Total Maximum Daily Load
For Sediment and Dissolved Oxygen
Little Floyd River
Sioux and O'Brien Counties, Iowa

2005

Iowa Department of Natural Resources
TMDL & Water Quality Assessment Section

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1. Executive Summary

Table 1a. Little Floyd River TMDL Summary

Waterbody Name:	Little Floyd River
Counties:	Sioux and O'Brien
Use Designation Class:	Class B(LR)
Major River Basin:	Floyd River Basin
Pollutant:	Sediment, Dissolved Oxygen
Pollutant Sources:	Point, nonpoint
Impaired Use(s):	Class B(LR)
2002 303d Priority:	Low
Watershed Area:	39,700 acres
Segment Length:	3.4 miles

Table 1b. Oxygen Demand Impairment Summary

Flow (Cu ft/hr)	Target DO Concentration (ppm)	Target DO Mass (lbs/hr)	Existing Max DO Daytime (lbs/hr)	Existing Nighttime Oxygen Demand (OD) (lbs/hr)	OD Load Reduction to Meet Nighttime Target (lbs/hr)	OD Load Allocation (lbs/hr)
68,400 (19cfs)	5.0	21.4	40.1	22.4	3.7	16.8
46,800 (13 cfs)	5.0	14.6	21.4	10.2	3.4	6.1
27,000 7.5 cfs)	5.0	8.4	10.2	3.8	2.0	1.6

Table 1c. Sedimentation Impairment Summary

Parameter	Value
Target Sediment Load	8,800 tons/yr
Existing Sediment Load	20,400 tons/yr
Sediment Load Reduction to Meet Target	11,600 tons/yr
Wasteload Allocation	0
Load Allocation	7,920 tons/yr
Margin of Safety	880 tons/yr

The Federal Clean Water Act requires the Iowa Department of Natural Resources (IDNR) to develop a total maximum daily load (TMDL) for waters that have been identified on the state's 303(d) list as impaired by a pollutant. The Little Floyd River has been identified as impaired by low dissolved oxygen and sedimentation. The purpose of the TMDL for the Little Floyd River is to calculate the maximum allowable oxygen demand (OD) and sediment loadings to the river while still allowing the river to meet water quality standards.

This document consists of TMDLs for OD and sedimentation designed to provide the Little Floyd River with water quality that fully supports its designated uses. OD is targeted for the dissolved oxygen impairment and erosion is targeted for the sediment impairment.

Phasing TMDLs is an iterative approach to managing water quality that becomes necessary when the origin, nature and sources of water quality impairments are not well understood. In Phase 1, the waterbody load capacity, existing pollutant load in excess of this capacity, and the source load allocations are estimated based on the limited information available. A monitoring plan will be used to determine if prescribed load reductions result in attainment of water quality standards and whether or not the target values are sufficient to meet designated uses. Monitoring activities may include routine sampling and analysis, biological assessment, fisheries studies, and watershed and/or waterbody modeling.

Section 5.0 of this TMDL includes a description of planned monitoring. The TMDL will have two phases. Phase 1 will consist of setting specific and quantifiable targets for OD and sediment. Phase 2 will consist of implementing the monitoring plan, evaluating collected data, and readjusting target values if needed.

Monitoring is essential to all TMDLs in order to:

- Assess the future beneficial use status;
- Determine if the water quality is improving, degrading or remaining status quo;
- Evaluate the effectiveness of implemented best management practices.

The additional data collected will be used to determine if the implemented TMDL and watershed management plan have been or are effective in addressing the identified water quality impairments. The data and information can also be used to determine if the TMDL has accurately identified the required components (i.e. loading/assimilative capacity, load allocations, in-lake response to pollutant loads, etc.) and if revisions are appropriate.

This TMDL has been prepared in compliance with the current regulations for TMDL development that were promulgated in 1992 as 40 CFR Part 130.7. These regulations and consequent TMDL development are summarized below:

1. **Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:** Little Floyd River, Sec. 1, T96N, R43W, south of Sheldon, Sioux County.

2. **Identification of the pollutant and applicable water quality standards:** The pollutants causing the water quality impairments are low dissolved oxygen associated with excessive quantities of oxygen demanding substances, and sediment associated with excessive soil erosion. The designated use for the Little Floyd River is Class B(LR). Excess OD and sediment loading have impaired aquatic life water quality narrative criteria (567 IAC 61.3(2)) and hindered the designated use.

3. **Quantification of the pollutant load that may be present in the waterbody and still allow attainment and maintenance of water quality standards:** The amount of oxygen demanding substances that may be present in the river and still maintain water quality standards during low flow conditions varies from 18.7

to 1.8 lbs/hr OD for streamflows varying from 68,400 to 27,000 cu ft/hr, respectively. The allowable sediment is 8,800 tons delivered per year.

4. **Quantification of the amount or degree by which the current pollutant load in the waterbody, including the pollutant from upstream sources that is being accounted for as background loading, deviates from the pollutant load needed to attain and maintain water quality standards:** The oxygen demand for critical low flow conditions exceeds the assimilation capacity of the stream by 3.7 to 2.0 pounds/hour of OD for stream flows of 68,400 to 27,000 cu ft/hr. Sediment exceeds the capacity of the stream by 11,600 tons/yr.

5. **Identification of pollution source categories:** Agricultural and urban nonpoint and background sources contribute to the oxygen demand and sedimentation pollutant loads.

6. **Wasteload allocations for pollutants from point sources:** The Sanborn WWTP discharges into an upper tributary in the watershed. Any discharges from this plant are insignificant for purposes of this TMDL. Therefore, the wasteload allocation will be set at zero.

7. **Load allocations for pollutants from nonpoint sources:** The OD load allocation for this TMDL varies from 16.8 to 1.6 lbs OD/hr with streamflows of 68,400 to 27,000 cu ft/hr, respectively. The allocation for sediment is 7,920 tons per year delivered to the stream.

8. **A margin of safety:** The excessive OD TMDL was developed based on hourly oxygen demand loadings using implicit and 10% explicit margins of safety (MOS). The sediment TMDL was developed using an explicit 10% MOS.

9. **Consideration of seasonal variation:** This TMDL was developed based on the loadings of oxygen demanding substances that will result in attainment of targets for flows less than 64,800 cu ft/hr and minimum water temperatures greater than 20 degrees Celsius. The sediment loading target is based on average annual values.

10. **Allowance for reasonably foreseeable increases in pollutant loads:** Major changes in landuse in the Little Floyd River watershed are not anticipated except for the Highway 60 bypass. The watershed is predominately used for agricultural purposes. Portions of the cities of Sheldon and Sanborn lie within the watershed. However, major expansion of these urban areas into the watershed is not anticipated. The Sanborn WWTP currently discharges into a tributary of the Little Floyd River. However, it rarely discharges during critical conditions. Additions or deletions of livestock feeding operations may impact the water quality of the Little Floyd River. However, changes in the number of operations or operation capacity cannot be predicted and are not considered in this TMDL.

    The Highway 60 bypass of Sheldon currently under construction does pass through the watershed. However, pollutant loadings from such an event were not specifically estimated nor included. However, the load reductions may need to be increased or decreased depending upon the net result of this landuse change in Phase 2 of this process.

11. **Implementation plan:** Although not required by the current regulations, an implementation plan is outlined in the body of the report.

2. Little Floyd River, Description and History

2.1 The River

The Little Floyd River runs primarily through northwest O'Brien County from Sanborn to Sheldon. Its mouth in Sioux County feeds into the Floyd River. This TMDL deals with the lower 3.4 miles of river.

Table 2. Little Floyd River Features

Waterbody Name:	Little Floyd River
Hydrologic Unit Code:	HUC10 1023000201
IDNR Waterbody ID:	IA 06-FLO-0080_0
Location:	Section 1 T96N R43W
Latitude:	43° 9' N
Longitude:	95° 52' W
Water Quality Standards Designated Uses:	Class B(LR)
Tributaries:	Many unnamed tributaries
Receiving Waterbody:	Floyd River
Length of Segment:	3.4 miles
Watershed Area:	39,700 acres

Hydrology

The Little Floyd River drains 39,700 acres in northwest O'Brien County. The watershed begins approximately two miles east-southeast of Sanborn. The river runs in a southwesterly direction and empties into the Floyd River two miles southwest of Sheldon. The streamflow is highly variable. Runoff caused by heavy rainstorms or rapid snow melt cause the streamflow to increase and decrease rapidly ("flashy"). Field drainage tile are used extensively in the watershed and exacerbate the flashy characteristic. Portions of the river and tributary streams have been straightened. Almost all of the ephemeral water courses have been tiled and converted into grass waterways or are straightened open drainage ditches.

The nearest United States Geological Survey (USGS) stream monitoring station (stream gage #006600100) is located 18 miles downstream of the junction of the Little Floyd River with the Floyd River (7). The Little Floyd River watershed comprises 23% of the area draining to this stream gage. Streamflow for the Little Floyd River was calculated using the stream gage values and multiplying by 23%. Average annual streamflow is 18.8 cubic feet per second (cfs). Monthly average streamflow is shown in Table 3.

Table 3. Average Monthly Streamflow for Little Floyd River, Water Years 1955-2004

--cubic feet per second (cfs)--												
Jan	**Feb**	**Mar**	**Apr**	**May**	**June**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Avg**
4.1	9.9	38.2	40.9	28.1	40.9	21.6	9.9	8.0	9.2	9.2	6.1	18.8

2.2 The Watershed

Land Use

The Little Floyd River drains approximately 39,700 acres. The land use map is shown in Figure B-2. The 2002 landuses and associated areas for the watershed were obtained from satellite imagery and are shown in Table 3.

