Missouri Department of Natural Resources
Water Pollution Control Program

Total Maximum Daily Loads (TMDLs)

for

Muddy Creek and Brushy Creek
Pettis County, Missouri

Completed: December 27, 2001
Approved:

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Total Maximum Daily Loads (TMDLs)
For Muddy Creek
Pollutant: Biochemical Oxygen Demand (BOD)
and
Brushy Creek (Fork)
Pollutants: Biochemical Oxygen Demand (BOD), Ammonia (NH_3-N) and Non-Filterable Residue (NFR)

Name: Muddy Creek

Location: Near Sedalia in Pettis County, Missouri

Hydrologic Unit Code (HUC): 10300103-040003

Water Body Identification (WBID): 0855

Missouri Stream Class: P[1]

Beneficial Uses:
- Livestock and Wildlife Watering
- Protection of Aquatic Life and Human Health associated with Fish Consumption
- General Warm Water Fishery

Size of Impaired Segment: 1 mile

Location of Impaired Segment: From NW ¼ Section 19, T46N, R21W (downstream) to SE ¼ Section 18, T46N, R21W (upstream)

Pollutant: Biochemical Oxygen Demand (BOD)

Pollutant Source: Sedalia Central Wastewater Treatment Plant

Permit Number: Missouri State Operating Permit No. MO-0023019 [2]

TMDL Priority Ranking: Low

Name: Brushy Creek (Fork)

Location: Near Sedalia in Pettis County, Missouri

Hydrologic Unit Code (HUC): 10300103-040003

[1] Class P streams maintain flow even during drought conditions. See the Missouri Water Quality Standards (WQS) at 10 CSR 20-7.031(1)(F)
[2] State Operating Permits are Missouri's substitute for the federal National Pollution Discharge Elimination System (NPDES) permits.

Water Body Identification (WBID): 0859

Missouri Stream Class: 3.0 miles from the mouth is Class P. The next 0.5 mile is C (Class C streams may cease to flow in dry periods but maintain permanent pools which support aquatic life.) [3]

Beneficial Uses:
- Livestock and Wildlife Watering
- Protection of Aquatic Life and Human Health associated with Fish Consumption
- Limited Warm Water Fishery[4]

Size of Impaired Segment: 1 mile[5]

Location of Impaired Segment: NW ¼ Section 19, T46N, R21W (mouth) to NW ¼ Section 30, T46N, R21W (upstream) Refer to footnote 4 and 5.

Pollutants:
- Biochemical Oxygen Demand (BOD)
- Ammonia (NH_3-N)
- Non-Filterable Residue (NFR)

Pollutant Source: Sedalia Central Wastewater Treatment Plant

Permit Number: Missouri State Operating Permit No. MO-0023019

TMDL Priority Ranking: Low

1.0 BACKGROUND AND WATER QUALITY PROBLEMS

1.1 History of the Area:

Muddy Creek is a fifth order, transitional prairie stream[6] with its headwaters in Johnson County. It flows northeasterly across north central Pettis County and empties into the Lamine River near the Cooper County boundary. It is a Class P stream, which means it maintains flow even during drought conditions. The watershed drains an area of nearly 300 square miles.

When the Osage Tribe lived in present day Pettis County, it was mostly open prairie. According to one history of Sedalia[7], there was waist high grass, Carolina parrots, passenger pigeons and plenty of bass in Pearl River, now called Sewer Branch, which runs through Sedalia. About 700 people lived in Pettis County when it was formed from west Cooper County and the southern two-thirds of Saline

[3] See 10 CSR 20-7.031(1)(F)
[4] Brushy Creek is classified as a Limited Warm Water Fishery because it is a non-Ozark Class C stream with a low flow of less that 0.1 cubic feet per second. See WQS 10 CSR 20-7.031(1)(C)6.
[5] The impaired section was erroneously listed as one mile on the 1998 303(d) list. This will be corrected to 3.4 miles in the next listing with the upstream legal of SE ¼ Sec. 31, T46N, R21W.
[6] Muddy Creek is considered transitional because it crosses from the Osage Plains ecoregion (prairie) to the Ozark Highlands ecoregion.
[7] The First One Hundred Years, Hurlbut Printing Co. Inc., Sedalia, Mo., just prior to the 1960 census.

County on Jan. 28, 1933. The county was named for Spencer Pettis, who was the third representative to congress from Missouri and served from 1828 to 1831. Pettis was a protégé of Senator Thomas Hart Benton.

A settler named Thomas Wasson established a gristmill on Muddy Creek at Pin Hook. The settlement that grew there became the first county seat in 1833 and was called St. Helena. The county seat was moved to Georgetown (three miles north of present-day Sedalia) in 1837, and it was there that George R. Smith settled his large family when they moved to Missouri from Kentucky. Smith camped on Muddy Creek when he first arrived in November 1833. In 1857 he bought acreage, laid out the city of Sedalia and raised money to attract the Missouri Pacific Railroad to build across the high plain past Sedalia instead of along the Missouri River. He named the town Sedville for his youngest daughter, Sarah E. Smith, whose pet name was "Sed". At the suggestion of a friend, he later changed the name to Sedalia.

During the Civil War, both the Union and the Confederacy actively recruited in Sedalia. Even though no major battles were waged in Pettis County, civilians there suffered at the hands of both armies.

The well-known benefactor of Sedalia, John H. Bothwell, arrived in 1871 at the age of 22. Sedalia's hospital, a hotel, a lodge and a rural school were all named after him. Of Muddy Creek, he commented that it was unfortunate a creek so important to the county had such a commonplace name. A picture of his niece, Ada Bothwell, appears on the cover of the book Pettis County, Missouri, A Pictorial History[8]. She is shown canoeing a section of Muddy Creek below Bothwell Lodge around 1910. The caption reads, "When highway 65 was relocated in the early 1960s, the state dug a new creek channel which effectively drained and destroyed this idyllic spot." On another note, untreated sewage was allowed to run into Flat and Muddy creeks until 1916.

Brushy Creek is a tributary to Muddy Creek. It is also referred to as Brushy Fork and was listed as such on the 1998 303(d) list. On topographic maps and in Missouri's Water Quality Standards, however, it is called Brushy Creek. The name will be corrected in the 2002 303(d) list. This third order stream runs along the border of the prairie and the Ozark ecoregions. Its headwaters drain the west side of Sedalia and it flows northerly nearly four miles to Muddy Creek. This stream is Class P from its mouth upstream for 3.0 miles. The next one-half mile of the creek is Class C and above that it is unclassified.

1.2 Soil Types and Land Use:

The soils in the Brushy-Muddy Creek watershed are in the Bluelick-Goss-Pembroke association. These soils all exhibit moderate permeability and moderate to fast runoff, depending on slope. Bluelick and Pembroke are gently to strongly sloping and Goss is a very cobbly silt loam with a 14-35 percent slope. The bottomland soils along the streams are the nearly level Dockery silt loam with moderate permeability and slow runoff. The rock that underlies these soils is shale and limestone.

Land use within the upper portion of the Brushy Creek watershed is mostly urban and industrial. Land use in the lower reaches of Brushy Creek and the portion of Muddy Creek watershed within the study area is a mixture of row crop, pasture and timber. 1993 data (30 meter resolution) obtained from Thematic Mapper imagery was used to calculate landuse statistics (Table 1) for both watersheds (Also see maps in Appendix A).

[8] Claycomb, Wm. B, and Ed Brummet, photo ed., 1998,The Donning Company Publishers, Virginia Beach, VA

Table 1. Thematic Mapper Land Use (1993) for Brushy Creek and Muddy Creek Watersheds

Land Use Class	Brushy Creek (%)	Muddy Creek (%)
Cool-Season Grassland	39.6	47
Row and Close Grown Crops	19	39
Urban Impervious	16	1.4
Urban Vegetated	11	0.6
Deciduous Woodland	8	3
Upland Deciduous Forest	4	5
Bottomland Deciduous Forest & Woodland	2	2
Barren or Sparsely Vegetated	0.4	1
Warm Season Grassland	<0.1	0.4
Open Water		0.4
Eastern Redcedar Woodland		0.2

1.3 The Impairments:

A map showing the impaired segments of both streams may be found in Appendix C.1. **Muddy Creek** is on the 1998 303(d) list due to high Biochemical Oxygen Demand (BOD). This was a result of several low flow stream surveys[9] conducted by department personnel and the Missouri Department of Conservation. Wastewater from sewage treatment plants or runoff containing fertilizer or manure (farm or urban) can be high in BOD. High BOD causes low dissolved oxygen in the receiving stream, and many aquatic organisms require high levels of oxygen to survive. The TMDL priority ranking for Muddy Creek is low.

Brushy Creek is on the 303(d) list for BOD (footnote 8), ammonia (NH_3-N)[10] and Non-Filterable Residue (NFR)[11]. Ammonia is a common by-product of wastewater treatment and under certain conditions can be toxic to aquatic life. NFR is the same thing as Total Suspended Solids (TSS) and is measured (analyzed) in the same way. It includes organic and mineral solids. The NFR in this case is sewage sludge. This sludge settles onto the bottom of the stream and smothers habitat, aquatic invertebrates and fish eggs. It is aesthetically displeasing and contributes to a sediment oxygen demand. This demand consumes oxygen from the water during the decomposition of the sludge. The TMDL priority ranking for Brushy Creek is low.

1.4 Source Assessment:

The largest permitted facility close to the impaired section of **Muddy Creek** is the Sedalia Central Wastewater Treatment Plant (WWTP)[12]. See Appendix B.1 for a list of all the permitted facilities in the watershed (above the confluence with Brushy Creek) and B.2 and B.3 for the accompanying maps. Based on design conditions, Sedalia Central contributed 77 percent of the baseflow BOD load to Muddy Creek in 1998. Other relatively larger sources of BOD, such as Whiteman Air Force Base (AFB) and the La Monte SE Lagoons, are not believed to significantly contribute to the impairment because of the distance between the facilities and the impaired reach of Muddy Creek. Whiteman AFB is approximately 23 miles from the impaired segment and La Monte Lagoons are 16 miles away. This

[9] These surveys were conducted in 1993, 1995 (the department) and 1997-8 (MDC).
[10] Listed due to 1993 and 1995 waste load allocation studies by the department, and the occurrence of fishkills recorded by Missouri Department of Conservation in 1992 and 1994.
[11] Listed due to low flow and waste load allocation studies conducted by the department from 1983-1995.
[12] State Operating Permit number MO-0023019

is significant because, even by conservative estimates that consider design flow and low-flow scenarios, the BOD would decay over that distance. These two facilities have relatively small discharges and other facilities in the watershed discharge even less.

Animal feeding operations can be sources of ammonia, non-filterable residue or low dissolved oxygen (DO); however, there are no permitted operations in the **Brushy Creek** watershed. It is also noted that while Brushy Creek drains the west side of Sedalia, storm water runoff from the city does not contribute to the impairments. This is because low flow conditions (when ammonia toxicity and low DO can be problems) are the critical period, not high flow, runoff events. Additionally, due to the small size of the watershed (7.1 mi^2) and the fact that Brushy Creek (upstream of the WWTP) does not have flow year around, any persistent suspended solids (NFR/sludge) problems during low flow periods are likely point source issues. Other than wastewater treatment facilities in Sedalia, sources of ammonia nitrogen and quantifiable sources of BOD and sewage sludge were not identified.

The largest permitted facility in the Brushy Creek watershed is the Sedalia Central WWTP, which contributes 98 percent of the flow. Other small point source discharges in this watershed (Appendix B.4) were not considered in this TMDL for the following reasons:

- Because Sedalia Central WWTP contributes the largest load of BOD to the watershed, it is believed to represent the primary cause of depleted or reduced dissolved oxygen in Brushy Creek.
- Data collection indicates dissolved oxygen averages *up*stream of the WWTP were greater than 5.0 mg/L, which is the state standard for DO. This indicates the water holds adequate oxygen before it gets to the WWTP.
- Ammonia limits and monitoring have only recently been required in the Sedalia Central WWTP operating permit and have not been included in other permits within the watershed. According to Missouri permitting protocols, ammonia monitoring is required if significant loading would occur as a result of discharge. Due to the relative difference in design flows, it is believed that the primary source of ammonia loading to Brushy Creek during low flow conditions is the Sedalia Central WWTP.

The Sedalia Central WWTP was recently upgraded from a trickling filter to an activated sludge facility with two final clarifiers. The design flow is 2.5 MGD (million gallons per day), which translates to 3.88 cubic feet per second (cfs). The facility discharges wastewater to Brushy Creek, and the outfall is located approximately 3.4 miles up from Brushy Creek's confluence with Muddy Creek. Brushy Creek is Class C at the point of discharge. The recent improvements to the facility were completed in May 2000 (See Appendix B.5).

On Sept. 3, 1992, there was a complete fish kill in 2.5 miles of Brushy Creek and one mile of Muddy Creek due to high levels of ammonia in the discharge from Sedalia Central. Another fish kill occurred on July 14, 1994 due to toxic concentrations of ammonia. The Missouri Department of Conservation (MDC) documented these fish kills and their causes. Low flow studies and waste load allocation surveys conducted by the Department of Natural Resources from 1983 to 1996 indicated that conditions were not protective of aquatic life in Brushy Creek and part of Muddy Creek. The ammonia was too high, the dissolved oxygen was too low and excessive deposits of sewage sludge were observed. The department conducted two stream surveys of Muddy and Brushy Creeks Aug. 24-26, 1993, and Aug. 29-31, 1995, as part of a waste load allocation study. Sedalia Central WWTP was planning to upgrade and improve its facility and wanted to know their permit limits. The surveys

resulted in confirmation of the problems and determination of limits for Sedalia's new permit that would be protective of water quality.

2.0 DESCRIPTION OF THE APPLICABLE WATER QUALITY STANDARDS AND NUMERIC WATER QUALITY

2.1 Beneficial Uses:

The beneficial uses of Muddy and Brushy Creeks, WBID 0855 and 0859 respectively, are:

- Livestock and Wildlife Watering
- Protection of Aquatic Life and Human Health associated with Fish Consumption
- Muddy Creek is a General Warm Water Fishery
- Brushy Creek is a Limited Warm Water Fishery[13]

The use that is impaired is Protection of Aquatic Life. The designated uses and stream classifications may be found in the Water Quality Standards at 10 CSR 20-7.031(1)(C), (1)(F) and table H.

2.2 Anti-degradation Policy:

Missouri's Water Quality Standards include the Environmental Protection Agency (EPA) "three-tiered" approach to anti-degradation, and may be found at 10 CSR 20-7.031(2).

Tier I defines baseline conditions for all waters and requires that existing beneficial uses are protected. TMDLs would normally be based on this tier, assuring that numeric criteria (such as dissolved oxygen and ammonia) are met to protect uses.

Tier II requires that no degradation of high-quality waters occur unless limited lowering of quality is shown to be necessary for "economic and social development." A clear implementation policy for this tier has not been developed, although if sufficient data on high-quality waters are available, TMDLs could be based on maintaining existing conditions, rather than the minimal Tier I criteria.

Tier III (the most stringent tier) applies to waters designated in the water quality standards as outstanding state and national resource waters; Tier III requires that no degradation under any conditions occurs. Management may prohibit discharge or certain polluting activities. TMDLs would need to assure no measurable increase in pollutant loading.

These TMDLs will result in the protection of existing beneficial uses, which conforms to Missouri's Tier I anti-degradation policy.

2.3 The Standards (Criteria) That Apply:

2.3.1 Biochemical Oxygen Demand (BOD)

Dissolved oxygen (DO) is the water quality standard that is exceeded in Brushy and Muddy creeks. DO is not a pollutant and cannot be allocated in a TMDL. Biochemical Oxygen Demand (BOD) is the parameter used to determine the impact that wastewater will cause on DO levels in a receiving stream. There is no numeric criterion in the Missouri Water Quality Standards (WQS) for

[13] Brushy Creek is classified as a Limited Warm Water Fishery because it is a non-Ozark Class C stream with a low flow of less that 0.1 cubic feet per second. See WQS 10 CSR 20-7.031(1)(C)6.

BOD. Since DO cannot be allocated, but **does** have a numeric criterion, DO is linked to BOD. BOD is a pollutant that is measurable and may be allocated in a TMDL.

BOD is composed of carbonaceous oxygen demand (CBOD) and nitrogenous oxygen demand (NBOD). NBOD is estimated directly from Total Kjeldahl Nitrogen (TKN), which is ammonia nitrogen (NH_3-N) plus organic nitrogen. The numeric link between DO and BOD is generated by the water quality model QUAL2E, and is supported by U. S. Environmental Protection Agency (EPA). The QUAL2E model calculates BOD by using $CBOD_5$, organic nitrogen, and ammonia data from actual sample analyses. State water quality standards for all Missouri streams except cold water fisheries call for daily minimum of **5 milligrams per liter (mg/L or parts per million) dissolved oxygen**[14] or the normal background level of dissolved oxygen, whichever is lower.[15]

2.3.2 Ammonia

Chronic criteria apply only to classified waters, according to Missouri's WQS 10 CSR 20-7.015(1)(F), while unclassified waters and mixing zones are subject to acute criteria. In Brushy Creek, the lower three and one-half miles are subject to chronic criteria while the mixing zone below the WWTP is protected with acute limits. The specific criteria for ammonia are found in 10 CSR 20-7.031 Table B. Ammonia limits are pH and water temperature dependent. To determine the ammonia criteria that apply to this TMDL, data was used from a draft 1997-1998 water quality study of Brushy Creek conducted by the Missouri Department of Conservation (Appendix D). Medians of temperature and pH (Table 2) were derived from this data and the 95th percentile was selected to provide the highest level of protection for the stream.

Table 2. Median temperature and pH values for Brushy Creek at Cloney Rd., MDC 1997-1998

Season	Parameter	Median	95th Percentile
Summer	Temperature (°C)	20.5	**25**
	pH (SU)	7.6	**7.9**
Winter	Temperature (°C)	6.2	**14**
	pH (SU)	7.4	**8.1**

The criteria for ammonia that apply to this TMDL were selected from Table B in 10 CSR 20-7.031 using the temperature and pH values from Table 2 (above). Where a value fell between two figures in Table B, the midway value was calculated. These are presented in Table 3. Note that all values in 10 CSR 20-7.031 Table B are given as total ammonia.

