfs)	Target Load (lbs/day)	Target Concentration (mg/L)	Existing Load (lbs/day)	Existing Concentration (mg/L)	Reduction Needed (lbs/day)	Reduction Needed (%)
95%	Low flow	0.67	0.27	0.075	1.47	0.41	1.20	82
75%	Dry conditions	1.48	0.60	0.075	1.66	0.21	1.06	64
50%	Mid Range	3.38	1.37	0.075	2.39	0.13	1.02	43
25%	Moist Conditions	13.41	5.42	0.075	38.75	0.54	33.32	86
5%	High Flow	176.69	71.48	0.075	1,101.43	1.16	1,029.95	94

Average existing load = 229.14 lbs/day, average existing concentration = 0.49 mg/L

Average reduction needed = 74%

Definitions for Tables 4-1 through 4-7:

cfs – cubic feet per second

Loading Capacity – The greatest amount of pollutant loading that a water body can receive without violating water quality standards.

Existing Loading – Estimated as the geometric mean of all observed *E. coli* loads within a specific flow range

Reduction Needed – Amount of reduction in bacteria loading needed to achieve Loading Capacity

Source: MoDNR

4.3 WATERSHED AND BMP MODELING TO ESTIMATE LOAD REDUCTIONS

4.31 DEER CREEK WATERSHED MODELING OF *E. COLI* REDUCTION DUE TO STORMWATER BEST MANAGEMENT PRACTICE IMPLEMENTATION

---2020 REPORT PREPARED BY EDM INCORPORATED FOR DEER CREEK WATERSHED ALLIANCE

In 2020, the Missouri Botanical Garden engaged EDM Incorporated to model *E. coli* reductions in the Deer Creek and Black Creek Watersheds from BMPs that were planned as part of the Deer Creek Watershed Initiative (See Appendix 4B). The BMPs include native soil rain gardens, pervious pavers, lawn alternatives, woodland restoration, engineered bio-retention, underground detention, and tree planting. Time periods analyzed include existing BMPs from May 2017 to May 2020 and planned BMPs in 5-year increments from 2020 to 2040.

EDM used the Simple Method to model *E. coli* load reductions. For all the BMPs, except Tree Planting, a removal efficiency factor was applied to the annual volume of water treated by the BMPs to determine the annual *E. coli* load reduction. Future load reduction estimates from the planned Tree Planting program were based on runoff reduction due to canopy size as calculated by the i-Tree Eco Program.

Data on the number and location of BMPs was provided by the Deer Creek Watershed Alliance and the City of Frontenac stormwater program, as available, to EDM. Rainfall data from St. Louis Lambert International Airport was used to calculate BMP treatment volumes. The Missouri Department of Natural Resources provided average existing *E. coli* loadings for Deer Creek and Black Creek.

BMP DEFINITIONS AND PRIORITIZATION STRATEGY

A key finding of the Deer Creek Watershed Management Plan is that because a relatively high 67% of the land in the Deer Creek Watershed is owned by single family residents, any successful implementation plan must be capable of reducing nonpoint source runoff from a substantial percentage of the land in the watershed and include a strategy to engage those residents in active watershed management for stream health. Therefore, implementation projects will be concentrated in a condensed sub-watershed area, involving as many landowners as possible in that sub-watershed in order to maximize the probability of making measurable improvements in water quality in that location. Key to reducing pollutant loads, including *E. coli*, is the reduction of stormwater runoff in the watershed. According to a 2010 USGS study of the Metropolitan St. Louis streams, “*E. coli* densities and loads typically were many times greater in storm events than at base flow, primarily because *E. coli* densities and flow—a major load component—increased as a result of runoff...bacteria contributions from the numerous combined and sanitary sewer overflows within the study area, as well as contributions from nonpoint source runoff, greatly increased instream *E. coli* densities.”⁴

Rainscaping BMPs most suitable for residential application to reduce runoff and pollutants are:

Native Soil Rain Gardens are shallow, landscaped depressions that catch and hold stormwater runoff from impervious surfaces, such as driveways, roofs, and compacted lawns, and allows it to infiltrate into the soil rather than enter stormwater sewers. Rain gardens are typically planted with native plants and grasses that have root systems that help soak up water and help water infiltrate the soil. Soil structure is gradually improved over time through the combined interactions of added well-aged compost, mulch, microbes, and deep-rooted plants to increase the infiltration of water into the soil.

