

DISTRICT OF COLUMBIA

**TOTAL MAXIMUM DAILY LOAD
FOR
BACTERIA
IN
CHESAPEAKE AND OHIO CANAL**

OCTOBER 2004



Government of the
District of Columbia
Anthony A. Williams, Mayor

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Executive Summary

This report details the development of a total maximum daily load for the Chesapeake and Ohio (C&O) Canal within the boundaries of the District of Columbia. The C&O Canal runs parallel to the Potomac River from the mouth of Rock Creek in Washington D.C. to Cumberland, Maryland. The C&O Canal was listed on the District's 1998 through draft 2004 Section 303(d) Lists of Impaired Waters due to exceedances of the District's fecal coliform water quality standards.

The C&O Canal was originally built and used to transport goods and supplies between the inland areas and coastal areas of United States. The Canal operated from 1850 to 1924, and today is preserved as a national historic park. The C&O Canal is comprised of 74 lift locks, 11 aqueducts, over 180 culverts, and over 50 waste weirs. The average depth of the Canal is approximately four to five feet, but there is significant depth variation in some sections of the Canal due to sediment deposition. The Canal is trapezoidal in shape, with an average width of 60 feet on the surface, and 40 feet on the Canal bottom.

The C&O Canal receives much of its water from the mainstem Potomac via intakes located along the length of the Canal. Water also enters the District portion of the Canal from the upstream sections located in Maryland, stormwater discharge, and direct runoff from an approximately 100 foot bank area that drains into the Canal. DOH sewershed GIS data indicate that stormwater drained from approximately 426 acres flows directly into the C&O Canal.

The principle source of water to the C&O Canal is the Potomac River Basin, which drains 14,670 square miles of land, and flows from its headwaters in the Allegheny Mountains to its discharge into the Chesapeake Bay. Land use in the headwaters of the Potomac River Basin is a combination of forested and agricultural lands. Significant urban development occurs in the lower reaches of the basin in and around the Washington D.C. metro area. Soils in the upland areas of the Potomac River Basin are generally well-drained, and are moderately deep to deep. Soils in the Coastal Plain lowland areas of the basin typically consist of finer grain sands than the upland areas.

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The Hydrologic Simulation Program-Fortran (HSPF) model was selected and used as a tool to predict the instream water quality conditions in the C&O Canal under varying scenarios of rainfall and fecal coliform loading. The results from the model developed for the C&O Canal were used to establish the TMDL allocations based on the existing fecal coliform load. HSPF is a hydrologic, watershed-based water quality model. Basically, this means that HSPF can explicitly account for the specific watershed conditions, seasonal variations in rainfall and climate conditions, and activities and uses related to fecal coliform loading.

TMDL allocations for the C&O Canal were based on the following equation:

$$\text{TMDL} = \text{WLA} + \text{LA} + \text{MOS}$$

Where: TMDL= Total Maximum Daily Load

WLA = Wasteload Allocation

LA = Load Allocation

MOS = Margin of Safety

The wasteload allocation represents the total pollutant loading allocated to permitted discharges, which in the C&O Canal consists entirely of outfalls covered under the District's MS4 permit. The load allocation represents the total pollutant loading allocated to nonpoint sources. An implicit or explicit margin of safety is a required TMDL element to account for uncertainties in TMDL development. An explicit margin of safety of one percent was used to develop the TMDL for fecal coliform bacteria in the C&O Canal.

The C&O Canal fecal coliform TMDL, including the existing and allocated load, margin of safety, and percent reductions required from each contributing source to meet the primary contact recreation fecal coliform standard, is presented in Table E-1. A summary of the C&O Canal fecal coliform TMDL is presented in Table E-2. The resulting fecal coliform concentrations under the TMDL allocation plan are presented in Figure E-1. As seen in Figure E-1, fecal coliform concentrations do not exceed the primary contact recreation fecal coliform standard of 200 MPN/100 mL under the TMDL allocation.

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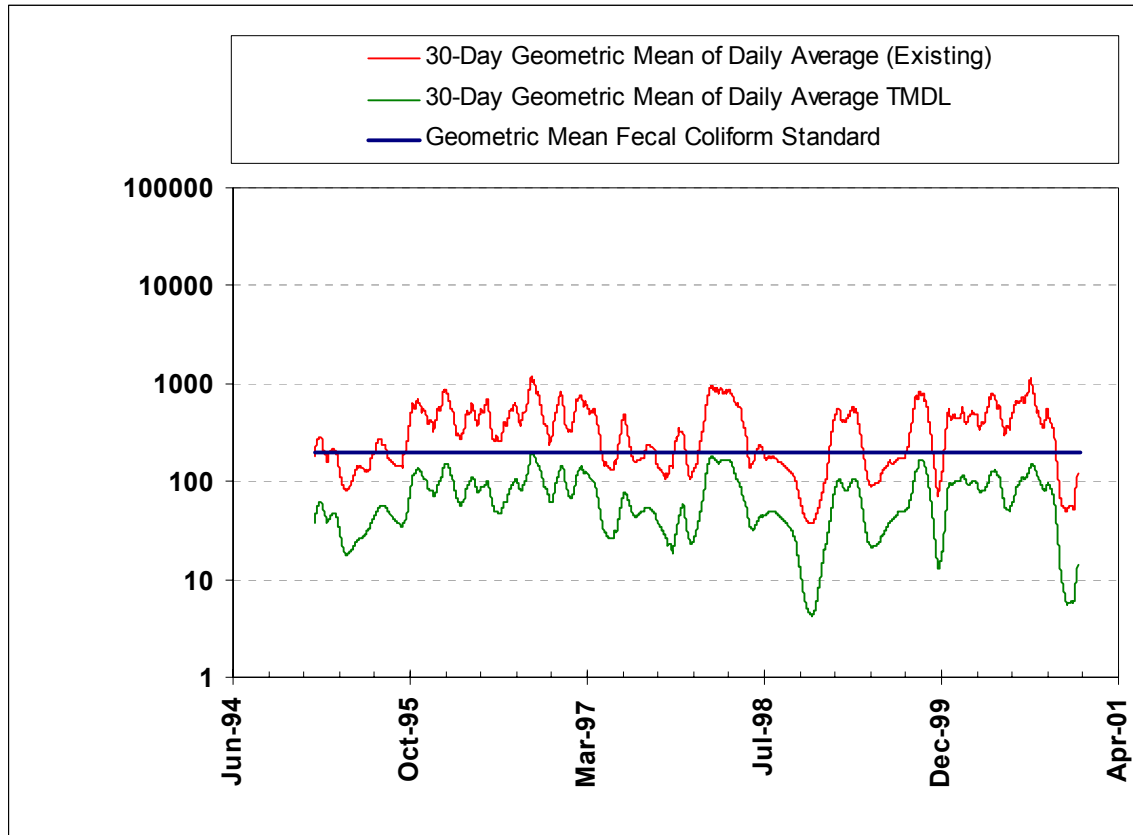
Table E-1: Existing Load, TMDL and Percent Reductions for the C&O Canal

Fecal Coliform Source	Existing Load (MPN/year)	TMDL Allocation (MPN/year)	Percent Reduction
Total Upstream Boundary Load	1.83E+11	9.14E+10	50%
Total Nonpoint Source Load	1.20E+13	1.15E+12	90%
Total Load from Sewershed	1.53E+13	7.72E+11	95%
Margin of Safety	–	2.01E+10	–
Total Load	2.75E+13	2.03E+12	93%

Table E-2: Fecal Coliform TMDL for the C&O Canal (MPN/year)

TMDL	Upstream Allocation	Load Allocation	Wasteload Allocation	Margin of Safety (1%)
2.03E+12	9.14E+10	1.15E+12	7.72E+11	2.01E+10

Figure E-1: Fecal Coliform Concentrations in the C&O Canal under Existing Conditions and TMDL Allocation



There is reasonable assurance that the goals of this TMDL can be met. The District sponsors several programs aimed at controlling stormwater runoff and nonpoint source

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pollution, and is a signatory to the Chesapeake Bay Agreement. The C&O Canal is also located within the Chesapeake and Ohio Canal National Historic Park, which is managed by the National Park Service. Public participation is an important part of the C&O Canal TMDL development process. The publication of this draft TMDL report will be public noticed, and the public will have the opportunity to comment on the draft report.

1 Introduction

1.1 Regulatory Guidance

Section 303(d) of the Clean Water Act and the Environmental Protection Agency's (EPA) Water Quality Planning and Management Regulations (40 CFR Part 130) require states and the District of Columbia to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are identified on the Section 303(d) List of Impaired Waters as not meeting their designated use(s). TMDLs represent the total pollutant loading from point, non-point, and natural background sources, including a margin of safety, which a waterbody can receive without violating water quality standards. The TMDL process establishes the allowable pollutant loadings for a waterbody based on the relationship between pollutant sources and instream water quality conditions. By following the TMDL process, water quality based controls can be established to reduce pollution from both point and non-point sources to restore and maintain water quality (EPA, 2001).

The regulatory agency for the District of Columbia is the Department of Health (DOH). As required by the Clean Water Act, DOH develops and maintains the Section 303(d) List of Impaired Waters in the District that details the pollutant(s) exceeding water quality standards and the potential source(s) of each pollutant. As part of the settlement of a TMDL lawsuit in the District, EPA agreed to develop or approve TMDLs for waters included on the District's 1998 Section 303(d) List of Impaired Waters under a specified timeframe. The TMDL in this report was developed in partial fulfillment of that lawsuit and addresses one waterbody on the District's 1998 Section 303(d) list, the Chesapeake and Ohio Canal.

