Missouri Department of Natural Resources Water Protection Program

Total Maximum Daily Load (TMDL)

for

Buffalo Ditch
Dunklin County, Missouri

Total Maximum Daily Load (TMDL)
For Buffalo Ditch
Pollutant: Low Dissolved Oxygen

Name: Buffalo Ditch

Location: Dunklin County, Missouri

Hydrologic Unit Code: 08020204-070001

Water Body Identification: 3118

Missouri Stream Class: P[1]

Designated Beneficial Uses:
- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health (Fish Consumption)
- Whole Body Contact Recreation – Category B.

Location of Impaired Segment: Arkansas State line to Section 11, T18N, R9E

Length of Impaired Segment: 18.0 miles

Location of Impairment within Segment: Just downstream of the Kennett Wastewater Treatment Plant to just upstream of Highway Y (refer to Figure 1)

Length of Impairment within Segment: 3.0 miles

Use that is impaired: Protection of Warm Water Aquatic Life

Pollutant: Low Dissolved Oxygen

TMDL Priority Ranking: High

---

[1] Class P streams maintain permanent flow even during drought conditions. See the Missouri Water Quality Standards at 10 Code of State Regulations 20-7.031(1)(F). The water quality standards can be found at the following uniform resource locator: http://www.sos.mo.gov/adrules/csr/current/10csr/10csr.asp#10-20

Contents

Figures

Tables

1 Introduction

This Buffalo Ditch Total Maximum Daily Load, or TMDL, is being established in accordance with Section 303(d) of the Clean Water Act. This water quality limited segment near Kennett in Dunklin County, Missouri is included on the Environmental Protection Agency, or EPA, approved Missouri 2008 303(d) List.

The purpose of a TMDL is to determine the maximum amount of a pollutant (the load) that a water body can assimilate without exceeding the water quality standards for that pollutant. Water quality standards are benchmarks used to assess the quality of rivers and lakes. The TMDL also establishes the pollutant load capacity necessary to meet the Missouri water quality standards established for each water body based on the relationship between pollutant sources and instream water quality conditions. The TMDL consists of a wasteload allocation, a load allocation, and a margin of safety. The wasteload allocation is the portion of the allowable load that is allocated to point sources. The load allocation is the portion of the allowable load that is allocated to nonpoint sources. The margin of safety accounts for the uncertainty associated with the model assumption and data inadequacies.

Section 2 of this report provides background information on the Buffalo Ditch watershed and its water quality problems, and Section 3 describes potential sources of concern. Section 4 presents the applicable water quality standards, and Section 5 describes the modeling that was done to support the TMDL. Sections 6 to 9 present the required TMDL elements, and Sections 10 to 14 summarize follow-up monitoring, TMDL implementation, reasonable assurances, and public participation. A summary of the administrative record is presented in Section 15, and the appendices provide water quality data and additional information on the modeling.

2 Background

This section of the report provides information on Buffalo Ditch and its watershed.

2.1 The Setting

Buffalo Ditch is situated in the low-lying Bootheel region of southeastern Missouri, comprised of Dunklin, Pemiscot, and New Madrid counties, in the broad, flat alluvial plain between the Mississippi and St. Francis Rivers. It originates at the city of Kennett, in Dunklin County, and flows southwest into Arkansas to its confluence with Honey Cypress Ditch (Figure 1). Buffalo Ditch drains approximately 57 square miles. It is part of the Little River Ditch complex that drains this area and ultimately flows into the St. Francis River. While Buffalo Ditch and its watershed extend into the state of Arkansas, this TMDL addresses only the portion of the watershed that lies within the state of Missouri. The classified segment of Buffalo Ditch is 18.0 miles in length and the impaired distance within this segment is 3.0 miles. The classified segment corresponds to that portion of the stream listed on Missouri's 2008 303(d) List and defined in Missouri's water quality standards; the impairment within the segment corresponds to that portion of the stream determined to not be meeting water quality standards.

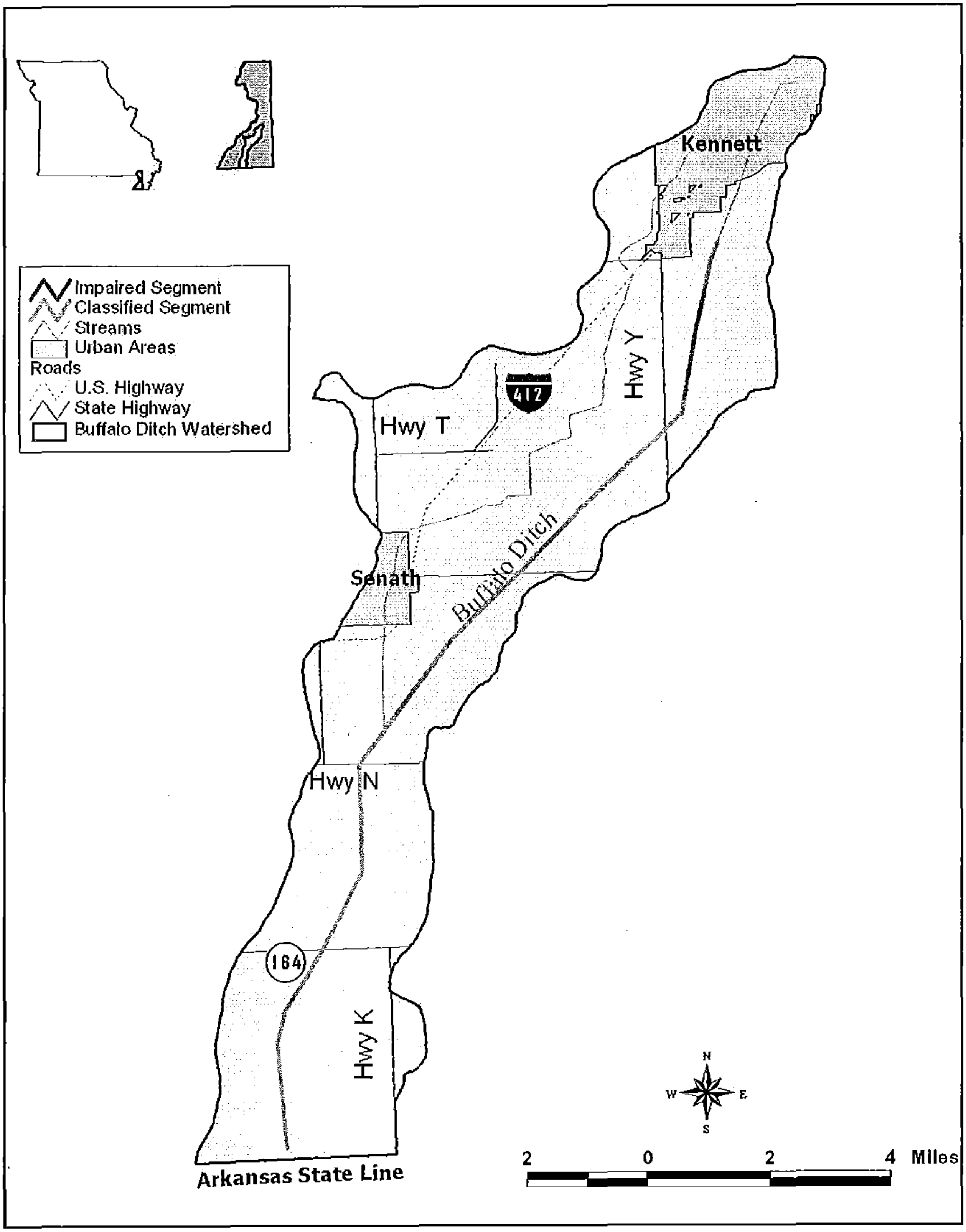


Figure 1. Location of Buffalo Ditch watershed showing impaired segment (3.0 miles).

Historically, most of the land in this area – perhaps as much as 90 percent – was inundated with water for at least part of the year and was dominated by tupelo-cypress swamp and mixed deciduous bottomland forests. The Bootheel was largely deforested in the late 19th century and, in 1907, the Little River Drainage District was formed with the goal of administering a large-scale drainage project in southeast Missouri to open the land up for settlement and agricultural production. This was accomplished through stream channelization and the construction of over 300 miles of levees and 958 miles of drainage ditches, draining an area today of 1.2 million acres – the largest drainage facility in the United States (Gideon School District, 1997). As part of this complex drainage network, the Missouri portion of Buffalo Ditch extends 18 miles from Kennett to the Arkansas border, with a total watershed area in Missouri of just over 36,300 acres.

Buffalo Ditch was first listed in Missouri's Section 303(d) List of impaired waters for biochemical oxygen demand in 1994. Biochemical oxygen demand is the measure of oxygen used by microorganisms to decompose organic matter. Therefore, an analysis of biochemical oxygen demand provides a possible link between sources of organic pollutants and the loss of oxygen in surface waters. The Missouri Department of Natural Resources (the Department) changed the name of the pollutant causing the impairment from biochemical oxygen demand to dissolved oxygen on the 2004/2006 303(d) List to provide a more understandable list to the general public. The causes of the impairments, and the data used to identify them, have not changed.

Ammonia, which at high concentrations can be toxic to aquatic life, was also added as a cause of impairment to the 2004/2006 303(d) List. However, the ammonia data have since been reassessed and no longer shows an impairment caused by this pollutant. As a result, Buffalo Ditch is not listed for an ammonia-related impairment on the 2008 303(d) List and no TMDL for ammonia is being developed at this time.

2.2 Geology and Soils

The Buffalo Ditch watershed is within the St. Francis Lowlands ecoregion of the Mississippi alluvial plain, a generally low-lying area with very little topographic relief. This region was formed predominantly of sand and gravel deposits from Pleistocene glacial outwash from the Mississippi and Ohio Rivers. Over time, this outwash has been covered with unconsolidated deposits of silty alluvium and alluvial sand generally ranging in depth from 5 to 15 feet, with some older deposits of greater than 100 feet (Chapman et al., 2002, Chapman et al., 2004).

Having developed within the Mississippi River floodplain, the three primary soil associations found within the Missouri portion of this watershed all share the characteristics of being deep and relatively level. The Malden-Canalou-Bosket association in the upper part of the watershed is comprised of predominantly sandy and loamy soils and the Dubbs association further to the south is formed mostly of silts. Between them, these soil associations range from moderately to excessively well-drained. The lower portion of this part of the watershed, extending across the Arkansas border, is made up of the Dundee-Silverdale association, loamy sands ranging from somewhat poorly drained to moderately well-drained. Soil fertility throughout the watershed ranges from medium to high, with a generally high degree of available water capacity. These characteristics are supportive of row crop agriculture as the dominant land use in this region (USDA Soil Conservation Service, 1979).

2.3 Population

The population within the Buffalo Ditch watershed is not directly available. However, the U.S. Census Bureau reports that the 2007 population for Kennett is 10,749 (Census Bureau, 2008) and the southern portion of the city is located in the watershed (Figure 1). Additionally, the rural population of the watershed can be roughly estimated based on the proportion of the watershed that is located in Dunklin County. Dunklin County covers an area of approximately 546 square miles and has a population of 31,623 (Census Bureau, 2008). By subtracting the population of the cities of Senath, Kennett, Malden, Campbell, Holcomb, Clarkton, Hornersville, Rives, and Cardwell from the total county population, the rural population in Dunklin County is estimated at approximately 7,931 persons. The rural population of the Buffalo Ditch watershed is therefore estimated as 770 persons [rural area of watershed (53 square miles) divided by 546 square miles multiplied by 7,931].

2.4 Land Use

The land use/land cover of the Buffalo Ditch watershed is shown in Figure 2 and summarized in Table 1 (MORAP, 2005). The primary land uses/land covers are cropland (91 percent) and urban (6 percent). The remaining categories comprise less than 3 percent of the watershed area.

Table 1. Land use in the Buffalo Ditch watershed.

Land Use Type	Watershed Area		Percent
	Acres	Square Miles	
Barren	152.34	0.24	0.42
Cropland	33104.68	51.73	91.14
Forest	54.49	0.09	0.15
Grassland	725.89	1.13	2.00
Herbaceous	49.15	0.08	0.14
Open Water	42.03	0.07	0.12
Urban	2170.12	3.39	5.98
Wetland	17.57	0.03	0.05
Total	36,316.27	56.76	100.00

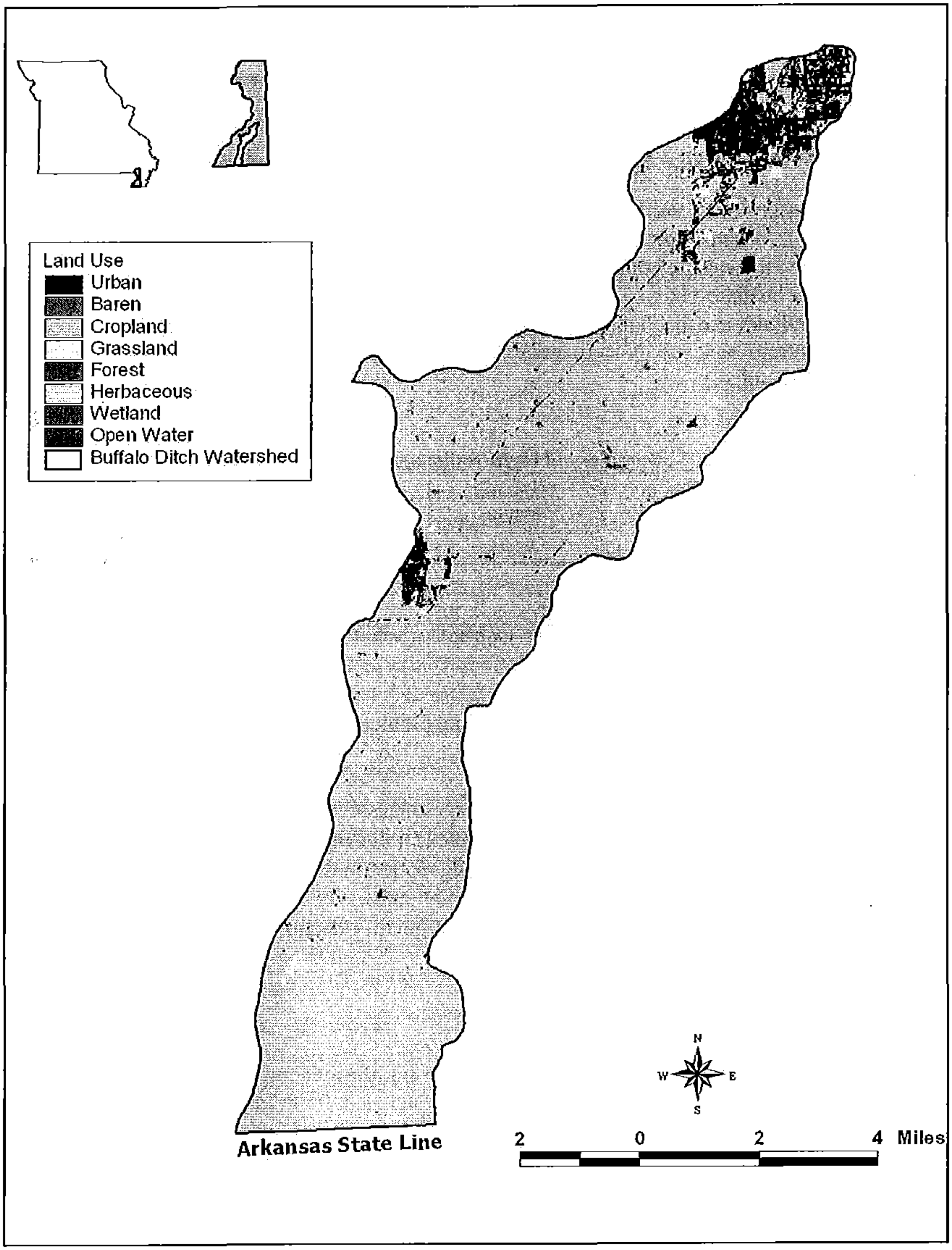


Figure 2. Land use/land cover in the Buffalo Ditch watershed (MORAP, 2005).

2.5 Defining the Problem

A TMDL is needed for Buffalo Ditch because it is not meeting the water quality criterion for dissolved oxygen. Low dissolved oxygen is an issue because concentrations have been measured at less than the water quality criterion of 5 mg/L.

Water from Buffalo Ditch was sampled and analyzed by the Department to produce water quality data in July 2003, August 2003, and January 2004. The data produced by the Department are of sufficient quality to evaluate compliance with water quality standards and to support TMDL development. The dissolved oxygen results for the three Department surveys are summarized in Appendix A and indicate that a minimum of 33 percent of the sampled dissolved oxygen concentrations from each survey were less than 5 mg/L. All of the data from these surveys are presented in Appendix A.

Table 2. Summary of MoDNR dissolved oxygen data for Buffalo Ditch.

Survey	Number of Samples	Minimum [a] (mg/L)	Average (mg/L)	Maximum (mg/L)	Percentage of Samples < 5 mg/L
July 2003	16	1.1	4.9	10.8	50%
August 2003	12	<1	5.5	12	58%
January 2004	3	4.8	5.3	5.6	33%

[a]Two of the August 2003 DO samples were less than the detection limit of 1 mg/L. These values were interpreted as 0.5 mg/L for calculation purposes.

As discussed in Section 4, the low dissolved oxygen problem could be due to one or more of the following:

- Excessive loads of decaying organic solids, as measured by biochemical oxygen demand.
- Too much algae in the stream as a result of excessive phosphorus or nitrogen loading.
- High consumption of oxygen from decaying matter on the streambed.
- Physical factors associated with low reaeration rates.
- Higher temperatures due to loss of riparian vegetative canopy.

3 Source Inventory

This section summarizes the available information on significant sources of nutrients and oxygen-consuming substances in the Buffalo Ditch watershed. Point (or regulated) sources are presented first, followed by nonpoint (or unregulated) sources.

3.1 Point Sources

The term "point source" refers to any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel or conduit, by which pollutants are transported to a water body. Point sources are regulated through the Missouri State Operating Permit program[2]. Point sources also include vessels or other floating craft from which pollutants are or may be discharged. The permitted facilities in the Buffalo Ditch watershed are listed in Table 3 and shown in Figure 3. There are two facilities with site-specific permits, one with a general permit, and four facilities with storm water permits. General permits (as opposed to site-specific permits) are issued to activities that are similar enough to be covered by a single set of requirements. Storm water permits are issued to activities that discharge only in response to precipitation events.

One of the storm water permits is for the city of Kennett, which is a permit for a municipal separate storm sewer system. This permit is based on Kennett having a 2000 census population of 10,000 or more, and covers the entire area incorporated by the city. The total area included within the Kennett municipal separate storm sewer system permit is 6.7 square miles. The portion of this permit within the Buffalo Ditch watershed is 5.2 square miles, or 9.1 percent of the watershed, and includes discharge from 7 out of 18 of the permitted storm water outfalls.