Table 3. 2002 Landuse in the Little Floyd River Watershed.

Landuse	Area in Acres	Percent of Area
Row Crop	35,250	88.8
Trees	80	0.2
Pasture	360	0.9
Grass/Hay/CRP	3,260	8.2
Farmsteads/Residential/Urban	750	1.9
Total	39,700	100

Current Watershed Conditions

A more recent field-level landuse assessment was completed in June 2004 by the IDNR. The 2004 assessment also shows that the major landuse is row crop and noted the presence of ten confinement animal feeding operations (CAFOs) and sixteen actively-used open feedlots within the watershed. The estimated animal units associated with CAFOs are 7,100 swine, 250 chickens, 630 turkeys, and 400 beef. Feedlots are estimated to contain 2,535 beef animal units. Small numbers of sheep and horses are also in the watershed.

Open feedlots are unroofed or partially roofed animal feeding operations in which no crop, vegetation, or forage growth or residue cover is maintained during the period that animals are confined in the operation. Runoff from open feedlots can deliver substantial quantities of nutrients and oxygen demanding materials to a waterbody dependent upon factors such as proximity to a water surface, number and type of livestock and manure controls. CAFOs are animal feeding operations in which animals are confined to areas which are totally roofed. CAFOs typically utilize earthen or concrete structures to contain and store manure prior to land application. Nutrients from CAFOs are delivered via runoff from land applied manure or from leaking/failing storage structures.

Topography and Soils

The watershed is predominately level to gently sloping (0-4%). Soils developed in loess or loess over glacial till under prairie vegetation. The most common soil series are Primghar, Galva, Marcus, and Sac on the uplands and Calco and Colo in the major drainageways.

3. TMDL for Dissolved Oxygen and Sediment

3.1 TMDL for Dissolved Oxygen

3.1.1 Problem Identification

Impaired Beneficial Uses and Applicable Water Quality Standards

The Surface Water Classification document (9 p.10) lists the designated use for Little Floyd River as Aquatic Life (Class B(LR)). In 1998, the Little Floyd River was included on the impaired waters list based on a 1990 stream use assessment conducted by the IDNR. The cause of the impairment at that time was *unknown*. Additional water quality monitoring and biological stream assessments by IDNR and UHL were completed to help determine the cause of the impairment. In 2004 using the additional information, a Stressor Identification (SI) (8) document was prepared for the Little Floyd River.

In 2000, Little Floyd River was not assessed due to a lack of updated information. In 2002 and 2004, the Class B designated use was re-assessed as “partially supporting.” The assessment of partial support was based upon biological monitoring conducted in 1999, 2001, and 2002 as well as monthly monitoring conducted by UHL and the DNR in 2001. Little Floyd River was listed based initially upon low scores on the Fish Index of Biotic Integrity (FIBI) and Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI). The biotic indexes rank the biological integrity of a stream sampling reach on a rising scale from 0 (minimum) to 100 (maximum). Table 4 summarizes the results of the biological assessments completed on the Little Floyd River. Figure 1 shows the locations of the assessment sites.

Table 4. Index of Biotic Integrity Scores for the Little Floyd River.

Site	Year	FIBI	BMIBI
Reference Standard		40	53
Site 1 (upstream of bridge)	**1999**	28 (fair)	41 (fair)
Site 52 (downstream of bridge)	**2001**	39 (fair)	65 (good)
Site 51 (downstream site)	**2001**	41 (fair)	34 (poor)
REMAP Site	**2002**	33 (fair)	52 (fair)

<u>Stressor Identification Protocol and Document for the Little Floyd River.</u> Because the cause (stressor) of the biological impairment in 1998 was *unknown*, a scientifically rigorous method called Stressor Identification (SI) was used to determine the existing stressor(s) on the biotic community of the Little Floyd River. The general process involves “critically reviewing available information, forming possible stressor scenarios that might explain the impairment, analyzing those scenarios, and producing conclusions about which stressor or stressors are causing the impairment.” (11 p. ES-1).

Following EPA guidance, an SI document was prepared in 2004 (8). In this document, identified causes of the impairment were/are ammonia, low dissolved oxygen, siltation and sediment, channelization, and temperature. Because the ammonia was linked to a single fish kill, and that a single fish kill does not qualify a water body for listing on the 303(d) list, ammonia will not be included in the TMDL.

Recommended actions, as stated in the SI document for the Little Floyd River (8 p. 13) are as follows:

> *Ammonia*
> Incorporation of applied manure and careful monitoring of the amount applied would be helpful in reducing the influence of ammonia in the watershed. In addition, regular inspection of pits and lagoons, particularly during wet-weather periods, will help prevent discharges related to structural failure.
>
> *Dissolved Oxygen*
> Dissolved oxygen levels are likely related to the thermal condition of the river. For this reason, addition of shade-providing trees and/or shrubs to the riparian zone and reductions in heat-holding sediment loads may help reduce oxygen stress. In addition, riffle structures would increase reaeration of the stream while providing improved habitat.
>
> *Silt/Sediment*
> A reduction in bed/bank, sheet/rill and gully erosion should decrease the siltation and sedimentation of the streambed.
>
> *Channelization*
> Limiting future channelization projects and the addition of meanders to the currently channelized stretched would help the recovery of the biological community in the Little Floyd River.
>
> High Temperature/Temperature Flux
> The thermal condition of the Little Floyd River could be improved by the addition of trees and/or shrubs to buffer areas and by reductions in heat-holding sediment loads.

Sediment load allocations are estimated for this TMDL. However, only a generic oxygen demand pollutant load, rather than to specific sources of oxygen demand, is being assigned in Phase 1 of this TMDL due to limited data and information. Additional monitoring and data collection will occur in the next five years to help quantify the loads and frequency of occurrences of pollutants with the purpose of allocating a more refined pollutant load(s) in Phase 2.

Data Sources

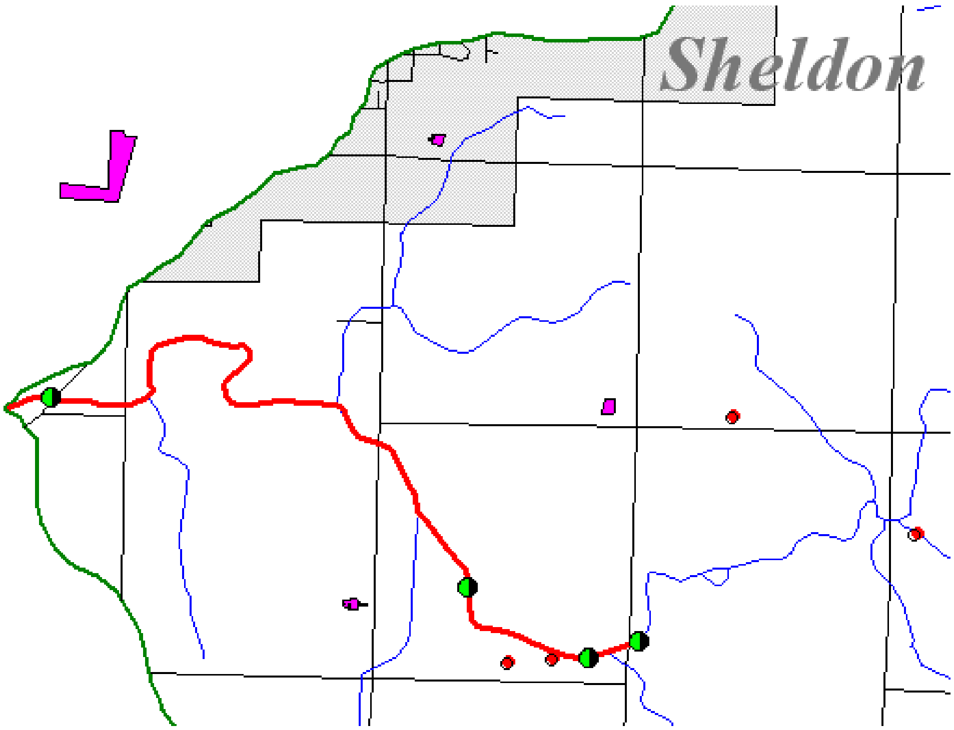
Information on the impacted biological community was collected through biological sampling at four locations in 1999, 2001, and 2002 and shown in Figure 1. Details of the sites sampled and the sample results may be found in Appendix I of the Stressor Identification (SI) document (8). The SI document can be obtained from the DNR TMDL and Water Quality Assessment Section.

Water chemistry data was collected by UHL from April through November of 2001 and March through October of 2003 at two of the sites where the biological monitoring was conducted. Several event samples were also collected at the downstream location. A data sonde was deployed for three weeks in 2003 to measure fluctuations in DO and temperature. Details may be found in Appendix II of the SI document.

Water chemistry, sediment, and fish tissue data was collected in association with a Regional Environmental Monitoring and Assessment Program (REMAP) study in the summer of 2002. A data sonde to measure DO and temperature was also deployed at the REMAP site for two weeks in 2002. See Appendix II of the SI document for further details.

Additional data is available from the City of Sanborn wastewater treatment facility, an Iowa Department of Environmental Protection study in 1976-1977, and a 1953 water quality report.

Figure 1. Little Floyd River Stream Assessment Locations 1999-2002.