Permeable Pavers are concrete blocks with gaps between them and clean gravel underneath that allow water to soak into the soil rather than runoff. In the process, the porous material filters runoff as well as allowing it to infiltrate the soil beneath.

Lawn Alternatives such as trees, shrubs, perennials, and/or prairie gardens, along with optional soil amendments and mulching, replace turf in order to more effectively manage rainwater. **Woodland Restoration** involves the removal of invasive plant species followed by replanting with a mix of native plant species that are appropriate for that particular woodland type (dry, upland woodland versus more moist, low woodland). Trees are excellent storm water pumps for managing and infiltrating runoff.

Native soil rain gardens will receive the highest rating per the funding selection criteria of the Rainscaping Cost-Share Program. Therefore, native soil rain gardens will be prioritized for installation. They can achieve the goal

⁴ Wilkison, D.H., Davis, J.V. (2010) Occurrence and sources of *Escherichia coli* in metropolitan St. Louis streams, October 2004 through September 2007: U.S. Geological Survey Scientific Investigations Report 2010–5150, 57 p <https://pubs.usgs.gov/sir/2010/5150/pdf/sir2010-5150.pdf>.

to capture the first 1.14 inches of rain without an underdrain and without replacing existing soil with a sandy soil mix in residential settings where no development is taking place. Initial infiltration rates must be .25 inches per hour or greater, and the rain garden must be planted with prairie or other deep rooted native plants. A healthy soil ecosystem with a high percentage of organic matter will result in aggregated soil particles, improved soil structure, and therefore improved infiltration rates. Where initial infiltration rates are lower than .25 inches per hour, installing lawn alternatives to improve soil infiltration rates by adding appropriate soil amendments and deep rooted plants across a wide section of the yard will be prioritized instead of rain gardens. These rainscaping BMPs are excellent alternatives to installing an engineered bioretention system with an underdrain as they have a greater estimated *E. coli* removal rate of 90%, TSS removal rate of 90%, TP of 65%, and TN of 58% and are more affordable for residential landowners to design, install, and maintain.

See Appendix 5B, A Case for Native Soil Landscaping BMPs, for a white paper documenting the scientific basis for these BMPs. One of the key references in this white paper is a 5-year USGS rain garden study (see Appendix 5C). Ninety percent of storms in the greater St. Louis region have historically been 1.14 inches of rainfall or less. These BMPs are not expected to handle all of the rainfall from large storms that are typically associated with flooding problems. However, they should capture most of the rainfall from these smaller, more frequent storm events to improve water quality. See mobot.org/rainscaping for a more detailed description of these BMPs.

Table 4-8 below provides the estimated number of these types of rainscaping BMPs to be installed in 5-year periods and the minimum estimated load reduction for *E. coli* and secondary pollutants of concern.

Table 4-8. Rainscaping BMPs to be installed in 5-year periods with minimum estimated load reductions

Implementation Schedule	Project Activity	Expected Deliverable Units to be Completed	Deliverable Units	Minimum Estimated Load Reductions after Implementation of each 5-Year Period			
				Annual TSS Removed (lbs)	Annual TP Removed (lbs)	Annual TN Removed (lbs)	<i>E. coli</i> (counts/day)
Years 1-5 (2020-2025)	Rainscaping Cost-Share Program in remaining Rounds 2023 & 2024	40*	BMPs	600	2	10	8.98E+07
	Ladue Riparian Corridor Restoration Plantings	5.38	ACRES	1,885	6	27	8.80E+08
	Brentwood Wetland Restoration	6.75	ACRES	10,261	28	85	1.84E+09
Years 6-10 (2026-2030)	Rainscaping Cost-Share Program	100	BMPs	1,420	4	20	2.69E+08

