UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue
Seattle, WA 98101

Reply To
Attn Of: OWW-134

JUN 15 2006

Lynn J. Tomich Kent, Director
Water Division
Department of Environmental Conservation
555 Cordova St.
Anchorage, AK 99501-2617

Dear Mr. Kent:

The U.S. Environmental Protection Agency (EPA) Region 10 is pleased to approve the Total Maximum Daily Loads (TMDLs) for fecal coliform bacteria for Campbell Creek and Campbell Lake in Anchorage, Alaska, submitted to us by the Alaska Department of Environmental Conservation (ADEC) on May 1, 2006. By EPA's approval, this TMDL is now incorporated into the State's Water Quality Management Plan under Section 303(e) of the Clean Water Act.

We are impressed by the commitment and hard work shown by the ADEC staff, in particular Tim Stevens, in developing these TMDLs.

We look forward to continuing to work collaboratively on water quality issues in the Campbell Lake and Campbell Creek watersheds. If you have any questions, please feel free to call me at (206) 553-7151, or Jayne Carlin of my staff at (206) 553-8512.

Sincerely,

Michael F. Gearheard
Director
Office of Water & Watersheds

cc: Tim Stevens, Division of Water, ADEC (Juneau)
Kent Patrick-Riley, Division of Water, ADEC (Anchorage)

Alaska Department of Environmental Conservation
555 Cordova Street
Anchorage, Alaska 99501

Total Maximum Daily Loads (TMDLs) for Fecal Coliform Bacteria in the Waters of Campbell Creek and Campbell Lake in Anchorage, Alaska

May 2006

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Acronyms

AAC	Alaska Administrative Code
ADEC	Alaska Department of Environmental Conservation
ASCE	American Society of Civil Engineers
AWSO	Anchorage Weather Service Office
BMP	best management practice
CFR	Code of Federal Regulations
CWP	Center for Watershed Protection
DHHS	Department of Health and Human Services
EPA	U.S. Environmental Protection Agency
FC it	Fecal Coliform Bacteria (Note: when the term "fecal coliform" is used in this document, has the same meaning as "Fecal Coliform bacteria.")
GIS	geographic information system
LA	load allocation
LID	low-impact development
MOA	Municipality of Anchorage
MOS	margin of safety
MS4	municipal separate storm sewer system
NCDC	National Climatic Data Center
NPDES	National Pollutant Discharge Elimination System
OGS	oil and grit separator
SMRC	Stormwater Manager’s Resource Center
TMDL	total maximum daily load
UAA	University of Alaska–Anchorage
USGS	U.S. Geological Survey
UWRRC	Urban Water Resources Research Council
WLA	wasteload allocation
WRCC	Western Regional Climate Center

Total Maximum Daily Loads for Fecal Coliform in the Waters of Campbell Creek and Campbell Lake in Anchorage, Alaska

TMDLS AT A GLANCE

Campbell Lake:	
Water Quality-limited?	Yes
Hydrologic Unit Code:	19020401
Criteria of Concern:	Fecal coliform bacteria (FC)
Designated Uses Affected:	Water supply and water recreation
Major Source(s):	Urban runoff
Loading Capacity:	Winter: 9.36×10^{10} FC/season Spring: 1.96×10^{11} FC/season Summer: 3.38×10^{11} FC/season
Wasteload Allocation:	Winter: 8.42×10^{10} FC/season Spring: 1.77×10^{11} FC/season Summer: 3.05×10^{11} FC/season
Load Allocation:	0 FC/season (all seasons)
Margin of Safety:	Winter: 9.36×10^{9} FC/season Spring: 1.96×10^{10} FC/season Summer: 3.38×10^{10} FC/season
Necessary Load Reductions (to meet WLA):	Winter: 0 percent Spring: 0 percent Summer: 37 percent
Campbell Creek:	
Water Quality-limited?	Yes
Hydrologic Unit Code:	19020401
Criteria of Concern:	Fecal coliform bacteria (FC)
Designated Uses Affected:	Water supply and water recreation
Major Source(s):	Urban runoff
Loading Capacity:	Winter: 1.27×10^{11} FC/season Spring: 2.67×10^{11} FC/season Summer: 4.59×10^{11} FC/season
Wasteload Allocation:	Winter: 1.14×10^{11} FC/season Spring: 2.40×10^{11} FC/season Summer: 4.13×10^{11} FC/season
Load Allocation:	0 FC/season (all seasons)
Margin of Safety:	Winter: 1.27×10^{10} FC/season Spring: 2.67×10^{10} FC/season Summer: 4.59×10^{10} FC/season
Necessary Load Reductions (to meet WLA):	Winter: 0 percent Spring: 23 percent Summer: 70 percent

Executive Summary

Campbell Creek and Campbell Lake are located in the Municipality of Anchorage (MOA), the urban center of the Anchorage Bowl in southcentral Alaska. The state of Alaska included Campbell Creek and Campbell Lake in its 2002/2003 Integrated Water Quality Monitoring and Assessment Report (ADEC, 2003) as water quality-limited due to fecal coliform bacteria (FC), identifying urban runoff as the expected pollutant source. Total Maximum Daily Loads (TMDLs) are established in this document to meet the requirements of Section 303(d)(1)(C) of the Clean Water Act and the U.S. Environmental Protection Agency's (EPA) implementing regulations (40 CFR Part 130), which require the establishment of a TMDL for the achievement of water quality standards when a waterbody is water quality-limited. A TMDL is composed of the sum of individual waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background loads. In addition, the TMDL must include a margin of safety (MOS), either implicit or explicit, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. A TMDL represents the amount of a pollutant the waterbody can assimilate while maintaining compliance with applicable water quality standards.

Applicable water quality standards for fecal coliform in Campbell Creek and Campbell Lake establish water quality criterion for the protection of designated uses for water supply, water recreation, and growth and propagation of fish, shellfish, other aquatic life, and wildlife. The TMDL is developed for the most stringent of these - the fecal coliform bacteria criteria for drinking, culinary, and food processing water supply that states that in a 30-day period, the geometric mean may not exceed 20 FC/100 mL, and not more than 10 percent of the samples may exceed 40 FC/100 mL. (18 AAC 70.020 (1)(A)(i)). If the water quality is restored to meet drinking water criteria it will also meet other designated use criteria.

Fecal coliform data indicate that Campbell Creek and Campbell Lake do not meet the applicable water quality standards. The largest and most frequent exceedances of the water quality criteria occur during summer months, likely due to increased stormwater runoff and source activity. Fecal coliform concentrations are lower during colder winter months that experience less stormwater runoff. Concentrations steadily increase during spring months, with increased surface runoff during spring thaw and breakup. Because of the substantial seasonal variation in fecal coliform levels, the Campbell Creek and Campbell Lake TMDLs are developed on a seasonal basis to isolate times of similar weather, runoff and instream conditions.

The Simple Method (Schueler, 1987), an empirical equation to calculate pollutant loading, was used for the TMDL analysis. The Simple Method is a lumped parameter empirical model used to estimate stormwater pollutant loadings under conditions of limited data availability. The approach calculates pollutant loading using drainage area, event mean pollutant concentrations, precipitation and a runoff coefficient based on impervious area in the watershed. The method was used to calculate existing fecal coliform loading based on observed fecal coliform data and the loading capacity for the stream based on instream concentrations representing water quality standards. The Campbell Creek and Campbell Lake watershed was divided into two subwatersheds to separate direct loading to the lake from loading to the impaired portion of the creek.

Table E-1 summarizes the results of the TMDL analysis. The MOS was included explicitly as 10 percent of the loading capacity. Because stormwater discharges in the MOA are regulated by a National Pollutant Discharge Elimination System (NPDES) stormwater permit for municipal separate storm sewer systems (MS4), watershed loads delivered to Campbell Creek and Campbell Lake are addressed through the wasteload allocation component of this TMDL. Therefore, the load allocations for the Campbell Creek

and Campbell Lake fecal coliform TMDLs are zero. Alaska Department of Environmental Conservation (ADEC) believes that waterfowl and wildlife contribute little fecal coliform through most of the watershed, but at some locations may contribute higher amounts at certain times of the year. As any contributions they provide are not resulting from human actions, they are not included in the TMDL loading allocations. This TMDL focuses on stormwater discharges as the main component. Because these discharges in the MOA are regulated by a NPDES storm water permit for MS4, watershed loads delivered to Campbell Creek are addressed through the wasteload allocation component of this TMDL. The fecal coliform wasteload allocations for Campbell Creek and Campbell Lake are provided as seasonal allocations and are equal to the loading capacity minus the MOS. Allocations for the three subwatersheds are discussed in Section 6.

Table E-1. Fecal coliform wasteload allocations for subwatersheds in the Campbell Creek and Campbell Lake watersheds

Season	Existing Loading (FC/season)	Loading Capacity (FC/season)	MOS[1] (FC/season)	Wasteload Allocation (FC/season)	Percent Reduction (for Wasteload Allocation)
Campbell Lake					
Winter	6.88×10^{10}	9.36×10^{10}	9.36×10^{9}	8.42×10^{10}	–
Spring	7.80×10^{10}	1.96×10^{11}	1.96×10^{10}	1.77×10^{11}	–
Summer	4.84×10^{11}	3.38×10^{11}	3.38×10^{10}	3.05×10^{11}	37%
Campbell Creek					
Winter	2.81×10^{10}	1.27×10^{11}	1.27×10^{10}	1.14×10^{11}	–
Spring	3.13×10^{11}	2.67×10^{11}	2.67×10^{10}	2.40×10^{11}	23%
Summer	1.39×10^{12}	4.59×10^{11}	4.59×10^{10}	4.13×10^{11}	70%

Implementation of the Campbell Creek and Campbell Lake TMDLs will be achieved through actions associated with the relevant MS4 permit regulating stormwater discharges. The MOA is subject to an MS4 permit that was issued by EPA Region 10 in 1998. New permit conditions are currently under draft. EPA recommends that for NPDES-regulated municipal and small construction stormwater discharges effluent limits should be expressed as best management practices (BMPs) or other similar requirements, rather than as numeric effluent limits. The policy recognizes the need for an iterative approach to control pollutants in storm water discharges and anticipates that a suite of BMPs will be used in the initial rounds of permits and that these BMPs will be tailored in subsequent rounds.

Follow-up monitoring will likely be conducted cooperatively by Alaska Department of Environmental Conservation (ADEC) and MOA to track the progress of TMDL implementation and subsequent water quality response, track BMP effectiveness, and track the water quality of Campbell Creek and Campbell Lake to evaluate future attainment of water quality standards.

1. Overview

Section 303(d)(1)(C) of the Clean Water Act and the U.S. Environmental Protection Agency's (EPA) implementing regulations (40 CFR Part 130) require the establishment of a Total Maximum Daily Load (TMDL) for the achievement of state water quality standards when a waterbody is water quality-limited. A TMDL identifies the amount of pollution control needed to maintain compliance with standards and includes an appropriate margin of safety. The focus of the TMDL is reduction of pollutant inputs to a level (or "load") that fully supports the designated uses of a given waterbody. The mechanisms used to address water quality problems after the TMDL is developed can include a combination of best management practices and/or effluent limits and monitoring required through National Pollutant Discharge Elimination System (NPDES) permits. This report presents the TMDLs for fecal coliform for Campbell Creek and Campbell Lake, Alaska.

1.1. Scope of the TMDLs

The Alaska Department of Environmental Conservation (ADEC) included Campbell Creek and Campbell Lake in its 2002/2003 Integrated Water Quality Monitoring and Assessment Report (ADEC, 2003) as water quality-limited due to fecal coliform. The creek and the lake were originally listed in 1990. At the time of the 1990 303(d) listing it was unclear if the entire Campbell Creek watershed was impaired or just the urban portion downstream of State and City park land. An analysis of the land use within the upper Campbell Creek watershed (i.e., above the confluence of North Fork and South Fork) show impervious surfaces cover approximately 1.1 percent of the land surface while forested, barren or wetlands cover 98.2 percent. Data show higher fecal coliform levels during the mid-summer months when there is generally more wildlife activity (e.g., moose, bear, beaver, and waterfowl) and after a relatively long period of little precipitation. Because of the pervious types of land use, few stormwater outfalls, and limited residential development within the upper Campbell Creek watershed ADEC believes fecal coliform input from humans or human-related sources are small compared to the size of the upper watershed and contributions by natural sources. Therefore, the TMDL for Campbell Creek calculates existing and allowable loads and associated load reductions for the lower portion of Campbell Creek, extending from the mouth to the confluence of North Fork Campbell Creek and South Fork Campbell Creek. Although the original 303(d) listing for Campbell Lake was for 25 acres, the TMDL is being developed to protect the entire 125 acres of the lake. Table 1-1 summarizes the information included on the 2002 303(d) list for Campbell Creek and Campbell Lake.

Table 1-1. 303(d) List Information for Campbell Creek and Campbell Lake

Alaska ID Number	Waterbody	Location	Area of Concern	Pollutant Parameter	Pollutant Sources
20401-004	Campbell Creek	Anchorage	10 miles	Fecal coliform	Urban runoff
20401-402	Campbell Lake	Anchorage	25 acres	Fecal coliform	Urban runoff

The following sections provide general background information on the Campbell Creek and Campbell Lake watershed. It should be noted that a fecal coliform TMDL for Little Campbell Creek has already been developed (ADEC, 2004). The TMDL for Little Campbell Creek was completed in conjunction with five other Anchorage streams with similar watershed sizes, stream characteristics and land uses. Therefore, Little Campbell Creek is excluded from the TMDL analysis for Campbell Creek.

1.2. Location

Campbell Creek and Campbell Lake are located in the Municipality of Anchorage (MOA), the urban center of the Anchorage Bowl in southcentral Alaska (Figure 1-1). The Anchorage Bowl is a broad valley bordered by the Chugach Mountain Range on the east and the Turnagain Arm and Knik Arm of Cook Inlet to the southwest and northwest. Campbell Creek is located in the southern portion of Anchorage. The creek has its headwaters in the Chugach Mountains and drains to the Turnagain Arm (Figure 1-2). The Campbell Creek watershed is approximately 72 square miles (mi^2) and includes drainages for its main tributaries—South Fork Campbell Creek (28.7 mi^2), North Fork Campbell Creek (16.5 mi^2) and Little Campbell Creek (13.3 mi^2). The upper portion of Campbell Creek watershed includes a portion of the Chugach State Park and is characterized by forested areas and steep gradients. The lower portions of the watershed have gentler slopes and are dominated by residential and developed land uses. Campbell Lake is located in a suburban portion of south Anchorage, at the downstream end of Campbell Creek and just upstream of the creek's outlet to the Turnagain Arm. The lake is approximately 125 acres and has a shoreline of approximately 3.5 miles.

1.3. Population

Population in the Anchorage area has steadily increased over the past decades. According to Census Bureau statistics, total population in Anchorage was approximately 174,000 in 1980, 226,000 in 1990 and 260,000 in 2000. As population has increased, land development increased and local watersheds experience higher densities of impervious areas and amounts of stormwater runoff.

Census data are available as geographic information system (GIS) data with population statistics by census blocks. The Census GIS data for 2000 were clipped to the area of the Campbell Creek and Campbell Lake watershed to estimate the watershed population. However, some Census blocks cross watershed boundaries. In this instance, a population density (people/acre) was calculated from the original block. These densities were assumed to be consistent across the Census block and were multiplied by the area contained within the watershed to estimate the population within the clipped portion of the Census block. Because population densities may vary spatially across the Census blocks with some portions of the blocks being more or less densely populated, the watershed populations calculated with the densities are considered estimates and are used as a reference of the relative magnitude of population in the watershed. The estimated population in the Campbell Creek and Campbell Lake watershed is 70,013. Approximately 18,400 are included in the Little Campbell Creek subwatershed.

1.4. Topography

Anchorage is a broad valley bounded by the Knik Arm and Turnagain Arm of Cook Inlet. The terrain rises gradually to the east for about 10 miles, with marshes interspersed with glacial moraines, shallow depressions, small streams and knolls (AWSO, 1997). Beyond this valley area, the Chugach Mountains are situated in a north-northeast to south-southwest direction, with average elevations between 4,000 and 5,000 ft and peaks up to 10,000 ft. Elevations in the Campbell Creek watershed vary, with the lower watershed just above sea level in the valley portion of the Anchorage Bowl and the headwaters in steeper topography in the Chugach Mountains. The mouth of Campbell Creek drains into Turnagain Arm at sea level and its headwaters begin in the Chugach Mountains at 5,000 ft. Campbell Lake is located just upstream of Turnagain Arm, between 0 and 100 ft above sea level.

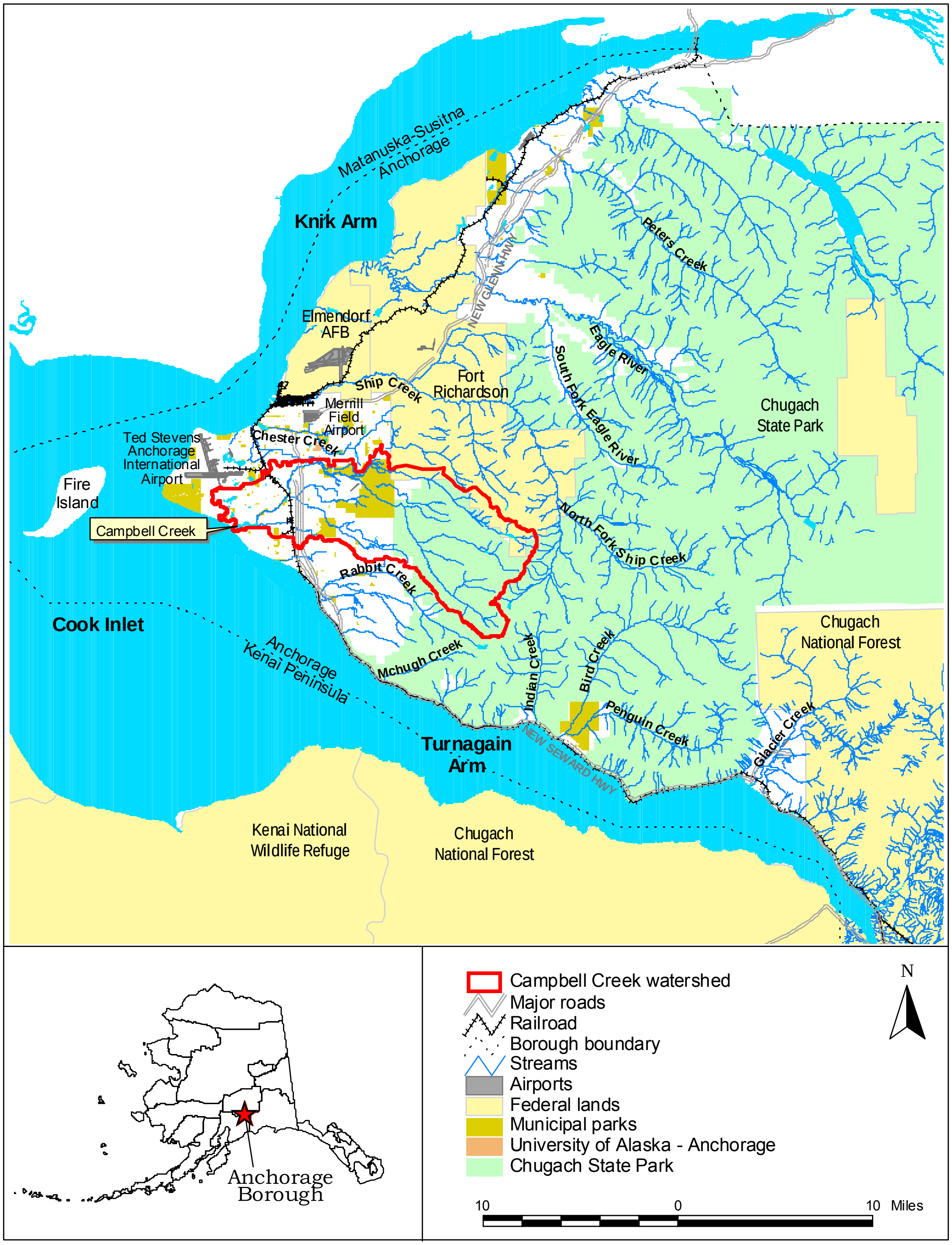


Figure 1-1. Location of Campbell Creek and Campbell Lake watershed

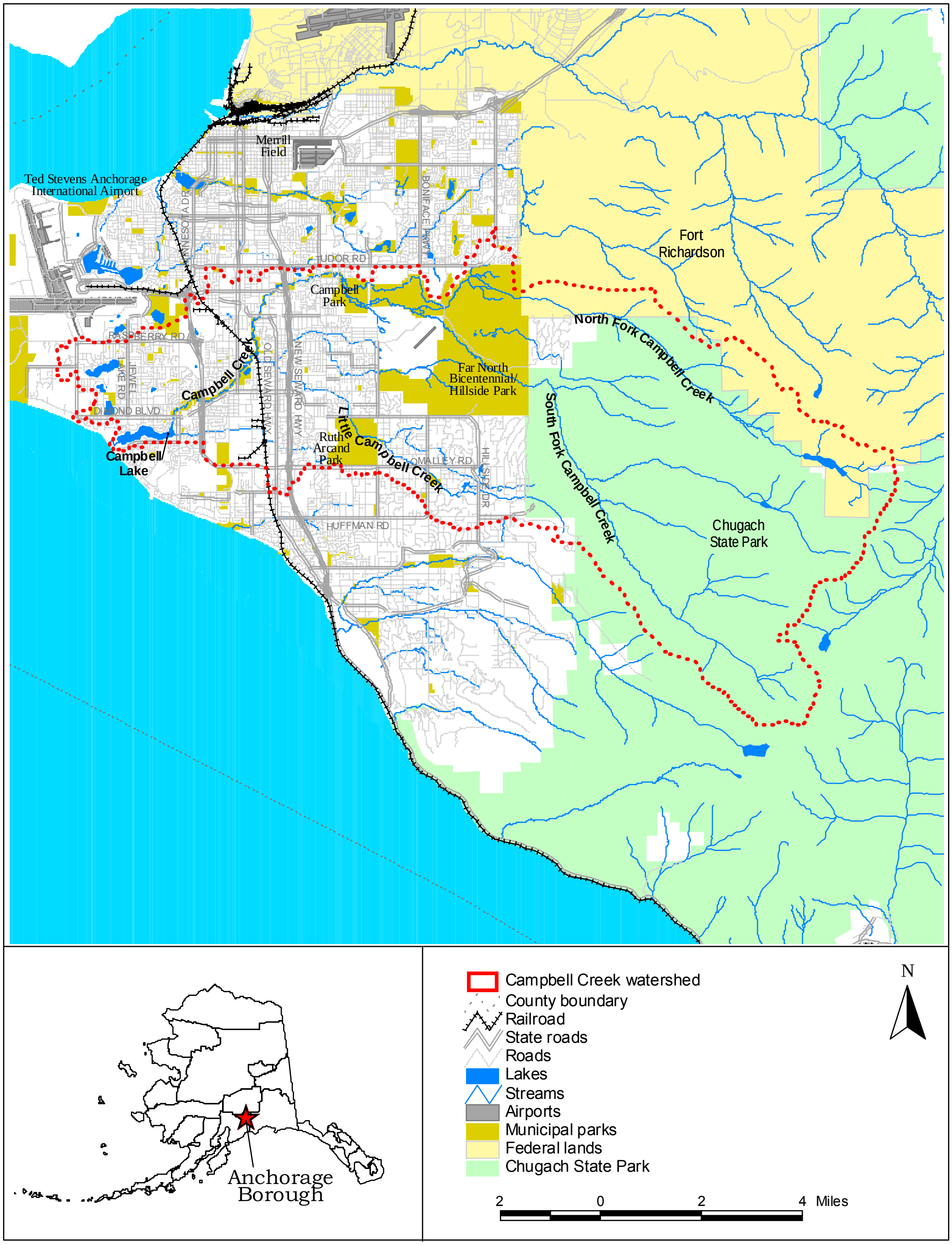


Figure 1-2. Campbell Creek and Campbell Lake watershed

1.5. Land Use

Land cover and uses in the Campbell Creek/Lake watershed were determined using GIS coverages available from MOA. MOA land use classifications include eight major categories (e.g., residential) with more detailed subcategories (e.g., single family detached, mobile home on lot). Appendix A contains a listing of the subcategories associated with each major category and Table 1-2 and Figure 1-3 present the land use distribution by major category for the watershed. Because the Little Campbell Creek watershed is not included in the TMDL calculations (see section 5) its land use areas were separated from the remainder of the Campbell Creek watershed in Table 1-2.

As shown in Figure 1-3 much of the area drained by the North Fork and South Fork of Campbell Creek are not included in the MOA's land use coverage. Much of the "missing" area of the watershed, identified in Figure 1-3 as Unclassified, is included in the Chugach State Park. Although additional digital land cover data are not available for the Anchorage area, U.S. Geological Survey (USGS) aerial photos can be viewed through USGS's Seamless Data Distribution System (http://seamless.usgs.gov/). Aerial photos indicate that the "missing" area is forested area, consistent with the surrounding parkland. Therefore, the 16,982 acres of the Campbell Creek watershed not included in the MOA land use coverage were assumed to be forest and were added to the Parks and Open Space category (Table 1-2).