Interpreting Little Floyd River Water Quality Data

High levels of ammonia have been detected infrequently in the Little Floyd River. However, application of hog manure on October 31, 2003 followed by a storm event caused a fish kill over a four-mile stretch of the river. The storm event triggered the UHL event sampler on November 1. The pre- and post-peak samples registered ammonia levels of 4.9 and 6.5 mg/l, respectively. The acute toxicity threshold for ammonia is 5.72 mg/L for the monitored conditions when the pre- and post-peak samples were collected. These ammonia levels exceed the chronic limit and are associated with a known fish kill that included the three upstream biological sampling sites.

Dissolved oxygen measurements taken over 2 separate two-week periods in August of 2002 and 2003 by data sondes show that oxygen levels fluctuate widely over a 24-hour period. The August samples show DO levels dipping below 4 mg/l for several hours per night on several nights each summer. Monthly grab samples collected by UHL show DO levels within acceptable limits except for a level of 3.3 mg/l at the downstream site on March 11, 2003. This same day, DO at the upstream site was 6.7 mg/l and the temperature was 0°C at both sites.

Potential Pollution Sources

Evaluation of effluent CBOD5 and ammonia values from the City of Sanborn wastewater treatment plant were used to estimate the impact of the discharge on impaired stream segment dissolved oxygen concentration. The plant consists of a conventional activated sludge treatment process followed by several storage and treatment lagoon cells. The storage capacity of these cells is sufficient to significantly reduce the frequency of discharge to the stream. The critical condition for the impaired segment is for a flow less than 19 cfs and a minimum daily temperature greater than 20 degrees Celsius. It will always be in July, August, and September when these conditions occur. In drier years, the plant discharges for only three or four months from the lagoon cells.

The table below shows the Sanborn lagoon discharge flow, CBOD5, and ammonia data for the last ten years as well as the estimated stream flow in the impaired segment when discharge occurred during July, August or September. On all but two occasions the estimated impaired segment stream flow exceeded the critical 19 cfs condition. These values are in Table 5.

Table 5. Monthly Average Data for Little Floyd River and Sanborn WWTP Attributes.

date	stream flow, cfs	plant flow, MGD	ammonia conc., mg/l	ammonia mass, lb/d	ammonia OD, lb/d	CBOD conc., mg/l	CBOD5 mass, lb/d	total OD, lb/d
07/31/2003	57	0.683	1.2	6.8	31.3	2.7	19.2	50.5
08/31/1998	5.1	0.436	0.2	0.7	3.2	4.8	18	21.2
09/30/1996	5.5	1.054	0.2	1.8	8.3	9	79	87.3
08/31/1995	85	1.174	0.4	3.9	17.9	3.2	31.3	49.2
9/31/95	30	1.454	0.4	4.9	22.5	5.6	67.9	90.4
07/31/1994	70	1.388	1.2	13.9	63.9	2	23.3	87.1
07/31/1993	201	1.084	1.5	1.6	7.4	7.4	67	74.4
08/31/1993	57	1.16	0.4	3.9	17.9	5.2	23	40.9
09/30/1993	40	0.972	0.15	1.2	5.5	2.7	21.9	27.4

The two times that the estimated flow was less than 19 cfs (shaded) were evaluated for CBOD5 using a Streeter Phelps Oxygen Sag model. For the modeling purposes at dry conditions it was assumed that the flow in the stream receiving the lagoon discharge was zero and that the plant flow was 1.054 million gallons per day (MGD) (July 1996) and that the receiving stream velocity is 0.1 feet per second (fps). Other model input values are:

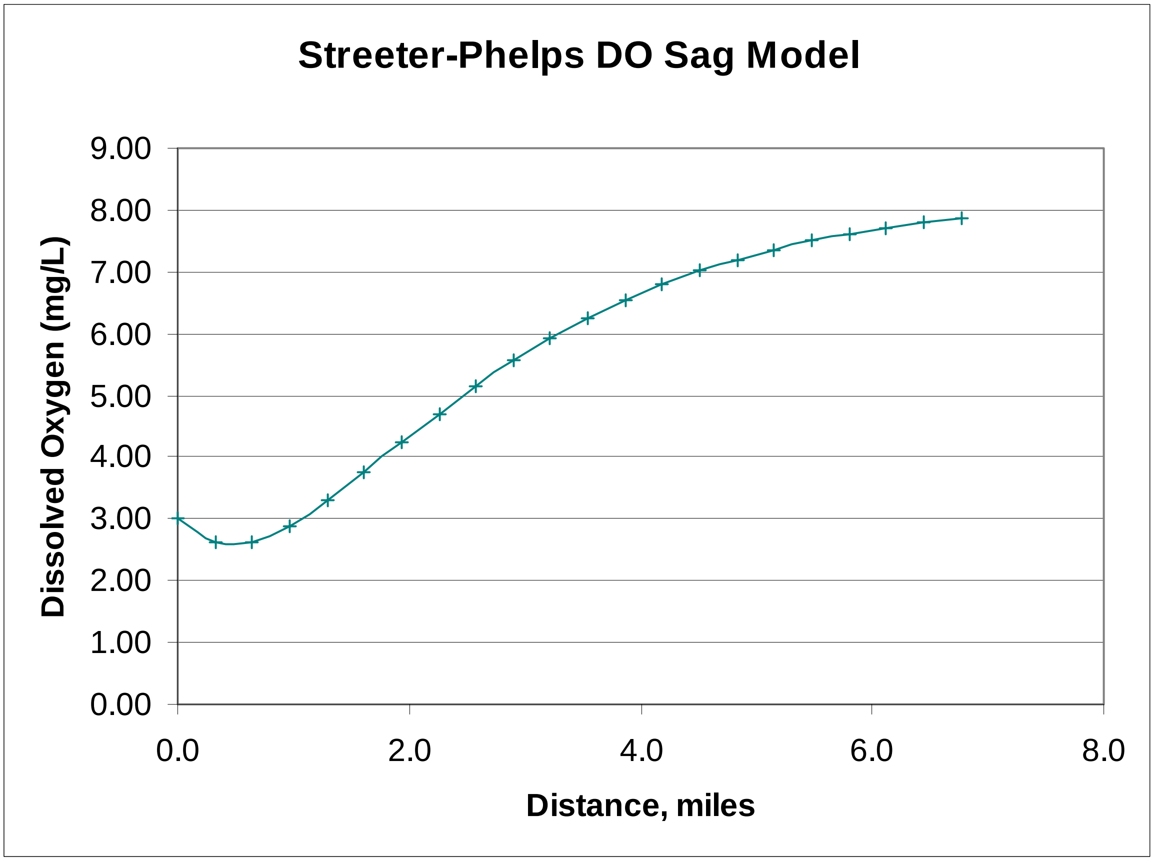
Effluent CBOD5 = 9 mg/l (measured)
Effluent BODL (Lw) = 13.5 mg/l
Stream depth (H) = 2 feet
Plant flow (Qw)= 0.7 cfs (1.054 MGD)
Effluent dissolved oxygen (DOw) = 3 mg/l
Effluent temperature (Tw) = 25 C

The re-aeration coefficient was calculated for a stream depth of 2 feet and a velocity of 0.1 feet per second using the O'Conner-Dobbins formula.

Ka = 12.9(velocity^0.5)/(depth)^1.5 = 1.44/day

The resulting oxygen sag curve is shown in Figure 2.

Figure 2. Sanborn WWTP Streeter Phelps Model Oxygen Sag Curve.



The distance from the Sanborn WWTP to the impaired segment of Little Floyd Creek is 10 miles. As can be seen from the Streeter-Phelps modeling the discharge from the plant has no impact on the DO in the impaired segment since it has risen to near saturation at about 6 miles based on impacts from the CBOD discharge. Model details can be found in Appendix E.

Natural Background Conditions

Background conditions are not separated from the current monitored conditions. Low DO is not usually considered a normal condition and is caused by oxygen demands resulting from point, nonpoint, and background sources.

3.1.2 TMDL Target

The Phase 1 water quality target of this TMDL for DO is 5.0 mg DO/L at all times as measured in the river. This target shall apply to the river segment classified as Class B(LR) from where the Little Floyd River empties into the Floyd River to the junction of the Little Floyd River with Lamkin Creek. In addition, the biological targets for ecoregion 47a will be met when the median BMIBI score is 53 or higher and the median FIBI score is 40 or higher for two consecutive sampling periods. According to the Methodology for Developing Iowa's 2002 Section 303(d) List of Impaired Waters (10), BMIBI scores of 53 or higher and FIBI scores of 40 or higher are considered 'supporting' for the aquatic life use.

Criteria for Assessing Water Quality Standards Attainment

The Water Quality Standards specifies in Table 2 of Chapter 61 (1 p.20) that Class B(LR) waters shall have the following criteria for DO: a minimum value of 5.0 mg/L for at least 16 hours of every 24-hour period and a minimum value of 4.0 mg/L at any time during every 24-hour period. Table 2 of Chapter 61 is summarized for the standard applicable for this TMDL.

Table 2. Criteria for Dissolved Oxygen
(all values expressed in milligrams per liter)

	B(LR)
Minimum value for at least 16 hours of every 24-hour period	5.0
Minimum value at any time during every 24-hour period	4.0

Selection of Environmental Conditions

The critical conditions for the DO impairment is when the average daily streamflow is equal to or less than 68,400 cu ft/hr (19 cfs) and minimum daily water temperature is greater than 20 degrees Celsius. Conditions meeting both of these criteria occur during the critical low-flow conditions (e. g. July, August, September). Appendix A illustrates the impact low flow and high water temperatures have on DO concentrations.

