Lake Edgar Brown TMDL
South Carolina Department of Health and Environmental Control

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Abstract: Lake Edgar Brown was listed in the 2000 303(d) list submitted to the United States Environmental Protection Agency by the South Carolina Department of Health and Environmental Control for violating aquatic life standards and not possessing a balanced indigenous aquatic community as defined by the state. Past management efforts have resulted in the lake possessing an overabundance of phosphorus with no potential for removal through normal hydrologic processes. The high phosphorus loading, in conjunction with the lake's physical characteristics and the region's long growing season have resulted in an ecosystem dominated by nuisance algae (primarily Polycystis aeruginosa) and other phytoplankton. During periods of high photosynthesis, the conversion of carbonate into carbon dioxide results in the release of excess hydroxide ions, raising the lake's pH above the state's water quality standard.

High phosphorus loads produce high primary productivity, which result in high pH. The objective of this TMDL is to restore ecological balance through the removal of excess phosphorus (thus decreasing primary productivity and lowering pH) until an average phosphorus concentration of 60 mg/m^3 is attained. This TMDL focuses on the effect reestablishing Turkey Creek as a tributary will have on the present phosphorus cycle in Lake Edgar Brown and how alterations in this cycle will affect primary production. Calculations indicate that a partial or complete reestablishment of Turkey Creek as a tributary to Lake Edgar Brown should have significant effects in reducing phosphorus contributions from the sediments, water column phosphorus concentrations, algal growth (as represented by chlorophyll *a* levels) and pH because: 1. The continuous flow of oxygenated water should reduce the instances of anoxia at the sediment water interface and limit phosphorus release from the sediments. 2. Increased flushing will remove phosphorus suspended in the water column and both phosphorus and chlorophyll incorporated in phytoplankton biomass. As long as the flushing rate exceeds plankton growth rates, recurring algal blooms will not be a problem. Removal of phytoplankton and decreasing primary production will result in decreased pH.

A 77% reduction in phosphorus loading is will be necessary to meet water quality standards during the critical period. By necessity, this reduction will come almost exclusively from the sediments.

Table of Contents

Abstract	2
Table of Contents	3
Introduction	6
Table 1. Physical and Hydrologic Characteristics of Lake Edgar Brown	6
Table 2. Estimated phosphorus inputs into Lake Edgar Brown since the diversion of Turkey Creek	7
Classification and Standard Violations	7
TMDL Development	8
Margin of Safety	9
Allocation of Load	9
Critical Conditions	10
Figure 1. Monthly Temperature Values: Lake Edgar Brown	11
Figure 2. Monthly Total Phosphorus Values: Lake Edgar Brown	11
Table 3. Seasonal Differences in Mean Values for Selected Parameters Lake Edgar Brown	12
Figure 3. Monthly Dissolved Oxygen Values: Lake Edgar Brown	12
Figure 4. Lake Edgar Brown Monthly pH Values	13
Figure 5. Monthly Measurements in Chlorophyll *a* Lake Edgar Brown	13
Current Lake Conditions	13

Determining the Effects of Reconnecting Turkey Creek to Lake Edgar Brown 15

Table 4. Seasonal Differences in Selected Parameters, Turkey Creek 15

Table 5. 7Q10, 7Q2, and Average Annual Flow and Discharge Volumes for Turkey Creek 16

Determining Flushing Rate of Lake Edgar Brown by Turkey Creek 16

Turkey Creek Loading 16

Table 6. Phosphorus Loading of Lake Edgar Brown by Turkey Creek 17

Determining the Steady State of Phosphorus 17

Table 7. Steady state of phosphorus in Lake Edgar Brown once Turkey Creek is reestablished as a tributary 17

Time to Reach New Steady State Equilibrium 17

Table 8. Time necessary for Lake Edgar Brown to reach new steady state conditions for phosphorus once Turkey Creek is reestablished as a tributary 18

Determining Phosphorus Loading Necessary to Reach Target Concentration of 60 mg/m^3 18

Table 9. Reduction in phosphorus loading from Lake Edgar Brown sediment necessary to reach phosphorus concentrations of 60 mg/m^3. 19

Relationship Between Phosphorus and Chlorophyll *a* 19

Figure 6. Regression Analysis between measured Chlorophyll *a* [ ] and totPhopshorus [ ] for Lake Edgar Brown Data 20

Table 10. Predicted Chlorophyll *a* Concentrations at New Steady State Phosphorus Concentrations Calculated for Lake Edgar Brown After the Rediversion of Turkey Creek 21

Relationship Between pH and Primary Productivity	21
Conclusions and Implementation	21
Table 11. Summary of TMDL Components: Lake Edgar Brown	22
References	24
Appendix A: Calculations	26
Appendix B: Maps	34
Appendix C: Storet Data	39
Appendix D: 303(d) Listing Documentation	47
Appendix E: 303(e) Public Participation	49

Introduction:

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop total maximum daily loads (TMDLs) for water bodies that do not meet designated uses. The development of a TMDL establishes an assimilative capacity loading for individual pollutants and other quantifiable constituents so that states may implement water quality based controls for all pollution sources to aid in the long-term restoration and maintenance of their waters.

Lake Edgar Brown:

Located in Barnwell County, South Carolina, Lake Edgar Brown was constructed by impounding Turkey Creek in the early 1960s. This 96-acre lake is owned and managed for recreational fishing by the South Carolina Department of Natural Resources. The lake is relatively shallow (mean depth 1m) with a maximum depth of three meters. In 1968, Turkey Creek was removed as a tributary by being diverted around the lake. Precipitation and runoff is from a limited area with multiple land uses.

Table 1. Physical and Hydrologic Characteristics of Lake Edgar Brown (Stecker, et al, 1991).

Watershed Area (m^2)	2,305,301
Lake Surface Area (m^2)	388,848
Mean Depth (m)	1
Maximum Depth (m)	3
Lake Volume (m^3)	388,848
Mean Annual Precipitation (m)	1.21
Mean Annual Evaporation (m)	.91
Residence Time (yr.)	.28
Discharge Volume (m^3/yr)	1,388,742.86

Pollution impacts are limited. There are no point sources discharging or otherwise affecting the lake, and runoff is limited to a lightly developed urban portion of the Town of Barnwell that abuts the lower end of the lake. Phosphorus loading due to runoff, derived using the USEPA National Eutrophication Survey Method (Omernik, 1977) is estimated to be 91.5 kg per annum (Stecker, et al., 1991).

Atmospheric deposition of phosphorus has been estimated to be 1.05 kg per year (Hendry, et al., 1989).

After the Turkey Creek diversion, the lake received annual treatments of fertilizer (20-20-5) during the summer to encourage algal growth and enhance the fishery. Annual phosphorus loading from these treatments was estimated at 1750 kg (Stecker, et al., 1991). The lake was fertilized from 1968 through 1977: this was discontinued after the appearance of extensive algal blooms, dominated by Polycystis aeruginosa. Since 1977, excessive algae have become a routine problem in Lake Edgar Brown (Stecker, et. al., 1991), no longer limited to summer months (SCDNR, pers. comm.).

Table 2. Estimated phosphorus inputs into Lake Edgar Brown since the diversion of Turkey Creek.

Source	Annual Load	Total Load	Reference
Fertilization (68-77)	1750 kg	17500 kg	Stecker, et al., 1991
Runoff (68-98)	91.5 kg	2836.5 kg	Stecker, et al., 1991
Atmospheric Deposition (68-98)	1.05 kg	32.55 kg	Hendry, et al., 1989
Total		20369.05 kg	

Classification and Standard Violations:

Lake Edgar Brown is classified as Freshwaters, defined as:

> "… suitable for primary and secondary recreation and as a source for drinking water supply after conventional treatment in accordance with the requirements of the Department. Suitable for fishing and the survival and propagation of a balanced indigenous aquatic community of fauna and flora. Suitable also for industrial and agricultural uses."(R. 61-68)

The term "balanced indigenous aquatic community" may be defined as a natural, diverse biotic community characterized by the capacity to sustain itself though seasonal variations, the presence of an intact food chain species and by a lack of domination by pollutant tolerant species. If any of these conditions are not met, it can be inferred that aquatic life uses are not being met.

Based upon information contained in the South Carolina Watershed Water Quality Management Assessment: Savannah-Salkahatchie Basin (SCDHEC, 1997), Lake

Edgar Brown was placed on the 2000 South Carolina 303(d) for not supporting aquatic life uses. Because of the P. aeruginosa dominated algal blooms, the lake no longer possesses a balanced indigenous aquatic community. This nuisance algal growth is driven by very high water column phosphorus concentrations. Between 1986 and 1995, there were 95 phosphorus samples collected from Lake Edgar Brown. These samples were collected monthly from two stations (CL-064 and CL-065) at various depths (several were also depth integrated). Ninety nine percent of the samples analyzed exceeded EPA recommended phosphorous concentrations for impoundments (USEPA, 1986).

Lake Edgar Brown was also listed on the 2000 303 (d) list due to pH levels that exceeded the state's standard range for classified Freshwaters (6 to 8.5). The high pH is a function of the excessive primary productivity in the lake (Wetzel, 1983).

Presently, there are no state numeric standards for phosphorus concentrations, thus it is left to the discretion of the State to determine a targeted phosphorus concentration. Based on analysis of data from the Piedmont and Southeastern Plains ecoregions of South Carolina, SCDHEC has determined that the maximum allowable levels of phosphorus and chlorophyll *a* for Lake Edgar Brown are 60 mg/m^3 and 40 mg/m^3, respectively. (The state is currently attempting to revise its water quality standards to incorporate geographically significant values for these criteria applicable to all lakes exceeding forty acres.)

TMDL Development:

Traditional total maximum daily loads (TMDLs) comprise the sum of individual wasteload allocations (WLAs) for point sources, and load allocations (LAs) for both nonpoint sources and natural background levels for a given watershed. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relation between pollutant loads and the quality of the receiving water body. Conceptually, this definition is denoted by the equation:

$$TMDL = 3\ WLAs + 3\ LAs + MOS$$

The TMDL is the total amount of pollutant that can be assimilated by the receiving water body while achieving water quality standards. TMDLs establish allowable waterbody loadings that are less than or equal to the TMDL and thereby provide the basis to establish water-quality-based controls.

Because there are no point sources to consider, the WLA allocation for this TMDL is zero.

The load allocation will be the reduction in phosphorus loading to Lake Edgar Brown to result in a total phosphorus concentration of 60 mg/m^3.

Margin of Safety:

There are two basic methods for incorporating the MOS (USEPA, 1991): 1) implicitly incorporate the MOS using conservative model assumptions to develop allocations, or 2) explicitly specify a portion of the total TMDL as the MOS; use the remainder for allocations.

This TMDL will incorporate both techniques in determining the MOS by using conservative assumptions regarding flow periods (7Q10, 7Q2, and average annual flow) and phosphorus loading (all calculated loadings will be theoretical maximums.

Lake Edgar Brown TMDL:

Allocation of Load:

Lake Edgar Brown cannot significantly benefit from the elimination or mitigation of external pollution sources. Excessive internal phosphorus loading drives the system. The source of phosphorus is historical and the process by which phosphorus enters the water column is natural. Eighty-five percent of the estimated phosphorus that has entered Lake Edgar Brown since the removal of Turkey Creek as a tributary can be attributed to the fertilization efforts of the 1970s. The lack of steady and routine flushing has essentially trapped phosphorus within Lake Edgar Brown, locking it in a temperature driven cycle of sedimentation, release, and biological uptake. During warm periods, increasing water temperatures, combined with periods of minimal precipitation and no discharge create stagnant, anoxic conditions at the sediment-water interface and allow for both denitrification and the release of phosphorus from the sediments. Under anoxic conditions, phosphorus release from sediments may be greatly accelerated (Goldman and Horne, 1983). Sediment samples taken from the lake contain greater than (state) average phosphorus concentrations, and water column phosphorus concentrations in Lake Edgar Brown have been shown to increase significantly during periods of little or no precipitation and high temperatures (Stecker, et al., 1991).