Table 3. Instream Criteria (Standards) for Brushy Creek as Total Ammonia
Criteria for a Limited Warm Water Fishery

Season	***Acute Limits***	***Chronic Limits***
Summer (April-September)	19.8	1.8
Winter (October-March)	14.3	1.8

[14] 10 CSR 20-7.031(4)(J)
[15] 10 CSR 20-7.031(4)(A)(3)

2.3.3 Non-Filterable Residue (NFR)

Several stream surveys conducted during summer low flows by the department resulted in Brushy Creek being placed on the 1998 303(d) impaired waters list for the presence of sewage sludge. Deposits of sewage sludge (represented as NFR) in waters of the state are interpreted as violations of the general (narrative) criteria of the Water Quality Standards. These standards may be found in 10 CSR 20-7.031(3)(A) and (C) where it states:

- "Waters shall be free from substances in sufficient amounts to cause the formation of putrescent, unsightly or harmful bottom deposits or prevent full maintenance of beneficial uses."
- "Waters shall be free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor or prevent full maintenance of beneficial uses."

2.4 <u>Numeric Water Quality Targets for These TMDLs:</u>

2.4.1 Biochemical Oxygen Demand

As stated in Section 2.3.2, chronic criteria apply to classified waterbodies, while unclassified waters and mixing zones are subject to acute criteria. Again, the lower 3.5 miles of Brushy Creek are subject to chronic criteria while the mixing zone is protected with acute limits. Muddy Creek is a classified permanent-flowing stream and is therefore subject to chronic criteria. The dissolved oxygen standard of 5.0 mg/l in the state of Missouri is interpreted as chronic criteria. Diurnal effects are taken into account by using a daily mean (average). Thus the goal of this TMDL is to maintain **5.0 mg/l dissolved oxygen** (as a daily average) in Muddy Creek and lower section of Brushy Creek.

Dissolved oxygen in water is depleted and renewed through several processes. These processes are presented in Figure 1. Biochemical oxygen demand (BOD) reflects the amount of oxygen consumed through two processes: carbonaceous biochemical oxygen demand (CBOD) and nitrogenous biochemical oxygen demand (NBOD). CBOD is the reduction of organic carbon material to its lowest energy state, CO_2, through the metabolic action of microorganisms. NBOD is the term for the oxygen required for the biological oxidation of ammonia to nitrate, called nitrification (Figure 2).

Sediment oxygen demand (SOD) is a combination of several processes. Primarily it is the decay of organic materials that settle to the bottom of the stream. SOD is usually considered negligible in free flowing streams like Brushy and Muddy creeks due to the frequency of scouring events (floods) that prevent long-term accumulation of organic materials.

Figure 1. Major Dissolved Oxygen Kinetic Processes

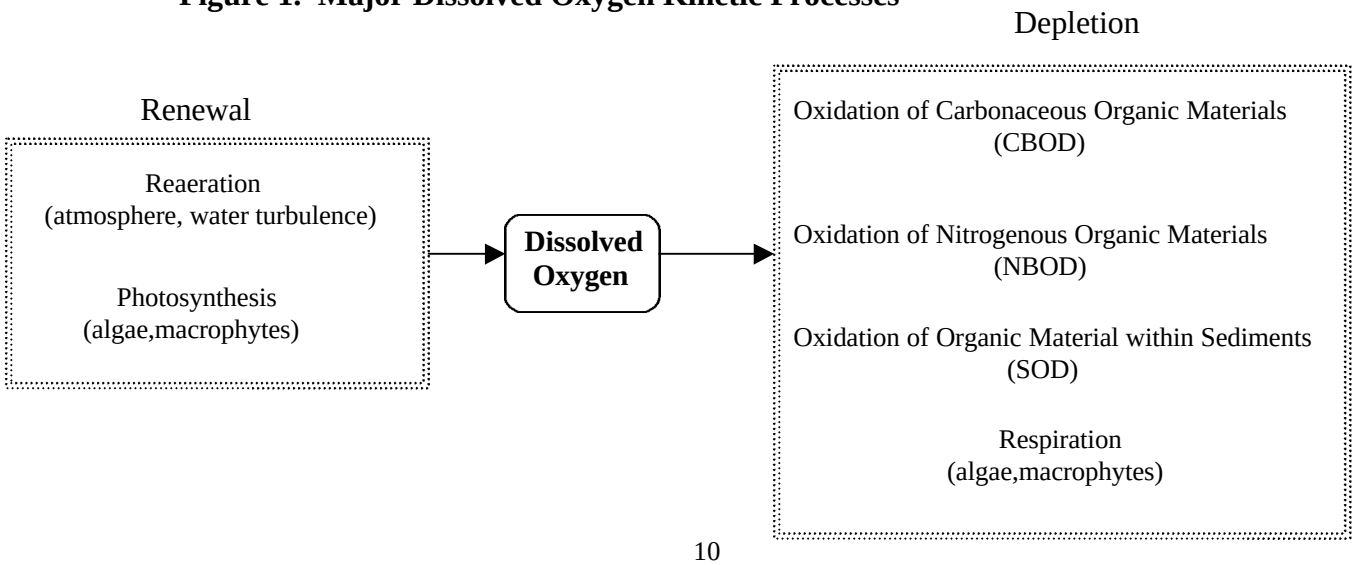
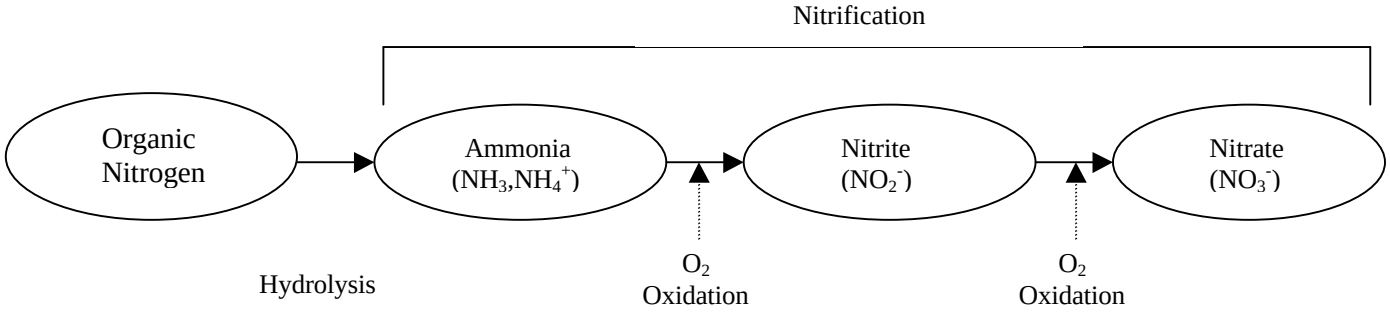


Figure 2. Nitrogen Decomposition Cycle



Appropriate levels of BOD (CBOD and NBOD) will be allocated such that dissolved oxygen of 5.0 mg/L (daily average) is maintained in Muddy Creek and the classified section of Brushy Creek.

2.4.2 Ammonia (NH_3-N)

The targets for this TMDL are listed in Table 4 as ammonia nitrogen (NH_3-N). As was mentioned in section 2.3.2, all values in 10 CSR 20-7.031 Table B are given as total ammonia. These values are converted to NH_3-N by **dividing** by 1.2.

Table 4. Ammonia Nitrogen (NH_3-N) Target Concentrations (Instream) for the Brushy Creek TMDL

Season	Acute Criterion (mg/L)	Chronic Criterion (mg/L)
Summer	**16.5**	**1.5**
Winter	**11.9**	**1.5**

The TMDL will allocate loads such that ambient concentrations of NH_3-N do not exceed chronic criteria in classified segments while not exceeding acute criteria in the mixing zone below the primary outfall. The mixing zone is defined by WQS, 10 CSR 20-7.031(4)(A)5.B.(I)(a), as the full width of the stream for one-quarter mile below the outfall. The NH_3-N target will be applied at the downstream end of the mixing zone.

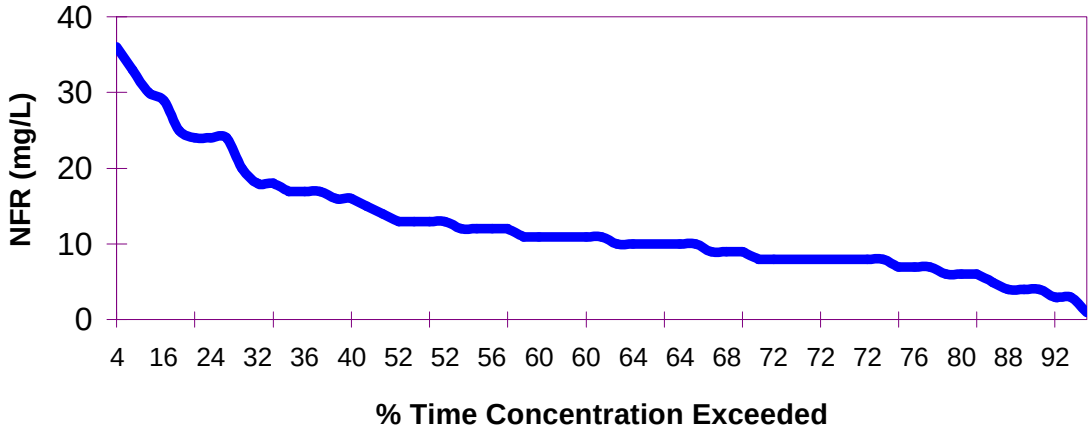
2.4.3 Non-Filterable Residue (NFR)

The Sedalia Central WWTP began plant facility upgrades in November 1998. These upgrades have improved effluent quality. The facility went from a trickling filter/anaerobic sludge digester to an activated sludge system with two final clarifiers, which lowers the NFR output. Upgrades were completed and operational by May 17, 2000. Prior to construction, permit limits for NFR were 60 mg/L as a weekly average and 40 mg/L as a monthly average. Following the upgrades, NFR limits were reduced to a 45 mg/L weekly average and 30 mg/L monthly average. The department conducted two low flow waste load allocation surveys in July 2001. During these surveys, no objectionable bottom deposits were observed. This may be an indication that the problem of excessive sewage deposition has been resolved through improved treatment technology at the WWTP.

TMDL (Total Maximum **Daily** Load) guidelines require that a maximum daily pollutant load be calculated which, if achieved, will fully maintain the designated use(s) of impaired waters. As has

been noted, Missouri does not have numeric standards for NFR. Since the stream is improving with the new permit limits, showing a 65 percent reduction in NFR since the facility upgrades, the target will be based on the **post**-upgrade Discharge Monitoring Report (DMR) from Sedalia Central. The DMR covering the years 1997-2001 may be found in Appendix G. Figure 3 is based on the post-upgrade DMR data. It shows that an acute maximum daily concentration of 35 mg/L was exceeded only 5 percent of the time. As compliance with daily maximum limits is measured by a 5 percent or less exceedence rate, a maximum daily permit limit of 35 mg/L should comply with permitting requirements. This is noteworthy because the facility just underwent the major upgrades already mentioned. By not requiring further upgrades to the facility at this time, it allows for assessment of the effect of the new upgrades. As this is a phased TMDL, the appropriateness of the established target will be re-evaluated based on future monitoring data.

Figure 3. Post-Upgrade Concentration Frequency Curve for Sedalia Central WWTP

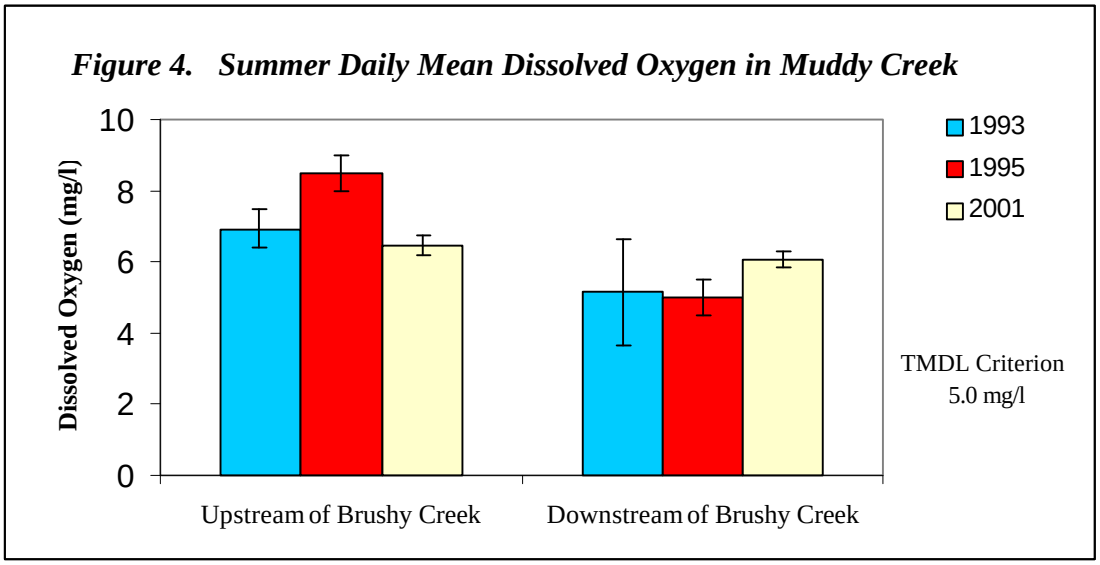


3.0 CALCULATION AND ALLOCATION OF LOADS

3.1 <u>Biochemical Oxygen Demand (BOD):</u>

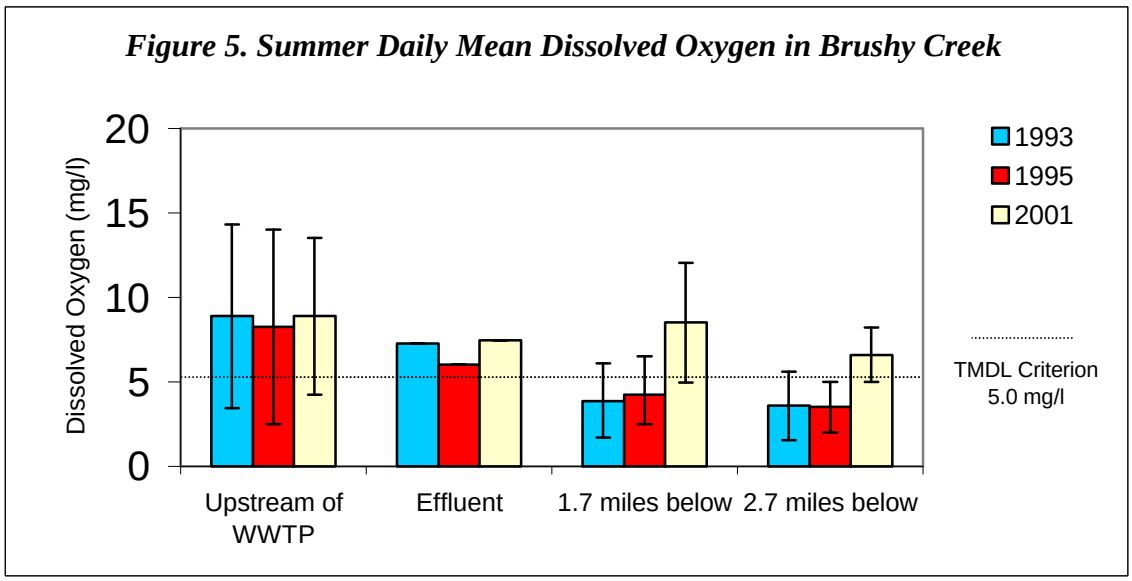
3.1.1 Existing Data

Muddy Creek: Data from summer waste load allocation studies indicate (Z_{rs} = -2.7, p = 0.007) reduced dissolved oxygen in Muddy Creek below the confluence of Brushy Creek (Figure 4 and Appendix C.2). Improvements to the Sedalia Central WWTP from 1998 to 2000 are observed in the increase in average dissolved oxygen below the Brushy Creek confluence. Due to laboratory quantification levels (less than 4 mg/L), $CBOD_5$ comparisons on Muddy Creek upstream versus downstream of the Brushy Creek confluence were not possible.



As previously stated, the largest permitted facility in the Muddy Creek watershed is the Sedalia Central WWTP, which contributed 77 percent to the baseflow BOD load to Muddy Creek in 1998. Of $CBOD_5$ samples taken upstream of the confluence with Brushy Creek from 1993 to 2001, 14 of the 16 were non-detects (less than 4 mg/L and less than 2 mg/L) while the remaining two were 2.00 mg/L (Appendix C.2). For these reasons, it is believed that reductions in BOD (CBOD + NBOD) limits in the Sedalia Central operating permit to levels that allow maintenance of at least 5.0 mg/L dissolved oxygen are removing the impairment in Muddy Creek.

Brushy Creek: The Sedalia plant upgrades may also explain increases in daily average dissolved oxygen below the treatment plant (Figure 5 and Appendix C.2). Also, in 1998 BOD_5 limits[16] of 10 mg/L in the summer and 20 mg/L in the winter were incorporated into the Sedalia permit. These limits are stated as monthly and weekly averages. In all years, *up*stream dissolved oxygen averages were greater than 5.0 mg/L. Only in 2001, after upgrades to the treatment plant and changes to the permit, did dissolved oxygen levels rise above 5.0 mg/L *down*stream.



