Citico Creek Watershed Simulation Plan

City of Chattanooga
Stormwater Management
Department of Public Works – Engineering

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Executive Summary

Watershed restoration and sustainable development have been increasingly accepted as effective tools to improve watershed functions and health, and thus maximize the ecological services such as clean and consistent water resource supply. As such, it is critical to identify and address significant knowledge gaps and to develop innovative techniques to support implementation of watershed restoration practices and policies. This Simulation Plan aims at illustrating the importance of developing an effective and integrated land management and monitoring approach for community stakeholders, which include local land owners, communities, authorities and resource managers, as they are required to make coherent, informed decisions regarding land resources and their future.

There has been a steady shift towards modeling and model-based approaches as primary methods of quantifying watershed-wide BMP effectiveness. The advantages of using models include, among others, immediate identification of impacts, and location-specific responses. In this context, we propose an integrated and collaborative approach of watershed management including the use of local knowledge, community partnerships, GIS and remote sensing technology, and biogeochemical and bacteria flux models to develop sound and defensible strategies for stormwater and watershed management.

The Citico Creek Watershed contains 2530 acres of which urban structures such as residential, commercial and industrial properties are the primary land uses. This creek is a runoff and spring-fed waterway that is fully contained in City of Chattanooga jurisdiction. Past and on-going monitoring conducted by the City of Chattanooga show consistently high pathogen levels throughout Citico Creek. Fecal coliform and *Escherichia coli* counts measured at ten sampling sites along the creek have been as high as 83,000 and 44,000 cfu $100mL^{-1}$, respectively. For these reasons, segments of the primary stream running through the watershed are categorized as only partially supporting their designated uses according to the 2006 Tennessee 303(d) list of impaired waterways prepared by the Tennessee Department of Environment and Conservation. The 2006 Tennessee 303(d) list also identifies low dissolved oxygen, nutrients (phosphorus), and habitat loss due to alteration in streamside cover as medium priorities. This document identifies pollutant sources such as Municipal Separate Storm Sewer System (MS4) discharges, hydromodification, and collection system failures.

The City of Chattanooga, as the owner and operator of the MS4, is authorized to discharge stormwater runoff in accordance with the State of Tennessee under the National Pollutant Discharge Elimination System (NPDES) and all elements and programs listed within. Under this permit, the City of Chattanooga is required to develop a comprehensive Watershed Characterization Report and standard reporting system for select waterways for which they have jurisdiction. Additionally, the city is required to perform hydrologic and pollutant loading modeling for select waterways and watersheds for which they have jurisdiction. The present document will serve as a road map to satisfying NPDES permit Section V.C. for the City of Chattanooga, as well as serve as a tool for watershed planning, resource allocation, and water quality management purposes.

The present document will serve as a short-term simulation plan for Citico Creek Watershed, identify needs (and knowledge gaps) for short- and long-term modeling activities, and be used to develop local standards for reporting characterization and simulation documentation. A final document reporting complete hydraulic and pollutant loading modeling will be completed and submitted no later than April 2008.

This Simulation Plan will identify needs for long-term modeling in Citico Creek and all other city jurisdictional watersheds. This document will present the major steps in developing the model application consisting of: 1) characterization and segmentation of the watershed (e.g. land use/land cover, impervious cover, and water quality data, Section 2), 2) collection and collation of model input data (e.g. spatial, hydraulic, meteorologic, Section 3), 3) conducting preliminary simulation work using the best available data at the time (Section 4) and 4) calibration and validation of the model (Section 5). The results of this, and any modeling and decision support tool, must be included with communication with stakeholders, i.e. those that create future change (planners and policy makers) or those that are expected to change practices (i.e. land owners).

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BMP – Best Management Practice
DO – Dissolved Oxygen
EMC – Event Mean Concentration
EPA – Environmental Protection Agency
GIS – Geographic Information System
HUC – Hydrologic Unit Code
IBI – Index of Biologic Integrity
NCDC – National Climate Data Center
NPDES – National Pollutant Discharge Elimination System
RMCF – Ready-Mix Concrete Facility
SEP – Supplemental Environmental Project
TDEC – Tennessee Department of Environment and Conservation
TMDL – Total Maximum Daily Load
TMSP – Tennessee Multi-Sector General Permit
TSS – Total Suspended Solids
USLE – Universal Soil Loss Equation
WPA – Works Progress Administration
WWTF – Waste Water Treatment Facility

1.0 Introduction

The deleterious effects of urbanization on water quality and quantity are evident across many parts of Tennessee. Urbanization is not a single condition or trend but rather a collection of actions that leads to recognizable landscape forms and, in turn, to changes in stream condition. In most urban areas, impervious surface area increases, which decreases infiltration and increases the rate and volume of surface runoff. Urban runoff containing common urban and residential pollutants can contribute to declines in biotic species richness of urban waterways, including fish populations. This cumulative process is reported to adversely impact the physical (sedimentation), chemical (eutrophication), and biological (benthic) characteristics of city and state waters.

Societal concerns about human effects on the environment are embodied in a variety of legislative mandates, as reflected in the Clean Water Act of 1972 (and as amended, US Code title 33, section 1251-1387). The objective of this act is to "restore and maintain the chemical, physical and biological integrity of (the) Nation's water' (US Code title 33, chapter 26, subchapter 1, section 1251a). While much of this mandate has successfully addressed point sources of pollution, a new emphasis is being placed on nonpoint sources. With increasing urban populations and demands for freshwater, the number and magnitude of nonpoint source stressors will continue to grow at the expense of the structure and ecological function of watersheds.

Concern about the effects of urbanization on stream ecosystem functioning has encouraged efforts to understand and manage urban development at the national, state, and city levels, as well as motivated research efforts at institutes of higher education. This academic and planning concern has led to the question of what is the best possible condition for urban streams, for which no definitive answer has been provided.

Mechanisms have been developed to restore select waterways through local accountability, management, planning, and restoration. Waters classified as impaired, and failing to meet one or all of their intended uses, must be listed under Section 303(d) of the Clean Water Act and the Water Quality Planning and Management regulation of 40 CFR Part 130. Several impacted waterways within the City of Chattanooga are listed as only partially supporting their designated uses according to the 2006 Tennessee 303(d) list prepared by the Tennessee Department of Environment and Conservation (TDEC 2006a). Citico Creek is a fully-contained, spring-fed waterway centrally located within the city (Figure 1.1), and as such will serve as a model city watershed for characterization and modeling.

The 2006 303(d) list for the Lower Tennessee River Watershed (HUC TN06020001), the waterbody into which Citico Creek deposits, cites 7.4 river miles as impaired, due to *Escherichia coli*, nutrients, low dissolved oxygen, and siltation leading to loss of biological integrity (TDEC 2006c). This waterway has been listed as impaired by the state since 2002 (TDEC 2004a). This document, along with supporting pathogen and siltation TMDLs, identify pollutant sources such as Municipal Separate Storm Sewer System (MS4) discharge, collection system failure, and hydromodification.

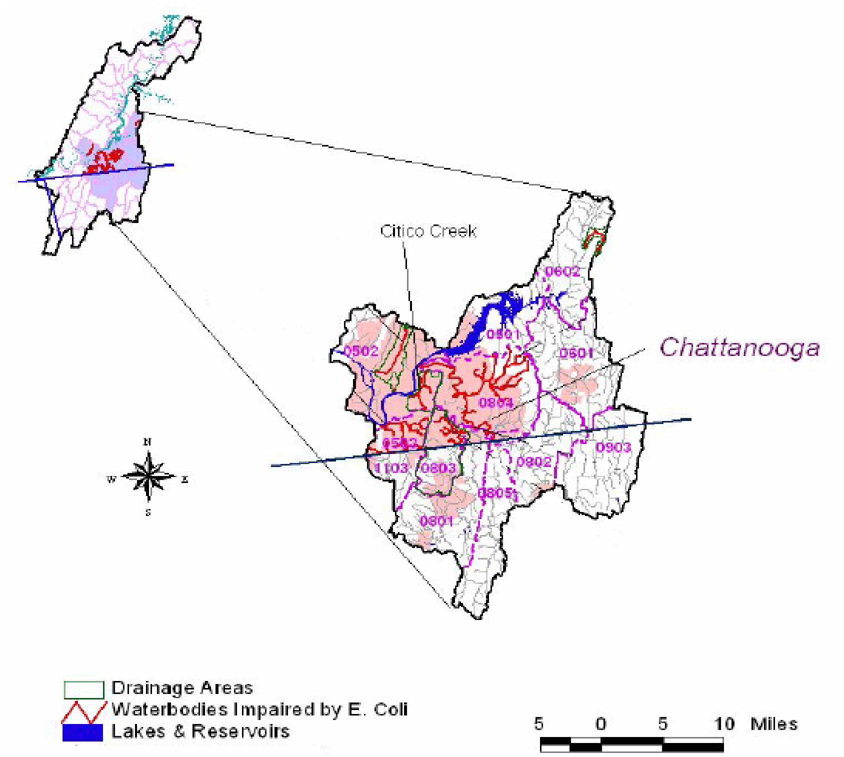

Figure 1.1. Map of Lower Tennessee River Watershed, location of impaired waterways as designated by the state, and Citico Creek; modified from TDEC 2006b.