By law, the term "point source" also includes concentrated animal feeding operations (which are places where animals are confined and fed). There are no concentrated animal feeding operations located in the Buffalo Ditch watershed.

Table 3. Permitted facilities in the Buffalo Ditch watershed.

Facility ID	Facility name	Receiving Stream	Design Flow (MGD)	Permit Expiration Date
MO0028568	Kennett Wastewater Treatment Plant	Buffalo Ditch	1.40	2007
MO0048666	Senath Wastewater Treatment Plant	Ditch to Buffalo Ditch	0.256	2011
MOG640095	Kennett Water Plant Settling Basin	Buffalo Ditch	General Permit	2008
MOR040069	Kennett	Buffalo Ditch	Storm Water Permit	2013
MOR12A030	Producers Mid-South	Buffalo Ditch	Storm Water Permit	2011
MOR203401	Manac Trailer USA Inc	Trib to Buffalo Ditch	Storm Water Permit	2009
MOR240473	UAP Mid-Senath	Local Drainage Ditch	Storm Water Permit	2014

[2] The Missouri State Operating Permit program is Missouri's program for administering the federal National Pollutant Discharge Elimination System program.

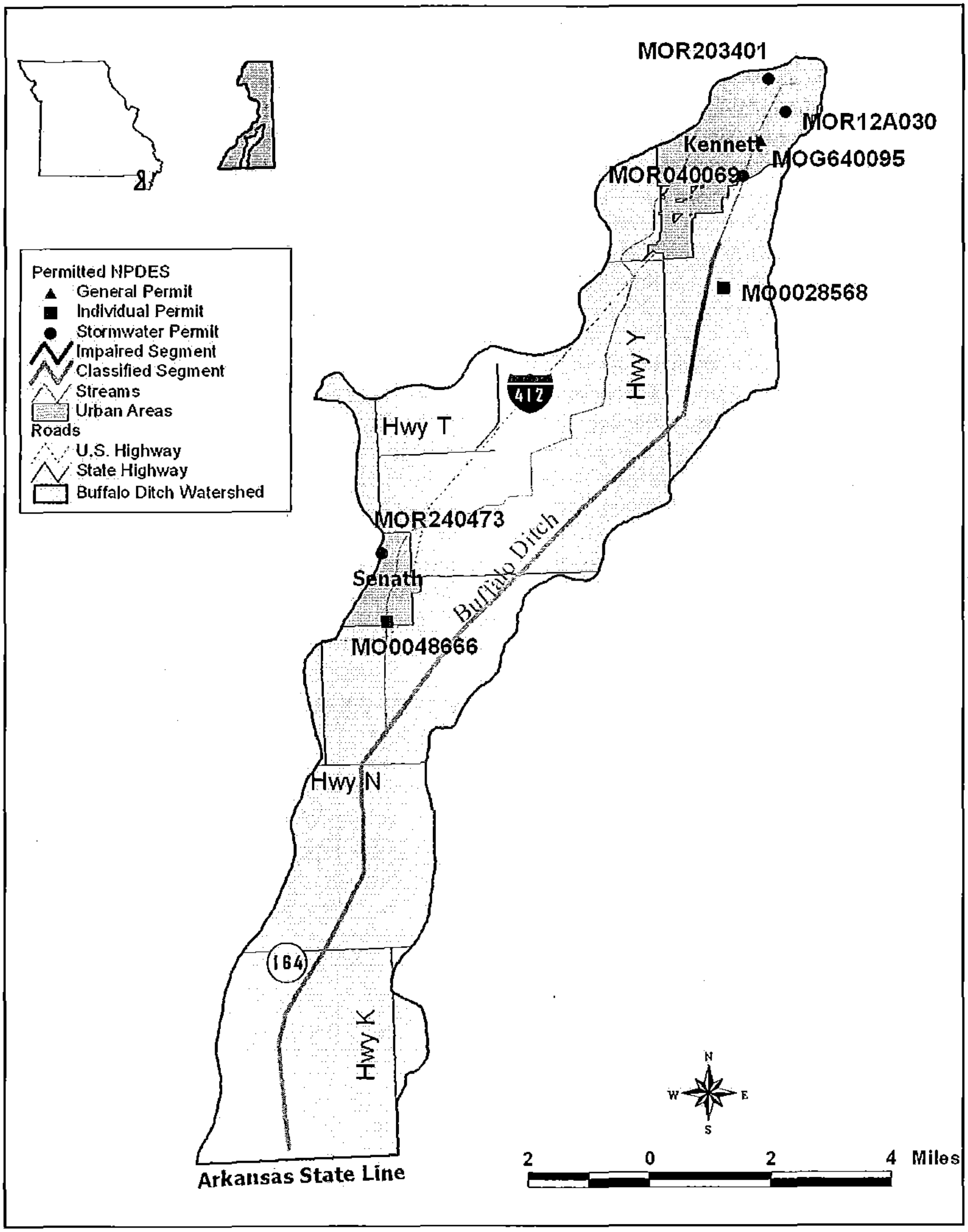


Figure 3. Location of permitted facilities in the Buffalo Ditch watershed.

The Senath Wastewater Treatment Plant discharges to Ditch to Buffalo Ditch through one outfall (#001) with a design flow of 0.256 million gallons per day. Ditch to Buffalo Ditch then flows into Buffalo Ditch. Prior to discharge, wastewater is treated in three-cell aerated earthen treatment basins. Sludge is retained in these basins and the design sludge production is 46.6 dry tons per year.

The Kennett Wastewater Treatment Plant discharges directly to Buffalo Ditch through one outfall (#001) with a design flow of 1.4 million gallons per day. Prior to discharge, wastewater is treated in an aerated lagoon. Sludge is retained in the lagoon and the design sludge production for the Kennett Wastewater Treatment Plant is 210 dry tons per year.

Illicit straight pipe discharges of household waste are also potential point sources in agricultural areas. These are discharges straight into streams or land areas and are different than illicitly connected sewers. There is no specific information on the number of illicit straight pipe discharges of household wastes in the Buffalo Ditch watershed.

3.2 Nonpoint Sources

Nonpoint sources include all other categories not classified as point sources. Potential nonpoint sources causing low dissolved oxygen in Buffalo Ditch watershed include runoff from agricultural areas, runoff from urban areas, onsite wastewater treatment systems, and various sources associated with riparian habitat conditions. Each of these is discussed further in the following sections.

3.2.1 Runoff from Agricultural Areas

Lands used for agricultural purposes can be a source of nutrients and oxygen-consuming substances. Accumulation of nitrogen and total phosphorus on cropland occurs from decomposition of residual crop material, fertilization with chemical and manure fertilizers, atmospheric deposition, wildlife excreta, and irrigation water. The land use/land cover data indicates that approximately 91 percent of the watershed consists of cropland (MORAP, 2005). Similarly, nearly 86 percent of the riparian corridor along Buffalo Ditch is classified as cropland (see Table 4). Since cropland covers a significant portion of the watershed, runoff from these areas could be an important source of the oxygen-consuming substances.

Countywide data from the National Agricultural Statistics Service (USDA, 2002) were combined with the land cover data for Buffalo Ditch watershed to estimate that there are approximately 235 cattle in the watershed[3]. The cattle are most likely located on the approximately 726 acres of grassland/pastureland in the watershed and runoff from these areas can also be potential sources

[3] According to the National Agricultural Statistics Service there are approximately 2,300 head of cattle in Dunklin County (http://www.nass.usda.gov). According to the 2005 Missouri Resource Assessment Program there are 11 square miles of grassland in Dunklin County. These two values result in a cattle density of approximately 208 cattle per square mile of grasslands. This density was multiplied by the number of square miles of grasslands in the Buffalo Ditch watershed to estimate the number of cattle in the watershed.

of nutrients and oxygen-consuming substances. For example, animals grazing in pasture areas deposit manure directly upon the land surface and, even though a pasture may be relatively large and animal densities low, the manure will often be concentrated near the feeding and watering areas in the field. These areas can quickly become barren of plant cover, increasing the possibility of erosion and contaminated runoff during a storm event. Based on previous TMDL projects by Tetra Tech and others, the density of cattle in the Buffalo Ditch watershed (4 cattle per square mile) is relatively low (OEPA, 2007; Tetra Tech, 2009). The National Agricultural Statistics Service also reports that there are 187 hogs and pigs in Dunklin County in 2002. No data are available to estimate the number of these other livestock that might be located in the Buffalo Ditch watershed.

3.2.2 Runoff from Urban Areas

Storm water runoff from urban areas can also be a significant source of nutrients and oxygen-consuming substances. Lawn fertilization can lead to high nutrient loads and pet wastes can contribute both nutrient loads and oxygen-consuming substances. For example, phosphorus loads from residential areas can be comparable to or higher than loading rates from agricultural areas (Reckhow et al., 1980; Athayde et al., 1983). Leaking or illicitly connected sewers can also be a very significant source of pollutant loads within urban areas. Warmer storm runoff from urban areas such as parking lots, buildings and roads can lead to higher water temperatures that lower the dissolved oxygen saturation capacity of streams. Excessive discharge of suspended solids from urban areas can also lead to streambed siltation problems.

Approximately 3.4 square miles, or 6 percent, of the Buffalo Ditch watershed is classified as urban based on an assessment of impervious land cover. Kennett's municipal separate storm sewer system permit (which can include both pervious and impervious land surfaces) accounts for 5.2 square miles, or 9.1 percent, of the watershed. Most nonpoint source urban runoff within the watershed therefore likely comes from the Senath municipal area and from roads outside of the Kennett incorporated area. Given this relatively small area, urban storm water runoff is not likely a significant source of substances and conditions contributing to low dissolved oxygen.

3.2.3 Onsite Wastewater Treatment Systems

Onsite wastewater treatment systems (e.g., septic systems) that are properly designed and maintained should not serve as a source of contamination to surface waters. However, onsite systems do fail for a variety of reasons. When these septic systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration) there can be adverse effects to surface waters (Horsley and Witten, 1996). Failing septic systems are sources of nutrients that can reach nearby streams through both surface runoff and ground water flows.

The exact number of onsite wastewater systems in the Buffalo Ditch watershed is unknown. However, as discussed in Section 2.2, the estimated rural population in the Buffalo Ditch watershed is approximately 770 persons. Based on this population and on an average density of 2.4 persons per household, there may be approximately 320 systems in the watershed. The Dunklin County Health Department does not know of any failing onsite wastewater systems along Buffalo Ditch but acknowledges that it is possible for some to exist (Karen Hunter, Dunklin County Health Department, personal communication, March 13, 2009). EPA reports that the statewide failure rate of onsite wastewater systems in Missouri is 30 to 50 percent (EPA, 2002).

3.2.4 Riparian Habitat Conditions

Riparian habitat[4] conditions can also have a strong influence on instream dissolved oxygen. Wooded riparian corridors are a vital functional component of stream ecosystems and are instrumental in the detention, removal, and assimilation of nutrients, soil, and other potential pollutants from or by the water column. Therefore, a stream with good riparian habitat is better able to prevent erosion and moderate the impacts of high nutrient loads than is a stream with poor habitat. Wooded riparian corridors can also provide shading that reduces stream temperatures and increases the dissolved oxygen saturation capacity of the stream.

Riparian areas can also be sources of natural background material that could possibly contribute to the low dissolved oxygen problem. For example, leaf fall from vegetation near the water's edge, aquatic plants, and drainage from organically rich areas like swamps and bogs are all natural sources of materials that consume oxygen.

As indicated in Table 4, almost 86 percent of the land within the riparian corridor is used for crop production (MORAP, 2005). Cropland provides limited riparian habitat compared to wooded areas and leaves this area more susceptible to soil erosion. In addition, wooded, and other naturally vegetated riparian zones, provide natural filters for many potential pollutants carried in surface runoff. When these areas are replaced with cropland, pollutant-laden runoff no longer has that filter to flow through before entering adjacent water bodies.

Another 10 percent of the land is classified as urban, which also often lacks an adequately vegetated riparian corridor, and can be associated with high nutrient loads associated with lawn fertilizers and pet waste. A lack of adequate riparian vegetation, therefore, should be considered as one possible component of water quality problems in Buffalo Ditch.

Table 4. Percentage land use within riparian corridor (30 meter) (MORAP, 2005).

Land Use/Land Cover	Percentage
Barren	0.03
Cropland	85.24
Herbaceous	0.78
Forest	1.03
Grassland	1.98
Wetland	0.36
Urban	10.26
Open Water	0.32

[4] A riparian corridor (or zone or area) is the linear strip of land running adjacent to a stream bank.

4 Applicable Water Quality Standards and Numeric Water Quality Targets

The purpose of developing a TMDL is to identify the pollutant loading that a water body can receive and still achieve water quality standards. Water quality standards are therefore central to the TMDL development process. Under the federal Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters (U.S Code Title 33, Chapter 26, Subchapter III (U.S. Code, 2009)). Water quality standards consist of three components: designated beneficial uses, water quality criteria to protect those uses, and an antidegradation policy.

4.1 Designated Beneficial Uses

The designated beneficial uses of Buffalo Ditch, WBID 3118, are:

- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health (Fish Consumption)
- Whole Body Contact Recreation – Category B

The use that is impaired is Protection of Warm Water Aquatic Life. The designated beneficial uses and stream classifications for Missouri may be found in the Water Quality Standards at 10 CSR 20-7.031(1)(C), (1)(F) and Table H (Missouri Secretary of State, 2008).

4.2 Numeric Criteria

This section presents Missouri's numeric criteria for dissolved oxygen and also provides a brief description of why dissolved oxygen is important to water quality, how it is measured, and how it is related to other water quality parameters.

Dissolved oxygen is one of the most critical characteristics of our surface waters because fish, mussels, macroinvertebrates, and most other aquatic life utilize dissolved oxygen in the water to survive. The water quality criterion for dissolved oxygen for all Missouri streams, except cold water fisheries, is a daily minimum of 5 milligrams per liter (mg/L) (10 CSR 20-7.031 Table A (Missouri Secretary of State, 2008)).

Dissolved oxygen in streams is affected by several factors including water temperature, the amount of decaying organic matter in the stream, turbulence at the air-water interface, and the amount of photosynthesis occurring in plants within the stream. Organic matter can come from wastewater effluent as well as agricultural and urban runoff, and the rate at which it decays and consumes oxygen is typically measured instream as biochemical oxygen demand.

Nitrogen and phosphorus can also contribute to low dissolved oxygen problems because they can accelerate algae growth in streams. Algae growth in streams is most frequently assessed based on the amount of chlorophyll *a* in the water. The algae consume dissolved oxygen during respiration at night and have the potential to remove large amounts of dissolved oxygen from the stream. The breakdown of dead, decaying algae also removes oxygen from water. The dissolved oxygen, biochemical oxygen demand, nitrogen, and phosphorus data for Buffalo Ditch are summarized in Section 5.

4.3 Antidegradation Policy

Missouri's water quality standards include EPA's "three-tiered" approach to antidegradation, which may be found at 10 CSR 20-7.031(2) (Missouri Secretary of State, 2008).

> Tier 1 – Protects existing uses and a level of water quality necessary to maintain and protect those uses. Tier 1 provides the absolute floor of water quality for all waters of the United States. Existing instream water uses are those uses that were attained on or after November 28, 1975, the date of EPA's first Water Quality Standards Regulation.
>
> Tier 2 – Protects and maintains the existing level of water quality where it is better than applicable water quality criteria. Before water quality in Tier 2 waters can be lowered, there must be an antidegradation review consisting of: (1) a finding that it is necessary to accommodate important economical or social development in the area where the waters are located; (2) full satisfaction of all intergovernmental coordination and public participation provisions; and (3) assurance that the highest statutory and regulatory requirements for point sources and best management practices for nonpoint sources are achieved. Furthermore, water quality may not be lowered to less than the level necessary to fully protect the "fishable/swimmable" uses and other existing or designated beneficial uses.
>
> Tier 3 – Protects the quality of outstanding national and state resource waters, such as waters of national and state parks, wildlife refuges, and exceptional recreational or ecological significance. There may be no new or increased discharges to these waters and no new or increased discharges to tributaries of these waters that would result in lower water quality.

Waters in which a pollutant is at, near or exceeds the water quality criteria are considered in Tier 1 status for that pollutant. Therefore, the antidegradation goal for Buffalo Ditch is to restore the stream's dissolved oxygen level to the water quality standards.

5 TMDL Development

5.1 Data Collection

To fully understand the cause of the low dissolved oxygen problems, additional water samples from Buffalo Ditch were analyzed in 2008 by Tetra Tech, under contract with EPA. These data are also of sufficient quality to evaluate compliance with water quality standards and to support

TMDL development as they were collected in accordance with required quality assurance procedures and Department sampling protocols (Tetra Tech, 2008a; 2008b; MDNR, 2005).

The location of the sampling sites in May and September 2008 are provided in Figure 4 and the data are summarized in Table 5 and Table 6. Data loggers were deployed at two of the locations (BU-2 and BU-4) during May 2008 and the 15-minute dissolved oxygen data from those are presented in Figure 5[5].

There are several issues worth noting from a review of the available Buffalo Ditch data:

- One location (BU-6, 4.4 miles downstream of the permitted Kennett Wastewater Treatment Plant) had an observed dissolved oxygen concentration below the water quality standard of 5 mg/L during the May 2008 sampling. Chlorophyll *a* at this and the two upstream sites were extremely high on the same date. Chlorophyll *a* concentrations at these sites were also elevated during the September 2008 sampling.
- Total phosphorus concentrations in the effluent of the Kennett Wastewater Treatment Plant were 3.8 mg/L in May 2008 and 3.2 mg/L in September 2008. This caused instream total phosphorus concentrations to be elevated for several miles downstream.
- The nitrite + nitrate concentration in the effluent of the Kennett Wastewater Treatment Plant in May 2008 was 12.3 mg/L. This caused instream nitrite + nitrate concentrations to be elevated for several miles downstream. Effluent nitrite + nitrate in September was reported as only 0.65 mg/L, which resulted in lower nutrient levels within Buffalo Ditch.
- The 15-minute dissolved oxygen data indicate a diurnal pattern, with concentrations higher during the late afternoon and lowest during early morning. Concentrations at all three sites decrease to well below 5 mg/L from about midnight until 9:00AM the next morning.

These data suggest that high nutrient loads are contributing to excessive algal growths in Buffalo Ditch. The excessive algal growths, in turn, are causing low dissolved oxygen to occur late at night when the algae are consuming but not producing oxygen. Large amounts of algae may also be contributing to low dissolved oxygen when the plants die and decay. The Kennett Wastewater Treatment Plant is contributing to the high nutrient loads but there might also be contributions from other upstream sources. Concentrations of other parameters in the Kennett wastewater effluent (e.g., ammonia and biochemical oxygen demand) were low during both the May and September sampling and were likely not directly contributing to the observed low dissolved oxygen. While there were diurnal fluctuations of dissolved oxygen upstream of the Kennett Wastewater Treatment Plant, the amplitude of these fluctuations was greater downstream of the wastewater treatment plant, as were measures of chlorophyll *a* in the water column.

