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DEPARTMENT OF
ECOLOGY

North Creek Watershed

Total Maximum Daily Load Evaluation for Fecal Coliform Bacteria

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Total Maximum Daily Load Evaluation for Fecal Coliform Bacteria

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Abstract

The Washington State Department of Ecology initiated a Total Maximum Daily Load for fecal coliform bacteria in North Creek, in south Snohomish County. Dry season concentrations higher than those in the wet season suggest that there is a continuous, steady component to the pollution loading. Since concentrations are relatively high during the wet season and flows are dramatically higher, there is also a storm-related component to the loading. Pollution sources in the basin are exclusively from diffuse sources (i.e., no municipal or industrial discharges). The predominant sources are agriculture, on-site disposal (septic) systems, and post-development activities attributable to urban development (e.g., domesticated animals).

The best approach when developing control measures for these diffuse sources is to maintain or increase flow rates throughout the dry season, while focusing on lowering concentrations in the water. Flow attenuation can be achieved in this watershed with detention ponds, establishing or restoring wetlands, and managing riparian corridors. A long-term monitoring strategy would be essential to track and evaluate the effectiveness of the source control measures.

Acknowledgements

The author would like to thank Jannine Jennings of the U.S. Environmental Protection Agency and also Deborah Cornett, Karol Erickson, Dave Garland, and Ralph Svrjcek of the Washington State Department of Ecology for their valuable comments on this draft report. Thank you also to Joan LeTourneau for editing and formatting the report.

Introduction

Total Maximum Daily Load Overview

Under the federal Clean Water Act, every state has its own water quality standards designed to protect, restore, and preserve water quality. Water quality standards consist of designated uses, such as cold water biota and drinking water supply, and numeric criteria to achieve those uses. When a lake, river, or stream fails to meet water quality standards after application of required technology-based controls, the Clean Water Act requires the state to place the waterbody on a list of *impaired* waterbodies and to prepare an analysis called a Total Maximum Daily Load (TMDL).

Section 303(d) of the Clean Water Act mandates that Washington State establish TMDLs of pollutants for surface waters that do not meet standards after application of technology-based pollution controls. The U.S. Environmental Protection Agency (EPA) has established new regulations[1] and developed guidance (EPA, 1991) for determining TMDLs.

The goal of a TMDL is to set baselines and boundaries for the discharge of pollution into discrete waterbodies in order to attain water quality standards. A TMDL includes a written, quantitative assessment of water quality problems and pollutant sources that cause the problems. The TMDL determines the amount of a given pollutant that can be discharged to the waterbody and still meet water quality standards. The TMDL also determines the loading capacity and allocates that loading capacity among the various sources. If the pollutant comes from a discrete source (point source) such as an industrial facility's discharge pipe, that facility's share of the loading capacity is called a wasteload allocation. If pollution comes from a diffuse source (nonpoint source) such as agricultural land or neighborhoods, that nonpoint share is called a load allocation.

The TMDL must include a margin of safety that takes into account lack of knowledge about the causes of the water quality problem or its loading capacity. The TMDL must also account for seasonal variability and address future growth. The sum of the individual allocations and the margin of safety must be equal to or less than the loading capacity.

This *North Creek Watershed Total Maximum Daily Load Evaluation for Fecal Coliform Bacteria* was an initial technical study developed by the Washington State Department of Ecology (Ecology) to verify the existence of the bacteria problem and provide a basis for future water cleanup efforts in North Creek. The geographic scope of this TMDL includes the mainstem and tributaries of North Creek as well as approximately 19,000 acres within the North Creek watershed. A water quality management plan (Water Cleanup Plan) will ultimately be established for North Creek to address impairments to contact recreation and to help protect fish and fish habitat that has been degraded due to low oxygen, high nutrient loading, and bacteria from fecal coliform sources. The Cleanup Plan will be developed collaboratively by Ecology and other interested parties.