In order to restore the balanced indigenous aquatic community and prevent excess algal growth, phosphorus must be removed from the system. In a diagnostic/feasibility study of Lake Edgar Brown, Stecker (et al., 1991) assessed twelve different commonly accepted restoration techniques. Of those twelve, only three (dredging, flushing, biological controls) were determined to be potentially effective for restoration and only one (flushing) could be implemented with minimal effect on the fishery.

This TMDL predicts the changes in phosphorus and chlorophyll *a* concentrations in Lake Edgar Brown if the lake were to be flushed with relatively nutrient poor water by reestablishing Turkey Creek as a tributary, and the reduction in phosphorus loading necessary to achieve total phosphorus concentrations of 60 mg/m^3.

Critical Conditions:

Time series plots of historical dissolved oxygen (DO), total phosphorus (totP), temperature (T), Chlorophyll *a* (Chl*a*), and pH data gathered from CL-064 and CL-065 exhibit similar trends (Figures 1 through 5). With little exception, T, totP, and pH values are all highest during the period of May through September. The lowest (and most variable) DO measurements are taken during the same period. Chlorophyll *a* values lag behind the rest by about a month, exhibiting higher measurements June through October. Based upon these graphs, two different time periods will be examined for Lake Edgar Brown: May through September (m-s) and October through April (o-a). Averaging the historical data for these two time periods does show significant differences.

Figure 1. Monthly T Values: Lake Edgar Brown (1981-1996)

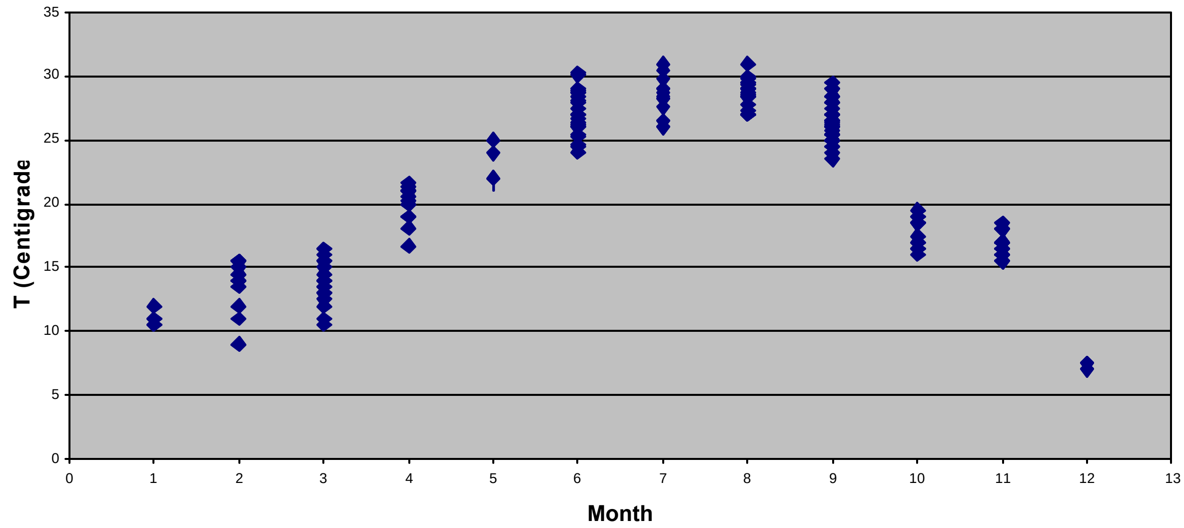


Figure 2. Monthly totP Values for Lake Edgar Brown (1981-1996)

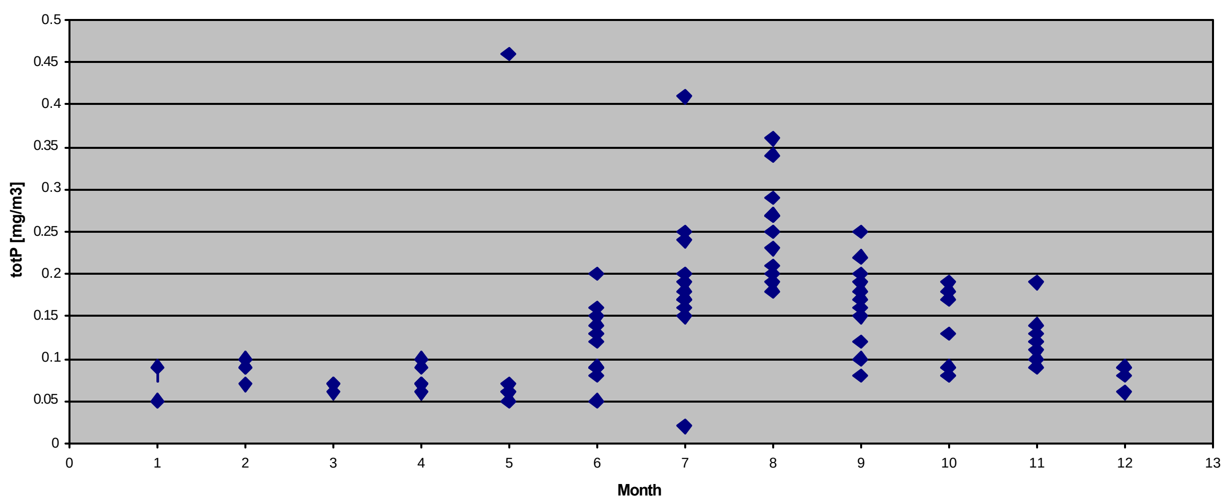


Table 3. Seasonal Differences in Mean Values for Selected Parameters, Lake Edgar Brown

	DO (mg/l)	T(C)	TotP (mg/m^3)	Chl*a* (mg/m^3)	pH
CL-064					
o-a	7.95	15.18	100	57.19	6.85
m-s	5.24	27.01	180	123.74	7.78
CL-065					
o-a	7.51	16.09	90	24.93	6.77
m-s	6.20	27.11	180	151.31	7.74
Composite					
o-a	7.77	15.55	90	42.01	6.81
m-s	5.53	27.11	180	138.34	7.77

As Table 3 shows, there is a significant difference in totP, Chl*a*, and T between the two time periods. The Composite values are derived from combining the data from both sampling stations and will be used to represent average lake conditions.

Figure 3. Monthly DO Values: Lake Edgar Brown (1981-1996)

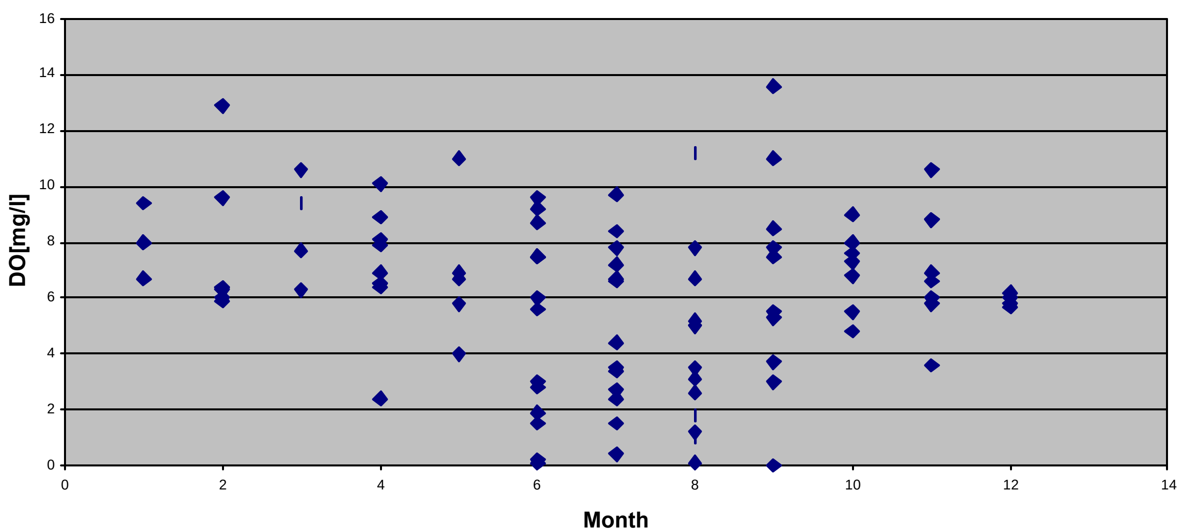


Figure 4. Lake Edgar Brown Monthly pH Values (1981-1996)

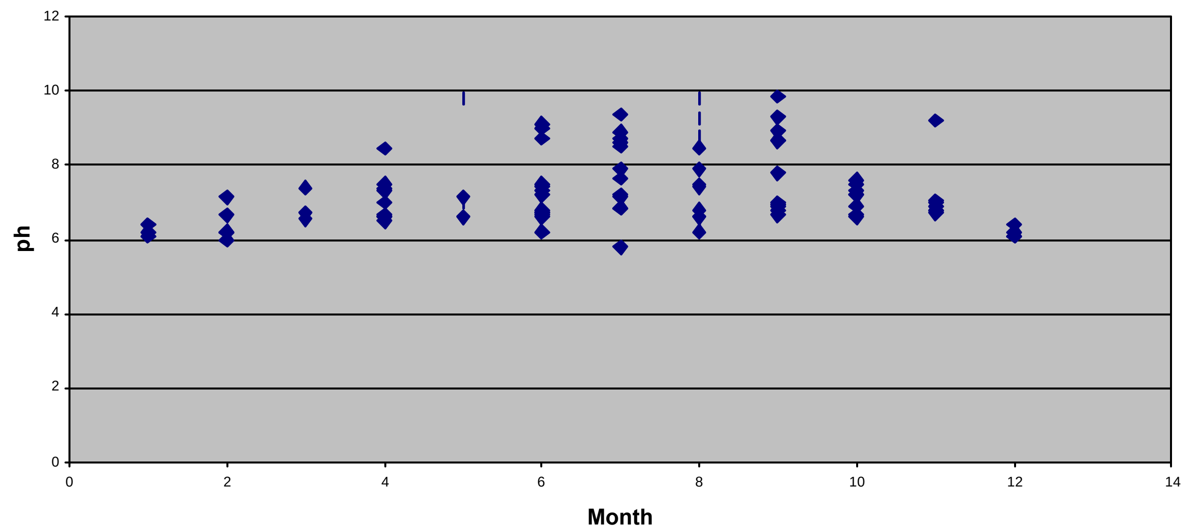
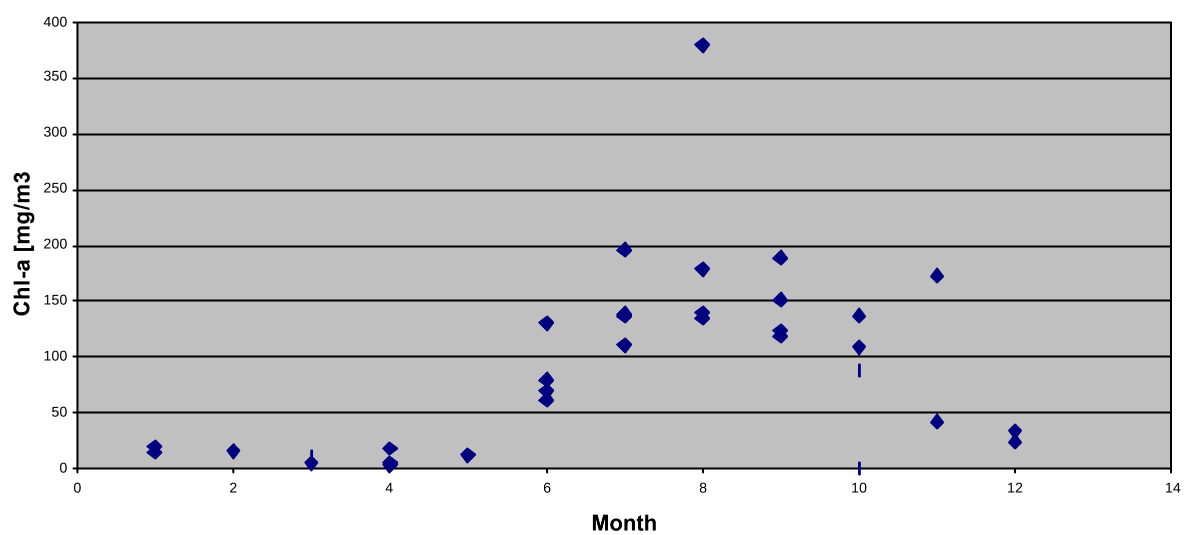


Figure 5. Monthly Measurements in Chloryphyll A: Lake Edgar Brown (1981-1996)



Current Lake Conditions:

Current P loading in Lake Edgar Brown:

Current phosphorus loading estimates from runoff and atmospheric deposition have been determined. Vollenweider (1969) gives the following equation that allows for load determination:

Pss = Load/Z (Kf+Ks) (Vollenweider, 1969)

Where:

Pss = Phosphorus concentration at steady state conditions
(Composite totP values are assumed to represent steady state.)
Pss o-a = Average [P] from October through April = 90 mg/m^3
Pss m-s = Average [P] from May through September = 180 mg/m^3

Kf = Flushing Rate = 3.6/yr.