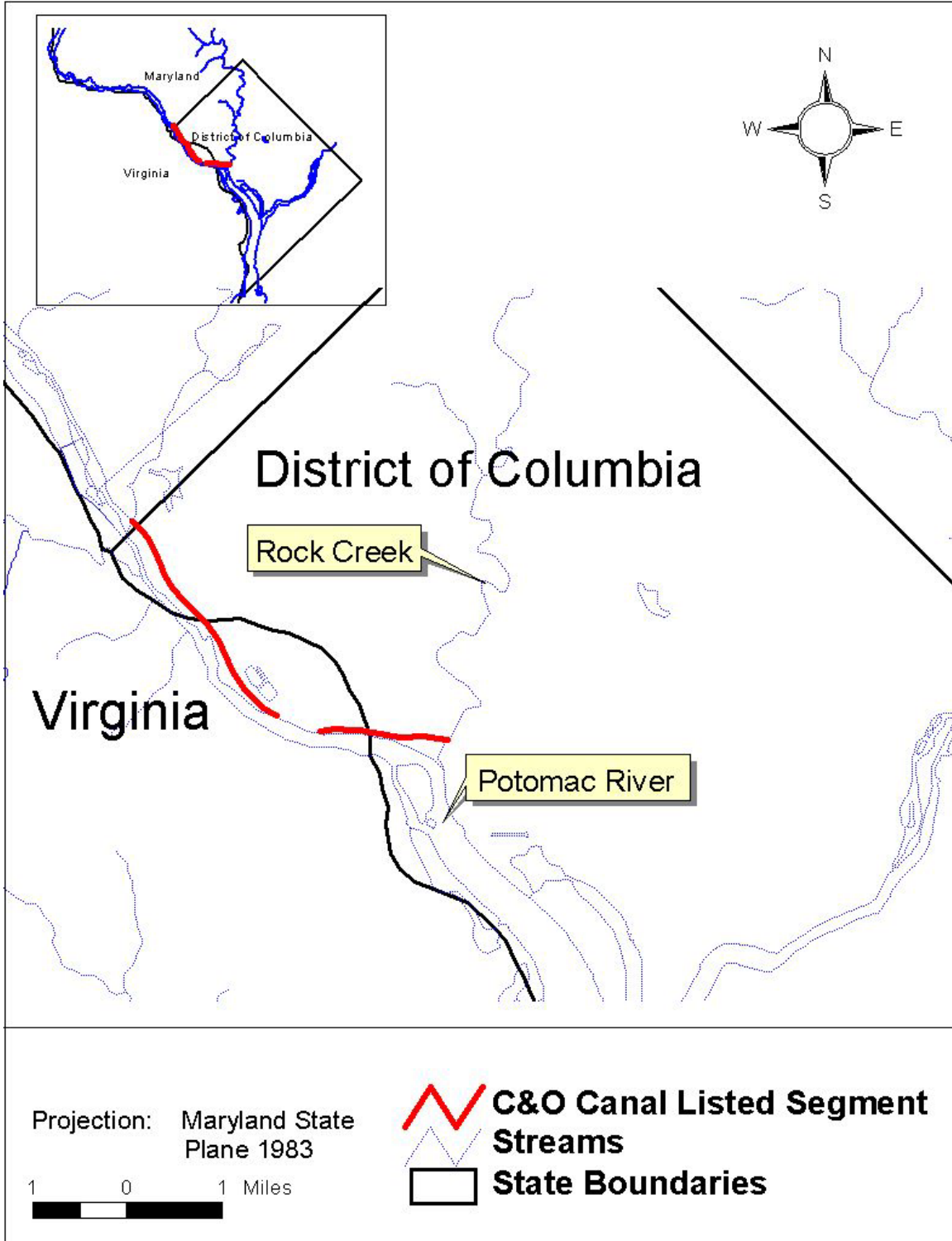
1.2 Impairment Listing

The Chesapeake and Ohio (C&O) Canal is listed on the District's 1998 through draft 2004 Section 303(d) List of Impaired Waters. The 1998 Section 303(d) list indicates that fecal coliform bacteria are the cause of impairment in the section of the C&O Canal present in the District. The C&O Canal runs parallel to the Potomac River from the mouth of Rock Creek in Washington D.C. to Cumberland, Maryland. This TMDL report

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will address fecal coliform impairment in the section of the C&O Canal located within the boundaries of the District (Figure 1-1).

Figure 1-1: Location of the C&O Canal



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1.3 Applicable Water Quality Standards

EPA regulations require that TMDLs be based on the applicable water quality standards. Water quality standards consist of designated uses for a waterbody and water quality criteria necessary to support those designated uses, as well as an antidegradation section. According to the District’s Water Quality Standards, “the surface waters of the District should be classified on the basis of their (i) current uses, and (ii) future uses to which the waters will be restored.” Designated use classifications are described below.

1.3.1 Designated Uses

The District’s Water Quality Standards (Section 1101 of the District of Columbia Municipal Regulations) define five categories of designated water uses which shall be protected, and upon which the development of water quality criteria shall be based. The five designated use categories, and the corresponding classes defined by the District, are presented in Table 1-1. These include the protection of primary and secondary contact recreation, as well as aesthetic enjoyment. The maintenance and propagation of aquatic life and the protection of human health related to fish and shellfish consumption are also protected as designated uses of the District’s waters. The District’s Water Quality Standards also serve to designate waters in the municipality for navigation.

Section 1101.2 of the DC Municipal Regulations classifies the C&O Canal under designated use classes A, B, C, D, and E. Current uses of the C&O Canal are specified as designated use classes B, C, D, and E.

Table 1-1: Designated Use Categories for District of Columbia Waters

Designated Use Categories for District of Columbia Waters	Designated Use Classes
Primary contact recreation	A
Secondary contact recreation and aesthetic enjoyment	B
Protection and propagation of fish, shellfish, and wildlife	C
Protection of human health related to consumption of fish and shellfish	D
Navigation	E

1.3.2 Water Quality Criteria

Water quality criteria for fecal coliform bacteria established by the District of Columbia and Maryland are presented below. The applicable water quality criteria for the C&O

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Canal TMDL are the District's water quality standards for fecal coliform. However, the C&O Canal must also meet Maryland water quality standards at the District/Maryland boundary, where the C&O Canal flows into the District from Maryland (Figure 1-1).

1.3.2.1 Fecal Coliform Criteria

The fecal coliform standards defined in the District's Water Quality Standards (Section 1104 of the DC Municipal Regulations) provide separate criteria for the maximum fecal coliform concentrations allowable in waterbodies designated for primary contact recreation (class A) and secondary contact recreation and aesthetic enjoyment (class B; DOH, 2003a). The standards specify the maximum allowable 30-day geometric mean fecal coliform concentration (computed from a minimum of five samples) for class A waters as 200 MPN/100 mL, where MPN/100 mL is defined as the "most probable number" of bacteria colonies in a 100 mL sample. The standards also specify the maximum allowable 30-day geometric mean fecal coliform concentration for class B waters to be 1,000 MPN/100 mL. Because both primary and secondary contact recreation are specified as designated uses of the C&O Canal, the more stringent class A fecal coliform standard of 200 MPN/100 mL is the applicable fecal coliform endpoint for the C&O Canal TMDL development.

The District's 2004 305(b) report indicates that fecal coliform concentrations in the C&O Canal exceeded the primary contact recreation fecal coliform standard 53% of the time, and exceeded the secondary contact recreation fecal coliform standard 11.8% of the time (DOH, 2004a). In concert with these findings, the District's 2004 305(b) report states that the C&O Canal did not support the overall use classification for waters with multiple uses (DOH, 2004a).

Maryland expresses its bacteria water quality standards in terms of *E. coli* rather than fecal coliform bacteria. The Maryland steady state geometric mean standard for *E. coli* in all areas is specified as 126 counts/100 mL (MDE, 1988). Maryland also specifies single sample maximum allowable density *E. coli* criteria as 235 counts/100 mL for waters with frequent full body contact recreation, 298 counts/100 mL for waters with moderately frequent full body contact recreation, 410 counts/100 mL for waters with occasional full

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body contact recreation, and 576 counts/100 mL for waters with infrequent full body contact recreation (MDE, 1988).

1.4 Compliance with Previously Established TMDLs

The C&O Canal fecal coliform TMDL is required to comply with previously developed TMDLs that specified necessary load reductions for source and receiving waters of the C&O Canal. The C&O Canal discharges into Rock Creek, a stream for which a fecal coliform TMDL was established in February 2004 (DOH, 2004b). The Rock Creek fecal coliform TMDL requires a 92.7 percent reduction in fecal coliform bacteria from combined-sewer outfalls, and a 95 percent reduction in fecal coliform bacteria from all other sources. Thus, as a waterbody discharging into Rock Creek, the C&O Canal is required to reduce fecal coliform concentrations by 95 percent. Additionally, a fecal coliform TMDL has recently been established for the Potomac River (DOH, 2004c), from which the C&O Canal receives much of its water. The Potomac River fecal coliform TMDL requires a 91.7 percent reduction in fecal coliform from combined-sewer outfalls, and a 50 percent reduction in fecal coliform from all other sources. Therefore, a 50 percent reduction is required for the C&O Canal upstream boundary load entering the District from Maryland, because a major intake at which the C&O Canal and Potomac River exchange water is located approximately at the District/Maryland border. Further explanation regarding the data and calculations used to determine the upstream boundary load is presented in Section 2.2.2, and information regarding the allocated TMDL reductions is presented in Section 4.0.

2 Description and Source Assessment

2.1 Description and Identification

2.1.1 Canal Description

The Chesapeake and Ohio (C&O) Canal is 184.5 miles long and runs parallel to the Potomac River, beginning at the mouth of Rock Creek in Georgetown, Washington D.C. (mile 0.0) and ending at Cumberland, Maryland (mile 184.5). The C&O Canal is comprised of 74 lift locks, 11 aqueducts, over 180 culverts, and over 50 waste weirs (Weeks, 2001). The average depth of the Canal is approximately four to five feet, but significant variation in depth exists in some sections of the Canal due to sediment deposition (CHOH personal communication, 2004a). The Canal has an average surface (top) width of 60 feet, and an average bottom width of 40 feet. The C&O Canal is encompassed by the Chesapeake and Ohio Canal National Historic Park (CHOH), and runs alongside the Potomac River for its entire length. The location of the C&O Canal was presented in Figure 1-1.

The section of the C&O Canal located in the District begins in Georgetown at river-mile 0.0, and extends approximately 5 miles to the Maryland state line. Four lift locks are present in the District section of the Canal, all located between 28th and 31st streets in Georgetown. Lift lock one is located at mile 0.25 of the Canal, and the four lift locks are each located approximately 100 feet apart from each other (CHOH personal communication, 2004b). Additionally, there are outflow weirs for water volume control located at miles 1.51 and 3.23 of the Canal, and intakes that exchange water between the Canal and the Potomac River at miles 0.60 and 5.02 (CHOH personal communication, 2004c). The water intake at mile 5.02 is located approximately at the District/Maryland boundary. Figure 2-1 depicts a lift lock located on the C&O Canal at 30th Street NW in Georgetown. Figure 2-2 depicts the Canal at Chain Bridge Road, near the District/Maryland border.