[1] Title 40, Part 130 of the Code of Federal Regulations or 40 CFR 130

All Water Cleanup Plans, which include the recommended loading allocations and a summary of the implementation strategy, must be made available for public comment before being submitted to EPA for approval. Following EPA's approval, a detailed implementation plan will be developed based on the information in this document and the summary implementation strategy.

Basin Overview

North Creek is located predominantly in south Snohomish County as shown in Figure 1. It originates in the Everett Mall Way area of south Everett and flows southerly for 12.6 miles before discharging to the Sammamish River, within the city of Bothell. The Sammamish River drains into Lake Washington and ultimately through the Ballard Locks to Puget Sound. The last mile-and-a-half of North Creek is located in King County. The stream gradient is flat, decreasing from about 50 feet per mile in the upper basin to less than 20 feet per mile near the mouth. The major tributaries are Penny Creek and Silver Creek/Tambark Creek.

The watershed is nearly 10 miles long, 3 miles wide, and encompasses an area of about 19,000 acres. Approximately 17 percent of the watershed lies within the city of Everett, 5 percent lies within King County (the city of Bothell), 10 percent lies within the city of Mill Creek, and the remaining 68 percent lies within unincorporated Snohomish County.

Land use within the watershed changed drastically from 1965 to 1975. The trend toward small ranches and hobby farms was replaced by a trend toward large residential developments and mobile home communities, interspersed with large shopping centers, many small businesses, and supporting facilities. This trend continues today, with emphasis on commercial, light industrial, and business parks.

The general land use zoning as provided in the 1977 North Creek Area Comprehensive Plan is classified as follows: 39% suburban family, 30% rural or low-density residential, 24% watershed site-sensitive area, nearly 3% high-density urban residential, and the remaining 4% divided among commercial, industrial, utility, and community facility uses. Only 3 acres are platted as agricultural land; however, many agricultural uses are included in the rural zoning designation (Snohomish County, 1977).

Water Quality Standards

North Creek is classified in Washington State's Water Quality Standards as a Class AA (extraordinary) waterbody because it is a feeder stream to a lake. The pertinent criteria are as follows:

- "Fecal coliform organism levels shall both not exceed a geometric mean value of 50 colonies/100 mL and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 100 colonies/100 mL."
- "Dissolved oxygen shall exceed 9.5 mg/L."