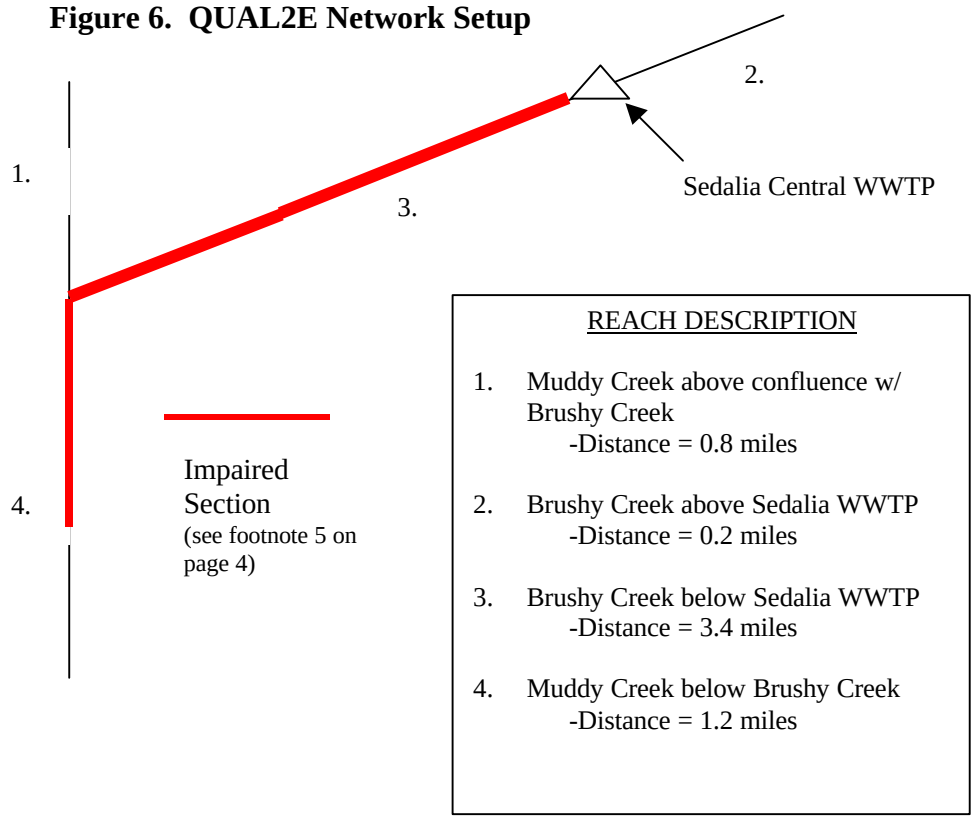
[16] BOD_5 is the amount of oxygen used to decompose the organic matter present in a water sample in a five-day period. BOD (total or ultimate BOD) is the amount of oxygen needed for complete oxidation, which can take up to 100 days.

Sedalia Central contributes 98 percent of the baseflow BOD loading to Brushy Creek. Also, Sedalia Central effluent discharge **is** the flow in Brushy Creek during 7Q10 conditions. No significant quantifiable nonpoint sources of BOD were identified. As with Muddy Creek, it is believed that the reductions in BOD (NBOD, CBOD) limits in the Sedalia Central operating permit are allowing maintenance of at least 5.0 mg/L dissolved oxygen. This eliminates the impairment.

3.1.2 The Model

A QUAL2E water quality model was calibrated and validated at steady state for use on Brushy and Muddy creeks using data obtained in July and August of 2001. QUAL2E simulates processes responsible for the breakdown of sewage-derived carbon and nitrogen by a series of first order decay reactions. Organic nitrogen levels in the effluent are assumed to be 1.15 mg/L year around (see Section 3.2.3). Ammonia nitrogen in the effluent is assumed to be 1.13 mg/L in the summer (from the waste load allocation of 23.6 lbs/day at design flow; refer to section 3.2.6) and 1.8 mg/L in the winter (37.7 lbs/day at design flow). Brushy and Muddy creeks as seen by the QUAL2E model are presented in Figure 6.

Figure 6. QUAL2E Network Setup



Model hydrology (Appendix F.1) and water quality coefficients (Appendix F.2) were adjusted to fit July 2001 data (calibration) and then compared to observations from August 2001 (verification).

3.1.3 Load Capacity

Load capacity (LC) is defined as the greatest amount of loading of a pollutant that a waterbody can receive without violating water quality standards. This load is then divided among the point source (waste load allocation) and nonpoint source (load allocation) contributions to the stream, with

an allowance for an explicit margin of safety. If the margin of safety is implicit, no numeric allowance is necessary. Critical conditions are considered when the LC is calculated.

Dissolved oxygen levels that threaten the integrity of aquatic communities generally occur during low flow periods, therefore this time is considered the critical condition. The 7Q10 flow is the lowest average flow for seven consecutive days that have a recurrence interval of once in 10 years. This represents the worse case flow scenario reasonably expected to occur. Allocations developed under 7Q10 conditions are believed to be protective during other seasons and expected flow scenarios, so they were chosen as the critical conditions.

Flat Creek in Pettis County (Appendix E.2) was used as a surrogate watershed (148 mi.^{2}) for the purpose of estimating 7Q10 conditions for the Muddy Creek watershed upstream of Brushy Creek (146 mi.^{2}) on the basis of watershed area and ecoregion. Using daily mean streamflow data from United States Geological Survey (USGS) gage 06906700, 7Q10 conditions were determined with the SWSTAT 4.0 USGS program. Both winter (Oct. 1– March 31) and summer (April 1– Sept. 30) 7Q10 flows were near 0.0 cubic feet per second (cfs) based on data from 1961–1966 (Appendix E.1). Though a few years record flow of greater than zero, the relatively few years of data at the Flat Creek gage station make the 0.0 cfs 7Q10 estimate the only defensible conclusion.

Starks Creek near Preston in Hickory County (Appendix E.4) was used as a surrogate watershed for the purpose of estimating 7Q10 conditions in Brushy Creek. Using daily mean streamflow data for USGS gage 06925200, 7Q10 conditions were determined with the SWSTAT 4.0 USGS program. Both winter (Oct. 1– March 31) and summer (April 1– Sept. 30) 7Q10 flows were 0.0 cfs based on data from 1957–1975 (Appendix E.3). Thus, under low flow 7Q10 conditions, Brushy Creek is dominated by discharge (effluent) from Sedalia Central WWTP.

Using the QUAL2E model, $CBOD_5$ allocations were developed for summer and winter periods. Model inputs that vary by season (climatology, headwater characteristics) were adjusted accordingly to calculate the load capacity (LC). Load Capacities were developed for both Muddy and Brushy creeks; however, since limits that will protect Brushy Creek will also protect Muddy, the Brushy Creek figures will be used. Based on the model results, the loading expressed as $CBOD_5$ is 7.1 mg/l in the summer and 65 mg/l in the winter.

The summer and winter LC for both creeks are dependent on WWTP discharge because nonpoint source contributions are zero and the stream is therefore the plant discharge. The LC is translated to pounds per day using the following formula (5.395 is the constant used to convert cubic feet per second (cfs) times milligrams per liter (mg/L) to lbs/day):

Load Capacity = (Design flow in cfs)(Limit in mg/L)(5.395)

Summer: LC_{CBOD5} = (3.88)(**7.1 mg/L**)(5.395) = **148.6 lbs/day**

Winter: LC_{CBOD5} = (3.88)(**65 mg/L**)(5.395) = **1360 lbs/day**

3.1.4 Load Allocation (Nonpoint Source)

Muddy Creek: The Load Allocation (LA) includes all existing and future nonpoint sources and natural background contributions (40 CFR § 130.2(g)). The six permitted animal feeding operations in Muddy Creek watershed are either no-discharge permits or are too small and too far away

to impact the impaired section of the creek. Upstream estimates of $CBOD_5$ and ammonia nitrogen in Muddy Creek have been undetectable in past sampling efforts and organic nitrogen values averaged 0.8 mg/L in the summer 2001 surveys. The 7Q10 condition is 0.0 cfs, however, so nonpoint source contributions (the LA) are calculated at 0.0 lbs/day for this TMDL.

Brushy Creek: No significant nonpoint sources of BOD have been identified in the Brushy Creek watershed. Upstream flow is considered 0.0 cfs during summer and winter in regard to 7Q10 conditions, so the LA for Brushy Creek is also 0.0 lbs/day.

3.1.5 Waste Load Allocation (Point Source)

The Waste Load Allocation (WLA) is the proportion of a receiving water's load capacity that is allocated to its existing or future point sources of pollution. Due to the reasons listed in Source Assessment (Section 1.4), it is believed that the Sedalia Central WWTP is the primary cause for the low dissolved oxygen impairment. The current BOD_5 limits for the Sedalia Central WWTP are 10 mg/L (as a weekly and a monthly average) in summer and 20 mg/L in winter. Output from the QUAL2E model indicates that a daily average of 5.0 mg/L dissolved oxygen will be achieved in the impaired sections of both creeks through current permit limits. The LC must be allocated to point and nonpoint sources and a margin of safety (MOS) and can be written as:

$$LC = LA + WLA + MOS$$

Summer: 148.6 lbs/day = 0.0 lbs/day +133.7 lbs/day +14.9 lbs/day

LC = (3.88)(7.1 mg/L)(5.395) = 148.6 lbs/day
LA = 0.0 lbs/day
WLA = (3.88 cfs)(6.39 mg/L)(5.395) = **133.7 lbs/day**
MOS = (3.88 cfs)(0.71 mg/L)(5.395) = 14.9 lbs/day

Winter: 1360 lbs/day = 0.0 lbs/day + 1224 lbs/day + 136 lbs/day

LC = (3.88)(**65 mg/L**)(5.395) = 1360 lbs/day
LA = 0.0 lbs/day
WLA = (3.88 cfs)(58.5 mg/L)(5.395) = **1224 lbs/day**
MOS = (3.88 cfs)(6.5 mg/L)(5.395) = 136 lbs/day

Where an allocation in lbs/day = (flow in cfs)(concentration in mg/L)(5.395 conversion factor)

Calculated as concentrations, the WLAs are 6.39 mg/L for summer and 58.5 mg/L for winter. Using these WLAs, the maximum daily limits (MDLs) are derived following EPA protocol[17] for developing permit limits. (Refer to Section 3.3.4 for a detailed example. The Coefficient of Variation for $CBOD_5$ is 0.7.) The MDLs calculated this way are 6.39 mg/L for summer and 58.5 mg/L for winter. The Average Monthly Limits (AMLs) are 3.7 (LTA = 6.39*0.281=1.79, @ the 99th percentile, n=4, CV =0.7) mg/L (summer) and 32 mg/L (winter) {LTA = 58.5*0.281=16.43, @ the 99th percentile, n=4, CV =0.7}. Again, refer to Section 3.3.4 for the method. Of note, Effluent Regulation 10 CSR 20 7.015(8)(B)6 allows 5 mg/L to be added to $CBOD_5$ for the BOD_5 limit. Adding this, the calculated

[17] *Technical Support Document (TSD) for Water Quality-based Toxics Control*, EPA/505/2-90-001

permit limits for MDL would be 11.4 mg/L (summer) and 63.5 mg/L (winter). AMLs would be 8.7 mg/L (summer) and 38 mg/L (winter).

3.1.6 Margin of Safety

For an overview of the Margin of Safety (MOS), see Section 4.0. Due to inherent inaccuracies in the QUAL2E model, and based on experience with similar streams in the region, 10 percent of the load capacities presented in Section 3.1.3 for both Muddy and Brushy creeks is an appropriate MOS for the purposes of this TMDL. The MOS is 14.9 lbs/day in summer and 136 lbs/day for winter.

3.1.7 Seasonal Variation

Dissolved oxygen, like other gases, is less soluble at higher temperatures and altitudes. Due to temperature considerations, both summer and winter TMDL allocations have been developed.

3.1.8 Total Maximum Daily Load (TMDL) Calculation

The TMDLs for both creeks may be found in Table 5 below. The TMDL is equal to the LC and is the sum of the WLA, LA and MOS. The generalized TMDL calculation is as follows:

TMDL = Load Capacity = Waste Load Allocation + Load Allocation + Margin of Safety

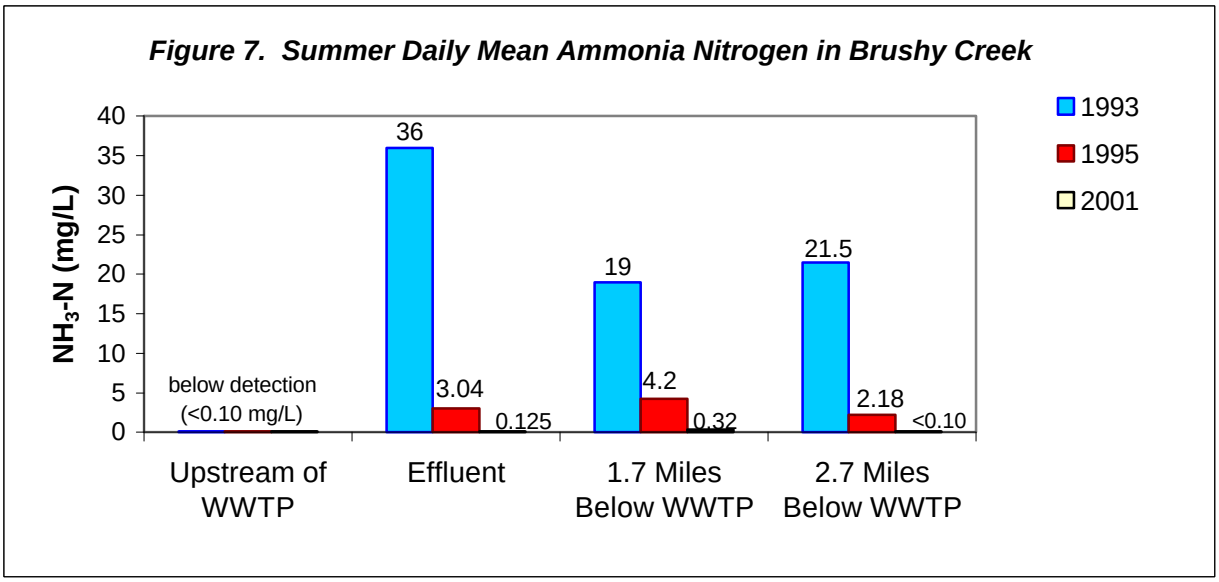
Table 5. Muddy Creek and Brushy Creek $CBOD_5$ Loads (lbs/day)

		Point Load (WLA)	Non-Point Load (LA)	Margin of Safety (MOS)	**TMDL**
Summer	$CBOD_5$	133.7	0.0	14.9	**148.6**
Winter	$CBOD_5$	1224.0	0.0	136	**1360**

3.2 <u>Ammonia (NH_3-N):</u>

3.2.1 Existing Data for Ammonia

Summer ammonia data from 1993 and 1995 indicate higher concentrations below Sedalia Central WWTP compared to upstream sites (Figure 7). Studies conducted in July 2001 show reduced ammonia concentrations below the WWTP relative to 1993-1995 that may be a result from improvements made to the plant from 1998 through 2000. Existing department data on Brushy Creek is listed in Appendix C.2.



Ammonia monitoring of effluent from Sedalia Central WWTP was optional until 1998 when the revised State Operating Permit instituted a summer ammonia nitrogen limit of 2.5 mg/L and a winter limit of 3.5 mg/L. There have been no violations of these limits as of August 2001.

3.2.2 The Nitrogen Cycle

The nitrogen in raw sewage is generally composed of organic nitrogenous compounds (amino acids, urea, protein) and ammonia. As part of the nitrogen cycle (Figure 8), organic nitrogen is eventually hydrolyzed into ammonia in a process called ammonification (Figure 9). Following ammonification, ammonia is oxidized to nitrite and then nitrate. Due to the ammonification processes, allocation of ammonia loads depends on levels of organic nitrogen as well as ammonia nitrogen.

Figure 8. Nitrogen Decomposition Cycle below Sedalia Central WWTP

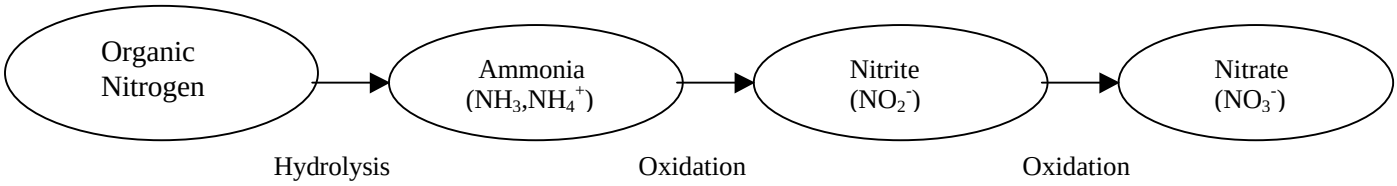


Figure 9. Decomposition of Urea in Natural Waters (Ammonification)

$$NH_2-\overset{\overset{\displaystyle O}{||}}{C}-NH_2 + H_2O \xrightarrow[\text{Urease}]{} 2NH_3 + CO_2$$

3.2.3 The Model for Ammonia

A QUAL2E water quality model was calibrated and validated at steady state for use on Brushy Creek using data obtained in July and August 2001. Earlier data sets were not used because some lacked organic nitrogen data and others lacked flow data. QUAL2E simulates the nitrogen cycle depicted in Figure 8 by a series of first order decay reactions. The small number of samples (n=2) of organic nitrogen limits the reliability of the coefficient of variation estimates needed for projecting maximum organic nitrogen concentration. For model input purposes, the maximum observed value (7/17/01) of 1.15 mg/L organic nitrogen will be assumed constant in the effluent. Although reasonable potential may exist for the effluent to contain more than 1.15 mg/L, conservative assumptions were built into the model and the TMDL to provide adequate protection to aquatic life. Brushy Creek as seen by the QUAL2E model is presented in Figure 6 (page 14).

Model hydrology (Appendix F.1) and water quality (Appendix F.3) coefficients were adjusted to fit July 2001 data (calibration) and then compared to observations from August 2001 (verification).

3.2.4 Load Capacity for Ammonia

Load capacity (LC) is defined as the greatest amount of loading of a pollutant that a waterbody can receive without violating water quality standards. This load is then divided among the point source (waste load allocation) and nonpoint source (load allocation) contributions to the stream, with an allowance for an explicit margin of safety. If the margin of safety is implicit, no numeric allowance is necessary. Critical conditions are considered when the LC is calculated.

