WATERSHED BASED PLAN FOR CROW CREEK

WBID: OK120420010090_00

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TABLE OF CONTENTS

TABLES

FIGURES

INTRODUCTION

Crow Creek is a small urban stream that runs through one of the older parts of Tulsa, Oklahoma. Residential properties, schools, businesses and parks border the stream. The stream is influenced by the impacts of urbanization including low, medium and high intensity development, extensive impervious surface and stormwater runoff. Twenty-one miles of the stream are enclosed in a stormwater drainage system; three stream miles are aboveground. Crow Creek is on the 2018 State of Oklahoma 303(d) list for *E. coli*, fish bioassessment and macroinvertebrate bioassessment (ODEQ, 2020). Residents support the restoration of Crow Creek. The Crow Creek Community watershed group has met regularly since March of 2015. Representatives from the City of Tulsa Stormwater Management Program, the Metropolitan Environmental Trust (MET), the Tulsa Zoo, the Tulsa County Conservation District, the Blue Thumb Program and a few Tulsa residents actively participate in the watershed group. The opening of the Gathering Place in 2018 and the demonstration site (the Crow Creek Meadow) at 1025 East 33rd Place in 2017 have increased public interest in restoration efforts. The Gathering Place has recently reached out to the Crow Creek Community watershed group. They are interested in supporting efforts in the watershed.

The purpose of this document is to chart a path toward attainment of the *E. coli* standard and full support of the Primary Body Contact Recreation use for Crow Creek. Acceptance of this watershed plan by the Environmental Protection Agency (EPA) will make the Crow Creek Community watershed group and other stakeholders eligible to apply for Clean Water Act (CWA) Section 319 funding to address nonpoint source pollution in the Crow Creek watershed.

This document includes estimated loadings and load reductions calculated using a tool called the Minnesota Pollution Control Agency (MPCA) Simple Estimator (MPCA, 2019a). The loadings and load reductions calculated using the tool are not meant to supersede the load duration curves and percent load reductions included in the *2015 Bacterial and Turbidity TMDL for Oklahoma Streams in the Arkansas and Neosho River Areas (Draft)* (ODEQ, 2015). The Estimator tool was used to generate estimate loadings for each land use type, and percent load reductions that could be expected from the suite of best management practices (BMPs) included in the tool.

This plan does not address Crow Creek's fish and macroinvertebrate bioassessment impairments. We believe these impairments are primarily due to habitat constraints rather than a pollutant or pollutants. Please see "Expected Load Reductions for Solutions Identified" (Element B, page 28) for more detail.

CAUSES OF IMPAIRMENT OR POLLUTANT SOURCES (ELEMENT A)

Watershed Characterization

Crow Creek is a tributary to the Arkansas River (HUC 111101010304; WBID OK120420010090_00). The second order stream flows roughly northeast to southwest. Three stream miles immediately above the confluence with the Arkansas River are aboveground; the remainder is enclosed in a City of Tulsa stormwater drainage system. Please see Figure 1 for a map of the above and belowground portions of the watershed.

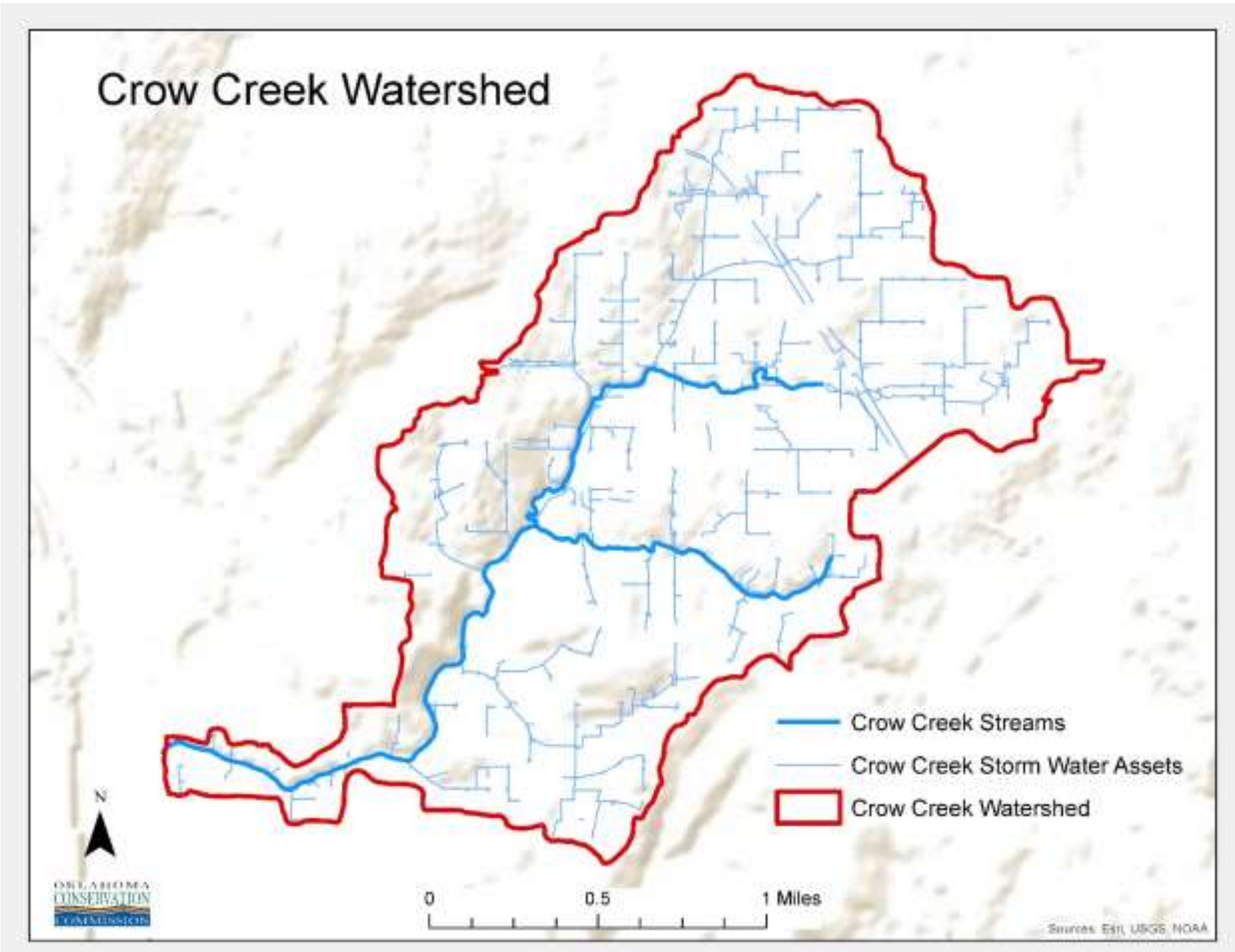

Figure 1: Above and Belowground Portions of Crow Creek Watershed, Tulsa County, Oklahoma

The watershed drains approximately 2.81 square miles (1,781 acres) of land area. Crow Creek is in the Omernik Level III Central Irregular Plains ecoregion (Woods et al., 2005). The Central Irregular Plains are characterized by a mix of rangeland, grassland, woodland, floodplain forests and farmland. Streams in the ecoregion are generally low gradient. Stream substrate and habitat quality vary within the ecoregion. Please see Figure 2 for an aerial photograph of the watershed with an outline of the watershed boundary, Figure 3 for a topographical map, and Figure 4 for a map of soils in the watershed.

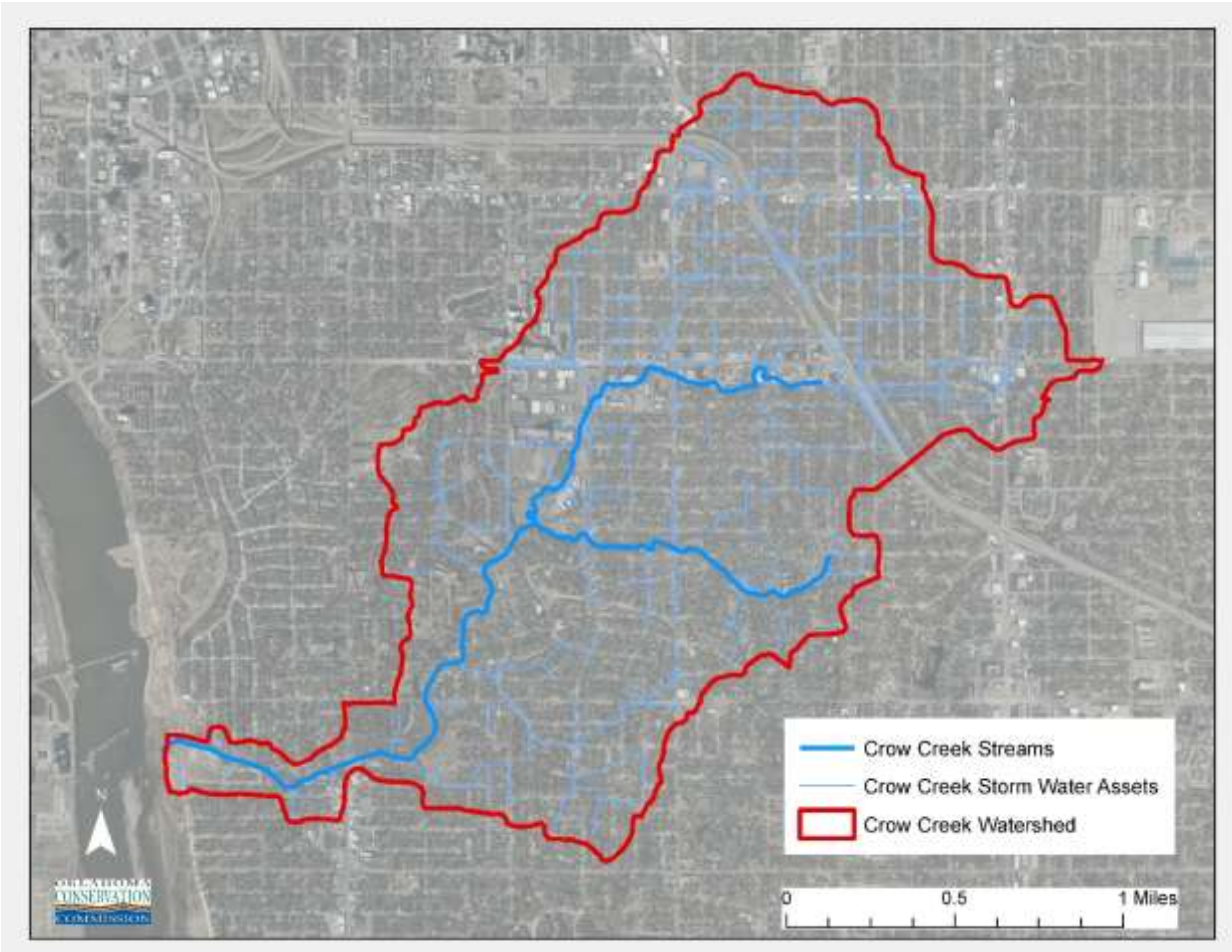

Figure 2: Aerial imagery of the Crow Creek Watershed (Red Boundary), Tulsa County, Oklahoma

