

**United States
Environmental Protection Agency
Region 10
1200 Sixth Avenue
Seattle, Washington 98101**

**Total Maximum Daily Load (TMDL)
for
Fecal Coliform Bacteria
in the Waters of
Duck Creek in Mendenhall Valley, Alaska**

In compliance with the provisions of the Clean Water Act, 33 U.S.C. §1251 et seq., as amended by the Water Quality Act of 1987, Public Law 100-4, the Environmental Protection Agency is establishing a Total Maximum Daily Load (TMDL) that will result in a decrease in fecal coliform contamination in Duck Creek to comply with the designated uses in Alaska's water quality standards.

This TMDL will become effective immediately. Subsequent actions must be consistent with this TMDL.

Signed this 20th day of December, 2000.

[original signed by]
Randall F. Smith
Director
Office of Water

**United States
Environmental Protection Agency
Region 10
1200 Sixth Avenue
Seattle, Washington 98101**

**Total Maximum Daily Load (TMDL)
for
Fecal Coliform Bacteria
in the Waters of
Duck Creek in Mendenhall Valley, Alaska**

December, 2000

Contents

Executive Summary	1
Overview	2
General Background	2
Land Use	4
Climate	4
Applicable Water Quality Standards	5
Designated Uses	5
Parameters of Concern	5
Applicable Water Quality Criteria and Numeric Target	6
Critical Conditions	6
Water Quality Analysis	6
Water Quality Data	7
1994-1998 U.S. Geological Survey Streamflow Monitoring	7
1992-1993 Alaska Water Watch Water Quality Monitoring	7
1994-1995 and 1998 Alaska Department of Environmental Conservation Water Quality Monitoring	9
Analysis of Coliform Data	9
Pollutant Sources	11
Point Sources	11
Nonpoint Sources	12
Ducks	12
Dogs	12
Analytical Approach	13
Modeling Approach	13
Model Setup	14
Model Input	14
Hydrologic Simulation	14
Water Quality Simulation	15
Loading Capacity	15
Wasteload Allocation	17
Load Allocation	17
Margin of Safety	18
Seasonal Variation	19
Monitoring	20
Possible Future Actions	21
Public Participation	21

Education	22
Restoration and Management	22
Flow Reservations	23
Monitoring	23
Stormwater Management	23
Public Participation Process	24
EPA's Response to Comments	24
Appendix: Water Quality and Flow Monitoring Data	25
1994-1998 U.S. Geological Survey Streamflow Monitoring	25
1992-1993 Alaska Water Watch Water Quality Monitoring	25
1994-1995 and 1998 Alaska Department of Environmental Conservation Water Quality Monitoring	26
References	27

List of Figures

Figure 1. Location of Duck Creek	3
Figure 2. Location of AWW and ADEC bacteria sampling	8
Figure 3. Observed fecal coliform bacteria per 100 mL vs. flow at Nancy Street	11
Figure 4. Existing conditions and allocation scenarios for Duck Creek	18

List of Tables

Table 1. Land use distribution in the Duck Creek watershed	4
Table 2. ADEC <i>E. coli</i> observations and calculated fecal coliform values	10
Table 3. Loading capacity of Duck Creek for fecal coliform bacteria	16
Table 4. Predicted annual exceedances of the water quality standards for fecal coliform bacteria in Duck Creek under the existing conditions scenario	16
Table 5. Fecal coliform loadings to Duck Creek under the existing conditions and load allocation scenarios	17
Table 6. Predicted annual exceedances of the water quality standards for fecal coliform bacteria in Duck Creek under the allocation scenario	18
Table A-1. Streamflow data from USGS gaging station at Nancy Street (15053200) and precipitation from NCDC Juneau International Airport Station (504100) from 1994 to 1998	25
Table A-2. AWW total and fecal coliform monitoring results	25
Table A-3. ADEC total coliform and <i>E. coli</i> monitoring results	26

**Total Maximum Daily Load for
Fecal Coliform Bacteria
in the Waters of Duck Creek in Mendenhall Valley, Alaska**

TMDL AT A GLANCE:

<i>Water Quality-limited?</i>	Yes
<i>Hydrologic Unit Code:</i>	19010301
<i>Standard of Concern:</i>	Fecal coliform bacteria
<i>Designated Uses Affected:</i>	Water supply; water recreation; growth and propagation of fish, shellfish, and other aquatic life, and wildlife
<i>Environmental Indicator:</i>	<i>E. coli</i> monitoring
<i>Major Source(s):</i>	urban runoff, including domestic animal and wildlife waste
<i>Loading Capacity:</i>	2.23 x 10 ¹¹ FC/yr at the mouth of Duck Creek
<i>Wasteload Allocation:</i>	No point sources; wasteload allocation set to zero
<i>Load Allocation:</i>	2.23 x 10 ¹¹ FC/yr at the mouth of Duck Creek
<i>Margin of Safety:</i>	Implicit MOS through conservative assumptions

Executive Summary

Duck Creek is listed on the 1998 303(d) list of impaired waters in Alaska for fecal coliform bacteria. The primary sources of fecal coliform bacteria in the creek are urban runoff and animal waste. As the watershed has become more developed, urban runoff and pet populations have increased. Based on the water quality standards for fecal coliform bacteria and the hydrologic conditions of Duck Creek, the loading capacity for fecal coliform bacteria was estimated at 2.23 x 10¹¹ FC/yr. It is recommended that proposed wetland, streamflow, and streamside restoration projects be carried out to reduce the inflow of fecal coliform bacteria to the creek and to increase baseflow in the creek. In addition, pet owners should be encouraged to cleanup and properly dispose of pet waste, and best management practices should be employed to control urban runoff.

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 degree 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.

The state of Alaska identified Duck Creek as being water quality-limited because of low dissolved oxygen, excess debris, metals (iron), fecal coliform, and turbidity (ADEC, 1998). A TMDL for turbidity was completed in December of 1999 (USEPA, 1999). This document addresses only the fecal coliform impairment to the creek.

The Duck Creek Advisory Group (DCAG), which was formed to coordinate, plan, initiate, and carry out activities to restore water quality and anadromous fish habitat, has drafted the Duck Creek Watershed Management Plan (DCMP). The DCMP states that urban runoff is among the most problematic of impairments to Duck Creek (Koski and Lorenz, 1999). The primary source of fecal coliform in urban runoff is animal waste, primarily from ducks and dogs (ADEC, personal communication, July 7, 2000).

Alaska's water quality standards designate the following uses of Duck Creek that must be protected: (1) water supply, (2) water recreation, and (3) growth and propagation of fish, shellfish, and other aquatic life, and wildlife (Alaska Administrative Code [AAC] § 18.70.050). Protection from fecal coliform and other pathogenic contamination is most important for waters designated for the first two of these uses. The presence of any fecal indicators indicates that a water supply is potentially unsafe for consumption. Also, excessive amounts of fecal bacteria in surface water used for recreation have been known to indicate an increased risk of pathogen-induced illness to humans. Illnesses due to pathogen-contaminated recreational waters include gastrointestinal, respiratory, eye, ear, nose, throat, and skin diseases (USEPA, 1986).

General Background

Duck Creek is located in Juneau, Alaska, in the Mendenhall Valley, a watershed that drains several streams into one of only a few major estuarine wetlands in Southeast Alaska (Figure 1).