Years 11-15 (2031-2035)	Rainscaping Cost-Share Program	100	BMPs	1,420	4	20	2.35E+08
Years 16-20 (2036-2040)	Rainscaping Cost-Share Program	60	BMPs	900	3	15	1.79E+08

*A list of eligible Rainscaping BMPs, a list of design, installation, and maintenance contractors that have successfully participated in the last 12 months of the Rainscaping Cost-Share Program (RCSP), and other RCSP materials will be maintained at deercreekalliance.org/cost-share for use by landowners choosing to voluntarily participate in the program. Contractors will be hired by individual landowners to design and install the most suitable Rainscaping BMP(s) for the site.

In addition to the Rainscaping BMPs identified on the eligible improvements list and above, a septic system inspection, maintenance repair and cleaning, and replacement option will be designed in the 4th quarter of 2023 and added as a pilot of the Rainscaping Cost-Share Program in Round 2024 to achieve a higher *E. coli* load reduction. Septic system parcel landowners in riparian corridors, within 500 feet of a stream, will be targeted for program participation. Forty-two parcels with potential septic systems have been preliminarily identified in the Deer Creek Watershed. **See Map 3-1 in Section 3.47 and Table 4-12 *E. coli* (counts/year) load reduction for septic system removal/ replacement or maintenance by type for single family homes** as these additional load reductions were not included in this table. If this septic system inspection, maintenance repair and cleaning, and replacement option is chosen by these targeted landowners, it must be paired with one of the plant-based solutions that removes and replaces a minimum of 100 square feet of established lawn, invasive species, impervious surface, or bare ground to achieve minimum load reduction and program goals. The desired outcome is that at least 4 to 5 of these targeted landowners will apply to and be funded through this program as part of this pilot in years 1 through 5 (2020-2025).

In addition to the implementation projects that will be installed via the RCSP, years 1 through 5 (2020-2025) will include the implementation of the Deer Creek Preserve in Ladue with a linear trail with one loop along the riparian corridor in 2023. This section of riparian corridor along Deer Creek will be restored, and the invasive honeysuckle will be removed and replaced with native plants. Years 1 through 5 (2020-2025) will also include the final design, implementation, and maintenance of a wetland restoration demonstration project in Brentwood in 2023, 2024, and 2025. The City of Brentwood plans to purchase the property south of Bi-State Metro Garage at Brentwood Blvd. and Marshall Ave. in Brentwood. Recommendations for this wetland restoration project came out of the DCWA Technical Advisory Group Metro Wetland Restoration Design Charrette in April 2017, sponsored by Great Rivers Greenway, City of Brentwood, and other partners. The recommendations from this charrette will lay a foundation for the final design to implement this project. Both of these projects will also be installed in identified high priority focus areas. **See Chapter 8 for a detailed outline of tasks by management objective with timeline for completion.**

See Section 5.4 Identifying Critical Areas, Map 5-1 for an alphanumeric identification of each subwatershed on page 5-13, and Table 5-2 for priority ranking and implementation schedule of Deer Creek subwatersheds on page 5-14.

MODELING APPROACH OF LOAD REDUCTIONS DUE TO BMP IMPLEMENTATION

The purpose of this discussion is to define a modeling approach for each stormwater BMP type using the Simple Model. For all but one BMP, this approach has two parts that need to be defined: 1) the *E. Coli* removal rate for the BMP and 2) the drainage area or volume treated by the average BMP unit of that type.

The BMPs to be addressed include native soil rain garden, engineered bio-retention, lawn alternatives, riparian/woodland restoration, pervious pavers, underground storage with under drains, and tree planting.

The modeling approach for tree planting will be to lower the runoff coefficient for the subwatershed based on the canopy of new tree cover. The impact will be a reduction in the overall runoff and the pollutant load.