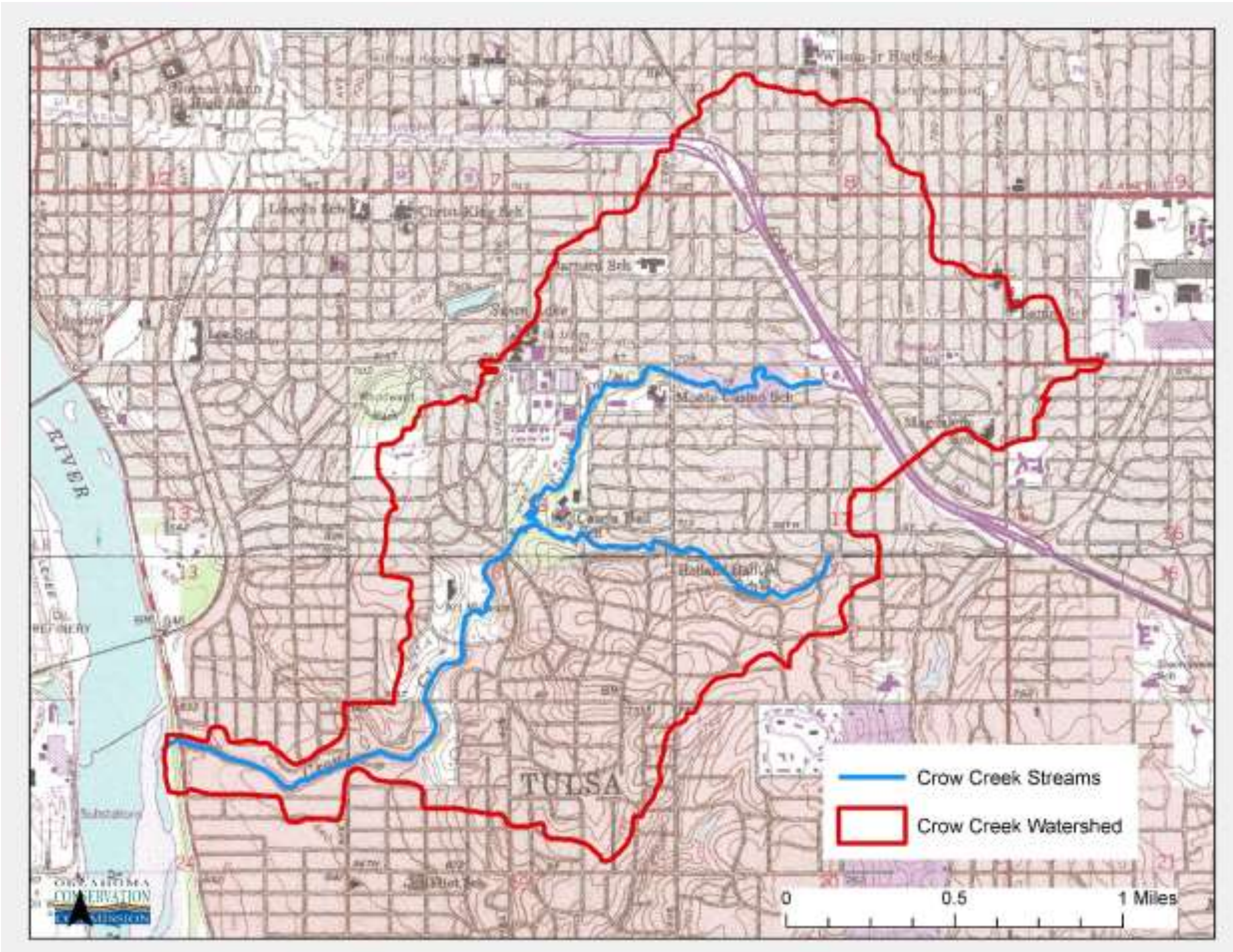

Figure 3: Topographic Map of the Crow Creek Watershed (Red Boundary), Tulsa County, Oklahoma

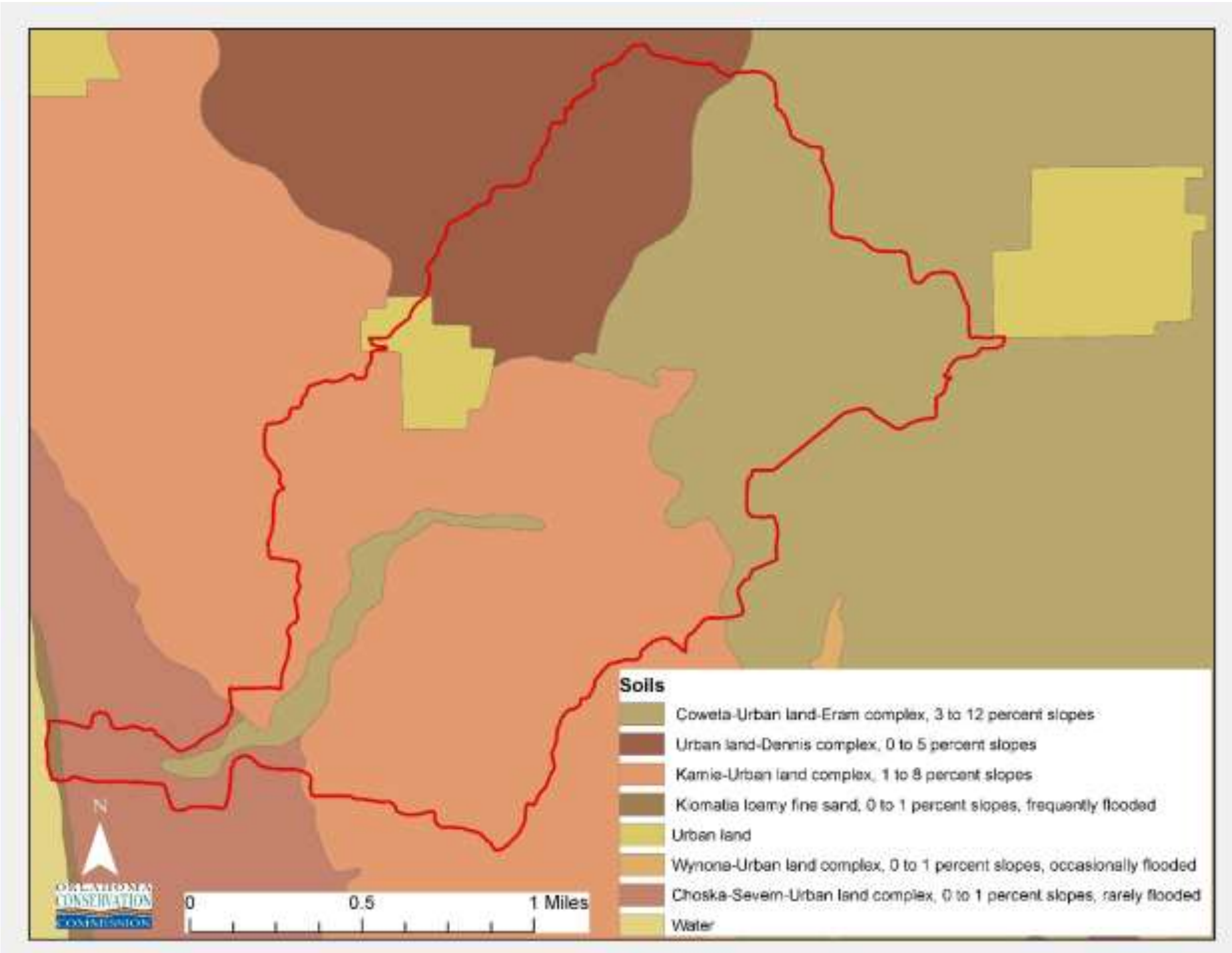

Figure 4: Soils Map of the Crow Creek Watershed (Red Boundary), Tulsa County, Oklahoma

Several sections of the stream are channelized with a mix of stone walls and riprap, some of which is in bad repair (Figure 5). Most of the original channelization was completed by the Works Project Administration in 1933 (personal communication with Jean Lemmon). There are two large sanitary sewer lines running along and in the creek (Figure 5). Crow Creek has many areas with little or no riparian buffer, but there are also stream reaches that have good canopy cover and healthy riparian vegetation. The assessed habitat (Zink Park) of the aboveground portion of Crow Creek is excellent when compared with high quality habitat in the Central Irregular Plains ecoregion. (The 2016 habitat assessment of Crow Creek resulted in a habitat score of 102.3 points. The average habitat score for high quality streams in the ecoregion is 86.8 points.)

Figure 5: Sanitary sewer main in creek (top left) and examples of riprap (top right) and channelization (bottom) along Crow Creek in Tulsa County, Oklahoma.

Crow Creek is in Tulsa County. The average annual temperature in Tulsa County is 60 degrees, with recorded temperatures ranging from -15°F to 115°F. Average annual precipitation is 41.91 inches (Oklahoma Climatological Survey, 2019). Heavy rains are common in Tulsa County, with an average of 50 thunderstorm days per year (Oklahoma Climatological Survey, 2019). The combination of heavy rains and impervious surfaces contributes to flooding in the watershed. Crow Creek Meadow is located on two city lots with a history of flooding. The City of Tulsa purchased the lots in 2004 and 2012, removed two homes and, in cooperation with the Crow Creek Community watershed group, created a demonstration meadow to help abate flooding. The meadow is enjoyed as a green space and is used to educate the public about stream health and nonpoint source pollution management.

Although 50% of the Crow Creek watershed falls into the “low intensity development” land use/land cover (LULC) category, the LULC immediately surrounding the aboveground portion of Crow Creek is highly developed. Please see Figure 6 for a map of LULC and Figure 7 for a pie chart of percentages of LULC types in the watershed. Development in the watershed ranges from low (developed open space) to high intensity development and includes both residential and commercial land uses. Most of the neighborhoods in the watershed are older and affluent. The watershed includes several schools, shopping centers, parks, a hospital and the Philbrook Art Museum, as well as other businesses. The Philbrook Art Museum is surrounded by 25-acres of carefully landscaped gardens.

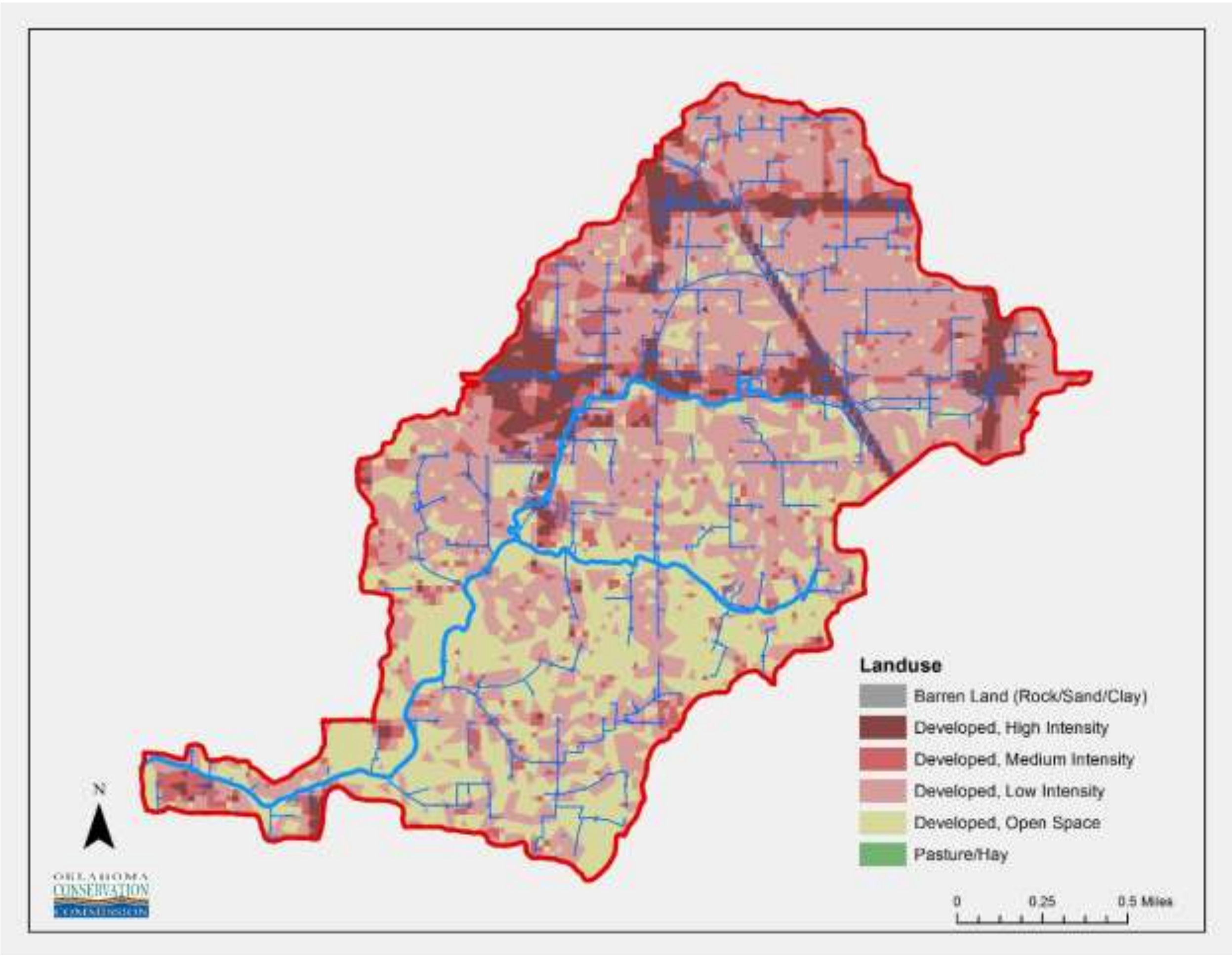

Figure 6: Land use/Land cover Map of the Crow Creek Watershed (Red Boundary), Tulsa County, Oklahoma