The City of Chattanooga, as the owner and operator of the MS4, is authorized to discharge stormwater runoff in accordance with the State of Tennessee under National Pollutant Discharge Elimination System (NPDES) permit number TNS068063, and all elements and programs listed within. Under this permitting document, the City of Chattanooga is required to develop a comprehensive Watershed Characterization Report and standard reporting system for select waterways for which they have jurisdiction. Additionally, the permittee is required to perform hydrologic and pollutant loading modeling for select waterways and watersheds for which they have jurisdiction. The present document will serve as a road map to satisfying NPDES permit Section V.C. for the City of Chattanooga, as well as serve as a tool for watershed planning, resource allocation, and water quality management purposes.

1.1 Planning Area

Citico Creek Watershed (HUC TN060100011240) is classified as a third-order stream, with several unnamed tributaries converging into one main channel near the outfall in to the (Lower) Tennessee River. The creek drains approximately 2,530 acres into the river, and as noted above, is the only watershed fully contained within Chattanooga city limits. Citico Creek is fed by a series of springs nested along Missionary Ridge which runs north-south through the city. The 12.49 mile creek then flows west through neighborhoods, industrial and commercial facilities, and a major railway station. As a result of this heavy urban land use and impervious cover (Schueler 1995), water quality in Citico Creek has been severely impacted.

Citico Creek Watershed lies within the Ridge-and-Valley physiographic system that is indicative, or occupies much of the eastern United States from central Mississippi to southern New York, along the Appalachian Mountain chain. As with most of the City of Chattanooga, the watershed occupies the low-lying valleys of this system, with elevations ranging from 1090 ft. at source springs to approximately 640 ft. at the Tennessee River outfall (Figure 1.2). As a result of this topography, sections of the watershed contain sensitive areas in the form of steep slopes and flood zones.

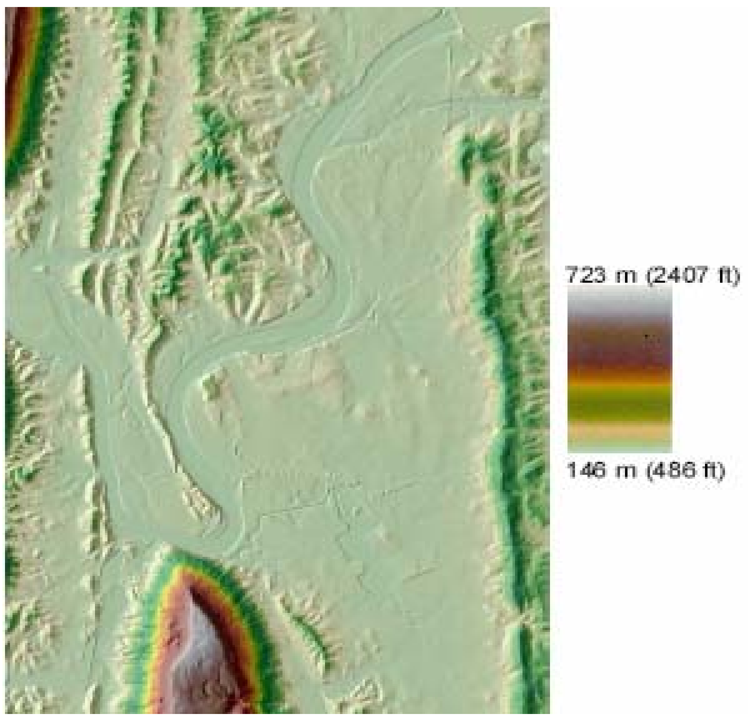

Figure 1.2. Topographic map of central Chattanooga displaying the Tennessee River meandering throughout the city, and Missionary Ridge running north-south. This map illustrates the problematic steep slopes and flood plain of Citico Creek Watershed.

1.2 Scope of Document

This Simulation Plan will supplement a previously published Preliminary Watershed Characterization Report developed by the City of Chattanooga Stormwater Management Division. This 2005 document identifies and describes in detail the watershed characteristics of Citico Creek and surrounding land uses. The present document will build upon that, and other relevant planning documents, and identify specific land and water data required (available or needed) to establish a hydrologic and/or pollutant loading model(s). In this context, this planning document will make use of local knowledge, GIS, and remote sensing technology to inform effective decision making and policy planning.

The time and funds available for this watershed characterization and simulation limit the detail with which available data may be analyzed. Consequently, certain assumptions have been made concerning the reliability and accuracy of the to-date data collection and processing. In particular, it is assumed that water quality samples were handled and processed in accordance with state accepted protocols. The raw data was not examined for errors in transcription, reporting, or censorship (i.e., values exceeding approved limits not reported). As a result of such limitations, the values depicted during this initial review should not be considered final, but still appropriate for planning purposes and model development.

Additionally, it is assumed that no local (statewide) standard for either a watershed characterization report or a simulation report have been established or published. As such, the present document will identify needs for long-term modeling in city jurisdictional watershed. This simulation plan will present the approach to be followed in constructing and calibrating such a simulation. The major steps in developing the model application consist of: 1) characterization and segmentation of the watershed (e.g. land use/land cover, impervious cover, and water quality data, Section 2), 2) collection and collation of model input data (e.g. spatial, hydraulic, meteorologic, Section 3), 3) conducting preliminary simulation work using the best available data at the time (Section 4) and 4) calibration and validation of the model (Section 5).

Surface water quality models have been developed as mathematical or theoretical descriptions of ecologic and hydrologic processes. The advantages of using models include: 1) multiple BMPs can be studied simultaneously; 2) the impacts of individual BMPs can be determined while also determining the effects of BMP combinations; 3) location-specific responses can be obtained; 4) modeling offers a practical means of analyzing various “what-if” management scenarios; and perhaps most beneficially 5) models offer relatively rapid and inexpensive assessments of current and projected stream and land condition.

This Simulation Plan is being prepared and distributed for review and comment by stakeholder agencies associated with Citico Creek Watershed, Tennessee River, City of Chattanooga, and the state of Tennessee.

2.0 Watershed Characterization

The watershed is the only watershed that begins and ends inside Chattanooga city limits. Citico Creek begins along the top of Missionary Ridge and meanders west through neighborhoods (Bushtown, Churchville, Avondale, and East Chattanooga), commercial and industrial facilities, and a major rail yard prior to discharging into the Tennessee River. The planning area includes 12.49 linear miles of creek draining 2,530 acres of watershed. To address spatial heterogeneity, Citico Creek Watershed has been divided into 23 sub-basins ranging in area from 10.5 to 369 acres. These 11-digit hydrologic units were derived from corresponding source streams or tributary watersheds (Figure 2.1, Table 2.1). These delineations are used in this planning document.

The reader is referred to a previously published City of Chattanooga document for a more thorough watershed characterization report, specifically providing estimates on demographics, imperviousness, current land use and zoning, and housing density. The Citico Creek Watershed Plan and Preliminary Characterization Report may be accessed via the internet at:

http://www.chattanooga.gov/Files/NPDES-CiticoWATERSHEDPLAN.doc.

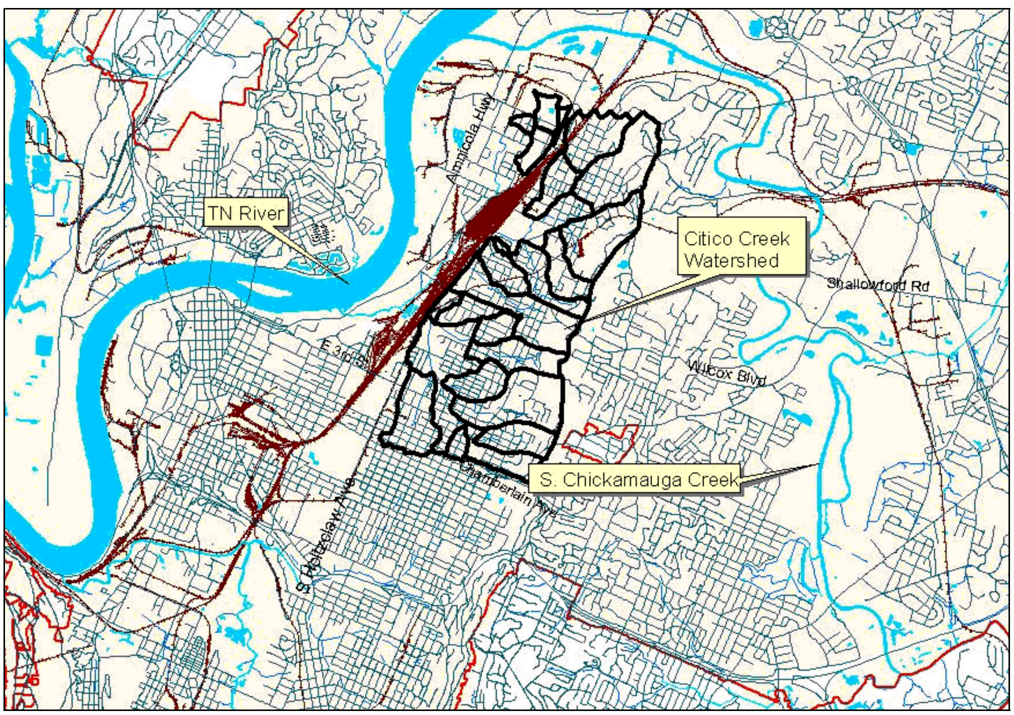

Figure 2.1 Citico Creek Watershed location and sub-basin delineation.