The critical conditions for ammonia are low flow conditions, which are most likely to accompany exceedences of ammonia standards. Under low flow conditions there is less water available to dilute pollutant loads. The 7Q10 flow is the lowest average flow for seven consecutive days that have a recurrence interval of once in ten years. This represents the worse case scenario reasonably expected to occur and is therefore considered the critical condition. Allocations developed under low flow 7Q10 conditions are believed to be protective during other seasons and expected flow scenarios.

As noted in Section 3.1.4, Starks Creek near Preston in Hickory County (Appendices E.3 and 4) was used as a surrogate watershed for the purpose of estimating 7Q10 conditions in Brushy Creek.

Using the QUAL2E model, ammonia nitrogen criteria and loads were developed for summer and winter periods. Model inputs that vary by season (climatology, headwater characteristics) were adjusted accordingly. Thus computed, the summer and winter load capacities for Brushy Creek are 1.25 mg/L and 2.0 mg/L respectively. Expressed as pounds per day, these loads are dependent on the WWTP discharge because nonpoint source contributions are considered zero. Because this is concentration based, the load will vary with the volume of discharge.

Load Capacity = (Design flow in cfs)(Limit in mg/L)(5.395 conversion factor)

Summer: LC = (3.88)(**1.25 mg/L**)(5.395) = **26.2 lbs/day**

Winter: LC = (3.88)(**2.0 mg/L**)(5.395) = **41.9 lbs/day**

3.2.5 Load Allocation (Nonpoint Source) for Ammonia

The Load Allocation includes all existing and future nonpoint sources along with the natural background contribution. As was discussed in Section 1.4 Source Assessment, no significant

quantifiable nonpoint sources of ammonia nitrogen have been identified in the Brushy Creek watershed. Due to the small watershed size (7.1 mi^2) and non-permanent nature of the stream, any persistent ammonia nitrogen problems observed during low flow periods are likely point source problems. Thus the load allocation is equal to 0.0 lbs/day in summer and winter with respect to 7Q10 conditions.

3.2.6 Waste Load Allocation (Point Source) for Ammonia

Waste Load Allocations are the proportion of receiving water's load capacity that is allocated to existing or future point sources of pollution. Sedalia Central WWTP (MO-0023019) is the only significant quantifiable point source of ammonia nitrogen. The current NH_3-N (ammonia nitrogen) limits for the Sedalia Central WWTP permit are 2.5 mg/L in summer and 3.5 mg/L in winter, as daily maximums. Output from QUAL2E indicates that these limits may not be protective of chronic ammonia criteria. Since this is a phased TMDL, further in-stream monitoring is required to determine whether this is the case.

Since the LC must be allotted to point and nonpoint sources and the margin of safety (MOS), LC can be written as:

$$LC = LA + WLA + MOS$$

Summer: 26.2 lbs/day = 0.0 lbs/day + 23.6 lbs/day + 2.6 lbs/day

LC = (3.88)(1.25 mg/L)(5.395) = 26.2 lbs/day
LA = 0.0 lbs/day
WLA = (3.88 cfs)(1.125 mg/L)(5.395) = **23.6 lbs/day**
MOS = (3.88 cfs)(0.125 mg/L)(5.395) = 2.6 lbs/day

Winter: 41.9 lbs/day = 0.0 lbs/day + 37.7 lbs/day + 4.2 lbs/day

LC = (3.88)(2.0 mg/L)(5.395) = 41.9 lbs/day
LA = 0.0 lbs/day
WLA = (3.88 cfs)(1.8 mg/L)(5.395) = **37.7 lbs/day**
MOS = (3.88 cfs)(0.2 mg/L)(5.395) = 4.2 lbs/day

Where an allocation in lbs/day = (flow in cfs)(concentration in mg/L)(5.395 conversion factor)

Calculated as concentrations, the WLAs are 1.13 mg/L for summer and 1.8 mg/L for winter. Using these WLAs, the maximum daily limits (MDLs) are derived following EPA protocol (the TSD) for developing permit limits. (Refer to Section 3.3.4 for a detailed example. The Coefficient of Variation for ammonia is 1.103.) The MDLs calculated this way are 2.1 mg/L for summer and 3.3 mg/L for winter. Because a TMDL relates to maximum daily loads or limits, flexibility may exist to use only daily maximum limits in the permit. Given that degree of flexibility, existing permit limits (which will be retained) are less stringent than required according to model output. As has been noted, this is a phased TMDL. Extensive monitoring will be conducted before any permit limits are adjusted. Of note, the Average Monthly Limit calculated according to the TSD is 0.8 mg/L (summer) and 1.3 mg/L (winter). Again, refer to Section 3.3.4 for the method.

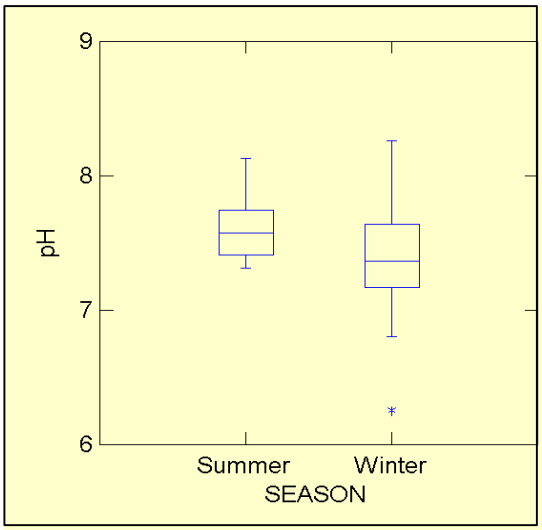
3.2.7 Margin of Safety for Ammonia

For an overview of the Margin of Safety (MOS), see Section 4.0. Due to inherent inaccuracies in the QUAL2E, and based on experience with similar streams in the region, 10 percent of the load capacities presented in Section 3.2.4 for Brushy Creek is an appropriate margin of safety for the purposes of this TMDL. The MOS is 2.6 lbs/day for summer and 4.2 lbs/day in winter.

3.2.8 Seasonal variation for Ammonia

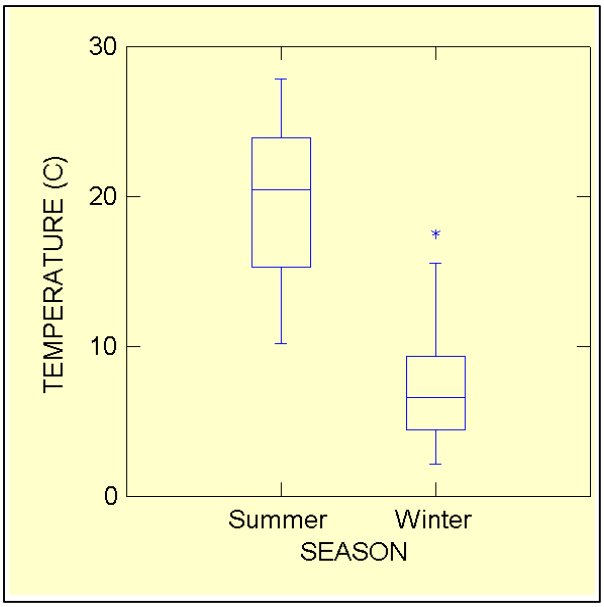
Toxicity of ammonia species (NH_3 & NH_4^+) to fishes and invertebrates is well documented[18]. High pH and temperature increase the proportion of the more toxic NH_3 form and thus ammonia toxicity limits are seasonal in nature. Listed below (Figure 10, Figure 11) are temperature and pH boxplots created from a draft 1997-1998 water quality study of Brushy Creek conducted by the Missouri Department of Conservation (Appendix D). The location for the study site is SE1/4, SE1/4, Section 24, T46N, R21W; Brushy Creek at Cloney Road.

Figure 10. Seasonal variation of pH within classified reaches of Brushy Creek, 1997-1998 Summer (April – September), Winter (October – March)



[18] *Ambient Water Quality Criteria for Ammonia-1984*, EPA 440/5-85-001, and *1999 Update of Ambient Water Quality Criteria for Ammonia*, EPA-822-R-99-014

Figure 11. Seasonal variation of temperature within classified reaches of Brushy Creek, 1997- 1998. Summer (April – September), Winter (October – March)



3.2.9 TMDL Calculation for Ammonia

As mentioned before, discharge from the Sedalia Central WWTP is the streamflow during 7Q10 conditions and thus no upstream considerations of flow or pollutant loading were given. TMDL results are summarized in Table 6. The TMDL is equal to the LC and is the sum of the WLA, LA and MOS. The generalized TMDL calculation is as follows:

TMDL = Load Capacity = Waste Load Allocation + Load Allocation + Margin of Safety

Table 6. Brushy Creek Ammonia Loads (lbs/day)

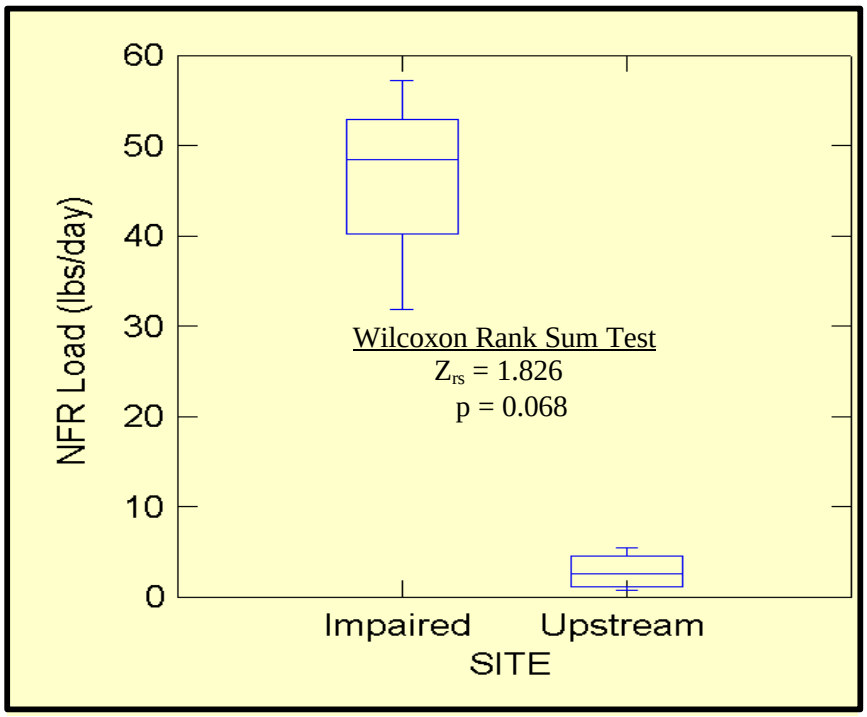
		Point Load (WLA)	Non-Point Load (LA)	Margin of Safety (MOS)	**TMDL**
Summer	Ammonia (NH_3-N)	23.6	0.0	2.6	**26.2**
Winter	Ammonia (NH_3-N)	37.7	0.0	4.2	**41.9**

3.3 <u>Non-Filterable Residue (NFR):</u>

3.3.1 Existing Data for NFR

Observations of excessive deposits of sewage sludge below the WWTP were made by the department personnel during low flow and waste load allocation surveys from 1983 to 1995 which resulted in listing on the 1998 303(d) list. However, in-stream NFR data were not collected until 2001. Waste load allocation studies conducted by the department in July 2001 (Appendix C.2) indicate ($p<0.069$) higher NFR loads downstream of Sedalia Central WWTP compared to upstream sites (Figure 12).

Figure 12. NFR Loading Upstream of Sedalia Central WWTP compared to downstream impaired segments.



The Discharge Monitoring Report (DMR) data from the treatment plant may be found in Appendix G. This appendix contains wastewater discharge (flow) and NFR data from 01/01/1997 – 9/28/2001.

3.3.2 Load Capacity for NFR

Load capacity (LC) is defined as the greatest amount of loading of a pollutant that a waterbody can receive without violating water quality standards. This load is then divided among the point source (waste load allocation) and nonpoint source (load allocation) contributions to the stream, with an allowance for an explicit margin of safety. Since the margin of safety for NFR is implicit in this case, no numeric allowance is necessary. Critical conditions are considered when the LC is calculated.

Excessive sewage sludge gets deposited during periods of receding and low stream velocities. Also, the relative impact of stress exerted by sediment oxygen demand is higher during warm weather, low-flow periods. For these reasons, and the fact that data from pre-1998 low flow surveys indicate an impairment, the critical period for this TMDL will be low flow, 7Q10 conditions. Allocations developed under these conditions are believed to be protective during other seasons and expected scenarios. Starks Creek near Preston in Hickory County was used as a surrogate watershed for the purpose of estimating 7Q10 conditions in Brushy Creek. See Section 3.2.4 and Appendices E.3-4.

The Load Capacity (LC) for NFR is 35 mg/L maximum daily limit, the target arrived at in Section 2.4.3. Expressed as pounds per day, the LC is dependent on the WWTP discharge because nonpoint source contributions are considered zero. It is calculated as follows (5.395 is the conversion factor):

LC in pounds/day = (design flow in cfs)(limit in mg/L)(5.395)

NFR: LC = (3.88 cfs)(35 mg/L)(5.395) = **732 lbs/day**

3.3.3 Load Allocation (Nonpoint Source Load) for NFR

Other than Sedalia Central WWTP (MO-0023019), no other significant quantifiable sources of sewage sludge have been identified. Thus the load allocation (LA) for NFR is equal to 0.0 lbs/day under 7Q10 conditions.

3.3.4 Waste Load Allocation (Point Source Loads) for NFR

The largest permitted facility (municipal, non-municipal, CAFO) in the Brushy Creek watershed is the Sedalia Central WWTP that contributes 96 percent of the potential baseflow loading of NFR. Appendix B.4 contains a map and a list of the facilities in this watershed. Due to the small watershed size (7.1 mi^2) and the fact that Brushy Creek does not have flow year around, any persistent suspended solids problems during low flow periods are likely point source problems.

Conversion of maximum daily permit limits to waste load allocations (WLA) is accomplished through back-calculation of long term averages according to EPA protocols[19] used for calculating permit limits.

Step 1. Convert Maximum Daily Limit (MDL) to a Long-Term Average (LTA) using a Percentile Occurrence Multiplier (POM), where POM equals 3.11 for a Coefficient of Variation (CV) of 0.6. This coefficient was calculated using the DMR data from Sedalia Central, and 3.11 was read from Table 5-2 in the EPA protocol for the 99th percentile corresponding to 0.6 CV. The length of time covered in the LTA is the extent of the available DMR data, in this case about 18 months. The LTA is calculated using the following equation:

$$LTA = MDL / POM$$
$$LTA = 35 / 3.11 = 11.254$$

Step 2. Convert the calculated LTA to a daily WLA concentration by dividing by a second POM, 0.321 taken from Table 5-1 in the EPA protocol for WLA multipliers corresponding to a CV of 0.6.

$$WLA = LTA / POM$$
$$WLA = 11.254 / 0.321 = 35 \text{ mg/L}$$

The fact that the WLA came out the same as the original concentration is a factor of the calculated CV and the chosen percentile (99th). The waste load allocation for the TMDL is then calculated as follows (5.395 is the conversion factor):

(design flow in cfs) (maximum daily limit in mg/L) (5.395) = WLA (lbs/day)

(3.88 cfs) (35 mg/L) (5.395) = 732 lbs/day

A weekly average was not calculated because the TSD recommends using monthly averages and daily maximums. Weekly averages were not suggested. Of note, the Average Monthly Limit that would be placed in Sedalia's operating permit is 17.4 mg/L. This is calculated using the LTA from above, and

[19] *Technical Support Document (TSD) for Water Quality-based Toxics Control*, EPA/505/2-90-001

drawing the POM from EPA Table 5-2 again, reading from the Average Monthly Limit (AML) section. Using the 95th percentile and reading from the "n=4" column (for weekly sampling at four times per month), the POM equals 1.55. Solving the following equation yields the AML:

$$AML = (LTA)(POM)$$

$$AML = (11.254)\ (1.55) = 17.4\ mg/L$$

Sedalia can technologically achieve NFR limits 5 mg/L above those of the BOD_5, or 15 mg/L for summer (low flow conditions). This is less than the 17.4 calculated above and monthly averages from the DMR data since the upgrades shows Sedalia has exceeded this only once, in July 2000. Thus, a 35 mg/L maximum daily NFR limit is achievable under the present permit limits.

3.3.5 Margin of Safety for NFR

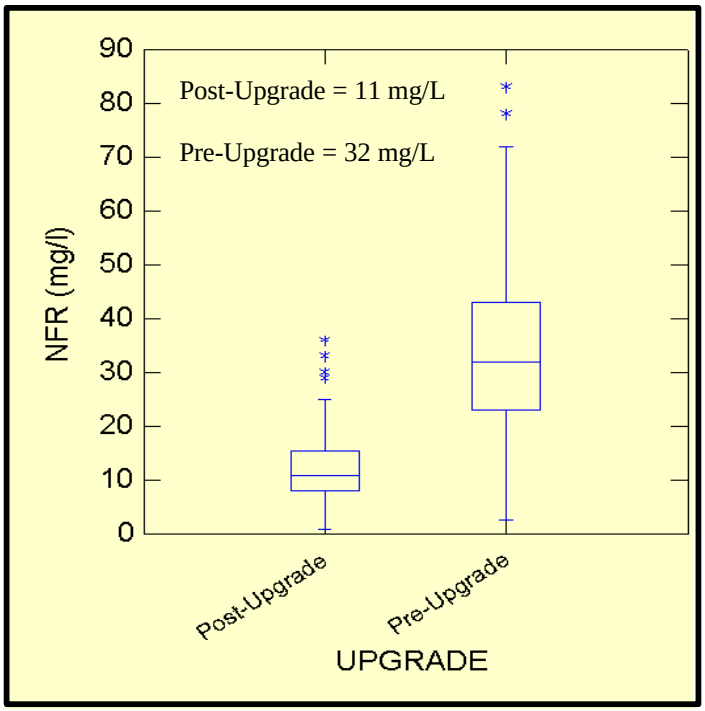
The margin of safety (MOS) is implicit for NFR in this TMDL and is recognized in two ways:

(1) Since Brushy Creek is effluent dominated, water quality is actually Sedalia Central's effluent quality. This means that there is little uncertainty between the effluent limits and resultant water quality during critical conditions.