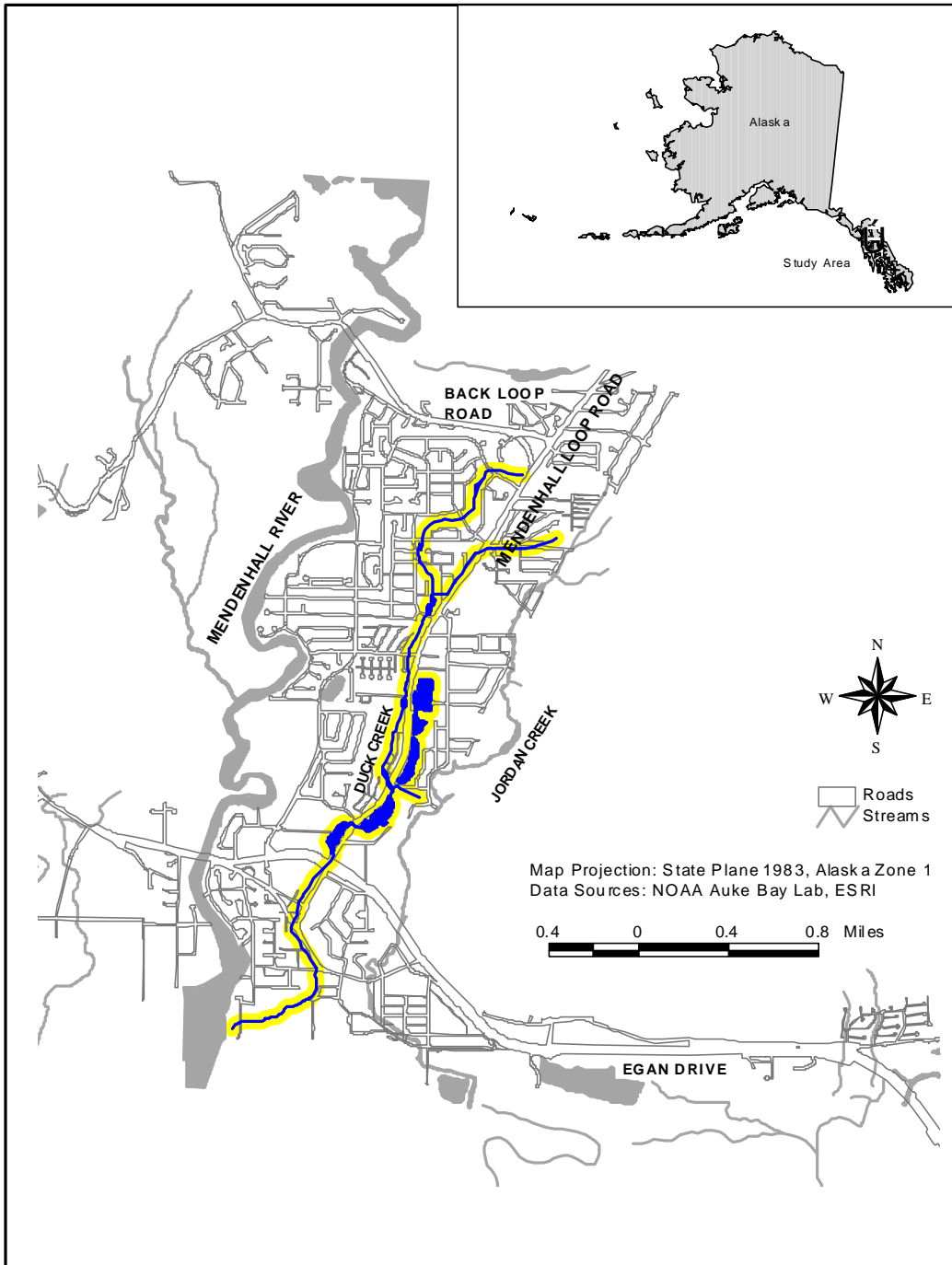


Figure 1. Location of Duck Creek

The Duck Creek watershed receives runoff and groundwater primarily from the floor of this large glacial valley. Duck Creek is a small stream of just over 3 miles in length that flows south through the middle of the heavily populated valley and enters the Mendenhall River and wetlands directly upstream of the Juneau International Airport runway. The creek is an anadromous fish stream (Alaska Department of Fish and Game Catalog No. 111-59-10500-2002) that historically supported runs of coho, pink, chum, and sockeye salmon. Based on descriptions from early residents, the creek originally had numerous beaver ponds and clear water that flowed year-round. Currently, the creek varies from about 5 to 15 feet in width and from a few inches to several feet in depth. Duck Creek has two main tributaries—East Fork and El Camino.

Land Use

Thirty-six percent of the 1,080-acre Duck Creek watershed is covered by impervious surfaces such as roofs, roads, and parking lots (Lorenz, 1998). The remainder is a mix of cultivated landscaping, nonvegetated athletic fields, natural vegetation, and wetlands. Nearly half of the watershed provides space for residential housing, yards, and driveways. Most of the housing is single-family construction. Another third of the watershed is used for transportation and commercial interests. Based on this land use distribution, the Duck Creek watershed was divided into the following land use categories and areas: residential (540 acres), transportation and utilities (83 acres), commercial (282 acres), and recreation and wetland (175 acres.) Table 1 summarizes the land use distribution.

Table 1. Land use distribution in the Duck Creek watershed

Land Use	Area (acres) ^a
Residential	540
Transportation	83
Commercial	282
Recreation/Wetland	175
Total	1,080

^a Estimated from land uses and information presented by Lorenz (1998).

The Duck Creek watershed is highly urbanized. Urban runoff is often a significant contributor of fecal coliform bacteria. The main source of fecal coliform bacteria in urban runoff in the Duck Creek watershed is animal waste, from both wildlife and domestic animals.

Climate

Historical climate data are available from the Juneau International Airport (Station 504100), adjacent to the lower reach of Duck Creek. The temperature ranges from a normal daily minimum temperature of 19 °F (-7.2 °C) in January and 48 °F (8.9 °C) in July to a normal daily maximum temperature of 29 °F (-1.7 °C) in January and 64 °F (18 °C) in July. Rainfall averages 54 inches

per year, ranging from less than 3 inches per month to well over 7 inches per month. Snowfall averages 99 inches per year, ranging from 0 to 26 inches per month. Wind averages about 8 mph daily (NOAA National Climate Data Center).

The meteorological station at the Juneau airport tends to underestimate rainfall in the Duck Creek watershed (ADEC, personal communication, August 1, 2000). In addition, the record available at the Juneau station consists of daily values, while the model selected for this TMDL requires hourly precipitation input. As a result, the precipitation data used in the model described below were based on two other stations thought to be more representative of rainfall in the watershed.

Applicable Water Quality Standards

Water quality standards designate the “uses” to be protected (e.g. drinking water, recreation, fish and wildlife habitat) and the “criteria” for their protection (e.g. how much of a pollutant can be assimilated by a waterbody without impairing its designated uses). TMDLs are developed to meet applicable water quality standards. Standards may be expressed as numeric water quality targets, narrative standards for the support of designated uses, and other associated indicators of support of beneficial uses. The numeric target identifies the specific goals or endpoints for the TMDL that equate to attainment of the water quality standard. The numeric 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 an appropriate numeric indicator and an associated numeric target level for the calculation of the TMDL.

Designated Uses

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. Duck Creek only partially supports these designated uses.

Parameters of Concern

The Alaska 1998 § 303(d) list of impaired waters identified Duck Creek as water quality-limited because of dissolved oxygen, debris, metals (iron), fecal coliform bacteria, and turbidity. This TMDL addresses only the fecal coliform bacteria impairment to the creek.

Applicable Water Quality Criteria and Numeric Target

Water quality criteria are developed for each designated use and give guidance on how much pollution a waterbody can accommodate by while still supporting the designated uses. The most stringent of Alaska’s water quality standards with respect to fecal coliform bacteria (FC) is for drinking, culinary, and food processing water supply. The applicable standard states that

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 (1)(A)(i))

The FC standard in Duck Creek, which is designated for use as a drinking water supply, is therefore a 30-day geometric mean of 20 FC/100 mL, with no more than 10 percent of the samples exceeding 40 FC/100 mL. Sufficient data are not available to determine the frequency of exceedance of the geometric mean standard. Of the 29 fecal coliform observations available for Duck Creek, 5 exceed 40 FC/100 mL, representing 17 percent of the samples.

Critical Conditions

Understanding when a waterbody is most vulnerable to pollutant loadings is critical to developing load reduction scenarios that will result in attainment of water quality standards. In Duck Creek, most exceedances of the fecal coliform water quality standard coincide with high flows, which indicates that nonpoint sources associated with storm water runoff contribute to the impairment. When an impairment is the result of point source contributions, it is usually most pronounced at low flows. This is because point source contributions are relatively constant over time. When streamflow is low, point source discharges constitute a relatively larger proportion of the total streamflow. If an impairment is more pronounced at higher flows, as is the case with the fecal coliform impairment to Duck Creek, the pollutant is associated with stormwater runoff and is therefore nonpoint in nature. The critical condition was accounted for through the use of continuous watershed and water quality simulation models that accounted for storm-driven loading to Duck Creek. A continuous simulation allows the contribution of stormwater runoff under representative meteorologic conditions to be estimated.