2.1 Physiography and Soils

The Ridge-and-Valley ecoregion, also referred to as Level III Ecoregion 67, is a lowland region between the Appalachian mountain chain to the east and the Cumberland Plateau to the west. As a result of extreme geologic folding and faulting events, the region's roughly parallel ridges and valleys have a variety of widths, heights, and geologic materials, including limestone, dolomite, shale, siltstone, sandstone, chert, mudstone, and marble. Springs and caves are relatively numerous. Valley floor streams have moderate to low gradients with bedrock, gravel, and sandy substrates. Streams of limestone-origin are generally well buffered and slightly alkaline.

The Southern Limestone/Dolomite Valleys and Low Rolling Hills (sub-Ecoregion 67f) form a heterogeneous region composed predominantly of limestone and cherty dolomite. Landforms are mostly low rolling ridges and valleys, with few steep ridges. Bedrock geology consists of Quaternary cherty clay solution residuum and Ordovician dolomite and limestone. Soils vary in their productivity under the soil series Colbert, Dewey, Fullerton, Sequatchie, and Talbott (USDA 1982). All of these soils are moderately- to well-drained with moderate to high permeability.

2.2 Land Use

Landscape and stream properties within a watershed reflect not only the physical and geologic context of the land, but also those associated with anthropogenic values and priorities. Such ideas are often reflected in the mix of land uses in an area, and in the diverse activities associated with a land use. Citico Creek Watershed is highly urbanized, with pockets of dense forest and small fields. White oak forests, bottomland oak forests, and sycamore-ash-elm riparian forests are the common forest types, which make up small discontinuous segments of woodlands scattered within urban areas. The Citico Creek Watershed Preliminary Characterization Report estimates 49% of the watershed is made up of single-family homes, and an additional 20.9% of the watershed as multiple family units (e.g. apartments, duplexes). Industry comprises 15.5% of the watershed land use and commercial properties make up 3.4%. Undeveloped land is estimated to comprise 11.2% of the watershed (City 2005). This land class would be classified as municipally owned parks, open lots, and forests.

As a result of the highly urbanized landscape, much of the planning area contains impervious surfaces, such as roadways, parking lots, sidewalks, and buildings. Such imperviousness changes the flow characteristics of streams within a watershed, including increased amounts of water the stream must carry during rain events (peak flows), increased flooding frequencies, and lower base flows. This often results in increased sediment loads and loss of aquatic and riparian habitat as soil and vegetation are scoured from the bottom and banks cave into the stream.

Employing a GIS database, percent imperviousness was estimated by tallying building and road acreage. Over the entire watershed, nearly 25% of the area, or 627 acres, is considered impervious; although individual values vary among each of the 23 sub-basins (Table 2.1). This value is classified as impacted or stressed after Schueler (1994a, b), and as such is considered to be a major source of pollutant loading. This classification affects stream health by altering natural hydrology, habitat structure, water quality and biodiversity of aquatic systems. At this stage, proper stormwater management can help mitigate any stream degradation.

Table 2.1. Impervious surface estimation by sub-basin for Citico Creek Watershed. Note that roadways account for 54% of all impervious area in the watershed, while buildings (rooftops) account for 46%. Road area was estimated using GIS analysis with road width varying between 25 and 70ft at each parcel.

Sub-basin ID	Total Area Bldgs (ac)	Total Road length (ft)	Total Road Area (ac)	Total Impervious Area (ac)	Total Watershed Area (ac)	% impervious Cover
002	40.97	46103	45.86	86.83	369	23.5
101	0.49	2510	2.88	3.37	25	13.5
102.01	30.94	24015	26.30	57.24	161	35.6
102.02	13.39	16540	16.71	30.1	89	33.8
102.03	33	22260	24.94	57.94	229	25.3
102.04	4.28	5515	6.08	10.36	26	39.8
102.05	12.34	10680	11.93	24.27	102	23.8
103	8.53	8745	9.89	18.42	63	29.2
104	7.48	8805	10.11	17.59	54	32.6
105	12.08	19765	20.22	32.3	119	27.1
301	24.46	14635	16.80	41.26	221	18.7
401	9.76	23220	24.56	34.32	78	44.0
501	9.17	16030	17.29	26.45	113	23.4
502.01	10.42	10880	10.56	20.98	93	22.6
503	13.8	12680	15.00	28.8	81	35.6
504	10.53	14415	14.56	25.09	206	12.2
505	18.34	26150	28.19	46.53	231	20.1
601	1.76	2135	2.45	4.21	16	26.3
602	4.41	2255	2.68	7.1	17	41.8
603	3.15	1734	2.65	5.8	39	14.9
604	0.9	1840	1.44	2.35	11	21.4
605	12.69	16905	19.40	32.09	142	22.6
007	6.76	5594	7.33	14.09	45	31.3
Total	289.65	313411	337.83	627.49	2530	24.8

For the purpose of this planning document, most pollutant sources within Citico Creek Watershed are classified as nonpoint sources, or diffuse sources which can not be identified as entering a waterbody through a single conveyance. The planning area does have however several designated point sources scattered throughout the watershed. The watershed contains a number of Multi-Sector General Permits for Industrial Activities (TMSP, Table 2.2), which monitors onsite stormwater management. Complete effluent discharge documentation over time is not available for these permitees and as such can not be adequately addressed in the present document. No Ready-mix Concrete Facilities (RMCF) with NPDES permits reside in the planning area as of January 2006, nor is there a WWTF.

Table 2.2. List of Sites with Coverage under the Tennessee Storm Water Multi-Sector General Permits for Industrial Activities, as of March 2007. Data from TDEC.

Permit Number	Permittee	Location
TNR050688	Accu Cast Operations	1911 Crutchfield
TNR051014	Array Chattanooga	3600 N. Holtzclaw
TNR050599	Cannon Equipment	950 Riverside
TNR053700	Chattanooga Wilbert Vault	1322 Stuart
TNR053888	Orange Grove Center	460 Dodson
TNR050413	Nu-Foam Products	1101 Wisdom
TNR051009	Roadtec, Inc.	2909 Riverside
TNR055069	TFS Fabricators, Inc.	806 N. Holtzclaw

Discharges from NPDES-regulated construction activities are considered point sources of sediment loading to surface waters and occur in response to storm events. However, since construction activities at a site are of a temporary, relatively short-term nature, the number of permitted sites and their environmental impacts at any given time or location varies. Although most land in the watershed is already built out, or designated as open space, construction activities likely still occur. Any current or future activities will need to be documented.

2.3 Water Quantity Assessment

The City of Chattanooga has been documenting the status and trends of water quantity and quality of Citico Creek over time since 2000. Surface waters in this watershed have been monitored, and continue to be monitored, as part of the stated requirements of the NPDES permit for the City of Chattanooga, Section V-A and -B. Figure 2.2 below displays the automatic sampling station at the outfall of the creek into the Tennessee River and 15 sampling sites scattered throughout the southern section of the watershed all monitored by the City of Chattanooga.

These monitoring data were instrumental in the development of a TMDL for Fecal Coliform in the Lower Tennessee River Watershed (TDEC 2006a) and a TMDL for Siltation and Habitat Alteration in the Lower Tennessee River Watershed (TDEC 2006b). Quarterly monitoring efforts are continuing by representatives from the City of Chattanooga along the 15 sites for the physical, chemical and biological parameters listed below:

Physical: temperature, electrical conductivity, flow, and turbidity
Chemical: pH, dissolved oxygen, chloride, and total phosphorus
Pathogens: fecal coliform, and *E. coli*

Between 1936 and 1941, the (now decommissioned) federal Works Progress Administration engineered and converted much of the large earthen ditches of Citico Creek, along with other city waterways, to concrete ditches. The bank sides were lined with rock and mortar while the bottom was lined with concrete. This created a smooth channel without the typical meandering pattern of ‘natural’ creeks. This process led to the ability to move more water because of the reduced friction and turbulence, which effectively eliminated pockets of standing and stagnant water. These ditches are now the primary channel for storm water drainage in the area. As a result of this activity, this urban stream is incorrectly viewed as drains, ditches and pipes, effectively disregarding the ecosystem services of value that may lead to any improvements in stream condition.

Flow data, which is inherently a function of rainfall, has been relatively stable for the watershed over time. Discounting a major rainfall event in January 2001 (4.45 inches in two days), the average flow for Citico Creek is approximately 1.3 ft^3/sec (n=32 dates from June 2000 to February 2007).