[5] High flows associated with the aftermath of Hurricane Ike precluded the deployment of the data loggers for the September 2008 sampling event. The data loggers were intended to sample dissolved oxygen data every fifteen minutes over a three day period.

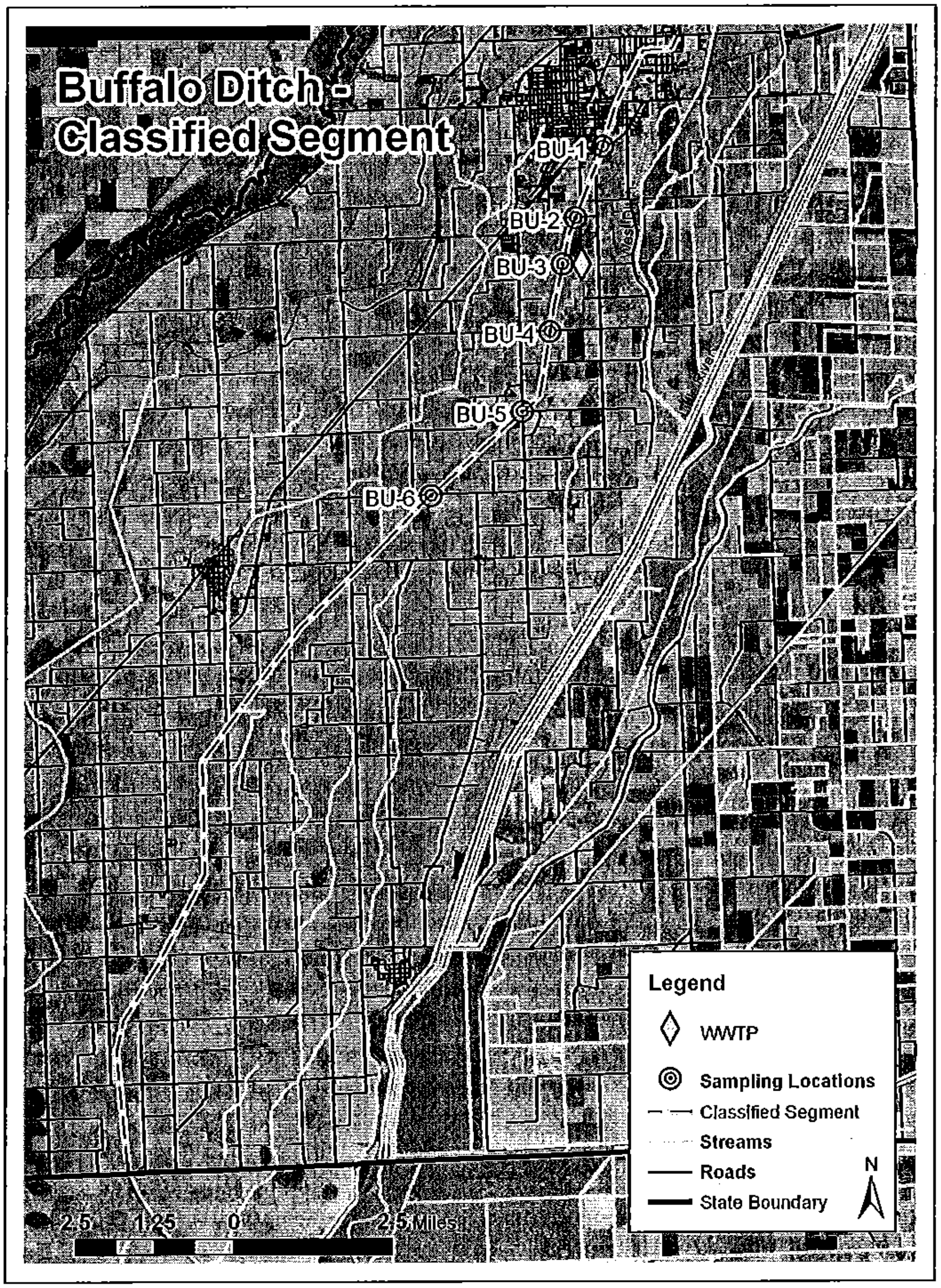


Figure 4. Location of the Buffalo Ditch sampling sites and classified segment.

Table 5. Buffalo Ditch water quality data collected on May 21, 2008. Average flow during this event was 3.2 cubic feet per seconds (cfs).

Sampling Location (Time)	Location	Chl. a (µg/L)	CBOD5 (mg/L)	Nitrogen, Ammonia (mg/L)	Nitrogen, TKN (mg/L)	Nitrogen, NO2+NO3 (mg/L)	DO (mg/L)	pH	Temp. (°C)	TP (mg/L)	TSS (mg/L)
BU-1 (1:50PM)	1.9 mi above WWTP	9	<2	<0.1	0.67	<0.1	5.23	7.14	21.7	0.180	15
BU-2 (12:40PM)	0.8 mi above WWTP	9	<2	<0.1	0.58	<0.1	8.64	7.17	26.6	0.280	11
BU-3 (11:50AM)	Kennett WWTP	12	8.6	<0.1	2.9	12.3	7.97	7.44	21.8	3.800	38
BU-4 (11:00AM)	1.1 mi below WWTP	448	4.4	0.76	3	3.9	10.6	7.33	21.1	1.700	47
BU-5 (10:00AM)	2.5 mi below WWTP	162	2.9	0.68	1.9	2.8	6.49	7.07	18.9	1.400	7
BU-6 (9:00AM)	4.4 mi below WWTP	90	2.3	0.22	1.5	1.4	3.95	6.85	19.2	0.810	55

Notes: Chl. A = Chlorophyll a; CBOD5 = Carbonaceous Biochemical Oxygen Demand (5 days); TKN = Total Kjeldahl Nitrogen; NO2+NO3 = Nitrite + Nitrate; DO = Dissolved Oxygen; Temp. = Temperature; TP = Total Phosphorus; TSS = Total Suspended Solids; BU-CO = Buffalo Ditch Control Site; UT = Unnamed Tributary

Table 6. Buffalo Ditch water quality data collected on September 5, 2008. Average flow during this event was 1.8 cubic feet per seconds (cfs).

Sampling Location (Time)	Location	Chl. a (µg/L)	CBOD5 (mg/L)	Nitrogen, Ammonia (mg/L)	Nitrogen, TKN (mg/L)	Nitrogen, NO2+NO3 (mg/L)	DO (mg/L)	pH	Temp. (°C)	TP (mg/L)	TSS (mg/L)
BU-1 (9:50AM)	1.9 mi above WWTP	9	<2	<0.1	<0.2	<0.1	5.32	6.71	21.4	<0.1	<5
BU-2	0.8 mi above WWTP	Creek Dry; No Samples Collected									
BU-3 (11:10AM)	Kennett WWTP	No Data	3.1	0.19	2.8	0.65	6.9	7.77	24.69	3.2	27.0
BU-4 (11:45AM)	1.1 mi below WWTP	123	2.7	0.71	2.9	0.18	6.19	7.73	22.4	3.0	60.0
BU-5 (12:15PM)	2.5 mi below WWTP	121	<2	0.63	2.8	0.15	7.15	7.77	22.01	2.5	67.0
BU-6 (12:45PM)	4.4 mi below WWTP	98	<6	0.39	2.2	<0.1	6.99	7.66	22.64	1.8	107

Notes: Chl. A = Chlorophyll a; CBOD5 = Carbonaceous Biochemical Oxygen Demand (5 days); TKN = Total Kjeldahl Nitrogen; NO2+NO3 = Nitrite + Nitrate; DO = Dissolved Oxygen; Temp. = Temperature; TP = Total Phosphorus; TSS = Total Suspended Solids; BU-CO = Buffalo Ditch Control Site; UT = Unnamed Tributary

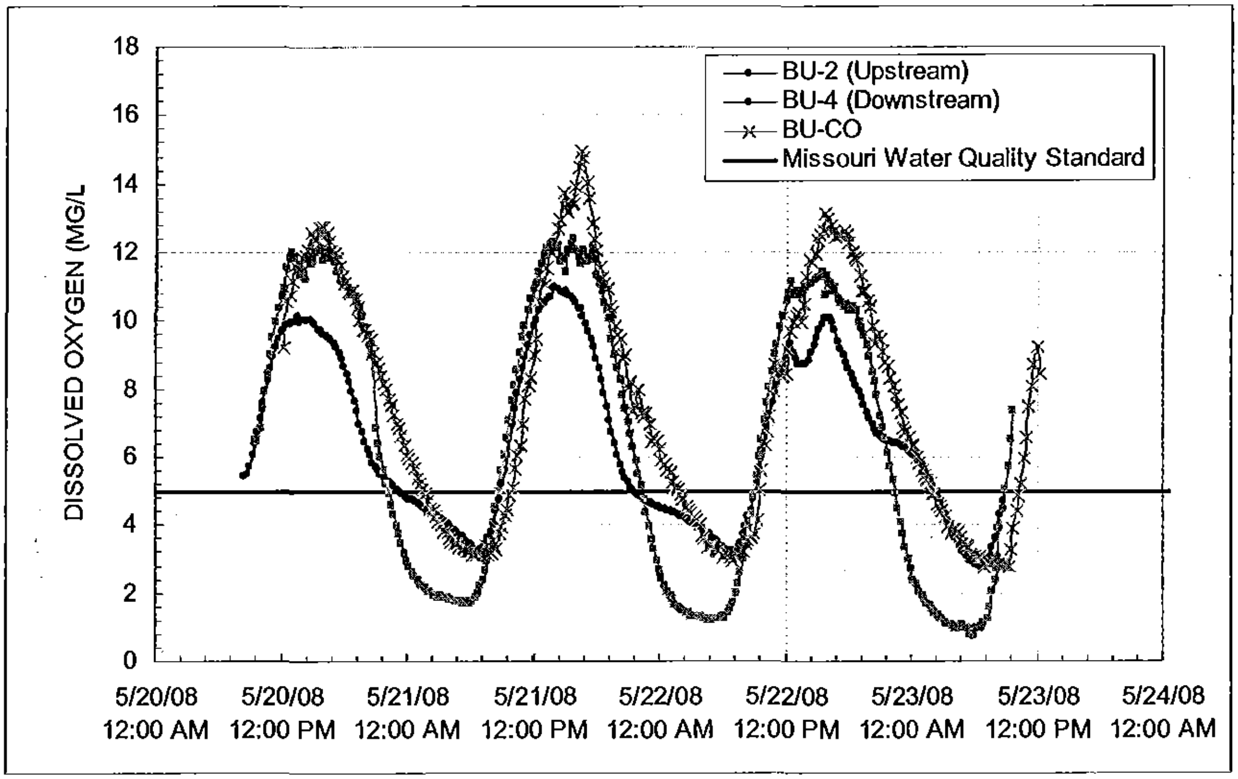


Figure 5. Continuous dissolved oxygen data observed at BU-2, BU-4, and the control sampling location[6] during late May 2008.

5.2 TMDL Modeling[7]

Dissolved oxygen in streams is determined by the factors of photosynthetic productivity, respiration (autotrophic and heterotrophic), reaeration, and temperature. These factors are influenced by natural and anthropogenic conditions within a watershed. Generally, reaeration is based on the physical properties of the stream and on the capacity of water to hold dissolved oxygen. This capacity is mainly determined by water temperature with colder water having a higher saturation concentration for dissolved oxygen. In a review of variables and their importance in dissolved oxygen modeling, Nijboer and Verdonschot (2004) categorized the impact of a number of variables on oxygen depletion. For this TMDL, the effects of temperature and the physical aspects of the stream itself were discounted. Even though the hydrological regime of historic alluvial streams was modified by changes in land cover and channelization, manipulation of these parameters does not address a pollutant and so is not the goal of a TMDL. Pollutants which result in oxygen concentrations below saturation are:

- fine particle size of bottom sediment
- high nutrient levels (nitrogen and phosphorus)
- suspended particles of organic matter

---

[6] Data from the control site was not used in EPA's modeling and is not included in this TMDL.
[7] EPA Region 7 performed the modeling for this TMDL

Because these three pollutants vary to a large extent based on anthropogenic influences, they are appropriate targets for a TMDL written to address an impairment of low dissolved oxygen.

Since fine particle sized sediment and suspended particles of organic matter are derived from similar loading conditions of terrestrial and stream bank erosion, this TMDL establishes an allocation for suspended solids (see Appendix B for discussion of development of suspended solids targets). This target was derived based on a reference approach by targeting the 25th percentile of total suspended sediment measurements (U.S. Geological Survey, or USGS, non-filterable residue) in the geographic region in which Buffalo Ditch is located (see Appendix A.3 for a list of sites and data). To address nutrient levels, the EPA nutrient ecoregion reference concentrations were used. For the ecoregion where Buffalo Ditch is located, the reference concentration for total nitrogen[8] is 0.82 mg/L, and the reference concentration for total phosphorus is 0.125 mg/L (EPA 2001a and EPA 2001b). This TMDL will not specifically target chlorophyll as a wasteload allocation, but will use a linkage between nutrient concentrations and chlorophyll response to achieve the ecoregion reference concentrations.

5.2.1 Load Duration Curves

To develop load duration curves for total nitrogen (total Kjeldahl nitrogen plus nitrate nitrogen) and total phosphorus, a method similar to that used for total suspended solids was employed. First total nitrogen and total phosphorus measurements were collected from USGS sites in the vicinity of the impaired stream. These data were adjusted such that the median of the measured data was equal to the ecoregion reference concentration. This was accomplished by subtracting the difference of the data median and the reference concentration. Where this would result in a negative concentration, the data point in question was replaced with the minimum concentration seen in the measured data. This resulted in a modeled data set which retained much of the original variability seen in the measured data. This modeled data was then regressed as instantaneous load v. flow. The resultant regression equation was used to develop the load duration curve.

To develop the TMDL expression of maximum daily loads the background discharge at the stream outlet was modified from the traditional approach using synthetic flow estimation. Since the design flow from permitted facilities would overwhelm the background natural low flow, the sum of permitted volumes was added to the derived stream discharge at all percentiles of flow to take into account the increases in flow volume as well as pollutant load. The TMDL curves in the load duration curves flatten at low flow because at these lower flows the TMDL target is dominated by the point source flow.

[8] Total Kjeldahl nitrogen and nitrate plus nitrite as nitrogen

5.2.2 QUAL2K

An essential component of developing a TMDL is establishing a relationship between the source loadings and the resulting water quality. For this TMDL, the relationship between the source loadings of biochemical oxygen demand and nutrients on dissolved oxygen is generated by the water quality model QUAL2K (Chapra et al., 2007).

QUAL2K is supported by EPA and it and its predecessor (QUAL2E) have been used extensively for TMDL development and point source permitting issues across the country, especially for dissolved oxygen studies. QUAL2K is well accepted within the scientific community because of its proven ability to simulate the processes important to dissolved oxygen conditions within streams. The QUAL2K model is suitable for simulating the hydraulics and water quality conditions of a small river. It is a one-dimensional model with the assumption of a completely mixed system for each computational cell. QUAL2K assumes that the major pollutant transport mechanisms, advection and dispersion, are significant only along the longitudinal direction of flow. The model allows for multiple waste discharges, water withdrawals, tributary flows, and incremental inflows and outflows. The processes employed in QUAL2K address nutrient cycles, algal growth, and dissolved oxygen dynamics. Once the QUAL2K model was setup and calibrated for Buffalo Ditch, a series of scenarios were run to evaluate the pollutant load reductions needed to achieve the dissolved oxygen criteria. These results are summarized in Table 10 and a detailed discussion of the QUAL2K model is included in Appendix C.

6 Calculation of Load Capacity

Load capacity, or LC, is defined as the greatest amount of loading of a pollutant that a water body can receive without violating water quality standards. This load is then divided among the point source (wasteload allocation, or WLA) and nonpoint source (load allocation, or LA) contributions to the stream, with an allowance for an explicit margin of safety, or MOS. If the margin of safety is implicit, no numeric allowance is necessary. This is expressed in the following manner:

$$LC = \sum WLA + \sum LA + MOS$$

The wasteload allocation and load allocation are calculated by multiplying the appropriate flow in cubic feet per second by the appropriate pollutant concentration in mg/l. A conversion factor of 5.395 is used to convert the units (cfs and mg/L) to pounds per day (lbs/day).

(stream flow in cfs)(maximum allowable pollutant concentration in mg/L)(5.395)= pounds/day

Critical conditions are considered when the load capacity is calculated. Dissolved oxygen levels that threaten the integrity of aquatic communities generally occur during low flow periods, so these periods are considered the critical conditions.

7 Load Allocation (Nonpoint Source Load)

The load allocations include all existing and future nonpoint sources and natural background contributions (40 CFR § 130.2(g)). The load allocations for the Buffalo Ditch TMDL are for all nonpoint sources of total phosphorus, total nitrogen, and total suspended solids, which could include loads from agricultural lands, runoff from urban areas outside of the Kennett municipal separate storm sewer system, livestock, and failing onsite wastewater treatment systems. The load allocations are provided in Tables 7 through 9 and were calculated based on the total of all headwater and lateral inflow loads used in the QUAL2K model for the allocation scenario model run. The load allocations are intended to allow the dissolved oxygen target to be met at all locations within the stream. During critical conditions when flow is at its lowest, and there is effectively no flow from nonpoint sources, the load allocations for all targeted pollutants is zero pounds per day.

8 Wasteload Allocation (Point Source Loads)

The wasteload allocation is the portion of the load capacity that is allocated to existing or future point sources of pollution. The sum of the design flows of all site-specific permitted dischargers with Missouri State Operating Permits (Table 3) in the Buffalo Ditch watershed, including the Kennett Wastewater Treatment Plant, is 1.66 million gallons per day. This does not include Kennett's non-municipal separate storm sewer system. To meet the targeted nutrient and total suspended solids critical condition targets outlined in this TMDL, the sum of the wasteload allocations was calculated by using nutrient ecoregion reference concentrations and 25th percentile total suspended solids concentrations, and the sum of the design flows of all permitted facilities in the watershed (with the exception of the municipal separate storm sewer system).

The municipal separate storm sewer system wasteload allocation is set based on the percentage of the watershed covered under the municipal separate storm sewer system permit. The entire Buffalo Ditch watershed is calculated at 57 square miles using the BASINS 4 modeling program. The portion of the municipal separate storm sewer system area within the watershed is calculated at 5.2 square miles using the 2000 census layer for the city boundary which overlaps the watershed. This results in the municipal separate storm sewer system permit receiving a wasteload allocation equivalent to 9.1% of the diffuse load to the stream. Therefore, the municipal separate storm sewer system wasteload allocation increases at higher storm flows as available diffuse flow increases.

The load duration curves for the targeted pollutants are depicted in Figures 6 through 8, where the TMDL line represents the total load capacity of all point and nonpoint sources of pollutants. The pollutant allocations under a range of flow conditions are outlined in Tables 7 through 9.