Ks = Sedimentation Rate = 10 m/yr. /mean depth (Vollenweider, 1976)
= 10m/yr/1m=10/yr
Z = Mean Depth = 1 m

To solve for Load:

Load = (Pss)[Z (Kf+Ks)]

Vollenweider's (1969) formula was developed to determine annual loading. To determine seasonally proportional loading, the formula should be modified to account for the fraction of the year each time period occupies (Time Coefficient)

Time Coefficients (Tc) o-a = .58 yr. m-s = .42 yr.

Therefore:

Load = (Pss)[Z (Kf+Ks)] (Tc)

For the two seasonal periods:

Loado-a = (90 mg/m^3)[(1m(10/yr. + 3.6/yr)) (.58 yr.)]
Loado-a = 709.92 mg/m^2

Loadm-s = (180 mg/m^3)[(1m(10/yr + 3.6/yr.)) (.42 yr.)]
Loadm-s = 1028.16 mg/m^2

The previous load numbers represent total seasonal phosphorus loading to the system, regardless of sources. Sediment loading can be calculated by subtracting the steady state load from the outside load derived from Table 3 (91 kg = 238 mg/m m^2yr):

Sediment Load = Load – Outside Load (Tc)

SLo-a = 709.92 mg/m^2 – (238 mg/m^2yr.)(.58 yr.)
SLo-a = 571.88 mg/m2

SLm-s = 1028.16 mg/m^2 – (238 mg/m^2yr.)(.42 yr.)
SLm-s = 928.20 mg/m^2

A total of 1500.08 mg/m^2 of phosphorus is released annually from the sediments, with the majority of the loading (62%) taking place during May through September.

Determining the Effects of Reconnecting Turkey Creek to Lake Edgar Brown:

Turkey Creek is a nutrient poor, blackwater stream that was originally used to create Lake Edgar Brown. The area the creek drains above the lake is dominated by forest, agriculture/grasslands, and scrub/shrub lands (see Land Use map in Appendix B). There are no point sources in discharging in the portion of the creek above the lake and all uses are being attained. There is one monitoring station within this portion of the creek (CSTL-514). Ambient monitoring data for CSTL-514 was seasonally segregated in a manner similar to the Lake Edgar Brown data.

Table 4. Seasonal Differences in Selected Parameters, Turkey Creek

CSTL-514	DO (mg/l)	T(C)	TotP (mg/m^3)	pH
o-a	9.26	12.54	38	7.05
m-s	7.86	20.06	53	6.93

When compared to Lake Edgar Brown data, DO is greater, T is less and totP is significantly less, regardless of periodicity.

The effects of reconnecting Turkey Creek to Lake Edgar Brown was assessed under three different flow regimes: 7Q10, 7Q2, and average annual flow. These flow estimates have been previously developed for Turkey Creek by SCDHEC's Bureau of Water's Wasteload Allocation Section (Nancy Sullins, pers. comm.).

Table 5. 7Q10, 7Q2, and Average Annual Flow and Discharge Volumes for Turkey Creek

Flow	7Q10	7Q2	Average Annual Flow (AA)
Discharge Volume (m^3/yr.)	6,510,695.5	9,770,508.5	24,292,306.94

Determining Flushing Rate of Lake Edgar Brown by Turkey Creek

Reestablishing Turkey Creek as a tributary to the lake would alter the flushing rate (Kf) and residence time. The new Kf would be determined by:

Flushing Rate = (Q present + Q Turkey Creek)/V Lake Edgar Brown
(Reckhow and Chapra, 1983)

Kf7Q10 = (1,388,742.86 m^3/yr. + 6,510,695.5 m^3/yr.)/388848m^3
Kf7Q10 = 20.31/yr.
Retention Time = .05 yr.

Kf7Q2 = (1,388,742.86 m^3/yr. + 9,770,508.5 m^3/yr.)/388848m^3
Kf7Q2 = 28.70/yr.
Retention Time = .03 yr.

KfAA = (1,388,742.86 m^3/yr. + 24,292,306.94 m^3/yr.)/388848m^3
KfAA = 66.04/yr.
Retention Time = .02 yr.

As flows increase, the flushing rate increases (and residence time decreases).

Turkey Creek Loading:

Phosphorus loading of Lake Edgar Brown by Turkey Creek will vary according to flow, and new loads should be calculated for each flow. To account for the periodicity of each loading, the time coefficients are again used to modify the equation. Summing the two seasonal loadings derives annual loading.

Pi = Load/Z (Kf) (Vollenweider and Dillion 1974)
Load = (Pi) Z (Kf)(Tc)

Table 6. Phosphorus loading of Lake Edgar Brown by Turkey Creek

Flow Period	Loado-a	Loadm-s	Annual Load
7Q10	447.63 mg/m^2	452.10 mg/m^2	899.73 mg/m^2
7Q2	632.55 mg/m^2	638.68 mg/m^2	1271.23 mg/m^2
Average Annual	1455.52 mg/m^2	1470.05 mg/m^2	2925.57 mg/m^2

Determining Steady State of Phosphorus:

Given current loadings and predicted loading from Turkey Creek, it is possible to calculate the steady state of phosphorus for both time periods under all three-flow conditions. Using Vollweider's (1969) equation modified by the time coefficient, new steady state conditions for phosphorus can be determined for all three flows:

Pss = ΣLoad/Z (Kf+Ks) Tc

Table 7. Steady state of phosphorus in Lake Edgar Brown once Turkey Creek is reestablished as a tributary.

Flow	Psso-a	Pssm-s
7Q10	65.85 mg/m^3	116.28 mg/m^3
7Q2	59.81 mg/m^3	102.55 mg/m^3
Average Annual Flow	49.10 mg/m^3	78.22 mg/m^3

The calculated new phosphorus concentrations are significantly lower than present phosphorus levels and approach the target concentration of 60 mg/m^3 for the October through April time period.

Time to Reach New Steady State Equilibrium

Once Turkey Creek is reestablished as a tributary, it will take time for the waters to mix and reach a new Pss. According to Cooke (et al., 1993), the time necessary to reach 90% equilibrium (T_{90}) can be calculated.

T_{90} = ln10/(Kf+Ks)

Table 8. Time necessary for Lake Edgar Brown to reach new steady state conditions for phosphorus once Turkey Creek is reestablished as a tributary.

Flow	T_{90} (years)
7Q10	.08
7Q2	.06
Average Annual Flow	.03

New steady state concentrations should be reached in a relatively short time.

Determining Phosphorus Loading Necessary to Reach TMDL Target Phosphorus Concentration of 60 mg/m^3

The reestablishment of Turkey Creek as a tributary to Lake Edgar Brown will not immediately result in critical period phosphorus concentrations meeting the TMDL target. Phosphorus loading from the sediment will keep concentrations high. Over time continued flushing of Lake Edgar Brown will remove phosphorus from the system and the amount of phosphorus available from the sediment will decrease. The loading necessary to obtain a phosphorus concentration of 60 mg/m^3 can be determined using Vollenweider (1969).

$$\Sigma \text{Load} = (Pss)\ [Z\ (Kf+Ks)]$$

To determine the sediment load portion, subtract the other know loads (runoff, atmospheric, and Turkey Creek) from the total load:

$$\text{Sediment Load} = \text{Load} - (\text{Turkey Creek Loading} + \text{Outside Loading})$$

Table 9. Reduction in phosphorus loading from Lake Edgar Brown sediment necessary to reach TMDL phosphorus concentrations (60 mg/m^3) during the critical period.

	7Q10	7Q2	AVERAGE ANNUAL FLOW
Pssm-s	**116.28 mg/m^3**	**102.55 mg/m^3**	**78.22 mg/m^3**
Turkey Creek Phosphorus Loading	**899.73 mg/m^2**	**1271.23 mg/m^2**	**2925.57 mg/m^2**
Outside Loading	**238 mg/m^2**	**238 mg/m^2**	**238 mg/m^2**
Sediment Loading	**1500.08 mg/m^2**	**1500.08 mg/m^2**	**1500.08 mg/m^2**
S Loading	**2637.81 mg/m^2**	**3009.28 mg/m^2**	**4663.65 mg/m^2**
Critical Period Conditions			
Turkey Creek Phosphorus Loading	**452.10 mg/m^2**	**632.55 mg/m^2**	**1470.05 mg/m^2**
Outside Loading	**99.96 mg/m^2**	**99.96 mg/m^2**	**99.96 mg/m^2**
Sediment Loading	**928.20 mg/m^2**	**928.20 mg/m^2**	**928.20 mg/m^2**
S Loading	**1480.26 mg/m^2**	**1666.84 mg/m^2**	**2498.21 mg/m^2**
TMDL			
TMDL Loading	**1818.60 mg/m^2**	**2322 mg/m^2**	**4562.40 mg/m^2**
TMDL Sediment Loading	**680.87 mg/m^2**	**812.77 mg/m^2**	**1398.83 mg/m^2**
Critical Period TMDL Loading	**736.81 mg/m^2**	**975.24 mg/m^2**	**1916.21 mg/m^2**
Critical Period TMDL Sediment Loading	**211.75 mg/m^2**	**236.60 mg/m^2**	**346.20 mg/m^2**
% Reduction (Critical Period)	**77.2**	**77.5**	**62.7**

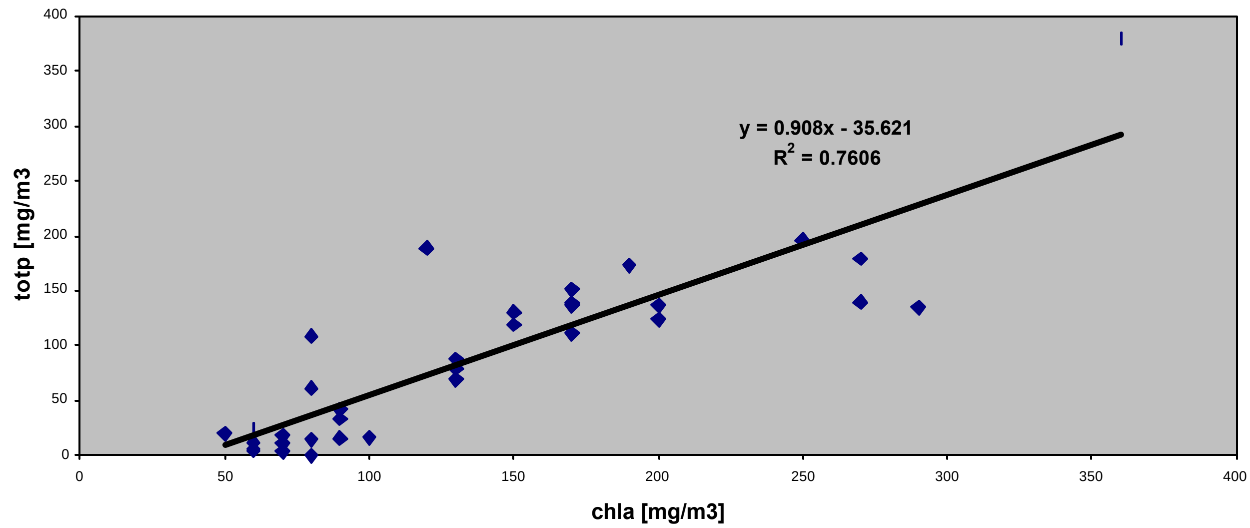
The calculations used in this TMDL assume that the phosphorus budget of Lake Edgar Brown (post diversion) will be a steady state system. While this assumption may be applicable to external phosphorus sources (for the foreseeable future), it is expected that sediment contribution of phosphorus will decrease over time. What cannot be determined, however, is rate at which this internal phosphorus source is reduced nor can the time lag necessary to reach the targeted phosphorus concentration be ascertained. Sample stations on Lake Edgar Brown are part of the state's ambient monitoring network and will allow the state to monitor any alterations in water quality.