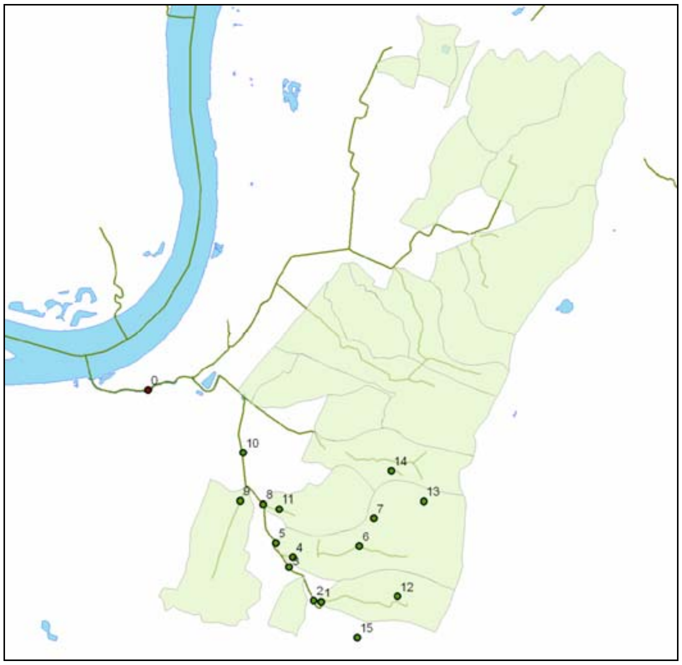

Figure 2.2. Location of City of Chattanooga sampling sites within Citico Creek Watershed.

2.4 Water Quality Assessment

The 2006 Tennessee 303(d) list identifies 7.3 stream miles of Citico Creek as impaired for one or more uses. Included in the watershed are 1.2 impaired miles of an unnamed tributary, and 6.2 impaired miles of Citico Creek (TDEC 2006c). These waterways are designated as unable to support fish and aquatic life, and recreation at the same level as the ecoregion reference stream. Identified priorities are *E. coli*, phosphates, habitat loss, and low dissolved oxygen; stemming from collection system failure, municipal point sources and hydromodification (TDEC 2006c).

The primary concern in the watershed is elevated pathogen levels posing health risks and prohibiting recreational opportunities. Data analysis efforts will therefore focus on data that will help characterize the sources of bacteria loads to the stream.

2.4.1 Physical and Chemical Parameters

Contracted by the City of Chattanooga, the University of Tennessee at Chattanooga completed a set of intensive water quality assessments on city waterways, including Citico Creek (Schorr et al. 2001). Conducted during the summers of 1998 and 1999, water quality parameters were monitored including biotic indicators, and benthic macroinvertebrates, among others. At four sites along Citico Creek, index of biotic integrity (IBI) scores were evaluated as a quantitative and qualitative evaluation of stream health. From May to July 1999, scores ranged from 16 to 32, or very poor to poor. During this same time window, other evaluated City waters had IBI scores as high as 40 (Mackey Branch). No IBI assessment has been conducted since this date.

Results from this assessment suggest a strong correlation in IBI scores and urban land use (r = -0.505, p = 0.019, Schorr et al. 2001), of which Citico Creek Watershed contains high concentrations. Other data highlights include summer water temperatures greater than 30.5ºC, violating the maximum temperature criterion established for "propagation and maintenance of fish and aquatic life" (TDEC 2004b). This is likely due to concrete-lined channels absorbing radiant heat. Low dissolved oxygen (DO) levels were also observed along Citico Creek during summers of 1998 and 1999, with several samples less than 5mg/L. Prolonged exposure to low dissolved oxygen levels (less than 5 to 6 mg/L oxygen) may not directly kill an organism, but will increase its susceptibility to other environmental stresses.

As a result, both temperature and DO levels failed to meet state Ecoregion stream levels (TDEC 2005). City-collected data since this assessment (October 2001 to June 2006) show improvements in both water temperature (< 30ºC) and DO (> 5mg/L; Figures 2.3 and 2.4).

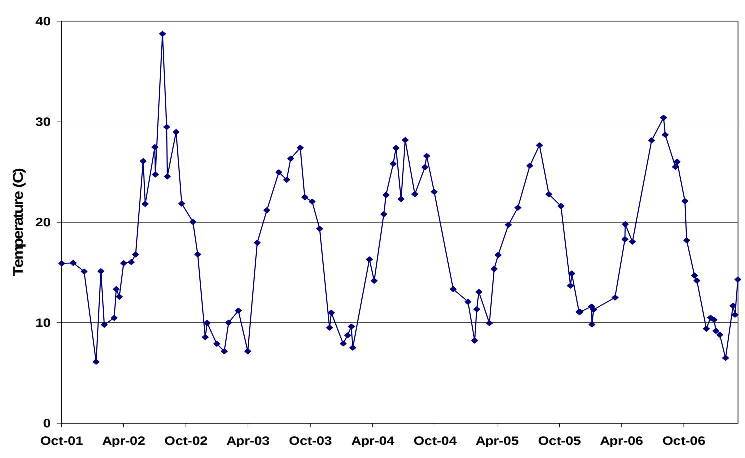

Figure 2.3. Water temperature (ºC) at the outfall of Citico Creek, sampled October 2001 through March 2007. The state target water temperature maximum is 30ºC which Citico Creek has surpassed only twice in five years.

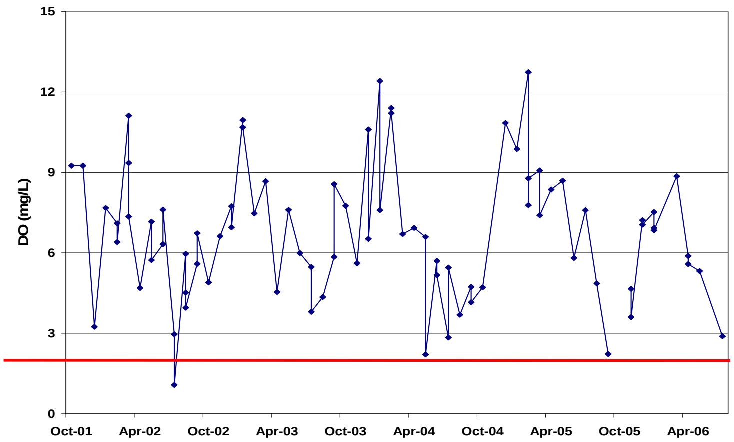

Figure 2.4. Dissolved oxygen (mg/L) concentration at the outfall of Citico Creek, sampled October 2001 through July 2006. The ecoregion reference DO level of 5mg/L is marked as a solid red line.

2.4.2 Pathogens

State water quality standards (TDEC 2004b) for the *E. coli* group require that the concentration shall not exceed 126 cfu per 100 mL, as a geometric mean based on a minimum of 5 samples collected from a given site over a period of not more than 30 consecutive days. Individual samples can range from 1 to 941 cfu per 100 mL. The single sample standard, as designated by TDEC was exceeded 10 out of 14 dates at a single sample site within the watershed (TDEC site CITIC1T0.3HM, City of Chattanooga site number 10), dated between June 2000 and May 2005. These data were used by TDEC for construction of load duration curves for *E. coli* (Figure 2.5). Based on water quality findings in the document, the TMDL proposes a required >90% reduction in pathogens for this site along Citico Creek. Sample data from a second site along the creek (TDEC site CITIC000.3HM, city automatic site) led to a required reduction of 32.3%. These two values will serve as targets for waste load reductions.

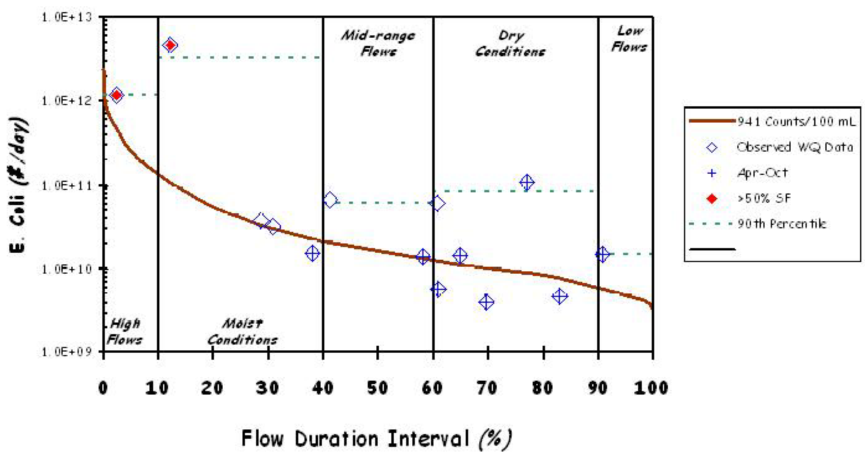

Figure 2.5. Load duration curve for *E. coli* at a single site along Citico Creek; from TDEC 2006a. Site is TDEC site CITIC1T0.3HM and City of Chattanooga site number 10.

The ongoing monitoring survey conducted by the City of Chattanooga has resulted in a site- and time-specific assessment of pathogen levels for Citico Creek. Previous analyses showed that as flow rates decreased, fecal levels increased (Logarithmic R^2 = 0.0206), suggesting that the pollutant source is due to chronic discharges rather than flow related releases (City 2005).

As of June 2005, the City of Chattanooga has developed a Supplemental Environmental Program (SEP) to reduce pathogen loading in the watershed via sanitary sewer infrastructure repair. Although this date is admittedly too recent to verify improvements in pathogen levels, Figures 2.6 and 2.7 display fecal and *E. coli* concentrations prior to and after June 2005 for the various monitoring sites along Citico Creek. Concentrations of fecal coliforms along the creek have declined 61% from 572 counts/100mL prior to June 2005 to 226 after this date. During this same time, levels of *E. coli* have declined 16% from 750 cfu/100mL prior to June 2005 to 634 cfu/100mL after this date. Although these values are lower than TDEC stated requirements of 941 cfu/100mL, several sites at several dates remain to exhibit higher concentrations than this threshold.