(2) An implicit MOS is present due to the Sedalia Central WWTP making upgrades to their facility from 1998 – 2000. This has resulted in improved effluent that is more consistent in quality.

Using the Discharge Monitoring Report (DMR) data from Sedalia Central from 1997-2001, a median of NFR concentration was calculated for before and after upgrades to the treatment plant. Using the Mann-Whitney Test ($U=1146$, $p<0.001$), NFR concentrations present in the effluent before and after upgrades (May 17, 2000) were significantly different. See Figure 13. A decline from 32 mg/L to 11 mg/L as a median NFR concentration (before and after the upgrades) is equivalent to a 65 percent reduction.

Figure 13. Post-Upgrade NFR Effluent Concentrations compared to Pre-Upgrade Concentrations



This is a Phased TMDL and any further uncertainty will be addressed through the monitoring plan.

3.3.6 Seasonal Variation for NFR

Summer and winter standards have not been developed for NFR and the percent reduction of NFR arrived at for this TMDL does not consider seasonality. However, since 7Q10 conditions are the critical ones, any allocations developed under these conditions are believed to be protective during all seasons and expected scenarios.

3.3.7 TMDL Calculation for NFR

The TMDL is equal to the Load Capacity and is the sum of all the loads plus the Margin of Safety. The calculation is as follows:

Waste Load Allocation + Load Allocation + Margin of Safety = Load Capacity = ***TMDL***
732 lbs/day + 0.0 lbs/day + 0.0 lbs/day (implicit) = **732 lbs/day = TMDL**

4.0 MARGIN OF SAFETY

A margin of safety (MOS) is developed due to uncertainties in scientific and technical understanding of water quality in natural systems. The MOS is intended to account for such uncertainties in a conservative manner. Based on EPA guidance, the MOS can be achieved through one of two approaches:

(1) Explicit - Reserve a portion of the loading capacity as a separate term in the TMDL.
(2) Implicit - Incorporate the MOS as part of the design conditions for the waste load allocation and the load allocation calculations (or conservative assumptions in the analysis).

While some parameters entered into a model are known with a higher degree of confidence, some are not. Evaluating model sensitivity and uncertainty requires an understanding of the inconsistency of input variables and parameters. The large data sets of model mixing, decay and hydraulic coefficients required to estimate variation are generally unavailable, therefore an MOS is necessary. For the specifics on each pollutant, refer to the MOS section for the pollutant in question.

5.0 SEASONAL VARIATION

Seasonal variation is simulated in the QUAL2E model via the use of different water temperatures, different ammonia and $CBOD_5$ (which are used to calculate BOD) decay coefficients and adjustments to seasonal low flow values. Seasonal limits for BOD_5 and ammonia are necessary because decay of these substances depends on many variables, including water temperature, and because dissolved oxygen gas saturation varies with water temperature. For more details, refer to the seasonal variation section of the pollutant in question.

6.0 MONITORING PLANS FOR TMDLs DEVELOPED UNDER THE PHASED APPROACH

To better assess the impact to Muddy and Brushy creeks from effluent discharged by the Sedalia Central WWTP, the continuous monitoring plan incorporates upstream and downstream monitoring sites for the pollutants of concern (Tables 7-9). A map showing these sites is presented in Appendix H.

As noted before, the Sedalia Central WWTP began constructing improved treatment technology in November 1998. These improvements to plant operation have resulted in ammonia nitrogen levels less than 2.5 mg/L in the summer and less than 3.5 mg/L in the winter (the present permit limits). Higher (improved) dissolved oxygen levels have also been recorded and the NFR shows a 65 percent reduction. Unless discharge-monitoring reports warrant, further WLA studies will not be scheduled. The department does plan, however, to conduct low flow visual qualitative and benthic examinations of these streams for the next two years (2002 and 2003). If the observed water quality improvements are **not** substantiated with this monitoring, the TMDL will be reopened and re-evaluated.

Table 7. Additional Monitoring Requirements for <u>All Outfalls</u> for MO-0023019

Parameter	Sample Frequency	*Sample Type
$CBOD_5$ (mg/L)	Weekly	24 hour Composite
Dissolved Oxygen (mg/l)	Weekly	24 hour Composite
Ammonia Nitrogen (mg/L)	Weekly	24 hour Composite
Organic Nitrogen (mg/L)	Weekly	24 hour Composite
Non-Filterable Residue (mg/L)	Weekly	24-hour Composite
Volatile Suspended Solids (mg/L)	Weekly	24-hour Composite
Settleable Solids (mg/L)	Weekly	24-hour Composite
Flow (MGD)	Daily	24-hour Total

*Stormwater Outfalls are to be grab sampled when discharging.

Tables 8 and 9. Instream Sampling Requirements for MO-0023019

Sampling Site: On Brushy Creek, upstream of all outfalls and below tributary downstream of bridge

Parameter	Sample Frequency	Sample Type
$CBOD_5$ (mg/L)	Monthly	Grab
Dissolved Oxygen (mg/l)	Monthly	Grab
Ammonia Nitrogen (mg/L)	Monthly	Grab
Organic Nitrogen (mg/L)	Monthly	Grab
Temperature	Monthly	Grab
pH	Monthly	Grab
Non-Filterable Residue (mg/L)	Monthly	Grab
Volatile Suspended Solids (mg/L)	Monthly	Grab
Settleable Solids (mg/L)	Monthly	Grab
Flow (cfs)	Monthly	24-hour Total

Sampling site: On Brushy Creek, below all outfalls and upstream of Sunset Village Branch.

Parameter	Sample Frequency	Sample Type
$CBOD_5$ (mg/L)	Monthly	Grab
Dissolved Oxygen (mg/l)	Monthly	Grab
Ammonia Nitrogen (mg/L)	Monthly	Grab
Organic Nitrogen (mg/L)	Monthly	Grab
Temperature	Monthly	Grab
pH	Monthly	Grab

Non-Filterable Residue (mg/L)	Monthly	Grab
Volatile Suspended Solids (mg/L)	Monthly	Grab
Settleable Solids (mg/L)	Monthly	Grab

7.0 IMPLEMENTATION PLANS

Implementation will be accomplished through permit action. The Sedalia Central State Operating Permit MO-0023019 was revised July 18, 1997, and expires May 22, 2002. According to the QUAL2E model (TMDL allocations) and the most recent data, the present effluent limits for BOD_5 are protective of aquatic life in both streams. The QUAL2E model prescribes lower limits for NH_3-N, however the present permit limits appear to be protective of the water quality in Brushy Creek, according to 2001 data. Since this is a phased TMDL, new NH_3-N limits will not be added when the permit comes up for renewal to allow time for evaluation with the new monitoring requirements.

Present permit limits for NFR (often referred to as TSS or Total Suspended Solids) also appear to be protective of the water quality in Brushy Creek. The 2001 monitoring showed no bottom deposits of sludge and the DMR data indicate a 65 percent reduction in NFR since the upgrades. The DMR data is significant because the effluent dominates the flow in this stream and the effluent quality is essentially the stream quality. For these reasons the NFR limits will not be modified when the permit comes up for renewal.

The additional monitoring requirements for the WWTP outlined in this document, however, will be added during the permit renewal process in 2002. If future monitoring data substantiates the improvements in water quality that were observed in 2000-2001 sampling data, Muddy and Brushy creeks will be proposed for delisting for the impairments of BOD, NH_3-N and NFR. If, however, data indicates the problems are not resolved by the existing plant upgrades, that WQS are not being met, the TMDL will be reopened and re-evaluated.

These TMDLs will be incorporated into Missouri's Water Quality Management Plan.

8.0 REASONABLE ASSURANCES

The department has the authority to write and enforce Missouri State Operating Permits, which should provide reasonable assurance that instream water quality standards will be met. Inclusion of the monitoring plans outlined in this TMDL will evaluate whether the stream water quality is truly protective of aquatic life. If there is no improvement, as has been stated before, the TMDL will be reopened and revised.

9.0 PUBLIC PARTICIPATION

These water quality limited segments are included on the approved 1998 303(d) list for Missouri. Six public meetings to allow input from the public on the proposed 1998 303(d) list were held between August 18 and September 22, 1999. No comments pertaining to the listing of Brushy or Muddy creeks were received during those meetings.

The Missouri Department of Natural Resources developed these TMDLs. This TMDL document was sent to EPA for examination and then the edited draft was placed on public notice from Nov. 9, 2001

to Dec. 9, 2001. Groups that received the public notice announcement included the Missouri Clean Water Commission, Sedalia Central WWTP, the Water Quality Coordinating Committee, the TMDL Policy Advisory Committee, Stream Team volunteers in the watershed (40), the appropriate legislators (4) and others that routinely receive the public notice of Missouri State Operating Permits. Additionally, a news release of the public notice was distributed to Pettis County. Comments were received during the public notice period and adjustments were made to the TMDL; however, since the adjustments did not impact the basic sense and outcome, no further public notice was needed. A copy of the notice, the comments received and the department responses may be found in the Brushy/Muddy Creek file.

10.0 ADMINISTRATIVE RECORD AND SUPPORTING DOCUMENTATION

An administrative record on the Muddy and Brushy Creek TMDL has been assembled and is being kept on file with the Missouri Department of Natural Resources. It includes the following:

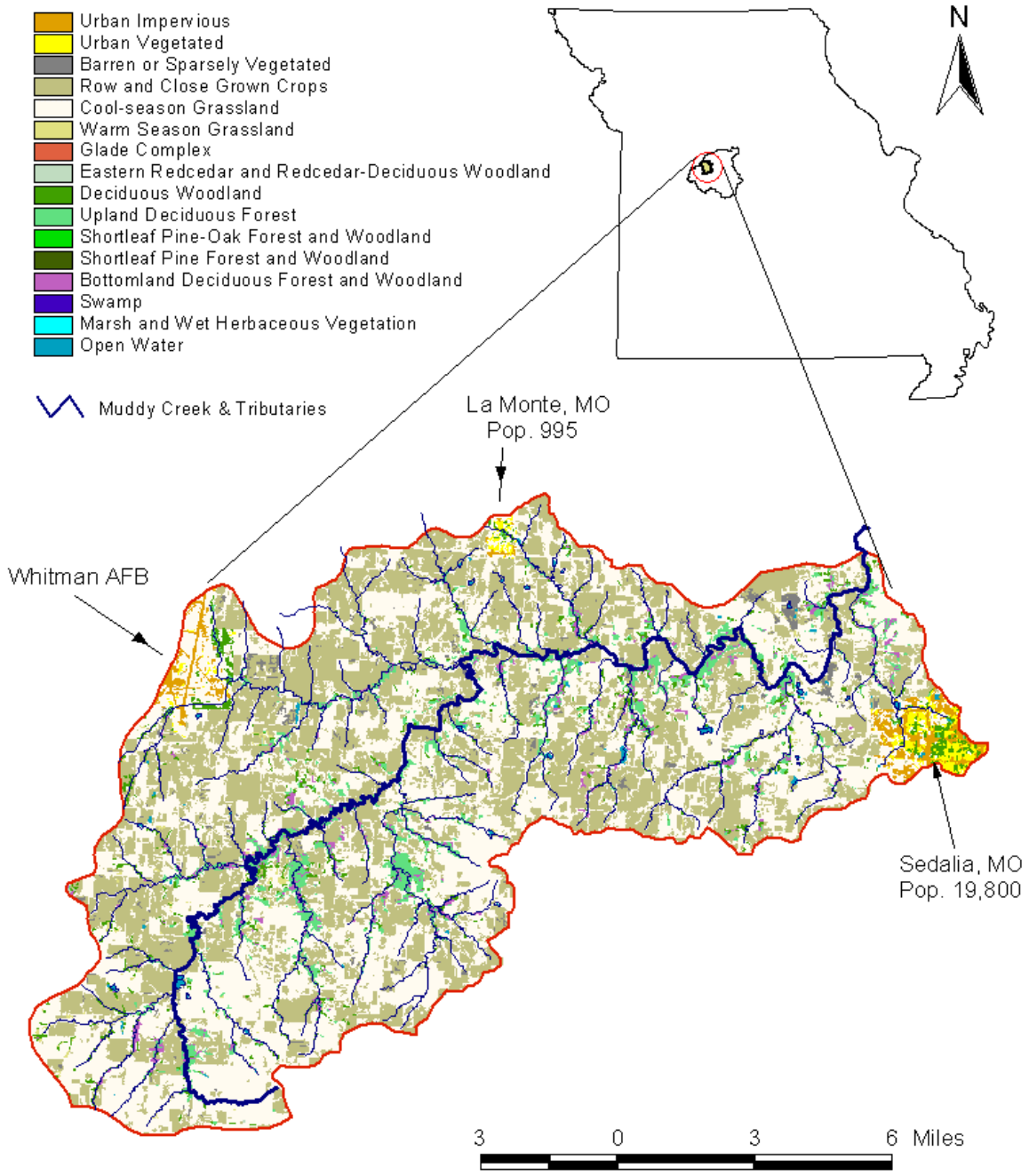
- Sedalia Central State Operating Permit MO-0023019
- Environmental Services Program stream surveys of August 24-26, 1993, and August 29-31, 1995
- Missouri Department of Conservation fish kill reports from 1992 and 1994
- Water Pollution Control Program 2001 data
- Department low flow surveys
- Input and output for QUAL2E
- Public Notice announcement
- Muddy Creek and Brushy Creek Information Sheet
- Public comments and the department's responses

11.0 APPENDICES

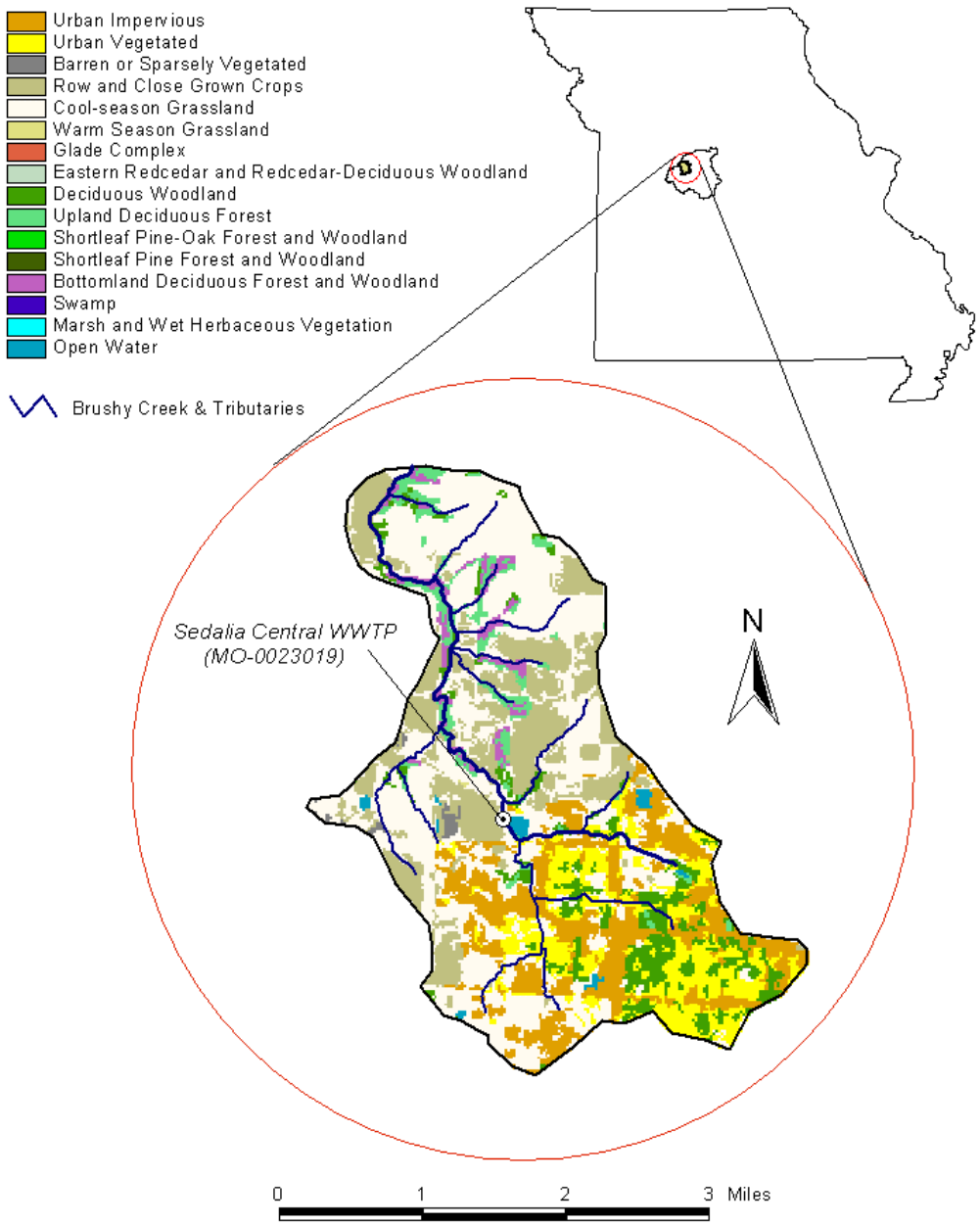
Appendix A – Land Use Maps for Muddy and Brushy Creek Watersheds
Appendix B – Permitted Facilities in Muddy and Brushy Creek Watersheds, including a list of the upgrades to the Sedalia Central WWTP
Appendix C – Map of Impaired Waterbody Segments with Sampling Sites and Corresponding Water Quality Data
Appendix D – Missouri Department of Conservation Temperature and pH data in Brushy Creek
Appendix E – 7Q10 Low Flow Data (Watershed Maps and USGS Stream Gage Data)
Appendix F – Hydrology and Water Quality Coefficients Used in QUAL2E
Appendix G – Sedalia Central WWTP Discharge Monitoring Report
Appendix H – Map of Instream Monitoring Sites