Water Quality Analysis

Very few data were available for the development of this TMDL. A total of 10 samples of total and fecal coliform bacteria were collected on two sampling dates by Alaska Water Watch (AWW), a volunteer monitoring program. Four of these samples exceeded the water supply criterion of 40 FC/100 mL. Nineteen total coliform and *Escherichia coli* (*E. Coli*) samples were collected by the Alaska Department of Environmental Conservation (ADEC). *E. coli* is a subset of fecal coliform bacteria, which in turn are a subset of total coliform bacteria. The applicable water quality criteria relate to fecal coliform bacteria. A relationship between *E. coli* and fecal coliform bacteria was assumed in order to estimate the fecal coliform counts associated with these 19 samples. Only one of the 19 estimates of fecal coliform bacteria developed using this relationship exceeded the 40 FC/100 mL criterion. The observed data were not sufficient to evaluate exceedance of the 30-day geometric mean standard of 20 FC/100 mL. The locations of the AWW and ADEC bacteria sampling sites are shown in Figure 2.

Water Quality Data

In general, the data available for the development of a fecal coliform TMDL for Duck Creek are characterized by spatially and temporally periodic water quality samples collected and analyzed for total coliform (TC), fecal coliform (FC), and *E. coli*. TMDL guidance (USEPA, 1991) provides that TMDLs should be developed using the best available information, especially when nonpoint sources are the primary concern.

1994-1998 U.S. Geological Survey Streamflow Monitoring

Daily streamflow has been measured since December 1993 at a United States Geological Survey (USGS) gaging station (15053200) downstream of Nancy Street in the Duck Creek watershed (Figure 2). The DCMP (Lorenz, 1998) indicates that flow at the gaging station represents discharges from approximately 75 percent of the watershed (approximately 810 acres). It is estimated that approximately 46 percent of the total precipitation that falls in the Duck Creek watershed is transported into the stream through overland runoff (Lorenz, 1998). The remaining 54 percent is believed to enter Duck Creek as groundwater or through sewer systems. Because flow in Duck Creek is heavily influenced by groundwater, there is a substantial lag between precipitation events and peak flow stages. Duck Creek has been observed to peak approximately 24 hours after the neighboring Jordan Creek. Peak monthly discharges and precipitation in the watershed occur on average during the months of September and October. This represents the period of maximum runoff and increased nonpoint source pollutant loading from areas in the Duck Creek watershed. Annual and monthly average flows and precipitation for 1994 to 1998 are presented in the Appendix, Table A-1.

1992-1993 Alaska Water Watch Water Quality Monitoring

During 1992 and 1993, local students from Juneau Youth Services, Miller House, collected water quality samples at nine sites in Duck Creek as part of the Alaska Water Watch (AWW) program. Parameters measured include water temperature, dissolved oxygen (DO), pH, turbidity, specific conductivity, alkalinity, and fecal coliform bacteria. Fecal coliform bacteria were collected at only five of the nine sites and are presented in the Appendix, Table A-2. The geographic

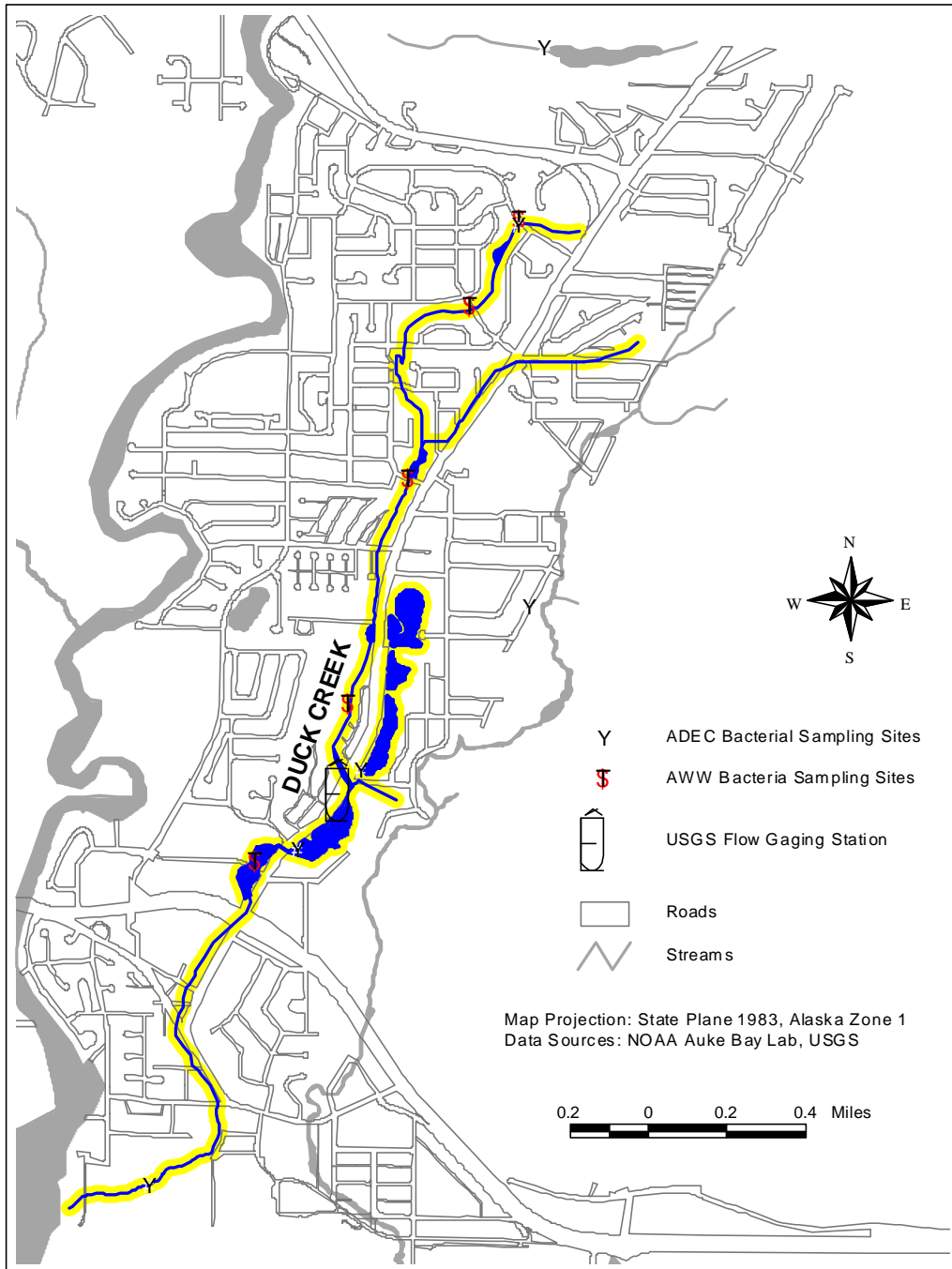


Figure 2. Location of AWW and ADEC bacteria sampling

locations of the five AWW coliform bacteria sampling stations are referenced by street names and are presented in Figure 2. The in-stream data collected at these sites did not have any corresponding flow, and the period of record did not have temporal overlap with the flow data collected at the Nancy Street USGS gaging station. For this reason, the coliform bacteria data available for two sampling events between 1992 and 1993 could not be used in model calibration. The values were, however, used to assess the frequency of exceedance of water quality standards.

1994-1995 and 1998 Alaska Department of Environmental Conservation Water Quality Monitoring

During 1994 and 1995, ADEC collected water quality samples at five locations on three dates. The samples were analyzed for five-day biochemical oxygen demand (BOD₅), chemical oxygen demand (COD), nitrate (NO₃), nitrite (NO₂), sulfate, total coliform bacteria (TC), and *E. coli*. Four additional samples were collected in 1998 at four sites in response to questions regarding some fill material. The geographic locations of the ADEC coliform bacteria sampling stations are presented in Figure 2. These samples were the only bacteria data that coincided with the flow record available for the Duck Creek watershed. Table A-3 in the Appendix presents the ADEC total coliform and *E. coli* monitoring results.