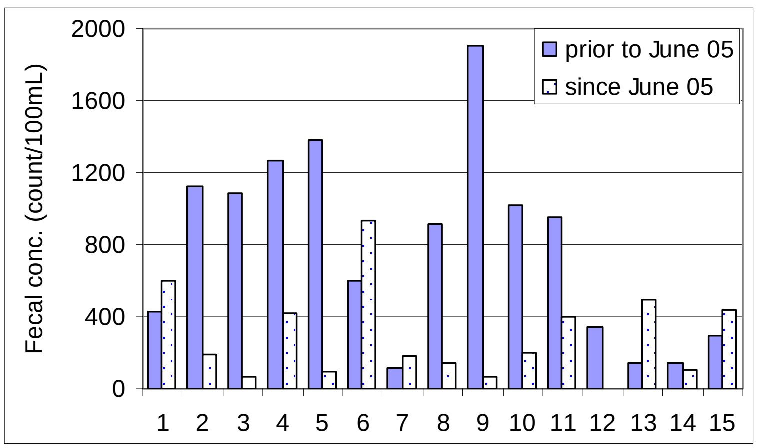

Figure 2.6. Concentration (geometric means) of fecal coliforms at various monitoring sites along Citico Creek before (n=13 to 25) and after (n=3) the city initiated SEP in June 2005.

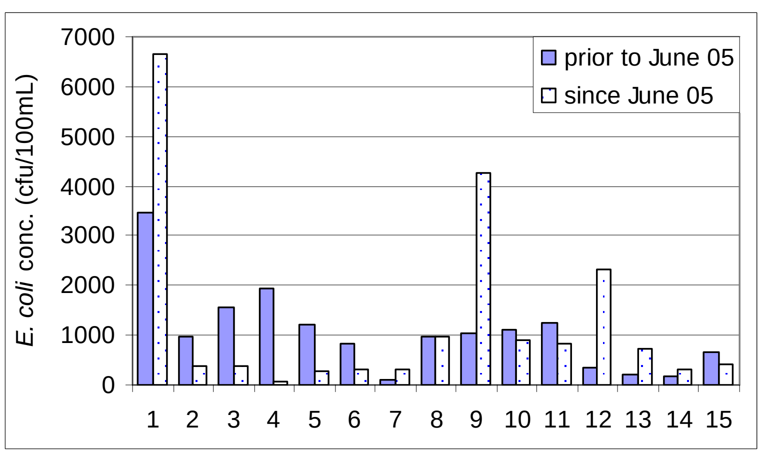

Figure 2.7. Concentration (geometric mean) of *E. coli* at various monitoring sites along Citico Creek before (n=13 to 25) and after (n=3) the city initiated SEP in June 2005.

2.5 Additional Characterization Needs

While the use of literature values in watershed characterization and modeling is helpful in preliminary analyses, it is important to characterize the flux and transport of select pollutants on a site- and time-specific basis. Transport of such pollutants is a function of local conditions that include topography, geology, land use and condition, and seasonal rainfall. As such, the monitoring and analyses required prior to proper assessment, design, and application of select stormwater BMPs may increase expenses in the short-term; however reliable data collection may save more expensive construction or implementation costs and may help stormwater designs improve local water quality and quantity.

To build upon the preliminary characterization report composed by the City of Chattanooga, to establish baseline water quantity and quality numbers, and to satisfy the NPDES permit for the City of Chattanooga Section V.C., additional watershed characterization data will need to be collected, collated, verified and/or established. Specific needs include:

- Ground-truth WPA ditch length and condition by sub-basin
- Establish natural stream corridor assessment by sub-basin
- Establish road bank (right-of-way) condition by sub-basin
- Verify land use / land cover for select sub-basins since the last assessment dated 2005
- Collect and collate relevant NPDES point source data; estimates from earlier time periods may be necessary to allow separate validations
- Collect and ground-truth construction activities, NPDES-permitted or otherwise
- Maintain the current monthly ambient monitoring regime for the consistent collection of flow, water temperature, and dissolved oxygen levels
- Conduct an IBI assessment to supplement the 1999 scores

3.0 Watershed Modeling

Biogeochemical models have increasingly been used to quantify and track local and regional nutrient budgets in order to determine whether specific areas or practices are sources or sinks for certain nutrients. Many methods are presently available to estimate the concentration and loading of pollutants to surface waters. Most models are deterministic in that the model outputs are uniquely determined by the inputs, and predictions consist of a single value at a given point in time and space. This assessment may be appropriate for developing management actions to meet water quality standards expressed in terms of average loads, such as TMDLs.

Models are inherently not definitive and rather should be used as a tool to generate loading estimates. These local assessments, such as those of an individual agricultural lot or a forest stand, can significantly contribute to the comprehension of ecosystem function by further qualifying and quantifying nutrient cycling. Such models may require substantial site-specific data for calibration over the range of expected conditions, but can be very effective when data exists and can simulate the most important physical, biological, and chemical aspects of the problem. The objectives of this section are to select and develop a model that will simulate pollutant fluxes and to evaluate the model in terms of specific land covers and/or land use practices. A final document reporting complete hydraulic and pollutant loading modeling will be completed and submitted to state and local stakeholders no later than April 2008.

3.1 Model Selection

In general, the wash-off of pollutants from a land area towards another land area, or a waterway is a loading factor. Techniques to estimate pollutant loading include generalized relationships to hydrology and soil and sediment movement. Since soil loss has been recognized as a major nonpoint source problem for many years, several standards have been established for erosion on various lands. These standards are based on the loss of a soil resource rather than any downstream environmental impact. Many of these accepted formulaic standards, including the Universal Soil Loss Equation (USLE, Wischmeier and Smith 1978), may be used to estimate pollution loading.

Citico Creek Watershed is currently classified as not fully supporting all of its listed uses due to high pathogen levels; although these annual pollution loads are inherently difficult to estimate for large areas. Previous work suggests that creek nitrogen loads are strongly related to creek total suspended solids, or TSS, loads (Ittekot and Zhang 1989, Ludwig and Probst 1996), and it is reasonable to infer that pathogen loads would also scale with TSS loads. We therefore consider in our model selection water quality models that can accurately and precisely simulate nutrients in the environment.

Several commonly accepted models are being evaluated including SWAT, SWMM, WARMF, and the EPA supported BASINS with HSPF or PLOAD. Specific criteria that will be considered in the screening of applicable models include, but are not limited to:

- Level of analysis
- Level of sophistication / Ease of use
- Temporal and spatial scale

- Hardware/software requirements
- Data input requirements
- Adaptability to local conditions
- Model availability (with documentation)
- Application history relevant to planning area

3.2 Model Setup

Water quality models attempt to emulate the accumulation, infiltration, and removal of pollutants within a receiving stream. Such applications often rely on general data and inferences on pollution concentrations and reactions in surface runoff and then predict the aggregation through an estimation of runoff volumes. The amount and type of required time, effort, and data in using water quality models depends on many factors, perhaps most importantly the complexity of the model employed. In cases when observed data are not readily available, input data may be collected and collated from literature for similar models. Conversely, best guesses and verification efforts may be required. Regardless of model selection, four basic steps define the procedure for calculating pollution loads generated by nonpoint sources (Chapra 1997). These include:

- Estimating typical concentrations of each water quality pollutant in runoff.
- Delineating these water quality data, defined as estimated mean concentrations (EMC), by pre-defined land use types.
- Calculating load from a given area by multiplying the calculated runoff volume from that area with the appropriate EMC value.
- Calculating total loads from the entire watershed by summing the loads from all the contributing sub-basins in the watershed.

A preliminary pollutant loading model using coarse inputs and assumptions is described and analyzed in Section 4.0. This early assessment should provide a basic framework for future modeling activities.

3.3 Required Inputs

Models may vary in their scope and output capabilities; however, some generalizations of the input data requirements are constant. These include watershed segmentation, drainage network, topography, land use or land cover, and rainfall frequency and volume.

Citico Creek Watershed was delineated into individual land and channel segments that are assumed to demonstrate relative homogeneous hydrologic and water quality responses. Based on both topography and hydrology, the planning area was divided into 23 sub-basins ranging in area from 10.5 to 369 acres (Figure 2.1). This segmentation provides the basis for assigning similar input or parameter values or functions to where they may be logically applied, such as runoff response or meteorologic conditions. Such delineation may be used to prioritize restoration efforts, efficiently and effectively apply funds, educate stakeholders, and improve implementation of stormwater BMPs.

It has been argued that stormwater runoff is produced by infiltration-excess overland flow. That is when rainfall intensity and volume exceed the infiltration capacity of the soil, the excess results in filled surface depressions and downslope and surface runoff begins. Such overland flow can generate large flood peaks, flashy hydrographs, and altered channel morphology (Meyer *et al*. 2005).