Table 1-2. Land use distribution in Campbell Creek and Campbell Lake watershed

	Campbell Creek and Lake		Little Campbell Creek		Total	
Land Use	Acres	Percent of Total Area	Acres	Percent of Total Area	Acres	Percent of Total Area
Commercial	678.2	1.8%	172.9	2.0%	851.1	1.8%
Industrial	783.0	2.1%	226.7	2.7%	1,009.7	2.2%
Institutional	802.2	2.1%	634.7	7.4%	1,436.9	3.1%
Parks and Open Space	27,441.9	72.7%	1,948.5	22.8%	29,390.4	63.5%
Residential	3,159.5	8.4%	3,074.3	36.0%	6,233.8	13.5%
Roads and Rights of Way	1,937.8	5.1%	1,030.2	12.1%	2,968.0	6.4%
Transportation[1]	7.6	0.0%	0.0	0.0%	7.6	0.0%
Vacant	2,696.5	7.1%	1,435.2	16.8%	4,131.7	8.9%
Waterbodies/Intertidal	242.8	0.6%	15.1	0.2%	257.9	0.6%
Total	37,749.4	100.0%	8,537.6	100.0%	46,287.0	100.0%

[1] Transportation includes railroads, airports and marine transport terminals.

As shown in Figure 1-3 and Table 1-2, the dominant land use in the Campbell Creek and Campbell Lake watershed is parks and open space, due to the upper portion of the watershed consisting of forested land of the Chugach State Park. Far North Bicentennial/Hillside Park also covers approximately 4,000 acres in the Little Campbell, North Fork and South Fork drainages. The industrial and commercial areas are concentrated in the middle portion of the watershed, mainly between Minnesota Drive and New Seward Highway, surrounding the Little Campbell Creek confluence. Residential areas dominate the lower portion of the watershed, surrounding Campbell Lake.

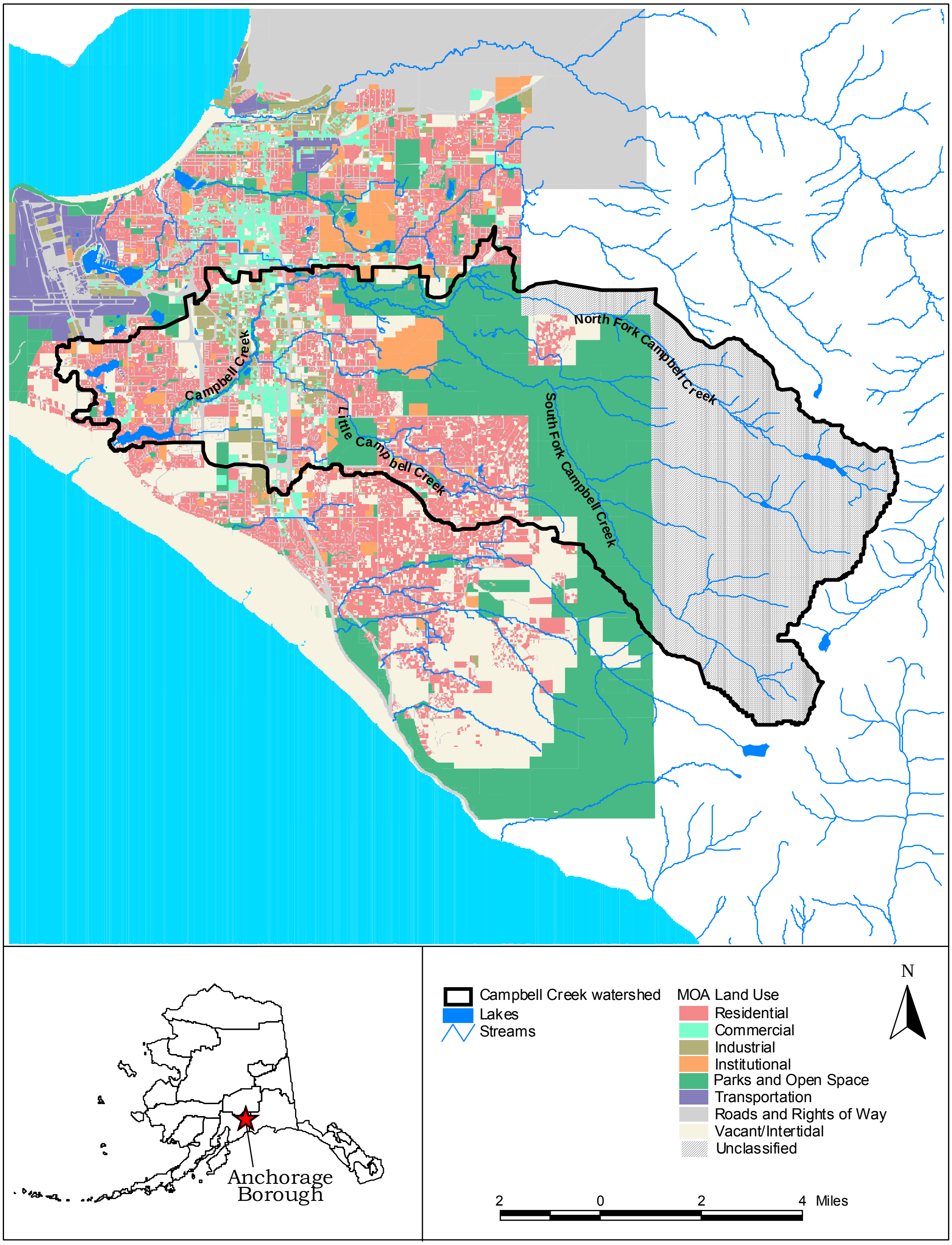
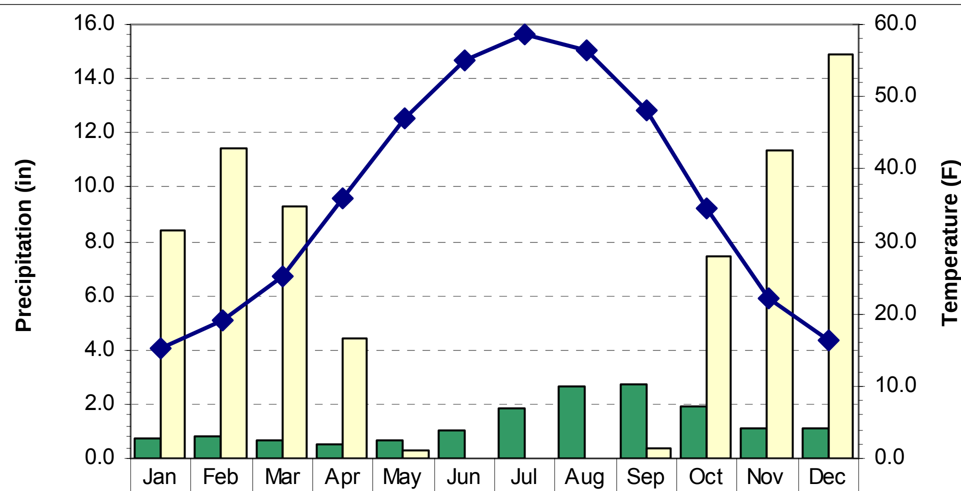


Figure 1-3. Land use distribution in the Campbell Creek and Campbell Lake watershed

1.6. Climate

The Anchorage area is contained in the "transition" climate zone of Alaska, between the maritime and continental zones. Temperatures in the transition zone typically range between zero and the low 60s degrees Fahrenheit (°F) (WRCC, 2002). The Chugach Mountains act as a barrier to the influx of warm, moist air from the Gulf of Alaska, resulting in annual precipitation amounts equal to 10 to 15 percent of that measured at weather stations located on the Gulf side of the Chugach Range. Annual snowfall varies from approximately 70 inches on the west side of Anchorage to about 90 inches on the east side. Snow totals increase steadily with increasing elevations in the Chugach Mountains where winter arrives a month earlier and stays a month longer at the 1,000 to 2,000 ft elevation (AWSO, 1997).

Summer temperatures average around 60 °F. Autumn begins in early September and ends in mid-October with temperatures falling in September and snowfalls increasing in October (AWSO, 1997). Winter lasts from mid-October to early April, with the coldest temperatures typically occurring in January. Spring begins in late April and May with less precipitation and increasing temperatures. Figure 1-4 presents a summary of monthly averages for rainfall, snowfall and temperature at the Anchorage Ted Stevens International Airport (500280), based on the period of record at the station from April 1952 to June 2005.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean precipitation	0.71	0.82	0.63	0.53	0.67	1.00	1.87	2.66	2.72	1.92	1.11	1.08
Mean snow fall	8.4	11.4	9.3	4.4	0.3	0.0	0.0	0.0	0.4	7.4	11.4	14.9
Mean temperature	15.2	19.1	25.3	36.1	46.9	54.9	58.5	56.5	48.2	34.6	22.1	16.3

Figure 1-4. Monthly average precipitation and temperatures at Anchorage Ted Stevens International Airport (1952-2005)

1.7. Hydrology

Campbell Creek has its headwaters in the Chugach Mountains and drains to Campbell Lake and then to the Turnagain Arm. Campbell Creek travels approximately 20 miles from its headwaters to its mouth and the Campbell Creek watershed is approximately 72 mi^2. The main tributaries to Campbell Creek are South Fork Campbell Creek, draining 28.7 mi^2, North Fork Campbell Creek, draining 16.5 mi^2, and Little Campbell Creek, draining 13.3 mi^2. There are approximately 110 miles of perennial streams in the Campbell Creek and Lake watershed. Campbell Lake is located at the downstream end of Campbell

Creek and just upstream of the creek's outlet to the Turnagain Arm. The lake is approximately 125 acres and has a shoreline of approximately 3.5 miles.

Several USGS gauges are located throughout the Campbell Creek watershed. Figure 1-5 presents the average daily flows at the following five gauges:

- USGS 15274600 (CAMPBELL C NR SPENARD AK)
- USGS 15274550 (L CAMPBELL C AT NATHAN DR NR ANCHORAGE AK)
- USGS 15274000 (SF CAMPBELL C NR ANCHORAGE AK)
- USGS 15274300 (NF CAMPBELL C NR ANCHORAGE AK)
- USGS 15273900 (SF CAMPBELL C AT CANYON MTH NR ANCHORAGE AK)

The figure shows that daily mean flows are highest in the summer months (June through October) and lowest during the winter and early spring. Rainfall and stormwater runoff increase during summer months resulting in the increased streamflows while baseflow levels dominate during frozen winter months. Flows begin to increase during late March through May due to snowmelt runoff.

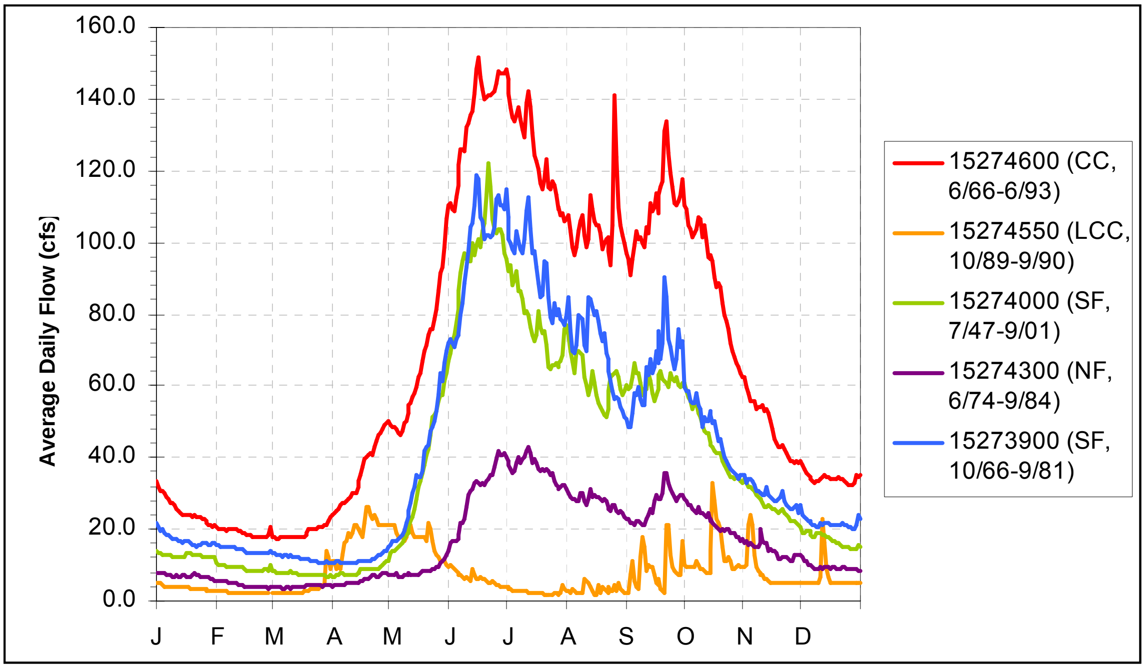


Figure 1-5. Average daily streamflow at USGS gauges in the Campbell Creek watershed

2. Water Quality Standards and TMDL Target

Water quality standards designate the "uses" to be protected (e.g., water supply, recreation, aquatic life) and the "criteria" for their protection (e.g., how much of a pollutant can be present in a waterbody without impairing its designated uses). TMDLs are developed to meet applicable water quality standards, which may be expressed as numeric water quality criteria or narrative criteria for the support of designated uses. The TMDL target identifies the numeric goals or endpoints for the TMDL that equate to attainment of the water quality standards. The TMDL target may be equivalent to a numeric water quality standard where one exists, or it may represent a quantitative interpretation of a narrative standard. This section reviews the applicable water quality standards and identifies appropriate TMDL targets for calculation of the fecal coliform TMDLs in Campbell Creek and Campbell Lake.

2.1. Applicable Water Quality Standards

Title 18, Chapter 70 of the Alaska Administrative Code (AAC) establishes water quality standards for the waters of Alaska, including the designated uses to be protected and the water quality criteria necessary to protect the uses. Designated uses established in the State of Alaska Water Quality Standards (18 AAC 70) for fresh waters of the state include (1) water supply, (2) water recreation, and (3) growth and propagation of fish, shellfish, other aquatic life, and wildlife, and are applicable to all fresh waters, unless specifically exempted. Fecal coliform water quality standards for each use and applicable to Campbell Creek and Campbell Lake are presented in Table 2-1. The TMDL must be developed to meet all applicable criteria. The most stringent of these is the following criteria for drinking, culinary, and food processing water supply:

> *In a 30-day period, the geometric mean may not exceed 20 FC/100 mL, and not more than 10% of the samples may exceed 40 FC/100 mL. (18 AAC 70.020(b)(2)(A)(i))*

Note, in accordance with 18 AAC 70.235(b), if the DEC finds that the natural condition of a waterbody is demonstrated to be of lower quality than the water quality criterion set out in 18 ACC 70.020(b), the natural condition constitutes the applicable water quality criterion. Before making such a determination, DEC will issue public notice and will provide opportunity for public comment, as outlined in 18 AAC 70.235.

2.2. Designated Use Impacts

Designated uses for Alaska's waters are established by regulation and are specified in the State of Alaska Water Quality Standards (18 AAC 70). For fresh waters of the state, these designated uses include (1) water supply, (2) water recreation, and (3) growth and propagation of fish, shellfish, other aquatic life, and wildlife. Campbell Creek and Campbell Lake do not support its designated uses of water supply and water recreation due to elevated fecal coliform levels. The presence of fecal coliform indicates an increased risk of pathogen contamination in a waterbody. Consumption of or contact with pathogen-contaminated waters can result in a variety of gastrointestinal, respiratory, eye, ear, nose, throat and skin diseases.

2.3. TMDL Target

The TMDL target is the numeric endpoint used to evaluate the loading capacity and necessary load reductions and represents attainment of applicable water quality standards. Campbell Creek and Campbell Lake have applicable numeric water quality criteria for fecal coliform for each designated use, and the

TMDL will be developed to meet the most stringent of these criteria—criteria for drinking, culinary, and food processing water supply (water supply). By meeting the criteria for water supply, Campbell Creek and Campbell Lake will also meet the criteria for all other uses. The water quality criterion of a geometric mean of 20 FC/100 mL in a 30-day period will be used as the basis for this TMDL. The not-to-exceed criterion will not be used directly in the TMDL calculation because available data are limited in number and temporal distribution and do not allow for a confident analysis to link the frequency of exceedances (e.g., not to exceed in 10 percent of the samples) to fecal coliform loading. The maintenance of the geometric mean criterion may also result in maintaining the not-to-exceed criterion. If water quality data become available that show the not-to-exceed criterion is not being met, the TMDL can be revised.

Table 2-1. Alaska water quality standards for fecal coliform

Water Use	Description of Standard
(A) Water Supply	
(i) drinking, culinary and food processing	In a 30-day period, the geometric mean may not exceed 20/FC/100 ml, and not more than 10% of the samples may exceed 40 FC/100 ml. For groundwater, the FC concentration must be less than 1 FC/100 ml, using the fecal coliform Membrane Filter Technique, or less than 3 FC/100 ml, using the fecal coliform most probable number (MPN) technique.
(ii) agriculture, including irrigation and stock watering	The geometric mean of samples taken in a 30-day period may not exceed 200 FC/100 ml, and not more than 10% of the samples may exceed 400 FC/100 ml. For products not normally cooked and for dairy sanitation of unpasteurized products, the criteria for drinking water supply, (1)(A)(i), apply.
(iii) aquaculture	For products normally cooked, the geometric mean of samples taken in a 30-day period may not exceed 200 FC/100 ml, and not more than 10% of the samples may exceed 400 FC/100 ml. For products not normally cooked, the criteria for drinking water supply, (1)(A)(i), apply.
(iii) industrial	Where worker contact is present, the geometric mean of samples taken in a 30-day period may not exceed 200 FC/100 ml, and not more than 10% of the samples may exceed 400 FC/100 ml.
(B) Water Recreation	
(i) contact recreation	In a 30-day period, the geometric mean of samples may not exceed 100 FC/100 ml, and not more than one sample or more than 10% of the samples if there are more than 10 samples, may exceed 200 FC/100 ml.
(ii) secondary contact	In a 30-day period, the geometric mean of samples may not exceed 200 FC/100 ml, and not more than 10% of the total samples may exceed 400 FC/100 ml.
(C) Growth and Propagation of Fish, Shellfish, other Aquatic Life and Wildlife	Not applicable

3. Data Analysis

The compilation and analysis of data and information is an essential step in understanding the general water quality conditions and trends in an impaired water. This section outlines and summarizes all of the data reviewed and includes the following information:

- Data inventory—describes the available data and information
- Data analyses—presents results of various data analyses evaluating trends in instream data

It should be noted that data for Little Campbell Creek are not included in this report. A fecal coliform TMDL for Little Campbell Creek has already been completed and contains a data inventory and data analyses (ADEC, 2004).

3.1. Data Inventory

There have been a number of monitoring efforts for fecal coliform in Campbell Creek and Campbell Lake. The data represents varying locations, frequency and time spans. Table 3-1 lists the stations with available fecal coliform data and the sources of the data, including the following:

- **MOA 1989-1990 Fecal Coliform Study—**From January 1989 through June 1990, MOA's Department of Health and Human Services (DHHS), Water Quality Section, conducted a study to evaluate the fecal coliform levels in Anchorage area streams (MOA, 1990). Because the study included samples collected a minimum of fives times every 30 days, most stations have at least weekly measurements over the study period. Six stations on Campbell Creek were included in this study (CA series stations). This study did not include any stations in Campbell Lake.

- **MOA Baseline Monitoring—**From 1988 to 1992 MOA's Water Quality Section collected fecal coliform data and other water quality parameters for baseline and trend monitoring at eight stations on Campbell Creek and three stations in Campbell Lake. Frequency of samples in this dataset varies by year and location, ranging from 1 to 11 samples per year. These data correspond to the CAM and CAL series stations.

- **ADEC Summer 2005 Monitoring—**During summer 2005, ADEC conducted water quality monitoring at four stations on Campbell Creek and four stations in Campbell Lake. Data were collected for fecal coliform and other water quality parameters during 15 sampling events occurring from mid-May through mid-October. These data represent the CC series stations on the creek and the CL stations for the lake.

- **USGS Monitoring—**USGS has collected fecal coliform at several stations in Campbell Creek and its tributaries. Many of those stations included data collected for only one or a few sampling events. Other stations represent periodic monitoring over several years or limited concentrated sampling for a specific study (e.g., Brabets and Wittenberg, 1983; Dorava and Love, 1999). USGS stations are identified by 8- or 15-digit numbers.

Table 3-1. Stations with fecal coliform data in Campbell Creek and Campbell Lake

Station	Location Description	Source
CC-1	Campbell Creek at east end of 48th Ave	ADEC 2005 monitoring
CC-2	Campbell Creek at the intersection of Nathan Drive and E 72nd Ave	ADEC 2005 monitoring

Station	Location Description	Source
CC-3	Campbell Creek at the intersection of Arctic Blvd and Dimond Blvd	ADEC 2005 monitoring
CC-4	Campbell Creek at Dimond Blvd, in vicinity of Victor Rd, at the gauging station	ADEC 2005 monitoring
CL-1	Eastern end of the lake near a stormwater out fall	ADEC 2005 monitoring
CL-2	Western end of the lake near the outfall (or spill way)	ADEC 2005 monitoring
CL-3	Western end of the lake, north shore adjacent to residential development	ADEC 2005 monitoring
CL-4	Mid-lake, northern shore, adjacent to residential development	ADEC 2005 monitoring
CA11	South Fork Campbell Creek at Campbell Airstrip Rd (approx)	MOA 89-90 study
CA12	Campbell Creek at Wright Street	MOA 89-90 study
CA13	North Fork Campbell Creek at Campbell Airstrip Rd	MOA 89-90 study
CA3	Campbell Creek at Dimond Blvd	MOA 89-90 study
CA4	Campbell Creek at Taku Park (exact location is unknown)	MOA 89-90 study
CA6	Campbell Creek at E. 76th Court	MOA 89-90 study
CAL1000	Campbell Lake at dam	MOA baseline monitoring
CAL2000	Campbell Lake at Arlene Drive	MOA baseline monitoring
CAL3000	Campbell Lake at Curlew Drive at lake inlet	MOA baseline monitoring
CAM1000	Campbell Creek at dam	MOA baseline monitoring
CAM2000	Campbell Creek downstream of Dimond Blvd	MOA baseline monitoring
CAM3000	Campbell Creek 30 ft upstream of Arctic Blvd	MOA baseline monitoring
CAM4000	Campbell Creek 20 ft above confluence with Little Campbell Creek	MOA baseline monitoring
CAM5000	Campbell Creek at Old Seward Hwy, on lawn of Artic Roadrunner restaurant	MOA baseline monitoring
CAM5010	North Fork Campbell Creek at confluence	MOA baseline monitoring
CAM6000	South Fork Campbell Creek 20 ft upstream of confluence	MOA baseline monitoring
CAM9000	Location unknown	MOA baseline monitoring
15273900	South Fork Campbell Creek at Canyon Mouth	USGS
15274000	South Fork Campbell Creek near Anchorage, AK	USGS
15274300	North Fork Campbell Creek near Anchorage, AK	USGS
15274395	Campbell Creek at New Seward Hwy near Anchorage, AK	USGS
15274557	Campbell Creek at C St near Anchorage, AK	USGS
15274600	Campbell Creek near Spenard, AK	USGS
15274710	Campbell Lake Outlet near Spenard, AK	USGS
610921149523100	Campbell Creek below Little Campbell Creek at Anchorage, AK	USGS
610922149522800	Campbell Creek above Little Campbell Creek near Anchorage, AK	USGS
611001149410200	North Fork Campbell Creek below end of Basher Dr near Anchorage, AK	USGS
611022149515800	Campbell Creek below Old Seward Hwy at Anchorage, AK	USGS
611042149501000	Campbell Creek at Lake Otis Pkwy near Anchorage, AK	USGS

Table 3-2 summarizes the available fecal coliform data for Campbell Creek and Campbell Lake. Stations are grouped and presented according to location, listed in downstream-to-upstream order. Figure 3-1 presents the monitoring station locations.

Table 3-2. Summary of available fecal coliform data for Campbell Creek and Campbell Lake

Site	Start Date	End Date	No.[1]	Min	Avg	Max	Note[2]
Below Campbell Lake							
CAM1000	6/15/88	11/18/92	12	3	58.0	510	
Campbell Lake							
CAL1000	5/25/88	9/28/92	11	2	92.0	300	
15274710	9/9/80	9/9/80	1	9	9.0	9	1/100%
CL-2	5/17/05	10/13/05	15	0	42.6	110	
CL-3	5/17/05	10/13/05	15	0	35.7	215	
CL-4	5/17/05	10/13/05	15	0	24.2	110	
CAL2000	5/25/88	5/23/91	8	2	37.3	126	
CL-1	5/17/05	10/13/05	15	13	105.7	700	
CAL3000	5/25/88	10/2/89	7	2	103.7	440	
Mainstem, Between Campbell Lake and Little Campbell Creek							
CC-4	5/17/05	10/13/05	15	13	79.1	300	
CAM2000	4/5/88	11/18/92	29	2	218.8	2750	
CA3	1/5/89	6/27/90	113	1	577.5	7345	
15274600	3/18/80	12/22/86	51	6	151.9	1300	17/33%
CAM3000	6/15/88	11/18/92	12	9	89.2	390	
CC-3	5/17/05	10/13/05	15	4	101.0	500	
15274557	3/15/00	7/21/00	3	11	48.7	76	1/33%
CA6	1/5/89	6/27/90	91	0	113.6	3480	
610921149523100	9/9/80	9/9/80	1	18	18.0	18	1/100%
Mainstem, Above Little Campbell Creek							
CAM4000	6/15/88	11/17/92	12	2	34.6	187	
CC-2	5/17/05	10/13/05	15	4	64.7	240	
610922149522800	9/9/80	12/22/86	7	3	30.6	93	4/57%
CAM5000	4/5/88	11/17/92	29	2	141.9	1080	
611022149515800	9/9/80	9/9/80	1	13	13.0	13	1/100%
15274395	3/16/00	6/2/00	2	5	7.0	9	2/100%
611042149501000	4/22/86	12/22/86	6	2	38.2	90	4/67%
CA12	1/5/89	6/29/90	96	0	66.3	660	
CC-1	5/17/05	10/13/05	15	7	69.6	240	
North Fork Campbell Creek							
CAM5010	6/16/88	11/18/92	11	2	171.5	1610	
CA13	1/5/89	12/21/89	60	0	10.7	102	
15274300	3/19/80	8/14/81	25	5	37.9	220	17/68%

611001149410200	8/28/98	8/28/98	1	1	1.0	1	
South Fork Campbell Creek							
CAM6000	6/16/88	11/18/92	11	2	30.4	108	
15274000	3/14/00	3/2/01	15	2	18.4	110	11/73%
CA11	1/5/89	6/29/90	90	0	57.8	920	
15273900	3/19/80	2/9/01	24	1	10.8	84	12/50%
Unknown Locations[3]							
CA4	1/5/89	6/27/90	91	1	256.4	9200	
CAM9000	3/7/91	11/18/92	7	2	3.6	6	

[1] Number of samples.
[2] Number and percentage of measurements marked as "estimated value."
[3] CA4 and CAM9000 are included in the available datasets but their locations are not provided on available maps and cannot be identified based on the station description.