Analysis of Coliform Data

The Alaska water quality standard is based on fecal coliform bacteria, whereas the ADEC monitoring data were collected for total coliform bacteria and *E. coli*. Fecal coliform bacteria are a subset of total coliform bacteria, and *E. coli* is a subset of fecal coliform. Theoretically, a regression relationship between fecal coliform bacteria and *E. coli* in Duck Creek could be used to convert the ADEC *E. coli* values to their equivalent fecal coliform counts. However, no simultaneous measurements of fecal coliform bacteria and *E. coli* have been made in Duck Creek. A review of the literature found several equations relating fecal coliform bacteria and *E. coli*. The best available relationship is a set of regressions developed for wet and dry weather conditions in the Lower Geddes Pond in Michigan (LTI, 1999):

- Wet weather: $E. coli = 0.7601 * \text{fecal coliforms}$ ($R^2 = 0.9307$)
- Dry weather: $E. coli = 0.7308 * \text{fecal coliforms}$ ($R^2 = 0.415$)

Because the major sources of fecal coliform bacteria in Duck Creek are nonpoint and storm-related sources, the wet weather regression was used to calculate fecal coliform counts from the *E. coli* observations. The ADEC *E. coli* observations and their corresponding fecal coliform values are presented in Table 2.

Table 2. ADEC *E. coli* observations and calculated fecal coliform values

Sampling Site	Date	<i>E. coli</i> (MPN/100 mL)	Fecal coliform (MPN/100 mL)
Dredge Lake	10/10/94	4	5
	2/6/95	9	12
	4/17/95	2	3
Taku Blvd	10/10/94	8	11
	2/6/95	2	3
	4/17/95	2	3
	4/18/98	2	3
	4/18/98	2	3
	4/18/98	2	3
Rainbow Row	10/10/94	30	39
	2/6/95	4	5
	4/17/95	2	3
Nancy Pond	4/6/98	5	7
Stump Lake	10/10/94	23	30
	2/6/95	17	22
	4/17/95	2	3
Airport Rd	10/10/94	13	17
	2/6/95	80	105
	4/17/95	2	3

All of the available in-stream measurements were combined by parameter and station to evaluate trends and possible exceedances of the water quality standards. The AWW data suggest the impounded water between Taku Boulevard and Nancy Street is a source of elevated coliforms. The ponds in this area might attract wildlife such as ducks. When compared, the data from AWW and ADEC for Taku Boulevard are consistent. Without flow data, however, the AWW data can not be used to estimate downstream impacts. The data that overlap the flow record were used to determine relationships with flow. Figure 3 shows the monitoring data for fecal coliform counts versus the flow at Nancy Street.

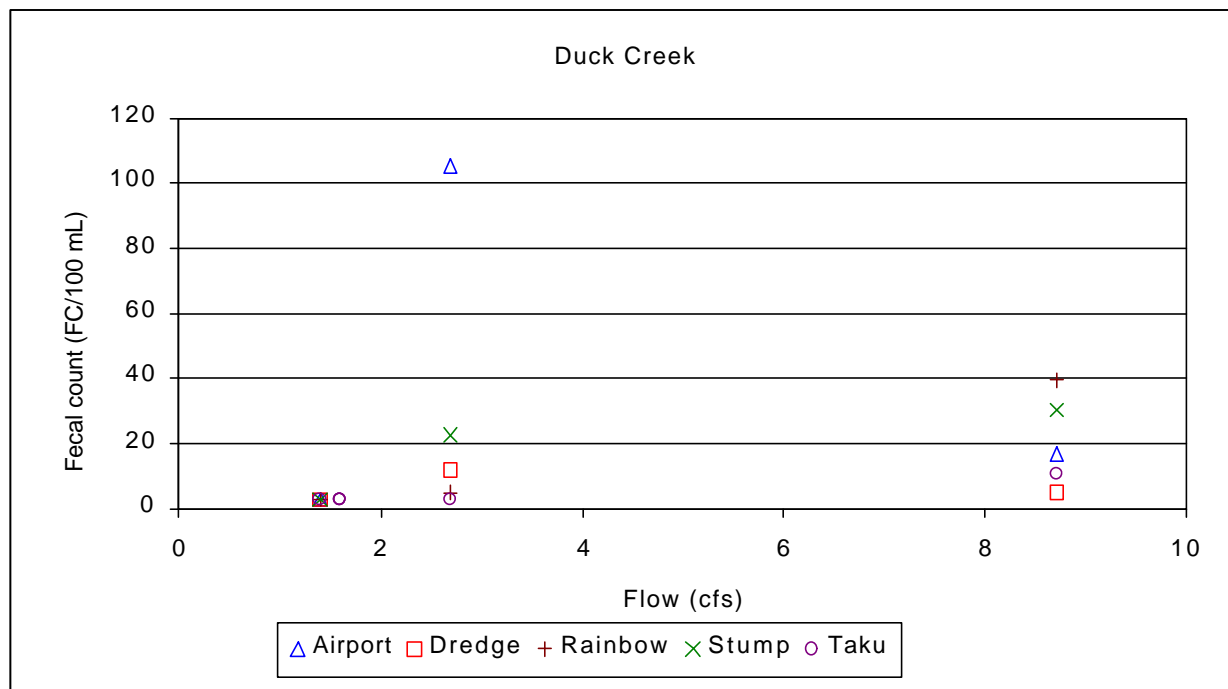


Figure 3. Observed fecal coliform bacteria per 100 mL vs. flow at Nancy Street

Pollutant Sources

An assessment of potential fecal coliform sources is needed to evaluate the type, magnitude, timing, and location of the bacteria loading to Duck Creek. The source assessment includes identification of the various types of sources (e.g., point, nonpoint, background), determination of the relative location and magnitude of loads from the sources, and the transport mechanisms of concern. Of particular concern are the loading processes that cause the impairment. Loadings are often evaluated using a variety of tools, including existing monitoring information, simple calculations, spreadsheet analysis using empirical methods, and a range of computer models.

Point Sources

No point sources are specified in the DCAG reports (Lorenz, 1998; Koski and Lorenz, 1999). A search of EPA's Permit Compliance System identified no point sources in the Duck Creek watershed. Because the entire Duck Creek Watershed is sewer, it is assumed that septic systems are not contributing to the fecal coliform impairment of Duck Creek (ADEC, personal communication, July 7, 2000). There are no reported sewage leaks in the watershed.

No data are available at this time to estimate the contribution of combined sewer overflows (CSOs) to the fecal coliform bacteria impairment of Duck Creek. However, any CSOs that might

exist in the Duck Creek watershed should be identified and corrected or controlled to the extent possible.

Due to the small size of Juneau, no municipal stormwater permits are currently required for this area. Therefore, urban runoff (storm water) is treated as a nonpoint source in this TMDL. In addition, there are currently no known industrial stormwater permits in this watershed.

Because of the lack of point source dischargers in the watershed, the wasteload allocation is set to zero.

Nonpoint Sources

Fecal coliform bacteria are a constituent of human sewage and animal waste and can be found in natural waters. A few strains of coliform bacteria can produce serious human illness, but their abundance is primarily used to assess the potential for the presence of other more virulent pathogens associated with sewage (Lorenz, 1998). Nearly half of the Duck Creek watershed provides space for residential housing, yards, and driveways, and another third of the watershed is used for transportation, commercial, or industrial interests (Lorenz, 1998). Because of the nature of the Duck Creek watershed, it is likely that storm water runoff is the primary means by which fecal coliform bacteria are transported to the creek. There are many potential sources of fecal coliform in urban runoff, but the major sources in Duck Creek are thought to be wildlife (mainly ducks) and domestic pets (mainly dogs). A horse stable that was previously thought to contribute fecal coliform bacteria to Duck Creek has since been relocated outside the watershed. Because storm water runoff integrates many watershed sources into a single source, it is difficult to determine the magnitude of the loads from individual sources. The following sections do, however, provide an estimate of the relative contribution of what are believed to be the largest of these sources (ducks and dogs).