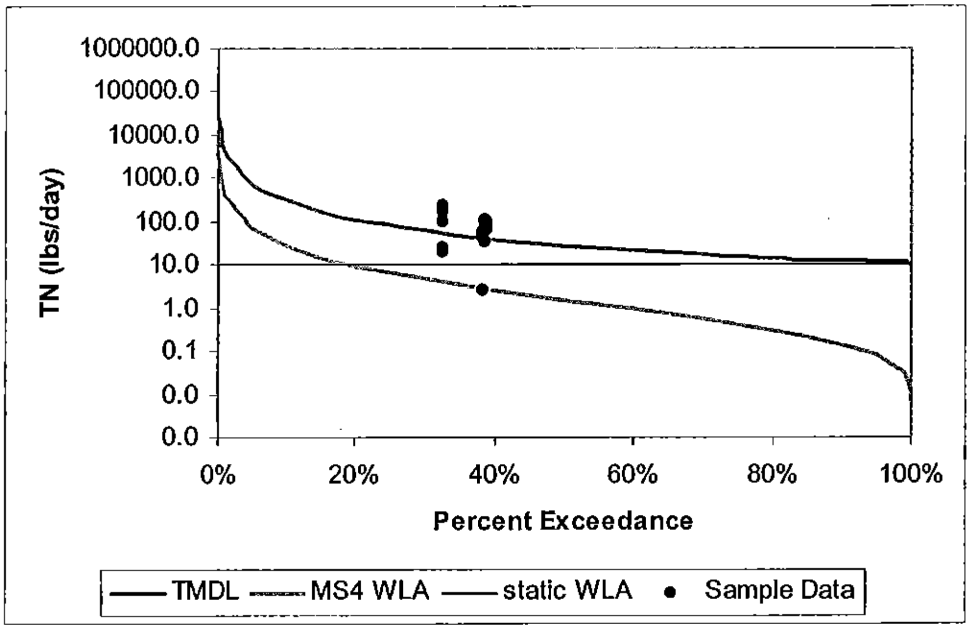


Figure 6. Load Duration Curve – Total Nitrogen.

Table 7. Total Nitrogen Allocations (lbs/day)

Percent Exceedance	Flow (cfs)	TMDL (LC)	WLA Kennett WWTP	WLA Kennett MS4	WLA (other permits)	LA
100	2.56	10.51	8.90	0	1.61	0
80	3.40	13.93	8.90	0.31	1.61	3.11
60	5.06	20.75	8.90	0.93	1.61	9.31
40	9.52	39.04	8.90	2.60	1.61	25.93
20	27.91	114.42	8.90	9.45	1.61	94.46

Note: MS4 = Municipal separate storm sewer system

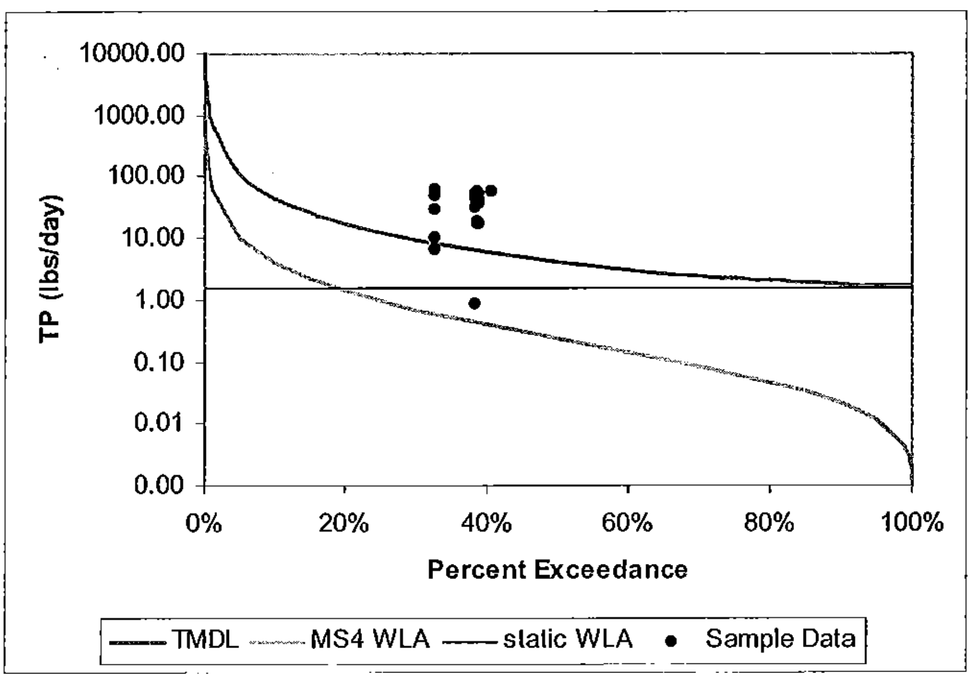


Figure 7. Load Duration Curve – Total Phosphorus.

Table 8. Total Phosphorus Allocations (lbs/day)

Percent Exceedance	Flow (cfs)	TMDL (LC)	WLA Kennett WWTP	WLA Kennett MS4	WLA (other permits)	LA
100	2.56	1.59	1.35	0	0.24	0
80	3.40	2.11	1.35	0.05	0.24	0.47
60	5.06	3.14	1.35	0.14	0.24	1.41
40	9.52	5.91	1.35	0.39	0.24	3.93
20	27.91	17.31	1.35	1.43	0.24	14.29

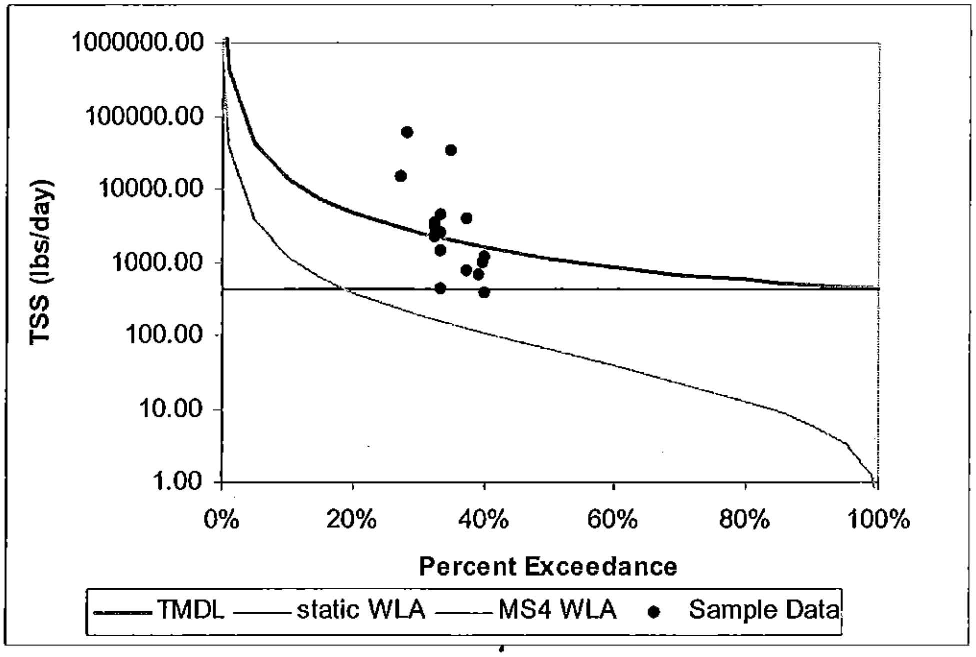


Figure 8. Load Duration Curve – Total Suspended Solids.

Table 9. Total Suspended Solids Allocations (lbs/day)

Percent Exceedance	Flow (cfs)	TMDL (LC)	WLA Kennett WWTP	WLA Kennett MS4	WLA (other permits)	LA
100	2.56	428.48	362.92	0	65.56	0
80	3.40	568.16	362.92	12.71	65.56	126.97
60	5.06	846.45	362.92	38.04	65.56	379.93
40	9.52	1592.44	362.92	105.92	65.56	1058.04
20	27.91	4667.30	362.92	385.73	65.56	3853.09

New wasteload allocations for the Kennett Wastewater Treatment Plant were calculated through the modeling process and are shown in Table 10. The wasteload allocations for total nitrogen, total phosphorus and total suspended solids were derived from the load duration curves at low flow, when inputs are set at the facility design flow of 2.17 cubic feet per second. The wasteload allocation for biochemical oxygen demand was derived from the QUAL2K modeling that resulted in meeting water quality standards.

The other permitted facilities in the watershed each discharge an insignificant volume of effluent compared to the Kennett Wastewater Treatment Plant and, with the exception of the Senath Wastewater Treatment Plant, are also unlikely to discharge during the critical low flow periods. Their wasteload allocations therefore remain equal to existing permit limits.

Table 10. Wasteload Allocations for Kennett Wastewater Treatment Plant

Pollutant	Concentration Limits	WLA at Design Flow (2.17 cfs)
TN	0.76 mg/L[9]	8.9 lbs/day
TP	0.115 mg/L	1.35 lbs/day
TSS	31 mg/L	362.9 lbs/day
BOD	5 mg/L	58.5 lbs/day

9 Margin of Safety

A margin of safety is required in the TMDL calculation to account for uncertainties in scientific and technical understanding of water quality in natural systems. The margin of safety is intended to account for such uncertainties in a conservative manner. Based on EPA guidance, the margin of safety 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 margin of safety as part of the critical conditions for the wasteload allocation and the load allocation calculations by making conservative assumptions in the analysis.

An implicit margin of safety was incorporated into the TMDL based on conservative assumptions applied to the QUAL2K model and used in the development of the TMDL load duration curves. Among the conservative approaches used was to calculate wasteload allocations by targeting the 25th percentile of total suspended solids concentrations in the geographic region in which Buffalo Ditch is located, and to establish wasteload allocations for the Kennett Wastewater treatment Plant under critical low flow conditions when discharge from this facility will dominate the stream flow.

[9] Adjusted ecological reference concentration value derived with methodology outlined in Section 5.2.1and used in development of load duration curve.

10 Seasonal Variation

Federal regulations at 40 CFR §130.7(c)(1) require that TMDLs take into consideration seasonal variation in applicable standards. The Buffalo Ditch TMDL addresses seasonal variation in two ways. One is by identifying a loading capacity that is protective of the critical low flow period. QUAL2K TMDL development for low dissolved oxygen during critical low-flow conditions are expected to be protective year round.

The second way in which the Buffalo Ditch TMDL takes seasonal variation into account is through the use of load duration curves. Load duration curves represent the allowable pollutant load under different flow conditions and across all seasons. The results obtained using the load duration curve method are more robust and reliable over all flows and seasons when compared with those obtained under critical low-flow conditions.

11 Monitoring Plan for TMDLs Developed under Phased Approach

Post-TMDL monitoring will be scheduled and carried out by the Department about three years after the TMDL is approved, or in a reasonable period of time following the compliance schedule outlined in the permit and the application of any new effluent limits. The Missouri State Operating Permit for the city of Kennett's wastewater treatment plant expired on May 16, 2007, and will be reissued with new permit limits based on the wasteload allocation developed in this TMDL.

The permit currently requires instream monitoring both upstream and downstream of the wastewater treatment plant and this requirement will be retained in order to provide additional data with which to assess the impact of the revised permit limits on Buffalo Ditch. Instream data currently collected monthly in Buffalo Ditch includes dissolved oxygen, ammonia, and flow. Permittee instream monitoring data will be used for screening purposes, to compare the stream's current condition with post-TMDL conditions. The wastewater treatment plant instream monitoring data are included in Appendix A.

Additionally, the Department will routinely examine physical habitat, water quality, invertebrate community, and fish community data collected by other state and federal agencies in order to assess the effectiveness of TMDL implementation. One example is the Resource Assessment and Monitoring Program administered by the Missouri Department of Conservation. This program randomly samples streams across Missouri on a five to six year rotating schedule.

12 Implementation Plans

Since low dissolved oxygen is an issue in Buffalo Ditch both upstream and downstream of the Kennett Wastewater Treatment Plant, addressing the sources of impairment in Buffalo Ditch will require developing nonpoint source, as well as point source, controls in the watershed. However, due to issues regarding low dissolved oxygen as a natural background condition, the department may develop revised dissolved oxygen criteria for Buffalo Ditch and similar streams during the next Triennial Review of the Water Quality Standards. The department acknowledges that, should revised criteria be developed, a revised Buffalo Ditch TMDL may be necessary. It also acknowledges that the revised criteria may result in no difference for Buffalo Ditch and that new loading calculations may not differ or offer relief from what is currently contained in this TMDL.

12.1 Point Sources

This TMDL will be implemented partially through permit action. The permit for the City of Kennett's wastewater treatment plant has been expired since May 17, 2007. The forthcoming renewal of this permit retains current limits of 65 mg/L weekly average and 45 mg/L monthly average for biochemical oxygen demand and 110 mg/L weekly average and 70 mg/L monthly average for total suspended solids. The current permit does not contain water quality-based effluent limits for ammonia, although such limits may be appropriate for this facility to protect water quality. A reasonable potential analysis should be conducted in accordance with 40 CFR 122.44(d)(1)(i) to determine whether water quality-based effluent limits for ammonia are required. In addition to any new requirements for ammonia, effluent monitoring for nutrient species and instream monitoring for dissolved oxygen, temperature, pH, ammonia and chlorophyll *a* will be required on the Kennett Wastewater Treatment Plant operating permit.

Wasteload allocations developed for this TMDL will be used to derive new effluent limits for biochemical oxygen demand and total suspended solids that are protective of the dissolved oxygen criterion and aquatic life use in Buffalo Ditch. However, it is the intention of the department that prior to implementation of these wasteload allocations, either the department or the city will determine whether the dissolved oxygen criterion of 5 mg/L found in 10 CSR 20-7.031, Table A is appropriate or if a site-specific dissolved oxygen criterion is required. This will likely coincide with the department's Triennial Review of the Water Quality Standards, currently scheduled for 2012 and 2015, when new dissolved oxygen criteria may be promulgated. Further, it is recommended that additional sampling, including biological sampling, be conducted in the affected segment of Buffalo Ditch prior to implementation of the wasteload allocations in order to assess the water bodies' attainment of designated beneficial uses. These sampling events should begin prior to the end of the calendar year 2012 and continue as necessary.

If it is determined that the current water quality criterion for dissolved oxygen is appropriate, the wasteload allocations from the TMDL will be implemented. If it is determined not to be appropriate, and a new dissolved oxygen criterion is promulgated, then new wasteload allocations will be calculated and implemented.

If post-TMDL monitoring indicates that point source reductions are not achieving the desired improvements in water quality, the department will reevaluate the TMDL for further appropriate actions. These actions may include additional permit conditions on the Kennett Wastewater Treatment Plant (including effluent limits for total nitrogen and total phosphorus), revised permit conditions on other permitted facilities, and further control of nonpoint sources through a nonpoint source management plan.

12.2 Nonpoint Sources

While this document identifies several potential contributors to nonpoint source pollution in the Buffalo Ditch watershed, modeling analysis identifies very little reduction in nonpoint source load allocations relative to the significant reductions in wasteload allocations recommended.

Although the TMDL will be implemented through permit action, if the wasteload allocations do not achieve desired improvements in water quality, the Department may need to also consider implementing efforts to reduce nonpoint source contributions. With cropland accounting for roughly 91 percent of the land area in the watershed, agricultural runoff is likely to be a chief component of any potential nonpoint source contributions. To further reduce the loading and effect of nutrients and organic sediment on Buffalo Ditch, efforts would be made to encourage farmers to adopt best management practices, or BMPs. BMPs are recommended methods, structures, or practices designed to prevent or reduce water pollution. The concept of BMPs is one of a voluntary and site-specific approach to water quality problems. In the Buffalo Ditch watershed, agricultural BMPs should focus on irrigation and water management, nutrient management, riparian buffers, and erosion control.

In an effort to most effectively implement these BMPs, the Department may work with the Natural Resources Conservation Service, or NRCS, and the local Soil and Water Conservation District, or SWCD, to encourage area farmers to implement these practices on their land. An additional approach may also be to work with the NRCS and SWCD to form a watershed group comprised of local stakeholders with a common interest in protecting water quality in Buffalo Ditch.

13 Reasonable Assurances

The Department has the authority to issue and enforce Missouri State Operating Permits. Inclusion of effluent limits determined from the allocations established by the modeling into a state permit, along with effluent monitoring that is reported to the Department, should provide a reasonable assurance that instream water quality standards will be met. The Department will work with the city of Kennett to discuss treatment plant upgrades and funding options and will issue a permit reflective of the water quality standards that must be met.

In most cases, "Reasonable Assurance" in reference to TMDLs relates only to point sources. As a result, any assurances that nonpoint source contributors of low dissolved oxygen will implement measures to reduce their contribution in the future will not be found in this section. Instead, discussion of reduction efforts relating to nonpoint sources can be found in the "Implementation" section of this TMDL.

14 Public Participation

This water quality limited segment of Buffalo Ditch is included on the EPA-approved 2008 303(d) List for Missouri. The public notice period for the draft Buffalo Ditch TMDL was from October 2, 2009 to November 1, 2009. Additional time was allowed for public notice from December 11, 2009 to December 28, 2009. Groups that received the public notice announcement include the Missouri Clean Water Commission, the Department's Water Quality Coordinating Committee, the Missouri Department of Conservation's Policy Coordinating Unit, Stream Team volunteers in the county, the Kennett Board of Public Works, the Dunklin County Soil and Water Conservation District, the Dunklin County Commission, the mayor of Kennett and the two state legislators representing Dunklin County. In addition, since Buffalo Ditch flows into the state of Arkansas, public notice announcements were also be sent to the Arkansas Department of Environmental Quality and the Arkansas Natural Resources Commission. Finally, the public notice, the TMDL Information Sheet, and this document were posted on the Department Web site, making them available to anyone with Internet access. Comments received, and the Department's response to those comments, have been placed in the Buffalo Ditch administrative record file, as noted below.

15 Administrative Record and Supporting Documentation

An administrative record on the Buffalo Ditch TMDL has been assembled and is being kept on file with the Department. It includes the following:

- Kennett WWTF State Operating Permit MO-0028568
- Stream Survey Sampling Report, Kennett Wastewater Treatment Plant, Buffalo Ditch, Kennett, Missouri, Dunklin County, July 7-9 and August 11-13, 2003, by Environmental Services Program (two 48-hour water quality studies)
- Stream Survey Reports
- Kennett Wastewater Treatment Plant Discharge Monitoring Report (DMR)
- Dunklin County Stream Team survey data
- Continuous dissolved oxygen data collected by Tetra Tech, May/September 2008.
- QUAL2K input and output files
- Buffalo Ditch TMDL Information Sheet
- Public notice announcement
- TMDL comments and comment responses

References

Athayde, D., P. Shelley, E. Driscoll, D. Gaboury and G. Boyd. 1983. Results of the Nationwide Urban Runoff Program, Volume I, Final Report. U.S. Environmental Protection Agency, 186 p.