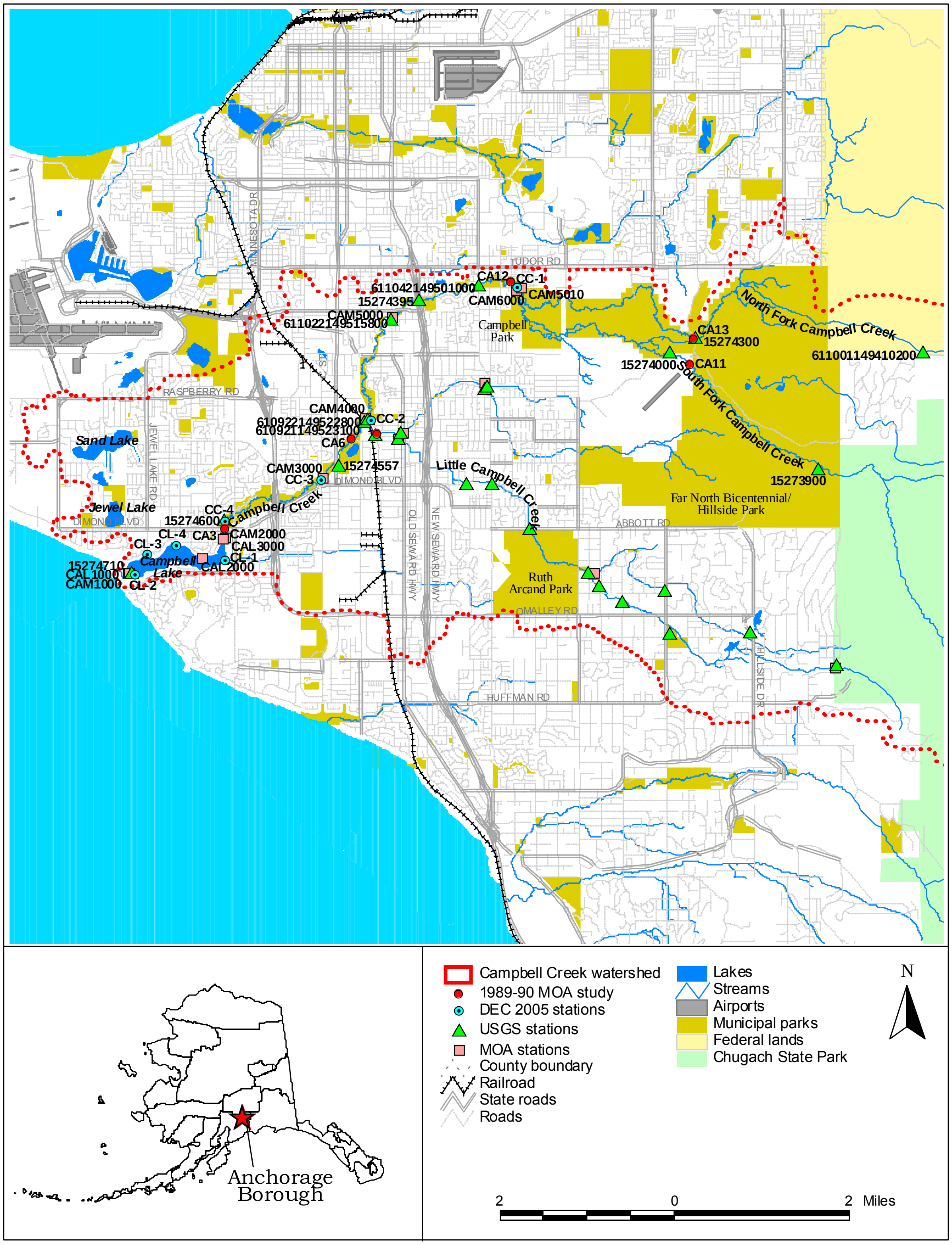


Figure 3-1. Location of water quality monitoring stations in Campbell Creek and Campbell Lake

3.2. Data Analysis

This section discusses data analyses conducted to evaluate any important trends or aspects of the fecal coliform levels throughout the Campbell Creek and Campbell Lake watershed. Bacteria concentrations are generally highly variable and can be heavily influenced by localized conditions and sources and inconsistent, occasional loading inputs. Without a long-term record of frequent measurements it is difficult to fully understand the patterns and trends of instream bacteria in a watershed. The following sections present available data for Campbell Creek and Campbell Lake to gain the best understanding of the conditions throughout the watershed given the available data.

Several sources of data were reviewed to characterize water quality in the watershed; however, some of the data was used for general and background information rather than specific analyses and calculation of the TMDL. Many of the datasets available for Campbell Creek and Campbell Lake contain limited number of samples (e.g., 1 sample, 10 samples over 6 years), do not capture seasonal differences, are older than other available data, or contain estimated (rather than measured) values. The following analyses were based primarily on the MOA data collected in Campbell Creek during the 1989-1990 water quality study of Anchorage Bowl streams, MOA baseline monitoring in the creek and lake from 1988-1992, and data collected by ADEC during the summer of 2005. Because most of the USGS data are older, contain only a few samples per station and include many estimated values they are not used in any of the analyses discussed in this section.

This section presents the following data analyses:

- Impairment analysis
- Relationship between flow and fecal coliform
- Temporal variations in instream conditions
- Spatial variations in instream conditions

3.2.1. Impairment Analysis

To generally evaluate the fecal coliform impairment in Campbell Creek and Campbell Lake, fecal coliform data at all MOA and ADEC stations were grouped by general location (e.g., South Fork) and also by overlapping time periods and are presented in Figures 3-2 through 3-8. These data represent instantaneous measurements and are plotted with the geometric mean criterion of 20 FC/100 mL and the not-to-exceed criterion of 40 FC/100 mL to provide a general picture of the frequency and magnitude of elevated bacteria measurements in these datasets. These graphs do not directly compare the data to the applicable water quality criteria by calculating geometric means or percent of samples exceeding the criteria; rather, they present the actual fecal coliform measurements with the water quality criteria to provide a general understanding of the magnitude, distribution and timing of fecal coliform levels in the creek and lake.

To further evaluate the timing of impairment and to compare data to the geometric mean criterion, fecal coliform data collected in Campbell Creek by MOA during 1989-1990 were added to a spreadsheet tool that identifies individual exceedances of the criterion and provides monthly summaries of bacteria levels and criterion exceedances. Data collected during the MOA 1989-1990 study were used because they include several samples within 30-day periods to better evaluate the geometric mean and also include several data points within each month to evaluate monthly and seasonal variations. These evaluations provide a general understanding of the pattern of fecal coliform impairment. While the magnitude of bacteria levels have likely decreased since the MOA study, the general trends and patterns are expected to be the same. (Comparison of older datasets to recent data is discussed in the Temporal Variation section.) Stations in Campbell Lake do not have sufficient data to conduct a meaningful analysis using the spreadsheet tool because they have data for only a few months out of the year, often with only one or two samples per month. Even combining data for all lake stations with data during the same time period results in months without data and still very limited data for individual months.

For comparison to the geometric mean criterion, the tool calculates geometric means for every possible 30-day period included in the dataset, based on all individual observations within that 30-day period. Figures 3-9 through 3-14 and Tables 3-3 through 3-8 summarize the calculated geometric means and their comparison to the geometric mean criterion of 20 FC/100 mL. Tables include the monthly average, median, minimum, maximum and 25th and 75th percentiles of all calculated geometric means. The table also presents a ratio and percentage of the number of 30-day geometric means included in each month that exceed the 20 FC/100 mL criterion ("Exceedances: Count" and "% of Exceedances").

The spreadsheet tool was also used to compare fecal coliform data for Campbell Creek to the not-to-exceed standard (i.e., not to exceed 40 FC/100 mL in more than 10 percent of the samples in a 30-day period). Although there are not enough data to confidently link the frequency of exceedances to fecal coliform loading to identify necessary TMDL allocations to meet the not-to-exceed standard, the existing data can be qualitatively evaluated to illustrate water quality conditions during the period of record for the dataset. Appendix B includes figures and tables summarizing the instantaneous concentrations for Campbell Creek stations as compared to the not-to-exceed criterion.

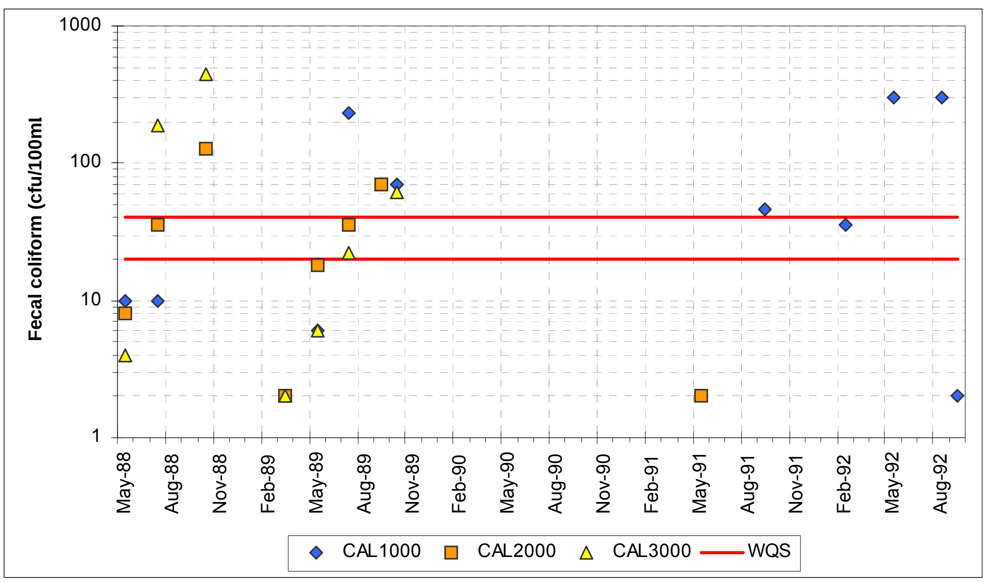


Figure 3-2. Observed fecal coliform concentrations at stations in Campbell Lake, 1988-1992 (CAL1000, CAL2000 and CAL3000)

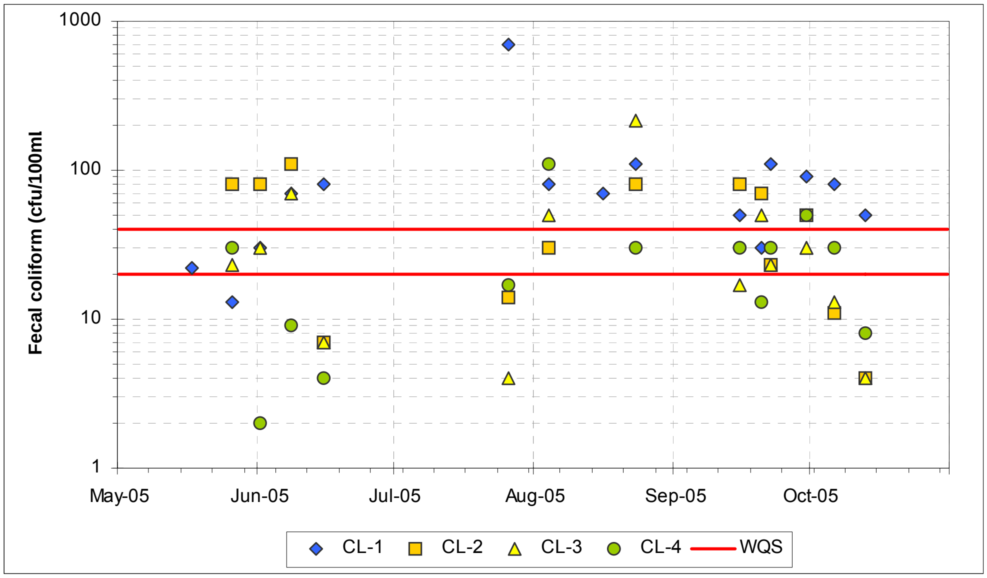


Figure 3-3. Observed fecal coliform concentrations at stations in Campbell Lake, 2005 (CL-1, CL-2, CL-3 and CL-4)

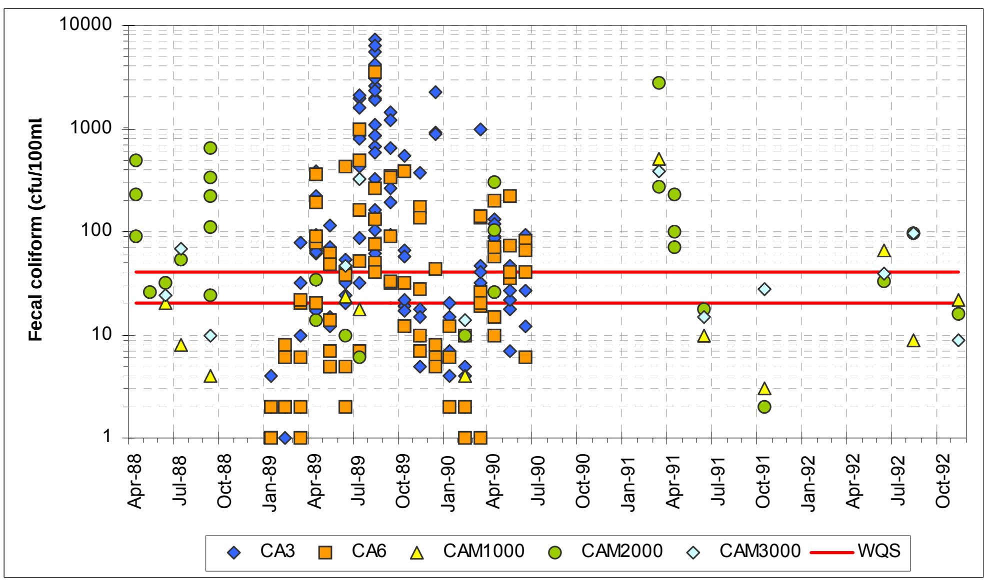


Figure 3-4. Observed fecal coliform concentrations at stations in Campbell Creek, below Little Campbell Creek, 1988-1992 (CA3, CA6, CAM1000, CAM2000 and CAM3000)

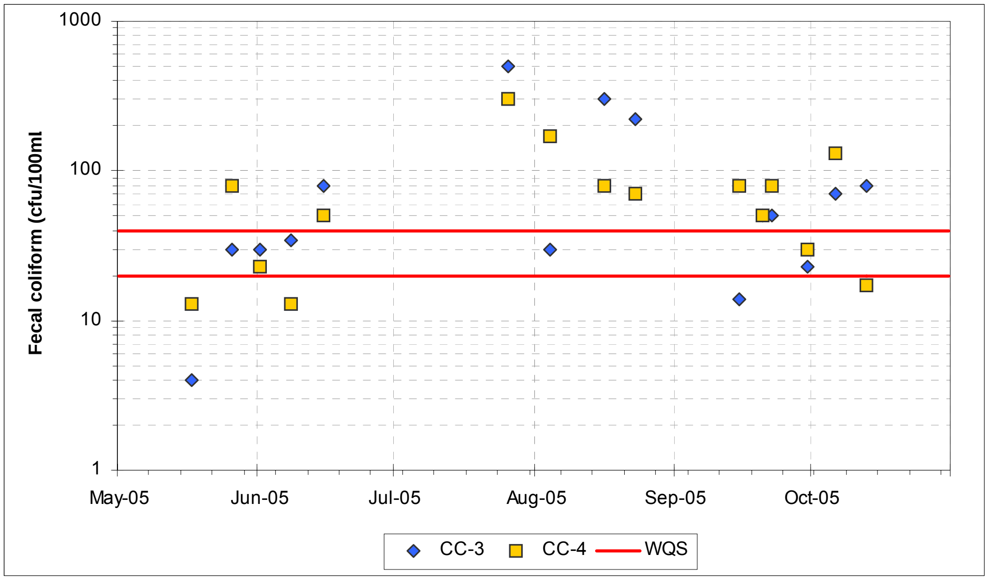


Figure 3-5. Observed fecal coliform concentrations at stations in Campbell Creek, below Little Campbell Creek, 2005 (CC-3 and CC-4)

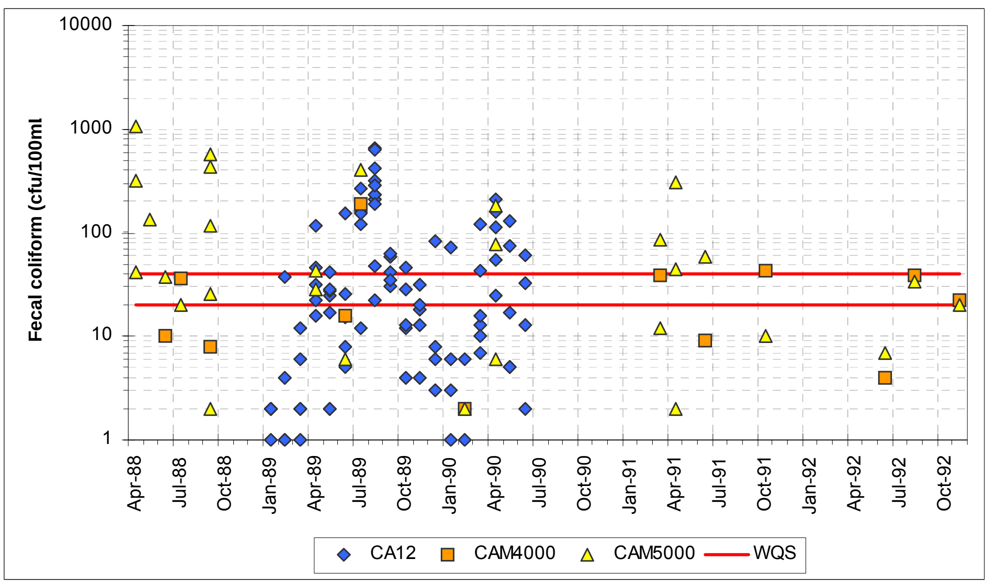


Figure 3-6. Observed fecal coliform concentrations at stations in Campbell Creek, above Little Campbell Creek, 1988-1992 (CA12, CAM4000 and CAM5000)

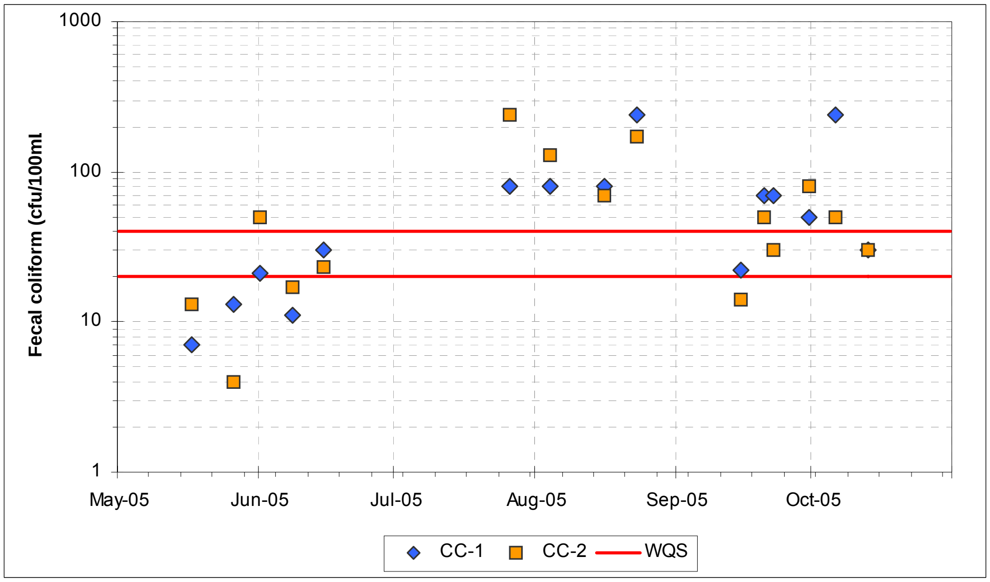


Figure 3-7. Observed fecal coliform concentrations at stations in Campbell Creek, above Little Campbell Creek, 2005 (CC-1 and CC-2)

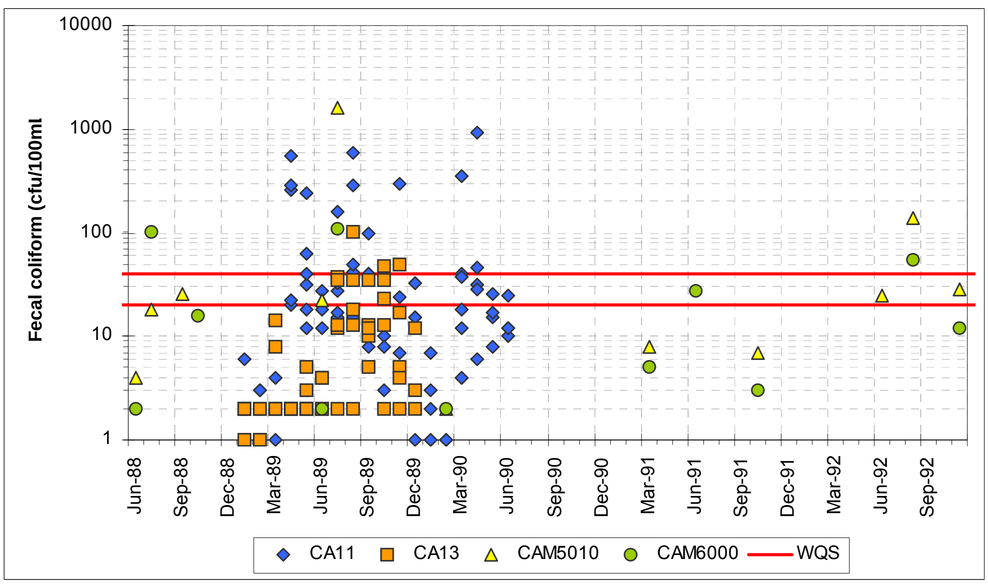


Figure 3-8. Observed fecal coliform concentrations at stations in North Fork and South Fork Campbell Creek, 1988-1992 (CA11, CA13, CAM5010 and CAM6000)

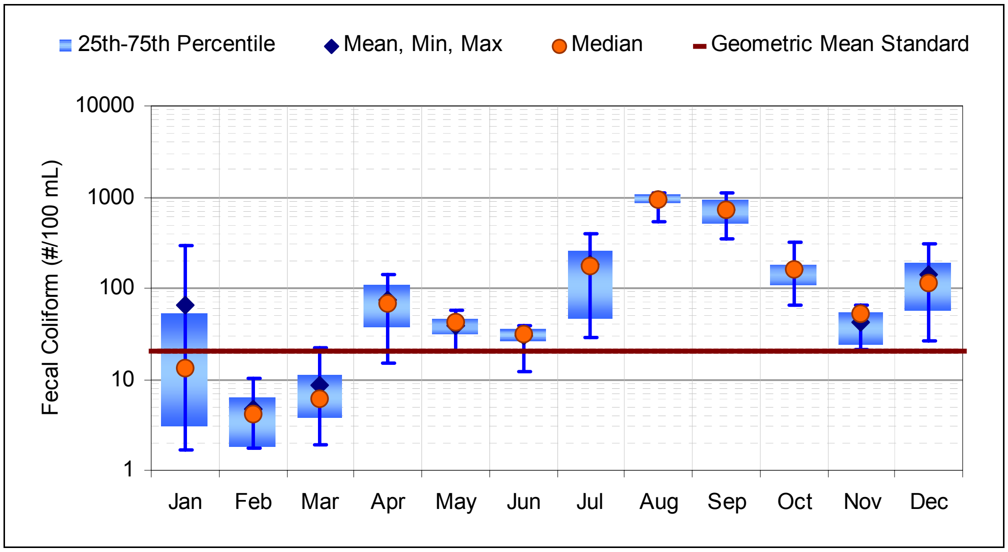


Figure 3-9. Summary of calculated geometric means of fecal coliform at CA3 (Campbell Creek at Dimond Boulevard)

Table 3-3. Summary statistics of geometric means calculated using fecal coliform data at CA3 (Campbell Creek at Dimond Boulevard)

Data: 1/5/89 to 6/27/90

Month	Average[1]	Median[1]	Min[1]	Max[1]	25th[1]	75th[1]	Exceedances: Count[2]	% of Exceedances[3]
Jan	64	13	2	293	3	52	2:6	33%
Feb	5	4	2	10	2	6	0:7	0%
Mar	9	6	2	22	4	11	1:7	14%
Apr	74	69	15	140	37	111	9:10	90%
May	39	43	20	57	32	46	18:18	100%
Jun	30	32	12	39	27	35	10:12	83%
Jul	181	177	28	396	45	261	5:5	100%
Aug	935	949	529	1092	853	1066	16:16	100%
Sep	730	726	356	1106	518	926	14:14	100%
Oct	163	159	66	325	110	185	7:7	100%
Nov	43	52	21	66	24	55	7:7	100%
Dec	140	112	26	310	58	194	4:4	100%

1 Average, median, minimum, maximum and 25th and 75th percentile values of all 30-day geometric means calculated for the month (i.e., using samples within the month).