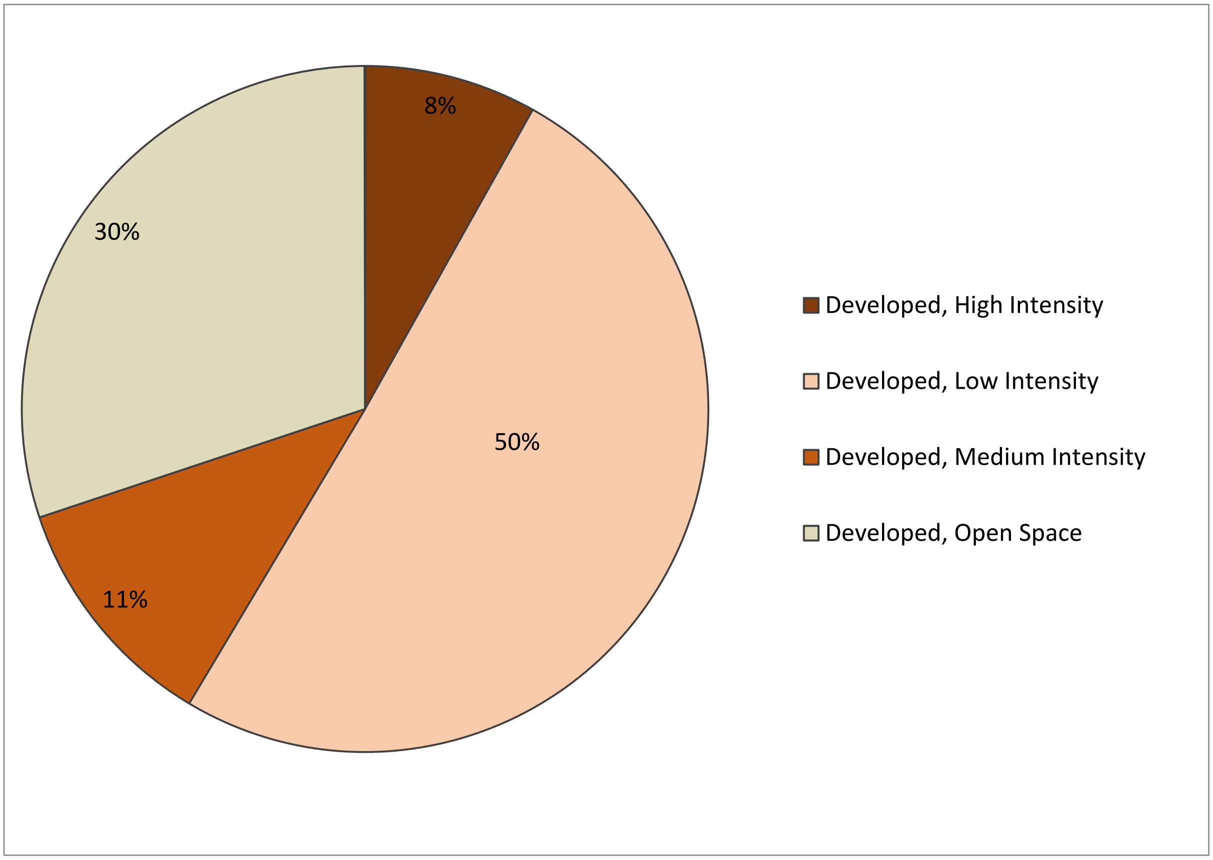

Figure 7: Pie Chart of Land use/Land cover Categories in the Crow Creek Watershed, Tulsa County, Oklahoma (LULC categories that comprise less than 1% of the watershed are not included in the pie chart)

The 2010 census data indicate that 8,943 people lived in the watershed at that time; the population density was 3,157 per square mile. Approximately, 87% of the people in the watershed self-identified as white. The median per capita income was $51,817 and the median household income was $67,117 (The preceding demographic data were provided by Vernon Seaman of Indian Nations Council of Governments. A copy of the demographic report is available upon request.). A search of homes for sale within a block of the creek yielded properties ranging from $299,000 to $1,895,000. A 7,753 square foot lot (with no home) near the creek was listed for $195,000 (data retrieved from Zillow.com on October 17, 2019).

Potential Pollutants

Beyond the City of Tulsa municipal separate stormwater sewer system (MS4), there are no permitted point source discharges in the watershed. The stream likely receives common stormwater pollutants such as sediment, nutrients, bacteria and lawn chemicals. Based on data submitted to the Oklahoma Department of Environmental Quality (ODEQ) for inclusion in the integrated reporting process, the only pollutant that currently exceeds water quality standards is the fecal indicator bacteria, *E. coli*. Please see the “Summary of Available Data” section for more details regarding measured parameters and the “Criteria to Protect Uses” section for details regarding applicable criteria. Please see the "Potential Sources Identified in the 2018 Integrated Report" and "Potential Sources Identified by the City of Tulsa" sections, below, for information about likely sources of *E. coli*.

Existing Land Management Practices

Land management practices in the watershed include commercial and residential landscaping, some of which is intensive, and lightly managed green spaces such as parks. Routine road maintenance such as road repairs and de-icing activities may also impact the creek.

Stormwater Management Activities and 319 Projects

The City of Tulsa implements many stormwater management activities in the Crow Creek watershed including, but not limited to:

- Mowing and applying herbicide around channels, streams and retention ponds
- Removing sediment from ponds, streams and roadside ditches
- Inspecting, cleaning and repairing storm sewer pipes, catch basins and inlets and pump stations
- Removing trash from ponds, channels and ditches
- Utilizing the Tulsa Stormwater Criteria Manual to minimize water quality degradation as a result of development or redevelopment
- Implementing the planning and review process to ensure City requirements are met in development and redevelopment projects
- Enforcing zoning ordinances
- Promoting low impact development
- Sweeping streets
- Removing trash on City-owned rights-of-way
- Implementing the Flood Management Project Design Review process
- Providing public education about the application of lawn chemicals to residents and commercial applicators
- Raising sanitary sewer manholes to grade
- Implementing an illicit discharge detection and elimination program
- Implementing a grease abatement program
- Sponsoring an annual creek clean-up
- Providing public education about reducing litter
- Providing public education about proper disposal of lawn waste and household hazardous waste
- Collecting stream data and preparing watershed characterizations for streams that receive stormwater discharges

The above list is a summary of some of the management practices identified in the City of Tulsa stormwater management plan. The document is entitled *Storm Water Management Programs for OPDES Permit #OKS000201* (City of Tulsa, 2012). The above list is not exhaustive. Many of the activities listed are implemented as needed. Activities required as a condition of the MS4 permit are not eligible for CWA Section 319 funding.

303(d) Listings

Crow Creek (OK120420010090_00) has use designations for primary body contact recreation (PBCR), fish and wildlife propagation (warm water aquatic community subcategory) (FWP-WWAC), aesthetics, agriculture, and fish consumption. Only the PBCR and WWAC uses have been assessed; available data are insufficient to assess the remaining uses. According to *Water Quality in Oklahoma: 2018 Integrated Report* (ODEQ, 2020), PBCR and WWAC are not supported. Crow Creek is on the 303(d) list for fish bioassessment, macroinvertebrate bioassessment and *E. coli*. Fish bioassessment and macroinvertebrate bioassessment pertain to the WWAC subcategory of the FWP use; *E. coli* pertains to PBCR. Fish and macroinvertebrate bioassessments are 5c impairments, which means that additional data are needed before a total maximum daily load (TMDL) is scheduled. *E. coli* is a 5a impairment, which triggers the TMDL process. A draft TMDL that addresses the *E. coli* impairment has been completed but not approved by EPA (ODEQ, 2015). Please see the “Summary of Available Data” section (below) for more information.

Criteria to Protect Uses

FWP-WWAC

The assessment of fish and macroinvertebrate data is complex and requires calculation of multimetric indices (MMIs) and comparison of these indices to indices for reference streams in the same ecoregion. For fish collections, the MMI (or score) is compared to a reference MMI for the ecoregion. These reference MMIs are known as “OKBIOCRIT.” OKBIOCRIT are available for most of the state (see the *Continuing Planning Process* document (CPP) (ODEQ, 2012), page 112). In regions where OKBIOCRIT are not available, an alternative assessment method called OKIBI can be used. When the OKBIOCRIT assessment protocol results an “undetermined” status, the OKIBI protocol can be used to help determine attainment (see Table 16 on pages 109-110 of the CPP).

For macroinvertebrates collections, calculated MMIs are compared to ecoregion-specific reference MMIs. Reference MMIs are available from the Oklahoma Conservation Commission. If the calculated MMI is greater than 80% of the reference MMI, the use is attaining with regard to bioassessment of the collection. If the calculated MMI is 50-80% of the reference MMI, attainment is undetermined. If the calculated MMI is less than 50% of the reference MMI, the use is not attaining with regard to bioassessment.

For fish, assessment can be completed based on between one and five collections (one index period per year for five years). For macroinvertebrates, assessment can be completed with a minimum of four collections completed over two years and a maximum of 10 collections completed over five years. Please see Table 1 for final use attainment determination based on macroinvertebrate collections. Biological collections must be completed during associated index periods.

Table 1: Final Fish and Wildlife Propagation Use Attainment Determination Based on Macroinvertebrates

Minimum Number of "Attaining" Collections	Number of "Undetermined" Collections	Number of "Not Attaining" Collections	Final Macroinvertebrate Assessment
2	any	0	Attaining
any	any	1	Undetermined
any	any	2 or more	Not Attaining

Note: Reprinted from ODEQ. 2012. Continuing Planning Process, p 111.

Where multiple sources of data exist, all data must be meeting for the use to be attained. If **any** of the chemical methodologies (DO, toxicants, pH, turbidity, oil and grease, and toxicants not assessed and not likely to occur or violate criteria) or **either** of the bioassessment methodologies (fish or macroinvertebrate bioassessment) are not meeting, the WWAC-FWP use is not supported. Please refer to the *Continuing Planning Process* document (ODEQ, 2012) for details regarding the assessment of fish and macroinvertebrate data.

PBCR

The PBCR use is attaining with regard to *E. coli* if the geometric mean of the samples does not exceed 126 colonies per 100 mL. Ten samples are required to complete an assessment unless the available samples ensure exceedance of the criterion. Samples must be collected during the recreation season (May 1-September 30).

Summary of Available Data

Blue Thumb Data

Chemical Data

Volunteers have collected data on Crow Creek since 1996. Chemical and observational data are collected independently by volunteers and samples are analyzed for the following parameters using screening-level Hach kits: dissolved oxygen, pH, ammonia nitrogen, nitrates and nitrites, chloride and orthophosphate. These data are not analyzed using EPA-approved methods and are therefore not appropriate for assessment and listing purposes, but they are useful for a general characterization of stream chemistry. Please see Table 2 for summary statistics of Blue Thumb chemical data collected between 1/30/2014 and 2/19/2018. During each sampling event, each test is completed twice. The results summarized in Table 2 are the mean of the two tests from all sampling events.