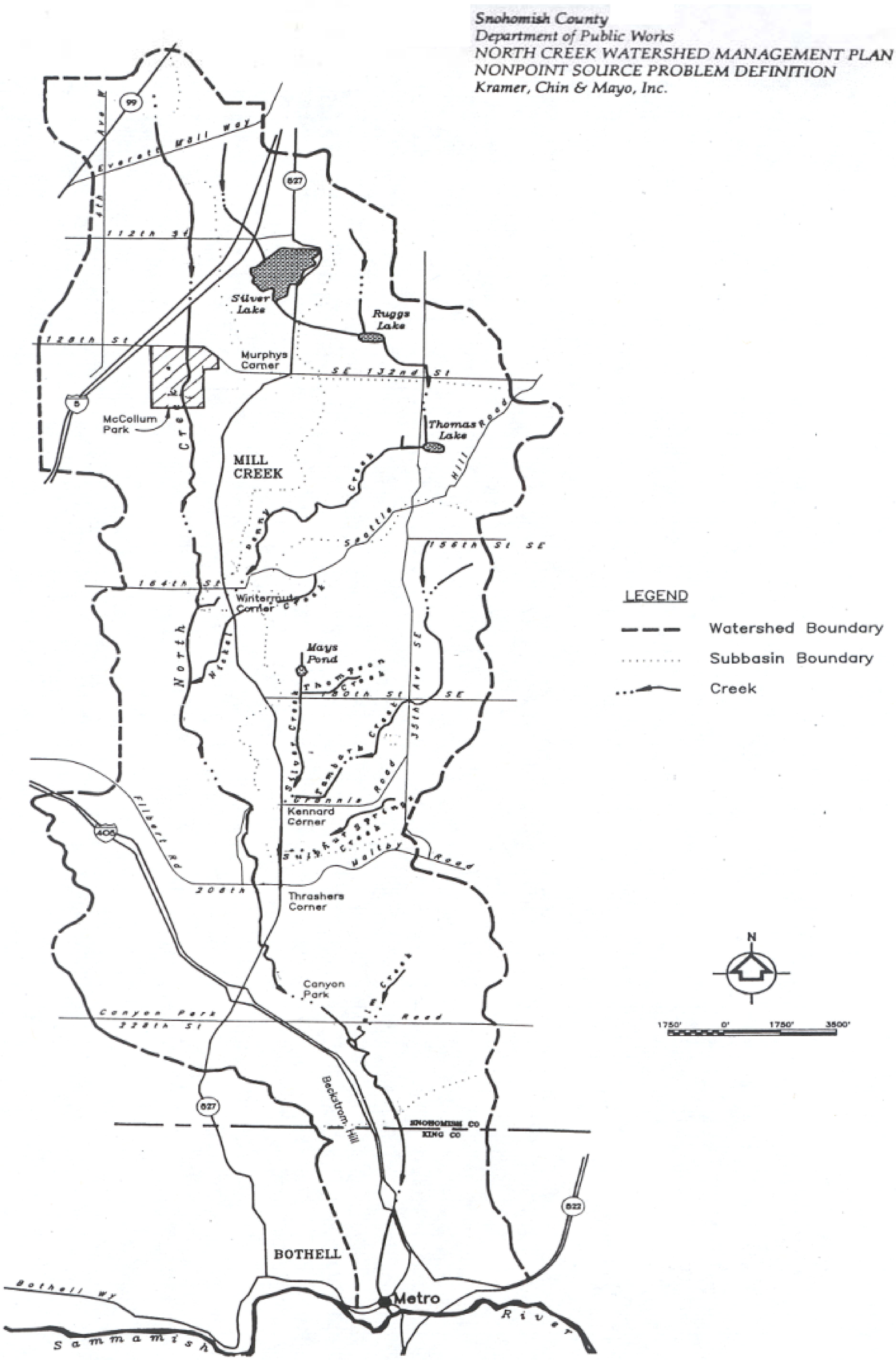

Figure 1. The North Creek Watershed

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As a Class AA waterbody, it must be capable of supporting characteristic (beneficial) uses that include the following:

- Water supply
- Stock watering
- Fish and shellfish rearing, spawning, migration, and harvesting
- Wildlife habitat
- Recreation (e.g., primary contact recreation, sport fishing, aesthetic enjoyment)

Appendix A contains the freshwater quality portion of the standards for a Class AA waterbody, including the characteristic uses and water quality criteria.

EPA, Washington State, and other states have questioned for some time whether fecal coliform bacteria are an optimal indicator of pathogenic bacteria in water. Ecology established a technical work-group to review the standards for bacteria, and a discussion paper was issued (Ecology, 1999). It appears that the freshwater standards are likely to change to Enterococci. Until then, it may be desirable to collect both fecal coliform bacteria and the new indicator simultaneously. After conversion to the new standard, it would also be desirable to monitor both fecal coliform bacteria and the new indicator simultaneously, to evaluate trends in fecal coliform bacteria as well as measure compliance with the new standards.

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Problem Definition

North Creek is a polluted urban stream system; water quality does not meet water quality standards for fecal coliform bacteria and dissolved oxygen. The creek and its tributaries are polluted because more people now live in the watershed and contribute to nonpoint pollution. Nonpoint pollution refers to pollution that comes from diffuse sources such as agricultural activities (e.g., hobby farms/animal-keeping), on-site disposal (septic) systems, and post-development activities (e.g., pet excrement and impervious surfaces/urban runoff).

303(d) Listings

The federal Clean Water Act, section 303(d), specifies that waterbodies that do not meet state surface water quality standards be placed on the state's list of impaired waterbodies, or 303(d) list. These listed waterbodies are where technology-based controls for point sources are insufficient and/or where the problem is nonpoint source related. States must then turn to water quality-based pollution control and TMDL evaluations (i.e., a TMDL must be established for each pollutant violating its water quality criterion).