Appendix A
Land Use Maps for Muddy Creek and Brushy Creek Watersheds

Appendix A.1 Muddy Creek 1993 Land Use



Appendix A.2 Brushy Creek 1993 Land Use



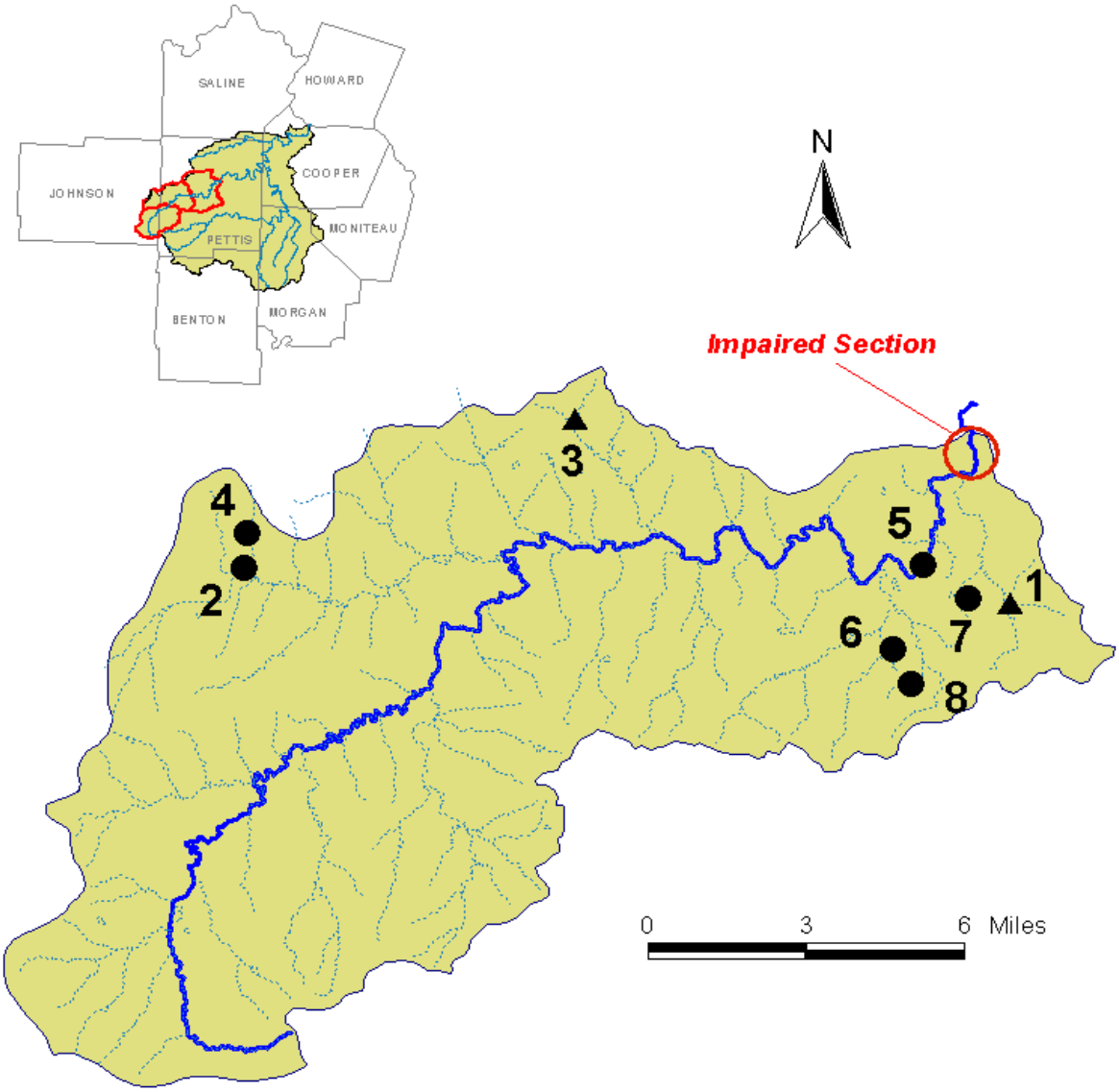
Appendix B

Permitted Facilities in Muddy Creek and Brushy Creek Watersheds

Appendix B.1 Permitted Facilities in the Muddy Creek watershed above the impaired segment

Permit #	Facility Name	Flow (cfs)	BOD_5 Limit (mg/L)
MO0023019	Sedalia Central WWTP	3.875	10 (was 40 in 1998)
MO0119644	Whiteman AFB	0.372	50
MO0108081	La Monte SE Lagoon	0.1705	45
MO0109142	Whiteman AFB Villages	0.155	45
MO0104540	Central MO Landfill	0.0775	45
MO0109592	Hunters Ridge Subdivision	0.07905	30
MO0091553	Sunset Village MHP	0.04185	45
MO0090263	Walnut Hills Subdivision	0.03565	45
MO0119547	Western View Estates	0.0186	30
MO0098132	Wire Rope Corporation	0.0124	30
MO0095290	Tyson Foods	0.00775	30
MO0004286	Alcan Cable Company	0.00775	30
MO0114031	Roadway Minimart	0.00155	45
MO0109754	El Rancho Motel	0.00155	30
LA3103743	BACON ACRES	0.003565	0
LA3103770	Private CAFO	0.00217	0
MO0118877	Johnson Co. Egg Farm	0.04805	0
MOG010031	Private CAFO	0	0
MOG010042	Private CAFO	0	0
MOG010116	Private CAFO	0	0
MOG490080	LaFarge Construction	0	0
MOG490295	LaFarge Construction	0	0
MOG490306	LaFarge Construction	0	0
MO0002593	Pittsburg Corning	0.01085	0

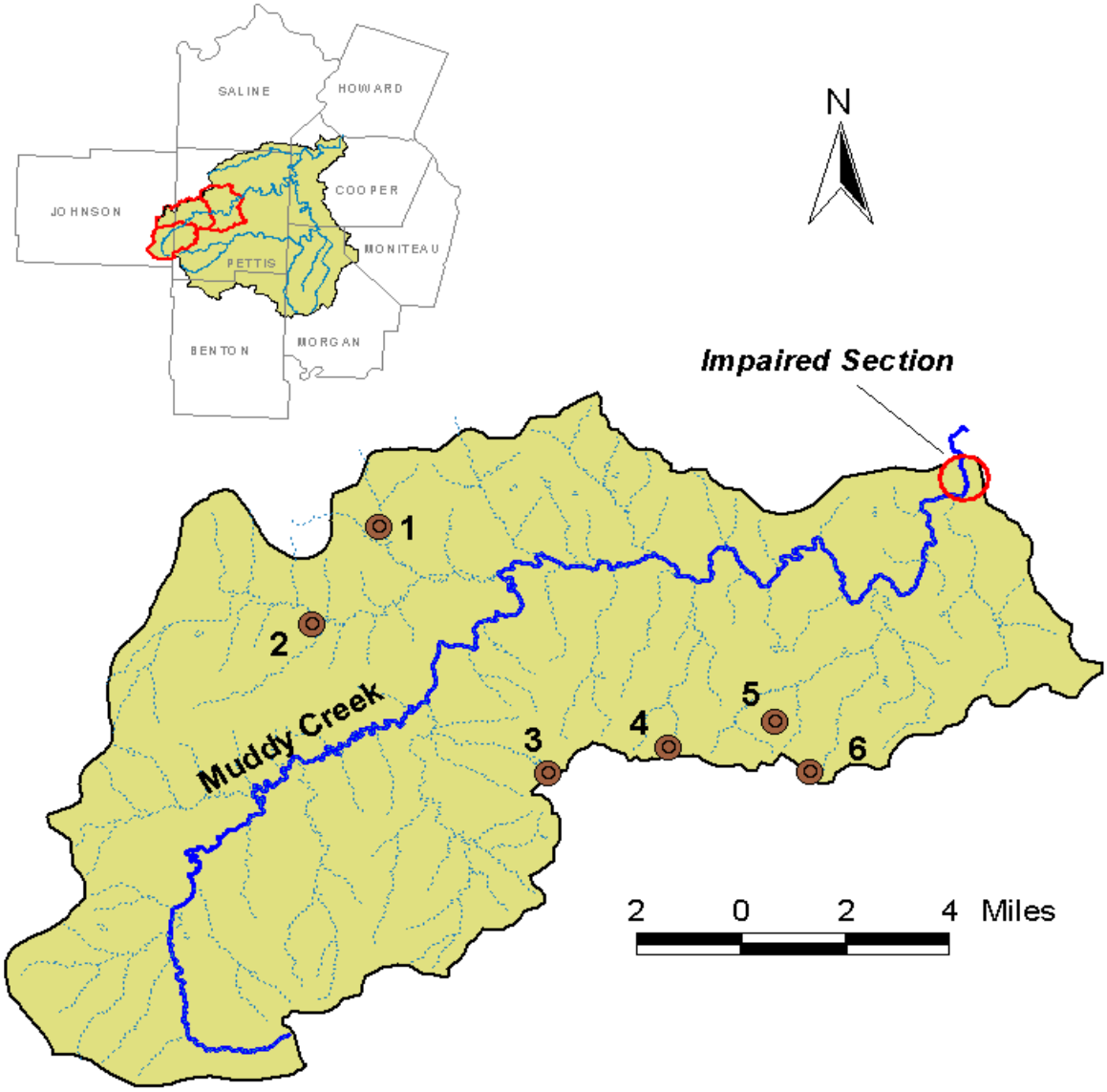
Appendix B.2 Permitted WWTPs in the Muddy Creek Watershed



Facilities Discharging >1% of total BOD Load

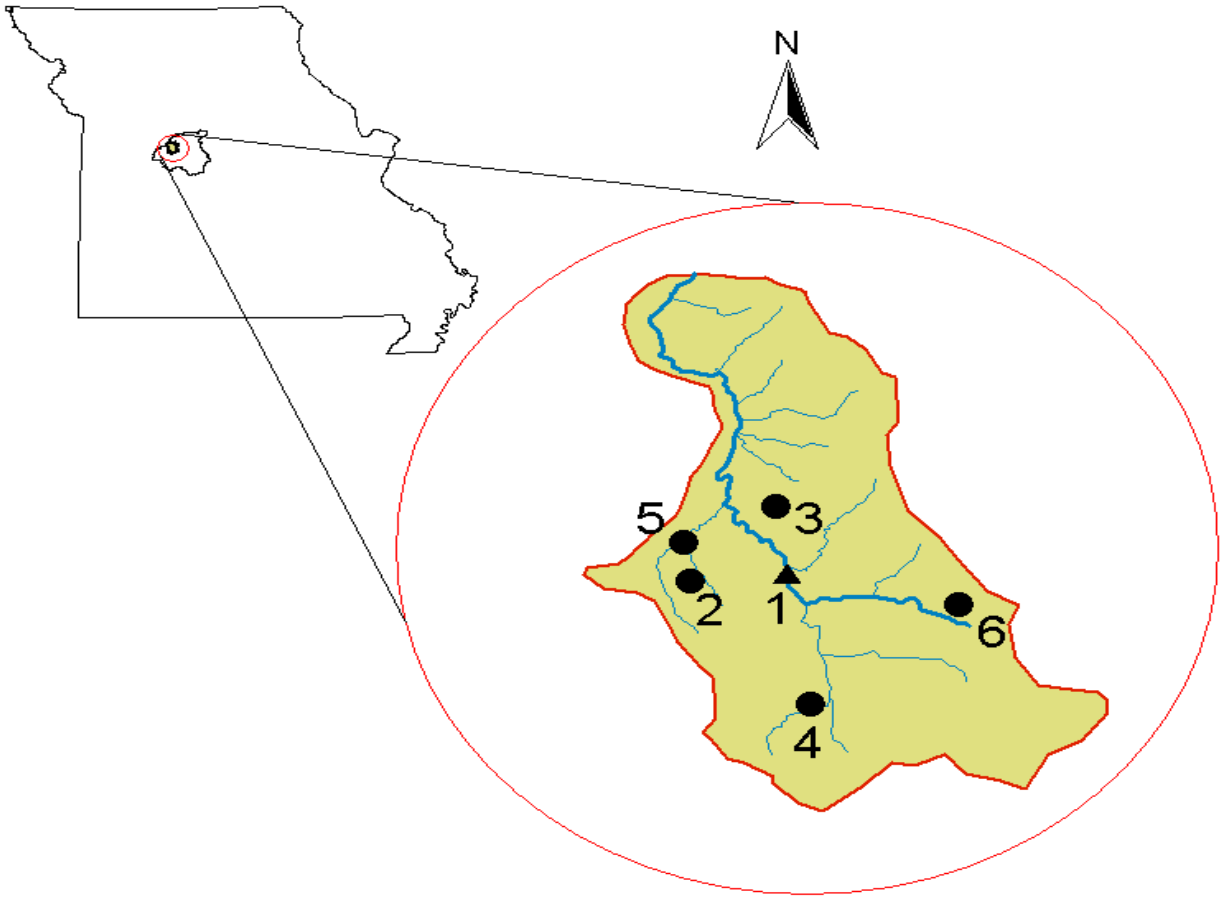
Map Number	NPDES#	Facility Name	Design Flow (cfs)	BOD Limit (mg/l)
1	MO-0023019	Sedalia Central WWTP	3.88	10 (summer), 20 (winter)
2	MO-0119644	Whiteman AFB	0.37	50
3	MO-0108081	La Monte SE Lagoons	0.17	45
4	MO-0109142	Whiteman AFB Villages	0.15	45
5	MO-0104540	Central MO Landfill	0.08	45
6	MO-0109592	Hunters Ridge Subdivision	0.08	30
7	MO-0091553	Sunset Village MHP	0.04	45
8	MO-0090263	Walnut Hills Subdivision	0.04	45

Appendix B.3 Permitted Animal Feeding Operations in the Muddy Creek Watershed



Map Number	NPDES Number	PE Design	Design Flow (MGD)
1	LA3103743	3088	0.0023
2	MO0118877	119700	0.062
3	MOG010042	16161	0.0
4	MOG010031	21539	0.0
5	LA3103770	756	0.0136
6	MOG010116	10770	0.0

Appendix B.4 Permitted Facilities in the Brushy Creek Watershed



Map Number	Facility Name	Design Flow	NFR Limit	BOD Limit
1	Sedalia Central WWTP	3.88 cfs	40 mg/l	40 mg/l
2	Sunset Village	0.04 cfs	70 mg/l	45 mg/l
3	Wire Rope Corp.	0.01 cfs	70 mg/l	30 mg/l
4	Pittsburg Corning	0.01 cfs	60 mg/l	0 mg/l
5	Western View Estates	0.02 cfs	30 mg/l	30 mg/l
6	LaFarge Construction	Stormwater	70 mg/l	0 mg/l

0 1 2 3 Miles

Note: NFR and BOD_5 permit limits are the monthly averages that were in effect when Brushy Creek was placed on the 1998 303(d) list.

Appendix B.5 Upgrades to Sedalia Central Wastewater Treatment Plant

Construction on improvements to the Sedalia Central WWTP began in 1998 and was completed May 2000. The following is quoted from Sedalia's Construction Permit and outlines the improvements that were planned.

Sedalia, Missouri Permit No. 2873

CONSTRUCTION PERMIT

Expand existing wastewater treatment facility. The expanded wastewater treatment facility will have a design flow of 2.5 MGD with a peak flow capacity of 7.0 MGD.

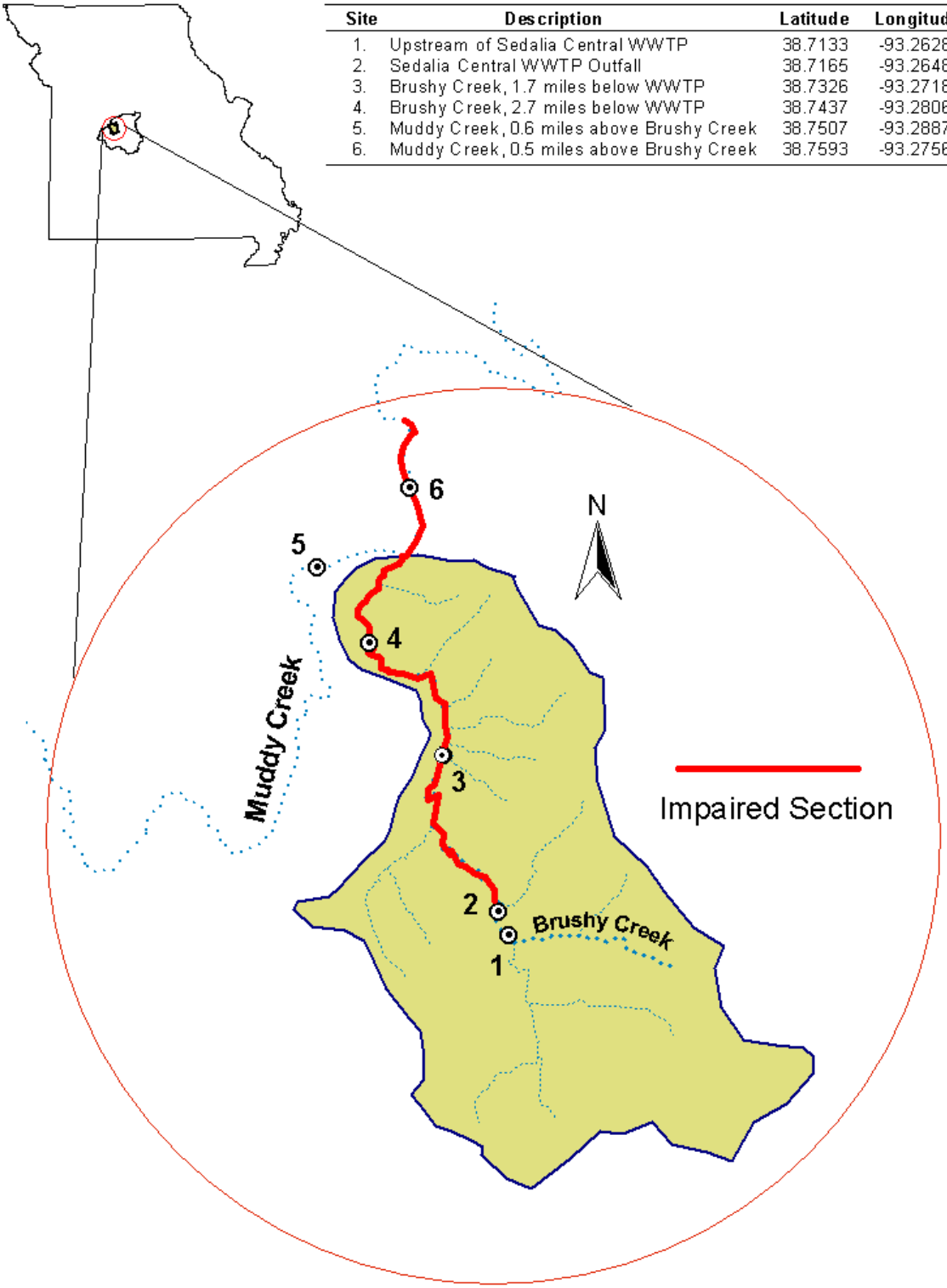
Work shall consist of constructing a peak flow sedimentation basin, influent pump station, aeration basin, two clarifiers, effluent flow measurement; installing a gravity belt thickener in the existing sludge handling facility; installing grease removal equipment; converting existing secondary clarifiers to sludge holding tanks; removing sludge from the existing peak flow lagoon; modifying outfall structure in existing peak flow lagoon; modifying existing bar screen; and modifying peak flow bypass structure.