The C&O Canal is located in the Potomac River Basin, and receives much of its water from the mainstem Potomac via intakes located along the length of the Canal. Water also enters the District portion of the Canal from the upstream sections located in Maryland,

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stormwater discharge, and direct runoff from an approximately 100 foot bank area that drains into the Canal. DOH sewershed GIS data indicate that stormwater drained from approximately 426 acres flows directly into the C&O Canal (DOH written communication, 2004).

The principle source of water to the C&O Canal is the Potomac River, which drains 14,670 square miles of land, and flows from its headwaters in the Allegheny Mountains to its discharge into the Chesapeake Bay. Because factors such as land use, soils, and physiography influence water quality in the Potomac River, and consequently water quality in the C&O Canal, they are discussed in the following sections.

Figure 2-1: Lift Lock on the C&O Canal Located at 30th Street in Georgetown (D.C.)



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Figure 2-2: C&O Canal at Chain Bridge Road, near District/Maryland Border



2.1.2 Land Use and Demography

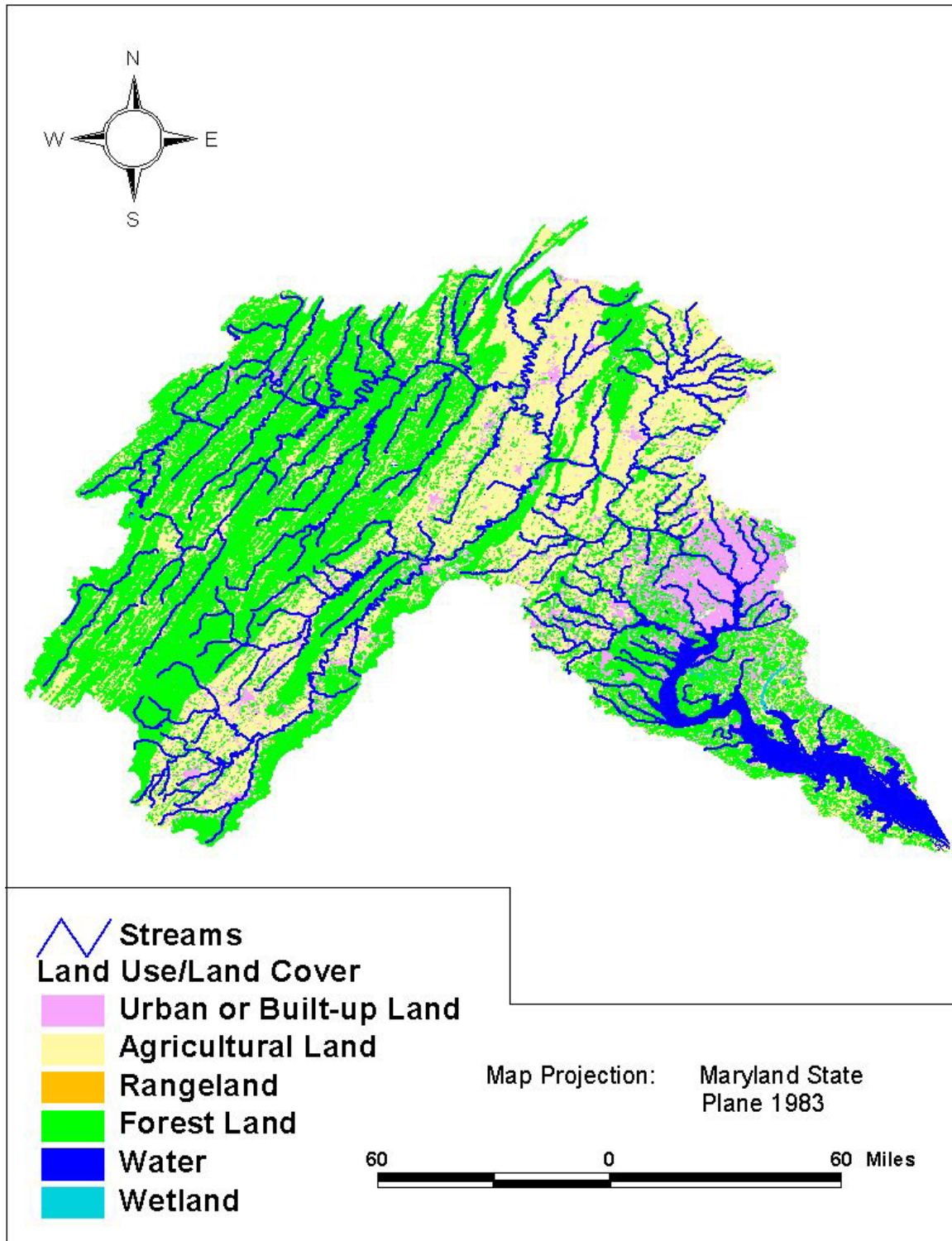
Land use in the headwaters of the Potomac River Basin is a combination of forested and agricultural lands. Significant urban development occurs in the lower reaches of the Basin in and around the Washington D.C. metro area. The land use distribution of the Potomac River Basin is presented in Figure 2-3.

U.S. Census Bureau data collected in 2000 indicate that approximately 5.2 million people reside in the Potomac River Basin. Much of the population is concentrated in the Washington D.C. metro area. It is estimated that the population within the Basin will increase about 19 percent to approximately 6.2 million between the years of 2000 and 2020 (Ator et al., 1998).

Within the District, the approximately 426 acres from which stormwater discharges into the Canal is comprised mainly of residential lands (DOH written communication, 2004). Storm runoff flowing directly into the Canal drains urban park land encompassed by the Chesapeake and Ohio Canal National Historic Park, as well as impervious surfaces such as roads.

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Figure 2-3: Land Use in the Potomac River Basin



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2.1.3 Physiography

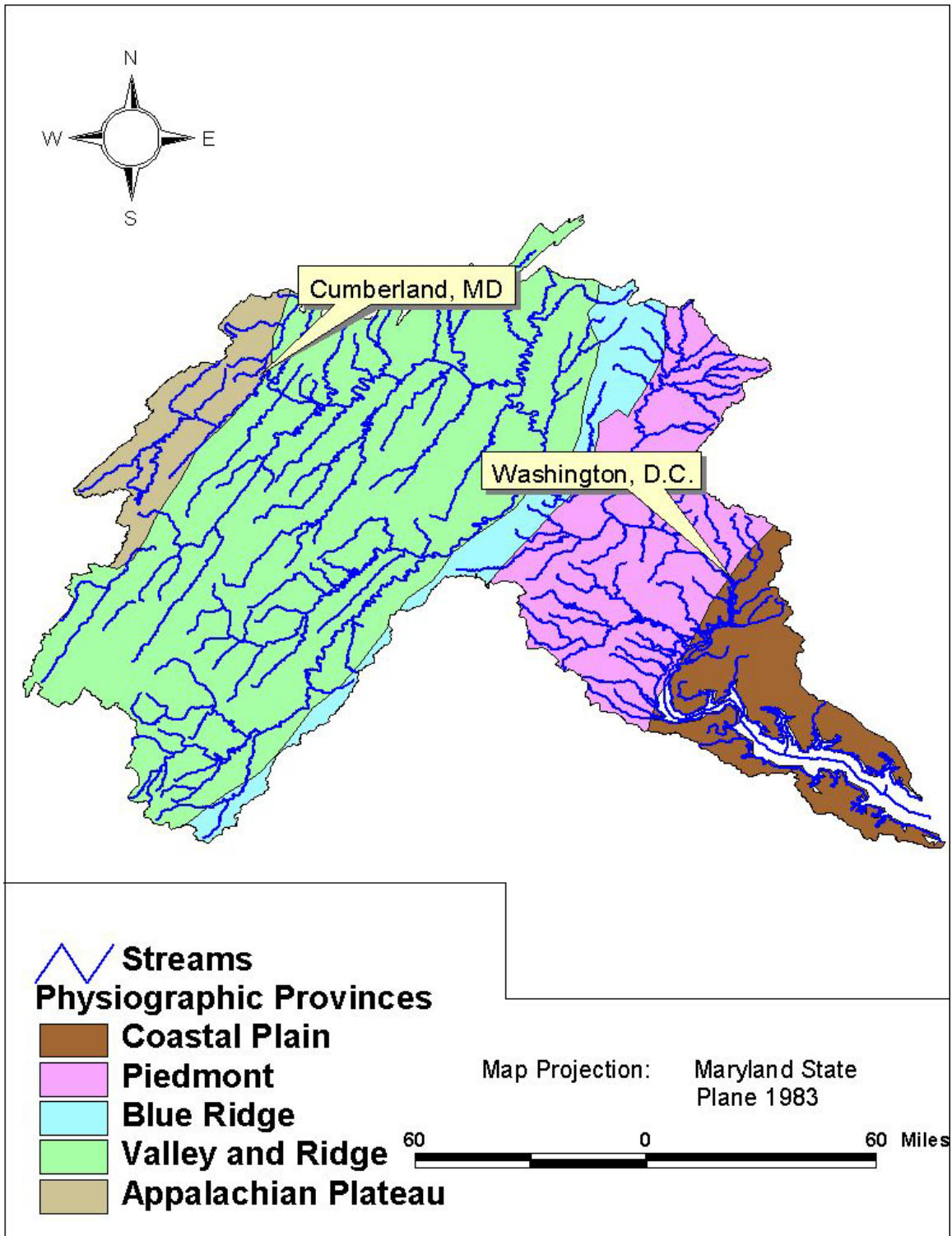
The C&O Canal flows through four physiographic provinces: Coastal Plain, Piedmont, Blue Ridge, and Valley and Ridge. These provinces run in parallel bands from the southwest to the northeast. The Coastal Plain is the easternmost province of the Potomac River Basin, and is bounded by Great Falls, Maryland to the west and the Chesapeake Bay to the east. The Piedmont province extends from Great Falls, Maryland in the east to the Blue Ridge Mountains in the west, and is characterized by gently rolling topography consisting of deeply weathered bedrock. The Blue Ridge province is mountainous and is characterized by steep slopes and narrow ridges. The Blue Ridge province is bounded by the Piedmont province to the east and Fort Frederick, Maryland to the west. The Valley and Ridge province extends from Fort Frederick in the east to Cumberland, Maryland in the west, and is characterized by elongated parallel ridges and valleys. The Appalachian Plateau province is also located in the headwaters of the Potomac River Basin, but the C&O Canal does not flow through this section of the Basin. The physiographic provinces of the Potomac River Basin are presented in Figure 2-4.