North Creek was included on Washington's 1996 303(d) list because of violations of fecal coliform (FC) bacteria standards; dissolved oxygen (D.O.) was added to the 1998 list (Ecology, 1998). Tables 1a and 1b provide the pertinent information regarding North Creek 303(d) listings. Ecology's Environmental Assessment Program conducts TMDLs, following a schedule and prioritization process administered by Ecology's Water Quality Program.

Table 1a. Ecology's 1996 303(d) Listing for North Creek.

Waterbody			Parameters	
Name	Old Segment ID #	New Segment ID #	D.O.	FC
North Creek	WA-08-1065	N/A	-	X

Table 1b. Ecology's 1998 303(d) Listing for North Creek.

Waterbody			Parameters	
Name	Old Segment ID #	New Segment ID #	D.O.	FC
North Creek	WA-08-1065	SM74QQ	X	X

Beneficial Uses Affected

Lower summer flows and questionable water quality limit the usefulness of North Creek as a significant source of water for the basin. A total of 69 water rights applications have been filed to date. Fifty-nine of these have been granted by Ecology, and 13 permits have been canceled.

Withdrawals for irrigation/stock watering and domestic use are the most common applications. Thirty-one applications have been filed to irrigate over 800 acres, primarily for small hobby farms and ranches located in the rural eastern portion of the watershed. The only known commercial agricultural operations are a bison ranch, chicken farm, and greenhouse. There are 33 applications for domestic use; it is not clear whether any of these surface water withdrawals are currently used as potable water supplies. No major manufacturing facilities operate in the basin.

The North Creek Watershed Management Committee ranked fisheries habitat as the most important beneficial use in North Creek (Snohomish County, 1994). North Creek is considered a valuable spawning stream by the Muckleshoot Indian Tribe. However, Penny Creek is not currently a productive salmon stream due to the presence of a barrier dam located just 0.5 miles upstream of its confluence with North Creek.

In addition to bacteria sources from small farms, both viruses and pathogenic bacteria have been detected in storm runoff from urban areas at densities high enough to suggest a potential health risk (EPA, 2001). At least one park, Snohomish County's McCollum Park, affords ready access to the creek (i.e., primary contact recreation). The beneficial uses affected in the watershed have been documented in the *Technical Supplement* to the *North Creek Watershed Management Plan* (Snohomish County, 1994).

Project Objectives

The TMDL strategy for North Creek calls for focusing initially on fecal coliform bacteria, recognizing that sources of bacteria are typically sources that also affect dissolved oxygen. After the bacteria control measures are implemented, follow-up monitoring will determine if dissolved oxygen is in compliance with the standard, or if a separate TMDL for dissolved oxygen will be necessary.

Objectives for the North Creek basin TMDL evaluation include:

- Define wet and dry seasons by analyzing existing streamflow monitoring data.
- Determine the need for additional fecal coliform data by analyzing existing data.
- Establish wet and dry season target reductions in order to meet fecal coliform criteria.
- Allocate the required target reductions in fecal coliform load among the various diffuse sources.
- Propose a strategy that incorporates use of control measures with appropriate best management practices (BMPs) to meet the load allocations.

Historical Data Review

Water Quantity

The U.S. Geological Survey (USGS) collected continuous streamflow data during a 2½-year period (1984-1987) at a gauging station near Bothell, as well as at other locations in the watershed. Figure 2 shows a box plot of the daily average values from this station, grouped by month. For purposes of this evaluation, seasons were established by studying Figure 2 and simply grouping the highest and lowest contiguous month's average flows. It is apparent from the plot that the dry season occurs in the months of June-October, while the wet season is November-May. Figure 3 shows a box plot of the data distributed according to these seasons.

The seasonal flow patterns are characteristic of many Puget Sound lowland streams (i.e*.,* the streams exhibit a flashy response to rainfall typical in urban watersheds). The highest flows occur as a result of winter storms; no spring snowmelt runoff is evident. Nearly 27 percent of the watershed is covered by impervious surfaces, with the concomitant loss of wetlands and groundwater recharge available to supplement late summer streamflow. There is a serious potential flooding problem, particularly in the lower reaches from the Canyon Park area south to the Sammamish River; but low flow during the dry summer months is also a problem.