Table 2: Summary Statistics for Blue Thumb Chemical Data from Crow Creek (2014-2018)

Analyte	Min	Max	Mean	Criterion or Threshold	Percent Exceedance
DO (mg/L)	6.0	14.5	9.3	10% or fewer of the samples are ≤6.0 mg/L from April 1-June 15, or 5.0 mg/L from June 16-March 31	0
pH	7.5	7.8	7.60	6.5 ≤ pH ≤ 9.0	0
Nitrate (mg/L)	0	2.0	0.475	N/A	N/A
Nitrite (mg/L)	0	1.25	0.063	N/A	N/A
Ammonia (mg/L)	0	0.20	0.020	N/A	N/A
Nitrate/Nitrite (mg/L)	0	2.00	0.538	N/A (The stream is not nutrient-threatened if the mean of nitrate/nitrite samples is less than or equal to 4.95 mg/L.)	N/A
Orthophosphate (mg/L)	0	.100	.0476	N/A (The stream is not nutrient-threated if the mean of total phosphorus samples is less than or equal to 0.24 mg/L.)	N/A
Chloride (mg/L)	20	280	54.17	The mean of all chloride samples should be less that the yearly mean standard. For this watershed, the yearly mean standard is 123 mg/L. No more than 10% of the samples should exceed the sample standard. For this watershed, the sample standard is 172 mg/L.	<10% (1 out of 21 samples exceeded the sample standard)

The DO and pH data meet criteria and the WWAC subcategory of the FWP use appears to be supported for these parameters. The mean of the nitrate/nitrite data is less than the value that is used to make a "nutrient-threatened" determination. The WQS do not specify criteria for ammonia or orthophosphate. The mean of all chloride samples is less than the yearly mean standard for this watershed identified in OAC 785:45, Appendix F.

Macroinvertebrate Data

Blue Thumb volunteers collect macroinvertebrate data twice per year during the summer and the winter index periods. Macroinvertebrate collections are always completed under the supervision of Blue Thumb staff and in accordance with Oklahoma Conservation Commission standard operating procedures (SOPs) (OCC, 2019), and these data are used for assessment and listing decisions. Please see Figure 8 for summer macroinvertebrate data and Figure 9 for winter macroinvertebrate data. Both figures display the ratio between the MMI for the macroinvertebrate collection from Crow Creek and the reference MMI. When that ratio is less than 50%, the attainment status for the macroinvertebrate collection is "not attaining." 50% is indicated by the red horizontal line in Figures 8 and 9. Use assessment can be based on a minimum of four collections taken over two years and a maximum of 10 collections over five years. If there are two or more “not attaining” collections in the collections assessed, the use attainment decision is “not attaining.” All of the summer percent reference values (calculated MMI/reference MMI) are less than 50% and most of the winter percent reference values are less than 50%. These data indicate that the WWAC subcategory of the FWP use is not attaining with regard to macroinvertebrate bioassessment.

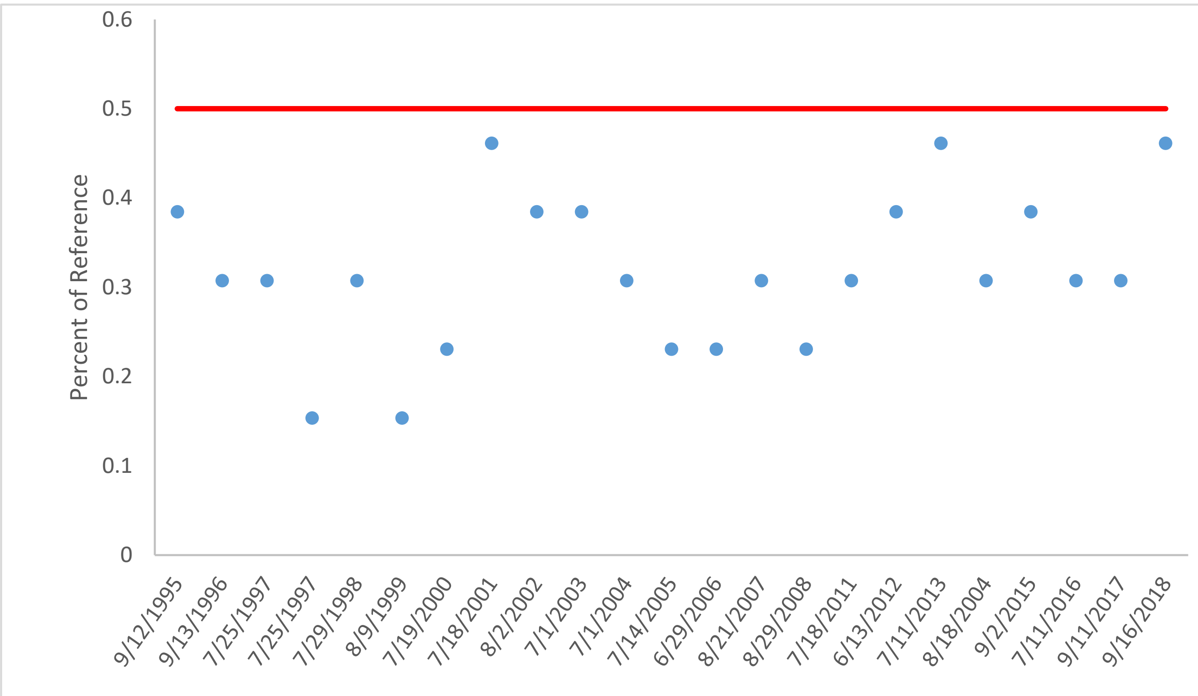

Figure 8: Summer Macroinvertebrate Data from Crow Creek. Blue dots represent the ratio of Crow Creek MMI to Reference MMI for each sample event. The red line represents the threshold below which a macroinvertebrate collection is considered “not attaining”.

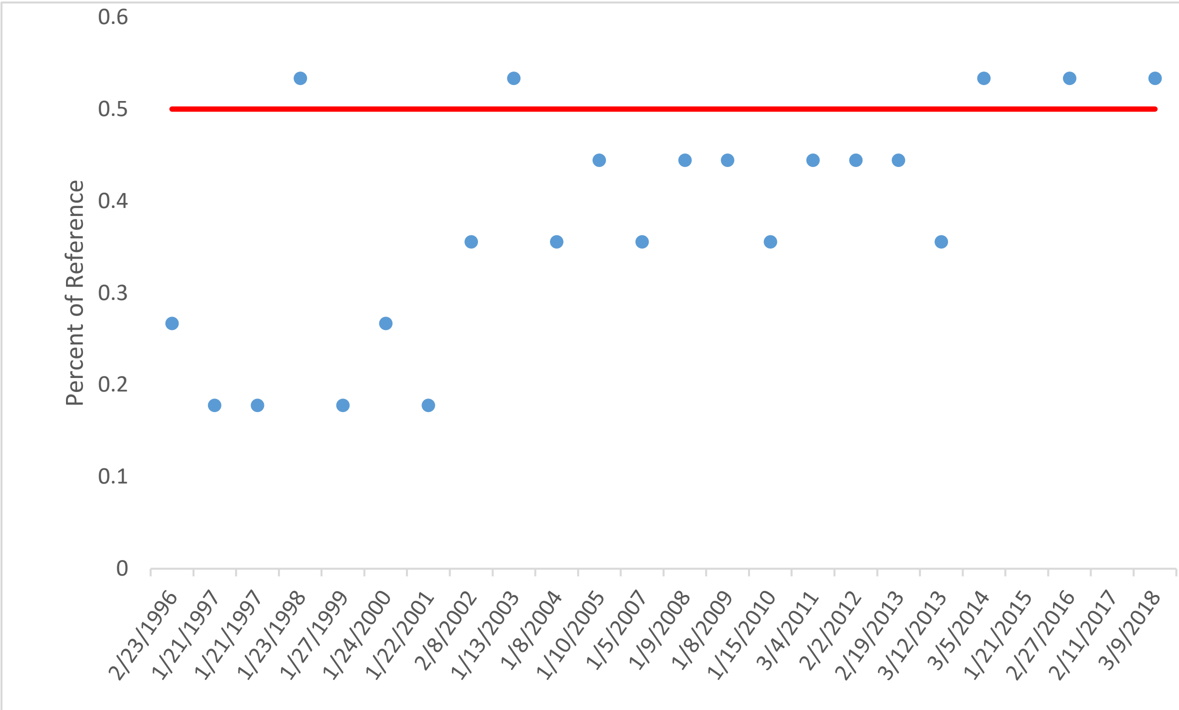

Figure 9: Winter Macroinvertebrate Data from Crow Creek. Blue dots represent the ratio of Crow Creek MMI to Reference MMI for each sample event. The red line represents the threshold below which a macroinvertebrate collection is considered “not attaining”.

Fish Data

Blue Thumb volunteers collect fish data once every four or five years. Fish collections were completed at Crow Creek in 2012 and 2016. Fish collections are always completed under the supervision of Blue Thumb staff in accordance with agency SOPs; as a result, fish data are used for assessment and listing decisions. Blue Thumb fish collections are completed using seines; electrofishing is not part of the protocol.

Five species were caught during 2012. OKBIOCRIT yielded a score of 25. Scores between 23 and 29 result in an “underdetermined” finding in the Central Irregular Plains ecoregion. The OKIBI protocol yielded an MMI that was 47% of the reference MMI. A ratio of 47% of reference is “not attaining.” An “undetermined” OKBIOCRIT finding and a “not attaining” OKIBI finding result in a “not attaining” attainment decision. A significant fire destroyed an old school in the watershed in 2012, but the fire occurred after the fish collection and did not impact this collection (personal communication with Jacob Hagen, City of Tulsa Stormwater Management Division). There are multiple fish barriers which impede movement of fish on Crow Creek. There is one fish barrier downstream of Zink Park where the Blue Thumb collections were completed; upstream barriers are unlikely to impact species richness at Zink Park.

Three species (mosquitofish, green sunfish and central stoneroller) were collected in 2016. The OKBIOCRIT protocol resulted in a score of 19. Scores less than 23 indicate that the stream is "not attaining" with regard to fish bioassessment.

City of Tulsa Data

Chemical Data

The City of Tulsa monitored Crow Creek in 2012-13 and 2016-17 as part of their MS4 permit (FTN Associates and Cherokee CRC, 2013). Please see Table 3 for a summary of the 2012-13 data and Table 5 for a summary of the 2016-17 data.

Table 3: Summary of 2012-13 Crow Creek Data from the City of Tulsa

Crow Creek					
Metric	**Water Quality Standard**	**Results-Mean**	**Results-Maximum**	**Number of Samples**	**Number of Attempts**
BOD(5) DAY (mg/L) (BDL 3)	Only applies to certain waters; stormwater discharges existing prior to June 25, 1992 are exempt; see OAC 785: 45-5-25	2.05	8.8	11	12
Cadmium, Total (µg/L) (BDL 1)	Function of hardness. See OAC 45, Appendix G, Table 2	0.62	2	11	12
Coliform, Fecal (CFU/100mL)	N/A	665	20000	11	12
Copper, Total (µg/L) (BDL 6)	Function of hardness. See OAC 45, Appendix G, Table 2	3.4	7	11	12
Diazinon (µg/L) (BDL 5)	0.17	*2.5	*2.5	11	12
E. coli CFU/100mL	126 (GM)	486	5700	11	12
Hardness, Total (mg/L)	N/A	173.27	200	11	12
Lead, Total (µg/L) (BDL 2.0)	Function of hardness. See OAC 45, Appendix G, Table 2	*1	*1	11	12
Nitrogen, Kjeldahl, Total (mg/L) (BDL 0.50)	N/A	0.34	1.5	11	12
Nitrogen, Total as N (mg/L) (BDL 0.50)	N/A	1.2	3.3	11	12

Metric	Water Quality Standard	Results-Mean	Results-Maximum	Number of Samples	Number of Attempts
Oil and Grease HEM (mg/L) (BDL 6.0-6.7)	No sheen or bottom deposits	4.67	6.45	11	12
Phosphorus, Total (mg/L) (BDL 0.010)	Only applies to certain waters; stormwater discharges existing prior to June 25, 1992 are exempt; see OAC 785: 45-5-25	0.06	0.2	11	12
Phosphorus, Total Dissolved (mg/L) (BDL 0.010)	N/A	0.04	0.16	11	12
Solids, Total Dissolved (mg/L) (BDL 10)	Sample: 1,868 Yearly: 1,496	280.8	350	11	12
Solids, Total Suspended (mg/L) (BDL 2)	Only applies to certain waters; stormwater discharges existing prior to June 25, 1992 are exempt; see OAC 785: 45-5-25	5.23	16	11	12
Zinc, Total (μg/L) (BDL 10)	Function of hardness. See OAC 45, Appendix G, Table 2	11.36	37	11	12
Temperature, Water (°C)	Depends on the receiving water; see OAC 785:45-5-12	13.91	27.08	11	12
pH (su)	6.5< pH < 9.0	-	7.6	11	12
Flow (cfs)	N/A	0.894	2.52	11	12

Note Adapted from FTN Associates, Ltd. and Cherokee CRC, LLC. 2013. City of Tulsa Watershed Characterization Program, Year 2 Biological Collection and Analytical Summary Report: Crow Creek. City of Tulsa, Tulsa, Oklahoma, USA, Table 3.5, page 10.
For this report, the table was modified to include additional information about water quality standards.
* The actual value was below the detection limit. The results are presented as one-half (1/2) the detection limit.
- Results-Minimum is not required by the permit for laboratory parameters.