Major contributors of oxygen to the water include atmospheric reaeration and plants and algae producing oxygen through photosynthesis. Major sources of oxygen demand include respiring plants, animals, and other organisms; decaying organic matter; and chemical processes requiring oxygen. The diurnal fluctuation of DO in the water is the shift of plants producing oxygen in excess of their respiration needs during daylight hours during photosynthesis to removing oxygen during respiration in the absence of sunlight. This diurnal fluctuation becomes more pronounced as the summer progresses due to: (1) the increased productivity of algae and other plants, (2) warmer temperatures that lower the amount of oxygen capable of being dissolved in the water, and (3) lower stream flows limiting the quantity of DO available to meet the oxygen demand.

The late summer streamflow conditions in 1999, 2001, and 2003 when stream assessments were completed and data collected were below the long term average flow for this stream. However, these flows are not unusually low. Relatively low flow levels occur every five to ten years. The stream biological communities of the Northwest Iowa Loess Prairies ecoregion (47a) are adapted to large seasonal and annual flow variations. Furthermore, BMIBI and FIBI scores sampled at ecoregion 47a reference sites during 2001-2003 (dry) field seasons averaged slightly higher than scores obtained from the same sites sampled during the 1995-1996 (wet) years, thereby suggesting the dry conditions and low flows by themselves were not responsible for aquatic life limitations in the Little Floyd River.

Waterbody Pollutant Loading Capacity

The Little Floyd River needs to have enough dissolved oxygen in the water column in order to assimilate existing oxygen demand while maintaining at least 5 mg/L of DO in the water. The oxygen demand varies with the streamflow. Table 6 shows the oxygen demand able to be assimilated and still meet the 5 mg/L standard.

Three dates of monitored low DO conditions were selected from the data as representative of critical low flow conditions. These dates are: August 16, 2003; August 19, 2003; and August 25, 2003. These dates represent an average daily streamflow range of 7.5 to 19 cfs. Each of these dates represents worse-case scenarios when DO concentrations at night were below 4.0 mg/L DO. Average daily streamflow was obtained from USGS stream gage #006600100 near Alton and multiplied by 23% as discussed in the *Hydrology* section. A constant daily streamflow was assumed. Comparing historical maximum and minimum daily flows supported this assumption. Dissolved oxygen concentrations were obtained from a dissolved oxygen and temperature data sonde (BioDevices, Ames, IA) at 6 minute intervals. This data was manipulated to provide hourly average values. Daytime and nighttime average DO concentrations were calculated by averaging 8-hour segments from the lowest contiguous 8-hours of DO concentration (nighttime) and the highest contiguous 8-hour segments of DO concentration (daytime). These eight hour average DO concentrations from the representative low-flow critical conditions were used to calculate the average DO hourly mass. Appendix D contains data used in the *Pollution Source Assessment* section.

The oxygen demand capacity is the difference between the calculated daytime maximum oxygen mass and the oxygen mass at 5 mg/L concentration.

Table 6. Oxygen Demand Capacity at Three Stream Flows.

Streamflow (cu ft/hr)	Oxygen Demand Load Capacity (lbs/hr)
68,400	18.7
46,800	6.8
27,000	1.8

3.1.3 Pollution Source Assessment

The data in the following section is based upon the monitoring data available. Pollutant loads to specific sources of oxygen demand will be allocated and more refined after additional monitoring is completed in Phase 2 of this TMDL.

Existing Load

The existing load of oxygen demand varies with stream flow. The existing load of oxygen demand is shown in Table 7. This existing oxygen demand load is the difference between the calculated daytime oxygen mass and the nighttime oxygen mass.

Table 7. Existing Oxygen Demand at Three Stream Flows.

Streamflow (cu ft/hr)	Existing Oxygen Demand Load (lbs/hr)
68,400	22.4
46,800	10.2
27,000	3.8

Departure from Load Capacity

The existing oxygen demand load exceeds the oxygen demand capacity of Little Floyd River during low flow conditions during the summer at night. This departure from load capacity varies with streamflow and is shown in Table 8. This departure is the difference between the mass of oxygen at 5 mg/L and the mass of oxygen at nighttime.

Table 8. Departure From Oxygen Demand Capacity at Three Stream Flows.

Streamflow (cu ft/hr)	Departure From Oxygen Demand Load Capacity (lbs/hr)
68,400	3.7
46,800	3.4
27,000	2.0

Identification of Pollutant Sources

Potential pollutant sources include both point and non point sources. The Sanborn WWTP does discharge into a tributary of the Little Floyd River. However, during the last ten years it discharged nine times (Table 5) when the critical conditions most likely exist (4). Therefore, any contributions from the Sanborn WWTP are insignificant and are not included. Non point sources include runoff from agricultural and urban areas.

Linkage of Sources to Target

Loads creating oxygen demand originate from non point sources. To meet the TMDL target and Iowa Water Quality Standards of 5.0 mg/L, oxygen demand needs to be reduced and/or dissolved oxygen levels in the river need to increase.

3.1.4 Pollutant Allocation

Wasteload Allocation

The Sanborn WWTP is the only point source in the watershed. However, the results from the Streeter-Phelps model detailed in the *Potential Pollution Sources* section and Appendix E show that the Sanborn WWTP does not contribute to the OD in the impaired stream segment. Therefore the wasteload allocation is set at zero.

Load Allocation

The load allocation varies with the streamflow. Table 9 shows the load allocation for three streamflows. [Load allocation = Oxygen demand capacity – explicit margin of safety (MOS)].

Table 9. Oxygen Demand Load Allocation at Three Stream Flows.

Streamflow (cu ft/hr)	Oxygen Demand Load Allocation (lbs/hr)
68,400	16.8
46,800	6.1
27,000	1.6

Margin of Safety

The margin of safety for this TMDL is implicit and explicit. Calculations were made using a DO target of 5.0 mg/L. The Iowa Water Quality Standards allow DO concentrations down to 4.0 mg/L for up to eight hours per 24-hour period. An explicit 10% of the oxygen demand capacity is also used as an additional MOS.

3.1.5 Dissolved Oxygen TMDL Summary

Table 10 summarizes the DO TMDL for a range of stream flows.

TMDL = wasteload allocation (WLA) + Load Allocation (LA) + margin of safety (MOS)

Table 10. TMDL for Oxygen Demand Summary at Three Stream Flows.

Streamflow (cu ft/hr)	TMDL (lb/hr)	WLA (lb/hr)	LA (lb/hr)	MOS (lb/hr)
68,400	18.7	0	16.8	1.9
46,800	6.8	0	6.1	0.7
27,000	1.8	0	1.6	0.2

3.2 TMDL for Sediment

3.2.1 Problem Identification

Impaired Beneficial Uses and Applicable Water Quality Standards

The Surface Water Classification document (9 p.10) lists the designated use for Little Floyd River as Aquatic Life (Class B(LR)). In 1998, the Little Floyd River was included on the impaired waters list based on a 1990 stream usel assessment conducted by the IDNR. The cause of the impairment at that time was *unknown*. Additional water quality monitoring and biological stream assessments by IDNR and UHL were completed to help determine the cause of the impairment. In 2004 using the additional information, a Stressor Identification (SI) (8) document was prepared for the Little Floyd River.

In 2000, Little Floyd River was not assessed due to a lack of updated information. In 2002 and 2004, the Class B designated use was re-assessed as "partially supporting." The assessment of partial support was based upon biological monitoring conducted in 1999, 2001, and 2002 as well as monthly monitoring conducted by UHL and the DNR in 2001. Little Floyd River was listed based initially upon low scores on the Fish Index of Biotic Integrity (FIBI) and Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI). The biotic indexes rank the biological integrity of a stream sampling reach on a rising scale from 0 (minimum) to 100 (maximum). Table 4 summarizes the results of the biological assessments completed on the Little Floyd River. Figure 1 shows the locations of the assessment sites.

The biotic indexes rank the biological integrity of a stream sampling reach on a rising scale from 0 (minimum) to 100 (maximum). Table 11 summarizes the results of the biological assessments completed on the Little Floyd River. Figure 1 (page 8) shows the locations of the assessment sites.

Table 11. Index of Biotic Integrity Scores for the Little Floyd River.

Site	Year	FIBI	BMIBI
Reference Standard		40	53
Site 1 (upstream of bridge)	**1999**	28 (fair)	41 (fair)
Site 52 (downstream of bridge)	**2001**	39 (fair)	65 (good)
Site 51 (downstream site)	**2001**	41 (fair)	34 (poor)
REMAP Site	**2002**	33 (fair)	52 (fair)

Data Sources

Information on the impacted biological community was collected through biological sampling at four locations in 1999, 2001, and 2002. Details of the sites sampled and the sample results may be found in Appendix I of the Stressor Identification (SI) document (8). The SI document can be obtained from the DNR TMDL and Water Quality Assessment Section or from the DNR website.

A field assessment was completed by the Iowa DNR in June 2004. This field assessment collected information on landuse and cropping practices. Information from the DNR geographical information system (GIS), local NRCS staff, and the field assessment was used to develop soil erosion estimates using the Revised Universal Soil Loss Equation (RUSLE) (3,5). Sediment delivery estimates were made using the NRCS Soil Erosion and Sediment Delivery procedure (2).