2.1.4 Soils

Soils in the upland areas of the Potomac River Basin are generally well-drained, and are moderately deep to deep. Soils in the Coastal Plain lowland areas of the Basin typically consist of finer grain sands than the upland areas. Floodplain soils in the Potomac River Basin are deep, poorly drained, and typically consist predominantly of silt loams and silty clay loam textures.

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Figure 2-4: Physiographic Provinces in the Potomac River Basin



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2.1.5 Permitted Facilities

The only NPDES permitted facility discharging into the C&O Canal is the District of Columbia's Municipal Separate Storm Sewer System (MS4, NPDES permit number DC0000221). MS4 permits are different from traditional discharge permits because they do not have a discrete point of discharge but rather cover an area that generates stormwater runoff and the structures that deliver that runoff to streams and rivers. DOH indicated that stormwater drained from approximately 426 acres flows directly into the C&O Canal (Figure 2-5; DOH written communication, 2004). It is assumed that these areas are covered under the District's MS4 permit. Therefore, for the purposes of TMDL development, stormwater and fecal coliform loads draining into the C&O Canal from these areas are considered to be point source loads.

2.2 Water Quality Monitoring

Fecal coliform data from several sources were used as part of the C&O Canal TMDL development. Observed fecal coliform concentrations in the C&O Canal were available from data collected as part of the DOH water quality monitoring program. Data collected by the U.S. Geological Survey on the Potomac River near the boundary of the District and Maryland were also analyzed and used to determine the fecal coliform concentration in the C&O Canal at the point it enters the District. In the remainder of this report, this load is referred to as the boundary or headwater load.

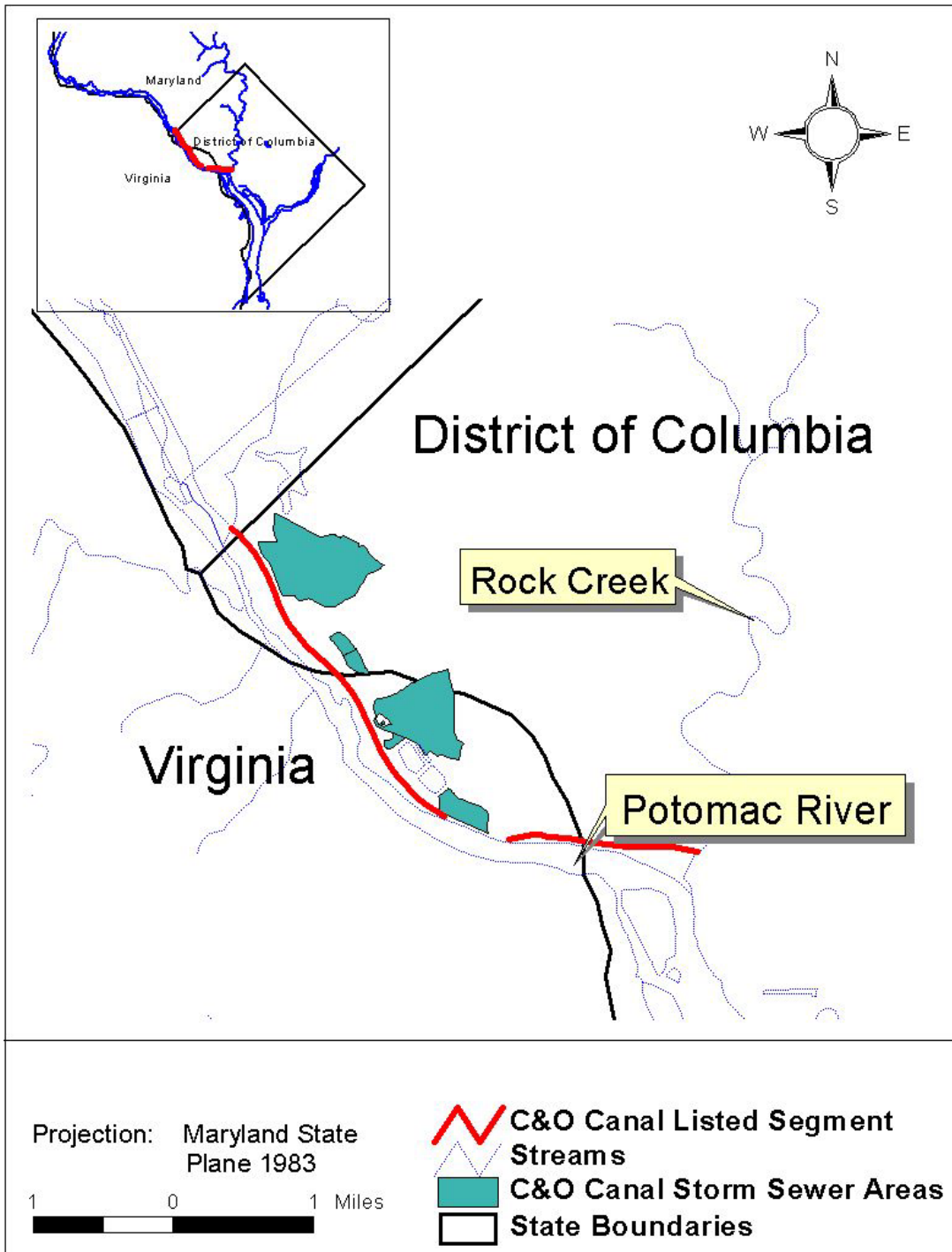
2.2.1 DOH Monitoring Data

Instream fecal coliform data were collected from 1991 to 2002 at two stations on the C&O Canal as part of the DOH water quality monitoring program. DOH monitoring station TCO01 is located at the downstream end of the C&O Canal, 75 feet west of 29th St. NW in Georgetown, immediately downstream of lift lock two. DOH monitoring station TCO06 is located at Fletcher's boathouse, Canal St. NW, downstream of the C&O Canal footbridge. The location of the monitoring stations on the C&O Canal is depicted in Figure 2-6. Fecal coliform data collected at monitoring stations TCO01 and TCO06 are presented in Figures 2-7 and 2-8, respectively. As shown in these figures, many of the observed fecal coliform concentrations at these stations exceed the District's geometric mean standard of 200 MPN/100 mL for class A waters, as well as the

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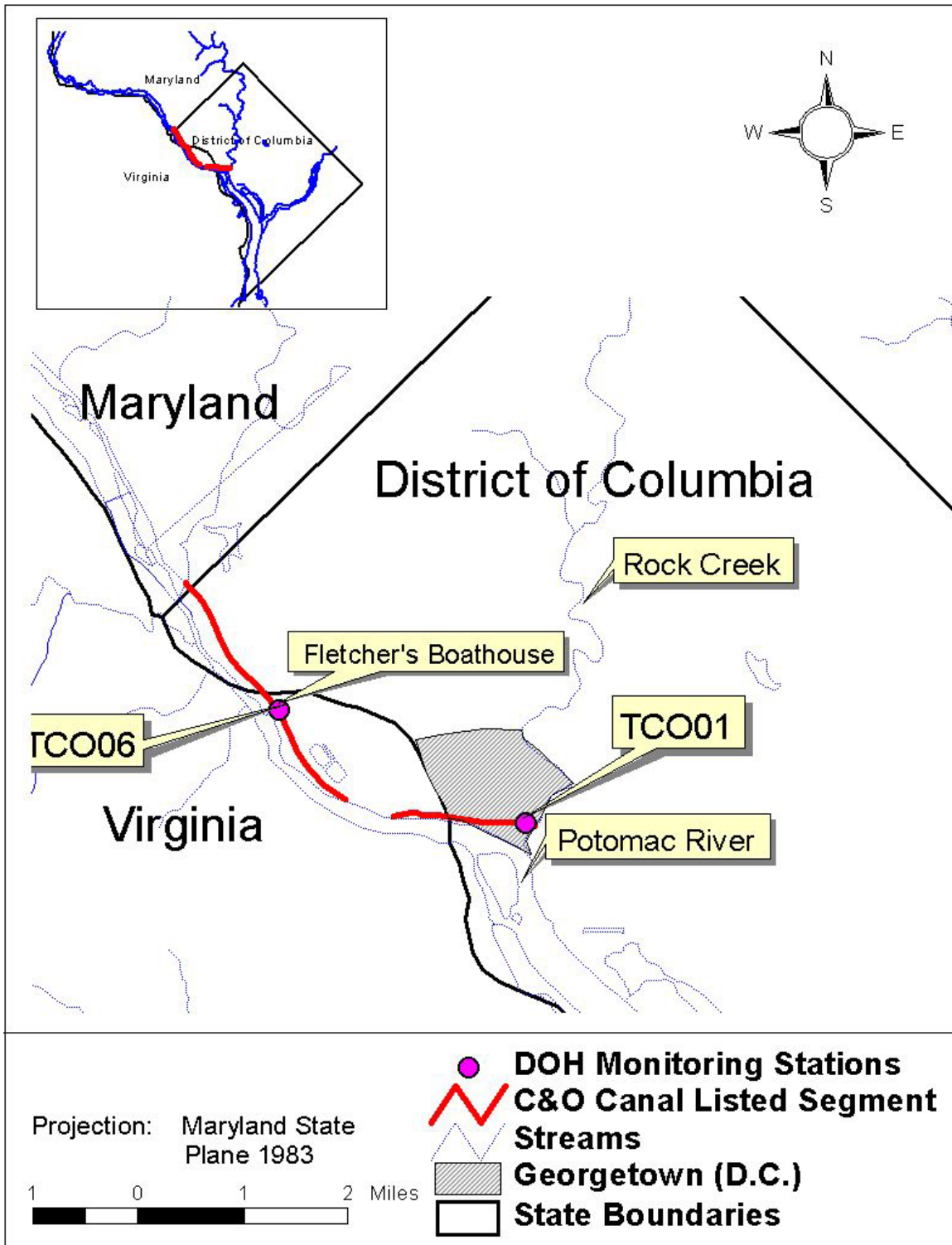
geometric mean standard of 1,000 MPN/100 mL for class B waters. Additionally, the District's fecal coliform standards were exceeded more often at station TCO01 than at station TCO06, indicating a potential increase in loading from sources in between the upstream and downstream monitoring stations.