Fifty percent of all daily flows in the dry season lie between 11 and 18 cfs, while 50 percent of wet season flows lie between 29 and 63 cfs. Streamflows below 10 cfs routinely occur during the dry season, while flood flows approaching 600 cfs and beyond have been recorded. The lowest flows typically occur between July and September, when the creek is intermittent in the upper reaches to a point below McCollum Park. Portions of Penny Creek are also intermittent.

Water Quality Studies

Water quality studies were conducted between 1971 and 1991 by Metro (now known as Metro/King County or MetroKC) using data collected at their Bothell sampling station (stream mile 1.0). They focused on the lower portion of the watershed that lies in King County. Although not necessarily representative of conditions throughout the watershed, the Metro data indicated that North Creek's water quality regularly violated water quality standards. Metro was a valuable impetus and source of information for the work that followed in the watershed.

In July 1990, Snohomish County initiated an Ambient Water Quality Monitoring Program for the urban areas of that county. Fecal coliform samples were collected through January 1991 at eight stations throughout the North Creek watershed. Collection was once per month, providing seven data points per station (for most of the stations). Monitoring was suspended in 1991 while a universal Ambient Water Quality Monitoring Program Quality Assurance Project Plan (QAPP) was prepared for all watersheds in Snohomish County.

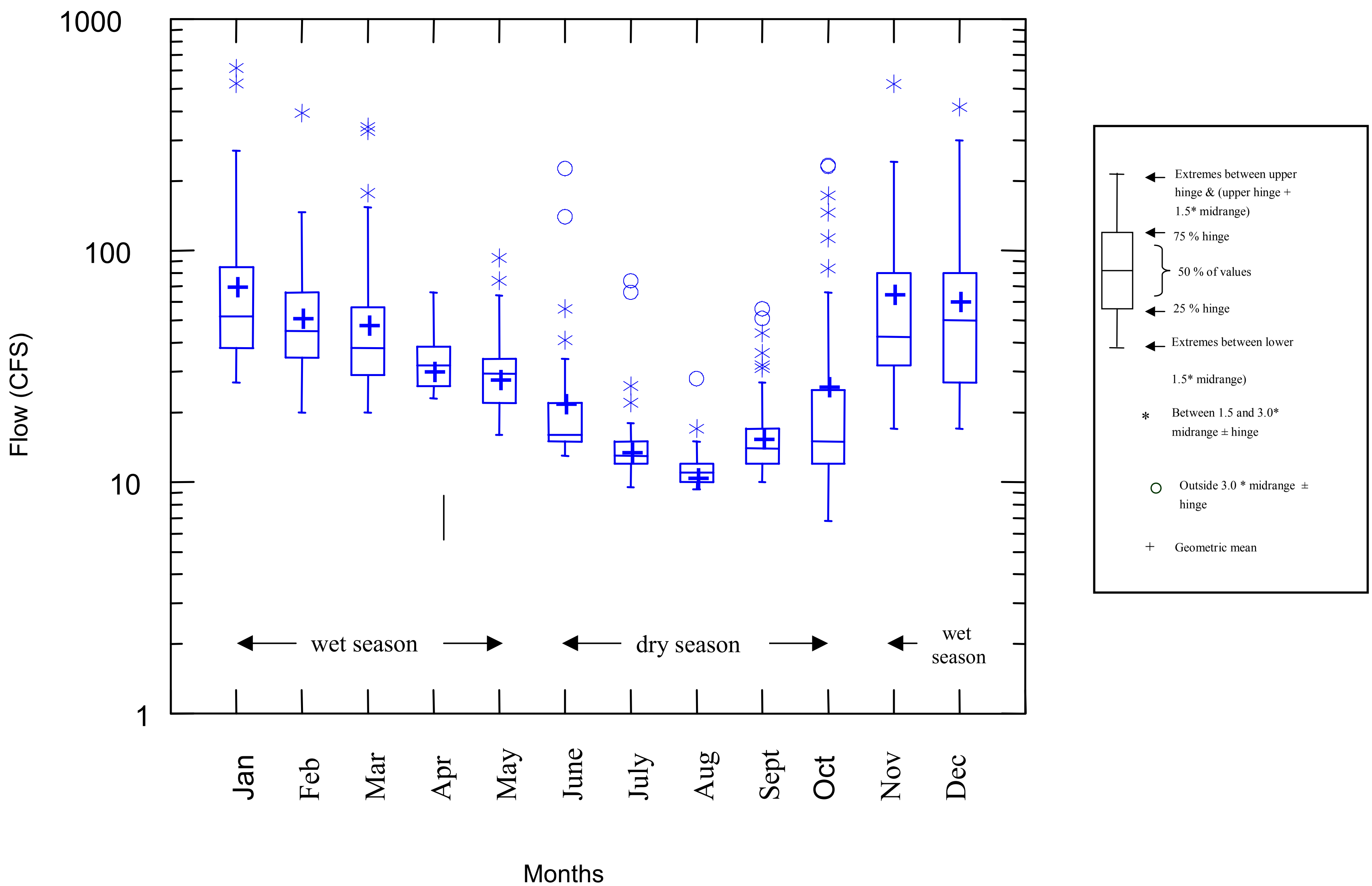

Figure 2. North Creek flows by month. USGS gauging station #12126100 near Bothell.