Ducks

It is estimated that there are approximately 50 ducks in residence along Duck Creek (ADEC, personal communication, July 7, 2000). The American Society of Agricultural Engineers has found that on average, ducks produce 2.43×10^9 fecal coliform bacteria per animal per day (ASAE, 1998). The estimated production of fecal coliform bacteria by ducks in Duck Creek is therefore calculated to be 4.43×10^{13} fecal coliform bacteria per year.

Dogs

It is estimated that there are approximately 1,250 dogs in residence in the Duck Creek watershed (ADEC, personal communication, July 7, 2000). Horsely and Whitten (1996) estimate that, on average, dogs produce 5×10^9 fecal coliform bacteria per animal per day. The estimated production of fecal coliform bacteria by dogs in Duck Creek is therefore calculated to be 2.28×10^{15} fecal coliform bacteria per year.

The estimates presented above suggest that domestic dogs contribute the vast majority of the total nonpoint source fecal coliform load in urban runoff, with ducks contributing the remaining 2 percent.

Analytical Approach

Development of 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 Duck Creek, the following core set of principles was identified and applied:

- *The TMDL 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 local agency staff.
- *The TMDL must use the best available data.* All available data in the watershed were reviewed and were used in the analysis when 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, with additional detail provided in the appendix. 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 load allocations presented below relies on the above principles and provides a TMDL calculation that uses the best available information to represent watershed and in-stream processes.

Modeling Approach

The objective of this section is to document and summarize the hydrologic and water quality modeling approaches applied to estimate in-stream fecal coliform concentrations and loadings in the Duck Creek watershed. The Storm Water Management Model (SWMM) simulates the quantity and quality of runoff produced by storms in urban watersheds (USEPA, 1997). SWMM allows for the representation of mixed-land-use watersheds using continuous simulation based on observed meteorologic conditions. At the subwatershed scale, SWMM provides for evaluation of in-stream conditions, allowing for direct comparison with the relevant water quality standards. The model represents Duck Creek as a series of hydrologically connected subwatersheds.

Hydrologic and water quality simulations of the watershed were performed for Duck Creek. The modeling approach used included continuous simulation of rainfall and runoff, as well as in-stream fecal coliform concentrations. Flow and in-stream fecal coliform concentrations and loadings were simulated as time series and summarized based on the subwatershed annual loadings. The estimates of in-stream concentrations and pollutant loadings to Duck Creek are used to estimate the

existing conditions in Duck Creek and to develop an allocation scenario that results in attainment of Alaska's water quality standards and minimizes the frequency of standard exceedances.

Model Setup

The Duck Creek system consists of the main stem and two major tributaries, El Camino and the East Fork. To capture the spatial distribution of the fecal coliform sources, the watershed was subdivided into six subwatersheds (four main stem and two tributary). The main stem, Duck Creek, was subdivided into four segments that coincide with sampling locations and tributary junctions. The main stem segments are

- Segment 1 - Above Taku
- Segment 2 - Taku to El Camino
- Segment 3 - El Camino to Nancy Street
- Segment 4 - Nancy Street to Mouth

Model Input

Hourly precipitation and climate data from Juneau Airport (504100) were not available for the simulation period (January 1, 1994 to January 1, 1996). Hourly precipitation data from Annette WSO Airport (AK0352) and Yakutat WSO Airport (AK9941) were combined using a normal-ratio method to create a continuous hourly precipitation record for the Duck Creek watershed. For the most recent 7 years of data, 1990 to 1996, a statistical summary of rainfall indicates that the mean annual rainfall is 69.6 inches with a maximum of 88 inches, a minimum of 55 inches, and a standard deviation of 12.3 inches. The simulation period, 1994 to 1996, was considered to be representative of the long-term annual and seasonal variability of rainfall in the watershed because of the similarity of the standard deviations for the simulation period and for the period of record.

Hydrologic Simulation

Existing data indicate that the number of fecal coliform bacteria is highest during higher flow events. To account for the delivery of fecal coliform loads during runoff-producing events, it was necessary to develop a model that captures the watershed runoff and the in-stream hydrologic regimes. The SWMM model was set up using data on watershed characteristics that influence runoff volume (e.g., land use distribution and percent imperviousness), and the available flow record from the Nancy Street gage. Once the model was calibrated to existing hydrology, it was used to simulate the effects of existing loadings on in-stream fecal coliform concentrations, as well as the load reductions necessary to attain water quality standards.

Water Quality Simulation

After calibrating the hydrologic component of SWMM, water quality was simulated by developing fecal coliform accumulation rates using information obtained on the number of animals and their typical fecal coliform counts. In the model, the fecal coliform loading to Duck Creek was

established as the relationship between fecal coliform buildup (which, among other things, is a function of time between runoff-producing events) and the wash-off of the buildup. The fecal coliform buildup was assumed to behave in a linear fashion; that is, it accumulates at a uniform rate and continues to accumulate at that rate (with no maximum) until some fraction is washed off during a storm event of sufficient intensity and duration. The uniform buildup rate was adjusted to obtain a best fit for monitoring data at Taku Boulevard and Nancy Street, Segments 1 and 3, respectively. Segment 4 was compared to Airport Road, which is located at the lower half of Segment 4. Once calibrated to the existing monitoring data, the model was used to simulate a continuous existing condition.

Loading Capacity

One of the essential components of a TMDL is identifying and representing the relationship between the desired condition of the stream (expressed as the water quality standard) and pollutant loadings. Once this relationship has been established, it is possible to determine the capacity of the waterbody to assimilate fecal coliform loadings and still attain water quality standards.

It is estimated that 75 percent of the watershed (810 acres) drains to the USGS gaging station at Nancy Street. Duck Creek currently experiences flow losses in the reach downstream of the Nancy Street station, to the point that flow is entirely absent from this reach during certain parts of the year. Several management options have been proposed to restore flow in this reach, including lining the streambed to prevent flow losses to groundwater and flow augmentation (Koski and Lorenz, 1999). Since no data are available on flow rates below Nancy Street, this analysis assumes that flow is conserved from Nancy Street to the mouth of the creek at Radcliff Road.

The loading capacity is the product of the instream flow and concentration. Using available flow and water quality monitoring data, a 2-year simulation period (January 1, 1994 to January 1, 1996) was used to estimate the loading capacity of Duck Creek for fecal coliform bacteria. The results of that simulation are presented in Table 3 for the four main stem segments modeled. The loading simulated in each model segment is input into the next downstream segment during the simulation. The loading capacity for the entire creek and for the TMDL is therefore represented by the loading in the most downstream segment, segment 4. Segment 4 has the largest loading capacity of the four segments, but it also contains the largest volume of flow. As a result, segment 4 has the lowest concentration of fecal coliform bacteria of the 4 segments. The use of segment 4 to set the loading capacity for the entire creek represents the most stringent estimate of the creek's loading capacity.

Table 3. Loading capacity of Duck Creek for fecal coliform bacteria

Segment Number	Segment Name	Simulated Annual Flow (Total ft ³ /yr)	Annual Loading Capacity (Total FC/yr)	Annual Average Concentration (FC/100 mL/yr)

1	Above Taku	1.28×10^7	4.98×10^{10}	14.54
2	Taku to El Camino	3.79×10^7	1.26×10^{11}	12.39
3	El Camino to Nancy	6.55×10^7	1.83×10^{11}	10.35
4	Nancy to Mouth	8.95×10^7	2.23×10^{11}	9.23

Existing conditions were simulated for the same time two year period. The model predicted an annual total of 58 exceedances of the 30-day geometric mean standard of 20 FC/100 mL and 90 exceedances of the 40 FC/100 mL standard which may not be exceeded in more than 10 percent of samples. Table 4 shows the predicted number of fecal coliform standard exceedances per year for the existing conditions scenario in Duck Creek for the four main stem segments modeled.