Relationship Between Phosphorus and Chlorophyll *a*

The decrease in phosphorus concentrations should result in a decrease in primary productivity in the lake. Many empirical relationships exists between chl*a* and total phosphorus (Alhgren, et al., 1988) that have good correlation, however, a high correlation coefficient may mask accuracy errors due to interlake and seasonal variations in cellular chl*a* concentrations, grazing, and other limiting variables such as light and nutrients. Individual lake relationships are more accurate and should be developed when such data is available (Smith and Shapiro, 1981).

The relationship between Lake Edgar Brown chlorophyll *a* and total phosphorus concentrations is shown in Figure 6 and produces a reasonable correlation coefficient (R^2 = .76) that allows for a chl *a* – phosphorus relationship to be developed. The regression equation in Figure 6 can be used to predict chl *a* concentrations for the steady state phosphorus concentrations determined in Table7.

Figure 6. Regression Analysis between measured Chlorophyll a [ ] and totPhosphorus [ ] for Lake Edgar Brown Data



As a precaution, the developed chl *a* – phosphorus relationship was compared with two of the most commonly cited chl *a* - phosphorus relationships (Cooke et al., 1993):

Log chl-a = 1.449 log totP-1.136 Dillion and Rigler (1974)

Log chl-a = 1.406 log totP- 1.09 Jones and Bachman (1976)

The results are found in table 9. Predicted chlorophyll *a* concentrations are similar for all three equations. All show a significant reduction in chlorophyll *a*, especially during the critical period (May-September), corresponding with reduction in total phosphorus.

Table 10. Predicted Chlorophyll *a* Concentrations at New Steady State Phosphorus Concentrations Calculated for Lake Edgar Brown After the Rediversion of Turkey Creek (All concentrations are express as mg/m^3).

Conditions	TotP	Measured Averages	Dillion and Rigler (1974)	Jones and Bachman (1976)	Linear Regression
Composite o-a	90	42.01	49.62	45.46	46.10
Composite m-s	180	138.34	135.48	122.23	127.82
7Q10o-a	65.85		31.56	29.44	24.17
7Q10m-s	116.28		71.93	66.33	69.96
7Q2o-a	59.81		27.45	25.86	18.69
7Q2m-s	102.55		59.96	54.62	57.49
AAo-a	49.10		20.62	19.31	8.96
AAm-s	78.22		40.50	36.93	35.40
TMDL Target	60		27.61	25.86	18.86

Relationship Between pH and Primary Productivity

Lake Edgar Brown does not support aquatic life uses due to pH levels exceeding the standard range established by the state (R 61-68). The high pH is a function of the high primary productivity (stimulated by excess phosphorus) and organic matter content found in Lake Edgar Brown. As phytoplankton convert carbonate into carbon dioxide, hydroxide (OH^-) is released into the water column, raising the pH (U.S. Environmental Protection Agency, 1996).

Although it cannot be mathematically shown, it is expected that the reconnection of Turkey Creek to Lake Edgar Brown will eventually lead to pH measurements approximating standards. Turkey Creek is a black water stream with naturally low pH (Table 4) and the influx of its water will dilute hydroxide concentrations. Better flushing of the lake should not only remove excess phosphorus (thereby lowering primary productivity), but also remove excess phytoplankton and organic matter and in effect lower the amount of hydroxide released during photosynthesis. These changes will be measured as part of state's routine ambient monitoring.

Conclusions and Implementation:

The current conditions at Lake Edgar Brown do not provide for a balanced indigenous aquatic community due to excessive alga growth driven by high phosphorus levels in the water column. At present, the overwhelming majority of this phosphorus is from sediment release during periods of anoxia at the sediment water interface. Conditions at Lake Edgar Brown (shallow depth, little freshwater input, minimal flushing, and high organic matter) exacerbate the situation so that periods of anoxic conditions, sediment phosphorus release, and subsequent algal blooms are no longer limited to summer extremes. The calculations presented indicate that although the majority of phosphorus is being released from the sediment May through September, there is a continuous release year round, as evidenced by algal blooms occurring during winter months.

Table 11. Summary of TMDL Components: Lake Edgar Brown

Annual Existing Phosphorus Load	1738.08 mg/m2
Annual Point Source Phosphorus Load	0
Annual Nonpoint Source Phosphorus Load	1738.08 mg/m^2
Critical Condition [TotP]	180 mg/m^3
TMDL Target	60 mg/m^3
WasteloadAllocation	0 %
Load Allocation	100 %
7Q10 Phosphorus Load	2,637.81 mg/m^2
Critical Condition Load	1,480.26 mg/m^2
Critical Condition 7Q10 [TotP]	116.28 mg/m^3
TMDL Targeted Concentration [p]	60 mg/m^3
7Q10 TMDL Load (Annual)	1818.6 mg/m^2
7Q10 TMDL Sediment Load	680.87 mg/m^2
% Reduction from Sediments	77.2%

The calculations also indicate that either a partial or complete reestablishment of Turkey Creek as a tributary to Lake Edgar Brown should have significant effects in reducing phosphorus contributions from the sediments, water column phosphorus concentrations, and resultant algal growth. The calculations, however, represent worst case conditions and actual phosphorus loadings and concentrations, and plant growth rates (as represented by chlorophyll a levels) should be lower than theoretical estimates because: 1. The continuous flow of oxygenated water should reduce the instances of anoxia at the sediment water interface and limit phosphorus release from the sediments. 2. Increased flushing will remove phosphorus suspended in the water column and both phosphorus and chlorophyll incorporated in phytoplankton biomass. As long as the flushing rate exceeds plankton growth rates, recurring algal blooms will not be a problem. Removal of phytoplankton and decreasing primary production should also result in drops in pH. Continued monitoring of Lake Edgar Brown (as part of the state's routine ambient monitoring network) will better document the changes and provide direction for future management activities.

The implementation phase of this TMDL will be the reestablishment of Turkey Creek as a tributary to Lake Edgar Brown. As the lake is owned by the South Carolina Department of Natural Resources, implementation of the TMDL will be their responsibility. Because the surface of the lake is higher than the surface of the creek, direct breaching of the dike that separates the creek and the lake is not an option. Any permanent structural intake would most likely have to be placed 150-300 m upstream (Stecker, et al., 1991).

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Appendix A: Calculations

Calculations

Determination of current Phosphorus loading in Lake Edgar Brown:

Pss = Load/Z (Kf+Ks) (Vollenweider, 1969)
Load = (Pss)[Z (Kf+Ks)]

Kf = Flushing Rate = 3.6/yr.
Z = Mean Depth = 1 m
Ks = Sedimentation Rate = 10 m/yr. /mean depth (Vollenweider,1976)
= 10m/yr/1m=10/yr

Time Coefficients (Tc)

$Tc_{o\text{-}a}$ = 7/12 = .58 yr.
$Tc_{m\text{-}s}$ = 5\12 = .42 yr.

Therefore:

Load = (Pss)[Z (Kf+Ks)] (Tc)

For the two seasonal periods:

Loado-a = (90 mg/m^3)[(1m(10/yr. + 3.6/yr)) (.58 yr.]
Loado-a = (90 mg/m^3)(7.89m)
Loado-a = 709.92 mg/m^2

Loadm-s = (180 mg/m^3)[(1m(10/yr + 3.6/yr.)) (.42 yr.)]
Loadm-s = (180 mg/m^3)(5.71m)
Loadm-s = 1028.16 mg/m^2

Pss o-a = Average P from October through April = 90 mg/m^3
Pss m-s = Average P from May through September = 180mg/m^3

Conversion of Phosphorus Runoff Contribution to Loading Values (Outside Load)

Outside Load =[(91 kg/yr.)(1,000,000 mg/1 kg)/ 388,848m^2]
Outside Load = 238 mg/m^2yr

Determination of Sediment Loading

Sediment Load = Load – Outside Load (Tc)

SLo-a = 709.92 mg/m^2 – (238 mg/m^2yr.)(.58 yr.)
SLo-a = 709.92 mg/m^2 – 138.04 mg/m^2
SLo-a = 571.88 mg/m2

SLm-s = 1028.16 mg/m^2 – (238 mg/m^2yr.)(.42 yr.)
SLm-s = 1028.16 mg/m^2 – 99.96 mg/m^2
SLm-s = 928.20 mg/m^2

Conversion of Turkey Creek flows from cfs to m^3/yr.

7Q10 = 7.29 cfs
7Q2 = 10.94 cfs
Average Annual Flow (AA) = 27.2 cfs

7Q10= (7.29cfs)(1l/min/.0005886cfs)(60min/1hr)(24 hr/1d)(365d/1yr)(1 m^3/1000l)
= 6,510,695.50 m^3/yr.

7Q2= (10.94cfs)(1l/min/.0005886cfs)(60min/1hr)(24 hr/1d)(365d/1yr)(1 m^3/1000l)
= 9,770,508.50 m^3/yr.

AA = (27.2cfs)(1l/min/.0005886cfs)(60min/1hr)(24 hr/1d)(365d/1yr)(1 m^3/1000l)
= 24,292,306.94 m^3/yr.

Determining Flushing Rate of Lake Edgar Brown by Turkey Creek

Flushing Rate = Q present + Q Turkey Creek/V Lake Edgar Brown
(Reckhow and Chapara, 1983)

Retention Time=1/Flushing Rate

Kf7Q10 = (1,388,742.86 m^3/yr. + 6,510,695.5 m^3/yr.)/388848m^3
Kf7Q10 = 7,899,438.36 m^3/ 388848m^3
Kf7Q10 = 20.31/yr.
Retention Time = .05 yr.

$Kf7Q2 = (1{,}388{,}742.86\ m^3/yr. + 9{,}770{,}508.5\ m^3/yr.)/388848m^3$
$Kf7Q2 = 11{,}159{,}250.86\ m^3/388848m^3$
Kf7Q2 = 28.70/yr.
Retention Time = .03 yr.

$KfAA = (1{,}388{,}742.86\ m^3/yr. + 24{,}292{,}306.94\ m^3/yr.)/388848m^3$
$KfAA = 25{,}681{,}049.80\ m^3/388848m^3$
KfAA = 66.04/yr.
Retention Time = .02 yr.