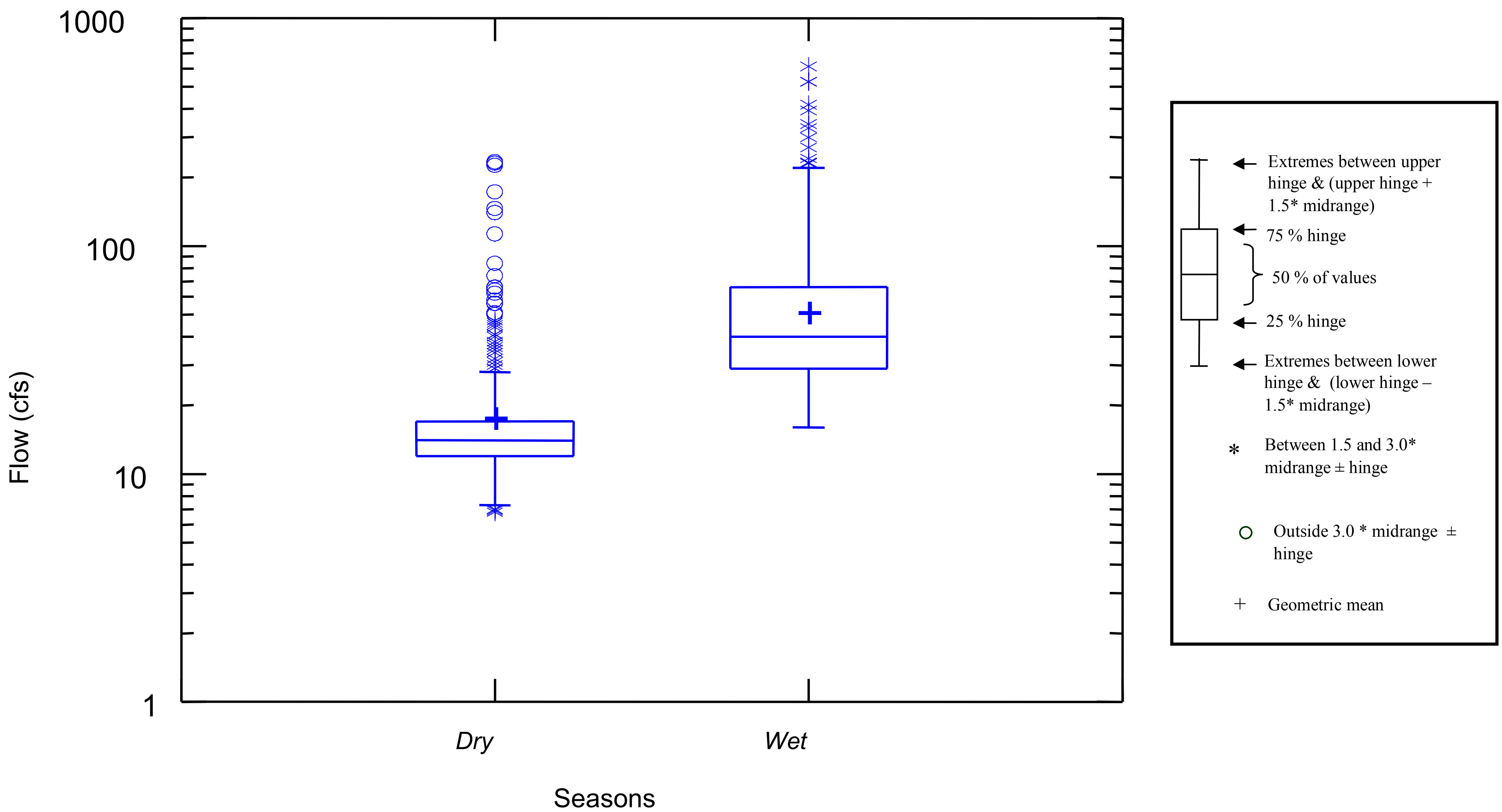

Figure 3. North Creek flows by season. USGS gauging station # 12126100 near Bothell.

The QAPP was approved by Ecology in May 1992. The goals of the QAPP included several types of water quality sampling studies:

- Assessment monitoring to characterize various aspects of site-specific problems.
- Long-term monitoring to detect temporal trends.
- Surveys to provide broad information about conditions within a region.

Assessment monitoring, which is more intensive monitoring for a period of one year, began in May 1992. It focused on correlating land use types with water quality in North Creek (and Swamp Creek) during this first year. The types of land use assessed as potential sources of bacteria were non-commercial hobby farming and single family residential. An interim project report summarized the findings from this first year of water sampling (Thornburgh, 1994). The pertinent findings are included below in the subsection on Fecal Coliform Bacteria and the later section on Sources of Pollution.

Long-term monitoring on North Creek was restarted by Snohomish County in May 1992 but at only two stations: McCollum Park and county line. Sampling was restarted at Metro's Bothell station in January 1993. All three sampling stations are in operation today. The USGS gaging station was at the same location as the Bothell station, but, as mentioned earlier, streamflow measurements ceased in 1987.