REMOVAL RATE FOR *E. COLI*

A rate for *E. coli* removal is not defined in The Simple Method model. However, the Minnesota Pollution Control Agency (MPCA) Simple Method model addresses *E. coli* removal rates and states "removal efficiencies are 100 percent for water that is infiltrated". Therefore, assuming that 90% of the rainfall will be infiltrated, the **removal rate for *E. coli* will be taken to be 90%.**

https://stormwater.pca.state.mn.us/index.php/Calculating_credits_for_infiltration

ENGINEERED BIO-RETENTION

E. coli/Bacteria removal rates for bio-retention varied in the sources reviewed. The default removal rate for the MPCA Simple Method model is 75%, but the Guidance page reports a 95% removal rate for bacteria. The New York State Stormwater Design Manual considers bio-retention as a filtering practice and lists a bacteria removal rate of 35%. For the purpose of this analysis, we will assume an *E. coli*/bacteria removal rate of 75% for the water filtered.

Bio-Retention BMPs will be modeled using the City of Frontenac design standards. This standard calls for a design based on a 2.5-inch rainfall. The 2.5-inch rainfall design will contain 99.3% of the daily rainfall based on Lambert Airport's daily rainfall data from 1938 to 2020. Assuming 99.3% of the water is filtered, the **removal rate for *E. coli* will be taken to be 75%.**

UNDERGROUND STORAGE

E. coli/bacteria removal rate for underground storage with underdrains will be based on the percent of annual rainfall infiltrated for an average City of Frontenac implementation. Four underground storage facilities were reviewed to determine an average percent of infiltrated rainfall. Two of the facilities are composed of clean rock, and two are composed of StormTech Chambers. The infiltration analysis was divided into 2 components. The first component was based on the percentage of storage below the underdrain for a system designed to handle the 2.5-inch rain. The average percent of storage below the underdrain for the 4 devices accounted for the first 0.32 inches of rainfall. Since the devices are designed to hold the 2.5-inch rain up to 24-hours, the second component was determined based on the amount infiltrated during the holding period for that rainfall. The St. Louis Lambert daily rainfall totals from 1938 to 2020 were analyzed for infiltration potential assuming any rainfall of 0.32 inches was infiltrated and, for larger rainfalls, up to 0.99 inches could be infiltrated. Clay loam native soil was assumed with a high infiltration rate of 0.028 in/hr. This infiltration rate was applied on rainfall between 0.32 inches to 2.5

inches (system capacity) for 0 to 24 hours, respectively. The total hourly amount infiltrated was added to the base infiltration of 0.32 inches. These values were summed and then divided by the total rainfall in the database to determine the percent of annual rainfall that will be infiltrated. This percentage of annual rainfall that will be infiltrated came to 65%.

TREE PLANTING

E. coli/Bacteria removal for trees is based on removal equal to 100% of the avoided runoff, which was estimated using the i-Tree Eco program. A detailed description of the model used in the program is outlined in a paper by Satoshi Hirabayashi titled "i-Tree Streets/Design/Eco Rainfall Interception Model Comparisons". The input in i-Tree is the diameter at breast height (DBH) for each tree species. The 2017 data at Lambert Airport was selected for the weather data, which had a total of 38.5 inches of total annual precipitation. A series of i-Tree projects were developed, one for each 5-year increment. All trees were given a 2" DBH as a typical size when planted. The DBH was increased based on 5-year incremental growth using the i-Tree Design v7.0 web application estimated future DBH.

DRAINAGE AREA OR VOLUME OF RUNOFF TO BE TREATED

The Deer Creek Watershed Alliance provided the following information to EDM Incorporated: the average number of BMPs installed per year, the total square foot installed for rain gardens, and the total square foot for six combined BMPs. The rain garden information was used to calculate an average size for Native Soil Rain Gardens. The total area for six BMP types included Lawn Alternatives, Riparian/Woodland Restoration, and Pervious Pavers and was used to determine an average area for these BMP types.

The Deer Creek Watershed Alliance reported that a native soil rain garden will treat a pervious area five times the size of the average rain garden. They also reported that Lawn Alternatives, Riparian/Woodland Restoration, and Pervious Pavers would treat a pervious area three times the size of these average BMPs.