Figure 2-5: Storm Sewer Areas Draining into the C&O Canal



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Figure 2-6: Location of DOH Monitoring Stations on the C&O Canal



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Figure 2-7: Existing Fecal Coliform Data Collected at Station TCO01 in the C&O Canal

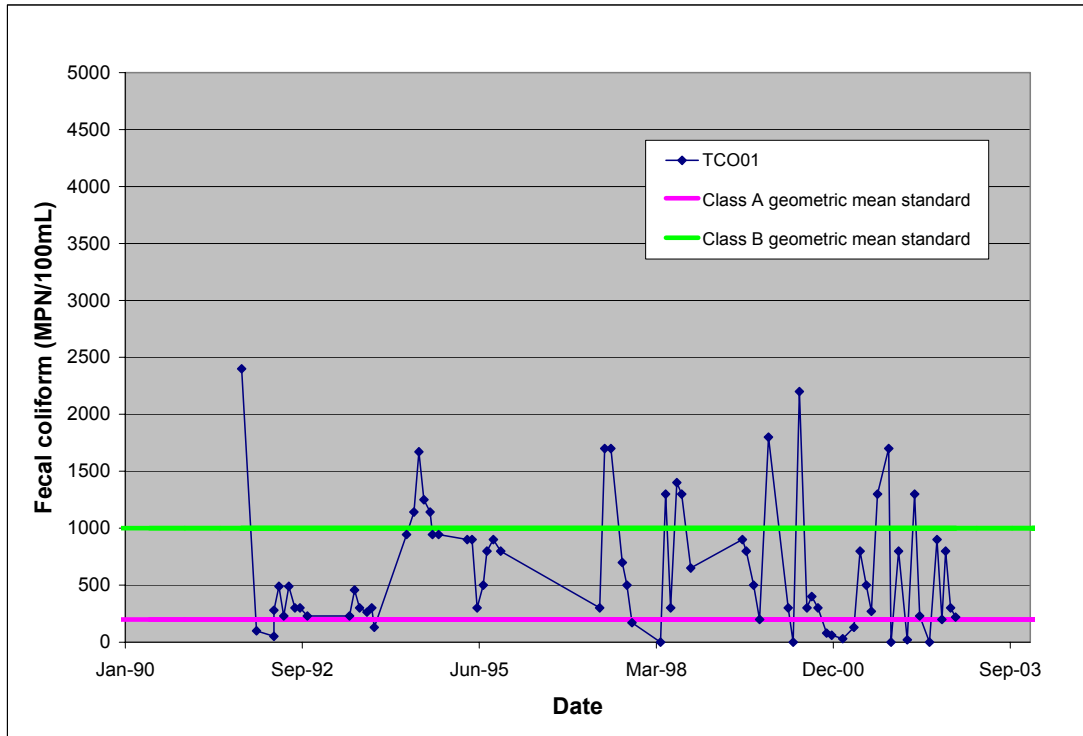
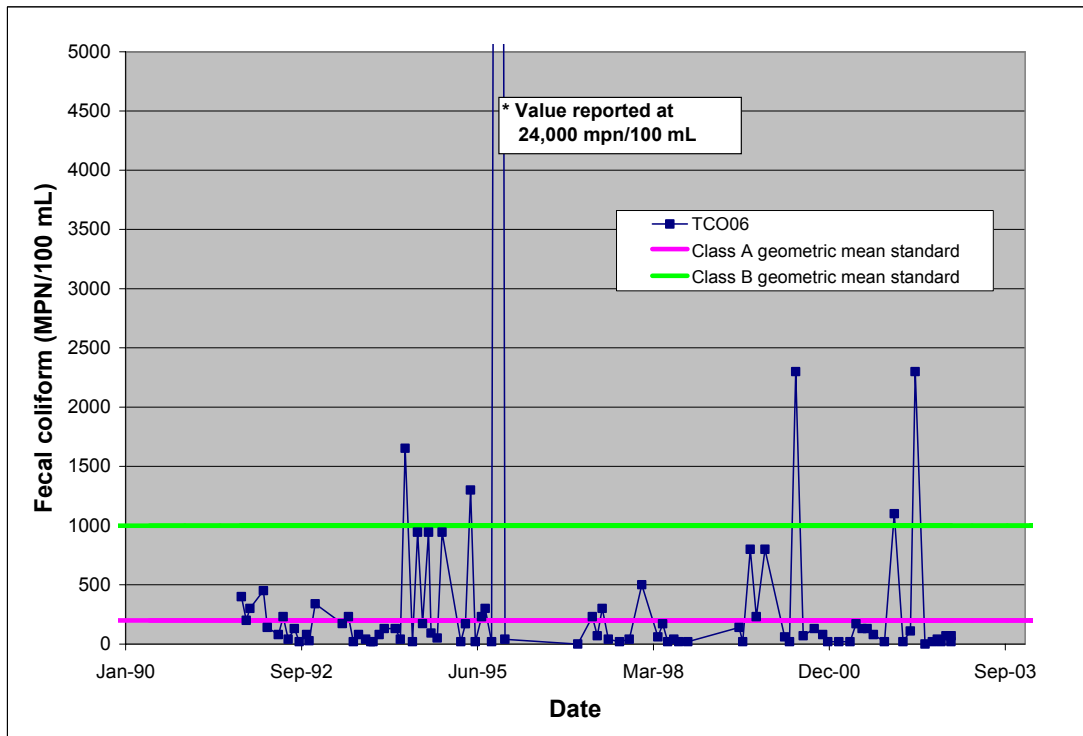


Figure 2-8: Existing Fecal Coliform Data Collected at Station TCO06 in the C&O Canal



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2.3 Fecal Coliform Sources Assessment

TMDL development for the C&O Canal needs to consider developed areas, pets, and wildlife (i.e., geese, raccoons, etc.) as potential sources of fecal coliform. The lower reaches of the C&O Canal, including the segments identified as impaired on the District's Section 303(d) lists, flow through highly developed areas, including Washington D.C. and its surrounding suburbs. Within the District, approximately one-third of the population is served by a combined sewer system, in which excess flow is discharged, untreated, through the combined sewer overflow when storms cause flows to exceed the pipe capacity leading to the treatment plant. However, the remaining two-thirds of the District's population are served by separate sanitary pipes for wastewater and storm sewer pipes for storm runoff, and DOH has indicated that all areas through which the C&O Canal flows are separate storm sewer system areas (DOH, written communication). Therefore, storm sewer pipes discharging to the C&O Canal should have no waste from sanitary sewers entering the system; however, these pipes do transport bacteria deposited by wildlife or pets on the land surface. DOH sewershed GIS data indicate that stormwater drained from approximately 426 acres flows directly into the C&O Canal (DOH written communication, 2004).

3 Technical Approach

3.1 Model Description

The Hydrologic Simulation Program-Fortran (HSPF) model was selected and used as a tool to predict the instream water quality conditions in the C&O Canal under varying scenarios of rainfall and fecal coliform loading. The results from the model developed for the C&O Canal were used to establish the TMDL allocations based on the existing fecal coliform load. HSPF is a hydrologic, watershed-based water quality model. Basically, this means that HSPF can explicitly account for the specific watershed conditions, seasonal variations in rainfall and climate conditions, and activities and uses related to fecal coliform loading.

It is important to note that the HSPF model was setup based on the best available instream water quality data and estimated flow conditions, but that these data are very limited. The modeling process in HSPF starts with the following steps:

- delineating the C&O Canal into smaller segments
- entering the physical data that describe each segment
- entering values for the rates and constants that describe the sources and the activities related to the fecal coliform loading in the watershed

3.1.1 Segment Delineation

The section of the C&O Canal located within the District's boundaries was delineated into seven smaller segments to represent the Canal's characteristics (Figure 3-1). Segments were determined based on the location of the lift locks, outflow weirs, and intakes in the section of the Canal located in the District. Each segment was assumed to be uniformly mixed in the HSPF model.