Turkey Creek Loading:

Pi = Load/Z (Kf) (Vollenweider and Dillion 1974)
Load = (Pi) Z (Kf)(Tc)

Load7Q10o-a = $(38\ mg/m^3)(1m)(20.31/yr.)(.58\ yr.)$
Load7Q10o-a = $447.63\ mg/m^2$

Load7Q10m-s = $(53\ mg/m^3)(1m)(20.31/yr.)(.58\ yr.)$
Load7Q10m-s = $452.10\ mg/m^2$

Load7Q2o-a = $(38\ mg/m^3)(1m)(28.7/yr.)(.58\ yr.)$
Load7Q2o-a = $632.55\ mg/m^2$

Load7Q2m-s = $(53\ mg/m^3)(1m)(28.7/yr.)(.58\ yr.)$
Load7Q2m-s = $638.68\ mg/m^2$

LoadAAo-a = $(38\ mg/m^3)(1m)(66.04/yr.)(.58\ yr.)$
LoadAAo-a = $1455.52\ mg/m^2$

LoadAAm-s = $(53\ mg/m^3)(1m)(66.04/yr.)(.58\ yr.)$
LoadAAm-s = $1470.05\ mg/m^2$

Determining Steady State of Phosphorus:

Pss = ΣLoad/Z (Kf+Ks) Tc Vollenweider's (1969)

Pss7Q10o-a = (709.92mg/m^2 + 447.63mg/m^2)/[(1m(10/yr. + 20.31/yr.))(.58 yr.)]
Pss7Q10o-a = 1,157.55 mg/m^2 /17.58m
Pss7Q10o-a = 65.85 mg/m^3

Pss7Q10m-s = (452.10mg/m^2 + 1,028.16 mg/m^2)/[(1m(10/yr. + 20.31/yr.))(.42yr.)]
Pss7Q10m-s = 1,480.26 mg/m^2 /12.73m
Pss7Q10m-s = 116.28 mg/m^3

Pss7Q2o-a = (709.92mg/m^2 + 632.55mg/m^2)/[(1m(10/yr. + 28.70/yr.))(.58 yr.)]
Pss7Q2o-a = 1,342.47 mg/m^2 /22.45m
Pss7Q2o-a = 59.81 mg/m^3

Pss7Q2m-s = (638.68mg/m^2 + 1028.16 mg/m^2)/[(1m(10/yr. + 28.70/yr.))(.42yr.)]
Pss7Q2m-s = 1,666.84mg/m^2 /16.25m
Pss7Q2m-s = 102.55 mg/m^3

PssAAo-a = (709.92mg/m^2 + 1,455.52mg/m^2)/[(1m(10/yr. + 66.04/yr.))(.58 yr.)]
PssAAo-a = 2165.44 mg/m^2 /44.10m
PssAAo-a = 49.10 mg/m^3

PssAAm-s = (1,470.05 mg/m^2 + 1028.16 mg/m^2)/[(1m(10/yr. + 66.04/yr.))(.42yr.)]
PssAAm-s = 2,498.21mg/m^2 /31.92
PssAAm-s = 78.22mg/m^3

Time to Reach New Steady State Equilibrium

T_{90} = ln10/(Kf+Ks) Cooke (et al.), 1993)

7Q10T_{90} = ln10/(Kf+Ks)
7Q10T_{90} = 2.30/(10/yr. + 20.31/yr.)
7Q10T_{90} = 2.30/(30.31/yr.)
7Q10T_{90} = .08 yr.

$7Q2T_{90}$ = ln10/(Kf+Ks)
$7Q2T_{90}$ = 2.30/(10/yr. + 28.70/yr.)
$7Q2T_{90}$ = 2.30/(38.70/yr.)
$7Q2T_{90}$ = .06yr.

AAT_{90} = ln10/(Kf+Ks)
AAT_{90} = 2.30/(10/yr. + 66.04/yr.)
AAT_{90} = 2.30/(76.04/yr.)
AAT_{90} = .03yr.

Determining Phosphorus Loading Necessary to Reach the TMDL Target of 60 mg/m^3

ΣLoad = (Pss) [Z (Kf+Ks)] Tc Vollenweider's (1969)

Sediment Load = Load – (Turkey Creek Loading m-s + Outside Loading m-s)

Load7Q10m-s = (60 mg/m^3) [(1m(10/yr. + 20.31/yr.)(.42 yr.)]
Load7Q10m-s = (60 mg/m^3) [(30.31m/yr.)(.42 yr.)]
Load7Q10m-s = (60 mg/m^3)(12.73m)
Load7Q10m-s = 763.81 mg/m^2

Sediment Load 7Q10m-s = 763.81 mg/m^2 - (452.10 mg/m^2 + 99.96 mg/m^2)
Sediment Load 7Q10m-s = 211.75 mg/m^2

Load7Q2m-s = (60 mg/m^3)[(1m(10/yr. + 28.70/yr.)(.42yr.)]
Load7Q2m-s = (60 mg/m^3) [(38.70m/yr.)(.42 yr.)]
Load7Q2m-s = (60 mg/m^3)(16.25m)
Load7Q2m-s = 975.24 mg/m^2

Sediment Load 7Q2m-s = 975.24 mg/m^2 - (638.68 mg/m^2 + 99.96 mg/m^2)
Sediment Load 7Q2m-s = 236.60 mg/m^2

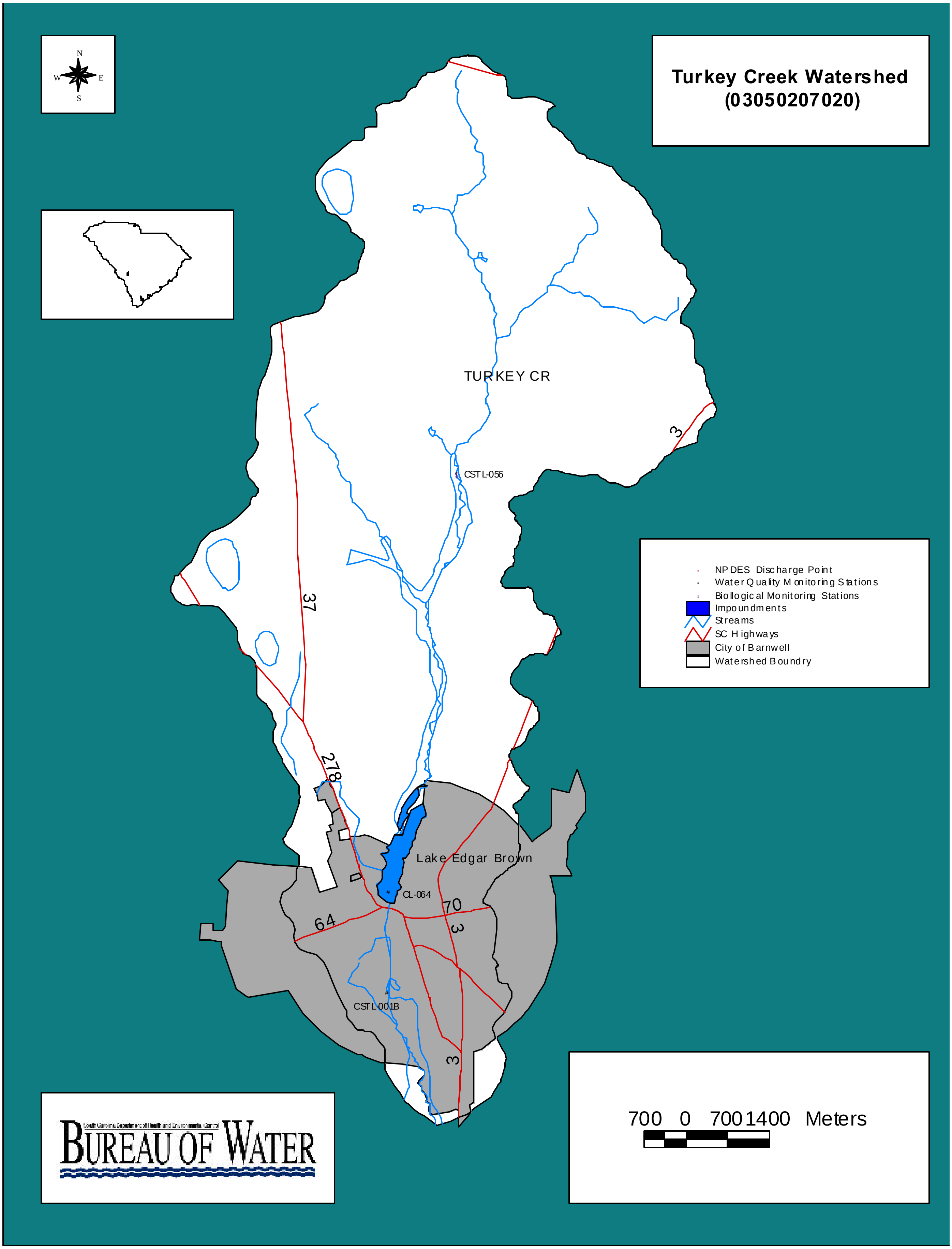
LoadAAm-s = (60 mg/m^3)[(1m(10/yr. + 66.04/yr.))(.42yr.)]
LoadAAm-s = (60 mg/m^3) [(76.04m/yr.)(.42 yr.)]
LoadAAm-s = (60 mg/m^3)(31.94m)
LoadAAm-s = 1916.21 mg/m^2

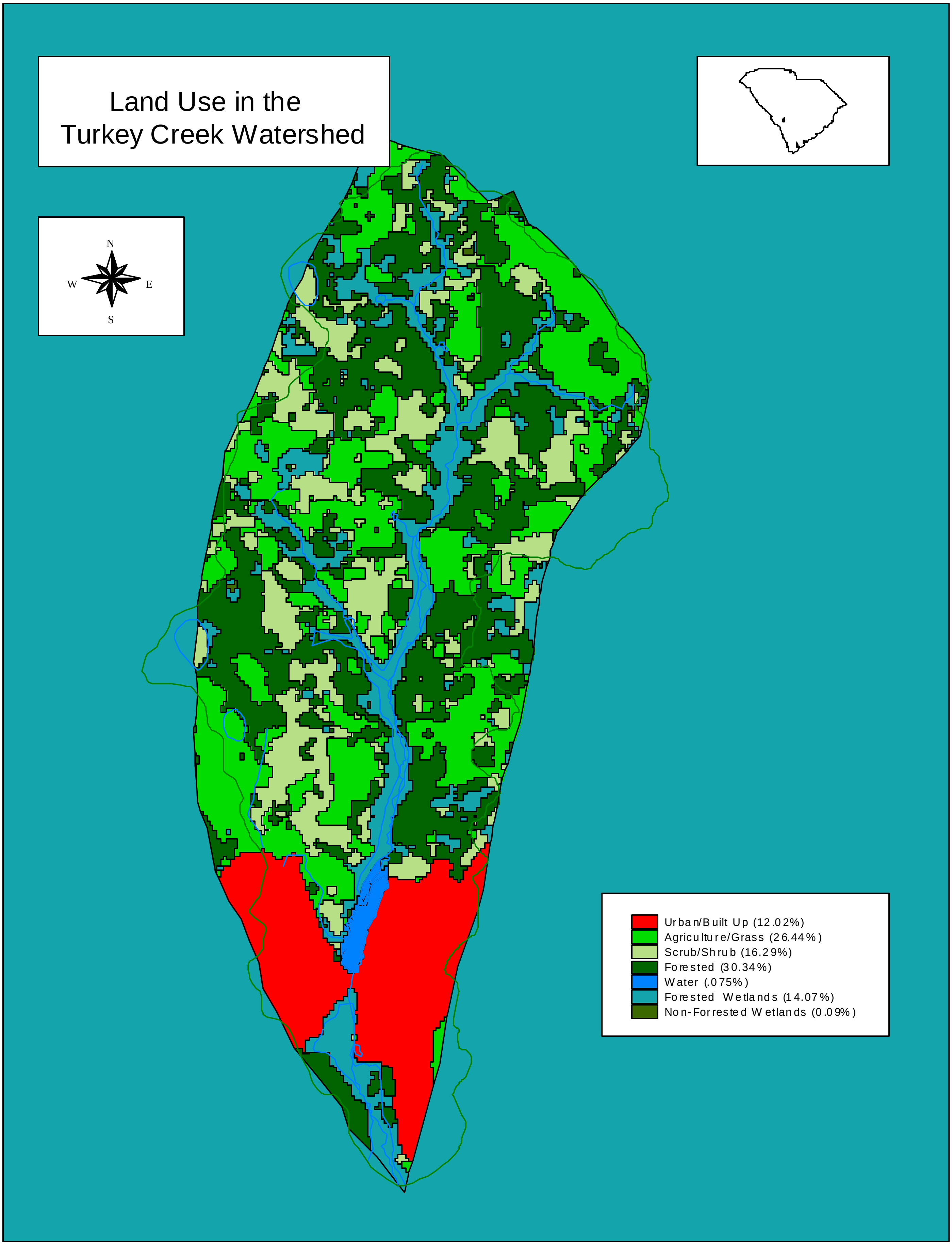
Sediment Load AAm-s = 1916.21 mg/m^2 - (1470.05 mg/m^2 + 99.96 mg/m^2)
Sediment Load AAm-s = 346.20 mg/m^2