Interpreting Little Floyd River Water Quality Data

Siltation and sedimentation problems are indicated by habitat data collected by the DNR/UHL biological assessment team (8, p. 14). The percent of total fine substrate is greater than the average and median for the ecoregion reference locations. The percent silt is far greater than expected based on reference sites. The relative lack of riffle also limits the diversity of habitats available to aquatic organisms and thereby limits the diversity of the organisms themselves. Table 12 summarizes this data.

Table 12. Comparison of siltation indicators at Little Floyd River sites to reference sites for the ecoregions. Reference values are average, median.

Parameter	9/14/1999 1999 Assessment	9/11/2001 Site 51 (downstream)	9/12/2001 Site 52 (upstream)	8/22/2002 Remap Site	Region 47a Reference
% total fines	95	85	75	80	62, 59
% silt	58	42	32	29	13, 13
% riffle	0	5	11	0	13, 15
% run	52	71	36	50	62, 60.5
% pool	48	23	54	50	24, 21.5

Potential Pollution Sources

The only potential sediment sources are nonpoint. There are no significant point sources of sediment in the watershed. The nonpoint sources of sediment are from sheet and rill erosion from row crop fields, gully erosion, and streambed and bank erosion.

Natural Background Conditions

Background sedimentation was not separated from the estimated sedimentation rate.

3.2.2 TMDL Target

According to the Methodology for Developing Iowa's 2002 Section 303(d) List of Impaired Waters (10), BMIBI scores of 53 or higher and FIBI scores of 40 or higher are considered 'supporting' for the aquatic life use. Excessive fine sediments reduce the availability of favorable spawning sites for fish and buries desirable habitat for benthic macroinvertebrates, thus reducing BMIBI and FIBI scores. Reducing sedimentation in Little Floyd River will help improve the BMIBI and FIBI scores by reducing the amount of fine sediments, reducing the amount of sediment oxygen demand, and reducing the amount of heat additions through heat absorption by dark-colored sediment.

Criteria for Assessing Water Quality Standards Attainment

There are no numeric standards for sediment. The stream has excessive amount of fine sediments on the stream bottom adversely affecting aquatic life. Water quality standards will be considered attained when the biological targets for ecoregion 47a are met. According to the Methodology for Developing Iowa's 2002 Section 303(d) List of Impaired Waters (10), BMIBI scores of 53 or higher and FIBI scores of 40 or higher are considered 'supporting' for the aquatic life use.

Selection of Environmental Conditions

The critical condition for this TMDL is the annual average sediment deposition in the stream. The RUSLE (3, 5) model estimates soil erosion rates based on long term averages. The estimated sheet and rill erosion rate in the watershed is approximately 2 tons per acre per year, or 81,600 tons per year. The NRCS Erosion and Sediment Delivery procedure (2) estimates 20 percent of the RUSLE-calculated erosion, or 16,300 tons per year, as being delivered to a water body. In addition, 25% of the sediment delivered by sheet and rill erosion (4,100 tons/yr) is estimated to be delivered by gully and stream bank and bed erosion (6) for a total of 20,400 tons per year delivered to Little Floyd River.

Waterbody Pollutant Loading Capacity

The loading capacity is the amount of fine sediment and silt that can be delivered to the river and still meet the BMIBI and FIBI scores of "fully supporting". The allowable fine sediment and silt delivery to the Little Floyd River is 8,800 tons per year.

3.2.3 Pollution Source Assessment

Existing Load

The existing load using the RUSLE and NRCS Erosion and Sediment Delivery (3, 2) procedure and estimates for gully and streambank erosion is 20,400 tons of sediment delivered to the river per year. The RUSLE map developed using data collected in 2004 is shown in Appendix C.

Departure from Load Capacity

The target is based upon the biologic indicators. Decreasing the amount of sediment will improve habitat and allow aquatic species to survive and reproduce. Metrics used to determine biologic indicators are used to compare monitored stream segments to stream reference sites within the same ecoregion. Stream segments having FIBI or BMIBI scores at the 25th percentile or lower of reference sites are considered impaired. The critical metric for sedimentation for the Little Floyd River is the percent silt on the streambed. The median percent silt observed during the stream assessments from 1999 to 2002 is 37%. The 25th percentile median percent silt in the reference streams from 1994 to 2002 is 16%. The percent silt in the streambed would need to be reduced from 37% to 16% silt, a 57% reduction. Assuming a 1:1 relationship between percent silt in the stream and sedimentation, a 57% reduction of sediment, or 11,600 tons per year is required. Data from the stream reference sites is found in Appendix F.

Identification of Pollutant Sources

The sediment originates from sheet and rill erosion from agricultural land, streambanks, and gullys.

Linkage of Sources to Target

Including background sources of sediment, the sources of sediment are entirely from nonpoint sources. The estimated sheet and rill erosion from agricultural land using the RUSLE model and the NRCS Erosion and Sediment Delivery Procedure is 16,300 tons per year plus and an additional 4,100 tons per year for sediment from streambanks and gullys.

3.2.4 Pollutant Allocation

Wasteload Allocation

There are no significant point source discharges of sediment. Therefore, the wasteload allocation is zero.

Load Allocation

The load allocation is set at 7,920 tons per year.

Margin of Safety

An explicit margin of safety is set at 10% of the load capacity, or 880 tons per year (8,800 t/yr x 10%).

3.2.5 Sediment TMDL Summary

TMDL = wasteload allocation + load allocation + margin of safety
= zero tons per year + 7,920 tons per year + 880 tons per year
= 8,800 tons per year

4. Implementation Plan

The Iowa Department of Natural Resources recognizes that an implementation plan is not a required component of a Total Maximum Daily Load. However, the IDNR offers the following implementation strategy to DNR staff, partners, and watershed stakeholders as a guide to improving water quality at Little Floyd River. Because OD and sedimentation interact and both adversely affect the aquatic life uses of Little Floyd River, an adaptive management approach is recommended. In this approach management practices to reduce both OD and sedimentation loads are incrementally applied and the results monitored to determine if water quality goals have been achieved. Also, the reductions in these loads will require land management changes that take time to implement. For these reasons, the following timetable is suggested for watershed improvements:

- Reduce the current excess OD and sediment loading by 40% by 2010.
- Reduce the current excess OD and sediment loading by an additional 30% by 2015.
- Reduce the current excess OD and sediment loading the last 30% by 2020.

The excessive oxygen demand impairment can be addressed by lowering the oxygen demand and/or by increasing the amount of oxygen in the river. Recommendations include:

- Install riffle structures in the stream channel to increase oxygen levels in the water and increase structure diversity in the river.
- Retain existing meanders in, or increase the sinuosity of, the river through appropriate incentives.
- Use existing incentive programs to encourage the installation of diverse riparian buffers including trees. Riparian buffers will trap sediment, increase the diversity of habitat for aquatic life, and provide shade lowering daily water temperature thereby increasing oxygen concentration.

Reducing the amount of sediment delivered to Little Floyd River can be addressed through a variety of management and structural measures. Soil erosion rates can be reduced even further by adopting conservation tillage systems, specifically no till and strip tillage. Terraces, grass waterways, and water and sediment control basins can be used where appropriate to control soil erosion.

Sediment delivery can be reduced by strategically placing contour grass buffer strips on sediment-producing slopes and filterstrips below sediment-producing areas. Riparian buffer strips along streams and drainage ditches can trap and filter out sediment before it can enter the water course. Excluding livestock from streams, minimizing the amount of time livestock have in the stream, or constructing crushed rock or concrete crossings will also reduce sedimentation in the stream caused by livestock.

Although the Stressor Identification protocol identified ammonia as one of the stressors causing the impairment of the Little Floyd River, allocations were not made in this TMDL. The ammonia listing was based upon a single manure spill containing ammonia that caused a fish kill in 2003. Allocations for this pollutant were deemed inappropriate due to the accidental nature of this single release. However, because the prevention of fish kill events is important to the maintenance of healthy aquatic communities, the DNR recommends the following:

- Incorporation of applied manure and careful monitoring of the amount applied to minimize the chance of manure running off into water courses or into tile intakes.
- Regular inspection of pits and lagoons, particularly during wet-weather periods, to prevent discharges related to structural failure.
- Rapid reporting of leaks and spills to the DNR to ensure that proper containment and clean-up procedures are implemented.

5. Monitoring

Further monitoring is needed on the Little Floyd River to followup on the implementation of the TMDL. This monitoring will meet the minimum data requirements established by Iowa's 305(b) guidelines for a complete water quality assessment (10 samples over two years, assessments conducted during the most recent five complete calendar years, etc.). This data will be collected by 2012 allowing time for measurable improvements in the biological system to develop after watershed improvements are in place. The TMDL program is committed to monitoring waters where TMDLs have been completed. In the absence of a statewide stream monitoring program, followup monitoring will be conducted through the TMDL program.

6. Public Participation

Public meetings were held June 15, 2004 with the O'Brien Soil and Water Conservation District. A review of the draft TMDL for Little Floyd River was held January 21, 2005. Comments received were reviewed and given consideration and, where appropriate, incorporated into the TMDL.