Table 4. Predicted annual exceedances of the water quality standards for fecal coliform bacteria in Duck Creek under the existing conditions scenario

Segment Number	Segment Name	20 FC/100 mL 30 day geometric mean standard (daily model output)		40 FC/100 mL standard not to be exceeded in more than 10% of samples (daily model output)	
		Number of Exceedances	Percent Exceedances	Number of Exceedances	Percent Exceedances
1	Above Taku	23	6.6%	32	8.8%
2	Taku to El Camino	21	6.0%	25	7.0%
3	El Camino to Nancy	10	2.7%	17	4.7%
4	Nancy to Mouth	4	1.3%	16	4.4%
Total Exceedances Under Existing Conditions Scenario		58	4.1%	90	6.2%

Wasteload Allocation

Because no point sources contribute to the fecal coliform impairment to Duck Creek, and because any CSOs that might contribute to the impairment must be controlled, the wasteload allocation is set to zero. At this point, there are no known CSOs.

Load Allocation

The load allocation was determined for the nonpoint source loads contributing to each of the segments of Duck Creek. The load allocation is expressed as an annual total number of fecal coliform bacteria and is presented for each segment, with the most downstream segment, segment 4, representing the loading capacity for the creek as a whole. The load allocation is indicative of a source loading reduction applied throughout the year that will result in meeting water quality standards. It is assumed that Best Management Practices (BMPs) used to control stormwater-driven nonpoint sources will be effective throughout the year, not just during storm events. Annual allocations for each segment are shown in Table 5, with segment 4 representing the total load allocation to the entire creek. The total load allocation is 2.23×10^{11} FC/yr. The allocation scenario loadings resulted in no exceedances of the geometric mean criterion. The not-to-exceed criterion was exceeded 2.1 percent of the time over the 2-year simulation period, thus, attaining the load allocations will lead to the attainment of Alaska's fecal coliform bacteria criteria for Duck Creek. This would require a 38% reduction from existing conditions. The results of the load allocation are shown in Figure 4.

Table 5. Fecal coliform loadings to Duck Creek under the existing conditions and load allocation scenarios

Segment Number	Segment Name	Simulated Annual Flow (Total ft ³ /yr)	Existing Conditions (FC/yr)	Load Allocation (FC/yr)	Percent Reduction Required
1	Above Taku	1.28×10^7	8.17×10^{10}	4.98×10^{10}	39%
2	Taku to El Camino	3.79×10^7	2.07×10^{11}	1.26×10^{11}	39%
3	El Camino to Nancy	6.55×10^7	2.99×10^{11}	1.83×10^{11}	39%
4	Nancy to Mouth	8.95×10^7	3.62×10^{11}	2.23×10^{11}	38%

The allocation scenario loadings resulted in no exceedances of the geometric mean criterion. The not-to-exceed criterion was exceeded 2.2 percent of the time over the 2-year simulation period, thus, attaining the load allocations will lead to the attainment of Alaska's fecal coliform bacteria criteria for Duck Creek. The total number of predicted exceedances for the allocation scenario is shown in Table 6.

Table 6. Predicted annual exceedances of the water quality standards for fecal coliform bacteria in Duck Creek under the load allocation scenario

Segment Number	Segment Name	20 FC/100 mL 30 day geometric mean standard (daily model output)		40 FC/100 mL standard not to be exceeded in more than 10% of samples (daily model output)	
		Number of Exceedances	Percent Exceedances	Number of Exceedances	Percent Exceedances
1	Above Taku	0	0.0%	12	3.4%
2	Taku to El Camino	0	0.0%	10	2.7%
3	El Camino to Nancy	0	0.0%	5	1.2%
4	Nancy to Mouth	0	0.0%	4	1.1%
Total Exceedances Under Load Allocation Scenario		0	0.0%	31	2.1%

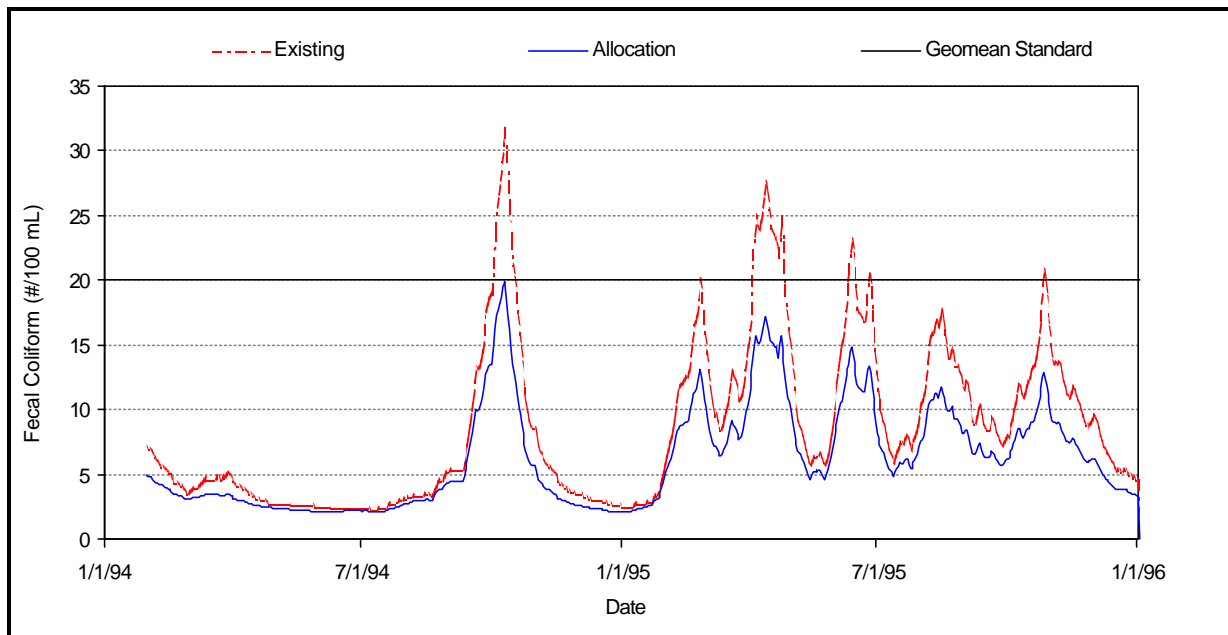


Figure 4. Existing conditions and allocation scenarios for Duck Creek

Margin of Safety

This section addresses the incorporation of a margin of safety (MOS) into the TMDL analysis. The MOS accounts for any uncertainty or lack of knowledge concerning the relationship between pollutant loading and 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 loadings) or a combination of both.

The MOS was included in this TMDL implicitly through a series of conservative assumptions. These conservative assumptions included:

- The use of a linear buildup rate for fecal coliform: other buildup methods, such as exponential buildup, would yield slower buildup in the first few days after a storm. Given the high frequency with which rain events occur in Juneau, a linear buildup rate will tend to estimate a higher amount of fecal coliform bacteria.
- No maximum was placed on the amount of fecal coliform bacteria buildup: in the field, fecal coliform bacteria will generally buildup to a maximum level at which the rate of buildup is balanced by the rate of die-off. No such maximum level was used in the model, allowing higher levels of buildup to occur between storms.
- The application of the geometric mean standard to continuous daily simulated values: a geometric mean is inherently conservative, in that a single elevated value can have a disproportionate effect on the overall mean. The simulated geometric mean was calculated using continuous 30 day blocks of values, such that every simulated daily value was taken into account.

Seasonal Variation

The generation and availability of fecal coliform bacteria in the Duck Creek watershed, primarily from wildlife and pets, is not expected to vary seasonally. The delivery of fecal coliform bacteria to the creek, however, will vary with climate and flow conditions, as discussed in the Critical Conditions and Modeling Approach sections above. The use of continuous simulation modeling accounts for these variations by reflecting seasonal climatic and hydrologic conditions as they occur throughout the year.

The observed data available for the simulation period (January 1, 1994 to January 1, 1996) were collected in only three months of the year (see Table A-3). It was not possible to accurately break the annual allocation into monthly allocations based on so few data. As additional data are collected in Duck Creek, sampling should be distributed throughout the year to better capture any seasonal variation in fecal coliform bacteria levels.