Install, modify or replace miscellaneous piping, appurtenances and general site work appropriate to the scope and purpose of the project. All construction shall be in accordance with the approved plans and specifications.

Appendix C

Appendix C.1 Map of Impaired Sections of Muddy and Brushy Creeks with Sampling Sites

Site	Description	Latitude	Longitude
1.	Upstream of Sedalia Central WWTP	38.7133	-93.2628
2.	Sedalia Central WWTP Outfall	38.7165	-93.2648
3.	Brushy Creek, 1.7 miles below WWTP	38.7326	-93.2718
4.	Brushy Creek, 2.7 miles below WWTP	38.7437	-93.2806
5.	Muddy Creek, 0.6 miles above Brushy Creek	38.7507	-93.2887
6.	Muddy Creek, 0.5 miles above Brushy Creek	38.7593	-93.2756



Appendix C.2 Water quality data collected on Muddy and Brushy Creeks during waste load allocation surveys.

Site	Description	Date	Time	Temp. (^oC)	D.O. (mg/L)	$CBOD_5$ (mg/L)	TKN (mg/L)	NH_3-N (mg/L)	NO_2+NO_3 (mg/L)	Flow (cfs)	NFR* (mg/L)
ESP #1	Upstream of WWTP, 0.1 mi.	08/25/93	8:20	25.5	4.1	<4	n/a	<.05	0.09	0.05	n/a
ESP #1	Upstream of WWTP, 0.1 mi.	08/25/93	12:45	34.0	13.8	<4	n/a	<.05	<.05	0.05	n/a
ESP #1	Upstream of WWTP, 0.1 mi.	08/26/93	7:30	26.0	2.8	<4	n/a	<.05	<.05	0.05	n/a
ESP #1	Upstream of WWTP, 0.1 mi.	08/26/93	12:50	35.0	14.8	<4	n/a	<.05	<.05	0.05	n/a
ESP #2	Sedalia Central WWTP Effluent	08/25/93	12:00	26.5	7.25	19	n/a	36	3.8	1.05	n/a
ESP # 3	Brushy Creek, 1.7 mi. below WWTP	08/25/93	13:10	29	6.1	<4	n/a	27	3.1	1.1	n/a
ESP # 3	Brushy Creek, 1.7 mi. below WWTP	08/26/93	6:50	25	1.6	<4	n/a	17	1.4	1.1	n/a
ESP # 3	Brushy Creek, 1.7 mi. below WWTP	08/26/93	13:20	30	5.9	<4	n/a	11	<0.25	1.1	n/a
ESP # 4	Brushy Creek, 2.7 mi. below WWTP	08/25/93	7:45	25	1.6	<4	n/a	28	1.7	1.1	n/a
ESP # 4	Brushy Creek, 2.7 mi. below WWTP	08/25/93	13:35	27	5.6	4	n/a	31	2.5	1.1	n/a
ESP # 4	Brushy Creek, 2.7 mi. below WWTP	08/26/93	7:15	26	1.5	5	n/a	12	1.7	1.1	n/a
ESP # 4	Brushy Creek, 2.7 mi. below WWTP	08/26/93	13:45	28	5.6	<4	n/a	12	2.7	1.1	n/a
ESP # 5	Muddy Creek, 0.6 mi. upstream of Brushy Creek	08/25/93	7:00	25	6	<4	n/a	<.05	0.21	1.4	n/a
ESP # 5	Muddy Creek, 0.6 mi. upstream of Brushy Creek	08/25/93	12:55	27	7.1	<4	n/a	<.05	0.15	1.4	n/a
ESP # 5	Muddy Creek, 0.6 mi. upstream of Brushy Creek	08/26/93	6:55	26.5	6.8	<4	n/a	<.05	0.11	1.4	n/a
ESP # 5	Muddy Creek, 0.6 mi. upstream of Brushy Creek	08/27/93	12:25	38.0	7.8	<4	n/a	<.05	0.09	1.4	n/a
ESP # 6	Muddy Creek, 0.5 mi. downstream of Brushy Creek	08/25/93	8:10	26.0	3.6	<4	n/a	22	2.5	2.5	n/a
ESP # 6	Muddy Creek, 0.5 mi. downstream of Brushy Creek	08/25/93	13:50	27.0	7.3	<4	n/a	19	2.8	2.5	n/a
ESP # 6	Muddy Creek, 0.5 mi. downstream of Brushy Creek	08/26/93	7:50	26.0	3.7	4.0	n/a	7	2.5	2.5	n/a
ESP # 6	Muddy Creek, 0.5 mi. downstream of Brushy Creek	08/26/93	13:05	28.0	6.0	<4	n/a	7	2.9	2.5	n/a
ESP #1	Upstream of WWTP, 0.1 mi.	08/30/95	6:50	23.0	2.0	2.0	n/a	<.05	<.05	0.7	n/a
ESP #1	Upstream of WWTP, 0.1 mi.	08/30/95	13:10	35.0	15.0	3.0	n/a	<.05	<.05	0.7	n/a
ESP #1	Upstream of WWTP, 0.1 mi.	08/31/95	6:45	25.0	3.0	<2	n/a	<.05	<.05	0.7	n/a
ESP #1	Upstream of WWTP, 0.1 mi.	08/31/95	12:15	30.0	13.0	<5	n/a	<.05	<.05	0.7	n/a
ESP #2	Sedalia Central WWTP Effluent	08/30/95	7:30	25.0	6.0	19.0	n/a	1.94	10.1	1.23	n/a
ESP #2	Sedalia Central WWTP Effluent	08/31/95	7:10	25.0	6.0	15.0	n/a	4.14	12.4	1.23	n/a
ESP #3	Brushy Creek, 1.7 mi. below WWTP	08/30/95	8:00	24.0	2.0	4.0	n/a	5.34	3.36	1.3	n/a
ESP #3	Brushy Creek, 1.7 mi. below WWTP	08/30/95	14:00	28.0	7.0	5.0	n/a	3.59	3.49	1.3	n/a
ESP #3	Brushy Creek, 1.7 mi. below WWTP	08/31/95	7:55	24.0	2.0	4.0	n/a	3.81	1.63	1.3	n/a
ESP #3	Brushy Creek, 1.7 mi. below WWTP	08/31/95	13:30	26.0	6.0	4.0	n/a	3.06	3.29	1.3	n/a
ESP #4	Brushy Creek, 2.7 mi. below WWTP	08/30/95	8:35	25.0	2.0	<2	n/a	3.95	2.84	1.3	n/a
ESP #4	Brushy Creek, 2.7 mi. below WWTP	08/30/95	14:20	27.0	6.0	<2	n/a	2.5	3.62	1.3	n/a
ESP #4	Brushy Creek, 2.7 mi. below WWTP	08/31/95	8:20	25.0	2.0	<2	n/a	1.02	2.73	1.3	n/a
ESP #4	Brushy Creek, 2.7 mi. below WWTP	08/31/95	03:00	26.0	4.0	<2	n/a	0.4	2.9	1.3	n/a
ESP #5	Muddy Creek, 0.6 mi. upstream of Brushy Creek	08/30/95	6:55	27.0	8.0	<2	n/a	<.05	0.14	1.9	n/a
ESP #5	Muddy Creek, 0.6 mi. upstream of Brushy Creek	08/30/95	13:10	28.0	10.0	2.0	n/a	<.05	0.29	1.9	n/a

Site	Description	Date	Time	Temp. (^oC)	D.O. (mg/L)	$CBOD_5$ (mg/L)	TKN (mg/L)	NH_3-N (mg/L)	NO_2+NO_3 (mg/L)	Flow (cfs)	NFR* (mg/L)
ESP #5	Muddy Creek, 0.6 mi. upstream of Brushy Creek	08/31/95	6:25	26.0	8.0	2.0	n/a	0.1	<.05	1.9	n/a
ESP #5	Muddy Creek, 0.6 mi. upstream of Brushy Creek	08/31/95	12:15	27.0	8.0	<2	n/a	0.05	<.05	1.9	n/a
ESP #6	Muddy Creek, 0.5 mi. downstream of Brushy Creek	08/30/95	7:52	27.0	5.0	<2	n/a	0.14	3.18	3.2	n/a
ESP #6	Muddy Creek, 0.5 mi. downstream of Brushy Creek	08/30/95	14:00	30.0	6.0	2.0	n/a	0.25	3.27	3.2	n/a
ESP #6	Muddy Creek, 0.5 mi. downstream of Brushy Creek	08/31/95	7:30	26.0	4.0	<2	n/a	0.16	3.95	3.2	n/a
ESP #6	Muddy Creek, 0.5 mi. downstream of Brushy Creek	08/31/95	13:00	27.0	5.0	<2	n/a	0.21	3	3.2	n/a
ESP #1	Upstream of WWTP, 0.1 mi.	07/17/01	6:00	23.0	5.5	<2.00	0.32	<0.05	0.23	0.11	9
ESP #1	Upstream of WWTP, 0.1 mi.	07/17/01	13:40	30.0	15.8	<2.00	0.29	<0.05	0.15	0.11	6
ESP #2	Sedalia Central WWTP Effluent	07/17/01		26.0	7.4	2.0	1.35	0.2	7.54	3.49	6
ESP #3	Brushy Creek, 1.7 mi. below WWTP	07/17/01	13:10	26.0	11.8	<2.00	0.39	0.24	7.01	3.6	2.499
ESP #3	Brushy Creek, 1.7 mi. below WWTP	07/17/01	6:35	22.0	5.9	<2.00	<0.20	0.39	7.47	3.6	2.499
ESP #3	Brushy Creek, 1.7 mi. below WWTP	07/17/01	13:10	26.0	11.8	<2.00	0.55	0.24	6.95	3.6	n/a
ESP #4	Brushy Creek, 2.7 mi. below WWTP	07/17/01	13:15	25.0	8.1	<2.00	0.64	<0.05	6.49	3.6	2.499
ESP #4	Brushy Creek, 2.7 mi. below WWTP	07/17/01	6:05	22.0	6.0	<2.00	<0.20	<0.05	6.36	3.6	2.499
ESP #5	Muddy Creek, 0.6 mi. upstream of Brushy Creek	07/17/01	13:40	26.0	6.5	<2.00	0.97	<0.05	0.69	26.6	n/a
ESP #5	Muddy Creek, 0.6 mi. upstream of Brushy Creek	07/17/01	6:25	24.0	6.4	<2.00	0.93	<0.05	0.68	26.6	n/a
ESP #6	Muddy Creek, 0.5 mi. downstream of Brushy Creek	07/17/01	14:00	26.0	6.4	<2.00	1.03	<0.05	1.32	30.2	n/a
ESP #6	Muddy Creek, 0.5 mi. downstream of Brushy Creek	07/17/01	6:50	24.0	6.6	<2.00	0.88	<0.05	1.46	30.2	n/a
ESP #1	Upstream of WWTP, 0.1 mi.	07/24/01	13:35	38.0	11.3	<2.00	0.39	<0.10	<0.05	0.07	6
ESP #1	Upstream of WWTP, 0.1 mi.	07/24/01	6:20	28.0	2.9	<2.00	0.41	<0.10	<0.05	0.07	2.499
ESP #2	Sedalia Central WWTP Effluent	07/24/01	13:45	28.0	6.5	3.0	1.13	<0.10	18.6	1.11	14
ESP #3	Brushy Creek, 1.7 mi. below WWTP	07/24/01	13:10	30.0	12.3	<2.0	<0.20	0.28	14.5	1.18	2.499
ESP #3	Brushy Creek, 1.7 mi. below WWTP	07/24/01	5:55	26.0	4.0	<2.00	<0.20	0.4	14.5	1.18	2.499
ESP #4	Brushy Creek, 2.7 mi. below WWTP	07/24/01	13:15	29.0	8.3	<2.00	<0.20	<0.10	10.8	1.18	9
ESP #4	Brushy Creek, 2.7 mi. below WWTP	07/24/01	5:50	28.0	4.0	<2.00	<0.20	<0.10	10.4	1.18	5
ESP #5	Muddy Creek, 0.6 mi. upstream of Brushy Creek	07/24/01	13:45	31.0	7.0	<2.00	0.82	<0.10	0.29	6.63	n/a
ESP #5	Muddy Creek, 0.6 mi. upstream of Brushy Creek	07/24/01	6:05	30.0	6.0	<2.00	0.69	<0.10	0.35	6.63	n/a
ESP #6	Muddy Creek, 0.5 mi. downstream of Brushy Creek	07/24/01	14:00	31.0	6.0	<2.00	1.29	<0.10	2.42	7.81	n/a
ESP #6	Muddy Creek, 0.5 mi. downstream of Brushy Creek	07/24/01	6:30	29.0	5.3	<2.00	0.88	<0.10	2.36	7.81	n/a

D.O.=Dissolved Oxygen; $CBOD_5$=Chemical Biochemical Oxygen Demand; TKN=Total Kjeldahl Nitrogen; NH_3-N=Ammonia as Nitrogen; NO_2+NO_3= Nitrite plus Nitrate as Nitrogen; NFR=Non-Filterable Residue

* Values reported as <5.00 mg/L were used and considered equivalent to 2.499 mg/L

Appendix D

MDC Temperature and pH Data in Brushy Creek at Cloney Road, 2.7 miles below WWTP outfall.

Date	Temperature (°C)	pH	Date	Temperature (°C)	pH
1/8/98	3.9	6.25	5/15/97	14.8	7.45
1/9/98	4.6	6.8	5/20/97	16.1	7.32
1/20/98	4.3	7.36	5/25/97	24.9	7.41
1/22/98	3.6	7.97	5/28/97	15.3	7.39
1/26/98	7.3	8.16	5/31/97	17.5	7.57
1/30/98	4.3	7.62	5/6/97	18	8.13
2/18/98	5.1	7.19	6/11/97	20.2	7.52
2/20/98	6.9	7.15	6/16/97	21.7	7.73
2/25/98	10.7	7.78	6/21/97	24.2	7.4
2/26/98	11.3	7.66	6/26/97	25.6	7.5
2/2/98	5.9	7.22	6/5/97	21.1	7.62
2/3/98	5.4	7.52	6/8/97	19.1	7.55
2/9/98	6.2	7.99	7/17/97	25.1	7.59
12/11/97	3.9	7.1	7/1/97	24.8	7.52
12/12/97	4	7.05	7/27/97	27.8	7.75
12/15/97	5.4	7.36	7/31/97	20.7	7.74
12/22/97	5.2	7.25	7/9/97	23.7	7.57
12/2/97	8.9	7.25	8/15/97	24.5	7.45
3/12/98	2.1	7.2	8/24/97	21.6	7.31
3/20/98	4.3	7.58	8/5/97	23.8	7.59
3/24/98	9.7	8.05	9/17/97	23.9	7.41
3/26/98	15.5		9/21/97	20.1	7.39
3/2/98	5.1	8.26	9/3/97	23.3	7.41
3/30/98	17.5		10/14/97	13.6	7
4/10/98	10.2	7.8	10/21/97	12	7.59
4/15/98	15.5	7.77	10/30/97	12.9	7.35
4/17/98	11.1	7.69	11/10/97	7.6	7.33
4/21/97	14	7.76	11/19/97	6.1	6.84
4/28/97	14	7.75	11/20/97	6.6	7.52
4/3/98	10.8	7.65	11/24/97	8.5	7.44
4/8/98	11.1	7.97	11/3/97	7.1	7.1

Source: Missouri Department of Conservation (MDC)