The Frontenac database was reviewed for approved engineered bio-retention and underground storage from May 2017 to January 2020. Average water quality volumes (treated water volume) were calculated for these BMP types.

The volume reduction of runoff for trees was modeled based on the canopy size for the projected year and number of trees identified by the Deer Creek Watershed Alliance.

Table 4-9. Summary of modeling approach

BMP Type	<i>E. coli</i> Removal Rate	Runoff Volume or Area Treated per Unit (Value)
Native Soil Rain Gardens	90%	Lawn areas equal to 5 times the average rain garden size (avg. 1,390 square feet of lawn area)
Pervious Pavers, Lawn Alternatives, Woodland Restoration	90%	Lawn areas equal to 3 times the average BMP size (avg. 2,200 square feet of lawn area)
Engineered Bio-Retention	75%	Average Water Quality Volume Provided (928 cubic feet)
Underground Detention	65%	Average Water Quality Volume Provided (812 cubic feet)
Tree Planting	100%	Load reduction equivalent to volume of runoff reduced

CALCULATIONS (FROM APPENDIX 4B)

The annual load reduction for the BMPs is a function of the annual runoff and the removal rate. The annual runoff (R) is:

$$R = P_A P_j R_v A$$

Where:

P_A = Annual Rainfall

P_j = % of rainfall events producing run-off

R_v = Runoff Coefficient

A = Drainage Area

Where the Runoff Coefficient is:

$$R_v = 0.05 + 0.9I_a$$

Where:

I_a = % Impervious

For the BMP types with an assumed previous drainage area, the percent impervious is assumed to be 5%. With P_A = 41.29 inches, P_j = 0.9 % and I_a = 5%, then the annual runoff R = 0.3 cubic feet per square foot (ft^3/ft^2).

For the BMP types with an assumed water quality volume provided the annual runoff is again:

$$R = P_A P_j R_v A$$

The BMPs are sized to provide a design volume:

$$V = P_D R_v A$$

Where:

P_D = BMP Design Rainfall

Which results in:

$$R = \frac{P_A}{P_D} P_j V$$

With P_A = 41.29 inches, P_D = 2.5 inches and P_j = 0.9 then the annual runoff R = 14.86 ft³

The annual load reduction (L_R) is then:

$$L_R = \varepsilon_R R L$$

Where:

ε_R = Removal Efficiency

L = Load

For the trees, the annual load reduction is a function of the avoided annual runoff:

$$L_R = R_A L$$

Where

R_A = Avoided Runoff

RESULTS

Table 4-10 provides the estimated *E. coli* load reduction for each type of average size BMP with average cost installed per unit. Table 4-11 provides the estimated *E. coli* load reduction for trees of various ages from Appendix 4B.

Table 4-10. *E. coli* load reduction for an average size BMP with average cost by type

BMP Type	Average Size of BMP	Deer Creek <i>E. coli</i> LR (counts/day)	Deer Creek <i>E. coli</i> LR (counts/year)	Black Creek <i>E. coli</i> LR (counts/day)	Black Creek <i>E. coli</i> LR (counts/year)	Average Cost Installed
Native Soil Rain Gardens	278 sf	1.74E+06	6.34E+10	2.40E+06	8.76E+10	\$12 - \$19.25 sf

Pervious Pavers, Lawn Alternatives, Woodland Restoration	733 sf	2.75E+06	1.00E+11	3.80E+06	1.39E+11	\$10 - \$23.54 sf
Engineered Bio-Retention	795 sf	5.32E+07	1.94E+12	7.35E+07	2.68E+12	\$167 sf
Underground Detention	2030 cf	4.03E+07	1.47E+12	5.58E+07	2.04E+12	\$46 cf

Table 4-11. *E. coli* (counts/day) load reduction per tree per 5-year periods

Sub-Watershed	Age			
	0-5	5-10	10-15	15-20
Deer Creek	1.56E+04	2.35E+04	3.24E+04	4.24E+04
Black Creek	2.15E+04	3.25E+04	4.47E+04	5.85E+04