Census Bureau. 2008. 2007 Population Estimates. Retrieved November 6, 2008, http://www.census.gov/

Chapman, S.S., Omernik, J.M., Griffith, G.E., Schroeder, W.A., Nigh, T.A., and Wilton, T.F., 2002, *Ecoregions of Iowa and Missouri (color poster with map, descriptive text, summary tables, and photographs)*: Reston, Virginia, U.S. Geological Survey (map scale 1:1,800,000).

Chapman, S.S., Kleiss, B.A., Omernik, J.M., Foti, T.L., and Murray, E.O., 2004, *Ecoregions of the Mississippi Alluvial Plain (color poster with map, descriptive text, summary tables, and photographs)*: Reston, Virginia, U.S. Geological Survey (map scale 1:1,150,000).

Chapra, S.C., G.J. Pelletier, and H. Tao. 2007. QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality, Version 2.07: Documentation and Users Manual. Civil and Environmental Engineering Dept., Tufts University, Medford, MA.,

Gideon School District, "The Little River Drainage". 1997. Retrieved December 18, 2008, from http://gideon.k12.mo.us/town/river3.htm.

Horsley and Witten, Inc. 1996. Identification and evaluation of nutrient and bacterial loadings to Maquoit Bay, New Brunswick and Freeport, Maine. Final Report.

Hunter, Karen. Dunklin County Health Department, personal communication, March 13, 2009

MDNR (Missouri Department of Natural Resources). 2005. Fiscal Year 2005 Quality Assurance Project Plan for Wasteload Allocations (FY-2005 QAPP-WLA).

Missouri Secretary of State. 2008. Code of State regulation-Title 10 Department of Natural Resources. Water Quality Standard 10 CSR 20-7.031. Retrieved February 19, 2009, from http://www.sos.mo.gov/adrules/csr/current/10csr/10csr.asp#10-20

MORAP (Missouri Resource Assessment Program). 2005. Land Use/Land Cover Data. Retrieved April 26, 2007, from http://www.msdis.missouri.edu

Nijboer, R.C. and P.F.M. Verdonschot. 2004. Variable selection for modeling effects of eutrophication on stream and river ecosystems. Ecol. Model. 177,17-39.

OEPA (Ohio Environmental Protection Agency). 2007. *Total Maximum Daily Loads for the Beaver Creek and Grand Lake St. Marys Watershed.* Final Report. August 29, 2007.

Reckhow, K. H., M. N. Beaulac, and J. R. Simpson. 1980. Modeling Phosphorous Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients. EPA-440/5-8-011, U.S. Environmental Protection Agency, Washington, D.C.

Tetra Tech, Inc. 2008a. Final Quality Assurance Project Plan for Data Collection for Missouri DO TMDLs. Prepared for U.S. EPA under USEPA Region 7. Contract No. GS-10F-0268F. Task Order No. EP077000109. October 2008.

Tetra Tech, Inc. 2008b. Sampling and Analysis Plan: Missouri DO TMDLs. Prepared for U.S. EPA under EPA Region 7. Contract No. GS-10F-0268F. Task Order No. EP077000109. October 2008.

Tetra Tech, Inc. 2009. *Total Maximum Daily Load Report for the Kankakee/Iroquois Watershed. Public Review Draft.* Prepared for the U.S. Environmental Protection Agency Region 5, Illinois Environmental Protection Agency, and the Indiana Department of Environmental Management. February 24, 2009.

U.S. Code. 2009. Title 33 of the U.S. Code. Retrieved February 19, 2009, from http://www.gpoaccess.gov/uscode/

USDA (U.S. Department of Agriculture). 2002. National Agriculture Statistics Service. Retrieved February 19, 2009, from http://www.nass.usda.gov/

USDA (U.S. Department of Agriculture). Soil Conservation Service. 1979. *Soil Survey of Dunklin County Missouri*. Retrieved March 16, 2009 from http://soildatamart.nrcs.usda.gov/Manuscripts/MO069/0/dunklin_MO.pdf

U.S. EPA. 2001a. Ambient Water Quality Criteria Recommendations: Rivers and Streams in Nutrient Ecoregion IX. U.S. Environmental Protection Agency, Washington DC. EPA 822-B-001-019.

U.S. EPA. 2001b. Ambient Water Quality Criteria Recommendations: Rivers and Streams in Nutrient Ecoregion X. U.S. Environmental Protection Agency, Washington DC. EPA 822-B-001-016.

U.S. EPA (U.S. Environmental Protection Agency). 2002. Onsite Wastewater Treatment System Manual. EPA/625/R-00/008. U.S. Environmental Protection Agency, Office of Water, Washington, DC, and Office of Research and Development, Cincinnati, OH. February 2002

Wang, W., 1980, Fractionation of sediment oxygen demand: *Water Research*, v. 14, p. 603-612.

Appendix A
Buffalo Ditch Water Quality Data
Appendix A.1 – Historic Data
Collected by the Missouri Department of Natural Resources 2003-2004

Site	Site Name	Year	Month	Day	Time	C	DO	pH	SC	TKN	NH3N	NO3N	TN	TP	VSS	Chl A	CBOD
3118/17.4	Buffalo Ditch 0.8 mi.ab. Kennett WWTP	2003	7	9	555	27	1.2	7.1	138								
3118/17.4	Buffalo Ditch 0.8 mi.ab. Kennett WWTP	2003	7	9	1215	30	5.8	7.3	136								
3118/17.4	Buffalo Ditch 0.8 mi.ab. Kennett WWTP	2003	7	8	644	27.5	1.1	7	137								
3118/17.4	Buffalo Ditch 0.8 mi.ab. Kennett WWTP	2003	7	8	1315	31.5	6.9	7.4	138								
3118/15.5	Buffalo Ditch 1.1 mi.bl. Kennett WWTP	2003	7	9	610	24.5	1.5	7.2	473	4.16	1.52	2.12	6.28	3.39	10	49.4	4.5
3118/15.5	Buffalo Ditch 1.1 mi.bl. Kennett WWTP	2003	7	9	1255	35.5	10.8	8.1	453	3.73	0.76	2.22	5.95	2.69	2.499	34.1	5.8
3118/15.5	Buffalo Ditch 1.1 mi.bl. Kennett WWTP	2003	7	8	555	25	1.4	7.2	472	4.2	1.57	2.18	6.4	3.31	12	47	
3118/15.5	Buffalo Ditch 1.1 mi.bl. Kennett WWTP	2003	7	8	1335	36	10.5	8.2	461	3.42	0.81	2.35	5.77	2.73	17	56.3	6.6
3118/14.1	Buffalo Ditch 2.5 mi.bl. Kennett WWTP	2003	7	8	610	24.5	1.6	7.2	467	3.69	1.68	0.67	4.36	2.42	13	35	0.99
3118/14.1	Buffalo Ditch 2.5 mi.bl. Kennett WWTP	2003	7	8	1310	32	8.6	7.8	436	3.41	1.19	1.04	4.45	2.26	12	39.1	2.9
3118/14.1	Buffalo Ditch 2.5 mi.bl. Kennett WWTP	2003	7	9	610	24	1.6	7.4	442	3.63	1.73	0.61	4.24	2.47	2.499	27.5	2.76
3118/14.1	Buffalo Ditch 2.5 mi.bl. Kennett WWTP	2003	7	9	1230	31	8.6	7.9	436	3.21	1.22	0.93	4.14	2.29	2.499	34.2	4.95
3188/12.2	Buffalo Ditch 4.4 mi.bl. Kennett WWTP	2003	7	8	620	22.5	2.1	7.35	367	1.73	0.64	0.25	1.98	1.11	20	23.2	0.99
3118/12.2	Buffalo Ditch 4.4 mi.bl. Kennett WWTP	2003	7	8	1325	30	7.15	8	339	1.82	0.55	0.17	1.98	1.03	9	32.6	2.6
3118/12.2	Buffalo Ditch 4.4 mi.bl. Kennett WWTP	2003	7	9	630	22	1.8	7.6	342	1.7	0.69	0.22	1.9	1.11	2.499	15	0.99
3118/12.2	Buffalo Ditch 4.4 mi.bl. Kennett WWTP	2003	7	9	1240	29	7	8	336	2.06	0.57	0.16	2.22	1.07	10	20.3	2.4
3109/3.1	Ditch #36 2 mi.SE of Kennett	2003	7	9	640	27	0.499	7	352								
3109/3.1	Ditch #36 2 mi.SE of Kennett	2003	7	9	1328	29	8.2	7.2	351								
3109/3.1	Ditch #36 2 mi.SE of Kennett	2003	7	8	630	27	0.499	7	350								
3109/3.1	Ditch #36 2 mi.SE of Kennett	2003	7	8	1400	30	8.8	7.3	354								
3120/10.4	Ditch to Buffalo Ditch 2 mi. SW of Kennett	2003	7	8	600	25	1.42	7.1	155								
3120/10.4	Ditch to Buffalo Ditch 2 mi. SW of Kennett	2003	7	8	1300	33	9.9	7.1	161								
3120/10.4	Ditch to Buffalo Ditch 2 mi. SW of Kennett	2003	7	9	600	24	1.2	7.2	172								
3120/10.4	Ditch to Buffalo Ditch 2 mi. SW of Kennett	2003	7	9	1225	33	12.2	7.2	150								
3118/16.6	Kennett WWTP effluent	2003	7	9	535	30	0.499	7.1	490	5.1	0.3	6.23	11.3	4.1	17	174.8	11.5
3118/16.6	Kennett WWTP effluent	2003	7	9	1230	31	2.2	7.2	488	6.14	0.33	6.06	12.2	4.24	23	99.3	20.9

Site	Site Name	Year	Month	Day	Time	C	DO	pH	SC	TKN	NH3N	NO3N	TN	TP	VSS	Chl A	CBOD
3118/16.6	Kennett WWTP effluent	2003	7	8	710	30	0.499	7	489	4.37	0.32	6.58	10.95	4.02	18	169.8	
3118/16.6	Kennett WWTP effluent	2003	7	8	1300	30.5	2.12	7.2	500	4.45	0.34	6.54	11	4.13	19	160.7	
3118/17.4	Buffalo Ditch 0.8 mi.ab. Kennett WWTP	2003	8	12	707	23	0.499	7.2	112								
3118/17.4	Buffalo Ditch 0.8 mi.ab. Kennett WWTP	2003	8	12	1335	30.5	4.5	7.9	102								
3118/15.5	Buffalo Ditch 1.1 mi.bl. Kennett WWTP	2003	8	12	647	23	0.499	7.4	511	3.97	1.43	0.31	4.28	4.48	13	124	4.37
3118/15.5	Buffalo Ditch 1.1 mi.bl. Kennett WWTP	2003	8	12	1305	29	12	8.4	488	3.14	0.71	0.57	3.71	3.54	15	74.1	
3118/14.1	Buffalo Ditch 2.5 mi.bl. Kennett WWTP	2003	8	13	630	23	1.7	7.4	487	2.62	1.08	0.09	2.71	3.35	9	47.1	4.11
3118/14.1	Buffalo Ditch 2.5 mi.bl. Kennett WWTP	2003	8	13	1245	27	10.1	7.9	461	2.36	0.59	0.22	2.58	2.92	7	61.7	4.12
3118/14.1	Buffalo Ditch 2.5 mi.bl. Kennett WWTP	2003	8	12	645	23	1.8	7.2	472	2.7	1.08	0.09	2.8	3.1	10	61.5	2.95
3118/14.1	Buffalo Ditch 2.5 mi.bl. Kennett WWTP	2003	8	12	1300	30	10.9	8.1	453	2.1	0.42	0.26	2.4	2.64	2.499	51.7	3.67
3118/12.2	Buffalo Ditch 4.4 mi.bl. Kennett WWTP	2003	8	13	645	22	3.4	7.6	350	1	0.26	0.02	1	1.15	6	15.6	0.99
3118/12.2	Buffalo Ditch 4.4 mi.bl. Kennett WWTP	2003	8	13	1300	25	7.9	8	352	1.03	0.17	0.00499	1.03	1.21	2.499	29.7	3.25
3118/12.2	Buffalo Ditch 4.4 mi.bl. Kennett WWTP	2003	8	12	700	21	2.3	7.4	345	0.94	0.24	0.02	0.96	1.12	6	22.4	0.99
3118/12.2	Buffalo Ditch 4.4 mi.bl. Kennett WWTP	2003	8	12	1310	28	10.9	8	348	1.02	0.17	0.00499	1.02	1.17	7	26.8	0.99
3109/3.1	Ditch #36 2 mi.SE of Kennett	2003	8	12	630	25	2	7.3	293								
3109/3.1	Ditch #36 2 mi.SE of Kennett	2003	8	12	1325	27	5	7.4	302								
3120/10.4	Ditch to Buffalo Ditch 2 mi. SW of Kennett	2003	8	13	615	25	2	6.9	49.99								
3120/10.4	Ditch to Buffalo Ditch 2 mi. SW of Kennett	2003	8	13	1230	28	7.6	7.5	49.99								
3120/10.4	Ditch to Buffalo Ditch 2 mi. SW of Kennett	2003	8	12	630	24	2.6	6.8	100								
3120/10.4	Ditch to Buffalo Ditch 2 mi. SW of Kennett	2003	8	12	1245	29	9.8	8.7	100								
3118/16.6	Kennett WWTP effluent	2003	8	12	610	28	5.4	7.6	495	5.03	0.17	1.87	6.9	4.09	31	312	7.95
3118/16.6	Kennett WWTP effluent	2003	8	12	1245	29	10.1	8.4	493	5.31	0.05	1.81	7.12	4.15	32	357	
3119/0.2	Buffalo Ditch 0.9 mi.ab. Kennett WWTP	2004	1	7	1350	4	5.6	7.3			0.76						
3118/14.7	Buffalo Ditch 1.9 mi.bl. Kennett WWTP	2004	1	7	1420	5	4.8	7			12.1						
3118/14.1	Buffalo Ditch 2.5 mi.bl. Kennett WWTP	2004	1	7	1435	4	5.6	7.2			7						
118/16.6	Kennett WWTP effluent	2004	1	7	1330		7.6	7.2									

See notes and definitions of abbreviations on the following page.

Additional information below regarding the available Buffalo Ditch water quality data.

Sampling Entity	Type of Data	Used for Modeling?
MoDNR	QA	No
Kennett WWTP - Instream	Screening	No

Notes:

QA = These data are of sufficient quality to evaluate compliance with water quality standards and to support TMDL development because they were collected in accordance with required quality assurance procedures and Department sampling protocols.

Screening = These can only be used for screening purposes (i.e., not to evaluate compliance with water quality standards or to support TMDL development).

Empty cell means no data available.
ab. = above
bl. = below
C= temperature in degrees Celsius
CBOD = Carbonaceous Biochemical Oxygen Demand
Chl a = Chlorophyll *a*
DO = Dissolved Oxygen
NH3N = Ammonia as N
NO3N = nitrate +nitrite as nitrogen
SC = Specific Conductivity
TKN = Total Kjeldahl Nitrogen
TN = Total Nitrogen
TP = Total Phosphorus
VSS = Volatile Suspended Solids
WWTP = Wastewater treatment plant

For Department data all units are milligrams per liter except chlorophyll *a* is µg/L, specific conductivity is umhos/cm, turbidity is nephelometric units. Detection limits and non-detects are expressed as "less-than" numbers and show up in this list as those data ending in 99. Example: <2 will appear as 0.99

Appendix A.2
Instream data collected by Kennett WWTP (Permit #MO-0028568) from 1/2005 to 1/2009

Note: Site 1 = Buffalo Ditch at County Road W
Site 2 = Buffalo Ditch at Highway Y
Site 5 = Buffalo Ditch upstream of WWTP

Date	Site	Flow (cfs)	DO (mg/L)	NH3N (mg/L)
1/31/2005	1	0	0.6	0.3
	2	0	0.6	0.3
	5	0	0.5	0.2
2/28/2005	1	0.52	0.7	0.4
	2	0.84	0.7	0.5
	5	1.29	0.5	0.4
3/31/2005	1	0.65	0.6	0.3
	2	1.03	0.5	0.2
	5	1.35	0.5	0.2
4/30/2005	1	1.6	0.7	0.4
	2	1.8	0.7	0.4
	5	2.1	0.6	0.3
5/31/2005	1	0.77	0.7	0.6
	2	0.9	0.8	0.7
	5	0.9	0.8	0.8
6/30/2005	1	1.35	0.8	0.8
	2	1.68	0.8	0.8
	5	2	0.7	0.6
7/31/2005	1	0.84	0.6	0.6
	2	0.9	0.7	0.5
	5	1.2	0.6	0.5
8/31/2005	1	0.71	0.7	0.6
	2	0.84	0.7	0.5
	5	1.03	0.6	0.6
9/30/2005	1	0.77	0.5	0.4
	2	0.9	0.6	0.5
	5	0.97	0.6	0.5
10/31/2005	1	0.64	0.6	0.5
	2	0.77	0.6	0.6
	5	0.90	0.7	0.5
11/30/2005	1	1.03	0.7	0.5
	2	1.23	0.7	0.5
	5	1.42	0.6	0.4
12/31/2005	1	0.84	0.7	0.5
	2	0.97	0.7	0.5
	5	0.77	0.6	0.6
1/31/2006	1	1.16	0.8	0.5
	2	1.29	0.7	0.5
	5	1.42	0.6	0.6
2/28/2006	1	0.84	0.7	0.6
	2	0.97	0.7	0.5
	5	1.3	0.6	0.5

Date	Site	Flow (cfs)	DO (mg/L)	NH3N (mg/L)
3/31/2006	1	1.16	0.8	0.5
	2	0.9	0.7	0.3
	5	1.1	0.7	0.3
4/30/2006	1	0.77	0.8	0.5
	2	0.84	0.7	0.5
	5	1.03	0.7	0.5
5/31/2006	1	0.77	1	0.7
	2	0.65	0.8	0.6
	5	0.84	0.7	0.6
6/30/2006	1	0.77	1.1	0.6
	2	0.84	0.7	0.7
	5	0.97	0.7	0.8
7/31/2006	1	0.84	0.8	0.6
	2	0.77	0.7	0.6
	5	0.97	0.6	0.5
8/31/2006	1	0.84	0.7	0.8
	2	0.97	0.6	0.8
	5	1.03	0.6	0.7
9/30/2006	1	1.03	0.7	0.7
	2	0.97	0.8	0.7
	5	0.84	0.6	0.9
10/31/2006	1	0.9	0.8	0.6
	2	1.03	0.7	0.6
	5	1.1	0.7	0.7
11/30/2006	1	0.84	8	0.8
	2	1.1	8	0.7
	5	1.03	7	0.6
12/31/2006	1	0.77	0.8	0.7
	2	0.90	0.7	0.7
	5	1.03	0.6	0.6
1/31/2007	1	0.84	0.7	0.6
	2	0.97	0.7	0.6
	5	1.23	0.6	0.5
2/28/2007	1	0.77	0.8	0.7
	2	0.84	0.7	0.7
	5	1.1	0.6	0.5
3/31/2007	1	0.84	0.9	0.8
	2	0.77	0.8	0.7
	5	0.77	0.7	0.7
4/30/2007	1	0.77	0.7	0.6
	2	0.42	0.5	0.5
	5	0.71	0.4	0.6
5/31/2007	1	0.9	0.6	0.7
	2	0.97	0.7	0.7
	5	0.97	0.6	0.6
6/30/2007	1	0.78	0.6	0.6
	2	0.91	0.6	0.5
	5	0.97	0.5	0.5