7. References

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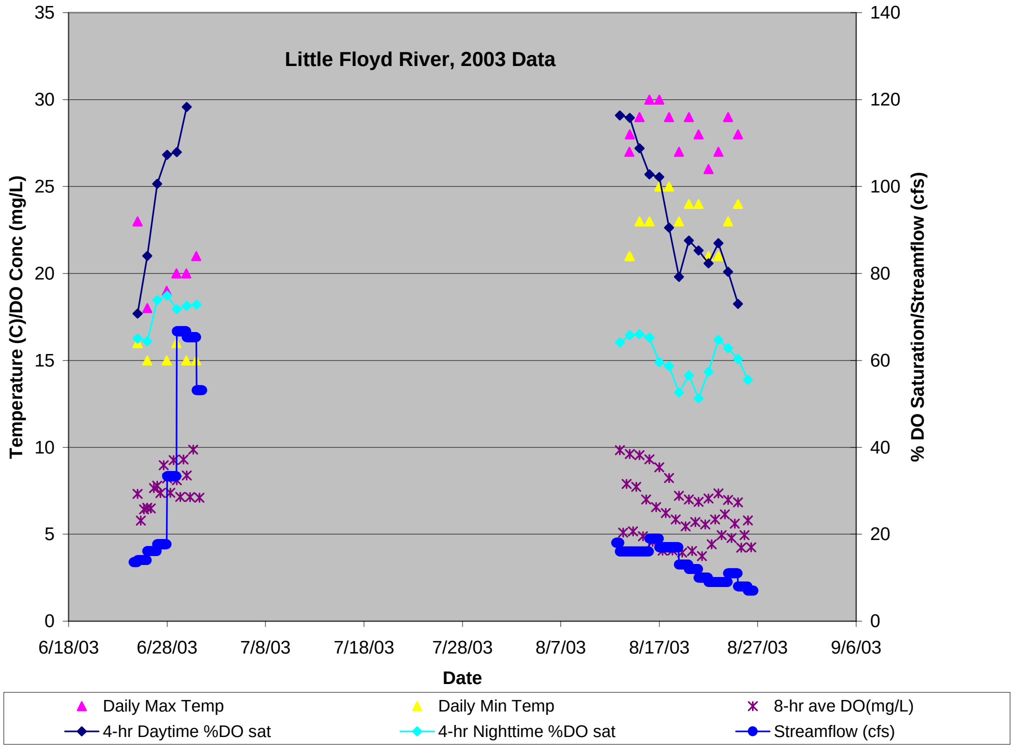
9. Water Resources Section, Water Quality Bureau, Environmental Services Division. 2004. Surface water classification. Iowa Department of Natural Resources, Des Moines, Iowa. [online]. Available at http://www.iowadnr.com/water/standards/files/swc.pdf (verified 17 Feb. 2005.)

10. TMDL and Water Quality Assessment Section, Water Quality Bureau, Environmental Services Division. 2002. Methodology for developing Iowa's 2002 Section 303(d) list of impaired waters. Iowa Department of Natural Resources, Des Moines, Iowa. [online]. Available at http://www.iowadnr.com/water/tmdlwqa/wqa/303d/2002/2002_303d_methodology.pdf (verified 17 Feb. 2005.)

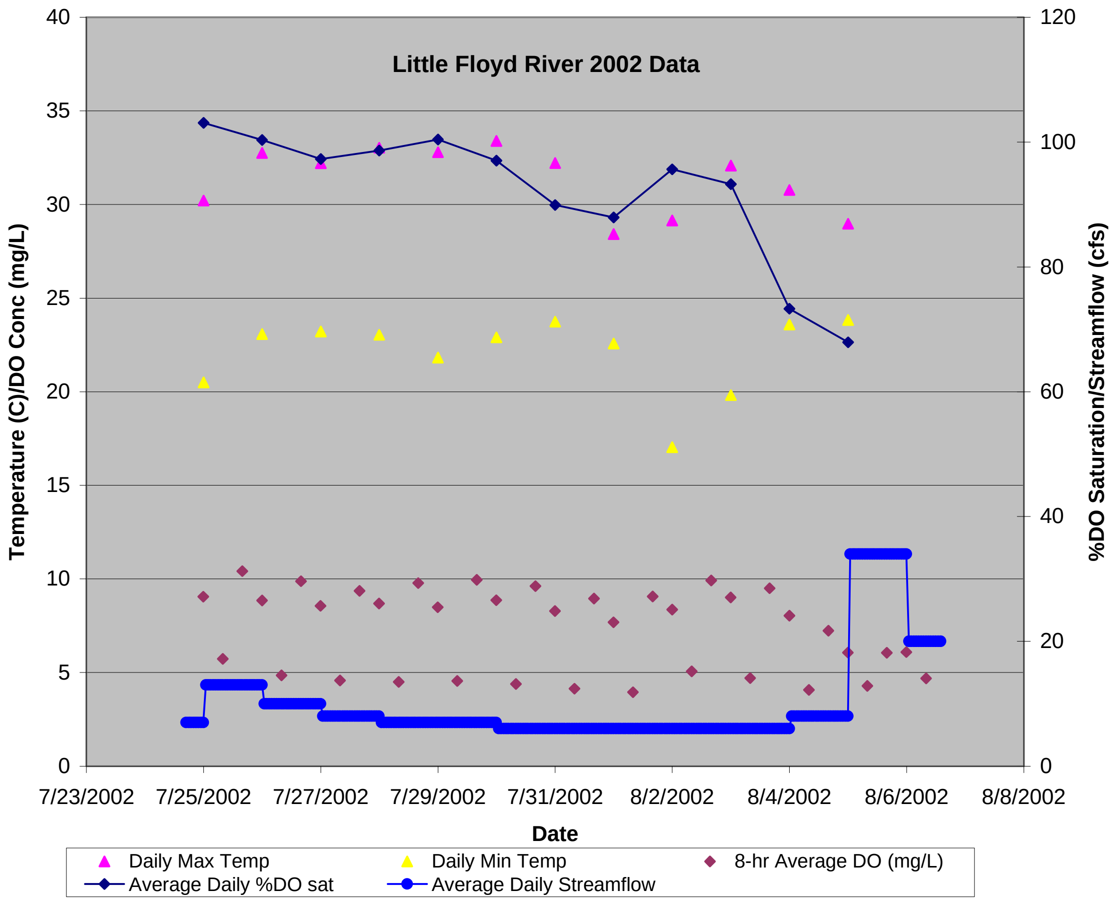
11. U. S. Environmental Protection Agency, Office of Water. 2000. Stressor Identification Guidance Document. EPA 822-B-00-025. United States Environmental Protection Agency, Washington DC.

8. Appendix A – Selected Water Monitoring Data for Determining Dissolved Oxygen Critical Criterion

Appendix A-1. Little Floyd River, 2003 Data.



Appendix A-2. Little Floyd River, 2002 Data.



9. Appendix B – Watershed Maps

Figure B-1. Watershed map of the Little Floyd River.