ADDITIONAL *E. COLI* REDUCTION FOR SEPTIC SYSTEM REMOVAL/ REPLACEMENT OR MAINTENANCE⁵

The Indiana *E. coli* Calculator (IEC) is a spreadsheet tool that estimates the Escherichia Coli (*E. coli*) contribution from multiple sources and calculates load reductions of best management practice (BMP) installations. The portions of the spreadsheet that calculate *E. coli* contributions are heavily based upon the Environmental Protection Agency's (EPA) Bacteria Indicator Tool (BIT). Table 4-12 provides the additional estimated annual load reduction for septic system removal/replacement or maintenance from the Indiana *E. Coli* Calculator.

Table 4-12. *E. coli* (counts/year) load reduction for septic system removal/ replacement or maintenance by type for single family homes

Septic System Type	<i>E. coli</i> LR (counts/year)	Distance to water
Straight Pipe	1.523E+13	N/A
Tank without Leachfield	2.418E+12	N/A
Straight Pipe w/ Overland Flow	2.640E+11	450 ft.
Tank with Overland Flow	4.190E+10	450 ft.
Straight Pipe Seasonal	7.770E+12	450 ft.
Tank seasonal	1.282E+12	350 ft.

Assumptions:

1. 100% delivery to perennial water.
2. Raw, Human Sewage has fecal coliform concentration of 6.3E+6 organisms per 100ml.
3. Fecal coliform concentration for septic liquid effluent 1.0 E+6 organisms per 100 ml.

⁵ Indiana Department of Environmental Management, Office of Water Quality. Revised September 17, 2020. Indiana *E. coli* Calculator, <https://www.in.gov/idem/nps/watershed-toolkit/planning/>

4. Average of 2.5 persons for each single dwelling home.
5. Average daily discharge to a septic system is 265 liters (70 gallons) per person.
6. **Untreated domestic waste water has an average Total Nitrogen concentration of 35mg/L**
7. **Untreated domestic waste water has an average Total Phosphorus concentration of 10mg/L**
8. Negative exponential relationship between distance and organism survival.
9. Overland flow distances greater than 500 feet will have minimal FC delivery to live water due to UV radiation, infiltration and residence time.
10. For seasonal Canal or Ditch flows 183 days (50%) of year.

*Conversion equation used: $E. coli = 0.403 (\text{fecal coliform})^{1.028}$ (From Ohio EPA, 2006)

*All septic calculations taken from Wyoming DEQ septic reduction spreadsheet

4.32 CHLORIDE AND SECONDARY POLLUTANT REDUCTIONS DUE TO STORMWATER BEST MANAGEMENT PRACTICE IMPLEMENTATION

REMOVAL RATES FOR CHLORIDE

It is apparent that the most effective chloride reduction strategy is to reduce the amount of road salt used since the largest exceedances of state water quality standards are observed in the cold-weather months. Applying brine or a 23% dissolved salt water mixture to roads as an anti-icing pretreatment practice to get roadways ready for winter storms can dramatically decrease the amount of salt used, expense, and the amount of salt that ends up in streams. According to the Public Works Department in the city of Webster Groves, which is partially located in the Deer Creek Watershed, approximately 200 tons less of rock salt was used due to their voluntary efforts to brine before winter storms in 2019-2020.

During a recent study, the contributions to chloride in urban stormwater from winter brine and rock salt application were compared by monitoring stormwater runoff from residential areas in six paired cities in St. Louis County during the winters of 2016–2017 and 2017–2018. One of the three cities included in this study that has adopted the use of brine is Webster Groves. The study concluded that the use of brining by city governments resulted in a 45% average reduction of chloride loads conveyed to streams, demonstrating that brining is a highly viable BMP for local municipal operations (Haake and Knouft 2019).⁶ Likewise, the state of Michigan's Chloride and Sulfate Implementation Plan states that during-storm direct liquid application (DLA) or applying a brine solution (23% salt/ 77% water) has been found to require 50% less salt.