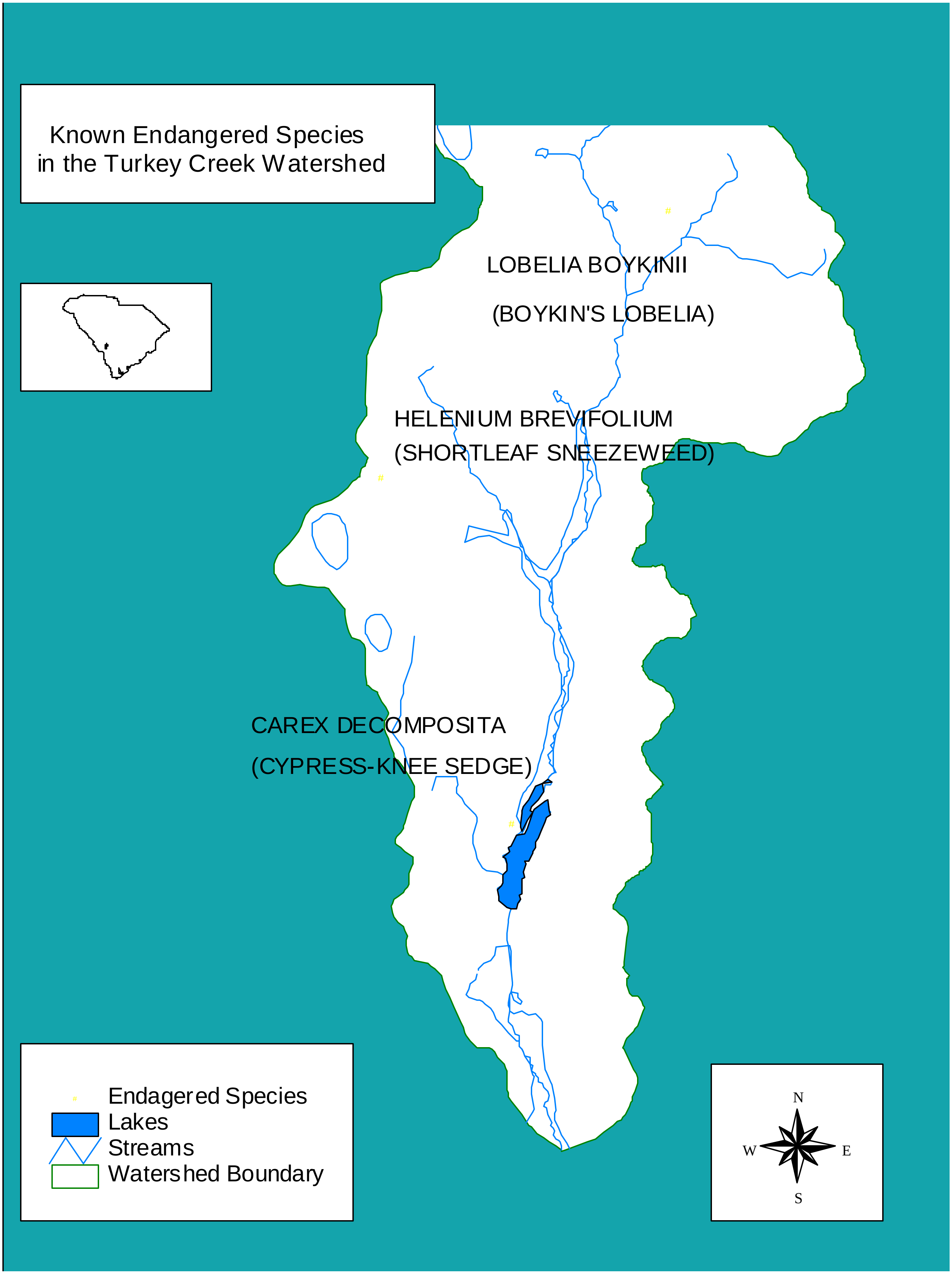
Predicting Chlorophyl-a Concentrations

Conditions	Log chl-a = 1.449 log totP-1.136 Dillion and Rigler (1974)	Log chl-a = 1.406 log totP- 1.09 Jones and Bachman (1976)	Regression: y = .908x-35.621
Composite o-a	Log chl-a = 1.449 log 90 mg/m^3-1.136 Log chl-a = (1.449)(1.95) mg/m^3-1.136 Log chl-a = 2.83 mg/m^3-1.136 Log chl-a = 1.70 mg/m^3 chl-a = 49.62 mg/m^3	Log chl-a = 1.406 log 90 mg/m^3-1.09 Log chl-a = (1.406)(1.95) mg/m^3-1.09 Log chl-a = 2.74 mg/m^3-1.09 Log chl-a = 1.65 mg/m^3 chl-a = 45.46 mg/m^3	y = (.908)(90 mg/m^3)-35.621 y = 81.72 mg/m^3-35.621 y = 46.10 mg/m^3
Composite m-s	Log chl-a = 1.449 log 180 mg/m^3-1.136 Log chl-a = (1.449)(2.26) mg/m^3-1.136 Log chl-a = 3.27 mg/m^3-1.136 Log chl-a = 2.13 mg/m^3 chl-a = 135.48 mg/m^3	Log chl-a = 1.406 log 180 mg/m^3-1.09 Log chl-a = (1.406)(2.26) mg/m^3-1.09 Log chl-a = 3.18 mg/m^3-1.09 Log chl-a = 2.09 mg/m^3 chl-a = 122.33 mg/m^3	y = (.908)(180 mg/m^3)-35.621 y = 163.44 mg/m^3-35.621 y = 127.82 mg/m^3
7Q10o-a	Log chl-a = 1.449 log 65.85 mg/m^3-1.136 Log chl-a = (1.449)(1.82) mg/m^3-1.136 Log chl-a = 2.64 mg/m^3-1.136 Log chl-a = 1.50 mg/m^3 chl-a = 31.56 mg/m^3	Log chl-a = 1.406 log 65.85 mg/m^3-1.09 Log chl-a = (1.406)(1.82) mg/m^3-1.09 Log chl-a = 2.56 mg/m^3-1.09 Log chl-a = 1.47 mg/m^3 chl-a = 29.44 mg/m^3	y = (.908)(65.85 mg/m^3)-35.621 y = 59.79 mg/m^3-35.621 y = 24.17 mg/m^3
7Q10m-s	Log chl-a = 1.449 log 65.85 mg/m^3-1.136 Log chl-a = (1.449)(1.82) mg/m^3-1.136 Log chl-a = 2.64 mg/m^3-1.136 Log chl-a = 1.50 mg/m^3 chl-a = 31.56 mg/m^3	Log chl-a = 1.406 log 116.28 mg/m^3-1.09 Log chl-a = (1.406)(2.07) mg/m^3-1.09 Log chl-a = 2.91mg/m^3-1.09 Log chl-a = 1.82 mg/m^3 chl-a = 66.33 mg/m^3	y = (.908)(116.28 mg/m^3)-35.621 y = 105.58 mg/m^3-35.621 y = 69.96 mg/m^3
7Q2o-a	Log chl-a = 1.449 log 59.81 mg/m^3-1.136 Log chl-a = (1.449)(1.78) mg/m^3-1.136 Log chl-a = 2.57 mg/m^3-1.136 Log chl-a = 1.44 mg/m^3 chl-a = 27.45 mg/m^3	Log chl-a = 1.406 log 59.81 mg/m^3-1.09 Log chl-a = (1.406)(1.78) mg/m^3-1.09 Log chl-a = 2.50 mg/m^3-1.09 Log chl-a = 1.41 mg/m^3 chl-a = 25.86 mg/m^3	y = (.908)(59.81mg/m^3)-35.621 y = 54.31 mg/m^3-35.621 y = 18.69 mg/m^3
7Q2m-s	Log chl-a = 1.449 log 102.55 mg/m^3-1.136 Log chl-a = (1.449)(2.01) mg/m^3-1.136 Log chl-a = 2.91 mg/m^3-1.136 Log chl-a = 1.78 mg/m^3 chl-a = 59.95 mg/m^3	Log chl-a = 1.406 log 102.55 mg/m^3-1.09 Log chl-a = (1.406)(2.01) mg/m^3-1.09 Log chl-a = 2.83 mg/m^3-1.09 Log chl-a = 1.74 mg/m^3 chl-a = 54.62 mg/m^3	y = (.908)(102.55 mg/m^3)-35.621 y = 93.12 mg/m^3-35.621 y = 57.49 mg/m^3
AAo-a	Log chl-a = 1.449 log 49.10 mg/m^3-1.136 Log chl-a = (1.449)(1.69) mg/m^3-1.136 Log chl-a = 2.45 mg/m^3-1.136 Log chl-a = 1.31 mg/m^3 chl-a = 20.62 mg/m^3	Log chl-a = 1.406 log 49.10 mg/m^3-1.09 Log chl-a = (1.406)(1.69) mg/m^3-1.09 Log chl-a = 2.38 mg/m^3-1.09 Log chl-a = 1.29 mg/m^3 chl-a = 19..33 mg/m^3	y = (.908)(49.10 mg/m^3)-35.621 y = 44.58 mg/m^3-35.621 y = 8.96 mg/m^3
AAm-s	Log chl-a = 1.449 log 78.22 mg/m^3-1.136 Log chl-a = (1.449)(1.89) mg/m^3-1.136 Log chl-a = 2.74 mg/m^3-1.136 Log chl-a = 1.607 mg/m^3 chl-a = 40..50 mg/m^3	Log chl-a = 1.406 log 78.22 mg/m^3-1.09 Log chl-a = (1.406)(1.89) mg/m^3-1.09 Log chl-a = 2.66 mg/m^3-1.09 Log chl-a = 1.57 mg/m^3 chl-a = 36..93 mg/m^3	y = (.908)(78.22 mg/m^3)-35.621 y = 71.02 mg/m^3-35.621 y = 35.40 mg/m^3
Target 60	Log chl-a = 1.449 log 60 mg/m^3-1.136 Log chl-a = (1.449)(1.78) mg/m^3-1.136 Log chl-a = 2.58 mg/m^3-1.136 Log chl-a = 1.441 mg/m^3 chl-a = 27.61 mg/m^3	Log chl-a = 1.406 log 60 mg/m^3-1.09 Log chl-a = (1.406)(1.78) mg/m^3-1.09 Log chl-a = 2.50 mg/m^3-1.09 Log chl-a = 1.41 mg/m^3 chl-a = 25..86 mg/m^3	y = (.908)(60 mg/m^3)-35.621 y = 54.48 mg/m^3-35.621 y = 18.86 mg/m^3