DO values are not included in Table 3, but the City of Tulsa provided the associated DO values which are presented in Table 4. Fewer than 10% of the DO measurements were below the associated criterion, so Crow Creek appears to be supporting FWP-WWAC with respect to DO. With the exception of *E. coli*, the data summarized in Tables 3 and 4 do not indicate violated water quality standards. The geometric mean of the *E. coli* data is 485 CFU/100 mL, which exceeds the criterion of 126 CFU/100 mL.

Table 4: City of Tulsa Dissolved Oxygen (DO) Values for Crow Creek (2012-13)

Analyte	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug
DO (mg/L)	4.45*	7.22	8.94	7.37	12.63	10.94	12.9	7.74	8.4	7.8	5.8	6.09

*This value is below the applicable threshold of 5.0 mg/L.

Table 5: Summary of 2016-2017 Data for Crow Creek from the City of Tulsa

Crow Creek						
Parameter	**Water Quality Standard**	**Sample Mean**	**Single Sample Maximum**	**No. of Samples**	**No. of Samples Required (WQS)**	**How Standard is Violated**
Cadmium (µg/L)	Acute: 102.36, Chronic: 2.46	0.50	0.50	12	5	Acute: No more than one sample concentration exceeding WQS Chronic: No more than one sample or 10% exceeding
Copper (µg/L)	Acute: 48.56, Chronic: 29.69	2.86	6.54	12	5	
Lead (µg/L)	Acute: 286.15, Chronic: 11.15	0.88	2.74	12	5	
Zinc (µg/L)	Acute: 269.64, Chronic: 244.23	16.26	39.60	12	5	
E. coli (MPN/100ml)	126	272	Na	12	5	Geometric mean not exceeding standard
Enterococcus (MPN/100ml)	33	264	Na	12	5	Geometric mean not exceeding standard
Oil and Grease (visual)	No visible sheen	none	Na	12	10	No more than 10% of observations with oil & grease
Total Phosphorus (mg/L)	0.24*	0.06	Na	12	10	No more than 10% of samples outside range
Nitrite – Nitrate (mg/L)	*4.95**	*1.08*	*Na*	*12*	*10*	*No more than 10% of samples outside range*
Total Dissolved Solids (mg/L)	Sample: 1868, Yearly: 1496	308	440	12	10	Mean of samples not exceeding yearly standard & no more than 10% exceeding sample standard
pH (s.u.)	6.5-9.0	7.5 – 7.9	Na	12	10	No more than 10% of samples outside range
Turbidity (NTU)	50	3.22	13.29	12	10	No more than 10% of samples outside of range
D.O. (mg/L)	*April -June 5.0*	*0 samples below 5.0*	*Na*	*3*	*10 total*	*No more than 10% of samples outside range*
	June -Mar 6.0	*1 sample below 6.0*	*Na*	*9*		
**Analytes in italics not required by permit* *Analytes in red exceed standards*						

Note: Reprinted from Bootenhoff, J. 2019. City of Tulsa Watershed Characterization Program, Comprehensive Watershed Characterization Year 1 (2016-2017): Crow Creek. City of Tulsa, Tulsa, Oklahoma, USA, Table 14, page 15.

* These values are not water quality standards. They are the appropriate thresholds to make a “nutrient-threatened” determination for Crow Creek.

As with the 2012-2013 data, the only violation of water quality standards in the 2016-2017 data relates to bacteriological parameters (*E. coli* and Enterococcus). In 2017, the City of Tulsa submitted three water samples for DNA analysis. Each sample was analyzed for human, dog and goose DNA. The first sample indicated over 4500 copies of dog DNA and over 1000 copies of human DNA. No dog, human or goose DNA was detected in the second sample. The third sample indicated between 200 and 300 copies of dog DNA (Bootenhoff, 2019). Although it would be unwise to place too much weight on only three samples, the limited data suggest that pet waste and human sewage are likely sources of bacteria in the watershed.

Macroinvertebrate Data

The City of Tulsa sampled benthic macroinvertebrates during the summer of 2012 and the winter of 2013. Both collections indicated an impaired macroinvertebrate fauna. Typically, four collections are required to do an assessment, but since the assessment protocol dictates that two or more "not attaining" collections result in an assessment decision of "not attaining," we can make an impaired assessment based on two collections. Please see pages 110-111 of the CPP (ODEQ, 2012) for more information regarding the assessment of macroinvertebrate data. The calculated MMI was 23.08% of reference condition for the summer 2012 collection and 26.67% of reference condition for the winter 2013 collection.

Fish Data

The City of Tulsa completed a fish collection in the summer of 2012. Only two species were captured (mosquitofish and green sunfish). An assessment based on this collection indicates that Crow Creek is not supporting FWP-WWAC with regard to fish bioassessment. The calculated MMI was 15; anything below 23 is not supporting for the Central Irregular Plains ecoregion. This fish collection was completed after a significant fire in the watershed in 2012. Fire-fighting chemicals washed into the creek in the aftermath of the fire. DO plummeted, and a fish kill was observed. Consequently, this fish collection may not be representative of the biological community. This collection was completed in Zink Park, the same site where the Blue Thumb collections were completed.

A second fish collection was completed in the winter of 2016. Nine species were collected. This collection was completed downstream from the Zink Park site and below all fish barriers. Assessment of this data using the OKBIOCRIT protocol resulted in an "undetermined" finding. The calculated MMI was 25. MMIs greater than 23 but less than 29 result in an "undetermined" finding. An assessment completed using the OKIBI protocol also resulted in an "undetermined" finding. The calculated MMI was 64% of the reference MMI.

The City of Tulsa electrofishes a 200-m reach and Blue Thumb seines a 400-m reach, so it may not be appropriate to compare the City of Tulsa fish data with Blue Thumb fish data.

Data from the 2015 Bacterial and Turbidity TMDL (Draft)(ODEQ, 2015)

The *2015 Bacterial and Turbidity TMDL for Oklahoma Streams in the Arkansas and Neosho River Areas (Draft)* (ODEQ, 2015) indicates that the calculations in the TMDL were based on 13 *E. coli* samples collected in 2003, 2004 and 2005. Samples were collected during the recreation season

(May 1-September 30). The geometric mean of the data is 448 CFU/100 mL which exceeds the WQS of 126 CFU/100 mL.

Potential Sources Identified in the 2018 Integrated Report

Water Quality in Oklahoma: 2018 Integrated Report (ODEQ, 2020) lists the following sources as possible sources of *E. coli* for Crow Creek: grazing in riparian zones, on-site treatment systems, rangeland grazing, residential districts, wastes from pets, wildlife other than waterfowl, and unidentified sources. Grazing in riparian zones and rangeland grazing are unlikely sources of significant *E. coli* loading in the watershed because there is little agricultural activity.

Common residential sources identified in the *2015 TMDL* (Draft)(ODEQ, 2015) include on-site treatment systems and waste from pets. Other possible sources of *E. coli* often associated with residential areas include leaky sewer pipes (exfiltration), illicit sanitary connections to the MS4, Porta-Potties, dumpsters, trash cans, garbage trucks, outdoor dining, restaurant grease bins, bars and stairwells (washdown areas), car washing, pools and hot tubs (Urban Water Resources Research Council, 2014). Because there are approximately 17 unsewered homes in the watershed (personal communication with Jacob Hagen of the City of Tulsa Stormwater Management Division, October 23, 2020), failing septic systems may contribute to *E. coli* loading. Waste from pets is the most likely source of significant *E. coli* loading in the watershed. The *2015 TMDL* (Draft)(ODEQ, 2015) estimates that there are 2,759 dogs and 3,112 cats in the watershed.

The *2018 State of Oklahoma Integrated Report* (ODEQ 2020) lists the following possible sources of impairment for fish bioassessment: grazing in riparian zones, highway/road/bridge runoff (non-construction related), impacts from land application of wastes, non-irrigated crop production, on-site treatment systems, petroleum/natural gas production activities (legacy), rangeland grazing, residential districts, wildlife other than waterfowl, and unknown sources. The 303(d) list also includes a source code 72 that is not identified in the table of cause codes. The same sources codes are listed for macroinvertebrate bioassessment, with the addition of drought-related impacts. Of this list, the sources most likely to significantly impact the biota in Crow Creek are highway/road/bridge runoff, residential districts, and drought-related impacts. The most pressing constraints on the fish and macroinvertebrate communities are physical, rather than chemical. Please see "BMPs to Address Biological Impairment for Macroinvertebrates**"** and "BMPs to Address Biological Impairment for Fish" for details.

Potential Sources Identified by the City of Tulsa

The City of Tulsa identifies pet waste and failing septic systems as the most likely sources of *E. coli* in the watershed (Bootenhoff, 2019). Sanitary sewer overflows may also contribute to the *E. coli* impairment. In 2017, there were 17.5 SSOs/mi^2 in the Crow Creek watershed (personal communication with Jacob Hagen of the City of Tulsa Stormwater Division, October 23, 2020).

Estimates of *E. coli* Loadings

Although there are many resources which identify best management practices (BMPs) to reduce bacteria loadings, most do not include quantitative data about expected load reductions. One of the tools that does enable the calculation of expected load reductions is the Minnesota Pollution Control Agency (MPCA) Simple Estimator (MPCA, 2019a). This tool is available online as part of the Minnesota Stormwater Manual Wiki. The Wiki provides guidance and examples for using the tool. The tool was developed to help Municipal Separate Storm Sewer Systems (MS4s) permittees complete TMDL Annual Reporting Forms.

The loadings calculated with the Estimator and the load duration curves in the TMDL serve different purposes and are calculated using different data. In the TMDL, each load duration curve includes graphs of two curves: one curve represents the existing *E. coli* load across flow conditions and the other represents the maximum *E. coli* load the stream can accommodate without exceeding the water quality criterion. For *E. coli*, the existing load is calculated by multiplying the geometric mean of all *E. coli* samples taken during the recreation season (May 1-September 30) by flow and a unit conversion factor. The second curve is generated by multiplying the criterion (126 CFU/mL) by flow and the same unit conversion factor. Crow Creek does not have a United States Geological Service gaging station. There are no upstream gages, and the nearest downstream gage is on the Arkansas River. As a result, flows for Crow Creek were estimated from a gage on an adjacent stream that drains a watershed of similar size and land use composition (Joe Creek, USGS gage number 07164600). The method for estimating flow is detailed in Appendix C of the TMDL (ODEQ, 2015).

In contrast, the Estimator generates estimated *E. coli* loadings for each land use category in the watershed. The purpose of these loadings is to calculate expected load reductions for BMPs included in the tool. The underlying data are median fecal coliform values in stormwater for each land use that have been converted to median *E. coli* values as per Cude (2005). We modified the tool to bring the estimated existing annual *E. coli* loading more in line with the existing load estimate in the *2015 TMDL* (Draft)(ODEQ, 2015) at a flow exceedance frequency of 50%. The unmodified tool generated an estimated annual loading significantly greater than the existing load estimate at a flow exceedance of 50% in the TMDL. The modifications we made to the tool are supported by the literature (Cappiella and Brown, 2001; Center for Watershed Protection, 2003). Please see Appendix A for a detailed description of the tool and the modifications made to generate estimated loadings and load reductions for this project. The loadings and estimated load reductions calculated using the Estimator are not meant to supersede the load duration curve for Crow Creek in the *2015 TMDL* (Draft)(ODEQ, 2015). Rather, the loadings generated by the Estimator are intended to guide the selection of BMPs to address the *E. coli* impairment.