Monitoring

Very limited data were available to support the development of this TMDL. The AWW observations believed to have been the basis for listing Duck Creek for fecal coliform bacteria did not have any corresponding flow values. And the ADEC data that coincide with the flow record were actually *E. coli* observations from which fecal coliform values had to be estimated. Recognizing these inherent uncertainties, EPA has encouraged the development of TMDLs using available information and data with the expectation that a commitment to additional monitoring will accompany the TMDL (USEPA, 1991). This approach allows proceeding with source controls while additional monitoring data are collected to provide a basis for reviewing the success of the TMDL. This approach enables stakeholders to move forward with resource protection based on existing data and less rigorous analysis.

The past and current coliform bacteria monitoring activities in the Duck Creek watershed have been minimal and are outlined in the water quality analysis section of this TMDL (and in the DCMP). Although the status of future monitoring programs is unknown, it is anticipated that water quality and flow monitoring will continue at the USGS sampling stations in the watershed. The collection of coliform bacteria data at these stations is strongly recommended. The monitoring data collected at these sites will provide data that

- Verify the assumption that urban runoff and animal waste, from both domestic pets and wildlife, are the primary nonpoint sources of fecal coliform in Duck Creek.
- Assess improvements in water quality.
- Verify the regression relationship applied to fecal coliform bacteria and *E. coli*.

In addition to continued collection of data at the USGS stations, water quality monitoring by other involved state and federal agencies (e.g., ADEC, National Marine Fisheries Service) and volunteer groups should continue in a coordinated manner.

The focus of the monitoring program should be on the assessment of stormwater, in-stream conditions, and impacts of stream restoration projects on water quality. The parameters sampled should include flow, total coliform bacteria, fecal coliform bacteria, and *E. coli* at a minimum, and sampling sites should be distributed along the length of the stream. The monitoring will provide information on in-stream improvements and show long-term trends. Implementation monitoring is often cited as the most cost-effective of the monitoring types because it provides information on whether restoration efforts are having the desired effect on water quality. Specific projects that potentially affect water quality conditions should be monitored to determine their immediate on-site effects.

Although it is not feasible to develop a detailed monitoring plan at this time, it is expected that upon TMDL adoption, participating parties will develop a cost-effective monitoring plan to assess the effectiveness of the restoration of Duck Creek.

Possible Future Actions

Public Participation

The Duck Creek Advisory Group (DCAG) was formed in 1993 to plan and coordinate restoration and protection of water quality and fish habitat in Duck Creek and its adjacent wetlands. The DCAG includes representatives of the City and Borough of Juneau, state and federal agencies, private businesses, conservation organizations, and homeowners. While the DCAG provides interagency coordination and addresses technical issues, the Mendenhall Watershed Partnership (the Partnership) which was formed in 1998, is a citizen group that provides direction and coordination for protection and restoration projects, public information and education, and volunteer activities throughout the watershed – including Duck Creek. Some of the activities sponsored by the MWP include the following:

- Adopt-a-stream: community groups volunteer to help keep streams in the Mendenhall watershed litter-free.
- Storm drain stenciling: the message “Dump No Waste, Drains to Stream” is stenciled on storm drains to let residents know that waste dumped into storm drains is transported directly to streams without treatment.
- Public education and events: field trips, community forums on important watershed issues, and technical workshops on erosion control and water pollution prevention are organized.
- Youth education: the MWP and Discovery Southeast host “Watershed Discovery Days” for youth to explore, do hands-on science, and help with a stewardship project in the watershed.
- Restoration projects: examples of projects include wetland habitat restoration and stabilization of eroding stream banks.
- Smart development: the MWP has worked with local builders and landowners to prepare user-friendly maps that will help them design their projects with better information about watershed resources.
- Flood control: record flooding in 1998 demonstrated the need for hydrologic studies of the watershed. MWP funding supports the USGS hydrologic studies in the valley.

Public attitudes and perceptions toward the importance of Duck Creek are already changing as a result of the work done by the DCAG and the Partnership, and it is hoped that these organizations will continue their efforts in the future. Public awareness of the impacts of urban runoff and animal waste on fecal coliform contamination in small streams such as Duck Creek will help foster a sense of ownership and a demand for stricter enforcement of water quality standards.

Education

Watershed education should include informing the public and development community about the fish and other wildlife that depend on good water quality, the causes of pollution, and the environmental safeguards in place to maintain and restore water quality and fish habitat. In particular, the community needs to understand the effects of land disturbing activities and other sources of pollution on water quality, and to be aware of the local ordinances and other regulations that are in place to prevent degradation of our aquatic resources.

Restoration and Management

Because of the high level of pollution and the substantial loss of aquatic resources in the watershed, a major effort will be needed to restore Duck Creek. The Duck Creek Watershed Management Plan (DCMP, 1999) identifies two areas in which restoration efforts should be focused – water quality and fish habitat. The plan recommends that water quality restoration efforts should concentrate on maintaining flow throughout the stream, creating wetlands to treat storm water, developing riparian greenbelts to serve as stream buffers, and reducing dissolved iron levels in the stream. Fish habitat restoration efforts should focus on the restoration of stream hydrology, including reduced flooding, and increased stream baseflow, and improved stream crossings.

A number of demonstration projects have already been completed, including several improved stream crossings, better snow management, revegetation, sediment removal and channel reconfiguration, and wetland creation. Planned projects include additional stream crossing improvements, wetland creation and riparian zone revegetation, control of dissolved iron, streamflow restoration, streambed lining or sealing, fine sediment removal, and public access and education. The selection and implementation of restoration projects should be balanced with residents' concerns regarding drainage and flood control, while focusing on storm water treatment and wetland management. Current and planned projects aimed at restoring wetlands, streamflow and streamside vegetation will be particularly useful in addressing the fecal coliform impairment to Duck Creek by increasing streamflow and filtering pollutants from runoff before it reaches the stream. The following projects and activities would also help address this impairment:

- Encourage the cleanup and proper disposal of pet waste by pet owners.
- Use BMPs to help control urban runoff (e.g., constructed wetlands, infiltration basins, grass swales).

Flow Reservations

One way to make sure that there is adequate water flow to maintain water quality and fish populations is through a "flow reservation." The Alaska Department of Natural Resources (ADNR) can allocate minimum flows to protect fish and water quality. Once a flow allocation is

granted, water can not be diverted to another use that would reduce flows below the minimum flow reservation. A first step toward the protection of instream flows was initiated by the Juneau Chapter of Trout Unlimited (TU) in 1993, when it filed an application for an instream flow reservation in Duck Creek to sustain fish production and habitat in the creek and its tributaries. This flow reservation has not yet been adjudicated by ADNR, and so it is not known how much of the requested reservation will be granted. An additional flow reservation request could be made to protect water quality and would force adjudication of the 1993 TU request. The prevention of additional decreases in instream flows in Duck Creek is critical for fish habitat restoration, as well as to achieve the water quality goals set forth in this TMDL.

Monitoring

A better understanding of surface and ground water flows in the Mendenhall Valley and Duck Creek would be helpful in the design of restoration and protection actions. In addition, ongoing flow and water quality monitoring are needed to determine the effectiveness of the TMDL in meeting water quality standards in Duck Creek.

Stormwater Management

The City and Borough of Juneau Planning Commission recently recommended that the Assembly amend the Comprehensive Plan to include development and implementation of a comprehensive borough-wide stormwater management plan. The requested amendment would include discussion of how the lack of stormwater management results in an increase in nonpoint source pollution, and calls for the development of a borough-wide plan that will include:

- A mapped inventory of current stormwater discharge points
- An inventory of sediment load and pollutants at each site
- An evaluation of how current standards for public and private development affect water quantity and quality and how they can be improved to help reduce water quantity and improve water quality before stormwater enters the storm drain system
- Development of performance standards, for public and private development, regarding the amount of pollution and sediment that gets transported with stormwater into the drainage systems and into the streams, lakes or channel
- An evaluation snow management practices
- Establishment of required BMP standards for erosion control.

The development and implementation of a borough-wide comprehensive stormwater management plan is integral to achieving the water quality goals set forth in this TMDL.