Appendix B: Maps


N
W
E
S
Turkey Creek Watershed
(03050207020)
TURKEY CR
CSTL-056
NPDES Discharge Point
Water Quality Monitoring Stations
Biological Monitoring Stations
Impoundments
Streams
SC Highways
City of Barnwell
Watershed Boundry
37
3
278
Lake Edgar Brown
CL-064
70
64
3
CSTL-001B
3
700 0 700 1400 Meters
BUREAU OF WATER


Land Use in the
Turkey Creek Watershed
N
W
E
S
Urban/Built Up (12.02%)
Agriculture/Grass (26.44%)
Scrub/Shrub (16.29%)
Forested (30.34%)
Water (.075%)
Forested Wetlands (14.07%)
Non-Forrested Wetlands (0.09%)


Known Endangered Species
in the Turkey Creek Watershed
LOBELIA BOYKINII
(BOYKIN'S LOBELIA)
HELENIUM BREVIFOLIUM
(SHORTLEAF SNEEZEWEED)
CAREX DECOMPOSITA
(CYPRESS-KNEE SEDGE)
Endagered Species
Lakes
Streams
Watershed Boundary
N
W
E
S

Appendix C: Storet Data

STATION	YEAR	MONTH	DAY	TIME	DO [mg/l]	PH	T (cent.)	tP [mg/l]	Chlr-A	Depth (m)
CL-065	80	11	11	1419				0.12		0
CL-065	80	11	11	1420	8.8		16.5			0.3
CL-065	80	11	11	1421	8.7		16.5			1
CL-065	86	6	30	1145	7.5	7.45	30.3	0.09		0.3
CL-065	86	6	30	1146	6.8		30.1			1
CL-065	88	6	14	1150	9.2	7.5	26	0.13	79.2	0.3
CL-065	88	6	14	1151	6.5		24.6			1
CL-065	88	6	14	1152	3		24.5	0.12		1.8
CL-065	88	6	28	1132	6	7.2	29	0.15	130.6	0.3
CL-065	88	6	28	1133	3		27.5			1
CL-065	88	6	28	1134	0.1	6.8	27	0.14		2
CL-065	88	7	5	1135	7.2	7.65	27	0.17	110.9	0.3
CL-065	88	7	5	1136	5.6		26.5			1
CL-065	88	7	5	1137	3.4	6.85	26	0.19		2
CL-065	88	7	19	1205	8.4	8.9	31	0.25	196	0.3
CL-065	88	7	19	1206	6.3		31			1
CL-065	88	7	19	1207	2.4	8.7	30.5	0.24		1.5
CL-065	88	8	9	1115	11.2	9.8	31	0.36	380	0.3
CL-065	88	8	9	1116	3		29.5			1
CL-065	88	8	9	1117	1.2	6.8	29.5	0.27		1.75
CL-065	88	8	23	1205	3.1	6.6	29	0.27	140	0.3
CL-065	88	8	23	1206	2.7		29			1
CL-065	88	8	23	1207	1.8	6.2	28.5	0.27		1.6
CL-065	88	9	13	1100	11	9.3	27	0.12	189	0.3
CL-065	88	9	13	1101	7.5		26			1
CL-065	88	9	13	1102	0	7.8	24.5	0.1		1.8
CL-065	88	9	20	1415	11.2	9.2	29			0.3
CL-065	88	9	20	1416	9.5		28			1
CL-065	88	9	20	1417	1.6	7.7	25.5			1.7
CL-065	88	9	20	1952	15.2	9.7	29.5			0.3
CL-065	88	9	20	1953	12.8		28.5			1
CL-065	88	9	20	1954	0.1	6.5	25.5			1.8
CL-065	88	9	20	2358	13.4	9.1	28.5			0.3
CL-065	88	9	20	2359	13.4		28.5			1
CL-065	88	9	20	2400	0	6.2	25.5			1.5
CL-065	88	9	21	715	11.8	9.35	27			0.3
CL-065	88	9	21	716	11.8		27			1
CL-065	88	9	21	717	0	6.75	25.5			1.8
CL-065	88	9	21	1010	12.8	9.85	27.5			0.3
CL-065	88	9	21	1011	11.8		27			1
CL-065	88	9	21	1012	0.2	6.9	26			1.7
CL-065	88	9	27	1445	5.3	6.9	25	0.2	124	0.3
CL-065	88	9	27	1446	5		25			1
CL-065	88	9	27	1447	3.7	6.8	25	0.19		1.6
CL-065	88	10	11	1200	8	7.2	19.5	0.13	88	0.3
CL-065	88	10	11	1201	8.4		19			1
CL-065	88	10	11	1202	8	7.2	18.5	0.18		1.7
CL-065	88	10	25	1230	7.3	7.6	17.5	0.08	0.1	0.3
CL-065	88	10	25	1231	7		17			1
CL-065	88	10	25	1232	5.5	6.9	16	0.09		1.7
CL-065	88	11	15	1245	8.8	7.05	18	0.09	41.8	0.3

STATION	YEAR	MONTH	DAY	TIME	DO [mg/l]	PH	T (cent.)	tP [mg/l]	Chlr-A	Depth (m)
CL-065	88	11	15	1246	6		16			1
CL-065	88	11	15	1247	3.6	6.8	15.5	0.11		1.7
CL-065	88	11	17	1543	8.7		18.5			0.3
CL-065	88	11	17	1544	8.5		18.5			1
CL-065	88	11	17	1545	6.2		18			1.7
CL-065	88	12	13	1310	6.2	6.2	7	0.06	24.2	0.3
CL-065	88	12	13	1311	6.1		7			1
CL-065	88	12	13	1312	5.8	6.4	7	0.08		1.6
CL-065	89	1	19	1220	8	6.2	12	0.08	14.3	0.3
CL-065	89	1	19	1221	7.3		11			1
CL-065	89	1	19	1222	6.7	6.1	10.5	0.05		1.5
CL-065	89	2	14	1130	6	6	14	0.09	15.6	0.3
CL-065	89	2	14	1131	6		14			1
CL-065	89	2	14	1132	5.9	6.2	14	0.1		1.6
CL-065	89	3	14	1315	9.4	6.7	13.5	0.07	10.7	0.3
CL-065	89	3	14	1316	8.2		13			1
CL-065	89	3	14	1317	7.7	6.55	13	0.07		1.6
CL-065	89	3	15	930	8.7	6.6	14			0.3
CL-065	89	3	15	931	8.7		14			0.7
CL-065	89	3	15	932	8.6		14			1.4
CL-065	89	3	15	1445	10.6	6.8	16.5			0.3
CL-065	89	3	15	1446	10.6		16.5			0.7
CL-065	89	3	15	1447	10.6		16			1.4
CL-065	89	4	4	1247	6.5	6.6	20	0.06	4.7	0.3
CL-065	89	4	4	1248	6.4		20			1
CL-065	89	4	4	1249	6.4	6.6	20	0.07		1.2
CL-065	89	4	18	1410	8.9	7	21.6	0.06		0.3
CL-065	89	4	18	1411	9		21.3			1
CL-065	89	4	18	1412	8.9	7.3	21	0.07		1.4
CL-065	89	5	2	1332	6.9	7	25	0.06	12.1	0.3
CL-065	89	5	2	1333	6.8		25			1
CL-065	89	5	2	1334	6.7	7.15	25	0.05		1.4
CL-065	89	8	9	1110	5	7.9	27	0.19		0.3
CL-065	89	8	9	1111	5		27			1
CL-065	89	8	9	1112	4.3		27			1.5
CL-065	89	11	16	1030	6.6	6.7	17	0.13		0.3
CL-065	89	11	16	1031	6.6		17			1
CL-065	89	11	16	1032	6.5		17			1.5
CL-065	90	2	8	1115	6.4	6.65	15.5	0.07		0.3
CL-065	90	2	8	1116	6.3		15.5			1
CL-065	90	2	8	1117	6		15.5			1.2
CL-065	90	4	18	1040	7.9	8.45	21	0.1		0.3
CL-065	90	4	18	1041	7.9		21			1
CL-065	90	4	18	1042	7.9		21			1.7
CL-064	80	11	11	1344				0.1		0
CL-064	80	11	11	1345	10.6		16.5			0.3
CL-064	80	11	11	1346	10.6		16			1
CL-064	80	11	11	1347	10.6		16			2
CL-064	80	11	11	1348	10.6		16			2.7
CL-064	81	2	17	1209				0.09		0
CL-064	81	2	17	1210	12.9		12			0.3

STATION	YEAR	MONTH	DAY	TIME	DO [mg/l]	PH	T (cent.)	tP [mg/l]	Chlr-A	Depth (m)
CL-064	81	2	17	1211	12.9		11			1
CL-064	81	2	17	1212	9.9		9			2
CL-064	81	2	17	1213	9.8		9			2.3
CL-064	81	5	5	1059				0.46		0
CL-064	81	5	5	1100	11	9.8	22			0.3
CL-064	81	5	5	1101	11		22			1
CL-064	81	5	5	1102	2.5		22			2
CL-064	81	5	5	1103	1		21.5			2.3
CL-064	81	7	27	1039				0.17		0
CL-064	81	7	27	1040	3.5	5.8	29			0.3
CL-064	81	7	27	1041	2.8		29			1
CL-064	81	7	27	1042	1		29			2
CL-064	81	7	27	1043	0		29			2.8
CL-064	86	6	30	1015	5.6	6.6	28.9	0.09		0.3
CL-064	86	6	30	1016	5		28.7			1
CL-064	86	6	30	1017	0.1		28.1			2
CL-064	88	6	14	1030	7.5	6.65	26.1	0.08	61.4	0.3
CL-064	88	6	14	1031	6.4		25.4			1
CL-064	88	6	14	1032	4.7		25.3			2
CL-064	88	6	14	1033	0.2	6.2	24.1	0.09		2.5
CL-064	88	6	28	1039	2.8	6.7	28	0.13	69.3	0.3
CL-064	88	6	28	1040	2.5		27			1
CL-064	88	6	28	1041	2.3		27			2
CL-064	88	6	28	1042	1.5	6.7	27	0.09		2.4
CL-064	88	7	5	1015	7.8	7.2	26.5	0.17	138.6	0.3
CL-064	88	7	5	1016	4.5		26.5			1
CL-064	88	7	5	1017	4.2		26			2
CL-064	88	7	5	1018	2.7	6.85	26	0.15		2.5
CL-064	88	7	19	1048	6.7	8.6	30	0.2	136.6	0.3
CL-064	88	7	19	1049	5.9		30			1
CL-064	88	7	19	1050	4		30			2
CL-064	88	7	19	1051	0.4	7.9	28.5	0.2		2.4
CL-064	88	8	9	1000	5.2	9.25	30	0.27	179	0.3
CL-064	88	8	9	1001	1.7		29			1
CL-064	88	8	9	1002	0.3		29			2
CL-064	88	8	9	1003	0.1	6.6	29	0.23		2.5
CL-064	88	8	23	1110	2.6	6.4	29	0.29	135	0.3
CL-064	88	8	23	1111	1.5		29			1
CL-064	88	8	23	1112	1.1		28.5			2
CL-064	88	8	23	1113	1	6.3	28.5	0.25		2.2
CL-064	88	9	13	1030	13.6	9.85	27	0.17	151	0.3
CL-064	88	9	13	1031	7.5		26			1
CL-064	88	9	13	1032	0.8		24			2
CL-064	88	9	13	1033	0	6.65	23.5	0.08		2.6
CL-064	88	9	20	1400	13	9.9	29			0.3
CL-064	88	9	20	1401	12.6		28			1
CL-064	88	9	20	1402	1.8		25			2
CL-064	88	9	20	1403	0.5	6.8	25			2.4
CL-064	88	9	20	1935	15.6	9.7	29.5			0.3
CL-064	88	9	20	1936	12		27			1
CL-064	88	9	20	1937	1.8		25			2