2 Ratio of number of calculated 30-day geometric means that exceed the water quality criterion to the number of calculated 30-day geometric means in the month.

3 Percentage of all calculated 30-day geometric means for the month that exceed the water quality criterion.

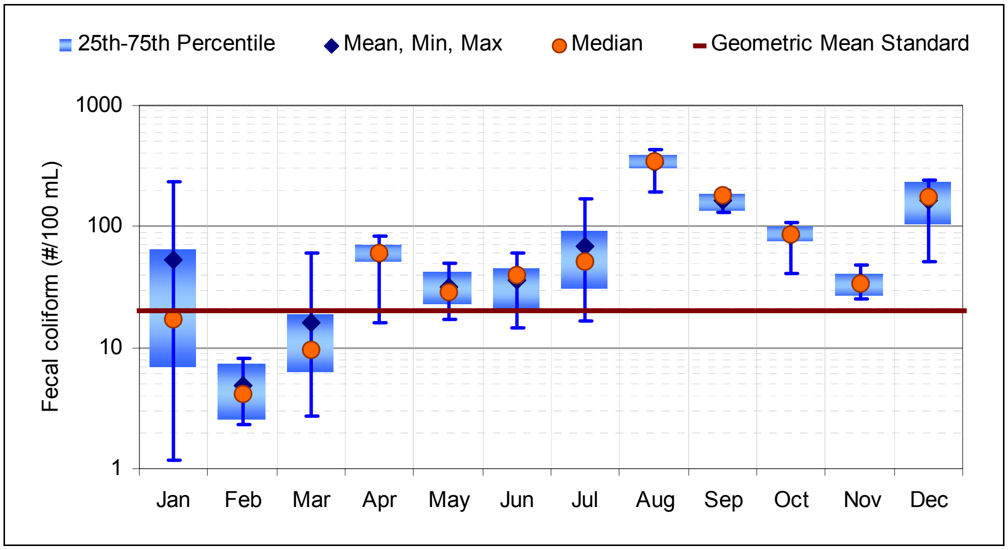


Figure 3-10. Summary of calculated geometric means of fecal coliform at CA4 (Campbell Creek at Taku Park; exact location is unknown)

Table 3-4. Summary statistics of geometric means calculated using fecal coliform data at CA4 (Campbell Creek at Taku Park; exact location is unknown)

Data: 1/5/89 to 6/27/90

Month	Average[1]	Median[1]	Min[1]	Max[1]	25th[1]	75th[1]	Exceedances: Count[2]	% of Exceedances[3]
Jan	54	17	1	235	7	65	4:8	50%
Feb	5	4	2	8	3	7	0:6	0%
Mar	16	10	3	61	6	19	3:10	30%
Apr	58	60	16	83	51	71	10:11	91%
May	32	28	17	49	23	43	11:12	92%
Jun	36	40	15	61	21	45	9:12	75%
Jul	69	52	17	167	30	93	5:6	83%
Aug	334	344	192	428	302	394	6:6	100%
Sep	166	179	130	198	136	184	5:5	100%
Oct	82	85	41	107	76	100	5:5	100%
Nov	35	34	25	48	27	41	6:6	100%
Dec	162	177	52	243	105	234	4:4	100%

1 Average, median, minimum, maximum and 25th and 75th percentile values of all 30-day geometric means calculated for the month (i.e., using samples within the month).
2 Ratio of number of calculated 30-day geometric means that exceed the water quality criterion to the number of calculated 30-day geometric means in the month.
3 Percentage of all calculated 30-day geometric means for the month that exceed the water quality criterion.

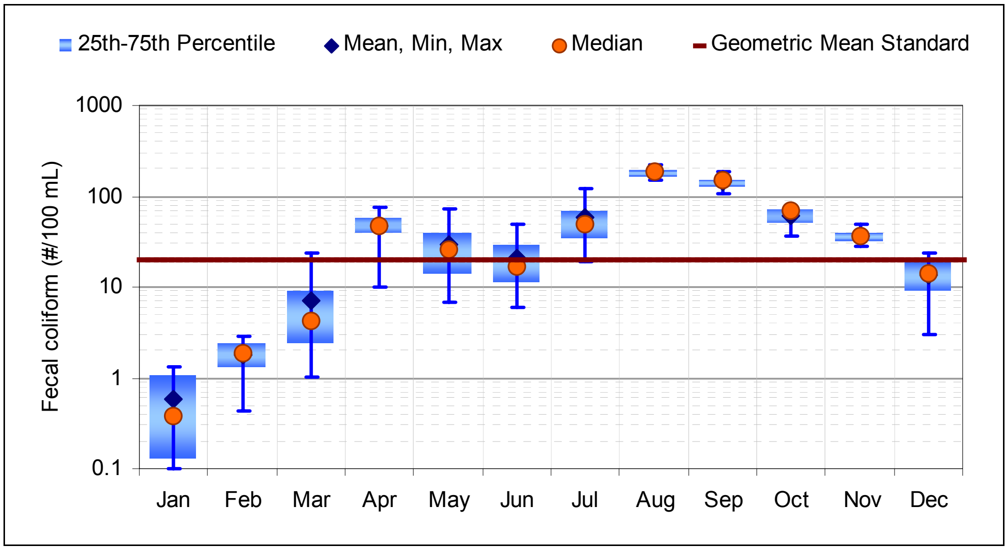


Figure 3-11. Summary of calculated geometric means of fecal coliform at CA6 (Campbell Creek at E. 76th Court)

Table 3-5. Summary statistics of geometric means calculated using fecal coliform data at CA6 (Campbell Creek at E. 76th Court)

Data: 1/5/89 to 6/27/90

Month	Average[1]	Median[1]	Min[1]	Max[1]	25th[1]	75th[1]	Exceedances: Count[2]	% of Exceedances[3]
Jan	1	0	0	1	0	1	0:8	0%
Feb	2	2	0	3	1	2	0:6	0%
Mar	7	4	1	24	2	9	1:10	10%
Apr	47	47	10	74	39	59	10:11	91%
May	29	26	7	72	14	40	7:12	58%
Jun	21	17	6	49	12	30	5:12	42%
Jul	58	49	19	123	35	70	5:6	83%
Aug	185	190	151	223	165	198	6:6	100%
Sep	142	147	106	183	125	150	5:5	100%
Oct	60	70	36	72	52	72	5:5	100%
Nov	37	36	29	49	32	39	6:6	100%
Dec	14	14	3	23	9	19	1:4	25%

1 Average, median, minimum, maximum and 25th and 75th percentile values of all 30-day geometric means calculated for the month (i.e., using samples within the month).
2 Ratio of number of calculated 30-day geometric means that exceed the water quality criterion to the number of calculated 30-day geometric means in the month.
3 Percentage of all calculated 30-day geometric means for the month that exceed the water quality criterion.

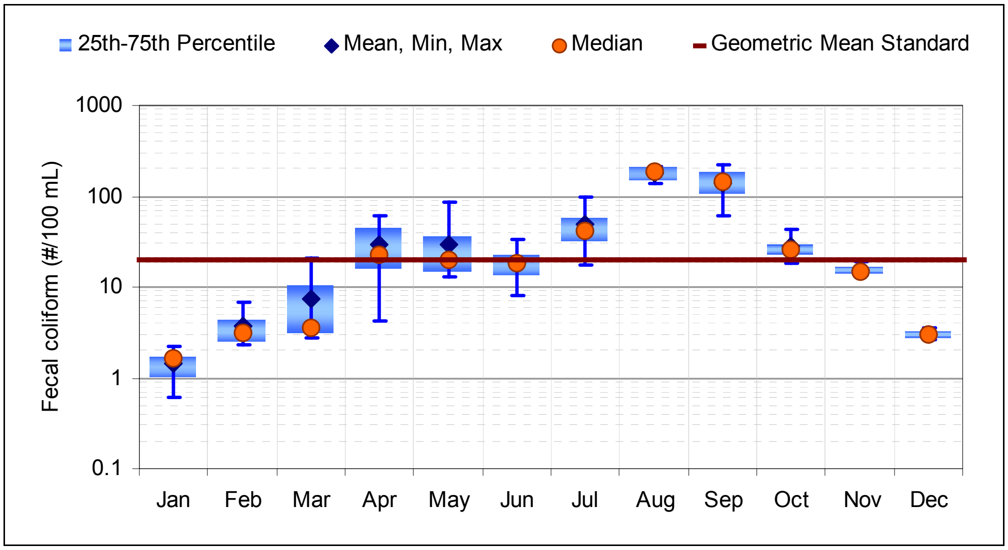


Figure 3-12. Summary of calculated geometric means of fecal coliform at CA12 (Campbell Creek at Wright Street)

Table 3-6. Summary statistics of geometric means calculated using fecal coliform data at CA12 (Campbell Creek at Wright Street)

Data: 1/5/89 to 6/29/90

Month	Average[1]	Median[1]	Min[1]	Max[1]	25th[1]	75th[1]	Exceedances: Count[2]	% of Exceedances[3]
Jan	1	2	1	2	1	2	0:8	0%
Feb	4	3	2	7	3	4	0:7	0%
Mar	7	4	3	21	3	11	1:9	11%
Apr	29	23	4	61	16	46	6:10	60%
May	29	20	13	88	15	36	7:14	50%
Jun	19	18	8	33	14	22	5:12	42%
Jul	49	42	18	99	32	57	5:6	83%
Aug	180	188	140	212	149	210	6:6	100%
Sep	141	143	61	226	107	190	9:9	100%
Oct	28	26	18	44	22	30	4:5	80%
Nov	16	15	14	19	14	17	0:6	0%
Dec	3	3	3	4	3	3	0:4	0%

[1] Average, median, minimum, maximum and 25th and 75th percentile values of all 30-day geometric means calculated for the month (i.e., using samples within the month).
[2] Ratio of number of calculated 30-day geometric means that exceed the water quality criterion to the number of calculated 30-day geometric means in the month.
[3] Percentage of all calculated 30-day geometric means for the month that exceed the water quality criterion.

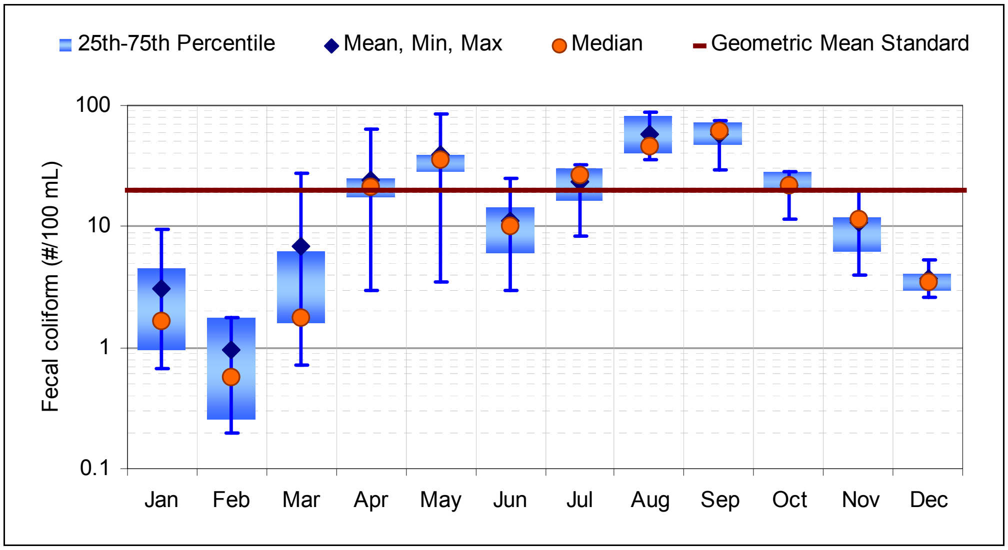


Figure 3-13. Summary of calculated geometric means of fecal coliform at CA11 (South Fork Campbell Creek at Campbell Airstrip Road)

Table 3-7. Summary statistics of geometric means calculated using fecal coliform data at CA11 (South Fork Campbell Creek at Campbell Airstrip Road)

Data: 1/5/89 to 6/29/90

Month	Average[1]	Median[1]	Min[1]	Max[1]	25th[1]	75th[1]	Exceedances: Count[2]	% of Exceedances[3]
Jan	3	2	1	9	1	5	0:8	0%
Feb	1	1	0	2	0	2	0:7	0%
Mar	7	2	1	28	2	6	1:9	11%
Apr	24	21	3	65	18	25	6:10	60%
May	39	36	4	86	28	40	12:14	86%
Jun	11	10	3	25	6	15	1:12	8%
Jul	23	27	8	33	16	30	4:6	67%
Aug	58	46	36	88	40	81	5:5	100%
Sep	57	62	29	75	47	72	4:4	100%
Oct	22	22	12	28	19	28	3:5	60%
Nov	11	12	4	20	6	12	0:6	0%
Dec	4	3	3	5	3	4	0:4	0%

[1] Average, median, minimum, maximum and 25th and 75th percentile values of all 30-day geometric means calculated for the month (i.e., using samples within the month).
[2] Ratio of number of calculated 30-day geometric means that exceed the water quality criterion to the number of calculated 30-day geometric means in the month.
[3] Percentage of all calculated 30-day geometric means for the month that exceed the water quality criterion.

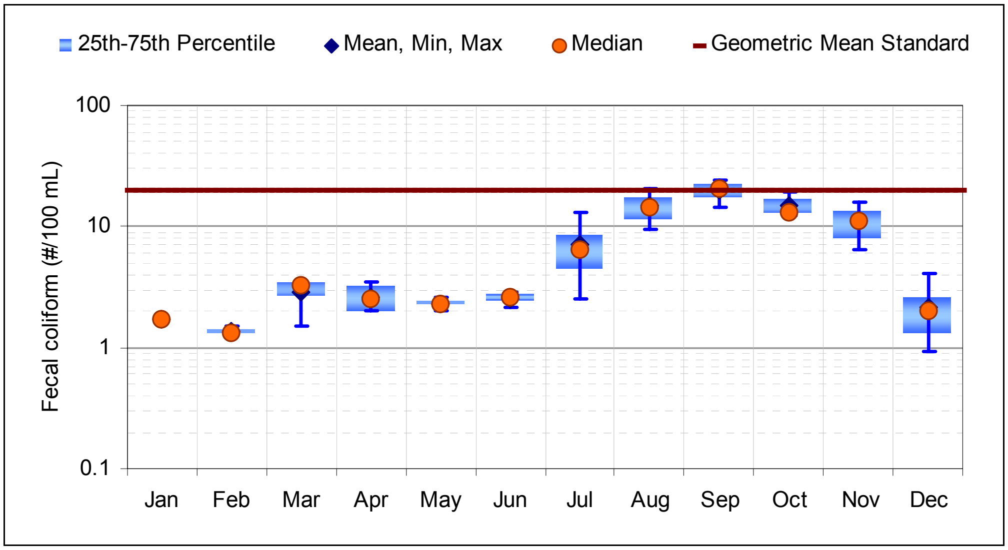


Figure 3-14. Summary of calculated geometric means of fecal coliform at CA13 (North Fork Campbell Creek at Campbell Airstrip Road)

Table 3-8. Summary statistics of geometric means calculated using fecal coliform data at CA13 (North Fork Campbell Creek at Campbell Airstrip Road)

Data: 1/5/89 to 12/21/90

Month	Average[1]	Median[1]	Min[1]	Max[1]	25th[1]	75th[1]	Exceedances: Count[2]	% of Exceedances[3]
Jan	2	2	2	2	2	2	0:2	0%
Feb	1	1	1	2	1	1	0:3	0%
Mar	3	3	2	3	3	3	0:4	0%
Apr	3	3	2	3	2	3	0:5	0%
May	2	2	2	3	2	2	0:8	0%
Jun	3	3	2	3	2	3	0:4	0%
Jul	7	6	3	13	5	9	0:6	0%
Aug	15	14	9	21	11	18	1:5	20%
Sep	20	20	15	24	18	23	2:4	50%
Oct	15	13	12	19	13	17	0:5	0%
Nov	11	11	6	16	8	14	0:6	0%
Dec	2	2	1	4	1	3	0:8	0%

[1] Average, median, minimum, maximum and 25th and 75th percentile values of all 30-day geometric means calculated for the month (i.e., using samples within the month).
[2] Ratio of number of calculated 30-day geometric means that exceed the water quality criterion to the number of calculated 30-day geometric means in the month.
[3] Percentage of all calculated 30-day geometric means for the month that exceed the water quality criterion.

3.2.2. Flow versus Fecal Coliform

Evaluation of the relationship between water quality and flow can indicate conditions under which loading and impairment occurs and can provide insight into the types of sources contributing pollutant loads. The only location in the Campbell Creek and Lake watershed that has overlapping bacteria and flow data is on Campbell Creek just above Campbell Lake—MOA station CA3 and USGS gauge 15274600. Flow and water quality measurements from matching days were isolated to evaluate the relationship between flow and fecal coliform, as shown in Figure 3-15. Although the relationship between the individual flow and fecal coliform values is not strong ($R^2 = 0.36$), there is a noticeable pattern of higher fecal coliform during higher flows. Figure 3-16 displays the instantaneous fecal coliform measurements plotted with the continuous flow data measured during the corresponding period of record, also showing that higher fecal coliform typically occurs during periods of higher flows.

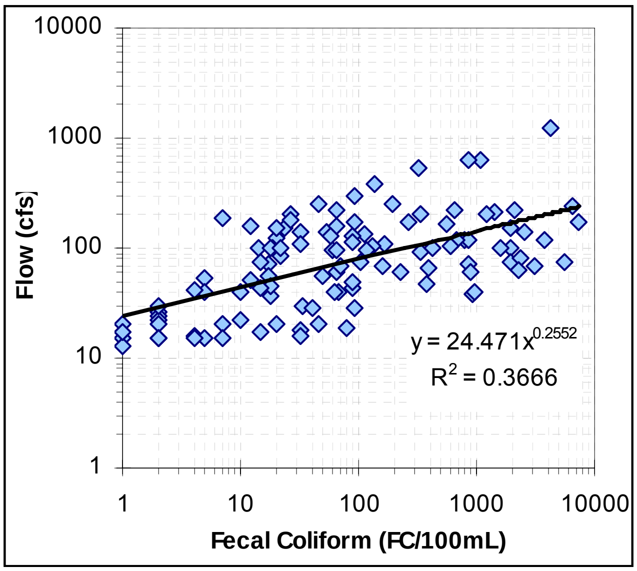


Figure 3-15. Flow versus fecal coliform at CA3 and USGS gauge 15274600

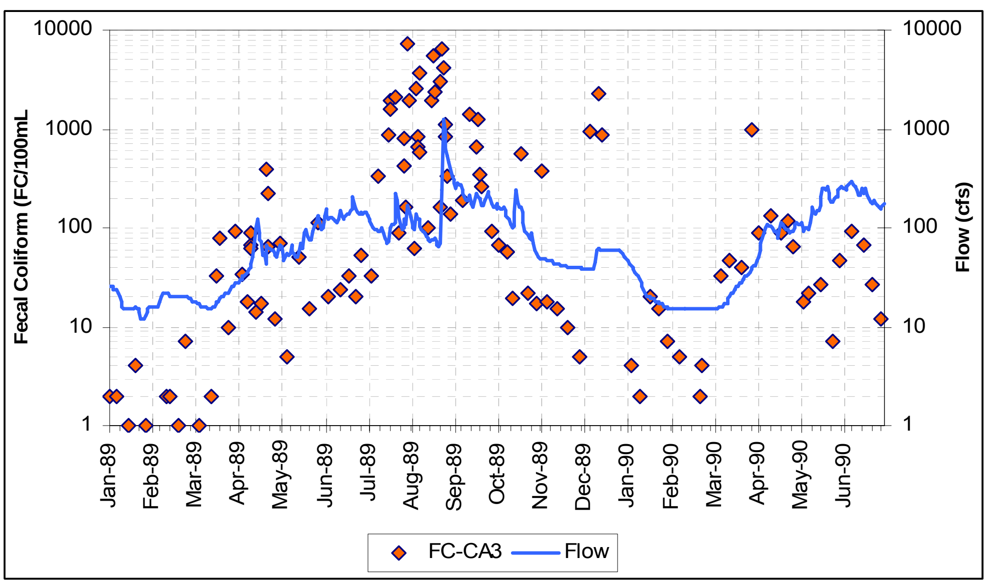


Figure 3-16. Continuous flow at USGS gauge 15274600 and instantaneous fecal coliform at CA3

3.2.3. Temporal Variation

Temporal patterns in fecal coliform concentrations are typically indicative of watershed source activity as well as weather patterns. Evaluating temporal variations in bacteria can help to identify potential sources in the watershed, seasonal variations and declining or improving water quality trends.

Figures 3-10 through 3-15 and Figures A-1 through A-6 in Appendix A present monthly distribution of fecal coliform observations at six stations throughout Campbell Creek. The highest levels of bacteria in Campbell Creek typically occur during the summer months (July-September) when Anchorage experiences its “rainy season” with increased rainfall and resulting stormwater runoff and streamflow. As winter approaches, there is less rainfall, decreasing surface runoff and resulting in lower instream bacteria levels during October and November. Winter experiences temperature almost consistently below freezing, resulting in little to no stormwater runoff and streams remaining at baseflow. Bacteria concentrations tend to be the lowest during winter months. Occasional observations of elevated bacteria during December and January are likely due to occasional periods of above-freezing temperatures and runoff-producing thaw or winter populations of wildlife (e.g., moose, ducks). Runoff from the spring break-up and thaw results in increasing bacteria levels in March and April. A dip in flows and bacteria may occur in some years and at some stations during late spring and early summer (May and June), after the spring melt and before the later summer rainy season. MOA (2003) provides additional information on the seasonal variations of bacteria levels in streams throughout Anchorage.

Figures 3-17 and 3-18 present individual fecal coliform measurements grouped by month for MOA baseline stations (CAL series) and ADEC 2005 stations (CL series). Data are limited for Campbell Lake and are not sufficient to confidently evaluate the seasonal patterns of bacteria in the lake. However, qualitative evaluation of the data suggests that bacteria data vary greatly both throughout the lake and across months. It is likely that the lake experiences the same seasonal patterns as watershed streams given local weather patterns, stream inputs to the lake and source activities. MOA (1993) indicates that violations of the bacteria standards in Anchorage lakes tend to occur during summer months when bacteria levels are highest; lowest levels of bacteria occur during the winter.

In addition to seasonal variations typical for most years, evaluation of temporal variation in bacteria data can also be used to look at long-term trends in bacteria. Data collected during the MOA 1989-1990 study were compared to data collected during the summer of 2005 to evaluate the change in average bacteria. Figures 3-19 and 3-20 present monthly geometric means of the “old” and “new” data collected just upstream of Campbell Lake (CA3 and CC-4) and at the confluence of North Fork and South Fork (CA12 and CC-1). Although data are not available consistently throughout the years and for all months, the data suggest that bacteria levels have likely decreased since 1990 as a result of best management practices (BMPs) implemented by the MOA. Although consistent data are not available for all months at corresponding locations in Campbell Lake, evaluation of historic and recent data suggest that the lake is also experiencing decreased bacteria levels.