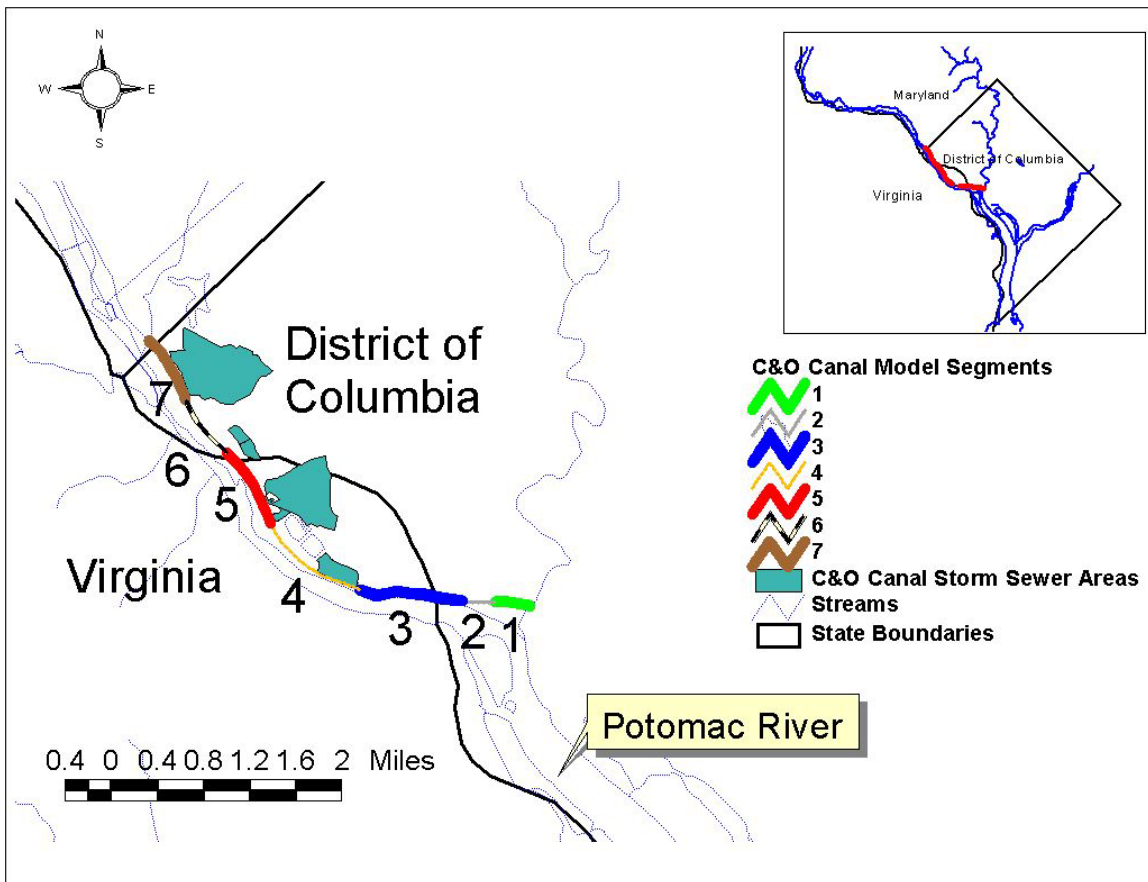
3.1.2 Physical Data

Data regarding the hydrography and stream geometry of the C&O Canal were obtained from the Reach File Version 3 (RF3) dataset contained in BASINS, as well as detailed channel mapping of the Canal conducted by the National Park Service (CHOH personal communication, 2004a). Information regarding the reach number, reach name, and

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length of each segment of the C&O Canal are included in the RF3 database, and are presented in Appendix A. Channel mapping data obtained from the National Park Service provided information on the Canal's physical dimensions. Segments of the C&O Canal were represented as rectangular channels. Representative channel dimensions were used based on discussions with the National Park Service. The channel slopes were estimated using the reach length and the corresponding change in elevation from the mapping data. The flow was calculated using Manning's equation with a roughness coefficient of 0.05. The stage flow relationship that is required by HSPF was developed based on discussions with the National Park Service regarding representative flow values for the Canal (CHOH personal communication, 2004a).

Figure 3-1: Segment Delineation for the C&O Canal



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3.1.3 Fecal Coliform Sources Representation

Potential fecal coliform sources in the areas draining to the C&O Canal were identified in Section 2.0. Following a review of the available water quality data, the physical conditions of the Canal and initial simulation results, it was determined that three major sources of fecal coliform should be represented in the HSPF model. These sources are:

- Headwater fecal coliform load. This represents the loading transported in the Canal into the District of Columbia across the Maryland state line.
- Nonpoint source fecal coliform load. This represents the fecal coliform load from the urban land areas draining to the C&O Canal, including park lands, and is essentially precipitation driven.
- Stormsewer (MS4) fecal coliform load. This represents the fecal coliform load from the sewered areas of the watershed.

3.1.4 Fecal Coliform Die-off Rates

Two representative fecal coliform decay rates are required to accurately represent watershed conditions and were included in the HSPF model: 1) on-surface fecal coliform die-off (i.e. the rate at which fecal coliform deposited on the land surfaces undergoes decay prior to being washed into streams), and 2) in-stream fecal coliform die-off. Decay rates of 1.37 and 1.152 per day were used to estimate die-off rates for on-surface and in-stream fecal coliform, respectively (EPA, 1985).

3.2 Model Set-up and Calibration

Calibration of the HSPF model involves the adjustment of model parameters to control various flow and water quality components (e.g. surface runoff, the shape of the hydrograph, instream pollutant concentrations) and make simulated values match observed conditions during the calibration period. The HSPF model calibration process ensures the model output is accurate for a given set of conditions. Water quality processes were calibrated following calibration of the hydrologic processes of the model.

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3.2.1 Stream Flow Data

As stated above, no stream flow data or other sources of flow information were available for the section of the C&O Canal located in the District. The Potomac River Basin contributes much of the water in the C&O Canal, and water intakes from the Potomac, outflow weirs and other mechanisms exert a large control on flow conditions within the Canal. Because there is a large exchange of water between the Potomac River and the C&O Canal at the Maryland/District line, the National Park Service flow estimates in the Canal upstream of the District boundary are not necessarily representative of flow conditions within the District. As a result, flow estimates for the District portion of the C&O Canal were developed from discussions with National Park Service engineers and scientists working in the Chesapeake and Ohio Canal National Historic Park (CHOH personal communication, 2004a and 2004c). The depth-discharge relationship in the C&O Canal was calculated using the physical dimensions of the Canal obtained from the National Park Service and the formula for flow over a sharp-crested weir at a lock. Flows were simulated for a 10-year period using hourly weather data.

3.2.2 Rainfall and Climate Data

Hourly weather data collected at Reagan National Airport in Arlington, Virginia were obtained from National Climatic Data Center (NCDC) and used to set up the HSPF model. The data include hourly precipitation, wind speed/direction, ceiling height, dry bulb temperature, dew point temperature, and solar radiation. Data collected at Reagan National Airport were available from 1948 to 2002.

3.2.3 HSPF Hydrologic Model Calibration

Since there are no flow data available for the DC portion of the C&O Canal, and the Canal is a unique waterbody controlled by a series of diversions and lift locks, the C&O Canal HSPF model was set up based on the National Park Service recommended flow estimates. The model was set up using an estimated input parameter headwater flow of 4 CFS. Because flows in the C&O Canal are regulated by human-engineered devices such as diversions and lift locks, flows in the Canal are less influenced by individual precipitation events than natural waterbodies with larger contributing drainage areas.

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However, the amount of precipitation received may influence the exchange of water between the Canal and the Potomac River.

In addition to the headwater flow, wet weather flows in the Canal were estimated using HSPF for two land uses, forested and urban lands. The land area contributing to the Canal was estimated as a 426 acre sewered area and a 100 ft buffer on the left channel bank that flows into the Canal.

3.2.4 HSPF Water Quality Model Calibration

Calibrating the water quality component of the HSPF model involves setting up the build-up, wash-off, and kinetic rates for fecal coliform that best describe fecal coliform sources and environmental conditions in the watershed. It is an iterative process in which the model results are compared to the available instream fecal coliform data, and the model parameters are adjusted until there is an acceptable agreement between the observed and simulated instream concentrations and the build-up and wash-off rates are within acceptable ranges. The water quality model was calibrated for the time period of October 1991 to September 1994, when water quality data are available for both the USGS Potomac River station and the C&O Canal. Bacteria sampling at USGS station 01646580 was discontinued after 1994, therefore, the period from 1994 to 2000 was used to validate the calibration.

The water quality results from the HSPF model are presented in Figure 3-2 and Figure 3-3 for stations TCO01 and TCO06, respectively. The results indicate that the model captures the range of fecal coliform concentrations under both wet and dry weather conditions.

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Figure 3-2: C&O Canal Water Quality Calibration and Validation at Station TCO01

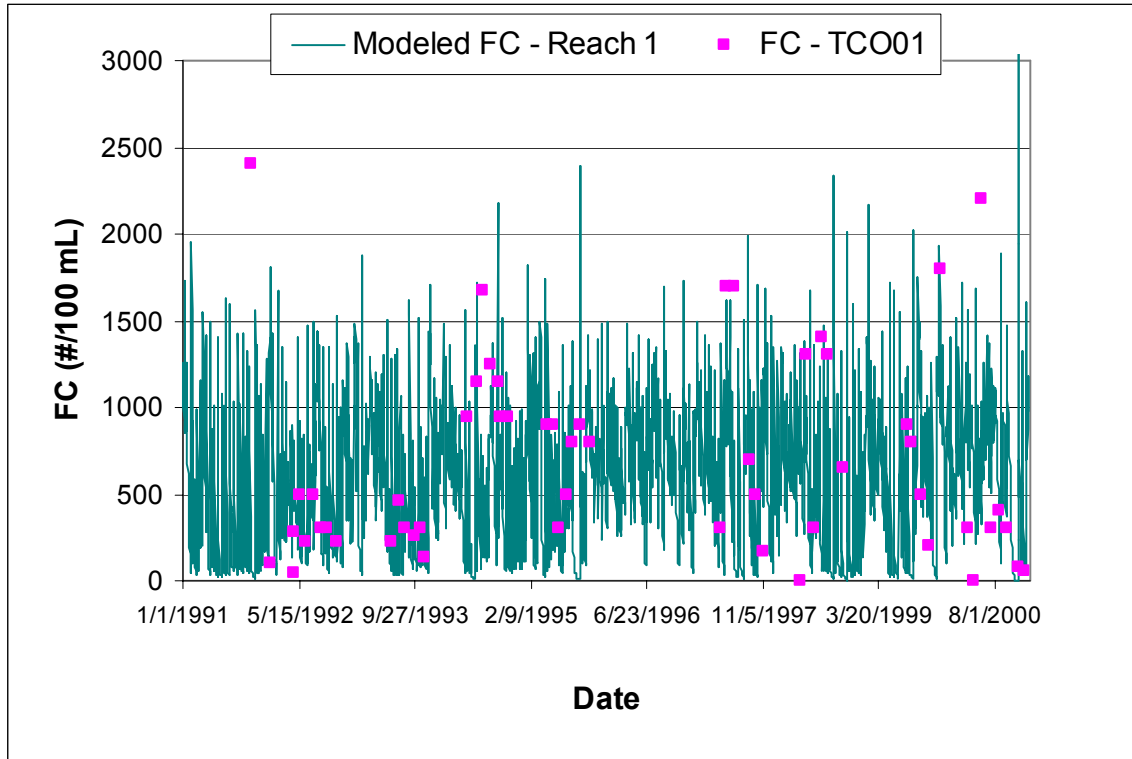
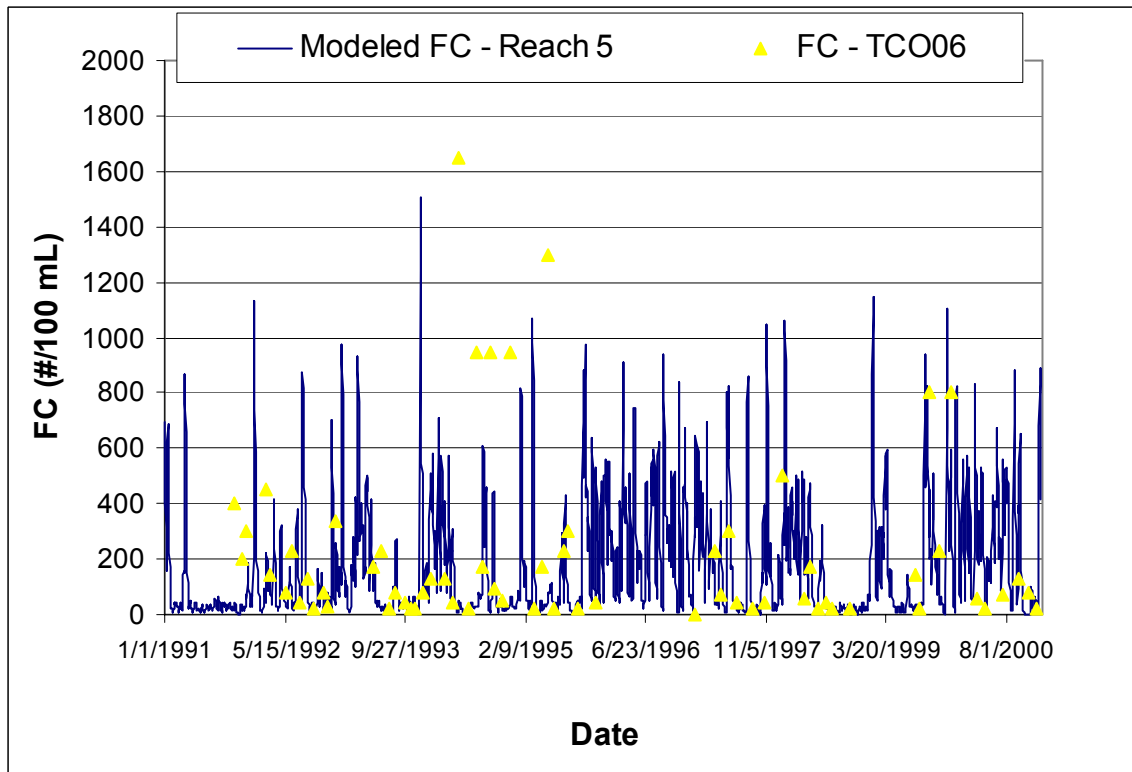