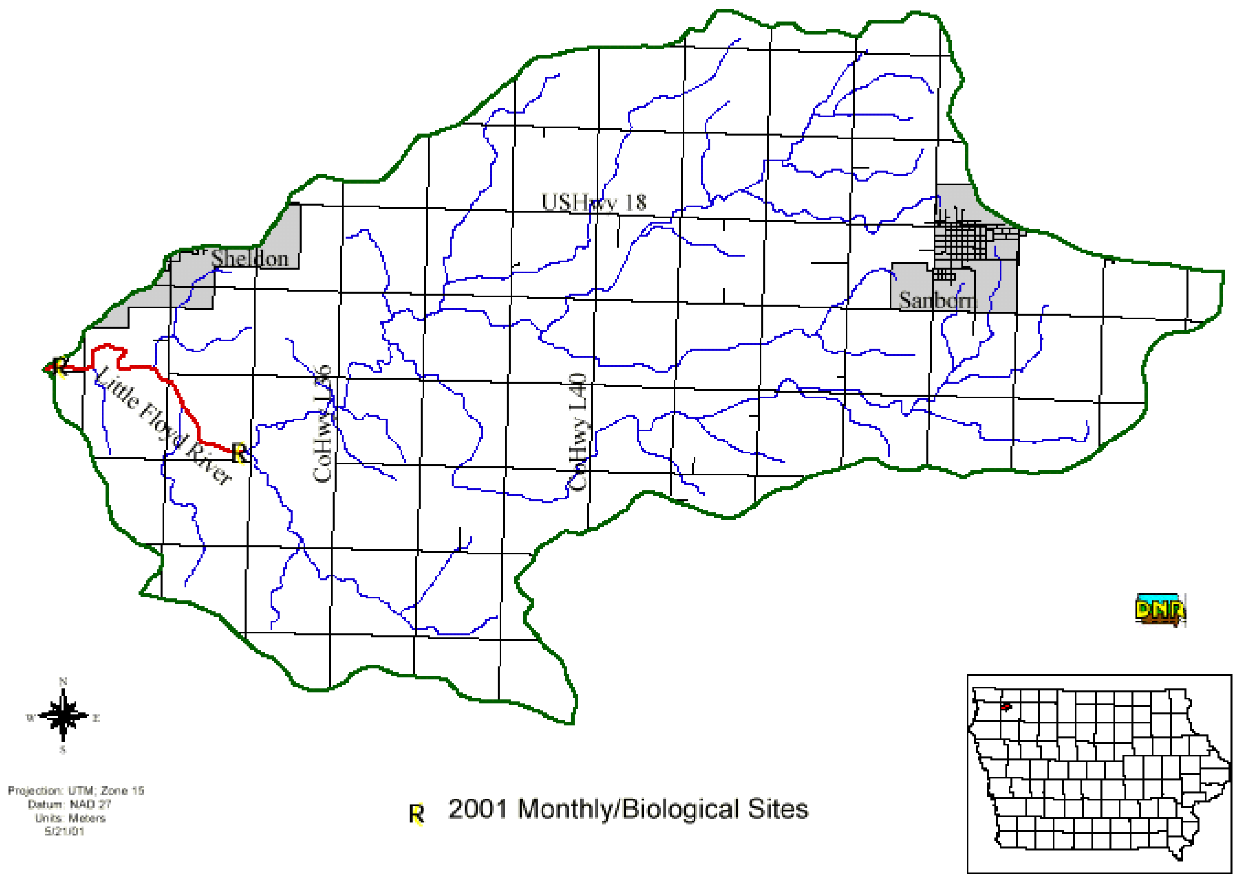
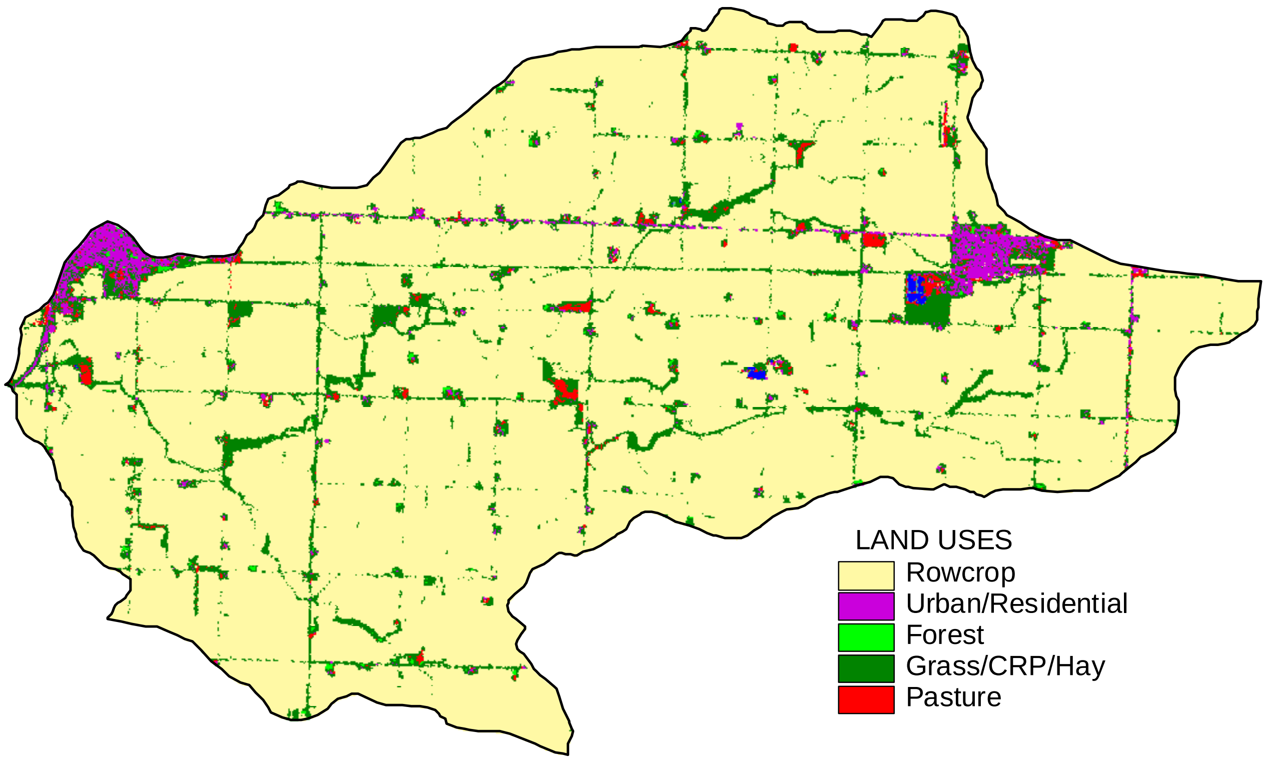
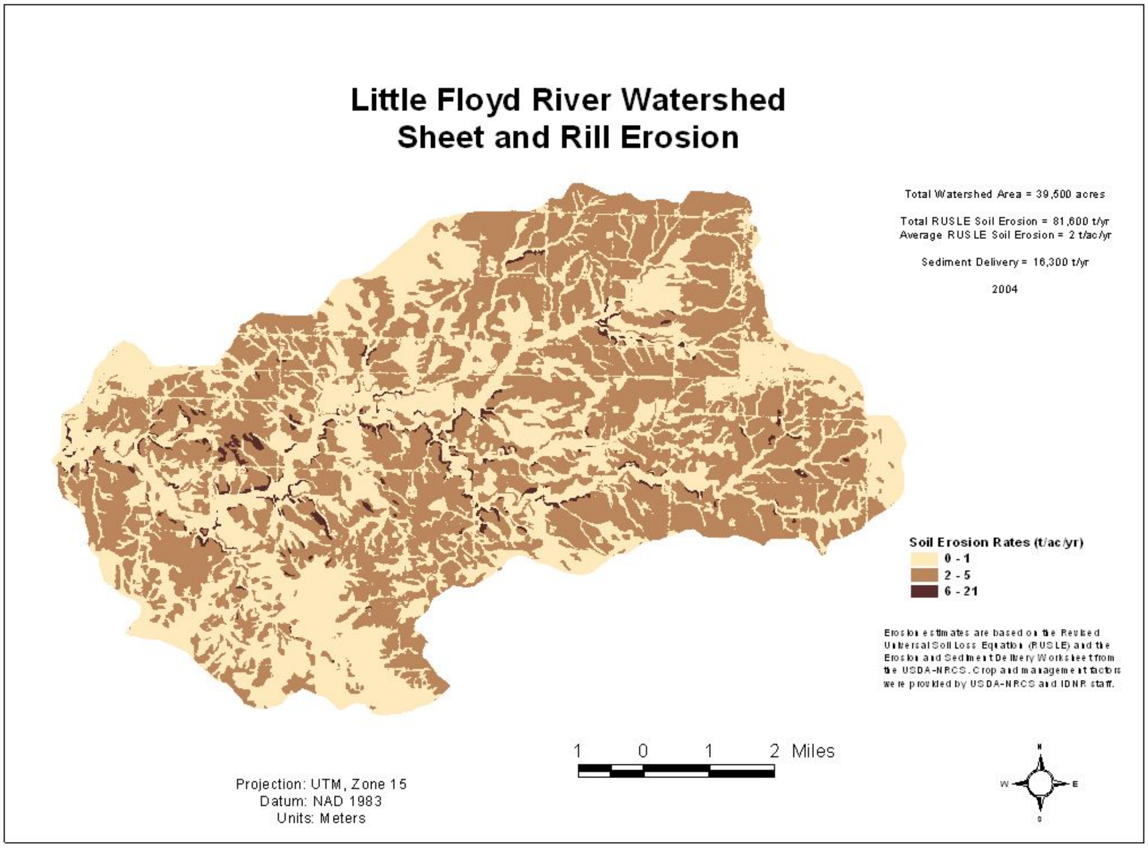


Figure B-2. Land use in the Little Floyd River Watershed based on 2002 satellite imagery.



10. Appendix C—Little Floyd River Watershed Soil Erosion Map



11. Appendix D—Data Used to Calculate Dissolved Oxygen and Oxygen Demand for Pollution Assessment

Date/Time	Flow (cfs)	Flow Mass (cu ft/hr)	TEMP (hr)	DO (mg/L)	DO(sat) @760 mm Hg	%DO sat	DOhr (lb)	DOhr 5ppm (lb)	Diff from 5ppm (lbs)
8/16/03 3:00			26	4.8	8.1	60	20.6	21.4	-0.7
8/16/03 4:00			26	4.3	8.1	53	18.2	21.4	-3.1
8/16/03 5:00			25	4.0	8.2	48	16.9	21.4	-4.4
8/16/03 6:00			24	3.9	8.4	46	16.5	21.4	-4.9
8/16/03 7:00			24	3.8	8.4	46	16.4	21.4	-5.0
8/16/03 8:00			23	3.9	8.6	45	16.6	21.4	-4.8
8/16/03 9:00			23	4.1	8.6	47	17.3	21.4	-4.0
8/16/03 10:00			23	4.5	8.6	52	19.0	21.4	-2.3
8/16/2003 night	**19**	**68400**		**4.1**		**50**	**17.7**	**21.4**	**-3.7**
8/16/03 15:00			27	8.8	8.0	110	37.4	21.4	16.0
8/16/03 16:00			28	9.5	7.8	122	40.8	21.4	19.4
8/16/03 17:00			29	10.0	7.7	130	42.6	21.4	21.3
8/16/03 18:00			30	10.3	7.5	136	43.8	21.4	22.4
8/16/03 19:00			30	10.1	7.5	133	42.9	21.4	21.6
8/16/03 20:00			30	9.5	7.5	126	40.6	21.4	19.2
8/16/03 21:00			30	8.8	7.5	117	37.6	21.4	16.3
8/16/03 22:00			30	8.2	7.5	108	34.8	21.4	13.5
8/16/2003 day	**19**	**68400**		**9.4**		**123**	**40.1**	**21.4**	**18.7**
8/19/03 3:00			26	4.1	8.1	51	12.0	14.6	-2.6
8/19/03 4:00			25	3.9	8.2	47	11.3	14.6	-3.3
8/19/03 5:00			25	3.8	8.2	46	11.0	14.6	-3.6
8/19/03 6:00			24	3.7	8.4	44	10.7	14.6	-3.9
8/19/03 7:00			24	3.5	8.4	42	10.4	14.6	-4.2
8/19/03 8:00			24	3.5	8.4	42	10.3	14.6	-4.3
8/19/03 9:00			24	3.7	8.4	44	10.9	14.6	-3.7
8/19/03 10:00			23	4.4	8.6	52	12.9	14.6	-1.7
8/19/2003 night	**13**	**46800**		**3.8**		**46**	**11.2**	**14.6**	**-3.4**
8/19/03 15:00			25	6.8	8.2	82	19.7	14.6	5.1
8/19/03 16:00			26	7.5	8.1	92	21.8	14.6	7.2
8/19/03 17:00			27	7.8	8.0	98	22.8	14.6	8.2
8/19/03 18:00			27	7.9	8.0	100	23.1	14.6	8.5
8/19/03 19:00			27	7.8	8.0	98	22.8	14.6	8.2
8/19/03 20:00			27	7.5	8.0	94	21.9	14.6	7.3
8/19/03 21:00			27	7.0	8.0	88	20.4	14.6	5.8
8/19/03 22:00			27	6.5	8.0	81	18.9	14.6	4.3
8/19/2003 day	**13**	**46800**		**7.3**		**92**	**21.4**	**14.6**	**6.8**