Date	Site	Flow (cfs)	DO (mg/L)	NH3N (mg/L)
7/31/2007	1	0.84	0.7	0.6
	2	0.9	0.6	0.4
	5	0.9	0.6	0.5
8/31/2007	1	0.84	0.6	0.7
	2	1.03	0.6	0.6
	5	0.97	0.5	0.5
9/30/2007	1	0.84	0.7	0.5
	2	0.90	0.6	0.5
	5	1.03	0.5	0.4
10/31/2007	1	0.84	0.6	0.7
	2	0.97	0.5	0.6
	5	0.97	0.5	0.7
11/30/2007	1	0.90	0.6	0.7
	2	0.97	0.5	0.7
	5	1.03	0.6	0.6
12/31/2007	1	0.71	0.6	0.7
	2	0.84	0.5	0.6
	5	0.77	0.6	0.6
1/31/2008	1	0.77	0.7	0.5
	2	0.84	0.6	0.5
	5	0.97	0.6	0.6
2/29/2008	1	0.84	0.6	0.5
	2	0.84	0.6	0.6
	5	0.90	0.6	0.5
3/31/2008	1	0.79	0.5	0.5
	2	0.83	0.6	0.6
	5	0.85	0.6	0.5
4/30/2008	1	0.77		0.4
	2	0.84	0.7	0.3
	5	0.84	0.7	0.3
5/31/2008	1	1.03		0.6
	2	0.90	5	0.6
	5	0.97	6	0.4
6/30/2008	1	0.9		0.5
	2	0.97	0.5	0.4
	5	0.97	0.6	0.4
7/31/2008	1	0.97	0.7	0.6
	2	1.03	0.7	0.6
	5	1.03	0.6	0.7
8/31/2008	1	0.84		0.5
	2	0.90	0.6	0.5
	5	0.84	0.6	0.6
9/30/2008	1	0.77	0.7	0.6
	2	0.84	0.6	0.6
	5	0.84	0.5	0.4
10/31/2008	1	0.83		0.3
	2	0.86	0.6	0.3
	5	0.87	0.5	0.2

Date	Site	Flow (cfs)	DO (mg/L)	NH3N (mg/L)
11/30/2008	1	0.77	0.7	0.5
	2	0.84	0.6	0.4
	5	0.97	0.6	0.2
12/31/2008	1	0.84	0.6	0.4
	2	0.90	0.7	0.4
	5	0.90	0.6	0.3
1/31/2009	1	0.97	0.5	0.5
	2	10.3	0.7	0.5
	5	1.1	0.7	0.4

Appendix A.3

Suspended solids and instantaneous discharge for reference targeting

Date	Discharge (cfs)	NFR (mg/L)	TN (mg/L)	TP (mg/L)
# USGS 07041000 LITTLE RIVER DITCH 81 NEAR KENNETT MO				
7/8/1993	67	39	0.53	0.2
# USGS 07046250 Little River Ditches near Rives, MO				
12/14/1993	184		0.48	0.92
12/14/1993	589		0.5	0.12
12/14/1993	184		0.54	0.12
12/14/1993	685		0.84	0.4
12/14/1993	557		2.3	0.81
1/6/1994	910	12	0.3	0.05
2/9/1994	254		0.6	0.14
2/23/1994	3440		2.7	0.79
3/16/1994	3460		1.3	0.24
4/13/1994	2680		4.4	1
5/5/1994	3690		1.4	0.31
6/15/1994	824	102	1	0.2
7/26/1994	511		0.71	0.2
8/9/1994	477	76	0.54	0.19
9/7/1994	331		0.66	0.2
10/4/1994	164		0.31	0.15
11/8/1994	8390	150	1.5	0.44
12/19/1994	433		1.5	0.44
1/24/1995	2110	70	0.96	0.31
2/14/1995	778			0.05
3/15/1995	272		0.7	0.2
4/19/1995	672		0.42	0.16
6/20/1995	139	64	0.54	0.23
7/12/1995	1260		1.2	0.15
7/26/1995	2670		1.5	0.35
9/5/1995	308		0.4	0.15
10/30/1995	520		1.3	0.55
11/28/1995	340	41	0.62	0.19
12/12/1995	376		0.27	0.06
1/30/1996	845	140	1.5	0.32
2/13/1996	503		0.4	0.08
3/13/1996	589		1.1	0.19
4/9/1996	775		0.68	0.1
5/7/1996	1550		2.1	0.38
6/11/1996	7800	520	3.7	0.54
7/18/1996	464		0.97	0.24
8/13/1996	334	48		0.18
9/10/1996	288			0.17
10/22/1996	257			0.13
11/20/1996	730	98	1.1	0.32
12/17/1996	7940		1.9	0.51
1/22/1997	6610	250	2.4	0.48
2/19/1997	1320		0.59	0.14
3/25/1997	1060		0.61	0.13
4/16/1997	2010		0.95	0.18
5/28/1997	14300		5.8	0.89

Date	Discharge (cfs)	NFR (mg/L)	TN (mg/L)	TP (mg/L)
6/11/1997	1220	56		0.1
7/22/1997	1060			0.2
8/6/1997	538	60		0.16
9/4/1997	425		0.64	0.16
11/4/1997	309	15		
1/6/1998	487	106		
8/10/1998	8900	50		
11/24/1998	509	20	0.33	0.1
12/15/1998	754		0.8	0.18
1/6/1999	4470	38	1.6	0.32
2/3/1999	5100		1.2	0.1
3/3/1999	916		0.93	0.23
4/7/1999	8870		3	0.99
5/13/1999	875		0.74	0.21
6/15/1999	1930	138	3.9	0.54
7/7/1999	612			0.28
8/17/1999	124	87		0.31
9/8/1999	150			0.32
10/19/1999	123			0.2
11/2/1999	147	30		0.17
12/14/1999	10900		3.6	0.66
1/19/2000	595	18	0.5	0.15
2/9/2000	575			0.1
3/21/2000	7970		2.2	0.47
4/11/2000	659			0.14
5/9/2000	592	41		0.2
6/20/2000	5200		0.74	0.236
7/18/2000	463	45		0.24
8/8/2000	461			0.24
9/12/2000	242			0.21
10/17/2000	249			0.18
11/14/2000	443	50	2	0.22
12/5/2000	1010		0.78	0.22
1/3/2001	1430	14	0.46	0.08
2/7/2001	411		0.62	0.15
3/13/2001	2160		1.1	0.43
4/3/2001	668		1	0.21
5/8/2001	507	46	0.4	0.18
6/19/2001	350		0.64	0.22
7/18/2001	275	56	E 0.56	0.2
8/15/2001	599		0.67	0.24
9/10/2001	478		E 0.56	0.18
10/23/2001	340	< 10	0.81	0.31
11/6/2001	291	38	0.78	0.35
12/4/2001	4590	26	E 0.98	0.51
1/15/2002	983	< 10	0.27	0.09
2/5/2002	5040	252	1.5	0.5
3/26/2002	10900	584	2.9	0.96
4/17/2002	4320	130	1.8	0.41
5/15/2002	16800	162	2.7	0.59
6/11/2002	6790	300	2.6	0.61

Date	Discharge (cfs)	NFR (mg/L)	TN (mg/L)	TP (mg/L)
7/9/2002	590	68		0.27
8/20/2002	520	27	0.88	0.18
9/17/2002	320	35	E 0.38	0.19
10/16/2002	331	17	0.48	0.19
11/5/2002	418	12		0.11
12/3/2002	566	< 10		0.1
1/22/2003	1190	< 10	0.27	0.08
2/26/2003	6510	90	1.5	0.46
3/11/2003	989	16		0.11
4/15/2003	963	34	0.55	0.14
5/13/2003	6320	258	2.5	0.64
6/4/2003	1080	54	0.59	0.19
7/23/2003	604	47		0.21
8/19/2003	687	41		0.22
9/3/2003	10700	120	1.4	0.52
10/15/2003	476	19		0.13
11/18/2003	819	36	0.49	0.2
12/3/2003	1100	86	1.2	0.43
1/14/2004	862	13	0.52	0.13
2/3/2004	3130	95	1.1	0.32
3/24/2004	1010	48	0.82	0.2
4/13/2004	748	16		0.11
5/12/2004	1470	160	1.7	0.39
6/8/2004	1240	38	0.97	0.19
7/28/2004	1220	82	1.1	0.34
8/18/2004	240	40		0.2
9/14/2004	186	47		0.19
10/19/2004	467	30		0.17
11/3/2004	13800	202	1.9	0.74
12/14/2004	1390	19	0.69	0.18
1/25/2005	1990	< 10	0.5	0.11
2/15/2005	3920	162	1.7	0.45
3/15/2005	835	< 10		0.09
4/19/2005	892	47	0.56	0.17
5/11/2005	769	43		0.2
6/14/2005	1540	102	5	0.3
7/19/2005	1840	38	1.5	0.23
8/3/2005	395	22		0.19
9/13/2005	163	42		0.21
10/25/2005	494	17		0.14
11/16/2005	267	23		0.14
12/6/2005	196	48	1.3	0.31
1/18/2006	1540	130	3.3	0.51
2/14/2006	1030	12	0.58	0.13
3/14/2006	8010	143	2.5	0.82
4/25/2006	427	61		0.21
5/9/2006	1200	102	1.9	0.32
6/13/2006	462	81		0.23
7/11/2006	1910	97	1.3	0.3
8/8/2006	355	39	E 0.54	0.22
9/12/2006	172	35		0.24

Date	Discharge (cfs)	NFR (mg/L)	TN (mg/L)	TP (mg/L)
10/31/2006	4530	31	1.3	0.47
11/28/2006	1820	15	0.34	0.12
12/19/2006	623	26	0.66	0.17
1/9/2007	4690	146	1.3	0.54
2/7/2007	650	< 10	0.38	0.09
3/20/2007	672	17		0.1
4/17/2007	3240	< 50	4.9	0.44
5/15/2007	629	35	1.4	0.25
6/26/2007	410	40	0.79	0.2
7/18/2007	409	39		0.2
8/13/2007	193	55		0.25
9/11/2007	288	56	E 0.66	0.22
10/16/2007	180	62	E 0.56	0.2
11/14/2007	643	12		0.16
12/18/2007	10800	114	1.3	0.56
1/15/2008	734	72	1	0.28
2/20/2008	3500	139	1.6	0.39
3/26/2008	9400	122	1.1	0.35
4/1/2008	12300	278	2.3	0.66
5/13/2008	674	71	0.86	0.22
6/17/2008	446	87	2.4	0.3
7/15/2008	732	94	3.1	0.34
8/12/2008	355	112	E 0.72	0.31
9/9/2008	225	88	E 0.64	0.22
10/14/2008	245	23		0.16
11/19/2008	898	26	1.3	0.27
12/15/2008	1340	137	2.3	0.63
1/6/2009	1380	58	0.96	0.32
2/4/2009	3650	76	2.1	0.37
4/28/2009	957	61	0.77	0.23
5/12/2009	2410	106	1.6	0.47
6/8/2009	1110	110	2.3	0.31
# USGS 07046001 Little River Ditches nr Kennett, MO				
7/25/1977	582	64		0.24
8/22/1977	791	92		0.22
9/21/1977	816	117		0.51
10/27/1977	495	40		0.17
11/29/1977	824	148		0.23
12/20/1977	1900	90		0.28
1/31/1978	1140	119		0.13
2/15/1978	3520	48		0.44
3/28/1978	2090	51		0.24
4/24/1978	1040	57		0.17
5/9/1978	1620	336		0.47
6/27/1978	770	85		0.41
7/26/1978	507	28		0.12
8/16/1978	460	55		0.11
9/12/1978	454	51		0.3
10/3/1978	296	36		0.12
11/28/1978	16700	216		0.47
12/12/1978	9000	85		0.31

Date	Discharge (cfs)	NFR (mg/L)	TN (mg/L)	TP (mg/L)
1/16/1979	1190	22		0.16
3/7/1979	11300	146		0.42
5/29/1979	1800	188		0.5
6/26/1979	889	85		0.61
7/17/1979	886	88		0.07
8/29/1979	726	95		0.13
9/25/1979	1180	54		0.2
10/25/1979	432	7		0.09
11/20/1979	507	24		0.09
12/18/1979	1260	72		0.37
1/21/1980	1010	60		0.18
2/26/1980	1110	56		0.14
3/25/1980	3350	326		0.35
4/15/1980	3320	324		0.39
5/28/1980	493	66		0.19
6/17/1980	531	51		0.18
7/21/1980	370	1		0.21
8/19/1980	216	38		0.16
9/9/1980	70	14		0.19
10/8/1980	145	76		0.16
11/4/1980	202	18		0.14
12/15/1980	272	62		0.26
1/20/1981	204	16		0.14
2/23/1981	309	42		0.18
3/31/1981	366	41		0.18
4/16/1981	285	3		0.18
5/12/1981	544	308		0.32
6/2/1981	793	488		0.07
7/7/1981	2470	16400		0.04
8/11/1981	110	70		0.15
9/2/1981	105	58		0.13
10/6/1981	246	41		0.17
11/3/1981	460	26		0.12
12/2/1981	630	64		0.34
1/6/1982	2000	272		0.96
2/8/1982	1250	76		0.29
3/3/1982	1020	62		0.22
4/12/1982	770	92		0.2
5/3/1982	535	62		0.22
6/1/1982	1570	212		0.37
7/12/1982	750	180		0.43
8/18/1982	271	58		0.21
9/7/1982	694	56		0.22
10/4/1982	221	19		0.13
11/1/1982	169	33		0.15
11/29/1982	8520	180		0.6
1/3/1983	4000	174		0.4
2/1/1983	950	30		0.15
3/1/1983	706			0.06
4/5/1983	2900	170		0.34
5/11/1983	3760	116		0.36

Date	Discharge (cfs)	NFR (mg/L)	TN (mg/L)	TP (mg/L)
6/6/1983	2200	210		0.77
7/12/1983	585	56		0.23
8/11/1983	276	44		0.23
9/14/1983	177	32		0.24
10/5/1983	160	45		0.2
11/8/1983	340	41		0.21
1/4/1984	1460	27		0.19
1/25/1984	6420	54		0.37
2/15/1984	4680	212		0.37
3/7/1984	3540	94		0.32
4/5/1984	5940	260		0.39
5/2/1984	1700	166		0.37
6/6/1984	350	79		0.16
7/18/1984	562	22		0.15
8/22/1984	182	19		0.17
9/11/1984	265	46		0.17
10/18/1984	3340	98		0.45
11/14/1984	1960	73		0.23
12/18/1984	4960	438		0.66
1/30/1985	1360	10		0.09
2/14/1985	3450	20		0.17
3/13/1985	1970	74		0.22
4/10/1985	2240	61		0.23
5/16/1985	1820	108		0.1
6/19/1985	1810	168		0.44
7/17/1985	682	85		0.27
8/13/1985	328	44		0.31
9/25/1985	197	15		0.15
10/23/1985	2840	40		0.3
11/21/1985	2260	206		0.42
12/18/1985	1180	59		0.16
1/23/1986	568	41		0.16
2/12/1986	1180	42		0.2
3/4/1986	682	16		0.08
4/8/1986	4980	440		0.67
5/13/1986	1060	273		0.32
6/10/1986	10400	152		0.53
7/15/1986	402	67		0.24
8/12/1986	374	39		0.18
9/16/1986	141	32		0.16
10/21/1986	180	32		0.03
11/13/1986	231	28		0.16
12/10/1986	4400	390		0.38
2/4/1987	968	150		0.39
3/3/1987	7060	370		0.7
4/2/1987	652	64		0.25
5/6/1987	530	55		0.14
6/3/1987	955	227		0.32
7/14/1987	523	44		0.25
8/4/1987	306	14		0.23
9/10/1987	162	17		0.13

Date	Discharge (cfs)	NFR (mg/L)	TN (mg/L)	TP (mg/L)
10/15/1987	160	15		0.08
11/9/1987	260	34		0.08
12/1/1987	1490	11		0.3
1/5/1988	2350	40		0.16
2/2/1988	12800	620		0.34
3/1/1988	1030	44		0.07
4/6/1988	2100	4		0.17
5/10/1988	516	58		0.08
6/7/1988	376	21		0.09
7/12/1988	297	202		0.2
8/2/1988	365	53		0.17
9/8/1988	1950	66		0.23
10/13/1988	650	16		0.11
11/3/1988	321	21		0.07
12/14/1988	860	26		0.16
1/12/1989	6600	574		0.32
2/7/1989	4470	132		0.38
3/8/1989	11700	150		0.42
4/13/1989	1630	35		0.16
5/16/1989	617	21		0.08
6/5/1989	550	44		0.1
11/11/1992	412	3		0.08
1/21/1993	4530	198	1.5	0.28
3/17/1993	1600	97	1.9	0.26
5/17/1993	595	56	0.5	0.16
7/8/1993	731	146	0.75	0.18
9/22/1993	344	17		0.1
# USGS 07046000 LITTLE RIVER DITCH 259 NEAR KENNETT MO				
7/8/1993	29	29	0.57	0.13
# USGS 07044000 LITTLE RIVER DITCH 251 NEAR KENNETT MO				
7/8/1993	160	80	0.91	0.03
# USGS 07042450 St. Johns Ditch at Henderson Mound, MO				
10/19/1999	57			0.185
11/3/1999	55	4	0.38	0.25
12/15/1999	285		2.3	0.46
1/11/2000	410	20	0.72	0.25
2/8/2000	82		0.38	0.19
3/14/2000	280		0.35	0.21
4/10/2000	325		0.35	0.12
5/10/2000	311	47	0.84	0.38
6/19/2000	352		1.4	0.37
7/25/2000	72	15	0.55	0.3
8/9/2000	79		0.62	0.31
9/13/2000	44		0.37	0.34
10/16/2000	40			0.23
11/14/2000	92	< 10	0.85	0.27
12/5/2000	104		0.43	0.21
1/17/2001	288	26	1.3	0.27
2/6/2001	205		0.29	0.17
3/13/2001	680		1.2	0.41
4/2/2001	334		1.3	0.32