<https://www.michigan.gov/egle/-/media/Project/Websites/egle/Documents/Programs/WRD/NPDES/chloride-sulfate-implementation-plan.pdf?rev=07c3a64eed2849a6aae7130eda1fe384>

Therefore, the removal rate for chloride for brining will be considered to be 45% which is the more site specific and conservative number from these two studies. If at least 5 or one-quarter of the municipalities in the watershed are encouraged to convert to brining through educational efforts every 5 years, this will yield an 11.25% removal rate for chloride by educating municipal landowners about brining. In twenty years, if all the municipalities have converted to brining, a 45% removal rate will be achieved through education. The additional removal rates needed will be achieved by educating residential landowners in the watershed.

⁶ Haake, D.M., J.H. Knouft. (2019) [Comparison of contributions to chloride in urban stormwater from winter brine and rock salt application](#). *Environmental Science & Technology*, 53, 11888-11895.

REMOVAL RATES, CALCULATIONS, AND RESULTS FOR SECONDARY POLLUTANTS OF CONCERN

The Deer Creek Watershed Alliance is currently modeling TSS, TN, and TP removal estimates for secondary pollutants of concern in pounds for native soil rain gardens, lawn alternatives, riparian/woodland restoration, and permeable pavers. These are modeled as rain garden – 1" or infiltration – 1", and have the same removal rates for TSS, TN, and TP. These BMPs appear to function similarly in that they infiltrate the 1.14-inch rain for the contributing drainage area. Bioswales, linear, shallow, planted depressions or swales that slow down, soak up, and guide water from one point to another, are also being modeled as swales with lower removal rates. See The Simple Method model equations and Tables 4-13 and 4-14 below for pollutant concentration by land use and pollutant removal rates by BMP type. Table 4-15 provides the estimated secondary pollutant load reductions for each type of average size BMP with average cost installed per unit.

The Simple Method⁷ model equations:

$$L = 0.226 * R * C * A$$

Where:

L = Annual Load (lbs)

R = Annual Runoff (inches)

C = Pollutant Concentration (mg/l)

A = Area (acres)

0.226 = Unit Conversion Factor

$$R = P * P_j * R_v$$

Where:

R = Annual Runoff (inches)

P = Annual Rainfall (inches)

P_j = % of rainfall events producing runoff

R_v = Runoff Coefficient

$$R_v = 0.05 + 0.9 * I_a$$

I_a = Impervious Fraction (%)

Table 4-13. Pollutant concentration by land use

Landuse1	% Impervious	TSS (mg/l)	TP (mg/l)	TN (mg/l)
Commercial	85	75	0.2	2
Industrial	75	120	0.4	2.5
Multifamily	60	100	0.4	2.2
Open Urban Land	9	48.5	0.31	0.74
Residential-High Density	40	100	0.4	2.2
Residential-Low Density	10	100	0.4	2.2
Residential-Med. Density	30	100	0.4	2.2
Residential Roof	100	19	0.11	1.5
Roadway/Parking Lot	80	150	0.5	3

⁷ CEI. 2008. The Simple Method. Published by Comprehensive Environmental Inc., (800) 725-2550

1 High density residential (<1/4 acre lots); Medium density residential (1/4 to 1/2 acre lots); Low density residential (>1 acre lots); Multifamily (>7 dwellings per acre).

Table 4-14. Pollutant removal rates by BMP type

BMP Type	TSS Removal (%)	TP Removal (%)	TN Removal (%)
Baffle Tank	70%	30%	0%
Constructed Wetland	80%	55%	30%
Detention Basin (dry)	48%	30%	30%
Infiltration - 1"	90%	65%	58%
Raingarden - 1"	90%	65%	58%
Swale	48%	30%	30%

Table 4-15. Secondary pollutant load reductions for an average size BMP with average cost