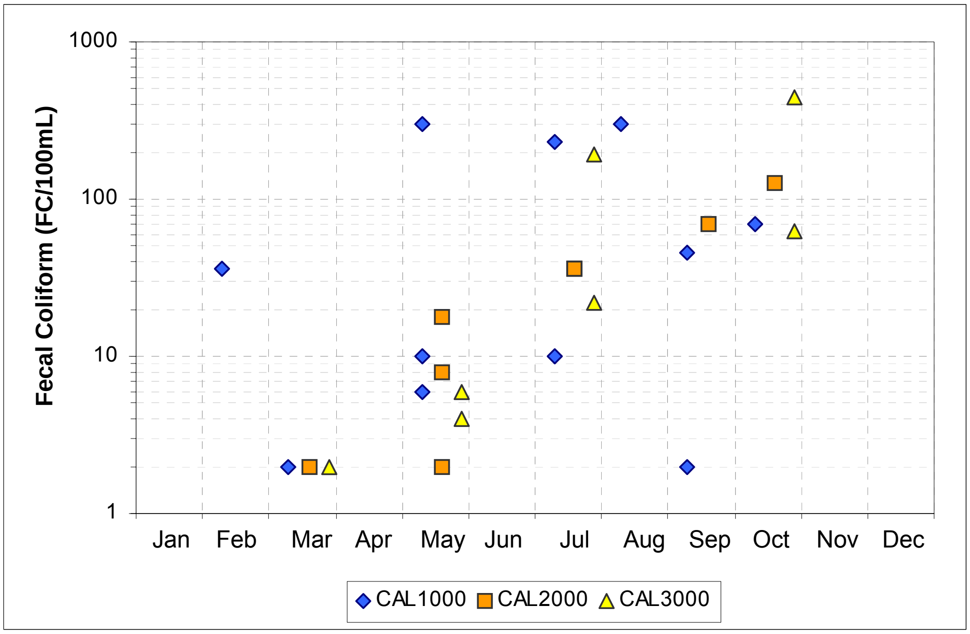


Figure 3-17. Monthly distribution of bacteria measurements in the MOA baseline data for Campbell Lake (1988-1992)

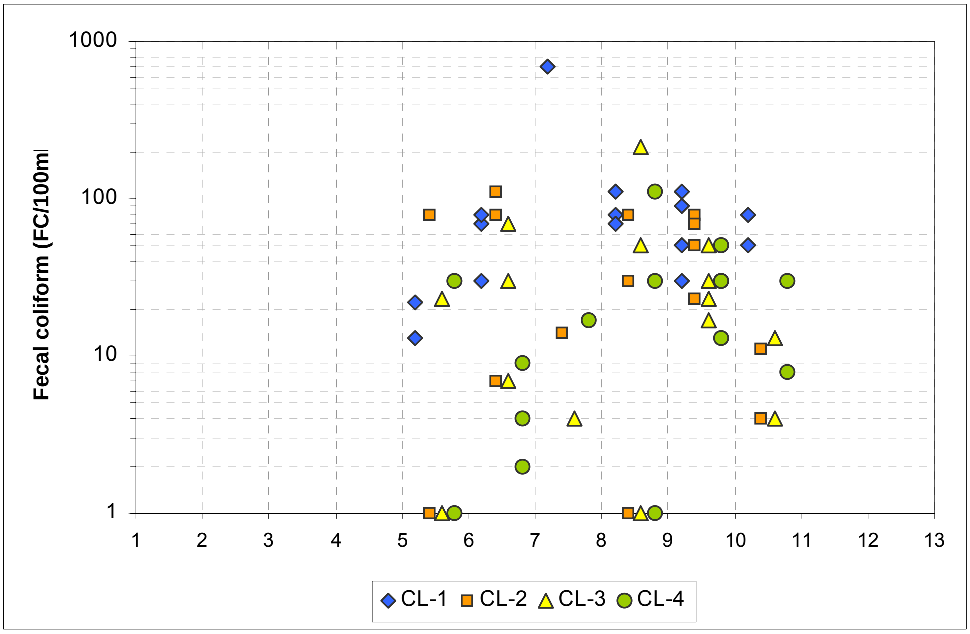
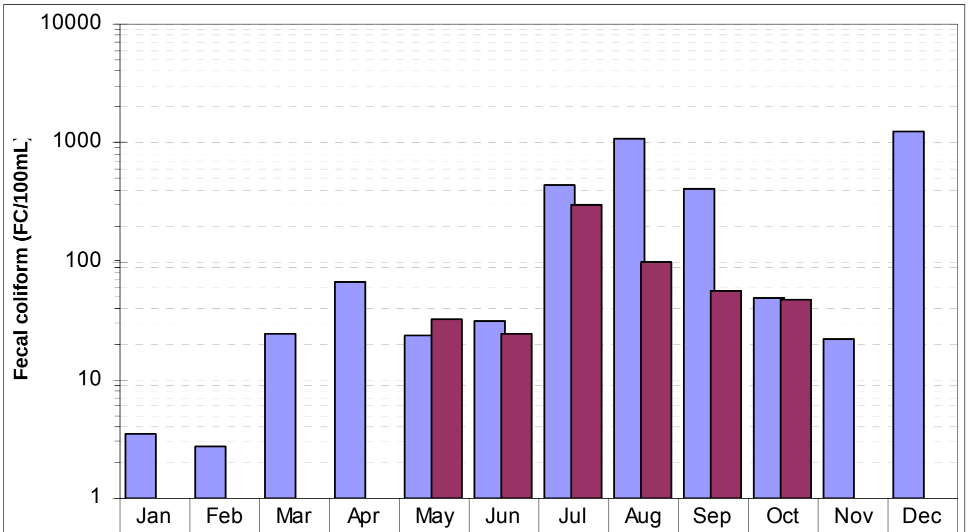
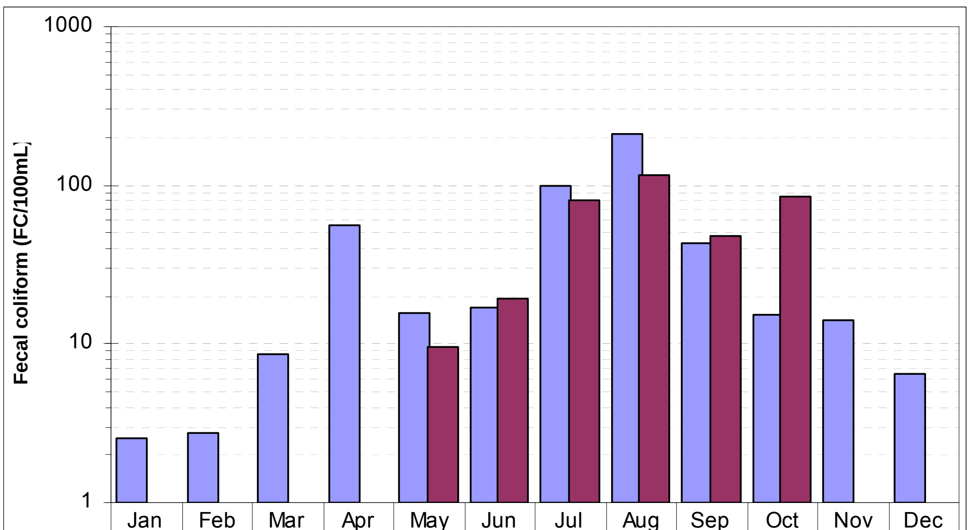


Figure 3-18. Monthly distribution of bacteria measurements in the ADEC 2005 data for Campbell Lake (2005)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
CA3	3.5	2.7	24.2	68.2	23.6	31.7	442.6	1070.6	408.4	49.6	21.9	1225.7
CC-4					32.2	24.6	300.0	98.4	55.7	47.0		

Figure 3-19. Monthly geometric means of fecal coliform samples at CA3 and CC-4



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
CA12	2.5	2.8	8.7	56.1	15.7	17.1	99.0	211.4	43.7	15.2	14.2	6.5
CC-1					9.5	19.1	80.0	115.4	48.2	84.9		

Figure 3-20. Monthly geometric means of fecal coliform samples at CA12 and CC-1

3.2.4. Spatial Variation

Evaluating spatial variation in bacteria concentrations throughout a watershed can help to identify areas of increased source activity and loading. Data collected during the MOA 1989-1990 study were used to look at variations in fecal coliform bacteria throughout the Campbell Creek watershed. These data were used because they have frequent measurements over 1.5 years. Because there are more data available in this dataset and the station-specific data cover the same time span, even the same days, these data will provide a better picture of variations throughout the watershed. In addition, more recent data were also evaluated to determine if the same patterns occur.

Figure 3-21 illustrates the monthly geometric mean fecal coliform concentrations for five stations monitored from January 1989 through June 1990. The stations are arranged with the most downstream station (CA3) in the back followed by stations located in the upstream direction. CA3 is located just above Campbell Lake; CA6 is located downstream of Little Campbell Creek; CA12 is located at the confluence of North Fork and South Fork; CA11 is located on South Fork; and CA13 is located on North Fork. Although data collected on individual days are highly variable, the general trend in fecal coliform geometric means is an increase in concentrations in the downstream direction. The South Fork station measures the lowest concentrations, followed by the North Fork station, for most months. Summer months indicate the most noticeable pattern of increasing fecal coliform from upstream to downstream. Variations in the winter and spring may be due to variations in climate. For example, further upstream stations at higher elevations may experience spring runoff later than downstream stations; CA3 has the spring peak during March while CA11 has a peak in April.

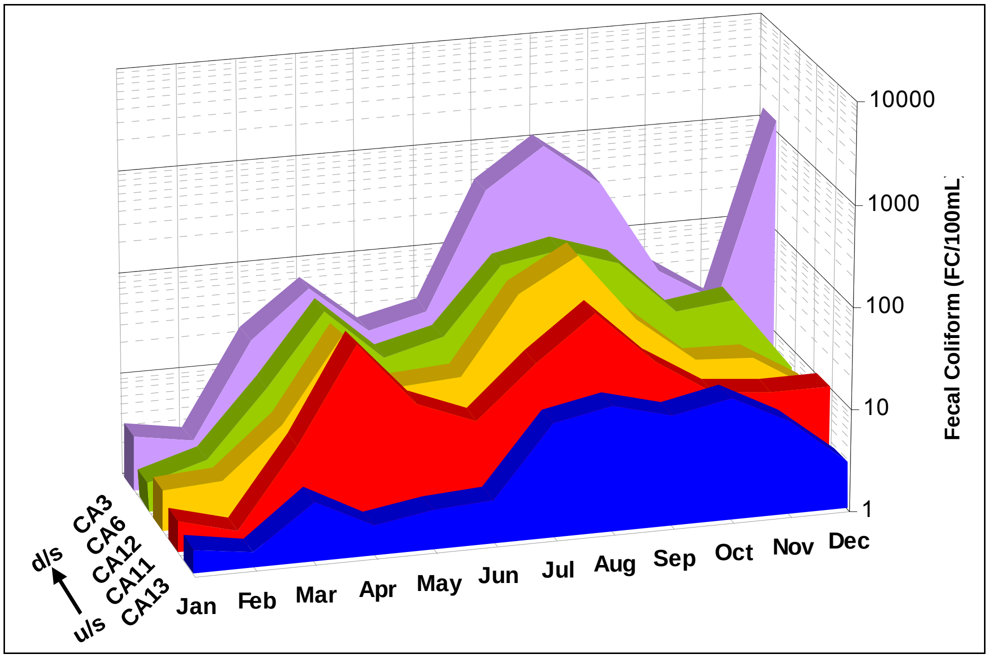


Figure 3-21. Monthly geometric means of fecal coliform at upstream and downstream stations included in the MOA 1989-1990 study

Data collected during summer 2005 are limited to May through October and exhibit highly variable concentrations within and across sampling events. Because of this they are inconclusive in identifying noticeable spatial patterns in bacteria in Campbell Creek and its tributaries. The data do, however, suggest that Little Campbell Creek influences the downstream concentrations in Campbell Creek; monthly geometric means of fecal coliform show an increasing trend between stations CC-2 and CC-3 for five of the six months monitored.

The limited data in Campbell Lake from both MOA baseline and summer 2005 monitoring do not show an identifiable pattern in fecal coliform variations throughout the lake. Summer 2005 data show the highest concentrations at CL-1 during many sampling events. CL-1 is located in an area of the lake that receives inflows from a storm drain carrying runoff from a large wetland complex on the east side of the lake. Concentrations throughout the lake are likely highly influenced by concentrations of Campbell Creek inflows, localized sources contributing directly to the lake and factors such as settling and dispersion within the lake.

4. Pollutant Sources

The identification of sources is important to the successful implementation of a TMDL and the control of pollutant loading to a stream. Characterizing watershed sources can provide information on the relative magnitude and influence of each source and its impact on instream water quality conditions. This section discusses the potential sources of fecal coliform to Campbell Creek and Campbell Lake, including point and nonpoint sources.

4.1. Point Sources

Stormwater runoff to Campbell Creek and Campbell Lake is expected to be a primary source of fecal coliform. Stormwater is traditionally considered a nonpoint source, carrying pollutants to receiving waters through surface runoff. However, when stormwater is permitted and carried through conveyances to discrete discharges to streams, it is considered a point source. Unlike most constant point sources (e.g., WWTP discharges), stormwater is precipitation-driven.

4.2. Nonpoint and Natural Sources

The Alaska 303(d) list identifies urban runoff as the primary source of fecal coliform to Campbell Creek and Campbell Lake. Snowmelt and rainfall transport bacteria that is deposited and accumulated on the surface of residential and urban areas. In 2003 MOA developed a document evaluating the sources and fate of fecal coliform in Anchorage streams (MOA, 2003). The document represents the MOA’s understanding based on recent and historical local data and relevant national research and was developed to support selection and implementation of effective and practical management practices.

MOA (2003) identifies animal sources as the primary source contributing to the persistent elevated fecal coliform concentrations in Anchorage streams. Expected animal sources include domestic pets (cats and dogs) as well as wild animals (terrestrial and aquatic birds, shrews, rabbits, rodents, foxes, coyotes, wolves, bears and moose). Although animals are likely the primary source of fecal coliform, the bacteria levels in streams is also very dependent on the transport of the animal waste to local streams. Some animals may impact streams by depositing fecal matter directly into streams (e.g., aquatic birds), but much of the fecal matter is likely deposited on watershed land surfaces and transported to local streams through stormwater runoff. Based on analysis of local data, MOA identified the important transport processes affecting the fecal coliform distribution in Anchorage streams, including the following:

- Domestic pets and wild animals represent a main source of fecal coliform in Anchorage watersheds. Wild animal impacts are likely concentrated in riparian areas that serve as nesting grounds and as seasonal migration pathways from the undeveloped mountainous uplands of a watershed’s headwaters to the tidal marshes and coastal wetlands near Cook Inlet. In addition, domestic animals may contribute bacteria loads in riparian areas where landscaped parks and trails are located next to or cross receiving waters. Domestic pets are expected to be a widespread source of fecal contamination in Anchorage stormwater, particularly from outdoor dog holding pens and, likely to a lesser degree, from areas of concentrated domestic animal activity (e.g., dog parks and equestrian trails) and large animal holding areas (e.g., stables, kennels).
- Although primary bacteria sources include domestic and wild animals, human contaminants might be contained in and transported in exposed garbage.
- Fecal coliform is directly responsive to runoff-producing snowmelt and precipitation events and increased seasonal streamflow. Accordingly, instream fecal coliform is elevated during summer,

associated with increasing rainfall and runoff, and decreases during winter baseflow conditions. This is shown in Campbell Creek data in Section 3.

- The degree of the response of instream fecal coliform concentrations to runoff-producing events is related to watershed characteristics (e.g., land use, storm drainage conveyances, stream modification). Fecal coliform loading is high in stormwater runoff originating from landscaped surfaces in densely urbanized areas drained by curb and gutter piped systems. Although Anchorage data indicate the coliform loading in this runoff originates from adjacent land uses and not from the street gutter materials, bacteria can adsorb to fine street sediments and be transported in stormwater to receiving streams.
- Fecal coliform loading in stormwater from Anchorage rural residential areas is smaller and occurs over a narrower seasonal time period than loading in runoff from more densely urbanized areas. This is due to the reduced runoff volume typical of Anchorage rural land development. Although the amount of source fecal material might be the same as at more densely urbanized areas, ditched storm water conveyances typical of rural areas significantly reduce rainfall runoff as a result of increased infiltration. This is illustrated by the lower fecal coliform levels at upstream stations (e.g., CA12, CA11, CA13) in Campbell Creek.
- Fecal coliform stored in fine-grained streambed sediments are an important element in the timing and magnitude of the observed elevated concentrations of fecal contaminants in Anchorage stream flow. Periodic settlement and scour of fine streambed sediments carrying fecal coliform is particularly aggravated by ill-advised stream channel modifications and washoff of fine grit used to improve winter street traction.

To further understand the potential sources affecting Anchorage streams, including Campbell Creek and ultimately Campbell Lake, MOA (2003) also identifies those sources that are least likely to contribute significantly to the fecal coliform impairments, including the following:

- Municipal community piped sanitary sewer systems are not a widespread source of fecal coliform in local streams. Anchorage has never operated combined sewer outfalls, and past intensive sewer system investigations have rarely discovered cross-connects to the separate storm drain piping.
- On-site wastewater disposal systems (i.e., septic systems) are not a widespread source of fecal coliform in streams. The MOA closely monitors design of on-site installations and past investigations suggest fecal coliform contamination from these systems is not readily mobilized to receiving waters. However, additional constraints in siting these facilities on sensitive landforms (e.g., glacial paleochannels and high-permeability ice contact deposits) may be warranted. Septic systems are a very unlikely source in the Campbell Creek and Campbell Lake watershed, which is approximately 80 percent sewered. There are no septic systems located within 100 feet of watershed streams and few within 500 feet.
- Street surfaces (and the materials applied to them) are not significant sources of fecal coliform in Anchorage. However, gutters and storm drain systems are important transport routes for fecal coliform originating from other sources, particularly from lawns and garbage collection.
- Fecal coliform growth within storm drainage systems is not a significant source of fecal coliform in Anchorage. However, deposition and scour from treatment devices installed along storm drain pipes and ditches can contribute to significant short-term variability in coliform loading in stormwater discharges.

5. Analytical Approach

Developing TMDLs requires a combination of technical analysis, practical understanding of important watershed processes, and interpretation of watershed loadings and receiving water responses to those loadings. In identifying the technical approach for development of the fecal coliform TMDL for Campbell Creek and Campbell Lake, the following core set of principles was identified and applied:

- ***The TMDLs must be based on scientific analysis and reasonable and acceptable assumptions.*** All major assumptions have been made based on available data and in consultation with appropriate agency staff.

- ***The TMDLs must use the best available data.*** All available data in the watershed were reviewed and were used in the analysis where possible or appropriate.

- ***Methods should be clear and as simple as possible to facilitate explanation to stakeholders.*** All methods and major assumptions used in the analysis are described. The TMDL document has been presented in a format accessible by a wide range of audiences, including the public and interested stakeholders.

The analytical approach used to estimate the loading capacity, existing loads, and allocations presented below relies on these principles and provides a TMDL calculation that uses the best available information to represent watershed and instream processes.

5.1. Analysis Background

The TMDL development approach for Campbell Creek and Campbell Lake uses a simple approach based on an empirical equation to calculate pollutant loading. This method was chosen to be consistent with TMDLs developed for six other Anchorage area fecal coliform TMDLs, including one for Little Campbell Creek. The Simple Method (Schueler, 1987) was used to calculate existing fecal coliform loading based on watershed characteristics and observed fecal coliform data. The method was also used to calculate loading capacity for the stream, based on instream concentrations representing water quality standards.

Because Campbell Creek experiences considerable seasonal variation in instream fecal coliform levels, the TMDL analysis calculates loads and reductions on a seasonal basis to isolate times of similar instream, weather, and flow conditions. The analysis is conducted for the three major seasons in the watershed—winter (October 1 – March 31), spring (April 1 – May 31), and summer (June 1 – September 30). During winter months, precipitation falls primarily as snow, resulting in little to no surface runoff. Snow and ice accumulated during winter melts with the increasing temperatures during spring, creating increased surface runoff and steadily increasing instream flows. Summer experiences warmer temperatures and summer storms that produce peaks of high instream flows.

The following sections discuss the TMDL analysis in more detail, including the data inputs and results.

5.2. Location of Load Calculations

To capture spatial variations in fecal coliform loading in the watershed, the load calculations were applied at multiple stations in the watershed and the watershed was divided into the following two subwatersheds (Figure 5-1):

- "Campbell Lake" subwatershed corresponds to the area draining directly to the lake, not through the Campbell Creek mainstem.
- "Campbell Creek" corresponds to the area draining to the mainstem of Campbell Creek, from the lake to the confluence of the North Fork and South Fork. This section of the creek also receives input from Little Campbell Creek. The area of the Little Campbell Creek subwatershed is not included in the TMDL calculations, since a TMDL has already been developed for Little Campbell Creek, including necessary load reductions specific to that subwatershed.

5.3. Evaluation of Existing Loads

The Simple Method (Schueler, 1987) was used to calculate fecal coliform loading to Campbell Creek and Campbell Lake. The Simple Method is a lumped parameter empirical model to estimate stormwater pollutant loadings under conditions of limited data availability. The approach calculates pollutant loading using drainage area, pollutant concentrations, a runoff coefficient and precipitation. In the Simple Method, the amount of rainfall runoff is assumed to be a function of the imperviousness of the contributing drainage area. More densely developed areas have more impervious surfaces, such as rooftops and pavement, causing more stormwater to runoff rather than be absorbed into the soil. The Simple Method equation is:

$$L = CF \cdot P \cdot Pj \cdot Rv \cdot C \cdot A$$

where:

L = Pollutant load (fecal coliform counts per time interval)
CF = Conversion factor (1,028,270 mL/in-acre)
P = Precipitation depth (inches) over desired time interval
Pj = Fraction of rainfall that produces runoff (assumed to be 0.9 [Schueler, 1987])
Rv = Runoff coefficient, which expresses the fraction of rainfall which is converted into runoff
C = Pollutant concentration (FC/100 mL)
A = Area of the watershed (acres)

The following sections discuss the identification of the parameters for calculation of fecal coliform loading to Campbell Creek and Campbell Lake using the Simple Method.

5.3.1. Precipitation (P)

Seasonal precipitation totals for use in the Simple Method were determined based on historical records at Ted Stevens International Airport, National Climatic Data Center (NCDC) Station 500280 (Figure 5-2). Precipitation totals measured at the NCDC station represent water-equivalent totals of rain, snow, and other forms of precipitation. Precipitation falling as snow during the winter months accumulates and does not result in surface runoff as rainfall would. Therefore, if precipitation totals from winter months are used in the Simple Method, the calculations result in unrealistic surface runoff and loading to the stream. To account for this, precipitation totals were modified to more realistically reflect runoff patterns in the area.

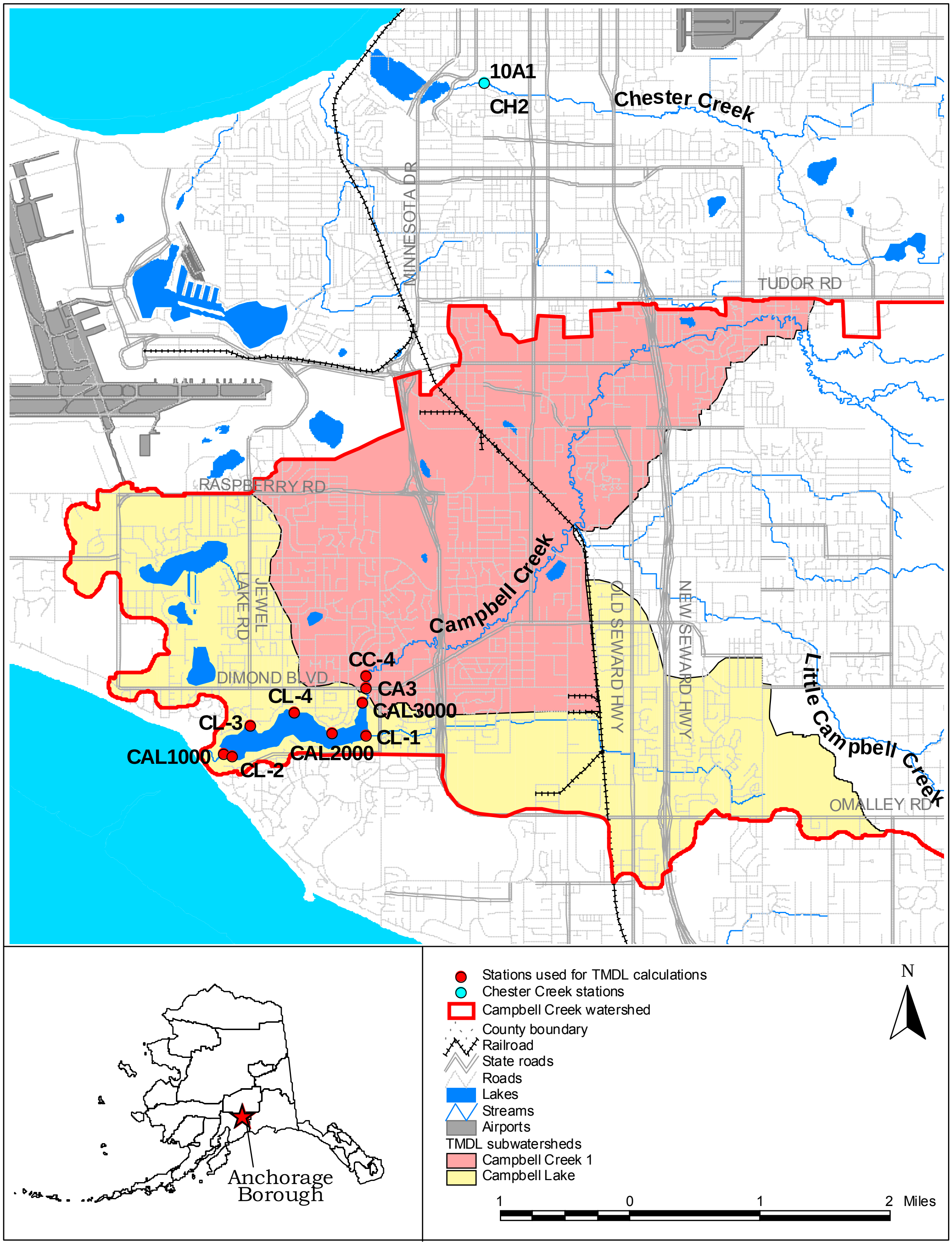


Figure 5-1. Locations for calculation of TMDL loads

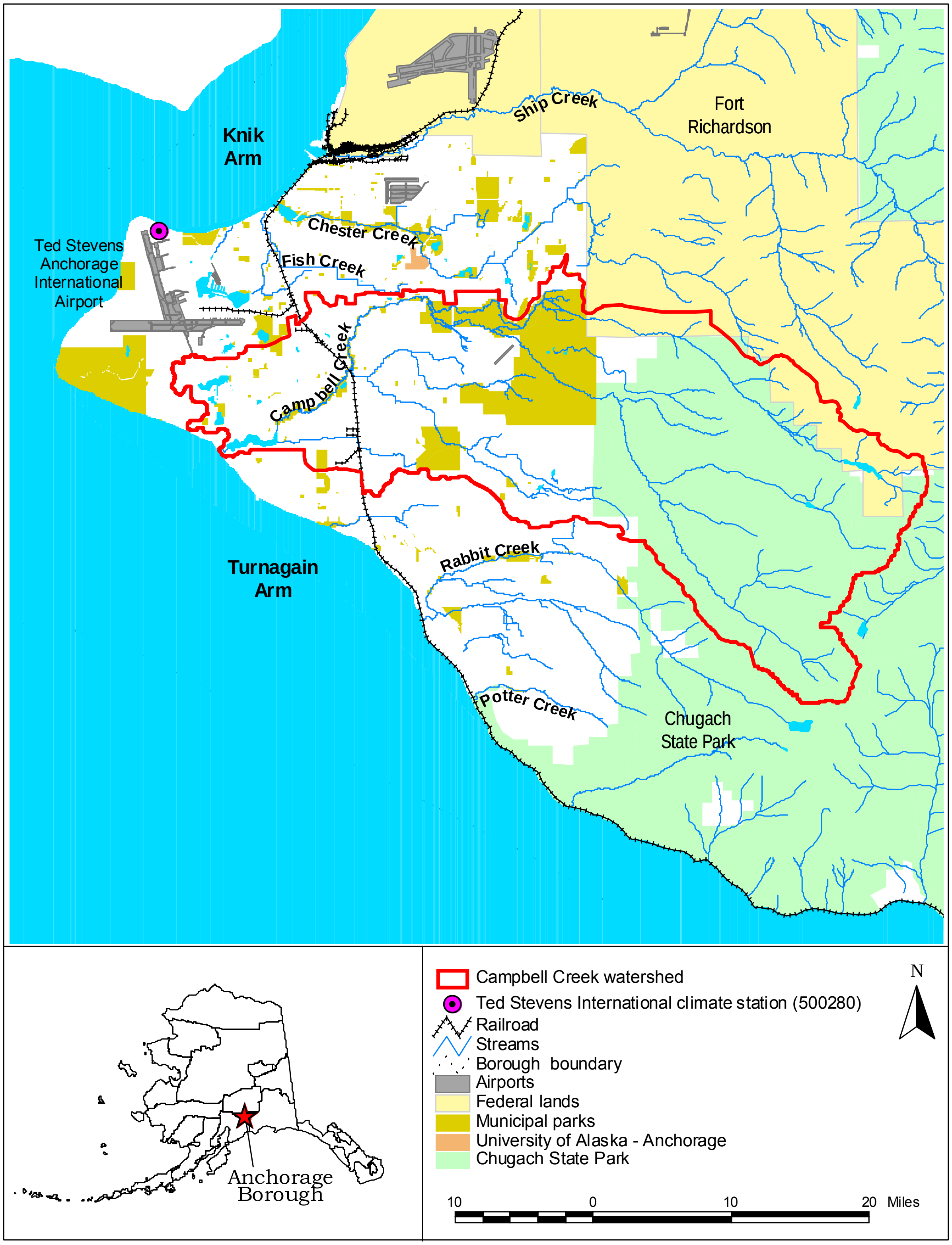


Figure 5-2. Location of Ted Stevens International Airport climate station (500280)

Precipitation during the winter months was divided into snow and rainfall to isolate the portion of measured precipitation that would result in runoff (i.e., rainfall) and that portion that would remain frozen on the watershed surface (i.e., snow). The snow portion was then added to the spring precipitation totals to reflect the time period that the accumulated snow would melt and contribute to surface runoff. To divide the precipitation into rainfall and snowfall portions, monthly snowfall totals from the airport were converted to water-equivalent precipitation and subtracted from the monthly precipitation totals also recorded at the airport.