As introduced, the USLE was developed as a theoretical simulation tool for estimating sheet and rill erosion from fields based on the variability of both the landscape and soil types within it (Wischmeier and Smith 1978). The USLE enables planners to estimate annual rates of erosion for combinations of land covers and management practices in association with soil properties, rainfall patterns, and topography. This translates into the following equation that has been updated via decades of application and research:

$$A = R \times K \times LS \times C \times P$$

Where:

A	= soil loss (tons/acre/year)
R	= rainfall energy factor
K	= soil erodibility factor
LS	= slope-length factor
C	= cropping management factor
P	= erosion control practice factor

These updates have provided better estimates of local soil erosion and now form the basis of many pollutant loading models. In the United States, the USLE is a reliable and accepted methodology for estimating soil loss erosion rates, and is required for assistance through several conservation programs. As such, the individual components of the USLE will need to be collected and adapted to the Citico Creek Watershed.

3.3.1 Hydrologic & Hydraulic

Water quality models simulate catchments and loading based on forcing data such as input rainfall and evaporation (or infiltration). These inputs are modified by area, land use, imperviousness, slope, and soil properties, among others. As land use parameters vary over space, so do rainfall, infiltration, runoff, and erosion properties, for which to account for. Site specific analyses on land use and imperviousness have been completed (cf. Section 2.2), although identification of slope and soil properties remains to be evaluated.

The level of precision needed for rainfall and evaporation will need to be analyzed to determine which timestep resolution will be required, i.e. 15-minute, hourly, daily, or annual timesteps. Preliminary simulations may need to be conducted at different timesteps to determine the sensitivity of forcing data. Some models require hourly timesteps, so data may need to be disaggregated from daily to hourly. Conversely, the seasonal variation in constituent concentrations may be valid for *post hoc* analyses. Regardless of timestep, a major requirement is a complete record (no missing data) for at least 30 years. No QA/QC documented weather station is located in Citico Creek Watershed; although nearby Lovell Field-Chattanooga Airport is approximately 3.5 miles southeast. This National Climatic Data Center (NCDC) site will satisfy the required complete record, with 30-yr averages shown in Table 3.1 below.

Although the watershed has minimal depression storage, evaporation data will be important in this analysis due to the size of most sub-basins. Evaporation data will also be highly applicable to this watershed because of the anticipated limited amount of infiltration due to the great amounts of imperviousness – including impervious channels. Evaporation (or evapotranspiration) data are generally less variable than rainfall data; therefore a complete 30-yr record as defined above is not necessary.

Table 3.1. 30-yr Average temperature and precipitation totals for Chattanooga Airport, along with USLE rainfall energy factor; data from NOAA, NCDC.

Month	Avg. temp. (ºF)	Monthly precip. (in.)	USLE R values
Jan	36.8	5.40	16
Feb	41	4.85	17
Mar	49.7	6.21	27
Apr	58.4	4.23	22
May	66.1	4.28	27
Jun	73.8	3.99	32
Jul	77.2	4.73	44
Aug	76.5	3.59	29
Sep	70.8	4.31	28
Oct	59.2	3.26	18
Nov	49.5	4.88	20
Dec	40.5	4.81	16
Total		54.54	296

3.3.2 Sediment & Pollutant Loading

A number of methods can be used to generate constituent concentrations for use in stormwater modeling. Many water quality models estimate nonpoint water pollution into watersheds based on the input of either event mean concentrations (especially for urban areas) or export coefficients (also referred to as build up calculations). Event mean concentrations represent the concentration of a specific pollutant contained in runoff originating from a particular land use, reported as mass per unit volume of water (usually mg/L). Export coefficients represent the average total amount of pollutant loaded annually into a system from a defined area, reported as mass per unit area per year. The watershed analysis will evaluate both approaches.

Most pollutant loading models treat loading as a function of the runoff rate to account for mobilization. Runoff rate is used instead of rainfall intensity, recognizing that runoff will generally lag the rainfall based on soil moisture holding capacity and obstructions, natural or otherwise. This is applied indiscriminately to all solids and does not account for the variation in runoff rate with particle size. For example, larger particles (> 400µm) require greater runoff intensities to induce substantial loading. However, most (80%) pollutants in the present analysis will be particles less than 400µm (EPA 1982). This relationship must be further evaluated for sites with high impervious cover, such as with areas in the current planning area.

An attempt must be made to express the relationship between rainfall and direct runoff via a runoff coefficient. This value is generally not considered a constant, but rather depends on antecedent soil moisture, rainfall intensity, rainfall volume, and, perhaps most importantly, degree of imperviousness. Any level of extrapolation of rainfall depth or energy to uniform coverage of the entire watershed will introduce error into the loading estimate. Runoff coefficients for the different land classes will be estimated using the following equation taken from the EPA (1990) report, “Urban Targeting and BMP Selection”.

Pollutant concentrations (mg/L) will be taken from the EPA’s National Urban Runoff Study (EPA 1982) in conjunction with local water conditions monitored and analyzed by various local, state and federal agencies. Values should be determined based on median and 90th percentile urban concentrations presented by EPA, plus high and low values from on-site sampling to obtain pollutant concentrations.

Due to the specific climatologic and physiographic characteristics of individual watersheds, regional and local land uses can exhibit a wide range of variability in nutrient and pathogen export (Omernik 1977, Reckhow et al. 1980). As such, there remain some reservations as to the applicability of employing export coefficients or event mean concentrations for different land uses developed from region to region. The coefficients included in this analysis will be screened using certain acceptance criteria, based on the accuracy, precision, local representativeness, and spatial and temporal extent of data sampling.

3.3.3 Pathogen Loading

Similar to sediment loading, pathogen models are based on several theoretical assumptions to emulate natural processes. Though not always, bacteria transport can generally be linked to soil transport in the form of runoff. So in most simple terms, bacteria loading can be expressed as concentration plus runoff. In more exact terms, the equation for pathogen loading may be:

$$\text{Load} = \text{Area} \times \text{Conc} \times \text{Runoff} \times 0.102790$$

Where:

Load	=	Bacteria Load (1.0E+11 cfu/yr)
Area	=	Drainage Area (ac), derived from GIS
Conc	=	Runoff or Event Mean Concentration (cfu/100mL)
Runoff	=	Runoff Potential (in)
0.102790	=	Liters of Runoff from 1 inch per acre

Here, Runoff is linked to:

rain events (single storm volume, annual rainfall frequency and volume),
soil properties (curve numbers for hydrologic soil groups),
land use (cover type, hydrologic condition, imperviousness), and
land disturbances, among other things.

Concentration here may either by event mean concentrations, or runoff coefficients; whichever is determined a best fit to observed levels.

3.4 Additional Data Needs

The previous sections have identified many of the data available for processing a hydrologic simulation and/or a pollutant loading model for Citico Creek Watershed. Through extrapolation, the text has also identified additional data needs for such processing and analyzing. The following section introducing preliminary pollutant loading modeling work utilizes coarse inputs not necessarily site- or time-specific. Additional analyses must be completed to better define such inputs. Based on the exposure to select water quality models, additional relevant data needs beyond those mentioned for watershed characterization include:

- Individual components of the USLE need to be evaluated on a site-specific basis, particularly:
    - K- Soil Erodibility, which may be addressed via soil permeability or texture characteristics;
    - LS – Length-Slope characteristics, which may be averaged over a sub-basin level for the purpose of TMDL implementation; and
    - C – Cover Management factors, such as vegetative properties (type and density) on open spaces.
- As runoff is primarily a function of land area and rainfall discharge, individual storm events and curve numbers must be evaluated at the sub-basin level.
- For each land class and pollutant, event mean concentrations will need to be calculated
- Pollutant loading models will require applicable runoff concentrations (mg/L) delineated by land use / land cover.
- Models may also require soil pollutant coefficients (weight of pollutant per weight of soil) delineated by land use / land cover.
- Degree of acceptable uncertainty associated with this analysis (see Section 5, this document).

4.0 Preliminary Watershed Modeling

Employing a relatively simple model developed during a NURP study in the Washington DC area, total suspended solid (TSS) pollutant loading from urban classes was analyzed. A pathogen (bacteria) model following the general equation listed in Section 3.3.3 above was used to estimate bacteria loading. Both approaches run on the assumption of pollutants entering the waterways solely via surface runoff, which is the primary source of stormwater. Some precision is lost as a result of model simplification, applicability to the planning area, and current data gaps. However, the approach remains adequate to be used in decision making at the City of Chattanooga planning level. The model uses a Microsoft Excel (Microsoft Corp. Redman, WA) workbook to perform the calculations and display the results in tabular and graphical form.

The workbook consists of sheets for the land use inventory, forcing and loading parameters, and a calculation sheet for each loading parameter, accompanied by graphs to display results. These parameters were developed as discussed below. Treatment scenarios can be explored by changing model parameters in the original model and viewing the changes in the linked output graphs and tables. These models can also be used to demonstrate the effect of potential nonpoint source and/or stormwater management strategies on pollutant loads.