BMP Type	Average Size of BMP	Annual TSS Removed (lbs)	Annual TP Removed (lbs)	Annual TN Removed (lbs)	Average Cost Installed
Native Soil Rain Gardens	278 sf	10	0.03	0.15	\$12 - \$19.25 sf
Pervious Pavers, Lawn Alternatives, Woodland Restoration	733 sf	17	0.05	0.24	\$10 - \$23.54 sf
Engineered Bio-Retention	795 sf	92	0.27	1.31	\$167 sf
Underground Detention	2030 cf	42	0.10	0.58	\$46 cf

4.4 SUMMARY OF PRIMARY AND SECONDARY POLLUTANTS OF CONCERN

Present and target pollutant loads, levels, or values for primary and secondary pollutants of concern in the Deer Creek Watershed are summarized in Table 4-16 below. The present and target loads are based upon the review of water quality data discussed in Chapter 3, load duration curves and estimates of the percent reduction needed for chloride, TN, TSS, and TP for Deer Creek prepared by the TMDL Unit at MoDNR, State of Missouri water quality standards, and the Bacteria TMDL for Black Creek and Deer Creek. As additional water quality data, state standards, TMDLs, and models become available, they will be assessed and present and target pollutant loads will be adjusted as necessary. Due to the nature of urban streams, reaching targeted standards for chloride, *E. coli* and other pollutants must of necessity be long range, and may take twenty or more years to achieve.

Table 4-16. Summary of present and target pollutant loads

Pollutant	Present pollutant load, level, or value	Target pollutant load, level or value
<i>E. coli</i>	<p>Average Existing load and mean concentration = 2.46E+12 counts/day or 9,161 counts/100mL for Black Creek (WBID 3825)</p> <p>Average Existing Load and mean concentration = 8.26E+12 counts/day or 6,628 counts/100mL for Deer Creek (WBID 3826)</p> <p>Average Existing Load = 1.97E+11 counts/day for Twomile Creek (WBID 4079)</p>	<p>Not to exceed geometric mean of 126 cfu/100mL for Deer Creek (WBID 3826) Category A and 206 cfu/100mL for Black Creek (WBID 3825) and Twomile Creek (WBID 4079) Category B Use for State of Missouri standards for Whole Body Contact during the recreational season. Average reduction in <i>E. coli</i> loading needed is 83% reduction in Black Creek, 70% reduction in Deer Creek, and 57% reduction in Twomile Creek to achieve these standards.</p>
Chloride	<p>Average Existing Load = 84,593 lbs/day for Deer Creek (WBID 3826)</p>	<p>Baseline concentration of chloride plus sulfate shall not exceed 1,000 mg/L, and on its own, chloride shall not exceed 230 mg/L (chronic) during non-winter months. And on its own, chloride shall not exceed 860 mg/L (acute) during winter months when road salt is being applied on roads. Average reduction in chloride loading needed is 65% reduction in Deer Creek.</p>
TN	<p>Average existing load = 1,192.10 lbs/day, average existing concentration = 3.60 mg/L for Deer Creek</p>	<p>Average reduction in TN loading needed = 72% in Deer Creek</p>
TSS	<p>Average existing load = 101,562.60 lbs/day, average existing concentration = 145.38 mg/L for Deer Creek</p>	<p>Average reduction in TSS loading needed = 89% in Deer Creek</p>
TP	<p>Average existing load = 229.14 lbs/day, average existing concentration = 0.49 mg/L for Deer Creek</p>	<p>Average reduction in TP loading needed = 74% in Deer Creek</p>

Rainscaping BMP projects installed	447 projects installed as of Sept. 30, 2021	760 projects installed by Dec. 31, 2040
Tons of organic debris, leaf litter & trash removed from or prevented from entering creek	8.5 tons of trash removed in 2021 as of Dec. 2021 (Note, approximately 540 pounds of this trash was removed from the water via a trash collector or trash trap in Deer Creek Park.)	At least 9 tons of trash, leaf litter and/or organic debris removed or prevented from entering the creek annually.
Linear feet of restored riparian corridor	200 linear feet or 1 acre of riparian corridor restored in FY 2021	At least 2000 linear feet or 10 acres of riparian corridor restored by 2040