Public Participation Process

EPA published a public notice on the proposed Duck Creek TMDL for fecal coliform bacteria in the *Juneau Empire*, the newspaper with the largest circulation in the Juneau area. The public comment was open from August 15, 2000 to September 15, 2000. Additionally, this proposed TMDL was presented at the Duck Creek Advisory Group's meeting on August 16, 2000. In the published public notice, EPA invited the public to attend this meeting. EPA developed a website, which included the public notice, a fact sheet and the draft TMDL and advertised the website address in the public notice. This website was posted on both EPA Region 10's website and linked from Alaska Department of Environmental Conservation's website. Additionally, EPA directly sent and e-mailed copies of the public notice and draft TMDL to key federal, state and local agencies, environmental groups and other local organizations.

Alaska Department of Fish and Game provided the only comments on this specific TMDL. Their comments pertained to instream flow reservations and flow augmentation discussed under future TMDL implementation actions. The responsiveness summary, which discusses how these comments are addressed, is provided under the following section "Response to Public Comments."

EPA's Response to Comments

EPA received three public comments from Alaska Department of Fish and Game on the proposed Duck Creek TMDL for Fecal Coliform Bacteria. This section of the TMDL summarizes the issues raised in the comment letters and provides EPA's response to those issues.

Issue 1: The proposed TMDL reports should acknowledge that the first step to protect Duck Creek instream flows has been initiated, but not completed. No reservations of water for general water quality or for recreation purposes have been filed to date.

Response: The following text has been added to the Possible Future Actions section of this TMDL:

One way to make sure that there is adequate water flow to maintain water quality and fish populations is through a "flow reservation." The Alaska Department of Natural Resources (ADNR) can allocate minimum flows to protect fish and water quality. Once a flow allocation is granted, water can not be diverted to another use that would reduce flows below the minimum flow reservation. A first step toward the protection of instream flows was initiated by the Juneau Chapter of Trout Unlimited (TU) in 1993, when it filed an application for an instream flow reservation in Duck Creek to sustain fish production and habitat in the creek and its tributaries. This flow reservation has not yet been adjudicated by ADNR, and so it is not known how much of the requested reservation will be granted. An additional flow reservation request could be made to protect water quality and would force adjudication of the 1993 TU request. The prevention of

additional decreases in instream flows in Duck Creek is critical for fish habitat restoration, as well as to achieve the water quality goals set forth in this TMDL.

Issue 2: ADF&G has two instream flow reservation applications pending adjudication by ADNR for protection of fish and wildlife within the Mendenhall River. These two reservations were filed on April 10, 1992 (LAS 13806 and LAS 13807). Impacts to these reservations should be included in the assessment of identifying water sources to augment flows within Duck Creek.

Response: The following text has been added to the Possible Future Actions section of this TMDL:

A better understanding of surface and ground water flows in the Mendenhall Valley and Duck Creek would be helpful in the design of restoration and protection actions. In addition, ongoing flow and water quality monitoring are needed to determine the effectiveness of the TMDL in meeting water quality standards in Duck Creek.

Issue 3: The instream flow reservation applications filed for Duck Creek and the Mendenhall River are pending adjudication. Until the adjudication processes for these and other water rights applications are completed, the ultimate amounts of water that ADNR will grant for these water reservations and other out-of-stream water uses will remain unknown.

Response: As mentioned in the response to Comment 1, the following text has been added to the Possible Future Actions section of this TMDL:

This flow reservation has not yet been adjudicated by ADNR, and so it is not known how much of the requested reservation will be granted.

Appendix: Water Quality and Flow Monitoring Data

1994-1998 U.S. Geological Survey Streamflow Monitoring

Table A-1. Streamflow data from USGS gaging station at Nancy Street (15053200) and precipitation from NCDC Juneau International Airport Station (504100) from 1994 to 1998

Year ^a	1994				1995		1996		1997		1998	
Annual mean flow (cfs)	3.87				2.65		3.67		3.85		3.75	
Annual runoff (acre-feet/yr)	2,800				1,920		2,660		2,790		2,710	
Annual precipitation (in/yr)	68.89				46.35		60.45		74.62		53.20	
Annual precipitation (acre-feet/yr)	6,200				4,170		5,440		6,720		4,790	
Month ^b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flow (cfs)	1.70	2.30	2.52	2.76	2.49	2.00	2.76	3.61	6.72	7.52	3.92	4.31
Precipitation (in/month)	3.27	4.77	4.25	3.10	2.86	3.50	5.43	5.27	8.74	8.27	4.32	6.92

^a Annual values are summarized by calendar year.

^b Monthly values are averages for 1994 to 1998.

1992-1993 Alaska Water Watch Water Quality Monitoring

Table A-2. AWW total and fecal coliform monitoring results

Sampling Site	Date	Total coliform (MPN/100 mL)	Fecal coliform (MPN/100 mL)
Taku Blvd	6/30/92	110	2
	8/2/93	90	2
Mendenhall Blvd	6/30/92	130	13
	8/2/93	170	2
McGinnis Dr	6/30/92	1,600	1,600
	8/2/93	1,600	700
Kodzoff Acres	6/30/92	1,600	500
	8/2/93	900	20
Mendenhall Mall Rd	6/30/92	500	17
	8/2/93	3,500	400

1994-1995 and 1998 Alaska Department of Environmental Conservation Water Quality Monitoring

Table A-3. ADEC total coliform and *E. coli* monitoring results

Sampling Site	Date	Total coliform (MPN/100 mL)	<i>E. coli</i> (MPN/100 mL)	Notes
Dredge Lake	10/10/94	900	4	
	2/6/95	33	9	
	4/17/95	27	2	
Taku Blvd	10/10/94	500	8	
	2/6/95	14	2	
	4/17/95	50	2	
	4/18/98	5	2	Between sample wells 2 & 3
	4/18/98	2	2	Downstream
	4/18/98	2	2	Above Culvert
Rainbow Row	10/10/94	90	30	East Fork
	2/6/95	130	4	East Fork
	4/17/95	300	2	East Fork
Nancy Pond	4/6/98	–	5	East Fork
Stump Lake	10/10/94	170	23	
	2/6/95	80	17	
	4/17/95	80	2	
Airport Rd	10/10/94	130	13	
	2/6/95	1,600	80	
	4/17/95	900	2	

References

- ADEC. 1998. Final 1998 Alaska 303(d) List of Impaired Waters. Alaska Department of Environmental Conservation.
- ADEC. 1999. *18 AAC 70, Water Quality Standards*. Alaska Department of Environmental Conservation. May 27, 1999.
- ASAE. 1998. *Standard Engineering Practices Data*. 45th ed. American Society of Agricultural Engineers, St. Joseph, MO.
- Doran, J.W., J.S. Schepers, and N.P. Swanson. 1981. Chemical and bacteriological quality of pasture runoff. *Journal of Soil and Water Conservation* (May-June):166-171.
- Horsley and Witten, Inc. 1996. *Identification and evaluation of nutrient and bacterial loadings to Maquoit Bay, New Brunswick and Freeport, Maine*. Final report. Horsley and Witten, Inc.
- Koski, K., and M. Lorenz. 1999. *Duck Creek Watershed Management Plan*. Prepared for the Duck Creek Advisory Group and the 319 Program of the Clean Water Act, Juneau, AK.
- LTI. 1999. *Lower Geddes Pond TMDL Development Approaches*. Limno-Tech, Inc.
- Lorenz, M., ed. 1998. *Draft Duck Creek Watershed Draft Management Plan*. Duck Creek Advisory Group, Juneau, AK.
- USEPA. 1991. *Guidance for Water Quality-based Decisions: The TMDL Process*. EPA 440/4-91-001. U.S. Environmental Protection Agency, Washington, DC.
- USEPA. 1997. *Compendium of Tools for Watershed Assessment and TMDL Development*. EPA 841-B-97-006. U.S. Environmental Protection Agency, Office of Water, Washington, DC.
- USEPA. 1999. *Total Maximum Daily Load (TMDL) for Turbidity in the Waters of Duck Creek in Mendenhall Valley, Alaska*. U.S. Environmental Protection Agency, Region 10, Seattle, WA.