4.1 Model Inputs

Pollutant loads from urban land uses (residential, commercial, and industrial) were estimated using a method described by the EPA (EPA 1990) using the following equation:

$$M = RainV \times Rv \times Area \times Conc \times 0.0001135$$

Where:

M	=	mass load (tons/year)
RainV	=	average annual rainfall (inches)
Rv	=	runoff coefficient (unitless)
Area	=	drainage area (acres), derived GIS
Conc	=	average runoff concentration (mg/L)
0.0001135	=	unit conversion factor

The areas used for each land class were generated by the GIS database. Annual rainfall estimates were obtained from a National Climatic Data Center weather station at Lovell Field - Chattanooga Airport TN (35.03°N 85.20°W, 689 ft asl). Estimates of annual rainfall for the area are 54.52 inches over the 23 sub-basins (NCDC 2007) and were applied at the sub-unit scale. No additional time delineations or disaggregations were applied. Runoff coefficients for the different land-use classes were estimated using the following equation taken from the EPA (1990) report, “Urban Targeting and BMP Selection”:

$$Rv = 0.050 + 0.009 \text{ (Percent imperviousness)}$$

The values used for percent impervious by land use/land cover class were determined by remote sensing as defined in Section 2.2 above. Pollutant concentrations (mg/L) were taken from the EPA's National Urban Runoff Study (EPA 1982) as describe in Section 3.3.2 above. Sub-basin acreages were delineated via GIS processes as displayed on Table 2.1 with additional model input values presented on Table 5.1.

Table 5.1. Runoff coefficients (unitless) and pollutant concentrations (mg/L) imported in to the pollutant loading model for urban land uses within Citico Creek watershed.

	Heavy Residential	Light Residential	Commercial	Heavy Industrial	Light Industrial
Runoff Coefficient	0.365	0.221	0.545	0.725	0.545
TSS Concentration (mg/L)	120	100	150	180	120
Percent Impervious	35	19	55	75	55

Loading estimates from construction activities will be derived using the same methods applied here, however location and potential impacts remain to be established and/or confirmed. Pollutant loading from areas designated as open space will require additional land analyses to be properly conducted, i.e. USLE factors. Similarly, any additional inputs from streambanks and roadbanks will require further analyses such as condition by sub-basin.

Pathogen (bacteria) loads were estimated using the equation presented in Section 3.3.3. Total and sub-basin drainage areas were derived from GIS analyses and runoff was generated using functions of single storm rain events (average of .48 inches per event), curve numbers (ranging from 75 for open spaces to 88 for industrial districts), and drainage areas.

4.2 Pollutant Loading Estimates

Based on early modeling efforts, urban land classes contribute nearly 582 tons of TSS per year to Citico Creek, or 460 lbs/ac/yr (Table 5.2). Most of this pollutant stems from heavy industrial sites, although commercial and industrial sites both contribute high loads per acre (Figure 5.1). Loading per acre values are generally a function of imperviousness and runoff, and are consistent with previously published modeling documents.

Due to the impact of heavy industrial sites, any and all sub-basins that contain a proportionally high acreage of these land uses are estimated to generate high loads of TSS. For example, sub-basins 301 and 102.01 contain high acreages of heavy industrial and subsequently contribute high amounts of TSS per year. Sub-basins 601, 602, 603, and 604 in the north also contain high acreages of industrial sites, relative to the overall acreage of these areas. As such, these areas have high load per acre values.

Bacteria loading modeling generated an annual estimate of 43,128 x 10^9 cfu across the watershed (Table 5.3). Loads stem from residential areas mostly (Figure 5.3), with lands designated as heavy residential accounting for 42% and light residential accounting for

43% of all loading. As such, sub-basins that contain high proportions of heavy residential categorized lands have high estimates of bacteria loads (Figure 5.4). City Parks and open spaces contributed the least amounts of bacteria per year and per acre per year, collectively contributing approximately 3% of all loads.

Table 5.2. TSS loading (ton/year and ton/acre/year) estimates from urban sites within Citico Creek Watershed.

	Residential	Commercial	Industrial	Total
ton/yr	248.8	35.5	297.5	581.8
ton/ac/yr	0.174	0.506	0.789	0.23

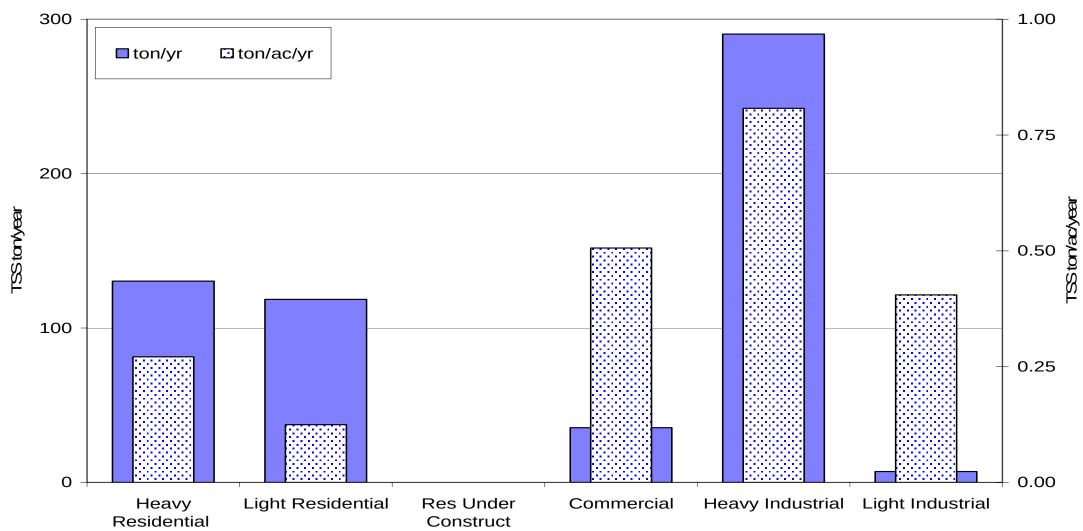

Figure 5.1. TSS loading (ton/yr and ton/ac/yr) from urban land uses within Citico Creek Watershed.

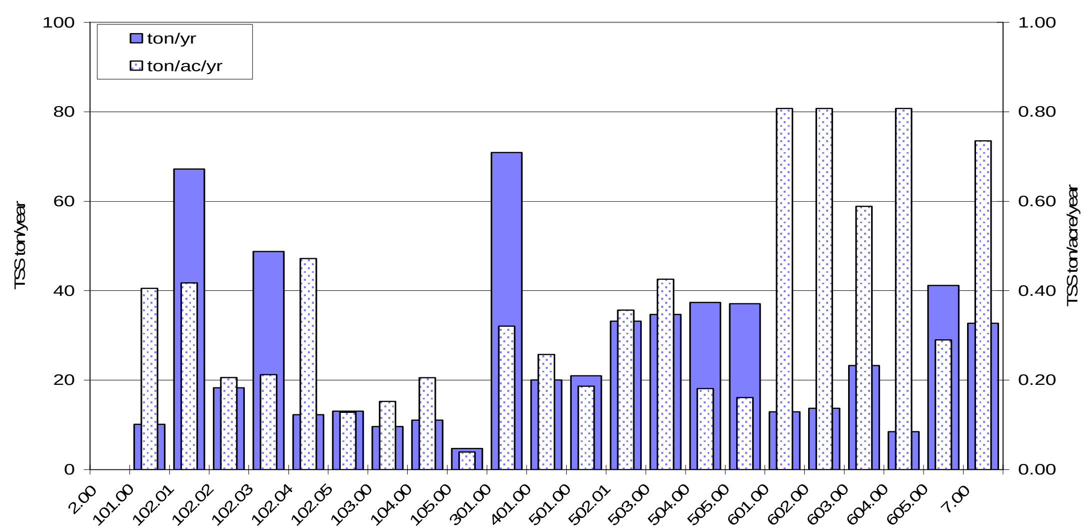

Figure 5.2. TSS loading (ton/yr and ton/ac/yr) from urban sites within Citico Creek Watershed delineated by sub-basin. Sub-basin 002 shows no loading as a result of incomplete land use analysis and delineation.

Table 5.3. Bacteria loading (1.0E+9 cfu/year and 1.0E+9 cfu/acre/year) estimates from Citico Creek Watershed.

	Residential	Commercial	Industrial	Open Space	Total
1.0E+9 cfu/yr	36,800.5	628.6	4,330.2	1,369.2	43,128.4
1.0E+9 cfu/ac/yr	25.8	9.0	11.5	4.7	17.0

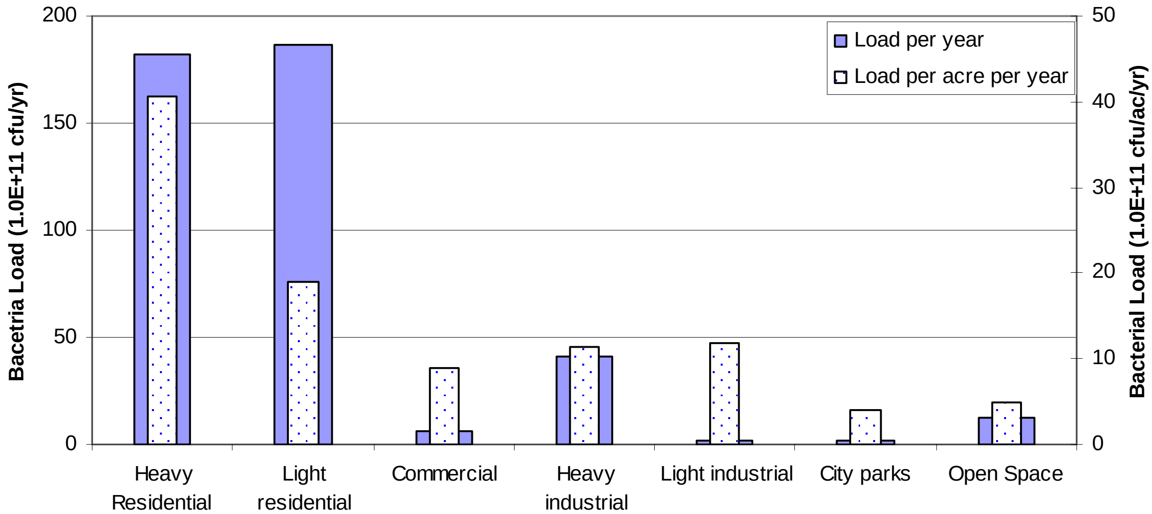

Figure 5.3. Bacteria loading (1.0E+11 cfu/year and 1.0E+11 cfu/acre/year) estimates by land use for Citico Creek Watershed.