8/25/03 4:00			26	4.2	8.1	52	7.0	8.4	-1.4
8/25/03 5:00			26	3.9	8.1	48	6.5	8.4	-1.9
8/25/03 6:00			25	3.7	8.2	44	6.1	8.4	-2.3
8/25/03 7:00			25	3.5	8.2	42	5.9	8.4	-2.6
8/25/03 8:00			25	3.5	8.2	43	5.9	8.4	-2.5
8/25/03 9:00			24	3.7	8.4	44	6.2	8.4	-2.2
8/25/03 10:00			25	3.9	8.2	48	6.6	8.4	-1.8
8/25/03 11:00			25	4.2	8.2	51	7.1	8.4	-1.3
8/25/2003 night	**7.5**	**27000**		**3.8**		**46**	**6.4**	**8.4**	**-2.0**
8/25/03 14:00			27	5.7	8.0	72	9.6	8.4	1.2
8/25/03 15:00			28	5.9	7.8	76	10.0	8.4	1.6
8/25/03 16:00			28	6.2	7.8	80	10.5	8.4	2.1
8/25/03 17:00			28	6.4	7.8	82	10.8	8.4	2.3
8/25/03 18:00			28	6.4	7.8	82	10.8	8.4	2.3
8/25/03 19:00			27	6.1	8.0	77	10.3	8.4	1.8
8/25/03 20:00			27	5.9	8.0	74	9.9	8.4	1.5
8/25/03 21:00			27	5.6	8.0	71	9.5	8.4	1.1
8/25/2003 day	**7.5**	**27000**		**6.0**		**77**	**10.2**	**8.4**	**1.7**

12. Appendix E—Sanborn Wastewater Treatment Plant Dissolved Oxygen (DO) Sag Curve.

Streeter-Phelps DO Sag Model

Waste Load

Q_w (m^3/s) =	**0.0190**
L_w (mg/L) =	**13.50**
DO_w (mg/L) =	**3.00**
T_w (C) =	**25.0**

Upstream Conditions

Q_r (m^3/s) =	**0**
L_r (mg/L) =	**5.00**
DO_r (mg/L) =	**5.00**
T_r (C) =	**25.0**

13.0

Stream velocity (m/s) = **0.03**

DO Saturation at T_a (mg/L) = 8.26

A

Mass Balance at Point of Mixing, A

Q_a (m^3/s) =	0.02
L_a (mg/L) =	13.50
DO_a (mg/L) =	3.00
T_a (C) =	25.0
D_a (mg/L) =	5.26

Instream Rate Coefficients

	Theta	20 C	T_a
BOD: k_d	**1.135**	**0.465**	0.877
O_2 Trans: k_r	**1.024**	**1.440**	1.621

Mimimum D (mg/L) = 5.68

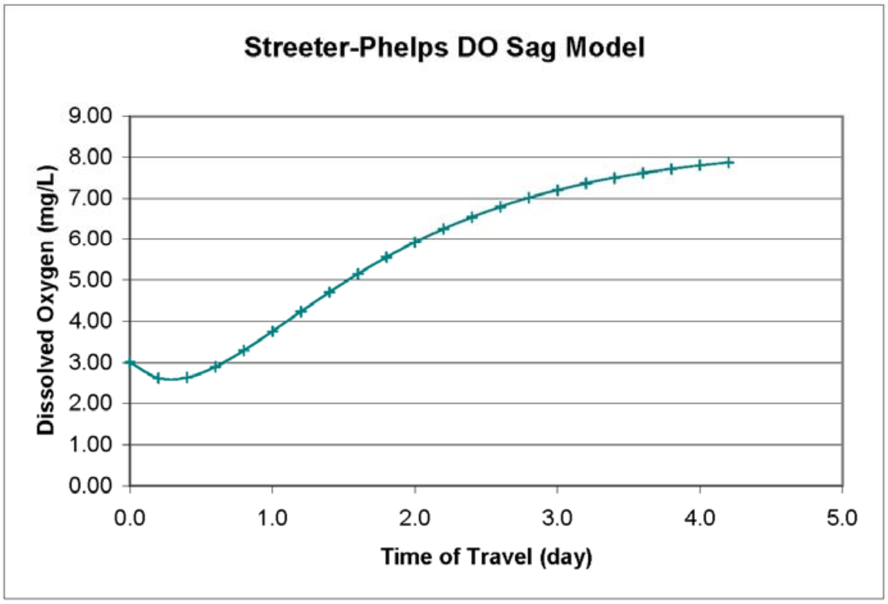
Minimum DO (mg/L) = 2.58

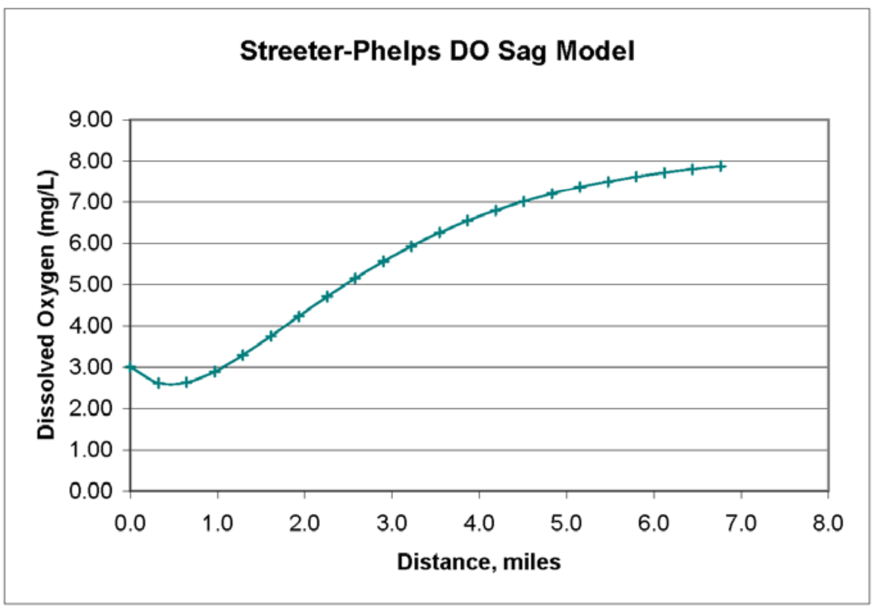
Time to Minimum DO (d) = 0.29

Location of Minmum DO (km) = 0.74

Dissolved Oxygen Computations

Time (d)	Distance (km)	D (mg/L)	DO (mg/L)	distance (miles)
0.0	0.00	5.26	3.00	0.0
0.200	0.52	5.65	2.61	0.3
0.4	1.04	5.63	2.63	0.6
0.6	1.56	5.37	2.89	1.0
0.8	2.07	4.98	3.29	1.3
1.0	2.59	4.51	3.75	1.6
1.2	3.11	4.03	4.23	1.9
1.4	3.63	3.56	4.70	2.3
1.6	4.15	3.11	5.15	2.6
1.8	4.67	2.71	5.56	2.9
2.0	5.18	2.34	5.93	3.2
2.2	5.70	2.01	6.25	3.5
2.4	6.22	1.72	6.54	3.9
2.6	6.74	1.47	6.79	4.2
2.8	7.26	1.25	7.01	4.5
3.0	7.78	1.06	7.20	4.8
3.2	8.29	0.90	7.36	5.2
3.4	8.81	0.76	7.50	5.5
3.6	9.33	0.65	7.62	5.8
3.8	9.85	0.55	7.72	6.1
4.0	10.37	0.46	7.80	6.4
4.2	10.89	0.39	7.88	6.8


Streeter-Phelps DO Sag Model
Dissolved Oxygen (mg/L)
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.0
1.0
2.0
3.0
4.0
5.0
Time of Travel (day)


Streeter-Phelps DO Sag Model
Dissolved Oxygen (mg/L)
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
Distance, miles

13. Appendix F—Ecoregion 47a Reference Sites Sediment Observations, 1994-2002.

Ecoregion 47a Biological Assessment Sediment Observations, 1994-2002

Site #	EcoReg Desig	Thermal	Sum Total Fines	Clay%	Silt%	Sand%	Soil%
73	47a	WW	43	0	26	17	0
74	47a	WW	62	0	13	43	6
75	47a	WW	55	2	22	31	0
76	47a	WW	93	0	13	80	0
77	47a	WW	94	0	4	90	0
78	47a	WW	28	0	6	22	0
79	47a	WW	56	6	6	44	0
80	47a	WW	66	0	14	52	0