The estimated annual *E. coli* load using the modified Estimator is 1.17×10^5 billion CFU/year, or an estimated daily load of 3.20×10^2 billion CFU/day. The approximate existing load estimate in the *2015 TMDL* (Draft)(ODEQ, 2015) is 5.0 or 6.0 billion CFU/day at a flow exceedance frequency of 50% (visually estimated from Figure 5-44 in the TMDL; ODEQ, 2015).

EXPECTED LOAD REDUCTIONS FOR SOLUTIONS IDENTIFIED (ELEMENT B)

BMPs to Address *E. coli* Impairment

BMPs Included in MPCA Estimator

The BMPs included in the Estimator are biofiltration, infiltration, filter strip, landscaped roof, permeable pavement, sand filter, swale wet basin and constructed wetland. The tool provides rough estimates of load reductions based on the implementation of these BMPs. The tool is not capable of modelling pollutant removal of BMPs in a series (treatment trains) or bypass from undersized BMPs. Other tools such as stormwater modelling programs should be utilized to inform the final selection of BMPs. Please see **"**Output from Modified MPCA Estimator" below, for details.

Pet Waste Education Program

Because dogs may be the most significant source of *E. coli* in the watershed, a pet waste education program may significantly reduce the *E. coli* loading. The MPCA does not include calculations for the effectiveness of a pet waste program, but the Watershed Treatment Model does. Please see **"**Expected Load Reduction from a Pet Waste Education Program" below, for details.

Repair or Replacement of Failing Onsite Wastewater Treatment Systems

According to the Onsite Wastewater Systems Treatment Manual (USEPA, 2002), an average of ten percent of onsite wastewater treatment systems are failing at any given time. Repair or replacement on failing septic systems may not significantly impact *E. coli* loading in Crow Creek because there are few septic systems in the watershed. Please see "Expected Load Reduction from Repairing or Replacing Failing Septic Systems" for more information.

Enterococci

The geometric mean of City of Tulsa enterococci data collected during 2016-2017 exceeds the criterion of 33 CFU/100 mL. These data were collected in fulfillment of the MS4 permit requirements and were not reported to ODEQ for inclusion in the integrated reporting process. The City of Tulsa is currently considering removing enterococcus as a monitored parameter because they have found the data to be highly variable (personal communication with Jacob Hagen of the City of Tulsa Stormwater Division on October 23, 2020). Additionally, assessment of the PBCR use can be completed with either *E. coli* or enterococci data. Because Crow Creek is not on the 303(d) list for enterococci, I have not attempted to quantify enterococci loadings or expected load reductions as a result of BMP implementation. However, because *E. coli* and enterococci are both fecal indicator bacteria, it is reasonable to assume that BMPs which reduce *E. coli* loadings will also reduce enterococci loadings. The two tools used to support development of this WBP (the modified Estimator and The Watershed Treatment Model (WTM)(Caraco, 2013)) do not include enterococcus as a pollutant. The WTM includes fecal coliform which was converted to *E. coli* using Cude (2005) and the Estimator includes fecal coliform and *E. coli*. For more regarding the calculation of expected load reductions, see "Output from Modified MPCA Estimator", "Expected Load Reduction from a Pet Waste Education Program" and the appendix.

BMPs to Address Biological Impairment for Macroinvertebrates

Only 12.5% of the linear length of Crow Creek is aboveground; the remaining 87.5 % is contained in a system of storm drains. The headwaters of Crow Creek are underground. Headwater areas are critical for recolonization of macroinvertebrates following a disturbance. Williams and Hynes (1976) identified four primary pathways of macroinvertebrate recolonization following a disturbance: aerial movement, downstream drift, upstream movement and vertical movement from deep substrates. According to Williams and Hynes (1976), downstream drift is usually the most important pathway of recolonization in perennial streams. Daylighting of a portion of Crow Creek that is buried would likely improve macroinvertebrate diversity and abundance by improving the opportunity for recolonization following disturbance events such as high flows. It is unlikely, however, that daylighting would be embraced by the City of Tulsa or by watershed residents. Reestablishment or improvement of riparian areas might improve macroinvertebrate diversity by providing habitat for the terrestrial life history phase of many aquatic insects. Prior to investing in riparian restoration or re-establishment, the areas of healthy and impaired riparian buffers should be quantified. The impoverished macroinvertebrate community in Crow Creek is believed to be due primarily to physical constraints, rather than pollutant loading. Consequently, this document does not attempt to quantify pollutant loadings, load reductions necessary to meet biocriteria for macroinvertebrate bioassessment, or load reductions expected from management measures for macroinvertebrates.

BMPs to Address Biological Impairment for Fish

Crow Creek experiences high flows during rain events that may flush fish downstream. Recolonization from the Arkansas River is inhibited by at least one fish barrier downstream of the Zink Park sampling site; there are further fish barriers upstream of the Zink Park sampling site. Removal of fish barriers would improve opportunities for recolonization. Reestablishment or improvement of riparian area would likely improve instream habitat and might promote the development of woody debris refugia where fish could shelter during high flows. The impaired macroinvertebrate community further limits the fish community. The impoverished fish community in Crow Creek is believed to be due primarily to physical barriers to upstream movement, rather than pollutant loading. Thorough mapping and quantification of fish barriers is a necessary step toward understanding the factors negatively impacting the fish community in Crow Creek. Because the fish impairment is likely due to habitat modifications rather than a pollutant or pollutants, this document does not attempt to quantify pollutant loadings, load reductions necessary to meet biocriteria for fish bioassessment, or load reductions expected from management measures for fish.

Estimates of Load Reductions

The load reductions discussed below are based on load estimates generated by the modified MPCA Estimator rather than load estimates from the *2015 TMDL* (Draft) (ODEQ, 2015). The load reduction expected from a pet waste program is derived from calculations in Caraco (2013). See the Appendix for details regarding the calculation of load estimates with the modified MPCA Estimator; please see below for details regarding the calculation of the expected load reduction from a pet waste education program and repair or replacement of failing septic systems.

Output from Modified MPCA Estimator

The modified MPCA Estimator calculates load reductions based on the number of acres in each land use type treated by each BMP. The number of acres treated by each BMP were selected by the Crow Creek Community watershed group, largely under the direction of employees of the City of Tulsa Stormwater Management Division. The estimates represent best case scenarios for the implementation of each BMP. BMP implementation will be difficult in the Crow Creek watershed because the land is divided into hundreds of small, privately owned lots. See Table 6 for the output from the modified MPCA Estimator. The acreages included in the table are across all four land use types. Acreages for each land use type are included in the tool, submitted with this document as a separate attachment.

Table 6: Expected Load Reductions for Best Case Scenario BMP Implementation in the Crow Creek Watershed, Generated by the Modified MPCA Estimator

BMP	Total Acres Under BMP	Expected Load Reduction (billion CFU/year)	Expected Percent Load Reduction
Bioinfiltration	588	2.83×10^4	23.96
Infiltration	58	3.46×10^3	2.93
Filter Strip	100	1.78×10^3	1.50
Landscaped Roof	50	3.90×10^3	3.30
Permeable Pavement	140	6.32×10^3	5.35
Sand Filter	33	1.64×10^3	1.39
Wet Basin	30	1.20×10^3	1.02
Wetland	35	1.25×10^3	1.06
TOTALS	**1,034**	**4.79×10^4**	**40.50**

* Swale is included as a BMP in the tool, but is not included in Table 9 because the removal efficiency for *E. coli* is 0 and the infiltration rate is 0.

Expected Load Reduction from a Pet Waste Education Program

Because dogs may be the primary source of *E. coli* in the watershed, an education and outreach campaign about properly managing pet waste is likely to result in a significant load reduction.

The MPCA Simple Estimator does not include management of pet waste as a BMP. Potential load reduction from a pet waste program is, however, evaluated in The Watershed Treatment Model (Caraco, 2013):

$R_p = H \bullet W \bullet C_W \bullet f_1 \bullet f_2 \bullet 365$

Where:

R_p = Potential load reduction from a pet waste program (lbs/year or billion colonies/year)

H = Number of households

W = Waste production (lbs/(dog•day) [default value is 0.32 lbs/(dog•day)]

C_W = Concentration of pollutant in dog waste (default value is 10 billion colonies of fecal coliform/lb)

f_1 = Fraction of households with a dog (model default is 0.4)

f_2 = Fraction of a pollutant delivered to a stream (model default is 0.35 for bacteria)

365 = Conversion factor (days/year)

First, we convert the fecal coliform constant to *E. coli* as per Cude (2005):

E. coli = 0.531 • (fecal coliform)^$^{1.06}$

E. coli = 0.531 • (10 billion CFU)^$^{1.06}$

E. coli =2.11×10^1 billion CFU/lb

Plugging in the default values (Caraco, 2013, page 6-13) and the number of households in the watershed (provided by Vernon Seaman of INCOG):

R_p = (4,401 households)•(0.32 lb/(dog•day))•(2.11×10^1 billion CFU/lb)•(0.4 dog/household)•0.35 •365 (days/year)

$R_p = 1.52 \times 10^6$ billion CFU/year

Treatability (T) of a pet waste program is defined as the fraction of the watershed that is the target audience for the program (Curaco, 2013); in this case, the target audience is the population of dog owners that walk their dogs and do not currently pick up their pet waste. The Watershed Treatment Model uses a default value of 0.2 for treatability.

$R_p \bullet T$ = (1.52×10^6 billion CFU/year)(0.2) = 3.04×10^5 billion CFU/year

= 8.33×10^2 billion CFU/day

Cat waste may also be a significant source of *E. coli* in the watershed. The TMDL estimates there are 3,112 cats in the watershed. The qPCR analyses completed at the request of the City of Tulsa did not include an assay for cat DNA. The effectiveness of an education and outreach program about pet waste would likely be improved by focusing on both dog and cat waste.

Expected Load Reduction from Repairing or Replacing Failing Septic Systems

The maximum load reduction expected from repairing or replacing failing septic systems can be estimated by the following equation:

$R_p = H \bullet I_H \bullet C \bullet Q \bullet f_1 \bullet f_2 \bullet f_3 \bullet D$

Where:

R_p = maximum load reduction

H = number of households expected to have failing septic systems at any given time

I_H = average number of individuals per household (default value of 2.7 individuals/household)

C = concentration of E. coli in wastewater (default value of 1.0×10^7 CFU fecal coliform/100 mL)

Q = average water use per individual per day (default value of 70 gallons/individual·day)

f_1 = conversion factor for bacteria (1.38×10^{-5})

f_2 = factor to convert gallons to mL (3,785 mL/gallon)

f_3 = degradation factor (default value of .02 outside the 100-ft buffer)

D = delivery ratio assuming each failing septic system is at least 100 feet from a streambank (default value of 0.5)

The equation above is modified from Caraco (2013); the default values and the conversion factors are also from Caraco (2013). 10% of septic systems are expected to be failing at any given time (USEPA, 2002). The equation, default values and conversion factors are built into the WTM.