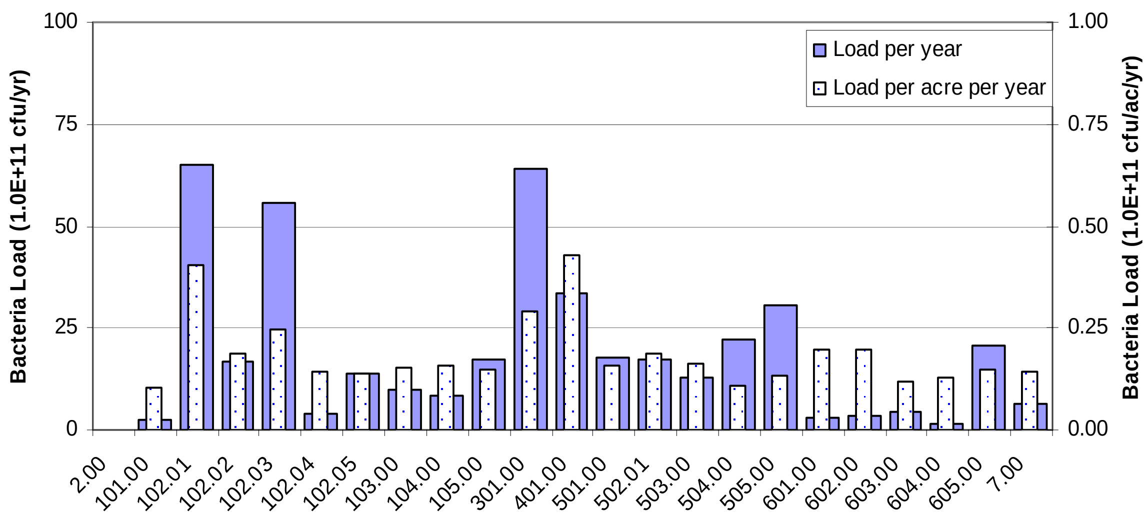

Figure 5.4. Bacteria loading (1.0E+11 cfu/year and 1.0E+11 cfu/acre/year) estimates by sub-basin for Citico Creek Watershed.

5.0 Model Calibration and Validation

Scientific uncertainty is present in all ecological modeling and risk assessment. Given the relative simplicity of simulation and loading models in comparison to the complexity of nature, it seems reasonable to question the legitimacy of any mathematical expression of natural patterns and processes. Uncertainty should not prevent stormwater management decision making, but rather it should provide structure to the analysis and present inferences in an appropriate way.

Simulation models are typically specified and constructed to describe average behavior over a given time, such as TSS tons/year as shown in Section 4. Regardless of the complexity of the model, or the model inputs, residual uncertainty due to natural variation, misrepresentation of data or measurement error will occur. This means that extremes are likely underestimated, such as the tail area of a distribution curve. Temporal and spatial scale issues are critical components of any watershed analysis, and as we upscale in either category, processes become increasingly complex. The level of expected accuracy of a given model must be tempered by the complexities of the land use characteristics, drainage pattern, the quality of available data, and water management activities. As such, a certain degree of tolerance of uncertainty must be agreed upon by stakeholders.

Uncertainties can be decreased by increasing the amount of calibration data. The suggested methodology for model calibration includes a cross validation, which is especially well-suited for cases where available data are limited (Rode et al. 2006), such as the present effort. Upon completion of a full analysis, three problem areas will need to be examined and addressed in detail: uncertainty about model structure, uncertainty in the estimated model parameter values, and the propagation of prediction errors associated with a model. The results of this study will help model users to define appropriate data collections and monitoring schemes.

Calibration procedures will include:

- Converting modeled load to concentration: average concentration of parameter n = modeled load of parameter n divided by estimated total discharge from the subwatershed times a units correction factor ($C_n = L_n/Q_{total} \times k$)
- Regressing modeled average concentrations against measured concentrations
- Adjusting model parameters to maximize R^2 within realistic bounds of relative values and get slope close to 1
- Appling values determined by regression on sub-basins to entire watershed to estimate total load

The ultimate goal of the planning process is to remove Citico Creek from the Tennessee 303(d) list of impaired waters. While the loading numbers presented in Section 4 are only estimates of annual TSS loading, the process identifies specific sites and land use classes that should be further evaluated and targeted to reduce such loading. Given the inherent errors in input and observed data, and the approximate nature of models in general, no model will offer absolute loading values. Thus, the entire modeling process should be used as a tool to identify regions and practices on which additional monitoring, modeling, and stormwater BMP implementation should concentrate. This targeted effort will prove to be an efficient approach to reduce pollutants on a watershed scale.

6.0 Planning Milestones

Measuring parameters to evaluate progress toward a goal requires the establishment of targets against which observed measurements may be compared. These targets are not necessarily goals themselves, because some of them may not be realistically obtainable. However, targets necessarily define water quality standards, as set forth by the State of Tennessee, or scientifically supported numbers that suggest trends to achieve said targets. Utilizing these numerical targets as targets for success will assist the stakeholders in deciding how to improve programs to reach both restoration and preservation goals and know when these goals have been successfully achieved. To this end, physical, chemical and biological conditions of the water will continue to be monitored to track progress, identify pollution source(s), and evaluate the success of efforts to improve Citico Creek water quality.

An established quantitative sampling regime is presently active by the City of Chattanooga as defined in Section 2. This campaign has successfully served its purpose of gathering baseline data to which post-initiative sample data may be compared. Upon reviewing the data collected over the years 2002 through 2005 for this waterway, and TDEC sampling documents for pathogens (TDEC 2004c) it is believed that the types of parameters monitored, the current operating procedures, and the number of sample locations in the watershed are sufficient to address this evaluation strategy.

Supplemental water quality data, specifically for *E. coli* will be compiled in the form of the collection of five samples in one month to develop a geometric mean, following TDEC protocols. These data will then be used to reevaluate 2004 TMDL required load reductions. This campaign will be conducted for at least one pre-established sample site along Citico Creek.

A proposed implementation schedule for Citico Creek Watershed Modeling is presented in Table 6.1 below. This 12-month timeline will begin following receipt of all stakeholder feedback, approval of this simulation plan, or June 1 2007, whichever occurs first. The milestones in Table 6.2 will be tracked to document the major components and their success of this simulation plan. The identification of critical areas developed by the land analysis should be verified via GIS exercises and/or site visits no later than December 31, 2007. Urban sites which should be verified for appropriate modeling include roadway and streambank assessments, WPA ditch assessments, and NPDES-permitted construction locations and impacts. Some of this work may be conducted through employing results from the City of Chattanooga’s recently completed As-Found project which ground-truthed much of the city’s stormwater infrastructure. Through both GIS exercises and on-site evaluation, this watershed characterization data may be incorporated into the watershed model.

The successful completion of watershed characterization including all items listed above will serve to adequately address knowledge gaps in modeling exercises. Establishing site- and time-specific model inputs will run concurrent with characterization efforts. Watershed Characterization will conclude in December 2007 and Modeling will conclude in April 2008.

Table 6.1. Proposed schedule of implementation to address characterization and modeling needs.

	2007								2008				
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Verify 3580 ft of WPA ditch length and condition by sub-basin		x	x	x	x	x	x	x					
Verify 5920 ft of streambank length and condition by sub-basin		x	x	x	x	x	x	x					
Verify 8.5 mi of roadbank length and condition by sub-basin		x	x	x	x	x	x	x					
Verify land-use/land cover for Sub-basin 002			x										
Verify land-use/land cover for Sub-basin 102.04				x									
Collect and collate NPDES-permitted point source data							x						
Monthly ambient monitoring of physical parameters	x	x	x	x	x	x	x	x	x	x	x	x	x
Collect sample geometric mean(s) of *E. coli*							x						
Conclude modeling exercises											x		
Compose Watershed Modeling Report											x	x	
Submit Characterization and Modeling Report to TDEC													x

Table 6.2. Characterization and Modeling milestones for Citico Creek Watershed.

Milestone	Anticipated Completion
Characterization	
Establish a natural stream corridor inventory and assessment program	June-07
Complete Watershed Characterization	December-07
Obtain geometric mean of *E. coli*	November-07
Conduct IBI assessment to compare with previous results to evaluate progress	August-07
Modeling	
Select site- and time-appropriate hydraulic and pollutant loading model(s)	June-07
Establish all site-specific modeling parameter inputs	August-07
Conduct uncertainty analysis	January-08
Complete Watershed Modeling	April-08

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