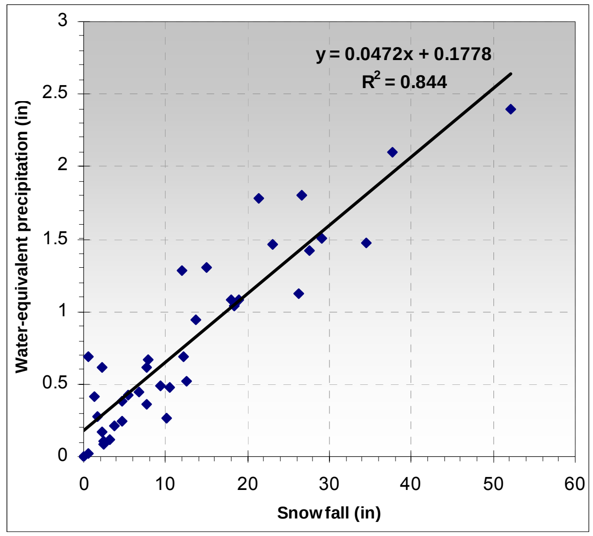


Figure 5-3. Relationship between snowfall and water-equivalent precipitation

To convert the snow to water-equivalent precipitation it was necessary to identify a conversion factor relating snow depth to water-equivalent depth. Monthly snowfall and total precipitation depths recorded at the Ted Stevens climate station for January, February and December of every year from 1980 through 2005[1] were evaluated to establish a relationship between the two measures. Monthly totals measured during months with average temperatures below 20° F were used to establish a correlation between snowfall and water-equivalent precipitation, as shown in Figure 5-3. The regression equation representing the relationship between the two parameters (also shown in Figure 5-3) was used to convert recorded winter snowfalls to water-equivalent precipitation.

Monthly average snowfall and rainfall precipitation values were then calculated based on weather data corresponding to the dates of data used in the TMDL analysis—January 1989 through May 1989, October 1989 through May 1990, and May 2005 through October 2005. The monthly averages were summed to calculate the corresponding seasonal totals. In addition, the average monthly snowfall totals for winter were summed and added to the spring totals to account for the effect of runoff during spring melt. Table 5-1 summarizes the seasonal precipitation totals and corrections for snowfall.

Table 5-1. Seasonal precipitation totals

Season	Total Measured Precip (in)	Snowfall Correction (in)	Corrected Precip (in)
Winter	6.84	-4.12	2.72
Spring	1.60	4.12	5.72
Summer	9.85	0.00	9.85

5.3.2. Runoff Coefficient (Rv)

Because site-specific runoff coefficients were not available for the Anchorage area, a relationship between watershed imperviousness and the storm runoff coefficient (Rv) developed by Schueler (1987) was used to determine the runoff coefficient (Rv) for the Campbell Creek and Campbell Lake watershed. Schueler (1987) used nationwide data collected for the Nationwide Urban Runoff Program study (USEPA, 1983) with additional data collected from Washington, DC, area watersheds to establish the relationship, represented by the following equation:

[1] Snowfall and precipitation depths from the winter months of 1999, 2000 and 2001 were not used because the records for those months were missing several days of data and did not accurately reflect monthly totals.

$$Rv = 0.05 + 0.9(I)$$

where:

I = Impervious fraction of the drainage area

A runoff coefficient for each subwatershed of the Campbell Creek and Campbell Lake watershed was calculated based on the amount of impervious area in the subwatershed, determined using land cover data provided by MOA. MOA created a complete land cover classification to provide the foundation for mapping inland areas according to their common surface hydrologic and gross pollutant generation potential. The "Storm Water Runoff" grid was derived through analysis of IKONOS satellite imagery and other geographic datasets (especially land use, streets, drainage, coastland and wetlands data). The dataset was built to provide information for stormwater management applications and includes five major classes: Impervious, Barren Pervious, Vegetated Pervious, Snow and Ice, and Water. These land cover classes are further subdivided to reflect changes in perviousness due to different land development applications. For example, impervious surfaces are classified as either street surface, directly connected impervious, and indirectly connected impervious and vegetation classes are classified as either landscaped or forested. The MOA land cover classifications are described in Table 5-2 with corresponding areas in the Campbell Creek and Campbell Lake subwatersheds.

Any category classified as impervious is assumed to be 100 percent impervious, while all other classes are 0 percent impervious. The total impervious area for each subwatershed was calculated based on the land cover dataset and divided by the total subwatershed area to determine the overall impervious fraction. This value (I) was used with the Schueler (1987) equation to determine the runoff coefficient (Rv) for the subwatersheds. Table 5-3 presents the total area, total impervious area and the resulting I and Rv values for each of the subwatersheds used in the TMDL analysis.

Table 5-2. MOA land cover classification system

		Area (acres)	
Land Cover	**Land Cover Description**	**Campbell Lake**	**Campbell Creek**
Impervious classes—Large paved areas, parking lots, rooftops.			
Directly Connected Impervious	Impervious features (not including roads) that are immediately adjacent to paved roads and spatially intersect a 60-foot buffer from the edge of pavement. For example, a large parking lot that extends beyond 60 feet from the edge of a paved road will be categorized as directly connected impervious as long as a portion of that feature enters a 60-foot buffer from an adjacent roadway.	1,052	1,613
Indirectly Connected Impervious	Areas that do not intersect the 60-foot buffer from the edge of pavement. These include impervious areas that are adjacent and/or within the vicinity of dirt or unpaved roads.	402	372
Streets	Paved roadways.	382	551
Pervious classes			
Landscaped	Parks, open fields, residential yards, large areas of non-forested and non-wetland vegetation.	566	607
Forested	Areas of tree canopy—natural forest.	1,009	768
Barren	Includes areas of zero or little vegetation, exposed soil, non-active land-cover.	0	0
Wetland	Moist areas containing vegetation, marshes, bogs.	427	803
Lakes/Water	Areas of exposed water bodies, reservoirs.	245	27
Total		4,082	4,741

Table 5-3. Information used to calculate runoff coefficients for Campbell Creek and Campbell Lake subwatersheds

Subwatershed	Total Area (acres)	Total Impervious Area (acres)	Overall Percent Imperviousness	Runoff Coefficient (Rv)
Campbell Lake	4,082	1,836	0.45	0.45
Campbell Creek	4,741	2,536	0.53	0.53

5.3.3. Pollutant Concentration (C)

The C value represents the average pollutant concentration, preferably the event mean concentration (EMC), which is a flow-weighted average concentration of samples taken over a runoff event. Because concentrations of pollutants can widely vary throughout a storm event and between events, a flow-weighted average can account for variability and result in a more representative "average" concentration. Unfortunately, consistent fecal coliform data are not available over individual storm events and flow data are not available with available fecal coliform data at all of the stations used in the TMDL analysis, prohibiting the calculation of EMCs. To minimize the impact of variability of concentrations in the stream during and between storm events (and to be consistent with water quality standards), the geometric mean of observed fecal coliform samples is used as the C value.

Data used to calculate the C value at each station is based on the MOA 1989-1990 study and ADEC data collected during summer 2005. Because the 1989-1990 dataset contains the most frequent and longest consistent record of data (weekly sampling over 18 months), this dataset was used as the basis for the TMDL calculations. However, recent 2005 data show decreases in fecal coliform levels from the 1989-1990 data, suggesting that the 1989-1990 data are likely not representative of current conditions. Therefore, the 2005 data are used to supplement and adjust the 1989-1990 dataset to create new datasets for use in calculating the TMDLs for Campbell Creek and Campbell Lake. ADEC data from 2005 include several samples during the summer months and are therefore used in the calculation of existing and TMDL loads for the summer season. However, the 2005 dataset does not include sufficient data for spring and winter to support load calculations. For spring and winter, the MOA data collected in 1989-1990 were adjusted based on seasonal reductions calculated comparing older data to 2005 data. The limited "new" data collected during 2005 and the "adjusted" 1989-1990 data for winter and spring were combined to create the dataset used in the TMDL load calculations—a dataset that is more robust, covers all months and seasons and is reflective of current conditions.

Process for Adjusting Historical Data

Reductions in fecal coliform levels have likely occurred since the 1989-1990 study because of management practices implemented by the MOA. To capture those declines and represent current levels in the TMDL analysis, the 1989-1990 data were adjusted to estimate current conditions during winter and spring using appropriate reduction ratios. Historical and recent data collected at co-located stations were compared to identify reductions. Data collected in 1989-1990 at station CA3 were compared to data collected in 2005 at station CC-4; these stations are both located at the downstream end of Campbell Creek, just above the lake (Figure 5-1).

Because there is a seasonal pattern in the observed fecal coliform concentrations as well as the recent reductions and because the TMDLs are calculated using seasonal loads, the data were used to evaluate seasonal reductions to apply to the historical data. Because 2005 data are only available from May through October, comparisons could only be made for the summer season (June through September). To evaluate if these reductions were comparable to nearby watersheds and to investigate developing fall and winter reductions based on data from other watersheds, data from Chester Creek were also evaluated. Chester Creek data were selected for comparison for the following reasons:

- The duration and timing (e.g., all months) of the fecal coliform data allow for comparison of older and recent data collected in Campbell Creek.
- The two watersheds are adjacent to each other and have close similarities in stream length, buffer widths, and land use.
- MOA has implemented similar types and numbers of stormwater BMPs in both watersheds.
- Both watersheds are sewered and have similar expected sources (e.g., domestic pets).

The University of Alaska–Anchorage (UAA) conducted a study for ADEC of fecal coliform concentrations throughout Chester Creek, located north of Campbell Creek watershed. For the study (UAA, 2005), fecal coliform was measured at several locations in the watershed from July 2004 through June 2005. To evaluate decreases in fecal coliform, data collected at CH2 during the MOA 1989-1990 study were compared to data collected at station 10A1 during the UAA study; these stations are located in the downstream portion of Chester Creek at Arctic Boulevard (Figure 5-1). Table 5-4 summarizes the identified decreases in the geometric means of older and newer data in Campbell Creek and Chester Creek.

Table 5-4. Observed reductions in seasonal fecal coliform geometric means in Campbell Creek and Chester Creek

Season	Campbell (at Dimond Boulevard)			Chester (at Arctic Boulevard)		
	CA3 (1/89-6/90)	CC-4 (5/05-10/05)	Reduction	CH2 (1/89-6/90)	10A1 (7/04-6/05)	Reduction
Winter	N/A[1]	N/A[1]	N/A[1]	130.5	19.7	85%
Spring	N/A[1]	N/A[1]	N/A[1]	65.2	29.1	55%
Summer	383.3	60.7	84%	591.3	19.2	97%

[1]Reductions were not evaluated for winter and spring because the 2005 dataset contains data for only 1 month of those seasons.

Chester data show higher reductions than those observed in the Campbell data, and applying the Chester reductions to Campbell Creek data would likely underestimate current bacteria levels in Campbell Creek. However, there are not enough data in Campbell for spring and winter to calculate approximate reductions for those seasons. Therefore, the Chester seasonal reductions were used as a base and adjusted based on the ratio between the summer observed reductions for Campbell and Chester. Table 5-5 summarizes the resulting reductions that are applied to 1989-1990 Campbell Creek data to estimate current fecal coliform levels during spring and winter.

Table 5-5. Seasonal reductions applied to 1989-1990 fecal coliform concentrations in Campbell Creek

Season	Campbell Reductions (CA3 → CC-4)	Chester Reductions (CH2 → 10A1)	Ratio of Campbell to Chester	Adjusted Campbell Reductions
Winter	Not enough data	85%	–	74%
Spring	Not enough data	55%	–	48%
Summer	84%	97%	0.87	84%

Local knowledge and recent bacteria data in the lake suggest that fecal coliform levels in Campbell Lake also have likely decreased over the last decade. Similar to the approach used for Campbell Creek, “old” and “new” data for the lake were compared to identify decreases. Because there were no data collected in the lake during the MOA 1989-1990 study, the MOA baseline data (1988-1992) were compared to the

ADEC summer 2005 data to estimate decreases in bacteria concentrations. In addition, because there are limited data available at each station in the lake and data vary throughout the lake, data for all the lake stations, both new and old, were combined to calculate seasonal geometric means for the lake. Table 5-6 summarizes the identified decreases in the geometric means of older and newer data in Campbell Lake. The reductions listed in Table 5-6 are applied to 1988-1992 Campbell Lake data to estimate current fecal coliform levels during spring and winter.

Table 5-6. Observed reductions in seasonal fecal coliform geometric means in Campbell Lake

Season	CAL1000, CAL2000 and CAL3000 (1/89-6/90)	CL-1, CL-2, CL-3 and CL-4 (5/05-10/05)	Reduction
Winter	22.7	14.7	35%
Spring	10.3	7.9	23%
Summer	43.5	28.6	34%

The seasonal C values were calculated as geometric means of all of the data collected within a given season for the respective station. Table 5-7 identifies the monitoring stations and corresponding data used for load calculations for each of the TMDL subwatersheds; stations and subwatersheds are also shown in Figure 5-1.

Table 5-7. Stations used for load calculations for Campbell Creek and Campbell Lake subwatersheds

Subwatershed	Stations for Adjusted Data	Stations for “New” Data
Campbell Lake	CAL1000, CAL2000, CAL3000	CL-1, CL-2, CL-3, CL-4
Campbell Creek	CA3	CC-4

Final TMDL Dataset

For the Campbell Creek subwatershed, 1989-1990 MOA data for winter and spring at CA3 were adjusted based on the decreases in Table 5-5 and the adjusted data were added to the ADEC summer 2005 dataset for station CC-4. The complete dataset for the Campbell Creek subwatersheds is presented in Figure 5-4. This dataset was then used to calculate the seasonal geometric means for the Campbell Creek.

For Campbell Lake, the MOA baseline data (1988-1992) were used with the ADEC summer 2005 data to calculate geometric means for the lake. MOA baseline data for all the lake stations (CAL1000, CAL2000, CAL3000) were combined for winter and spring and adjusted based on the reductions in Table 5-6 and then added to the dataset from summer 2005 (CL-1 through CL-4). This new dataset is presented in Figure 5-5 and was used to calculate seasonal geometric means for the lake. As discussed previously and as shown in Figure 5-5, there are limited data for spring and winter months in Campbell Lake. Because these are the only data available for the lake, available data from the MOA baseline data for all lake stations were combined to capture the most sample dates and months.

The resulting seasonal C values for Campbell Creek and Campbell Lake are included in Table 5-8.

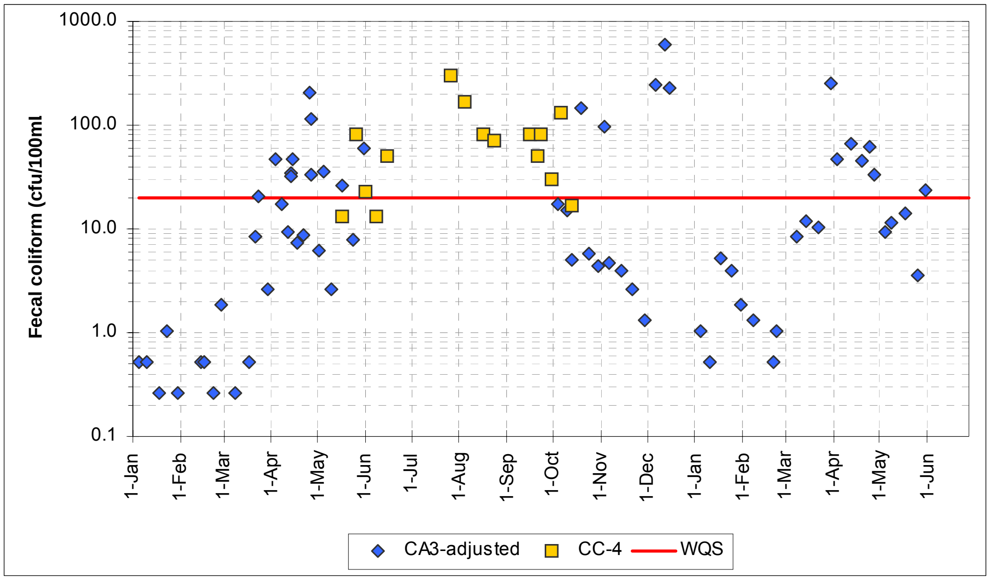


Figure 5-4. TMDL dataset for Campbell Creek subwatershed

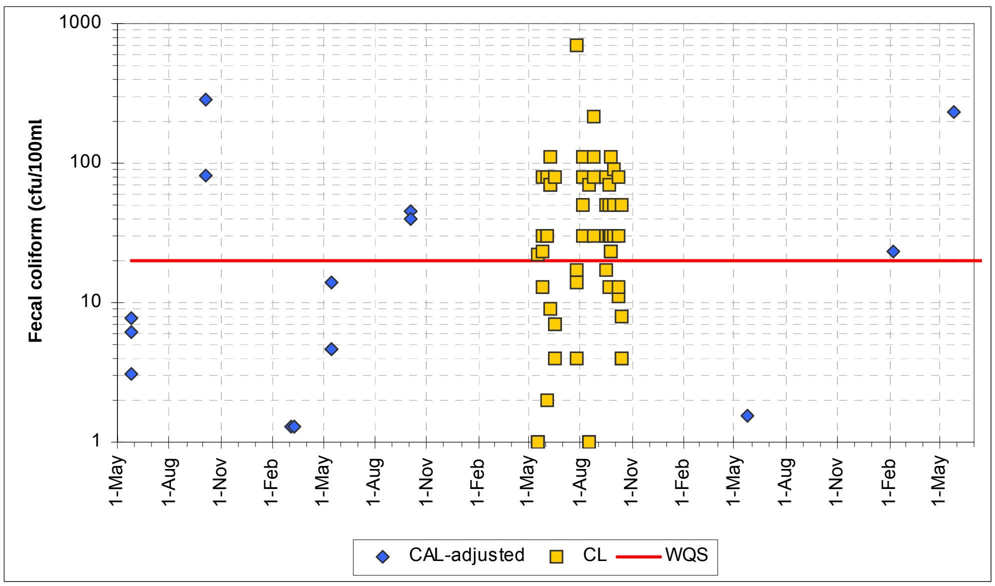


Figure 5-5. TMDL dataset for Campbell Lake subwatershed

5.3.4. Calculation of Existing Load

Table 5-8 summarizes the information used to calculate the seasonal fecal coliform loads for each subwatershed using the Simple Method and includes the resulting loads.

Table 5-8. Simple Method values and resulting fecal coliform loads for Campbell Creek and Campbell Lake subwatersheds

Season	P (in)	Pj	Rv	C (FC/100 mL)	A (acres)	Existing Loading (FC/season)
Campbell Lake						
Winter	2.72	0.90	0.45	14.71	4,082.03	6.88×10^{10}
Spring	5.72	0.90	0.45	7.94	4,082.03	7.80×10^{10}
Summer	9.85	0.90	0.45	28.63	4,082.03	4.84×10^{11}
Campbell Creek						
Winter	2.72	0.90	0.53	4.42	4,740.86	2.81×10^{10}
Spring	5.72	0.90	0.53	23.45	4,740.86	3.13×10^{11}
Summer	9.85	0.90	0.53	60.67	4,740.86	1.39×10^{12}

5.4. Evaluation of Loading Capacity

The Simple Method was also used to calculate seasonal loading capacities. The parameters representing watershed characteristics (e.g., precipitation, runoff coefficients and area) remain the same for the loading capacity calculation; however, the pollutant concentration (C) is changed to reflect TMDL conditions—conditions meeting water quality standards. Therefore, the C value for calculation of loading capacities is equal to the geometric mean water quality criterion of 20 FC/100 mL. The calculated loading capacities are summarized in Table 5-9, along with the existing loadings and resulting load reductions.

Table 5-9. Seasonal fecal coliform loading capacities for Campbell Creek and Campbell Lake subwatersheds

	Campbell Lake			Campbell Creek		
Season	Existing Loading (FC/season)	Loading Capacity (FC/season)	Percent Reduction	Existing Loading (FC/season)	Loading Capacity (FC/season)	Percent Reduction
Winter	6.88×10^{10}	9.36×10^{10}	N/A	2.81×10^{10}	1.27×10^{11}	N/A
Spring	7.80×10^{10}	1.96×10^{11}	N/A	3.13×10^{11}	2.67×10^{11}	15%
Summer	4.84×10^{11}	3.38×10^{11}	30%	1.39×10^{12}	4.59×10^{11}	67%

6. TMDL

A TMDL represents the total amount of a pollutant that can be assimilated by a receiving water while still achieving water quality standards. A TMDL is composed of the sum of individual waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background loads. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this definition is denoted by the equation

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

Table 6-1 summarizes the fecal coliform TMDLs for Campbell Creek and Campbell Lake.

This TMDL will be implemented using adaptive management and will be revised, as necessary, based on future information on sources and instream conditions. Adaptive management is an approach where monitoring and source controls are used to provide more information for future review and revision of a TMDL. This process recognizes that water quality monitoring data and knowledge of watershed dynamics may be insufficient at the time a TMDL is developed, but that the TMDL uses the best information available during its development. An adaptive management strategy seeks to collect additional monitoring data to understand better how systems react to BMPs and reduced pollutant loading into a system. Information from an adaptive management process can then be used to refine a future TMDL, so that the future TMDL and allocations best represent how to improve water quality in a specific watershed.

Table 6-1. Summary of the Campbell Creek and Campbell Lake fecal coliform TMDL

Season	Existing Loading (FC/season)	Loading Capacity (FC/season)	MOS[1] (FC/season)	Wasteload Allocation (FC/season)	Percent Reduction (for Wasteload Allocation)
Campbell Lake					
Winter	6.88×10^{10}	9.36×10^{10}	9.36×10^{9}	8.42×10^{10}	–
Spring	7.80×10^{10}	1.96×10^{11}	1.96×10^{10}	1.77×10^{11}	–
Summer	4.84×10^{11}	3.38×10^{11}	3.38×10^{10}	3.05×10^{11}	37%
Campbell Creek					
Winter	2.81×10^{10}	1.27×10^{11}	1.27×10^{10}	1.14×10^{11}	–
Spring	3.13×10^{11}	2.67×10^{11}	2.67×10^{10}	2.40×10^{11}	23%
Summer	1.39×10^{12}	4.59×10^{11}	4.59×10^{10}	4.13×10^{11}	70%

[1]MOS was included explicitly as 10 percent of the loading capacity.