First, we convert the fecal coliform constant to *E. coli* as per Cude (2005):

$$E.\ coli = 0.531 \bullet (\text{fecal coliform})^{\wedge 1.06}$$

$$E.\ coli = 0.531 \bullet (1.0 \times 10^7\ \text{CFU})^{\wedge 1.06}$$

$$E.\ coli = 1.40 \times 10^7\ \text{CFU/100 mL}$$

$$R_p = (1.7\ \text{households})(2.7\ \text{individuals/household})(1.40 \times 10^7\ \text{CFU/100 mL})(70\ \text{gal/individual·day})(1.38 \times 10^{-5})(3{,}785\ \text{mL/gallon})(0.5)(.02)$$

$$R_p = 2.34 \times 10^4\ \text{CFU/day}$$

$$R_p = (2.34 \times 10^4\ \text{CFU/day})(365\ \text{days/year}) = 8.54 \times 10^6\ \text{CFU/year}$$

These calculations represent the maximum load reduction assuming that the inspection process was 100% successful at locating failing septic systems (assumed to be 1.7 failing systems at any given time as per USEPA (2002)). This load reduction is negligible and suggests that repairing or replacing failing septic systems in the watershed might not be an efficient use of funds. To put the potential load reduction from repairing or replacing failing septic systems into perspective, the load reduction potential from repairing or replacing failing septic systems is less than 1/100,000th of a percent of the expected load reduction of an effective pet waste education program:

Expected load reduction from repairing or replacing failing septic systems: 8.54×10^{6} CFU/year

Expected load reduction from an effective pet waste education program: 3.04×10^{5} billion CFU/year

8.54×10^{6} CFU/year = 8.54×10^{-3} billion CFU/year

8.54×10^{-3} billion CFU/year = n/100 (3.04×10^{5} billion CFU/year)

n = 2.81×10^{-6} %

The proper maintenance and operation of septic systems will be part of the educational efforts in the watershed, however. Please see **ELEMENT E** and **Table 7** for details about planned educational efforts.

DESCRIPTION OF NPS MANAGEMENT MEASURES THAT WILL NEED TO BE IMPLEMENTED TO ACHIEVE NECESSARY LOAD REDUCTIONS, AND A DESCRIPTION OF CRITICAL AREAS IN WHICH THOSE BMPs WILL BE IMPLEMENTED (ELEMENT C)

Pet Waste Education Program

The load reduction equations built into the Watershed Treatment Model (Curaco, 2013) predict a daily load reduction in *E. coli* of 8.33×10^{2} billion CFU/day as the result of an effective pet waste education program. The mean daily load of *E. coli* generated by the modified MPCA Estimator is 3.23×10^{2} billion CFU/day. The models use slightly different inputs to calculate loadings, so the results are not necessarily directly comparable. However, a comparison of the results of the two models suggests that implementation of an effective pet waste education program will likely result in a significant reduction in *E. coli* loading in Crow Creek and may, in fact, be sufficient to restore beneficial use support of the PBCR use. Critical areas for implementation include parks and green spaces where people walk their dogs as well as residential areas.

Installation of Additional Pet Waste Stations

The addition of additional pet waste stations in the watershed would support educational efforts regarding the proper disposal of pet waste.

Other NPS Management Measures that Need to Be Implemented to Achieve Necessary Load Reductions

It is possible that a pet waste education program will be insufficient to achieve the necessary load reduction for *E. coli*. The most cost-effective path forward would be to implement a pet waste education program in the watershed and monitor *E. coli* during the recreation season to assess the effectiveness of the program. If a pet waste education program does not result in the necessary load reduction, more advanced modelling should be completed prior to the selection of additional BMPs. The Modified MPCA Load Estimator uses removal efficiency rates greater than 70% for the following BMPs: bioinfiltration, landscaped roof, permeable pavement, wet basin and wetland. The removal efficiency rate for infiltration is 0%, but runoff that is infiltrated is assumed to have 100% load reduction. Because the data suggest domestic pets as the primary contributor to *E. coli* loading, landscaped roofs may not have a large impact on loading even though the estimated removal efficiency rate is 90%.

ESTIMATE OF THE AMOUNT OF TECHNCIAL AND FINANCIAL ASSISTANCE NEEDED TO IMPLEMENT PLAN, AND POTENTIAL PARTNERS (ELEMENT D)

An effective pet waste education program should include the following components:

1. Pet waste ordinances
2. Pet waste disposal stations: cost of materials, installation and one year of weekly maintenance is approximately $1,429 per station (Wood, 2017)
3. Education and outreach

The City of Tulsa already has a pet waste ordinance. Owners may be charged up to $200 per offense for allowing animals to defecate (without the owner, keeper, or harborer removing the excreta deposited) on any public or private property other than that of the owner (Title 2, Chapter 1, Section 101 of the Tulsa, Oklahoma Code of Ordinances). Approximately 10 pet waste stations are available in the Crow Creek watershed; two are located in Zink Park. Additional pet waste stations would likely reduce bacterial loading. The cost of installing 10 additional pet waste stations, supplying them with bags, and emptying the stations weekly would be approximately $15,000. We estimate that an effective education and outreach campaign would cost about $30,000 per year. This estimate is approximately half of the expected cost to cover salary and fringe benefits for a full-time environmental educator. We estimate a cost of $1,000/year to complete *E. coli* sampling during the recreation period.

Currently engaged partners include the City of Tulsa Stormwater Management Division, the Tulsa County Conservation District, the Crow Creek Community (CCC), Metropolitan Environmental Trust, the Tulsa Zoo and the Blue Thumb Program. Possible additional partners include the Philbrook Museum, Cassia Hall Preparatory School and the Gathering Place. The CCC will coordinate efforts in the watershed. The City of Tulsa will provide technical expertise regarding the best placement for pet waste stations and will help the CCC find a contractor to complete the installation of pet waste stations. If monitoring results indicate that an effective pet waste education program is insufficient to address the *E. coli* impairment, the City of Tulsa will provide guidance on the selection and siting of structural BMPs. The City of Tulsa will also continue monitoring Crow Creek as part of the requirements of their MS4 permit. Blue Thumb will continue to support a volunteer monitor on Crow Creek and will share the data with interested organizations. The City of Tulsa, Blue Thumb, the Tulsa County Conservation District, the Tulsa Zoo and the Metropolitan Environmental Trust will assist with education efforts in the watershed. The rolls of potential partners (the Philbrook Museum, Cassia Hall Preparatory School and the Gathering Place) have not been determined.

We estimate an annual cost of $46,000 would be required to implement years two through six of an effective pet waste program. Presumably, the need for new pet waste station installations would decrease by year six of the program and costs would decrease accordingly. Possible funding sources include CWA 319 funding and EPA Environmental Education funding. Funding from 319 requires a 40% match; potential funding sources for the match requirement have not been identified but might be met (at least in part) by in-kind donations of time from participating partners. EPA Environmental Education Grants do not have a match requirement. The Blue Thumb Program will help the Crow Creek Community prepare funding proposals.

DESCRIPTION OF THE INFORMATION AND EDUCATION COMPONENT OF THE PLAN TO FACILITATE SUCCESSFUL IMPLEMENTATION (ELEMENT E)

The Crow Creek Community watershed group has been actively involved in education in the watershed since 2015. In 2019, the Crow Creek Community held the following educational events:

- Crow Creek Meadow Work Day, January 18
- Crow Creek Meadow signage meeting, February 8
- Crow Creek Meadow signage meeting, February 22
- Crow Creek Meadow Work Day, April 5
- Crow Creek Meadow sign dedication, May 10
- Crow Creek Community meeting, June 6
- Crow Creek Meadow Work Day, June 20
- Crow Creek Community exhibit at Brookside Market in Tulsa, July 10
- Crow Creek Community exhibit at Cherry Street Market in Tulsa, July 20
- Crow Creek Community meeting in Tulsa, September 9
- Crow Creek Meadow Work Day, September 13
- Crow Creek Meadow Halloween event, October 31
- Crow Creek Cleanup at Zink Park in Tulsa, November 9

In addition to the education and outreach events listed above, the Crow Creek Community held the following meetings to work on the WBP:

- Crow Creek Watershed Based Plan meeting in Tulsa, July 10, 2019
- Crow Creek Watershed Based Plan meeting in Tulsa, October 23, 2019

- Crow Creek Watershed Based Plan meeting in Tulsa, November 20, 2019
- Crow Creek Watershed Based Plan meeting in Tulsa, January 15, 2020

Currently, the educational efforts in the watershed focus on a variety of issues including flooding, native species, lawn care, and water quality monitoring. To address the *E. coli* impairment, current educational efforts need to be supplemented with a focused and sustained program that provides clear and actionable information to the public about the bacteria impairment. The primary focus of the *E. coli* education program will be a program to educate residents about the proper management of pet waste. The program will include the following:

1. Development of short, on-line educational videos about the proper management of pet waste
2. Educational pamphlets or flyers included in utility mailings.
3. Face-to-face outreach at parks and in neighborhoods.
4. Targeted educational events hosted by the Crow Creek Community.
5. A program for homeowners' associations or other groups to apply for grants to cover the installation of a pet wet station and 12 months of weekly maintenance.

Each component of the educational program will include the following information:

1. The PCBR beneficial use, and why Crow Creek is not supporting this use.
2. The possible human health hazards connected with *E. coli*.
3. Actions residents can take to reduce *E. coli* in Crow Creek.
4. The monitoring program that will be used to gage progress toward support of the PBCR use.

Failing onsite wastewater treatment systems may also contribute to the *E. coli* impairment in Crow Creek. Because there are only 17 unsewered households in the watershed, the education program will reach out individually to each unsewered household and provide information about proper maintenance of onsite septic systems.

Finally, the education program should include elements that support improvement of the biota in Crow Creek. An education program that supports the improvement of the fish and macroinvertebrate communities in Crow Creek should include the following information:

1. The benefits of daylighting portions of the stream enclosed in storm sewers.
2. Protection of existing stretches of high-quality riparian area.
3. Establishment or restoration of riparian zones along the stream where the vegetation is mowed to the bank or where riparian area is not functioning as it should.
4. Management practices that improve the ecological functioning of riparian zones.

Education about reducing the use of pesticides and other lawn chemicals might also support improvement of the biota in Crow Creek.

Although the data do not indicate that Crow Creek is nutrient-threated, education and outreach regarding synthetic lawn chemicals and reducing runoff from urban lawns might help ensure that Crow Creek does not become nutrient-threatened in the future. The Yard By Yard Community Resiliency Project is an educational program that encourages urban homeowners manage their lawns in ways that improve soil health and water quality, increase infiltration, provide habitat for wildlife and benefit human health. The project was launched in Tulsa County in 2020 and homeowners in the Crow Creek watershed are eligible to participate. In Tulsa County, Yard By Yard is sponsored by the Tulsa County Conservation District, the Oklahoma Conservation Commission, Friends of Blue Thumb and the Oklahoma Association of Conservation Districts. Homeowners apply to have their yard certified. In order to receive a lawn certification, homeowners must commit to not using synthetic pesticides on their lawn and implement five practices across four program areas. The program areas are soil, water, food and wildlife habitat. Suggested practices include composting, xeriscaping, planting native plants, rain gardens and rain barrels. Participants receive an educational sign to place in their yard to educate others about the program.

In addition to Yard By Yard, the Oklahoma Conservation Commission is currently developing an education program to help urban and suburban residents, businesses and municipalities manage riparian areas in ways that improve water quality. The program will help landowners and land managers understand the benefits of maintaining healthy riparian buffers in urban areas and offer a suite of practices that can be implemented in urban settings. We expect to launch the program in 2021. The City of Tulsa has been identified as a potential partner.

SCHEDULE FOR IMPLEMENTING NPS MANAGEMENT MEASURES (ELEMENT F) AND DESCRIPTION OF INTERIM MEASURABLE MILESTONES (ELEMENT G)

Table 7: Proposed Schedule for Implementation of NPS Management Measures in the Crow Creek Watershed

Timeframe	Project Actions	Responsible Agency or Organization	Deliverable
2021	Submit two funding proposals to support pet waste education program.	CCC with assistance from Blue Thumb	N/A
2022	Design educational materials, install 10 pet waste stations, attempt to negotiate an agreement with City of Tulsa to assume responsibility for maintenance of pet waste station after 12-month period covered by grant; monitor Crow Creek for *E. coli* 10 times during the recreational period.	CCC, Blue Thumb, City of Tulsa	Quarterly, semi-annual or annual reports, per grant requirements.
2023	Post three online educational videos, provide two educational pamphlets or flyers in utility mailings, reach 50 pet owners through face-to-face contact at parks or in neighborhoods, host two educational events about pet waste and water quality at Crow Creek, install 10 additional pet waste stations, provide information about the maintenance of onsite septic systems to approximately four unsewered households, monitor Crow Creek for *E. coli* 10 times during the recreational period.	CCC, City of Tulsa, MET, Tulsa County CD, Tulsa Zoo, Blue Thumb	Quarterly, semi-annual or annual reports, per grant requirements.