Figure 3-3: C&O Canal Water Quality Calibration and Validation at Station TCO06



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3.3 Consideration of Critical Conditions

In order to accurately quantify fecal coliform loading, it is necessary to examine loading rates under the full range of representative climatic conditions. As stated in Section 3.2.1, flows were simulated in the C&O Canal for a 10-year period using hourly weather data. This approach accounts for seasonal and climatic variations that influence fecal coliform loading. Because fecal coliform loading in developed areas is linked primarily to stormwater runoff, the wet weather condition is considered to be the critical condition in the C&O Canal. Storm events increase fecal coliform loads in the Potomac River, and thus to the Canal, and also cause fecal coliform to be washed off from the area draining into the Canal.

4 TMDL Development and Allocation

The purpose of TMDL development and allocation is to quantify the fecal coliform load reductions necessary for the C&O Canal to achieve water quality standards. The TMDL endpoint is the 200 MPN/100 mL geometric mean primary contact recreation numeric criterion for fecal coliform established by the District and specified in Section 1.0 of this TMDL report.

4.1 Basis for TMDL Allocations

The TMDL is defined as the sum of the wasteload allocations (WLA) plus the sum of the load allocations (LA), which also considers the natural background condition, and the margin of safety (MOS). The TMDL is commonly expressed as the following equation:

$$\text{TMDL} = \Sigma\text{WLA} + \Sigma\text{LA} + \text{MOS}$$

Where:

TMDL= Total Maximum Daily Load

WLA = Wasteload Allocation

LA = Load Allocation

MOS = Margin of Safety

The wasteload allocation represents the total pollutant loading allocated to permitted discharges, which in the C&O Canal consists entirely of outfalls covered under the District's MS4 permit. The load allocation represents the total pollutant loading allocated to nonpoint sources. An implicit or explicit margin of safety is a required TMDL element to account for uncertainties in TMDL development. An explicit margin of safety of one percent was used to develop the TMDL for fecal coliform bacteria in the C&O Canal.

4.2 Existing Fecal Coliform Loading

The C&O Canal fecal coliform TMDL was developed using the HSPF model described in Section 3.0. Because instream fecal coliform data were available from USGS for the period of 1978 to 1991, and from DOH for the period of 1991 to 2002, the HSPF model was run for the period of 1991 to 2000. Average annual rainfall data collected at Reagan

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National Airport from 1988 to 2000 is presented in Table 4-1, and illustrates that the time period used for modeling encompasses both wet (i.e., 1996) and dry (i.e., 1991) years, as well as normal weather years. The table also indicates that the annual rainfall for the selected simulation period is consistent with the previous DC TMDLs that used the 1988 to 1990 rainfall in TMDL development.

The resulting existing fecal coliform loads are presented as average annual loads based on five years of the simulation period, from January 1995 to December 1999. The existing fecal coliform load in the District section of the C&O Canal, presented by year and source, is presented in Table 4-2. It should be noted that the C&O Canal headwater load represents the fecal coliform load entering the C&O Canal at the Maryland state line. This load was calculated using the National Park Service flow estimate of 4 CFS and the average fecal coliform concentration based on the available USGS monitoring data for the period of 1991 to 1994. The existing conditions are plotted in Figure 4-1. As evidenced by Figure 4-1, fecal coliform concentrations in the C&O Canal violate the 200 MPN/100 mL geometric mean primary contact recreation fecal coliform standard most of the time under existing conditions.

Table 4-1: Average Annual Precipitation Data Collected at Reagan National Airport (Arlington, Virginia)

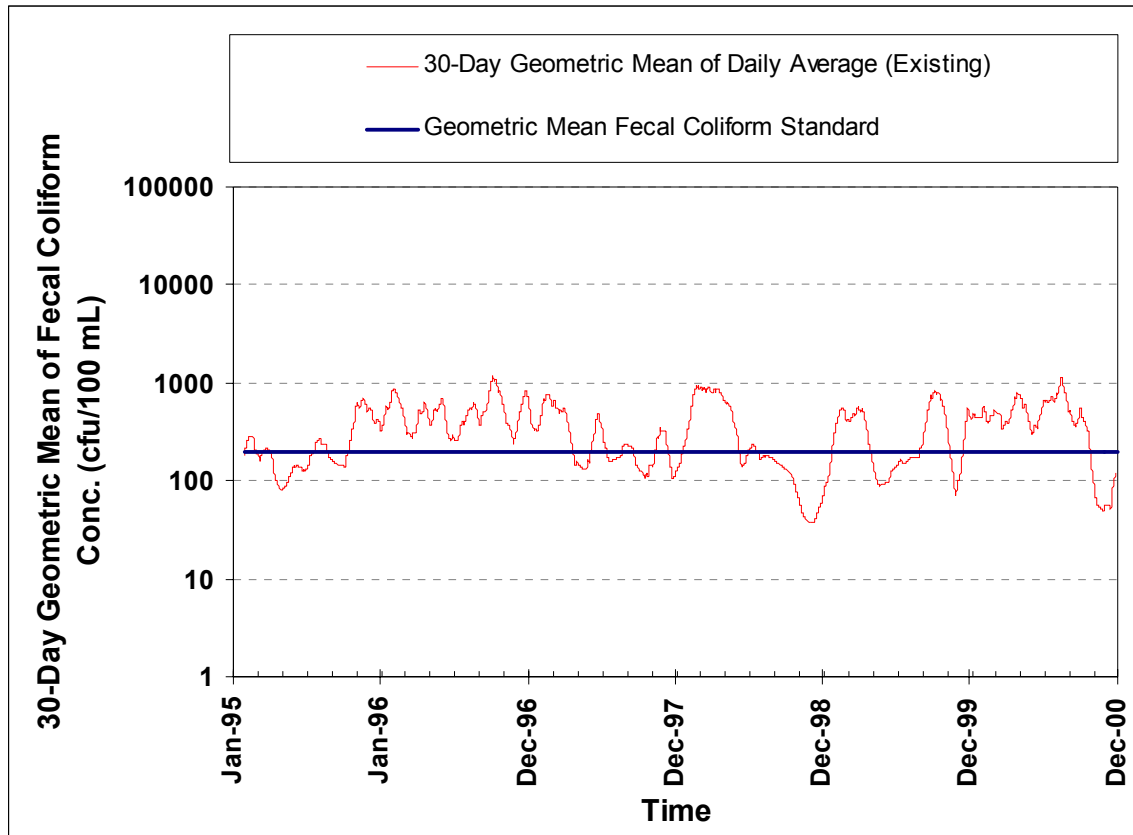
Year	Average Annual Precipitation (inches/year)
1988	31.7
1989	50.3
1990	40.8
1991	29.6
1992	36.4
1993	41.4
1994	37.6
1995	39.9
1996	50.2
1997	32.2
1998	33.3
1999	40.0
2000	39.3
Average	38.7

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Table 4-2: Average Annual Fecal Coliform Loading under Existing Conditions (MPN/year)

Year	Total Load from Sewered Area (MS4)	Total Load from Nonpoint Sources	Total Upstream Boundary Load	Total Existing Load
1995	1.25E+13	1.14E+13	1.83E+11	2.42E+13
1996	2.29E+13	1.33E+13	1.83E+11	3.65E+13
1997	1.47E+13	1.20E+13	1.83E+11	2.66E+13
1998	1.11E+13	1.14E+13	1.83E+11	2.30E+13
1999	1.53E+13	1.20E+13	1.83E+11	2.75E+13
Average	1.53E+13	1.20E+13	1.83E+11	2.75E+13

Figure 4-1: Fecal Coliform Concentrations in the C&O Canal under Existing Conditions



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4.3 Total Maximum Daily Load Development

4.3.1 Reduction Scenarios

To determine allocated loads, a number of source reduction scenarios were simulated using the HSPF model, as presented in Table 4-3. After evaluating each of the developed scenarios, allocation scenario 9 was determined to be the final allocation scenario that was used to develop the fecal coliform TMDL, because this scenario achieved the applicable fecal coliform standard of 200 MPN/100 mL at all times during the simulation, and also complied with the load reductions specified in previously established TMDLs for the C&O Canal's source and receiving waters (DOH, 2004b and 2004c).