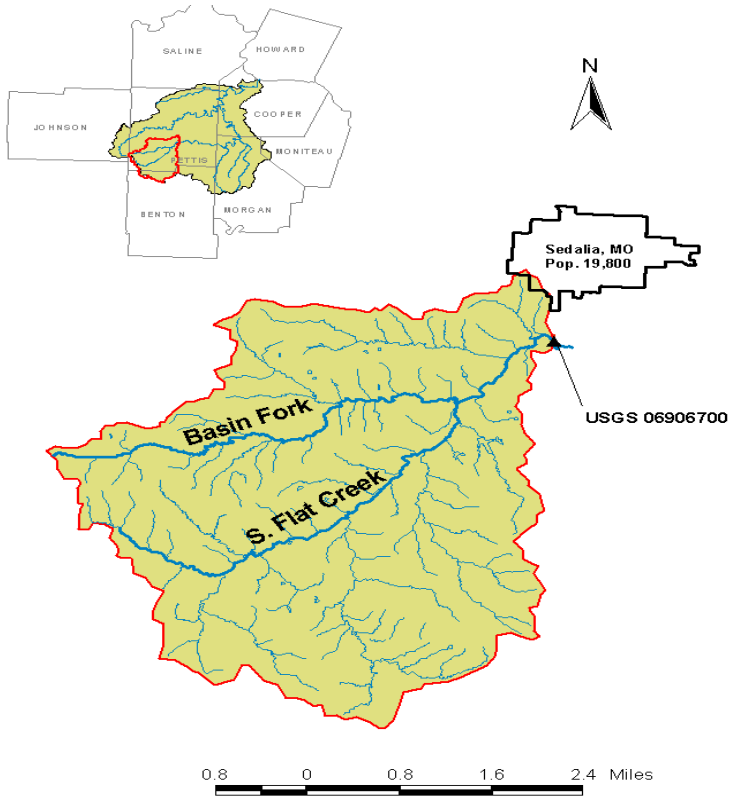
Appendix E

7Q10 Low Flow USGS Stream Gage Data and Watershed Maps

Appendix E.1 7-day Consecutive Low Flows for Flat Creek, USGS Gage 06906700

Year	April - September Low Flow (cfs)	October - March Low Flow (cfs)
1961	1.3	2.4
1962	0.0	0.3
1963	0.0	0.0
1964	0.0	0.0
1965	0.9	2.0
1966	0.1	

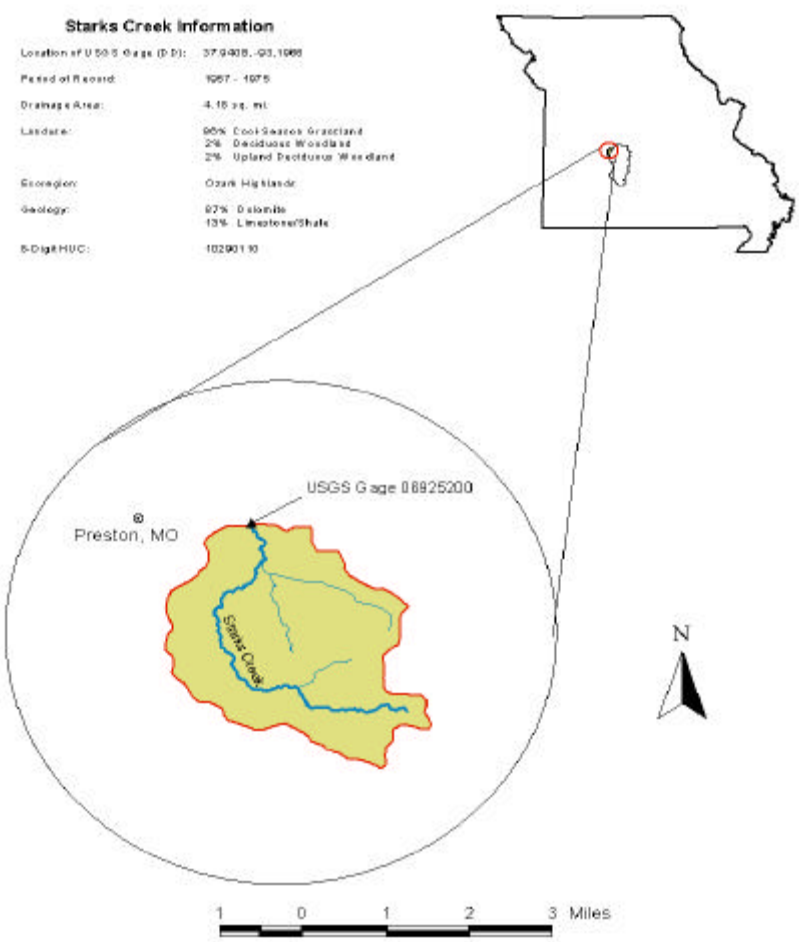
Appendix E.2 Flat Creek above USGS Gage 06906700



Appendix E.3 7-day Consecutive Low Flows for Starks Creek, USGS Gage 06925200

Year	April - September Low Flow (cfs)	October - March Low Flow (cfs)
1957	0.0	0.0
1958	0.0	0.0
1959	0.0	0.0
1960	0.0	0.49
1961	0.0	0.0
1962	0.0	0.0
1963	0.0	0.04
1964	0.0	0.0
1965	0.0	0.0
1966	0.0	0.24
1967	0.0	0.0
1968	0.0	0.37
1969	0.0	0.0
1970	0.0	0.0
1971	0.0	0.36
1972	0.0	0.0
1973	0.0	0.0
1974	0.0	0.24
1975	0.0	0.06

Appendix E.4 Upper Reaches of Starks Creek



Appendix F

Hydrology and Water Quality Coefficients Used in QUAL2E

Appendix F.1 Hydraulic Calibration and Coefficients

Point estimates of depth and water velocity were taken four sites listed below on 07-24-01 by the Environmental Services Program. Effluent discharge was obtained from Sedalia Central WWTP operators the day of the survey. Cross-sectional area and total flow were calculated by integration over a definite interval using Simpson's Rules. Channel slopes were calculated using topographic maps and Mannings N was adjusted to reach observed velocity measurements with the model.

Reach	Dispersion	Mannings N	Slope 1	Slope 2	Width (ft)	Bed Slope
1	350	0.054	12.1	18.2	37.3	0.00055
2	100	0.2	7	6.75	2.4	0.00408
3	200	0.119	4	12.5	0.8	0.00381
4	400	0.133	17.9	7.54	17.5	0.0005

Appendix F.2 Validated BOD/DO Coefficients used in the QUAL2E Model

Reach	BOD Decay	BOD Settling	SOD Rate	Reaeration Option
1	1.03	0	0.45	Owens and Gibbs
2	1.05	0	0.1	Owens and Gibbs
3	0.9	0.1	0.17	Owens and Gibbs
4	0.85	0	0.16	Owens and Gibbs

Appendix F.3 Validated Nitrogen Decay Coefficients used in the QUAL2E Model

Reach	Organic Nitrogen Hydrolysis	Organic Nitrogen Settling	NH_3 Oxidation	NH_3 Benthos Source	NO_2 Oxidation
1	0.1	0	1.2	0	2.5
2	0.1	0	7	0	2.5
3	5	0.1	4.8	0	2.5
4	0.05	0	1.2	0	2.5

Appendix G

Sedalia Central WWTP Discharge Monitoring Report (DMR) 1997 – 2001

Date	Flow (MGD)	NFR (mg/L)
9/28/01	1.394	13
9/21/01	1.437	4
9/12/01	1.251	4
9/5/01	1.505	7
8/30/01	2.073	17
8/22/01	1.42	8
8/15/01	1.25	16
8/8/01	1.424	11
8/1/01	1.405	13
5/30/01	1.575	11
5/23/01	2.837	3
5/16/01	1.48	6
5/9/01	1.377	10
5/2/01	1.486	6
4/25/01	1.576	1
4/19/01	2.243	12
4/11/01	3.412	12
4/3/01	1.194	10
3/27/01	0.756	8
3/20/01	1.305	7
3/9/01	1.092	10
3/1/01	1.834	30
2/23/01	0.823	12
2/15/01	1.523	14
2/6/01	0.79	16
1/30/01	3.819	8
1/25/01	0.535	25
1/17/01	1.378	13
1/12/01	1.439	10
1/3/01	1.423	24
12/28/00	1.123	29
12/19/00	1.124	8
12/13/00	0.851	17
12/6/00	0.389	13
11/28/00	0.491	11
11/22/00	0.506	8
11/15/00	0.684	7
11/8/00	1	8
11/1/00	0.955	11
10/24/00	1.633	9
10/17/00	2.153	11
10/9/00	0.643	9
10/3/00	1.05	9
9/26/00	1.743	3
9/19/00	0.974	18
9/13/00	1.229	6

Date	Flow (MGD)	NFR (mg/L)
3/2/99	1.129	28
2/23/99	1.48	31
2/16/99	0.5	43
2/16/99	1.692	27
2/10/99	2.24	21
2/8/99	1.6	41
2/2/99	3.058	35
2/1/99	0.54	2.6
1/26/99	1.622	8.5
1/21/99	1.364	60
1/13/99	3.09	29
1/5/99	0.861	59
12/8/98	1.854	56
12/1/98	1.759	16
11/24/98	0.968	22
11/17/98	1.157	35
11/11/98	2.183	40
11/3/98	2.712	32
10/27/98	1.062	14
10/22/98	2.614	32
10/14/98	1.311	14
10/6/98		20
10/6/98	0.75	64
9/29/98	1.557	17
9/22/98	2.302	32
9/15/98	3.804	23
9/8/98	0.996	16
9/2/98	2.104	13
8/25/98	1.485	26
8/18/98	1.733	21
8/11/98	2.551	29
8/4/98	2.663	20
7/28/98	2.622	19
7/27/98	1.1	63
7/21/98	0.897	21
7/14/98	0.855	25
7/7/98	1.543	12
6/30/98	n/a	47
6/23/98	n/a	48
6/22/98	7.14	40
6/16/98	n/a	46
6/9/98	n/a	59
6/3/98	n/a	15
5/26/98	n/a	64
5/21/98	n/a	32
5/12/98	n/a	21

Date	Flow (MGD)	NFR (mg/L)
9/6/00	0.96	24
8/31/00	1.25	5
8/23/00	1.235	15
8/16/00	1.44	36
8/9/00	1.573	8
8/1/00	1.118	11
7/26/00	1.278	17
7/19/00	2.474	18
7/12/00	1.894	33
7/1/00	2.469	24
6/28/00	2.027	8
6/21/00	3.327	10
6/14/00	1.248	20
6/7/00	0.956	4
5/31/00	1.176	10
5/25/00	1.02	8
5/17/00	0.929	12
5/10/00	1.717	25
5/3/00	0.679	53
4/26/00	0.346	18
4/19/00	0.38	31
4/12/00	0.58	41
4/5/00	0.422	50
3/29/00	1.002	26
3/22/00	1.066	40
3/15/00	1.499	40
3/8/00	0.846	53
3/1/00	0.897	22
2/23/00	1.021	40
2/17/00	0.665	20
2/9/00	0.66	71
2/3/00	0.786	70
1/26/00	0.696	57
1/19/00	0.61	71
1/13/00	0.78	78
1/4/00	1.006	28
12/29/99	0.62	40
12/22/99	0.769	48
12/17/99	0.965	27
12/8/99	0.929	33
12/1/99	0.66	61
11/23/99	1.074	48
11/16/99	0.667	72
11/9/99	0.682	36
11/1/99	0.465	40
10/26/99	0.681	69
10/18/99	0.813	31
10/12/99	0.775	33
10/5/99	0.959	24
9/28/99	1.664	23
9/21/99	0.915	28
9/14/99	0.856	25

Date	Flow (MGD)	NFR (mg/L)
5/5/98	n/a	8
4/29/98	1.5	30
4/28/98	n/a	42
4/28/98	4.3	8.5
4/21/98	n/a	20
4/14/98	n/a	27
4/7/98	n/a	51
4/1/98	0.54	
3/31/98	n/a	18
3/24/98	n/a	42
3/17/98	n/a	42
3/17/98	1.5	31
3/10/98	n/a	32
3/9/98	0.5	27
3/3/98	1.107	23
2/24/98	1.558	29
2/19/98	2.82	47
2/13/98	2.435	41
2/12/98	0.0487	37
2/3/98	0.811	51
1/27/98	0.96	32
1/20/98	1.151	27
1/14/98	1.439	56
1/6/98	1.754	30
12/30/97	1.673	21
12/23/97	1.567	19
12/16/97	1.397	33
12/9/97	1.431	32
12/2/97	1.466	11
11/25/97	0.695	22
11/18/97	0.712	31
11/11/97	1.101	43
11/4/97	1.008	
10/28/97	1.711	
10/21/97	0.801	27
10/14/97	1.581	32
10/7/97	0.77	42
9/23/97	0.655	27
9/16/97	0.614	18
9/9/97	0.771	10
9/2/97	0.707	65
8/25/97	0.998	29
8/19/97	1.575	58
8/12/97	0.804	13
8/5/97	0.857	27
7/29/97	0.817	4
7/22/97	0.875	33
7/15/97	0.859	26
7/8/97	1.459	35
7/1/97	1.728	29
6/24/97	1.34	10
6/17/97	2.231	11

Date	Flow (MGD)	NFR (mg/L)
9/7/99	0.831	28
9/1/99	1.069	40
8/24/99	1.111	17
8/17/99	1.039	42
8/10/99	0.925	13
8/3/99	0.857	32
7/27/99	0.787	36
7/20/99	0.896	39
7/13/99	1.006	28
7/6/99	0.824	20
6/30/99	1.691	12
6/24/99	1.76	40
6/17/99	0.962	29
6/10/99	0.942	53
6/1/99	0.85	4.9
5/28/99	1.223	55
5/18/99	3.754	37
5/11/99	1.669	50
5/4/99	2.003	48
4/27/99	3.845	21
4/20/99	1.612	38
4/13/99	1.093	26
4/7/99	1.062	8
3/30/99	1.111	25
3/23/99	1.516	24
3/20/99	1.386	15
3/10/99	3.474	37
3/7/99		40

Date	Flow (MGD)	NFR (mg/L)
6/10/97	1.252	43
6/3/97	2.927	48
5/27/97	4.13	25
5/27/97	3.68	37
5/21/97	1.328	37
5/13/97	1.271	27
5/6/97	1.151	57
4/29/97	2.63	35
4/22/97	2.202	60
4/22/97	1.16	59
4/15/97	2.022	23
4/8/97	1.426	38
4/1/97	1.262	23
3/26/97	2.052	28
3/18/97	1.53	21
3/11/97	2.523	39
3/4/97	2.454	30
2/27/97	0.75	23
2/25/97	2.697	44
2/21/97	9.1	46
2/18/97	1.224	48
2/10/97	1.25	19
2/4/97	2.953	44
1/28/97	1.534	14
1/21/97	1.666	49
1/15/97	0.93	53
1/7/97	0.8	20
1/1/97	0.737	37

Appendix H

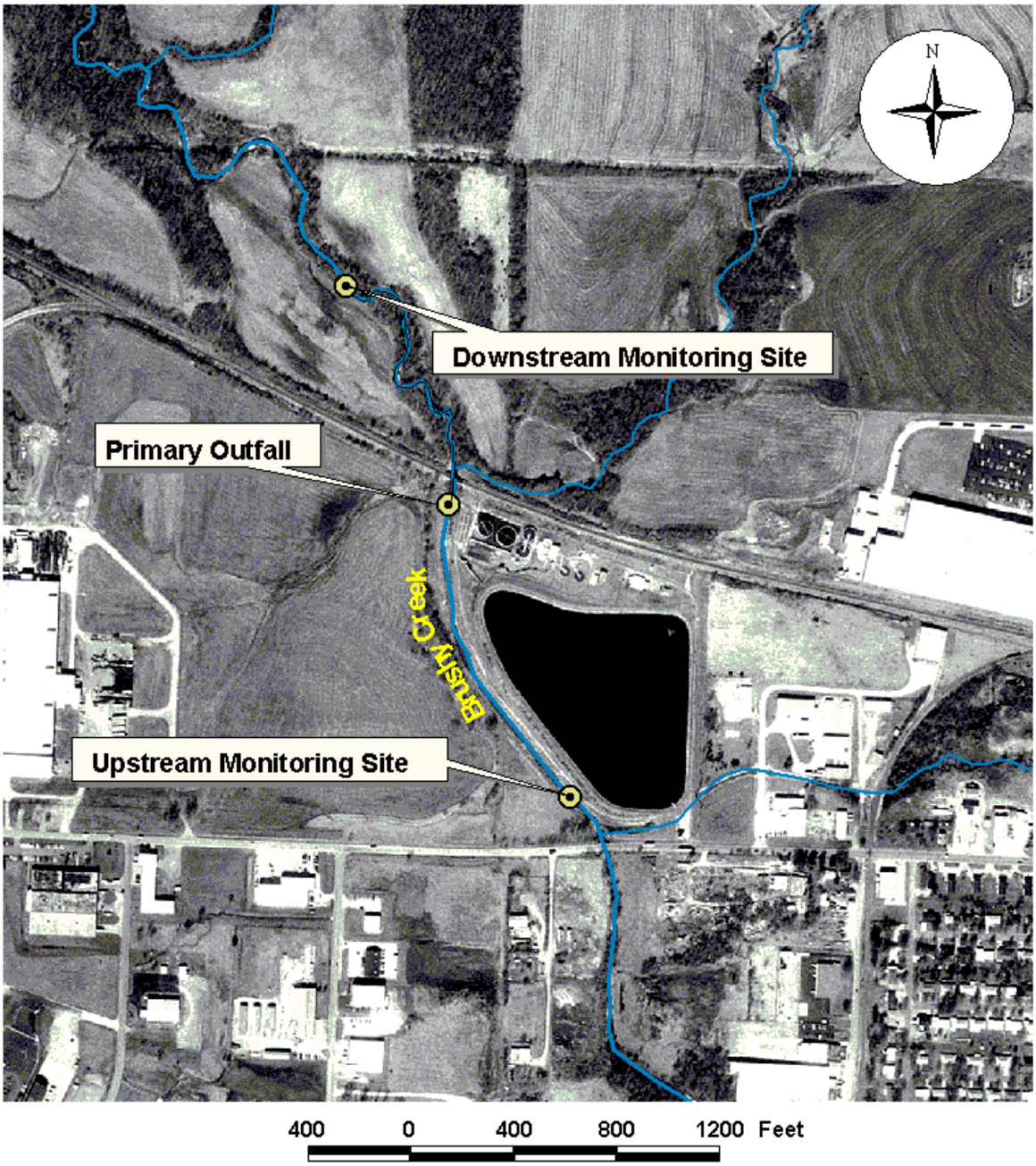



Figure 22. Locations of Instream Monitoring Sites for Sedalia Central WWTP