6.1. Margin of Safety

The MOS accounts for any uncertainty concerning the relationship between pollutant loading and receiving water quality. The MOS can be implicit (e.g., incorporated into the TMDL analysis through conservative assumptions) or explicit (e.g., expressed in the TMDL as a portion of the loading) or a combination of both. For the Campbell Creek and Campbell Lake TMDL, the MOS was included explicitly as 10 percent of the loading capacity.

6.2. Load Allocation

Nonpoint sources are typically represented by loads carried to receiving waters through surface runoff resulting from precipitation events. However, because stormwater discharges in the MOA are regulated by a NPDES stormwater permit for municipal separate storm sewer systems (MS4), watershed loads delivered to Campbell Creek and Campbell Lake are addressed through the wasteload allocation component of this TMDL. Therefore, the load allocations for the Campbell Creek and Campbell Lake fecal coliform TMDLs are zero. If data or information from future monitoring efforts can be used to identify and quantify stormwater or natural loads that are not delivered through the stormwater conveyances, the TMDL and its allocations will be revised accordingly.

6.3. Wasteload Allocation

The only permitted source of fecal coliform in the watershed of the impaired segments of Campbell Creek and Campbell Lake is stormwater runoff. The MOA is subject to an MS4 permit that regulates stormwater discharges. EPA Region 10 issued the NPDES permit in 1998 and new permit conditions are currently under draft. EPA policy and regulation indicate that stormwater runoff regulated by the NPDES program through an MS4 permit must be addressed through wasteload allocations in a TMDL (USEPA, 2002). Therefore, the Campbell Creek and Campbell Lake TMDLs establish wasteload allocations for watershed loads of fecal coliform.

The fecal coliform wasteload allocations for Campbell Creek and Campbell Lake are provided as seasonal allocations for the subwatersheds. Because the load allocation is zero, the wasteload allocations are equal to the loading capacity minus the MOS. Loading capacity, MOS, wasteload allocations and necessary load reductions are summarized in Table 6-1 and Figures 6-1 and 6-2. Allocations are not established for future loads because ADEC does not anticipate any future permits for the discharge of fecal coliform to Campbell Creek or Campbell Lake. In addition, if data or information from future monitoring efforts can be used to identify and quantify stormwater or natural loads that are not delivered through the stormwater conveyances, the TMDL and its allocations will be revised accordingly.

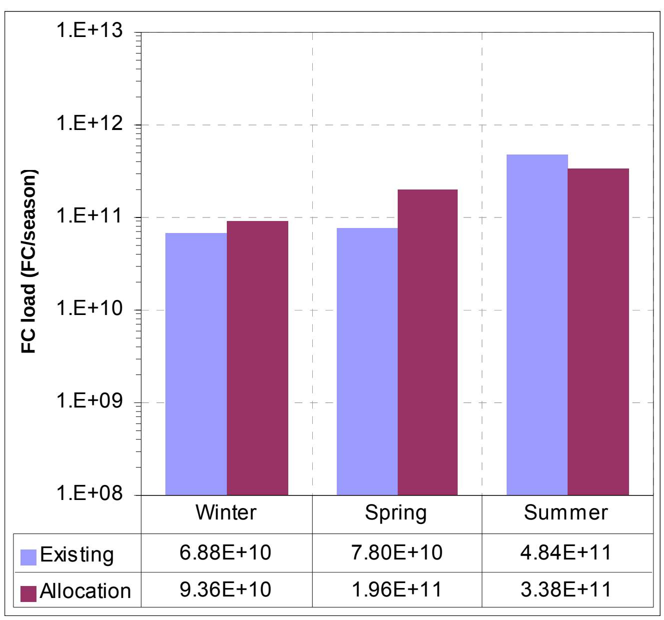


Figure 6-1. Summary of existing and allocated fecal coliform loads for Campbell Lake subwatershed

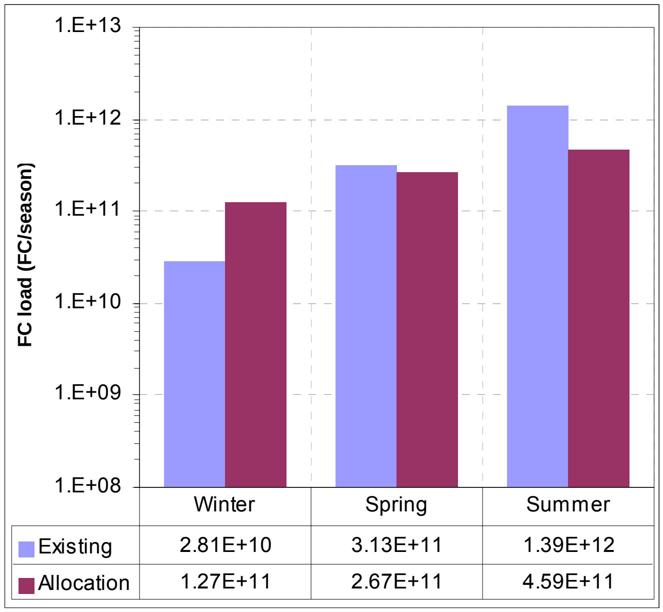


Figure 6-2. Summary of existing and allocated fecal coliform loads for Campbell Creek subwatershed

6.4. Seasonal Variation

Fecal coliform concentrations and loading to Campbell Creek and Campbell Lake vary seasonally, likely due to variations in weather and source activity. To account for this seasonality, this TMDL establishes seasonal allocations. Seasonal allocations represent loads allocated to time periods of similar weather, runoff, and instream conditions and can help to identify times of greatest impairment and focus TMDL implementation efforts by identifying times needing greater load reductions, as illustrated in Figure 6-3.

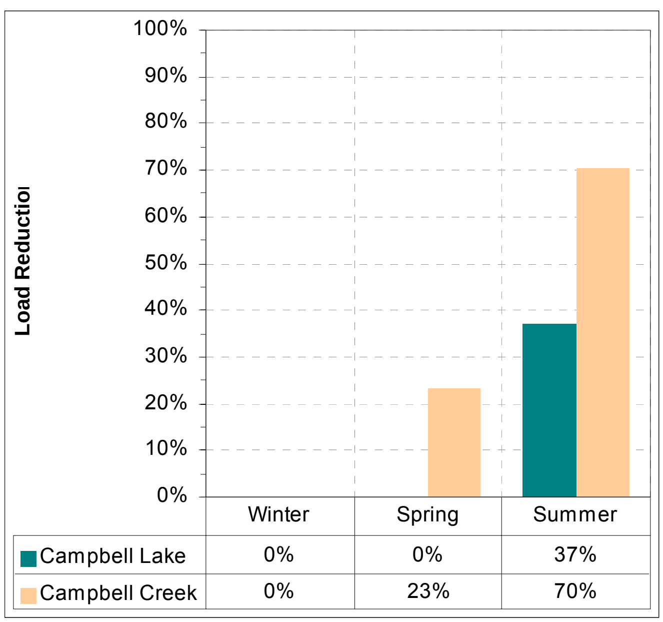


Figure 6-3. Seasonal variation in necessary load reductions

7. Implementation

According to EPA policy on addressing regulated stormwater in TMDLs (USEPA, 2002), wasteload allocations can be translated to effluent limitations in the applicable permit through the use of BMPs. The following discussion summarizes information contained in USEPA (2002).

NPDES permits must contain effluent limits and conditions consistent with the requirements and assumptions of the wasteload allocations in the relevant approved TMDL. Typically, those effluent limitations to control the discharge of pollutants are expressed in numerical form. However, because storm water discharges are due to storm events that are highly variable in frequency and duration and are not easily characterized, EPA's policy recognizes that only in rare cases will it be feasible or appropriate to establish numeric limits for municipal and small construction storm water discharges. Therefore, EPA recommends that for NPDES-regulated municipal and small construction stormwater discharges effluent limits should be expressed as BMPs or other similar requirements, rather than as numeric effluent limits. The policy recognizes the need for an iterative approach to control pollutants in storm water discharges. Specifically, the policy anticipates that a suite of BMPs will be used in the initial rounds of permits and that these BMPs will be tailored in subsequent rounds.

Appropriate BMPs will be identified for implementation in the Campbell Creek and Campbell Lake watershed in the relevant stormwater permit. The implementation of these TMDLs will be a locally led process and will consider the site-specific characteristics of the watershed as well as past management activities and local experience. The information included in this section is provided as a potential framework for developing the implementation plan to reduce fecal coliform levels and achieve water quality goals for which the TMDL allocation was developed.

7.1. Types of BMPs

Some studies on BMP effectiveness have evaluated the ability of certain BMPs to remove fecal coliform and other bacteria. The Center for Watershed Protection has compiled a stormwater treatment database containing information from studies conducted from 1990 to the present. Schueler (2000) provides a summary of the information in the database. The included studies do not provide sufficient fecal coliform data to statistically evaluate the effectiveness of BMPs in removing bacteria from urban runoff, but Schueler (2000) indicates that mean fecal coliform removal rates typically range from 65 to 75 percent from ponds and wetlands and 55 percent for filters. Schueler (2000) and SMRC (2000) also reports that water quality swales (including biofilters and wet and dry swales) consistently exported bacteria. Although it is possible that the bacteria thrive in the warm swale soils, the studies do not account for potential sources of bacteria directly to the swales, such as wildlife and domestic pets. Table 7-1 provides examples of BMP removal efficiencies for bacteria. Because information on BMP efficiency for fecal coliform is limited, information in Table 7-1 should be applied with consideration of local knowledge of the environmental conditions and BMP performance in the Anchorage area.

CWP (1997) discusses the use and effectiveness of BMPs in cold climates. Many BMPs that are suitable in warm climates are not appropriate or require modifications for use in cold climates, due to issues such as sustained freezing temperatures and large spring snowmelt events. Table 7-2 provides a summary of the applicability of BMPs to colder climates.

Many BMPs that are shown in Table 7.2 provide stormwater treatment at the end of the stormwater conveyance. In addition to these BMPs, the MOA is increasing efforts to use BMPS that intercept and treat stormwater at or near the source, where stormwater can be more cost-effective to treat, and which also have the benefit of reducing peaks storm flows and improving base flows.

Table 7-1. Fecal coliform removal for various BMPs

BMP Type	Fecal Coliform Bacteria Removal (%)
Detention and Dry Extended Detention Ponds	78
Wet Ponds	70
Shallow Marsh Wetland	76
Submerged Gravel Wetland	78
Filters (excluding vertical sand filters)	37
Infiltration Basins	90
Water Quality Swales	-25
Ditches	5
Adapted from Schueler (2000) and SMRC (2000).	

Table 7-2. Applicability of BMPs to cold climate conditions (CWP, 1997)

Type	BMP	Classification	Notes
Ponds	Wet Pond	◗	Can be effective, but needs modifications to prevent freezing of outlet pipes. Limited by reduced treatment volume and biological activity in the permanent pool during ice cover.
	Wet Extended Detention Pond	●	Some modifications to conveyance structures needed. Extended detention storage provides treatment during the winter season.
	Dry Extended Detention Pond	◗	Few modifications needed. Although this practice is easily adapted to cold climates, it is not highly recommended overall because of its relatively poor warm season performance.
Wetlands	Shallow Marsh	❍	In climates where significant ice formation occurs, shallow marshes are not effective winter BMPs. Most of the treatment storage is taken up by ice, and the system is bypassed.
	Pond/Wetland System	◗	Pond/Wetland systems can be effective, especially if some extended detention storage is provided. Modifications for both pond and wetland systems apply to these BMPs. This includes changes in wetland plant selection and planting.
	Extended Detention Wetland	●	See Wet Extended Detention Pond. Also needs modifications to wetland plant species.
Infiltration	Porous Pavement	❍	This practice is restricted in cold climates. It cannot be used on any pavement that is sanded, because the pavement will clog.
	Infiltration Trench	◗	Can be effective, but may be restricted by groundwater quality concerns related to infiltrating chlorides. Also, frozen ground conditions may inhibit the infiltration capacity of the ground.
	Infiltration Basin	◗	See infiltration trench.
Filtering Systems	Surface Sand Filter	❍	Frozen ground considerations, combined with frost heave concerns, make this type of system relatively ineffective during the winter season.

Type	BMP	Classification	Notes
	Underground Sand Filter	●	When placed below the frost line, these systems can function effectively in cold climates.
	Perimeter Sand Filter	❍	See Surface Sand Filter.
	Bioretention	◗	Problems functioning during the winter season because of reduced infiltration. It has some value for snow storage on parking lots, however.
	Submerged Gravel Wetlands	◗	Some concerns of bypass during winter flows. Has been used in relatively cold regions with success, but not tested in a wide range of conditions.
Open Channel Systems	Grassed Channel	◗	Reduced effectiveness in the winter season because of dormant vegetation and reduced infiltration. Valuable for snow storage.
	Dry Swale	◗	Reduced effectiveness in the winter season because of dormant vegetation and reduced infiltration. Very valuable for snow storage and meltwater infiltration.
	Wet Swale	◗	Reduced effectiveness in the winter season because of dormant vegetation. Can be valuable for snow storage.
	Vegetated Filter Strip	◗	See Dry Swale.

● Easily applied to cold climates; can be effective during the winter season.
◗ Can be used in cold climates with significant modifications; moderately effective during the winter season.
❍ Very difficult to use in cold climates. Generally not recommended.

7.2. Considerations for Implementing BMPs in Anchorage

In 2003 MOA developed a document evaluating the sources and fate of fecal coliform in Anchorage streams (MOA, 2003). The document identifies important considerations for selecting and implementing BMPs in the Anchorage area. The following paragraphs summarize the important elements affecting fecal coliform control options as identified in MOA (2003).

MOA (2003) concludes that functional control options for fecal coliform in Anchorage are intimately tied to the characteristics of local basins and their storm water drainage systems and to the channel characteristics of the receiving streams. Effective control strategies must differentiate between densely urbanized areas drained by curb and gutter piped systems and rural areas drained predominantly by ditches. However, in both cases, source control of storm water runoff hydraulics will be a primary factor in controlling fecal coliform contamination.

Stream channel and riparian zone management must also be considered as central program elements. The effects of pollutant concentration during settlement, and subsequent pulse elevation in water column concentrations by their re-suspension during flood flows, will aggravate the instream problem and might mask positive effects of land use controls.

Because Anchorage is a northern city located in a precipitation shadow it has unique climatic conditions that provide specific challenges for implementing stormwater controls. Storm events are generally long in duration, yielding low amounts of precipitation, with fewer intense periods of precipitation. Being located in a northern climate a high percentage of storm events produce snow that generally accumulates until the spring melt. The MOA is addressing the climatic challenges by moving away from end of pipe BMPs and implementing Low Impact Development (LID) BMPs. Rain gardens and yard breaks are two LID BMPs currently being encouraged for both new construction and retrofitting of existing landscapes. Both BMPs allow for infiltration of stormwater at the site where it is generated.

Ultimately, controls should focus on 'leverage' points in the entire fecal coliform transport system, including management of contaminant sources, treatment at or near contaminant sources, stormwater hydraulics, and stream channel and riparian zone quality. Specific management practices to consider should include:

- Providing public education, including signage, describing storm water system uses, management, and impacts.
- Implementing and enforcing setback and storm water controls for all animal holding areas, including formal design requirements for all large-scale facilities.
- Restricting use of on-site drain-field systems for select landforms.
- Implementing on-site storm water detention and infiltration standards (low-impact development or LID) for all commercial and residential development and redevelopment.
- Disconnection of stormwater outfalls allowing stormwater to infiltrate into soils before entering surface waters rather than directly connecting stormwater flows to surface waters.
- Optimizing use of ditch and swale designs for storm water drainage systems, including required application of these structures to all 'headwater' streets.
- Implementing requirements for installation of storm water runoff sheet flow controls ("yard breaks") for all driveways, and yards, and other landscaping served by curb and gutter piped drainage systems.
- Optimizing street sweeping practices and schedules to remove fine particulates for all curb and gutter road systems.
- Optimizing storm water hydraulic connection to natural wetlands, or to detention and water quality treatment basins.
- Implementing riparian zone conservation and recovery programs (including implementation of function-based setback standards), and restricting stream channel ditching and armoring.
- Implementing non-obstructive stream crossing design standards and retrofit of existing constricted stream crossings (MOA, 2003).

There are several other guidance documents to support the selection and implementation of BMPs for the Campbell TMDLs. Many of these guidance documents were prepared by the MOA and are available online at the MOA Watershed Protection Section Web site (http://wms.geonorth.com/library/LibraryReportsDocuments.aspx). The following is a brief outline of the information available on the Web site.

Erosion and Sediment Control and Materials Containment Guidance Manual
Most construction activities within the Municipality must comply with specific Municipal storm water permitting requirements. MOA's requirements for storm water controls for construction activities are outlined in this guidance document.

Anchorage Storm Water Treatment in Wetlands: 2002 Guidance
Natural wetlands can provide an important service through filtration of storm water and can be an effective and economic design element in permanent storm water controls. The MOA's preliminary design guidance for discharge of storm water to wetlands is contained in this document and its appendices.

Stormwater Treatment Plan Review Guidance Manual
Land development design within the Municipality must incorporate Municipal requirements for permanent storm water treatment controls. MOA's general requirements for permanent storm water

controls for new land development are detailed in this guidance document.

Anchorage Oil and Grit Separator (OGS) and Street Sweeping as Storm Water Controls: Performance Analysis
MOA and Department of Transportation rely principally on application of sand to winter roads to enhance trafficking safety, resulting in large sediment loading on Anchorage streets. This document summarizes a comparative analysis of OGS and street sweeping performance efficiency at Anchorage and includes recommendations for Anchorage street sweeping practices.

Anchorage Parking Lots: 2002 Best Management Practices Guidance
Parking lots, public and private, are a primary source of pollutant generation. This document provides preliminary design and maintenance management guidance for all parking lots.

Anchorage Street Sweepings Management Plan
This document assesses the environmental quality of waste sand and detritus swept from Anchorage streets and provides recommendations for their safe disposal.

Guidance for Design of Biofiltration Facilities for Stream Water Quality Control
Swales can be a desirable storm water control because of opportunities for filtration and infiltration, but have some limitations in cold climates. This document provides WMS guidance for design of biofiltration storm water treatment facilities in the MOA.

Low Impact Development in Anchorage, Concept and Criteria (Draft).
This draft document promotes the Municipality's move to address stormwater contaminants at or near their source instead of treatment at the end of pipe.

Also available online is The National Stormwater Best Management Practices database (http://www.bmpdatabase.org/) provides access to BMP performance data in a standardized format for over 190 BMP studies conducted over the past fifteen years. The database was developed by the Urban Water Resources Research Council (UWRRC) of American Society of Civil Engineers (ASCE) under a cooperative agreement with the EPA.

8. Monitoring

Follow-up monitoring for a TMDL is important in tracking the progress of TMDL implementation and subsequent water quality response as well as in evaluating any assumptions made during TMDL development. Monitoring results can be used to support any necessary future TMDL revisions and to track BMP effectiveness. Most importantly, monitoring will track the water quality of Campbell Creek and Campbell Lake to evaluate future attainment of water quality standards.

USEPA (2002) outlines EPA regulatory requirements for and provides guidance on establishing WLAs for stormwater in TMDLs. The memorandum also provides information on the implementation of effluent limitations through NPDES permits consistent with the TMDL WLAs. The policy outlined affirms the appropriateness of an iterative, adaptive management BMP approach, whereby permits include effluent limits (e.g., a combination of structural and non-structural BMPs) that address stormwater discharges, implement mechanisms to evaluate the performance of such controls, and make adjustments (i.e., more stringent controls or specific BMPs) as necessary to protect water quality.

USEPA (2002) indicates that where BMPs are used to implement the WLAs, the NPDES permit should require the monitoring necessary to assess if the expected load reductions attributed to BMP implementation are achieved (e.g., BMP performance data), although the permitting authority has the discretion under EPA's regulations to decide the frequency of such monitoring. EPA recommends that such permits require collecting data on the performance of the BMPs. The monitoring data can provide a basis for revised management measures and indicate any necessary adjustments to the BMPs. Any monitoring for stormwater required as part of the permit should be consistent with the state's overall assessment and monitoring strategy.

9. Public Comments

The fecal coliform bacteria Total Maximum Daily Loads (TMDLs) for Campbell Creek and Campbell Lake were developed over several years with extensive opportunity for feedback from affected parties. In 1994, Alaska's Department of Environmental Conservation (DEC) published an assessment of Campbell Lake and Campbell Lake (ADEC, 1994) based on consultation with the Municipality of Anchorage (MOA) and others. This assessment assembled much of the information on the watershed that was used in developing this document. In 1999, DEC developed, with the Environmental Protection Agency (EPA) and its contractor (Tetratech) an approach for developing fecal coliform bacteria TMDLs that would be appropriate for Anchorage area streams. Using this document, DEC consulted with the MOA, Alaska Department of Transportation (ADOT), and others in developing TMDLs for nine other Anchorage Streams. Drafts were shared with key stakeholders for feedback through emails, meetings, and phone conversations. To the extent possible and relevant, DEC revised the TMDLs based on the stakeholder comments. TMDLs on the other six Anchorage Streams were submitted in 2004 and 2005.

DEC completed the public draft TMDLs for Campbell Creek and Campbell Lake in March 2006. Copies were provided to the MOA, Alaska Department of Transportation and others. ADEC published a public notice on these TMDLs on the State of Alaska's website on March 24, 2006 and in the Anchorage Daily News, on March 26, 2006. A fact sheet describing the TMDL was also posted on ADEC's website, along with the draft TMDL. The public comment period was open through April 25, 2006. A public informational workshop was held on April 6, 2006 in ADEC's Anchorage office. In addition, DEC sent electronic copies of the draft TMDL to the MOA, ADOT, and all relevant federal, state, and local agencies, and the major citizen group involved with Anchorage water quality issues (Anchorage Waterways Council) which has cooperated with DEC and MOA in monitoring fecal coliform bacteria in Campbell Creek and other Anchorage Streams.

One person (an EPA staff) attended the workshop and ADEC only received written comments from the MOA. ADEC believes the low level of response was a result of including the stakeholders in reviewing earlier drafts of these TMDLs, and also because these TMDLs were modeled on the earlier Anchorage area TMDLs. The comments were relatively minor, and all addressed the type of BMPs appropriate for Anchorage, as discussed in Section 7. In brief, the MOA requested the TMDL note there are cold climate considerations for implementation of stormwater detention techniques and infiltration methods that vary in Alaska from those implemented in other states. These considerations include differences in precipitation types and timing, plant species available for erosion control, soil types, sizing and effectiveness of LID techniques, and amount of snowmelt. The also requested more focus on LID implementation in Alaska. ADEC concurred with the MOA's recommendations, and to the extent possible and where appropriate, ADEC made the changes requested in Section 7.