Timeframe	Project Actions	Responsible Agency or Organization	Deliverable
2024	Post three online educational videos, provide two educational pamphlets or flyers in utility mailings, reach 50 pet owners through face-to-face contact at parks or in neighborhoods, host two educational events about pet waste and water quality at Crow Creek, install 10 additional pet waste stations, provide information about the maintenance of onsite septic systems to approximately four unsewered households, monitor Crow Creek for *E. coli* 10 times during the recreational period. During the last quart of 2024, evaluate 2022-2024 E. coli data and determine if there is a measurable reduction in E. coli. If there is not a measurable reduction, work with partners and EPA to further strengthen education program.	CCC, City of Tulsa, MET, Tulsa County CD, Tulsa Zoo, Blue Thumb	Quarterly, semi-annual or annual reports, per grant requirements.
2025	Post three online educational videos, provide two educational pamphlets or flyers in utility mailings, reach 50 pet owners through face-to-face contact at parks or in neighborhoods, host two educational events about pet waste and water quality at Crow Creek, install 10 additional pet waste stations, provide information about the maintenance of onsite septic systems to approximately four unsewered households, monitor Crow Creek for *E. coli* 10 times during the recreational period.	CCC, City of Tulsa, MET, Tulsa County CD, Tulsa Zoo, Blue Thumb	Quarterly, semi-annual or annual reports, per grant requirements.
2026	Post three online educational videos, provide two educational pamphlets or flyers in utility mailings, reach 50 pet owners through face-to-face contact at parks or in neighborhoods, host two educational events about pet waste and water quality at Crow Creek, install 10 additional pet waste stations, provide information about the maintenance of onsite septic systems to approximately four unsewered households, monitor Crow Creek for *E. coli* 10 times during the recreational period. Evaluate 2025 and 2026 *E. coli* data. If the data do not indicate support of the PBCR use, apply for additional funding to complete modelling to guide the selection of additional BMPs to reduce *E. coli* loading in the watershed.	CCC, City of Tulsa, MET, Tulsa County CD, Tulsa Zoo, Blue Thumb	Quarterly, semi-annual or annual reports, per grant requirements.

Measurable milestones include number of pet waste stations installed, number of people reached through social media, number of people reached through mailings, number of people reached through face-to-face outreach efforts, number of educational events held, and number of attendees at educational events. These interim milestones will be tracked monthly and reported quarterly, semi-annually, or annually to the funding agency as per grant requirements.

CRITERIA THAT CAN BE USED TO DETERMINE WHETHER LOADING REDUCTIONS ARE BEING ACHIEVED AND PROGRESS IS BEING MADE TOWARD ACHIEVING WATER QUALITY STANDARDS (ELEMENT H)

The success of the program should be measured by a reduction in in-stream concentrations of *E. coli*. By the end of Year 4 of the program, we hope to see a measurable reduction in *E. coli* concentrations in Crow Creek. We have estimated $1,000 per recreation season to complete *E.*

coli sampling. The sample collection and analysis methodologies should be appropriate for delisting. The sampling may be completed by City of Tulsa or by the Blue Thumb volunteer. If the samples are collected by the City of Tulsa, the monitoring can be carried out under their monitoring QAPP. If the sampling is completed by a Blue Thumb volunteer, the Blue Thumb QAPP will have to be revised to include sample collection and analysis methodologies appropriate for delisting.

If the data indicate that Crow Creek is not supporting the PBCR use by the end of Year 6 of the program, we recommend completing detailed modelling to guide the selection of additional BMPs to be installed in the watershed to reduce the amount of bacteria that reaches the creek. The BMPs included in the MPCA Estimator provide a starting point for further modelling efforts.

MONITORING COMPONENT TO ESTABLISH THE EFFECTIVENESS OF IMPLEMENTATION EFFORTS OVER TIME (ELEMENT I)

We recommend that 10 *E. coli* samples be collected during each recreation season beginning as soon as funding is procured and continuing until data indicate Crow Creek is supporting the PBCR use. The aboveground portion of the Crow Creek watershed is a single assessment unit so one sampling location is sufficient to track progress toward use attainment.

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APPENDIX: USING THE MPCA SIMPLE ESTIMATOR TO CALCULATE EXISTING LOADINGS AND EXPECTED PERCENT LOAD REDUCTIONS

The Minnesota Pollution Control Agency (MPCA) Simple Estimator was chosen for this project because it is one of the few tools that calculates expected load reductions for best management practices (BMPs) to reduce *E. coli* loadings, and because the tool is simple to use. Version 2 of the Estimator includes *E. coli* as a pollutant. Version 3 (MPCA, 2019b) includes total phosphorus and total suspended solids, but does not include *E. coli* as a pollutant. *E. coli* was removed from the tool in Version 3 due to changes to MS4 permittee requirements. However, the *E. coli* estimator in Version 2 is still functional (Personal Communication with Mike Trojan, Minnesota Stormwater Pollution Control Agency, October 22, 2019). Therefore, the estimates in this report were generated with a modified Version 2 of the tool. We modified the tool because (1) the tool calculated load reductions in CFU/year and almost all publications that report *E. coli* loadings use units of billion CFU/year and (2) the loading estimates generated by the unmodified tool were significantly greater than the loading estimates in the *2015 TMDL* (Draft) (ODEQ, 2015). We reduced the loading estimates by using more conservative runoff coefficients and by using 0.9 for P_j in the equation for runoff. These modifications are supported by the literature (Cappiella and Brown, 2001; Center for Watershed Protection, 2003). Please see detailed descriptions and justifications of the modifications, below.

Modified runoff coefficients (R_v) were calculated using the following equation from *Impacts of Imperious Cover on Aquatic Systems* (Center for Watershed Protection, 2003):

$R_v = 0.05 + .91\ (I_a)$, where I_a is the fraction of impervious cover.

To calculate R_v, we used I_a values for mean impervious cover from *Impervious Cover and Land Use in the Chesapeake Bay Watershed* (Cappiella and Brown, 2001). Please see Table 8 for a comparison of runoff coefficients used as default values by the MPCA tool, and calculated runoff coefficients resulting from our modification.

Table 8: Comparison of Default Runoff Coefficients in the MPCA Estimator and Calculated Coefficients in the Modified MPCA Estimator

Land Use	Default R_v	Calculated R_v
Commercial	0.8	0.71
Light Industrial	0.8	0.53
Institutional	0.75	0.37
Multi-use	0.5	0.05
Municipal	0.5	0.05
Open Urban Land	0.2	0.13
Residential - high density (Multifamily Residential)	0.44	0.45
Residential - low density (1/8 Acre Lot Residential)	0.34	0.30
Residential - medium density (1/4 Acre Lot Residential)	0.4	0.35
Transportation	0.8	0.05

The tool calculates runoff (R) as:

$R = P \bullet R_v$, where P is annual rainfall in inches and R_v is the runoff coefficient.

In the modified version of the tool, we calculated runoff (R), as:

$R = P \bullet P_j \bullet R_v$, where P is annual rainfall in inches, P_j is the fraction of total rainfall that results in runoff, and R_v is the runoff coefficient.

We used 0.9 as a default value for P_j as per Center for Watershed Protection (2003). Center for Watershed Protection (2003) defines P_j as "fraction of annual rainfall events that produce runoff", but since the number of rainfall events is not a variable in the equation, describing P_j as the fraction of annual rainfall that produces runoff is more accurate. The above modifications to the tool resulted in lower loading estimates than the unmodified tool and in an estimated average daily load more in line with the *2015 TMDL* (Draft)(ODEQ, 2015).

The numbers of acres in each land use were taken from the *2015 TMDL* (ODEQ, 2015, page 1-24). The land uses in the tool did not exactly correspond with the land uses in the TMDL, or with the land uses in the OCC dataset (see Table 9).

Table 9: Comparison of Land Use Categories in the MPCA Estimator and the 2015 TMDL for Crow Creek

Land Use Categories in MPCA Estimator	Corresponding Land Use Categories in TMDL and OCC Landcover/Landuse Dataset	Number of Acres in the Watershed in each Land Use Category
Open space	Developed, Open Space	544
Residential, Low Density	Developed, Low Intensity	932
Residential, Medium Density	Developed, Medium Intensity	156
Residential, High Density	Developed, High Intensity	147

The MPCA Estimator provides estimates of loading using the Simple Method (Center for Watershed Protection, 2003). The equation for calculating bacteria loads is:

$$\mathbf{L = 1.03 \times 10^{-3} \bullet R \bullet C \bullet A}$$

Where: L = Annual load (billion colonies)
R = Annual runoff (inches)
C = Bacteria concentration (CFU/100 mL)
A = Area (acres)
1.03×10^{-3} = Unit conversion factor

The tool calculates loadings for each land use and then sums loadings over all land uses to calculate total annual load.

$$\mathbf{L} = \sum_i^n (\mathbf{1.03 \times 10^{-3} \bullet R \bullet C}_i \bullet \mathbf{A}_i)$$

Where: L = Annual load (billion colonies)
R = Annual runoff (inches)
C_i = Bacteria concentration for each land use (CFU/100 mL)
A_i = Number of acres in each land use
1.03×10^{-3} = Unit conversion factor
i = Land use category
n = n^{th} land use category

The estimated annual load using the modified Estimator is 1.17×10^5 billion CFU/year, or an estimated daily load of 3.20×10^2 billion CFU/day. The approximate existing load in the *2015 TMDL* (Draft) (ODEQ, 2015) is 5.0 or 6.0 billion CFU/day at a flow exceedance frequency of 50% (visually estimated from Figure 5-44 in the TMDL; ODEQ, 2015). The load estimates generated by the tool are based on median concentrations of pollutants in stormwater. The concentrations used by the tool are median fecal coliform values for each land use that have been converted to median *E. coli* values as per Cude (2005). The fecal coliform data can be found in Table 3-10 of Shaver et al. (2007, page 3-60). Shaver et al. cite the National Stormwater Quality Database (2004) as the original source of the data in Table 3-10. The tool uses the same median values for low density residential, high density residential and medium density residential land uses. The TMDL estimates are based on instream concentrations of pollutants. As a result, the estimates generated by the tool are higher than the estimates in the TMDL. We were unable to find a direct comparison of stormwater and instream concentrations of *E. coli*, but *A Probabilistic Methodology for Analyzing Water Quality Effects of Urban Runoff on Rivers and Streams* (USEPA Office of Water, 1989) includes the results of a model verification test with measured event mean concentrations (EMCs) and instream values for four pollutants (total suspended solids (TSS), chemical oxygen demand (COD), total phosphorus (TP) and lead (Pb)). For each pollutant, stormwater concentrations are approximately an order of magnitude higher than the instream concentrations upstream of the outfall (see Table 10). The estimates generated by the tool seem to have reasonable agreement with the estimates in the TMDL when the expected difference between stormwater concentrations and instream concentrations is taken into account.

Table 10: Comparison of Stormwater Pollutant Concentrations and Instream Pollutant Concentrations Upstream of the Outfall

Item	Mean		Median	Coefficient of Variation
Stream flow (CFS)	Q_S	104	90.5	0.57
Runoff flow (CFS)	Q_R	17.5	12.6	0.96
Runoff Concentration(C_R)	TSS	3689	2760	0.89
	COD	219	195	0.52
	TP	2198	1435	1.16
	Pb	382	253	1.13
Upstream Concentration (C_S)	TSS	325	158	1.80
	COD	30	25	0.66
	TP	206	100	1.80
	Pb	19	4	4.7
Calculated Downstream Concentration	TSS	822	523	1.21
	COD	58	47	0.74
	TP	500	293	1.38
	Pb	73	35	1.79

Note: Reprinted from United States Environmental Protection Agency. 1989. A probabilistic methodology for analyzing water quality effects of urban runoff on rivers and streams. USEPA Office of Water, Washington, DC, USA, Figure 5-2, page 5-3.

The Estimator computes pollutant reductions using BMP performance data from the *2012 International BMP Database* (2012). The *International BMP Database* is available at www.bmpdatabase.org.