Table 4-3: Reduction Scenarios for C&O Canal TMDL Development

Scenario Number	Source Type (Percent Reduction)			Percent Exceedence of Primary Contact Recreation Fecal Coliform Standard (200 MPN/100 mL)
	Sewered Area (MS4)	Nonpoint Sources	Upstream Boundary	
0	--	--	--	79%
1	100	--	--	5%
2	100	100	--	0%
3	100	50	--	0%
4	100	50	50	0%
5	80	60	50	16%
6	80	100	50	0%
7	80	80	50	2%
8	90	90	50	0%
9	95	95	50	0%

4.3.2 TMDL Allocation

Scenario 9 was selected as the TMDL allocation scenario because it complies with the TMDLs previously established for Rock Creek and the Potomac River, and does not exceed the District's primary contact recreation fecal coliform criterion at any time. It should be noted that it was not necessary to reduce the fecal coliform loads from sewered areas and nonpoint sources to the full 95 percent reduction specified in the Rock Creek TMDL in order to meet the applicable fecal coliform standard in the Canal. The fecal coliform water quality standard was met in the Canal with a 90 percent reduction in these sources, but additional reductions are necessary to meet the requirements of the Rock Creek fecal coliform TMDL.

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The allocated fecal coliform loads for the C&O Canal based on scenario 9 are presented in Table 4-4. Table 4-5 presents a comparison of the existing and allocated loads by source as well as the percentage reductions required from each source. The C&O Canal fecal coliform TMDL, including the load allocation, wasteload allocation and margin of safety is presented in Table 4-6. The resulting fecal coliform concentrations under the existing and TMDL allocation scenarios are presented in Figure 4-2. As seen in Figure 4-2, fecal coliform concentrations do not exceed the primary contact recreation fecal coliform standard of 200 MPN/100 mL geometric mean under the TMDL allocation scenario.

Table 4-4: Average Annual Fecal Coliform Loading under TMDL Allocation Scenario (MPN/year)

Year	Total Sewered Load (MS4)	Total Nonpoint Source Load	Total Upstream Boundary Load	Total Allocated Load
1995	6.31E+11	9.86E+11	9.13E+10	1.71E+12
1996	1.15E+12	1.52E+12	9.16E+10	2.77E+12
1997	7.40E+11	1.08E+12	9.13E+10	1.88E+12
1998	5.61E+11	9.46E+11	9.13E+10	1.63E+12
1999	7.72E+11	1.21E+12	9.13E+10	2.07E+12
Average	7.72E+11	1.15E+12	9.14E+10	2.01E+12

Table 4-5: Existing Load, TMDL and Percent Reductions for the C&O Canal

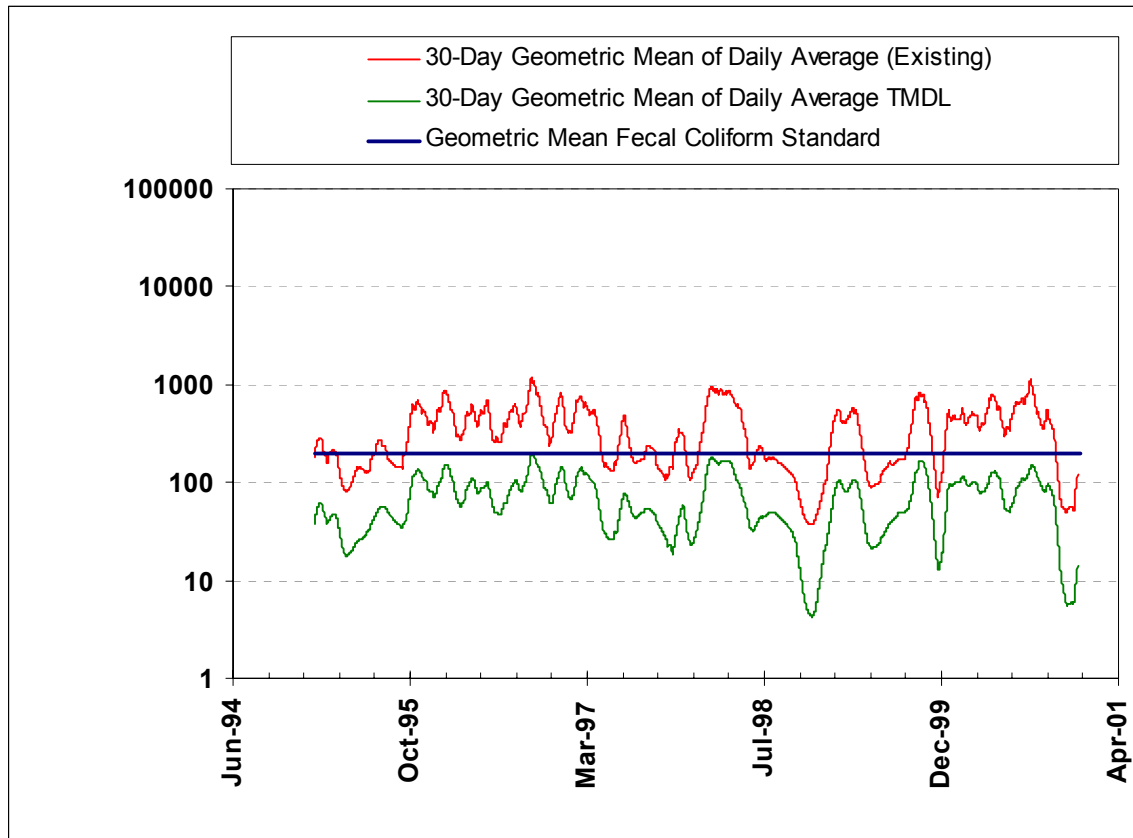
Fecal Coliform Source	Existing Load (MPN/year)	TMDL Allocation (MPN/year)	Percent Reduction
Total Upstream Boundary Load	1.83E+11	9.14E+10	50%
Total Nonpoint Source Load	1.20E+13	1.15E+12	90%
Total Load from Sewershed	1.53E+13	7.72E+11	95%
Margin of Safety	–	2.01E+10	–
Total Load	2.75E+13	2.03E+12	93%

Table 4-6: Fecal Coliform TMDL for the C&O Canal (MPN/year)

TMDL	Upstream Allocation	Load Allocation	Wasteload Allocation	Margin of Safety (1%)
2.03E+12	9.14E+10	1.15E+12	7.72E+11	2.01E+10

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Figure 4-2: Fecal Coliform Concentrations in the C&O Canal under TMDL Allocation



5 Reasonable Assurance

There is reasonable assurance that the goals of this TMDL can be met. The District sponsors several programs aimed at controlling stormwater runoff and nonpoint source pollution. Additionally, the District is a signatory to the Chesapeake Bay Agreement, which seeks to significantly reduce nonpoint pollutant loads to the Chesapeake Bay (Chesapeake Bay Program, 2000). The C&O Canal is also located within the Chesapeake and Ohio Canal National Historic Park, which is managed by the National Park Service.

5.1 Stormwater Load Reductions

The District has several ongoing programs and regulations whose objectives are to limit nonpoint source loading from stormwater runoff. These include the following:

- Street sweeping programs coordinated by the DC Department of Public Works
- Stormwater control regulations
- Regulatory programs that restrict illegal storm sewer discharges
- Environmental education and citizen outreach programs to reduce activities that cause pollution related to pet waste

In addition to these programs, the District also has a Nonpoint Source Management Plan to reduce nonpoint source pollution (DOH, 2002), as well as an MS4 permitting system that provides additional mechanisms for reducing bacteria and other nonpoint source pollutant loads from stormwater.

5.2 Chesapeake 2000 Agreement

On June 28, 2000, Mayor Williams of the District, along with the U.S. Environmental Protection Agency and other government entities and stakeholders, signed the Chesapeake 2000 Agreement. The goals of the Agreement set ambitious goals for reducing nonpoint source loads entering the Chesapeake Bay, and include the following objectives:

“Achieve and maintain the water quality necessary to support the aquatic living resources of the Chesapeake Bay and its tributaries and to protect human health...”

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and

“By 2010, correct the nutrient and sediment related problems in the Chesapeake Bay and its tidal tributaries sufficiently to remove the Bay and the tidal portions of its tributaries from the lists of impaired waters under the Clean Water Act.”

The Chesapeake 2000 Agreement demonstrates a clear commitment to restore the Potomac River Basin, including the C&O Canal, and provides assurance that the bacteria load reductions specified in the C&O Canal TMDL will be achieved.

5.3 Chesapeake and Ohio National Historic Park

The Chesapeake and Ohio Canal National Historic Park (CHOH) encompasses the entire 184.5 miles of the C&O Canal, and is managed by the National Park Service. As a national park, management of CHOH’s aquatic resources is guided by several legislative and executive orders, including: the 1972 Clean Water Act, the National Environmental Policy Act, and Executive Order 1988, which requires all federal agencies to “restore and preserve the natural and beneficial values weaved by the floodplain.” Additionally, National Park Service has developed a resource management plan for CHOH, which describes specific management practices needed to protect and manage the park’s natural resources (National Park Service, 1996), as well as a water resources scoping report that describes the natural resources and significant water-related issues in CHOH and the C&O Canal (Weeks, 2001).

5.4 Public Participation

Public participation is a required part of the C&O Canal TMDL development process. The draft TMDL report will be public noticed. The public will have the opportunity to comment on the draft TMDL report, and public comments will be received and addressed.

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APPENDIX A

Chesapeake and Ohio Canal Reach File Version 3 (RF3) Database Information

Table A-1: RF3 Database Information for the Section of the C&O Canal Located in the District

Reach Name	Location	Reach Number	Length (miles)
Chesapeake and Ohio Canal	District of Columbia	2070010 149 0.00	1.35
Chesapeake and Ohio Canal	District of Columbia	2070010 753 0.00	2.58