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Appendix A: Land Use Categories and Descriptions

CODE	MOA Description	MOA Secondary Description
1000	RESIDENTIAL	MAIN CATEGORY
1001	Single Family Detached	SINGLE FAMILY DETACHED
1002	Single Family Attached to one other unit on a diff	SINGLE FAMILY ATTACHED
1003	SF Attached to two or more other units on different lots	SINGLE FAMILY ATTACHED
1099	SF Structure that physically crosses lot lines	SINGLE FAMILY DETACHED
1102	Bldg.(s) with 2 units on the same lot	DUPLEX
1103	Bldg.(s) with 3 units on the same lot -- Triplex	MULTI FAMILY 3 & 4 Plex
1104	Bldg.(s) with 4 units on the same lot -- Fourplex	MULTI FAMILY 3 & 4 Plex
1105	Bldg.(s) with 5 to 9 units on the same lot	MULTI FAMILY 5+
1110	Bldg.(s) with 10 to 19 units on the same lot	MULTI FAMILY 5+
1120	Bldg.(s) with 20 to 49 units on the same lot	MULTI FAMILY 5+
1150	Bldg.(s) with 50 or more units on the same lot	MULTI FAMILY 5+
1199	Multi-Family Structure that physically crosses lot	MULTI FAMILY 3 & 4 Plex
1201	Mobile Home on Lot	MOBILE HOME
1220	Mobile Home Park (count is number of units in park)	MOBILE HOME
1240	Associated with mobile home park - no structure	MOBILE HOME
1299	Mobile Home that physically crosses lot lines	MOBILE HOME
1400	Group Quarters	INSTITUTIONAL
1500	Mixed Commercial/Residential	MULTI FAMILY 3 & 4 Plex
1600	Mixed Religious/Residential	SINGLE FAMILY DETACHED
1700	Mixed Industrial/Residential	SINGLE FAMILY ATTACHED
1800	Unsound Residential Structure	VACANT LAND
1920	Non-Residential structure assoc. with multi family	MULTI FAMILY 3 & 4 Plex
1930	Lot with no structure assoc. with adjoining duplex	DUPLEX
1940	Lot with no structure assoc. with adjoining multi	MULTI FAMILY 3 & 4 Plex
1950	Residential Structure Under Construction	RESIDENTIAL UNDER CONST.
1970	Open space (common/dedicated)	PRIVATE OPEN SPACE
1980	Non-Res. structure assoc. with adj. SF/duplex lot	SINGLE FAMILY ATTACHED
1990	Lot with no structure assoc. with adjoining single	SINGLE FAMILY ATTACHED
2000	COMMERCIAL	MAIN CATEGORY
2100	Commercial Retail	COMMERCIAL
2110	General Merchandise/Goods	COMMERCIAL
2120	Building Materials	COMMERCIAL
2130	Automobiles, Boats, Aircraft, Trailers	COMMERCIAL
2140	Retail Petroleum Products Sales	COMMERCIAL
2150	Food and Liquor	COMMERCIAL

CODE	MOA Description	MOA Secondary Description
2151	Supermarkets	COMMERCIAL
2152	Convenience stores	COMMERCIAL
2153	Liquor stores	COMMERCIAL
2160	Eating and Drinking Establishments	COMMERCIAL
2200	Commercial Office	COMMERCIAL
2210	Finance, Insurance, Real Est. Legal	COMMERCIAL
2220	Medical Services, (out-patient)	COMMERCIAL
2300	Other Commercial Services	COMMERCIAL
2310	Construction/Special-Trade	COMMERCIAL
2320	Repair Services	COMMERCIAL
2330	Commercial Transportation Services	COMMERCIAL
2340	Personal and Home Services	COMMERCIAL
2350	Commercial Education Services	COMMERCIAL
2351	day care and pre-schools	COMMERCIAL
2360	Commercial Recreation	COMMERCIAL
2361	Indoor commercial recreation	COMMERCIAL
2362	Outdoor commercial recreation	COMMERCIAL
2370	Transient Lodging	COMMERCIAL
2371	Overnight campground or recreational vehicle	COMMERCIAL
2380	Communication-Related	COMMERCIAL
2390	Commercial Parking Lots	COMMERCIAL
2391	Parking structures	COMMERCIAL
2400	Commercial Horticulture	COMM HORTICULTURE
3000	INDUSTRIAL	MAIN CATEGORY
3100	Truck and Heavy Equipment Repair, Automotive	INDUSTRIAL
3200	Construction/Special Trade Contractors	INDUSTRIAL
3300	Manufacturing and Processing	INDUSTRIAL
3400	Natural Resource Extraction	INDUSTRIAL
3500	Bulk Products and Outdoor Storage	INDUSTRIAL
3510	Bulk building materials	INDUSTRIAL
3520	Junk and wrecked autos, salvage	INDUSTRIAL
3530	Bulk petroleum storage	INDUSTRIAL
3600	Warehousing, Wholesale Distribution	INDUSTRIAL
3610	Air Freight Terminals	INDUSTRIAL
3700	Motor Vehicle Transportation	TRANSPORTATION
3800	Utility-Related Facilities	UTILITIES
3810	Electric Utility Related	UTILITIES
3820	Natural Gas Utility related	UTILITIES

CODE	MOA Description	MOA Secondary Description
3830	Water Utility related	UTILITIES
3840	Sewer Utility related	UTILITIES
3850	Solid Waste Utility related	UTILITIES
3851	Hazardous waste incinerators	UTILITIES
3860	Storm Drainage Facilities	UTILITIES
3870	Snow Disposal Sites	UTILITIES
3880	Communications Facilities	UTILITIES
4000	INSTITUTIONAL	MAIN CATEGORY
4100	Educational Facilities	INSTITUTIONAL
4110	Public Elementary School	INSTITUTIONAL
4120	Public Jr. High School	INSTITUTIONAL
4130	Public High School	INSTITUTIONAL
4140	Public College or University	INSTITUTIONAL
4150	Other Public Schools	INSTITUTIONAL
4160	Private Elementary School	INSTITUTIONAL
4170	Private College or University	INSTITUTIONAL
4200	Government Facilities	INSTITUTIONAL
4210	Municipal Government-all	INSTITUTIONAL
4211	Municipal police	INSTITUTIONAL
4212	Municipal fire protection	INSTITUTIONAL
4220	State Government-all other	INSTITUTIONAL
4230	Federal Government-all other	INSTITUTIONAL
4231	Post office	INSTITUTIONAL
4300	Social/Civic/Fraternal Organizations	INSTITUTIONAL
4400	Churches,Synagogues,Temples,etc.	INSTITUTIONAL
4500	Social Service Facilities	INSTITUTIONAL
4600	Hospitals and Related Facilities	INSTITUTIONAL
4700	Cultural Facilities	INSTITUTIONAL
4800	Other Specific Institutional Uses	INSTITUTIONAL
4810	Correctional Facilities	INSTITUTIONAL
4820	Cemeteries	INSTITUTIONAL
5000	PARKS, OPEN SPACE AND RECREATION AREAS	MAIN CATEGORY
5100	Municipal Parks, Open Space	PARKS, OPEN SPACE
5200	Chugach State Park	STATE PARK
5300	Federal Parks and Recreation Areas	FEDERAL PARK
6000	TRANSPORTATION-RELATED	MAIN CATEGORY
6100	Aircraft Transportation	RR, PORT, AIRPORT
6200	Railroad Transportation	RR, PORT, AIRPORT

CODE	MOA Description	MOA Secondary Description
6300	Marine Transportation	RR, PORT, AIRPORT
7000	OTHER LAND USES	MAIN CATEGORY
7100	Street and Highway R.O.W.'s	ROAD ROW
7200	Railroad R.O.W.'s	RAILROAD ROW
7300	Military Reservation	MILITARY
8000	VACANT LAND	VACANT LAND
8100	Intertidal Areas	INTERTIDAL
8200	Waterbodies	WATER

Appendix B: Comparison of Bacteria Data with the "Not-to-exceed" Water Quality Criterion

The spreadsheet tool discussed in Section 3.2.1 was also used to compare fecal coliform data for Campbell Creek to the not-to-exceed standard (i.e., not to exceed 40 FC/100 mL in more than 10 percent of the samples in a 30-day period), as summarized in Figures B-1 through B-6 and Tables B-1 through B-6. Although there are not enough data to confidently link the frequency of exceedances to fecal coliform loading to identify necessary TMDL allocations to meet the not-to-exceed standard, the existing data can be qualitatively evaluated to illustrate water quality conditions during the period of record for the dataset. The following figures and tables summarize the instantaneous concentrations for Campbell Creek stations as compared to the not-to-exceed criterion. For a summary of the instantaneous concentrations, the tables include the average, median, minimum, maximum, and 25th and 75th percentiles of all values within each month. For comparison to the criterion, samples within any possible 30-day period were compared to the not-to-exceed criterion and the calculated exceedances are summarized in the tables ("Exceedances: Count" and "% of Exceedances"). For example, there are 9 possible 30-day periods that include samples collected in March at station CA3. In 3 of those 9 periods (or 33 percent), more than 10 percent of the values exceeded 40 FC/100 mL.

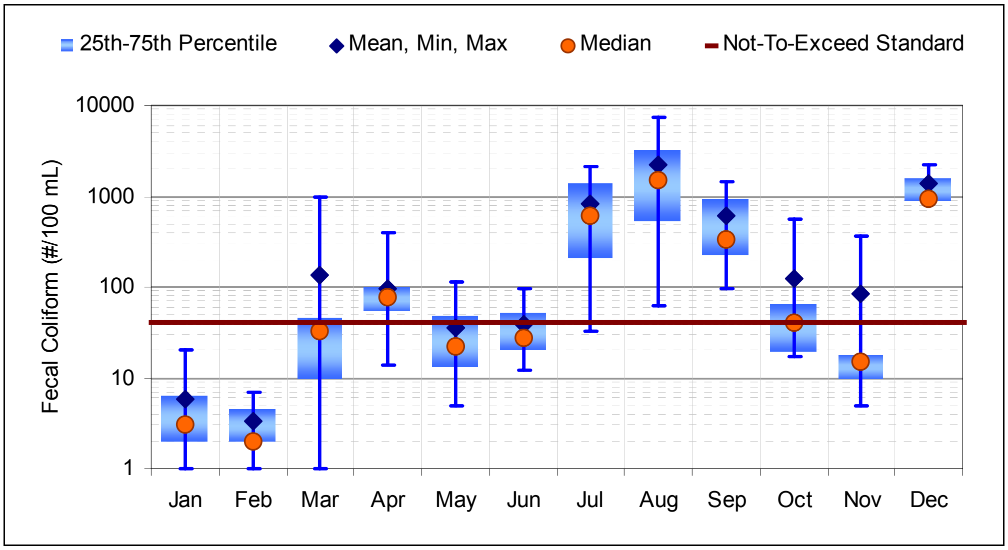

Figure B-1. Summary of instantaneous fecal coliform levels at CA3 (Campbell Creek at Dimond Boulevard)

Table B-1. Summary statistics for the evaluation of the not-to-exceed criterion at CA3 (Campbell Creek at Dimond Boulevard)

Data: 1/5/89 to 6/27/90

Month	Average[1]	Median[1]	Min[1]	Max[1]	25th[1]	75th[1]	Exceedances: Count[2]	% of Exceedances[3]
Jan	6	3	1	20	2	6	0:10	0%
Feb	3	2	1	7	2	5	0:7	0%
Mar	136	32	1	980	10	46	3:9	33%
Apr	98	78	14	392	55	99	12:16	75%
May	35	22	5	114	14	48	4:11	36%
Jun	39	27	12	94	20	53	3:9	33%
Jul	835	609	32	2109	205	1403	9:10	90%
Aug	2194	1509	61	7345	526	3230	20:20	100%
Sep	602	340	94	1430	229	945	7:7	100%
Oct	122	40	17	550	20	64	3:6	50%
Nov	84	15	5	370	10	18	1:5	20%
Dec	1353	930	880	2250	905	1590	3:3	100%

1 Average, median, minimum, maximum and 25th and 75th percentile values of all fecal coliform samples for the month.
2 Ratio of number of observed fecal coliform values that exceed the water quality criterion to the number of observed values in the month.
3 Percentage of all observed fecal coliform values for the month that exceed the water quality criterion.

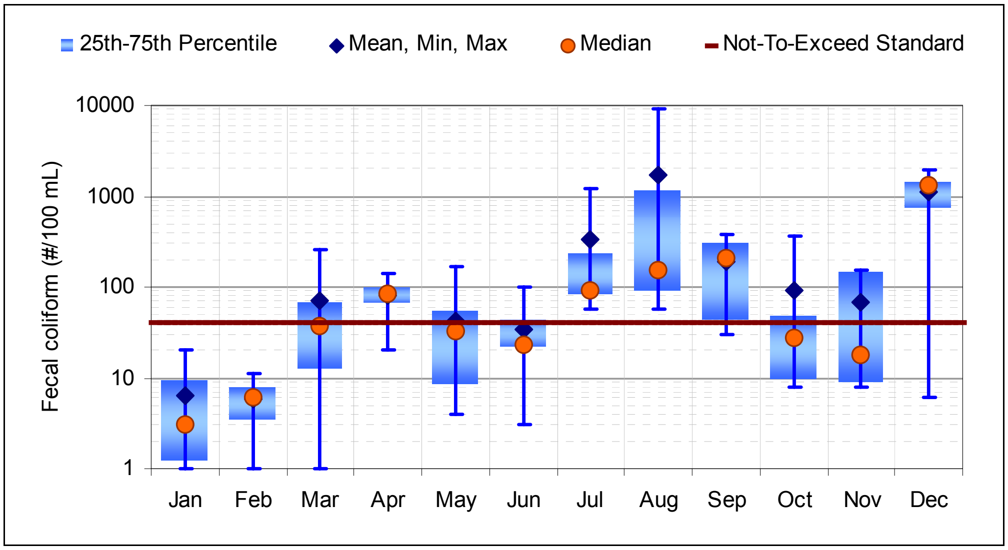

Figure B-2. Summary of instantaneous fecal coliform levels at CA4 (Campbell Creek at Taku Park; exact location is unknown)

Table B-2. Summary statistics for the evaluation of the not-to-exceed criterion at CA4 (Campbell Creek at Taku Park; exact location is unknown)

Month	Average[1]	Median[1]	Min[1]	Max[1]	25th[1]	75th[1]	Exceedances: Count[2]	% of Exceedances[3]
Data: 1/5/89 to 6/27/90								
Jan	6	3	1	20	1	10	0:10	0%
Feb	6	6	1	11	4	8	0:8	0%
Mar	70	37	1	260	13	69	4:11	36%
Apr	81	85	20	140	67	101	8:10	80%
May	42	32	4	167	9	55	4:11	36%
Jun	34	23	3	100	22	44	3:9	33%
Jul	335	92	58	1200	84	240	5:5	100%
Aug	1703	153	58	9200	92	1165	7:7	100%
Sep	194	210	30	380	44	304	4:5	80%
Oct	93	28	8	370	10	48	2:5	40%
Nov	67	18	8	152	9	150	2:5	40%
Dec	1101	1340	6	1950	740	1470	4:5	80%

[1] Average, median, minimum, maximum and 25th and 75th percentile values of all fecal coliform samples for the month.
[2] Ratio of number of observed fecal coliform values that exceed the water quality criterion to the number of observed values in the month.
[3] Percentage of all observed fecal coliform values for the month that exceed the water quality criterion.

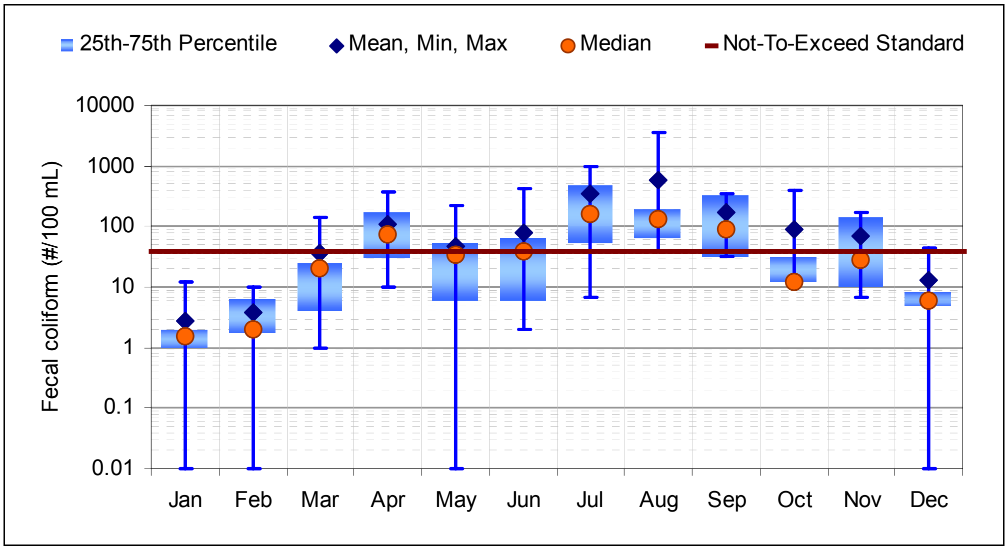

Figure B-3. Summary of instantaneous fecal coliform levels at CA6 (Campbell Creek at E. 76th Court)

Table B-3. Summary statistics for the evaluation of the not-to-exceed criterion at CA6 (Campbell Creek at E. 76th Court)

Data: 1/5/89 to 6/27/90

Month	Average[1]	Median[1]	Min[1]	Max[1]	25th[1]	75th[1]	Exceedances: Count[2]	% of Exceedances[3]
Jan	3	2	0	12	1	2	0:10	0%
Feb	4	2	0	10	2	7	0:8	0%
Mar	36	20	1	140	4	24	2:11	18%
Apr	110	74	10	360	30	170	7:10	70%
May	46	35	0	220	6	55	4:11	36%
Jun	79	40	2	430	6	66	3:9	33%
Jul	338	160	7	980	52	490	4:5	80%
Aug	595	130	40	3480	63	196	6:7	86%
Sep	168	90	32	350	33	336	3:5	60%
Oct	92	12	12	390	12	32	1:5	20%
Nov	71	28	7	172	10	138	2:5	40%
Dec	13	6	0	44	5	8	1:5	20%

[1] Average, median, minimum, maximum and 25th and 75th percentile values of all fecal coliform samples for the month.
[2] Ratio of number of observed fecal coliform values that exceed the water quality criterion to the number of observed values in the month.
[3] Percentage of all observed fecal coliform values for the month that exceed the water quality criterion.

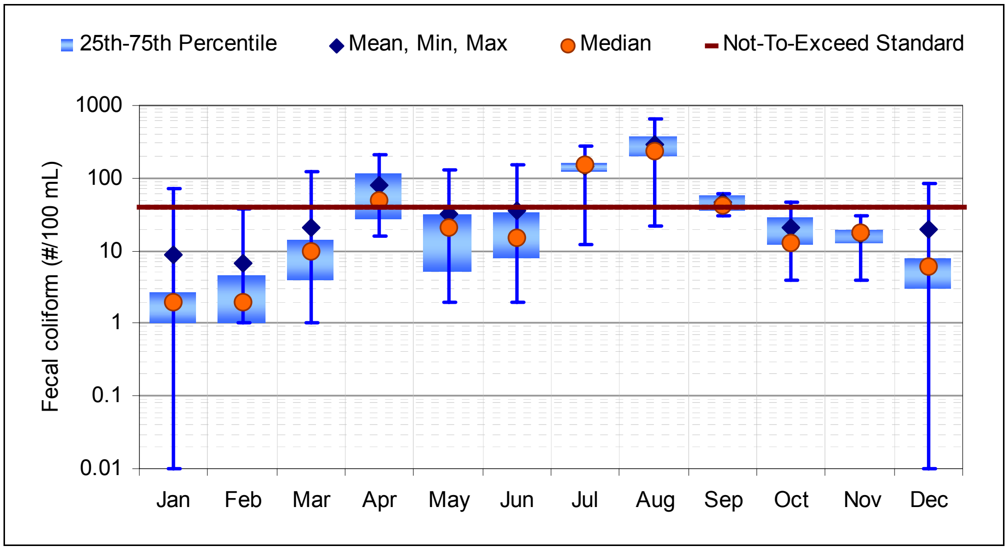

Figure B-4. Summary of instantaneous fecal coliform levels at CA12 (Campbell Creek at Wright Street)

Table B-4. Summary statistics for the evaluation of the not-to-exceed criterion at CA12 (Campbell Creek at Wright Street)

Data: 1/5/89 to 6/29/90								
Month	**Average[1]**	**Median[1]**	**Min[1]**	**Max[1]**	**25th[1]**	**75th[1]**	**Exceedances: Count[2]**	**% of Exceedances[3]**
Jan	9	2	0	72	1	3	1:10	10%
Feb	7	2	1	37	1	5	0:8	0%
Mar	21	10	1	120	4	15	2:11	18%
Apr	80	50	16	210	27	115	6:10	60%
May	31	21	2	130	5	32	3:12	25%
Jun	35	15	2	156	8	33	2:9	22%
Jul	143	153	12	270	120	160	4:5	80%
Aug	297	230	22	660	201	374	10:11	91%
Sep	45	42	30	62	35	58	3:5	60%
Oct	21	13	4	46	12	28	1:5	20%
Nov	17	18	4	31	13	20	0:5	0%
Dec	20	6	0	82	3	8	1:5	20%

[1] Average, median, minimum, maximum and 25th and 75th percentile values of all fecal coliform samples for the month.
[2] Ratio of number of observed fecal coliform values that exceed the water quality criterion to the number of observed values in the month.
[3] Percentage of all observed fecal coliform values for the month that exceed the water quality criterion.

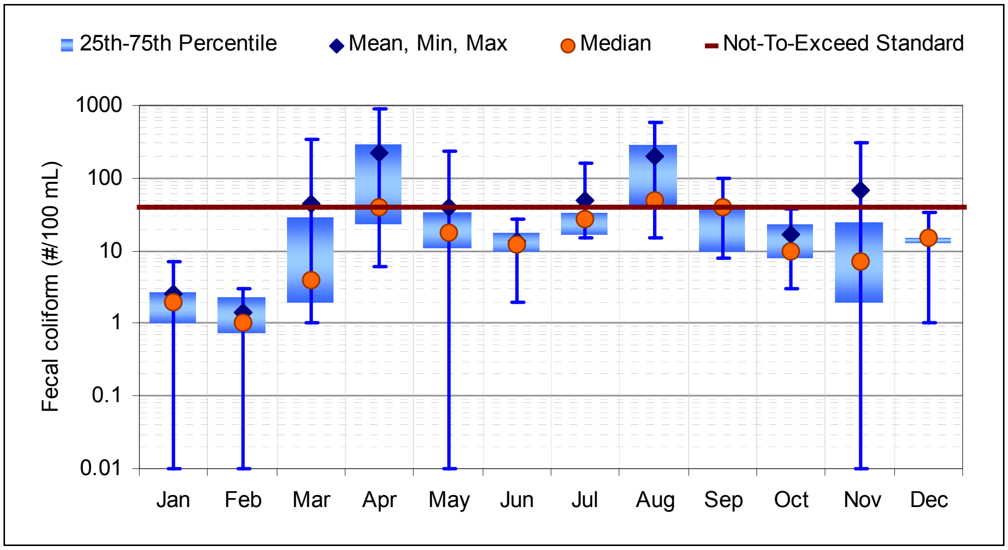

Figure B-5. Summary of instantaneous fecal coliform levels at CA11 (South Fork Campbell Creek at Campbell Airstrip Road)

Table B-5. Summary statistics for the evaluation of the not-to-exceed criterion at CA11 (South Fork Campbell Creek at Campbell Airstrip Road)

Data: 1/5/89 to 6/29/90

Month	Average[1]	Median[1]	Min[1]	Max[1]	25th[1]	75th[1]	Exceedances: Count[2]	% of Exceedances[3]
Jan	3	2	0	7	1	3	0:10	0%
Feb	1	1	0	3	1	2	0:8	0%
Mar	43	4	1	350	2	28	1:11	9%
Apr	217	39	6	920	24	283	5:10	50%
May	39	18	0	240	11	33	2:12	17%
Jun	13	12	2	27	10	18	0:9	0%
Jul	50	27	15	160	17	33	1:5	20%
Aug	197	50	15	590	42	290	4:5	80%
Sep	40	40	8	100	10	40	1:5	20%
Oct	16	10	3	38	8	23	0:5	0%
Nov	67	7	0	300	2	24	1:5	20%
Dec	15	15	1	33	13	15	0:5	0%

1 Average, median, minimum, maximum and 25th and 75th percentile values of all fecal coliform samples for the month.
2 Ratio of number of observed fecal coliform values that exceed the water quality criterion to the number of observed values in the month.
3 Percentage of all observed fecal coliform values for the month that exceed the water quality criterion.

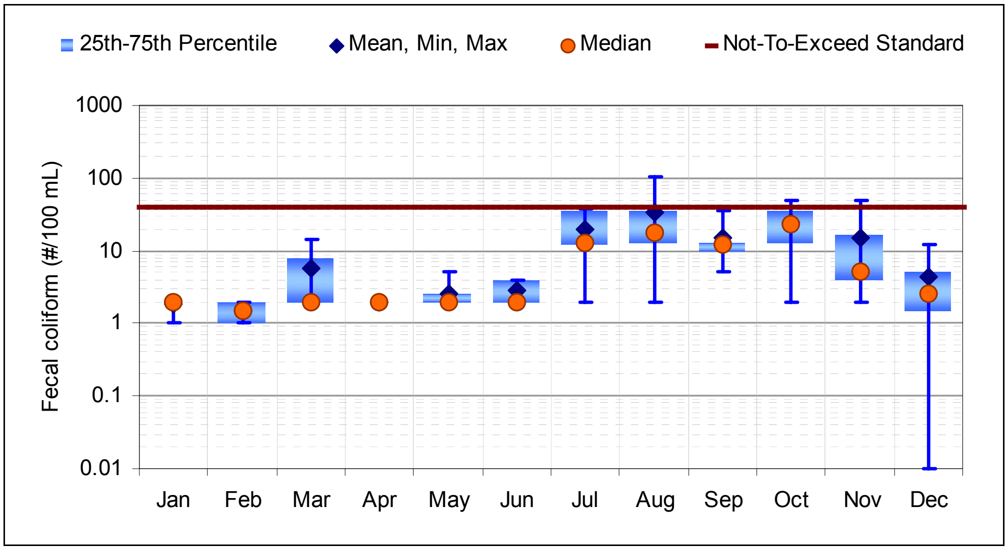

Figure B-6. Summary of instantaneous fecal coliform levels at CA13 (North Fork Campbell Creek at Campbell Airstrip Road)

Table B-6. Summary statistics for the evaluation of the not-to-exceed criterion at CA13 (North Fork Campbell Creek at Campbell Airstrip Road)

Data: 1/5/89 to 12/21/90

Month	Average[1]	Median[1]	Min[1]	Max[1]	25th[1]	75th[1]	Exceedances: Count[2]	% of Exceedances[3]
Jan	2	2	1	2	2	2	0:5	0%
Feb	2	2	1	2	1	2	0:4	0%
Mar	6	2	2	14	2	8	0:5	0%
Apr	2	2	2	2	2	2	0:5	0%
May	3	2	2	5	2	3	0:7	0%
Jun	3	2	2	4	2	4	0:5	0%
Jul	20	13	2	37	12	35	0:5	0%
Aug	34	18	2	102	13	35	1:5	20%
Sep	15	12	5	35	10	13	0:5	0%
Oct	24	23	2	48	13	35	1:5	20%
Nov	15	5	2	49	4	17	1:5	20%
Dec	4	3	0	12	2	5	0:4	0%

[1] Average, median, minimum, maximum and 25th and 75th percentile values of all fecal coliform samples for the month.
[2] Ratio of number of observed fecal coliform values that exceed the water quality criterion to the number of observed values in the month.
[3] Percentage of all observed fecal coliform values for the month that exceed the water quality criterion.