Date	Discharge (cfs)	NFR (mg/L)	TN (mg/L)	TP (mg/L)
5/3/2001	165	22	0.44	0.26
6/18/2001	420		0.97	0.54
7/19/2001	111	45	0.77	0.31
8/14/2001	102		0.85	0.32
9/11/2001	324		0.36	0.26
10/23/2001	201	< 10	0.73	0.32
11/7/2001	158	10	0.45	0.24
12/5/2001	564	20	0.62	0.34
1/16/2002	487	< 10	0.42	0.2
2/6/2002	1160	22	0.68	0.24
3/20/2002	2150	108	1.5	0.39
4/16/2002	915	54	1.6	0.39
5/14/2002	932	106	1.4	0.37
6/10/2002	762	141	1.4	0.69
7/10/2002	340	51	0.68	0.32
8/21/2002	146	45	0.82	0.34
9/11/2002	84	10	0.66	0.32
10/16/2002	161		0.66	0.22
11/5/2002	229	10	0.64	0.22
12/3/2002	180	< 10	E 0.39	0.17
1/23/2003	359	< 10	0.24	0.16
2/26/2003	615	11	0.8	0.22
3/12/2003	474	29	0.34	0.26
4/15/2003	417	46	0.59	0.32
5/14/2003	461	25	0.82	0.26
6/5/2003	417	44	0.79	0.32
7/22/2003	226	28	0.58	0.31
8/18/2003	166	19	0.47	0.26
9/4/2003	1520	55	1	0.44
10/16/2003	187	< 10	0.39	0.2
11/19/2003	1080	172	2.6	0.8
12/2/2003	409	< 10	0.56	0.22
1/13/2004	315	< 10	0.51	0.21
2/2/2004	405	20	0.6	0.22
3/16/2004	287	< 10	0.33	0.18
4/14/2004	224	14	0.37	0.22
5/13/2004	219	42	0.63	0.3
6/7/2004	240	< 10	0.48	0.2
7/27/2004	107	24	0.68	0.26
8/17/2004	81	< 10	0.36	0.21
9/13/2004	137	< 10	0.42	0.23
11/2/2004	1110	96	1.5	0.62
2/14/2005	918	137	1.5	0.4
3/14/2005	320	< 10	0.29	0.18
5/10/2005	288	41	0.6	0.34
7/18/2005	487	82	1.4	0.39
9/13/2005	59	13	0.74	0.31
11/14/2005	60	< 10	E 0.25	0.22
1/18/2006	301	66	1.4	0.35
3/13/2006	1110	202	1.9	0.61
5/8/2006	206	70	1	0.4

Date	Discharge (cfs)	NFR (mg/L)	TN (mg/L)	TP (mg/L)
7/12/2006	533	120	2	0.53
9/13/2006	78	16	0.47	0.31
11/27/2006	418	16	0.47	0.24
1/8/2007	1050	68	0.99	0.32
2/6/2007	564	< 10	0.42	0.17
3/20/2007	553	43	0.72	0.29
4/16/2007	568	57	2.7	0.34
5/15/2007	451	76	0.84	0.38
6/26/2007	266	180	2.2	0.54
7/18/2007	180	25	0.43	0.32
9/11/2007	48	< 10	0.95	0.29
11/15/2007	204	14	0.53	0.26
1/15/2008	564	< 10	0.57	0.2
3/25/2008	1090	42	0.9	0.3
5/13/2008	508	65	0.74	0.26
7/14/2008	338	70	1.1	0.43
9/9/2008	90	14	0.81	0.3
10/15/2008	76	< 15	0.48	0.29
1/6/2009	256	24	0.63	0.25
3/4/2009	353	< 15	0.36	0.18
4/27/2009	526	24	0.57	0.24
5/12/2009		17	0.73	0.23
6/8/2009	438	72	0.97	0.43
# USGS 07042000 LITTLE RIVER DITCH 1 NEAR KENNETT MO				
7/8/1993	225	159	0.79	0.35

Appendix A.4
USGS gaging sites used for synthetic flow development

Gage	Period of Record
USGS 07042500 Little River Ditch 251	10/01/1989 - 02/02/1992
USGS 07021000 Castor River	10/01/1989 - 06/30/2009
USGS Little River Ditch 1	10/01/1989 - 06/30/2009
USGS 07040100 St Francis River (corrected by 07039500 tail water gage)	10/01/1989 - 06/30/2009
USGS 07025400 N. Fk. Obion River, Martin, TN	10/01/1989 - 09/30/2008
USGS 03612000 Cache River, Forman, IL	10/01/1989 - 06/30/2009

Appendix B
Development of Suspended Solids Targets Using Reference Load Duration Curves

Overview

This procedure is used when a lotic[10] system is placed on the 303(d) List for a pollutant and the designated use being addressed is aquatic life. In cases where pollutant data for the impaired stream is not available a reference approach is used. The target for pollutant loading is the 25th percentile calculated from all data available within the ecological drainage unit (EDU) in which the water body is located. Additionally, it is also unlikely that a flow record for the impaired stream is available. If this is the case, a synthetic flow record is needed. In order to develop a synthetic flow record calculate an average of the log discharge per square mile of USGS gaged rivers for which the drainage area is entirely contained within the EDU. From this synthetic record develop a flow duration from which to build a load duration curve for the pollutant within the EDU.

From this population of load durations follow the reference method used in setting nutrient targets in lakes and reservoirs. In this methodology the average concentration of either the 75th percentile of reference lakes or the 25th percentile of all lakes in the region is targeted in the TMDL. For most cases available pollutant data for reference streams is also not likely to be available. Therefore follow the alternative method and target the 25th percentile of load duration of the available data within the EDU as the TMDL load duration curve. During periods of low flow the actual pollutant concentration may be more important than load. To account for this during periods of low flow the load duration curve uses the 25th percentile of EDU concentration at flows where surface runoff is less than 1 percent of the stream flow. This result in an inflection point in the curve below which the TMDL is calculated using load calculated with this reference concentration.

Methodology

The first step in this procedure is to locate available pollutant data within the EDU of interest. These data along with the instantaneous flow measurement taken at the time of sample collection for the specific date are recorded to create the population from which to develop the load duration. Both the date and pollutant concentration are needed in order to match the measured data to the synthetic EDU flow record.

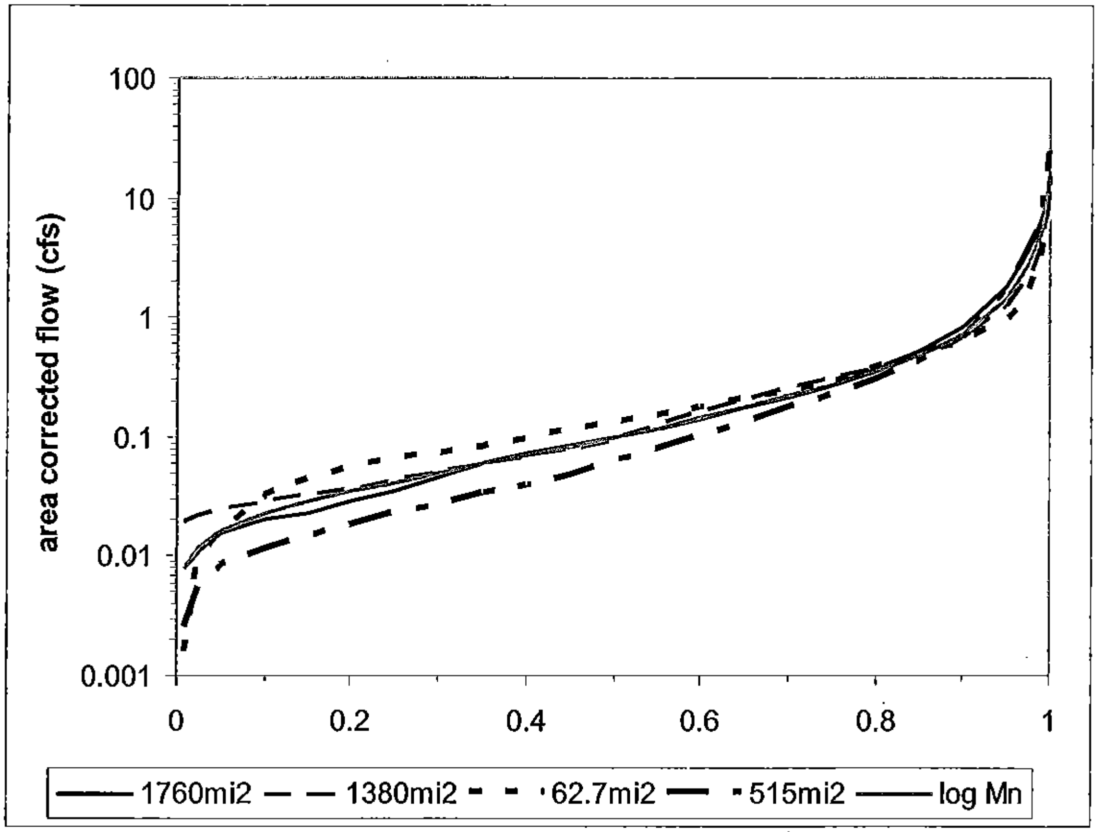
Secondly, collect average daily flow data for gages with a variety of drainage areas for a period of time to cover the pollutant record. From these flow records normalize the flow to a per square mile basis. Average the log transformations of the average daily discharge for each day in the period of record. For each gage record used to build this synthetic flow record calculate the Nash-Sutcliffe statistic to determine if the relationship is valid for each record. This relationship must be valid in order to use this methodology. This new synthetic record of flow per square mile is used to develop the load duration for the EDU. The flow record should be of sufficient length to be able to calculate percentiles of flow.

The following examples show the application of the approach to one Missouri EDU.

---

[10] Lotic = pertaining to moving water

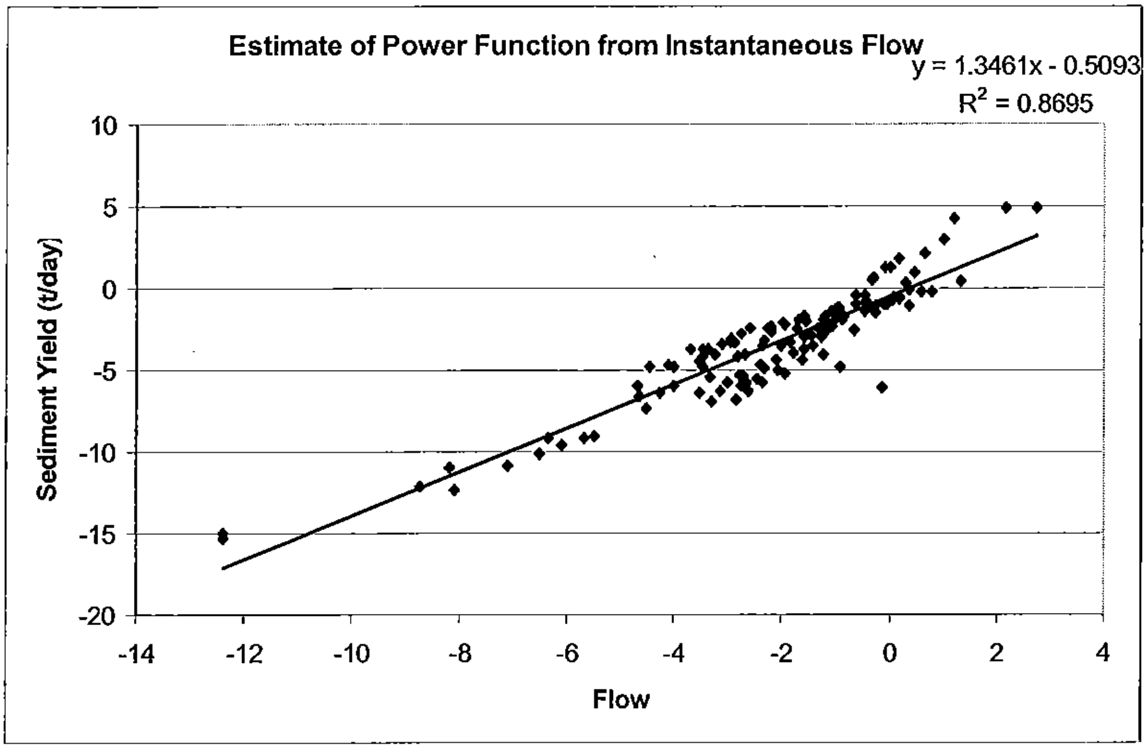
The watershed-size normalized data for the individual gages in the EDU were calculated and compared to a pooled data set including all of the gages. The results of this analysis are displayed in the following figure and table:



Gage	gage	area (mi^2)	normal Nash-Sutcliffe	lognormal Nash-Sutcliffe
Platte River	06820500	1760	80%	99%
Nodaway River	06817700	1380	90%	96%
Squaw Creek	06815575	62.7	86%	95%
102 River	06819500	515	99%	96%

This demonstrates the pooled data set can confidently be used as a surrogate for the EDU analyses.

The next step is to calculate pollutant-discharge relationships for the EDU, these are log transformed data for the yield (tons/mi^2/day) and the instantaneous flow (cfs/mi^2.) The following graph shows the EDU relationship:



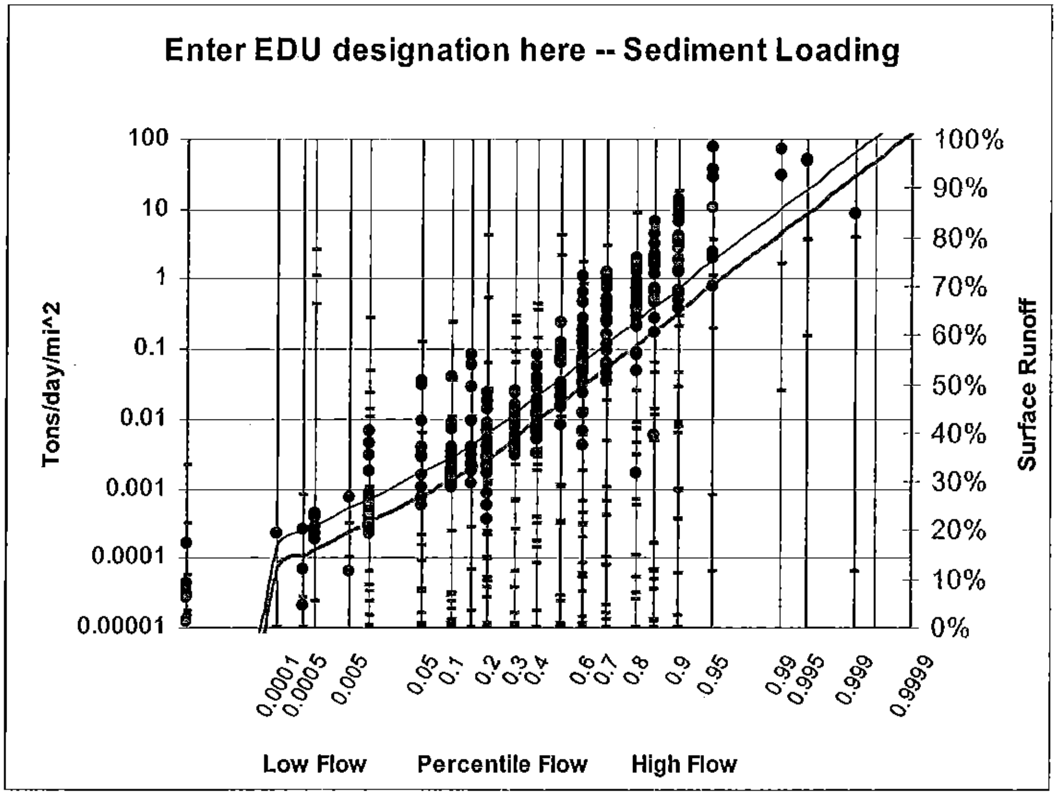
Further statistical analyses on this relationship are included in the following Table:

m	1.34608498	b	-0.509320019
Standard Error (m)	0.04721684	Standard Error (b)	0.152201589
r^2	0.86948229	Standard Error (y)	1.269553159
F	812.739077	DF	122
SSreg	1309.94458	SSres	196.6353573

The standard error of y was used to estimate the 25 percentile level for the TMDL line. This was done by adjusting the intercept (b) by subtracting the product of the one-sided Z_{75} statistic times the standard error of (y). The resulting TMDL Equation is the following:

*Sediment yield (t/day/mi²) = exp (1.34608498 * ln (flow) - 1.36627)*

A resulting pooled TMDL of all data in the watershed is shown in the following graph:



To apply this process to a specific watershed would entail using the individual watershed data compared to the above TMDL curve that has been multiplied by the watershed area. Data from the impaired segment is then plotted as a load (tons/day) for the y-axis and as the percentile of flow for the EDU on the day the sample was taken for the x-axis.

Appendix C
Buffalo Ditch QUAL2K Modeling

I. Modeling Approach

1.1 Hydraulics/Hydrology

a. Hydraulic geometry relations were developed from the May 2008 flow measurements. Relationships between mean flow depth, width and velocity as a function of discharge were estimated from the water level measurements. These relationships were used in the QUAL2K calibration model.

b. The hydraulics/hydrology of the system was modeled assuming a water balance at the time of the sampling on May 21, 2008. The water balance was calculated using the estimated flows at the sampling sites and the wastewater treatment plant discharge (at BU-3). Lateral inflows from contributing areas were estimated based on the water balance, i.e., nonpoint source flows were determined from the difference of the inflow and outflow of the modeled reaches.

1.2 Water Quality

a. Using the calibrated hydraulics model, the water quality model was setup and calibrated using the water chemistry data from May 21, 2008 sampling. The WQ model was calibrated by matching the observed diurnal dissolved oxygen data at sampling station 4 which is 1.1 mile downstream of the wastewater treatment plant discharge.

b. Kinetic rates were adjusted such that the predicted water chemistry parameters were reasonably simulated. Greater emphasis was placed on matching the biochemical oxygen demand decay downstream of the wastewater treatment plant discharge.

c. Since the weather condition of the May sampling was not generally representative of critical conditions, the calibrated model was modified using a representative day in August, 2008. Weather data from the Missouri mesonet station in Cardwell, Missouri was used in the modified model. The critical condition model was run using the design discharge of the Kennett Wastewater Treatment Plant at 2.17 cubic feet per second (1.4 million gallons per day).

d. The critical condition model described above was used in various scenario runs to establish the wasteload allocation. Simulations were performed to determine the reduction in nutrients and biochemical oxygen demand necessary to meet the dissolved oxygen standard (5.0 mg/l) downstream of the plant discharge. The scenarios were:

d.1. **Model A** - Critical condition, design discharge, calibrated wastewater treatment plant biochemical oxygen demand load (8.6 mg/l), current condition nonpoint source loads (from calibration).

d.2. **Model B** - Critical condition, design discharge, permitted biochemical oxygen demand limits (45 mg/l), current condition NPS loads (from calibration).

d.3. **Model C**- Critical condition, design discharge, point source EDU reference Chlorophyll-A (8 ppb), TN (0.82 mg/l) and TP (0.125 mg/l) for the wastewater treatment plant discharge, wastewater treatment plant biochemical oxygen demand (8.6 mg/l).

d.4. **Model D** - Critical condition, design discharge, point source and non-point source EDU reference chlorophyll *a* (8 ppb), TN (0.82 mg/l) and TP (0.125 mg/l), wastewater treatment plant biochemical oxygen demand of 5.0 mg/l (Allocation run).