STATION	YEAR	MONTH	DAY	TIME	DO [mg/l]	PH	T (cent.)	tP [mg/l]	Chlr-A	Depth (m)
CL-064	88	9	20	1938	0	6.5	25			2.5
CL-064	88	9	20	2330	14.6	9.6	28			0.3
CL-064	88	9	20	2331	9.8		26.5			1
CL-064	88	9	20	2332	1.8		25.5			2
CL-064	88	9	20	2333	0	6.2	25			2.4
CL-064	88	9	21	700	9.2	9	26.5			0.3
CL-064	88	9	21	701	9.5		26.5			1
CL-064	88	9	21	702	1.4		25			2
CL-064	88	9	21	703	0	6.5	25			2.5
CL-064	88	9	21	950	12.6	9.7	27			0.3
CL-064	88	9	21	951	11.4		26.5			1
CL-064	88	9	21	952	2.2		25.5			2
CL-064	88	9	21	953	0	6.8	25			2.6
CL-064	88	9	27	1355	5.5	7	25.5	0.15	119	0.3
CL-064	88	9	27	1356	5.3		25			1
CL-064	88	9	27	1357	4		25			2
CL-064	88	9	27	1358	3	6.95	24.5	0.18		2.7
CL-064	88	10	11	1115	9	7.3	19	0.17	137	0.3
CL-064	88	10	11	1116	8.9		18.5			1
CL-064	88	10	11	1117	8.5		18.5			2
CL-064	88	10	11	1118	7.6	7.5	18.5	0.19		2.4
CL-064	88	10	25	1145	6.8	6.65	17	0.08	109	0.3
CL-064	88	10	25	1146	6.5		16.5			1
CL-064	88	10	25	1147	5		16.5			2
CL-064	88	10	25	1148	4.8	6.6	16.5	0.09		2.3
CL-064	88	11	15	1135	6.9	6.9	17	0.19	173	0.3
CL-064	88	11	15	1136	6.4		16			1
CL-064	88	11	15	1137	6.8		15.5			2
CL-064	88	11	15	1138	6	7	15.5	0.12		2.3
CL-064	88	11	17	1425	8		18			0.3
CL-064	88	11	17	1426	7.8		18			2
CL-064	88	11	17	1427	3		17			2
CL-064	88	11	17	1428	1.4		16.5			2.6
CL-064	88	12	13	1230	6	6.1	7.5	0.09	33.4	0.3
CL-064	88	12	13	1231	5.9		7.5			1
CL-064	88	12	13	1232	5.8		7.5			2
CL-064	88	12	13	1233	5.7	6.1	7.5	0.09		2.2
CL-064	89	1	19	1150	9.4	6.4	11	0.05	19.6	0.3
CL-064	89	1	19	1151	9.5		11			1
CL-064	89	1	19	1152	8.4		10.5			2
CL-064	89	1	19	1153	8	6.4	10.5	0.09		2.3
CL-064	89	2	14	1050	6.4	6.2	14	0.1	16.2	0.3
CL-064	89	2	14	1051	6.4		14			1
CL-064	89	2	14	1052	6.4		13.5			2
CL-064	89	2	14	1053	6.3	6.2	13.5	0.1		2.2
CL-064	89	3	14	1220	10.6	7.4	13.5	0.06	5	0.3
CL-064	89	3	14	1221	10.3		12			1
CL-064	89	3	14	1222	7.6		11			2
CL-064	89	3	14	1223	6.3	6.7	10.5	0.07		2.3
CL-064	89	3	15	905	10.3	6.5	14			0.3
CL-064	89	3	15	906	10.1		14			0.7

STATION	YEAR	MONTH	DAY	TIME	DO [mg/l]	PH	T (cent.)	tP [mg/l]	Chlr-A	Depth (m)
CL-064	89	3	15	907	10.1		13			1.4
CL-064	89	3	15	908	8.9		12.5			2.1
CL-064	89	3	15	1500	11.5	6.55	15.5			0.3
CL-064	89	3	15	1501	11.4		15.5			0.7
CL-064	89	3	15	1502	11.2		15			1.4
CL-064	89	3	15	1503	9.7		14.5			2.1
CL-064	89	4	4	1200	6.9	6.65	19	0.07	3.3	0.3
CL-064	89	4	4	1201	6.6		19			1
CL-064	89	4	4	1202	6.5		19			2
CL-064	89	4	4	1203	6.5	6.6	19	0.07	18.2	2.2
CL-064	89	4	18	1255	10.1	7.35	20.6	0.07		0.3
CL-064	89	4	18	1256	10.2		20.2			1
CL-064	89	4	18	1257	9		18.1			2
CL-064	89	4	18	1258	2.4	6.5	16.7	0.09		2.6
CL-064	89	5	2	1249	5.8	6.6	24.5	0.06		0.3
CL-064	89	5	2	1250	5.7		24.5			1
CL-064	89	5	2	1251	4.7		24			2
CL-064	89	5	2	1252	4	6.6	24	0.07		2.4
CL-064	89	8	9	1134				0.18		0
CL-064	89	8	9	1135	5.5	7.3	27			0.3
CL-064	89	8	9	1136	5.3		27			1
CL-064	89	8	9	1137	5.1		27			2
CL-064	89	8	9	1138	5.1		27			2.7
CL-064	89	11	16	954				0.14		0
CL-064	89	11	16	955	5.8	9.2	17			0.3
CL-064	89	11	16	956	5.9		17			1
CL-064	89	11	16	957	5.9		17			2
CL-064	89	11	16	958	4.7		17			2.8
CL-064	90	2	8	1044				0.09		0
CL-064	90	2	8	1045	9.6	7.15	15.5			0.3
CL-064	90	2	8	1046	9.1		15			1
CL-064	90	2	8	1047	8.1		14.5			2
CL-064	90	2	8	1048	7.4		14.5			2.5
CL-064	90	4	18	1109				0.1		0
CL-064	90	4	18	1110	8.1	7.5	21			0.3
CL-064	90	4	18	1111	8.1		21			1
CL-064	90	4	18	1112	8.1		21			2
CL-064	90	4	18	1113	8.1		21			2.2
CL-064	95	6	14	1050	9.6	9	26.4	0.16		2
CL-064	95	6	14	1051	8.9	9	26.2			1
CL-064	95	6	14	1052	7.5	8.73	26	0.2		2
CL-064	95	6	28	1100	8.7	9.11	28.8	0.05		0.3
CL-064	95	6	28	1101	7.7		28.4			1
CL-064	95	6	28	1102	1.9	7.32	26.7	0.09		2
CL-064	95	7	10	1045	9.7	9.37	30.3	0.41		0.3
CL-064	95	7	10	1046	9	7.65	29.8			1
CL-064	95	7	10	1047	2	7.44	28.6			2
CL-064	95	7	10	1048	1.5	7.15	28.1	0.02		2.3
CL-064	95	7	24	1030	6.6	8.5	30	0.16		0.3
CL-064	95	7	24	1031	5.6		30			1
CL-064	95	7	24	1032	5.3		29.5			2

STATION	YEAR	MONTH	DAY	TIME	DO [mg/l]	PH	T (cent.)	tP [mg/l]	Chlr-A	Depth (m)
CL-064	95	7	24	1033	4.4		29.5	0.18		2.5
CL-064	95	8	8	1040	6.7	8.47	28.5	0.21		0.3
CL-064	95	8	8	1041	6.6	8.3	28.6			1
CL-064	95	8	8	1042	5.3	7.65	28.4			2
CL-064	95	8	8	1043	5	7.46	28.4	0.2		2.2
CL-064	95	8	22	1050	7.8	8.78	29.9	0.25		0.3
CL-064	95	8	22	1051	5.9		29.4			1
CL-064	95	8	22	1052	3.5	7.41	29	0.34		2
CL-064	95	9	5	1105	8.5	8.92	26.3	0.16		0.3
CL-064	95	9	5	1106	8	8.72	26.2			1
CL-064	95	9	5	1107	8	8.7	26.1			2
CL-064	95	9	5	1108	7.8	8.69	26.1	0.22		2.2
CL-064	95	9	19	1110	7.5	8.65	26	0.25		0.3
CL-064	95	9	19	1111	7		26			1
CL-064	95	9	19	1112	7	8.46	26			1.9
CL-064	96	7	10	1240	8.3	7.95	28.7			0.3
CL-064	96	7	10	1241	7.4		28.3			1
CL-064	96	7	10	1242	7.1		28.2			2
CL-064	96	7	10	1243	5.7	7.5	27.6			2.3
CL-064	96	8	29	1400	6	7.2	28.8			0.3
CL-064	96	8	29	1401	4.7		27.8			1
CL-064	96	8	29	1402	2.6		27.3			2
CL-064	96	8	29	1403	2.5	6.76	27			2.3
CL-064	96	9	17	1250	7	7.5	26.6			0.3
CL-064	96	9	17	1251	6.7		26.5			1
CL-064	96	9	17	1252	4	7.24	25.8			1.9

STATION	YEAR	MONTH	DAY	TIME	DO [mg/l]	PH	T (cent.)	tP [mg/l]	Chlr-A	Depth (m)
CSTL-514	88	6	14	930	8.8	6.45	18.3	0.05		0.3
CSTL-514	88	6	28	930	7.8	6.7	23.5			0.3
CSTL-514	88	6	28	1000				0.05		
CSTL-514	88	7	5	900	8	7.2	19			0.3
CSTL-514	88	7	5	930				0.05		0.3
CSTL-514	88	7	5	1400						0.3
CSTL-514	88	7	19	1030				0.05		0.3
CSTL-514	88	7	19	1040	7.9	7.4	22			0.3
CSTL-514	88	8	9	1330	7.6	7	22	0.07		0.3
CSTL-514	88	8	23	1015	7.6	7	21			0.3
CSTL-514	88	8	23	1030				0.05		0.3
CSTL-514	88	8	23	1345						0.3
CSTL-514	88	9	13	930	7.4	6.8	20	0.05		0.3
CSTL-514	88	9	13	1230						0.3
CSTL-514	88	9	27	830						0.16
CSTL-514	88	9	27	1045	7.8	6.8	19			0.3
CSTL-514	88	9	27	1100				0.03		0.3
CSTL-514	88	10	11	1040	9	7.1	13.5	0.05		0.3
CSTL-514	88	10	25	1030	8.9	7	12.5	0.05		0.3
CSTL-514	88	11	15	1345	8.5	7.25	15	0.03		0.3
CSTL-514	88	12	13	1100	11.1	6.9	7	0.03		0.3
CSTL-514	89	1	19	1015	9.8	6.9	9.5	0.02		0.3
CSTL-514	89	2	14	1015	9	7.1	14.5	0.06		0.3
CSTL-514	89	3	14	1100	9.1	6.85	12	0.04		0.3
CSTL-514	89	4	4	1030				0.03		0.3
CSTL-514	89	4	18	1157	8.7	7.1	15.8	0.03		0.3
CSTL-514	89	5	2	1100	7.2	6.5	18	0.05		

Appendix D: 303(d) Listing Documentation

Appendix E: Public Participation

This TMDL was available for public review and comment from August 14, 2000 through September 13, 2000. No comments sent to the Bureau of Water.