II. Model Results

2.1 Hydraulics/Hydrology

a. Figure -1 shows the hydraulic geometry functions for the flow measurements on May 21, 2008.

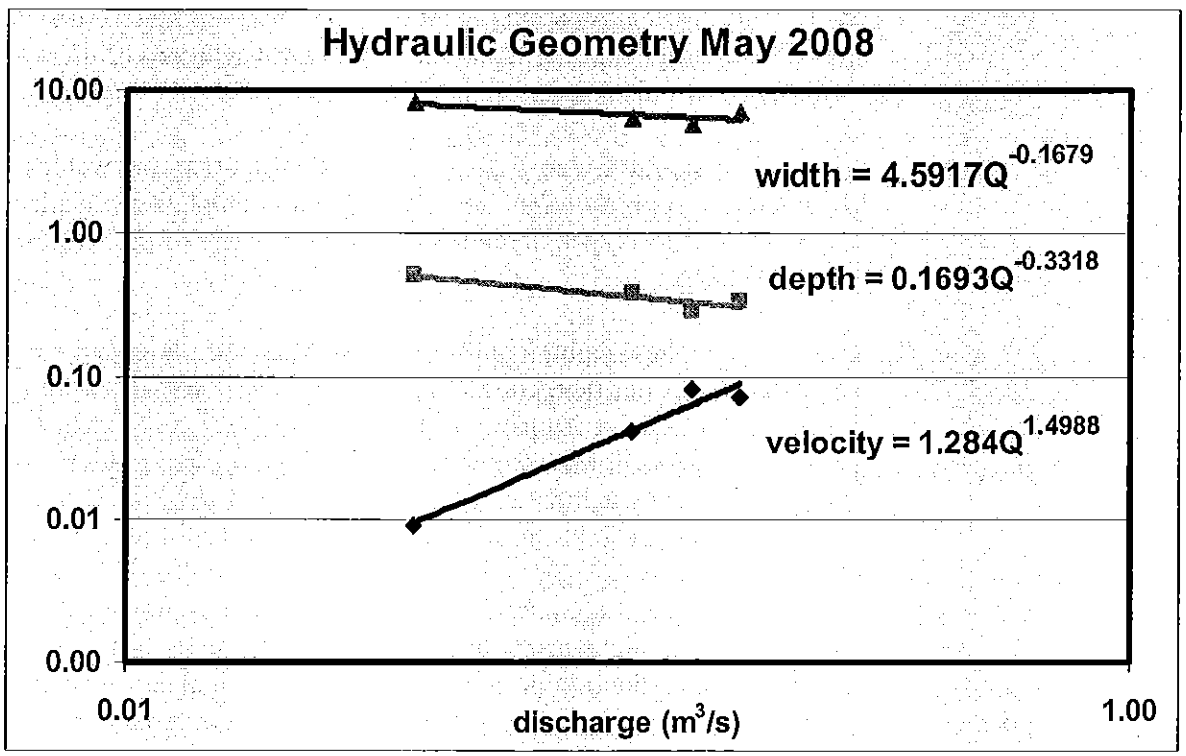


Figure C-1.Hydraulic geometry functions for Buffalo Ditch, May 2008.

b. Figure –C-2 shows the results of the flow, depth and velocity calibration using the measured data on May 21, 2008.

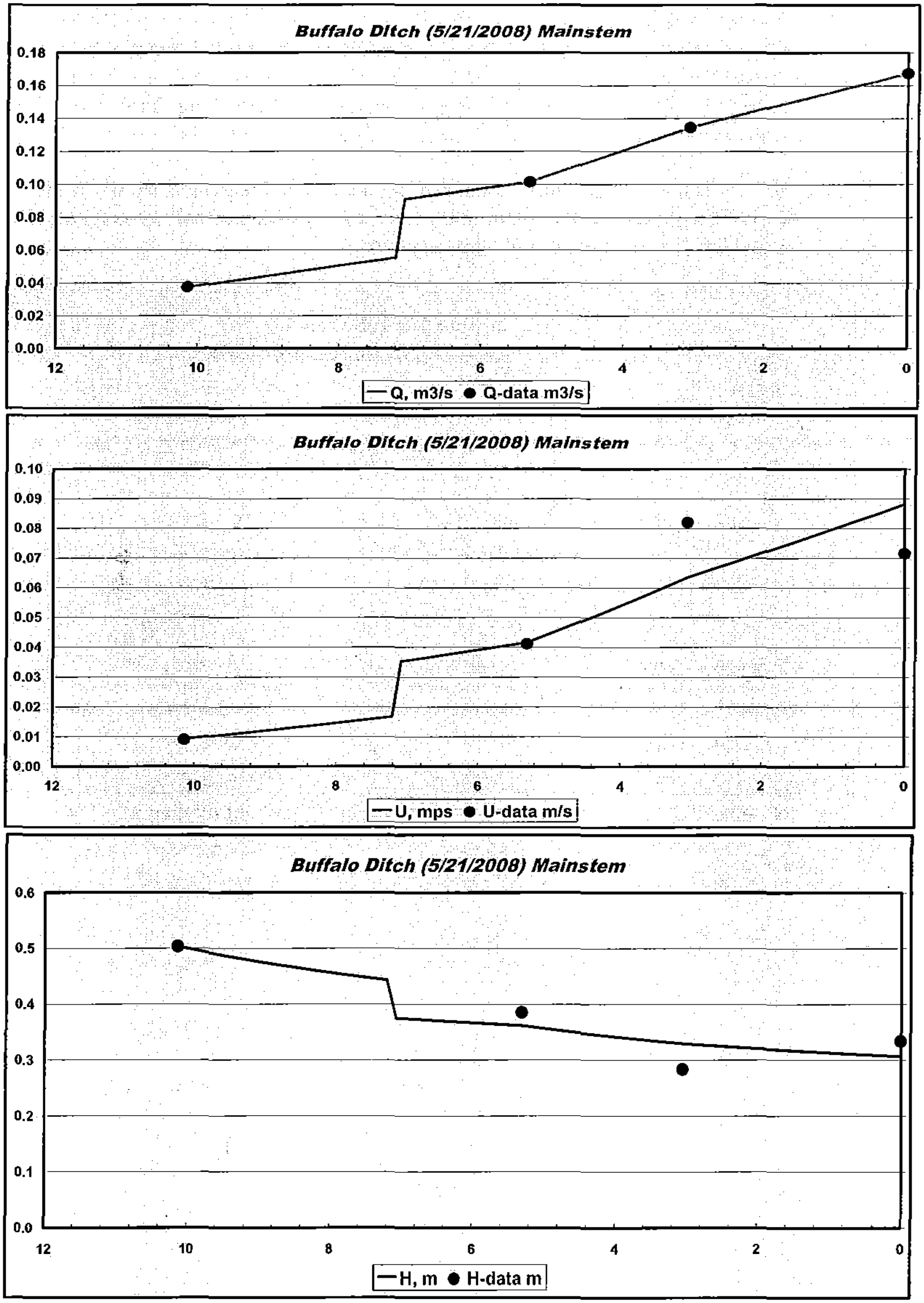


Figure C-2. Observed and simulated flow (Q), velocity (U) and depth (H).

2.2 Water Quality

a. The comparison of observed and predicted diurnal dissolved oxygen at BU-4 (1.1 mile downstream of the Kennett Wastewater Treatment Plant) is shown in Figure C-3. The model adequately predicts the minimum and maximum dissolved oxygen.

b. The predicted longitudinal profile of dissolved oxygen is shown in Figure C-4. Also plotted are the minimum, maximum and mean dissolved oxygen at BU-2 and BU-4 from the diurnal measurements.

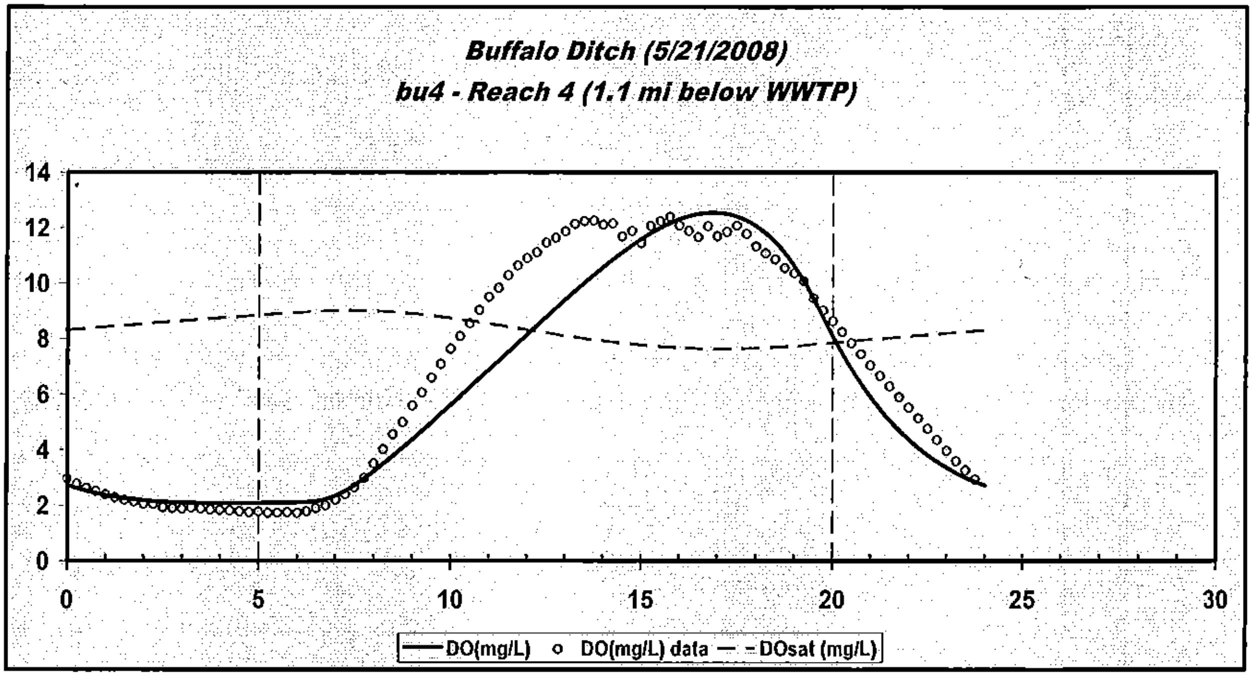


Figure C-3. Observed and predicted diurnal dissolved oxygen at ST-4.

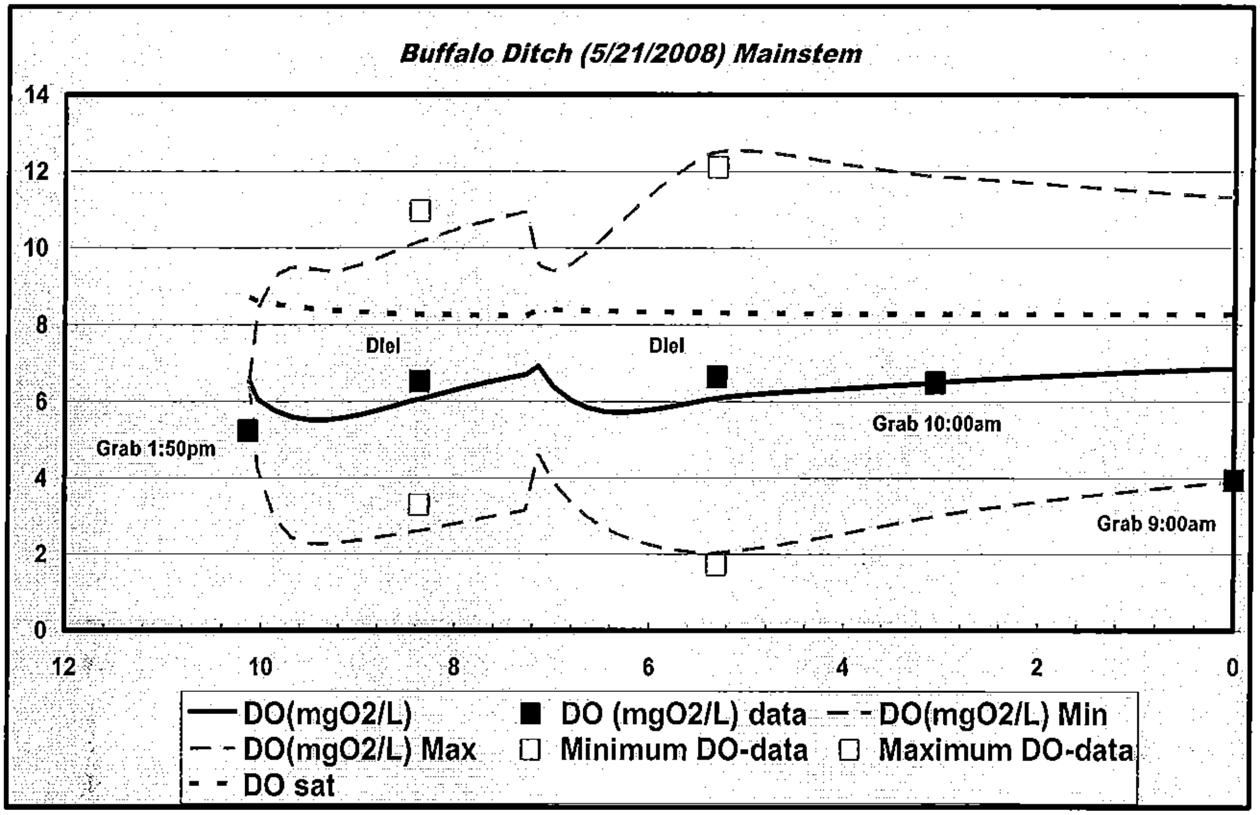


Figure C-4. Predicted longitudinal profile of minimum, maximum and mean dissolved oxygen.

c. Figure C-5 shows the predicted longitudinal profile of minimum dissolved oxygen corresponding to the various scenarios described in Section 1.2.d. As shown in the predicted profile from model D, under critical condition the dissolved oxygen criterion is met downstream of the wastewater treatment plant when the biochemical oxygen demand is limited to 5 mg/l and with the EDU reference concentrations for chlorophyll *a*, total nitrogen and phosphorous for both point and nonpoint sources.

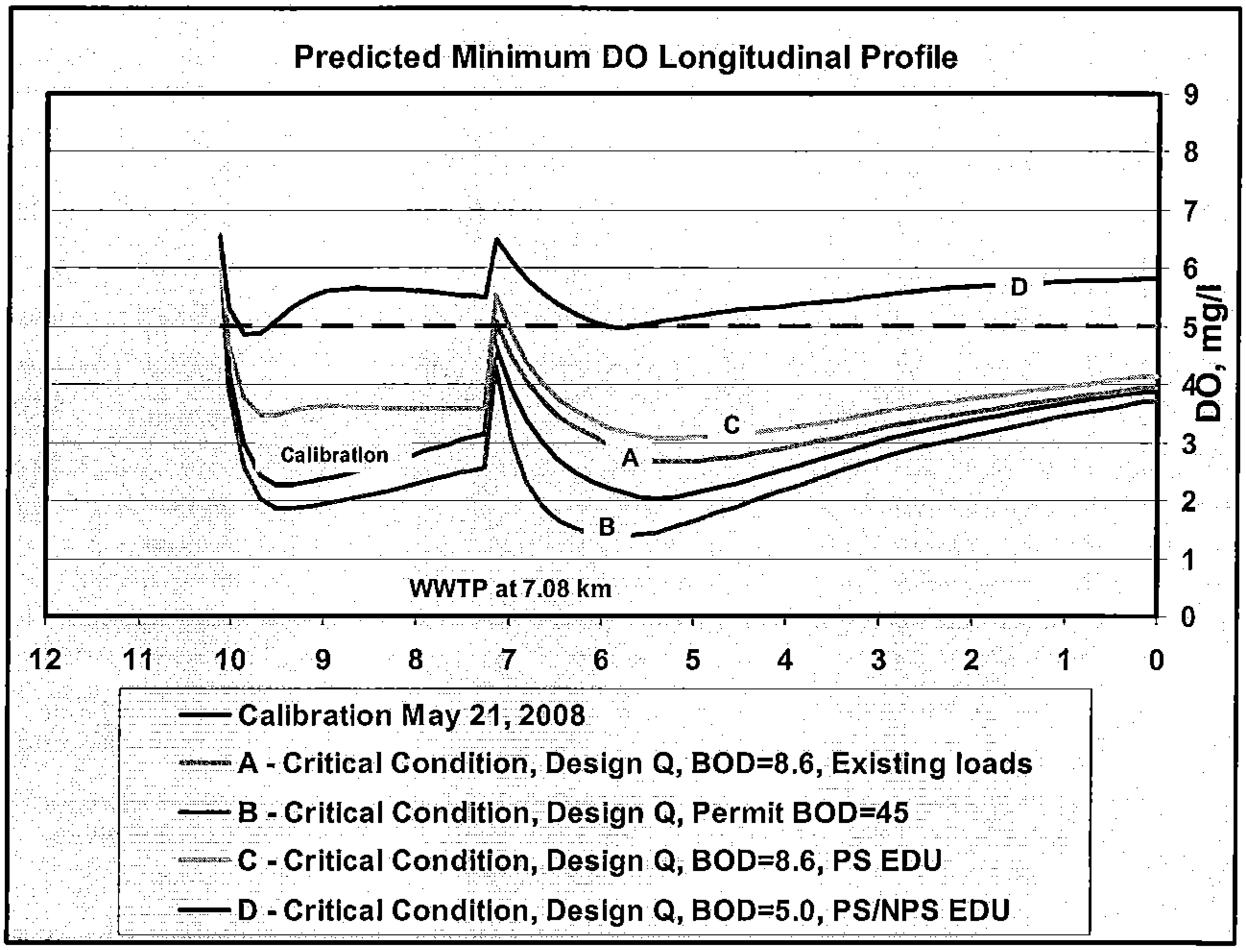


Figure C-5. Predicted longitudinal profile of minimum dissolved oxygen for various simulation scenarios.

III. Wasteload Allocation

The wasteload allocation for the Kennett Wastewater Treatment Plant is calculated based on the results of model D and is summarized in Table C-1.

Table C-1. Wasteload Allocation for Buffalo Ditch

Kennett WWTP	Concentration Limits	WLA at Design Flow Q = 2.17 cfs (1.4 MGD)
BOD	5 mg/l	58.5 lbs/day
Chl-A	8 μg/l	0.1 lbs/day