Data from the three permanent sampling stations confirmed that water quality does not meet Class AA standards because of low dissolved oxygen and elevated fecal coliform bacteria counts. Samples have been analyzed at city of Everett and MetroKC laboratories, both of which are accredited by the state of Washington for these parameters. Figure 4 shows the location of the gaging and sampling stations that will be mentioned in the ensuing discussion.

A field survey was conducted on selected segments of the North Creek watershed during April 1991. A consultant had begun work on a watershed management plan for North Creek in early 1991, and the field survey was part of the water quality assessment task for the plan. The survey provided firsthand data on current stream bank conditions, water quality, riparian and instream vegetation, aquatic biota, fisheries, and wildlife habitat.

The *North Creek Watershed Management Plan*, prepared in accordance with Chapter 400-12 of the Washington Administrative Code (WAC), was completed and approved by Ecology in September 1994 (Snohomish County, 1994). Appendix B contains the raw data from the three sampling stations for all parameters sampled. Major findings of the field survey are summarized by stream segment in Appendix C.

Fecal Coliform Bacteria

Fecal coliform bacteria are indicators of animal wastes. Livestock, failing septic systems, domestic pets, and wildlife can all contribute to elevated levels. Violations of fecal coliform water quality standards were frequent at all three long-term monitoring stations (e.g., 72 of 86 samples at the King County Department of Natural Resources [formerly Metro/King County] station were violations, with a high of 4,800 colonies/100 mL).

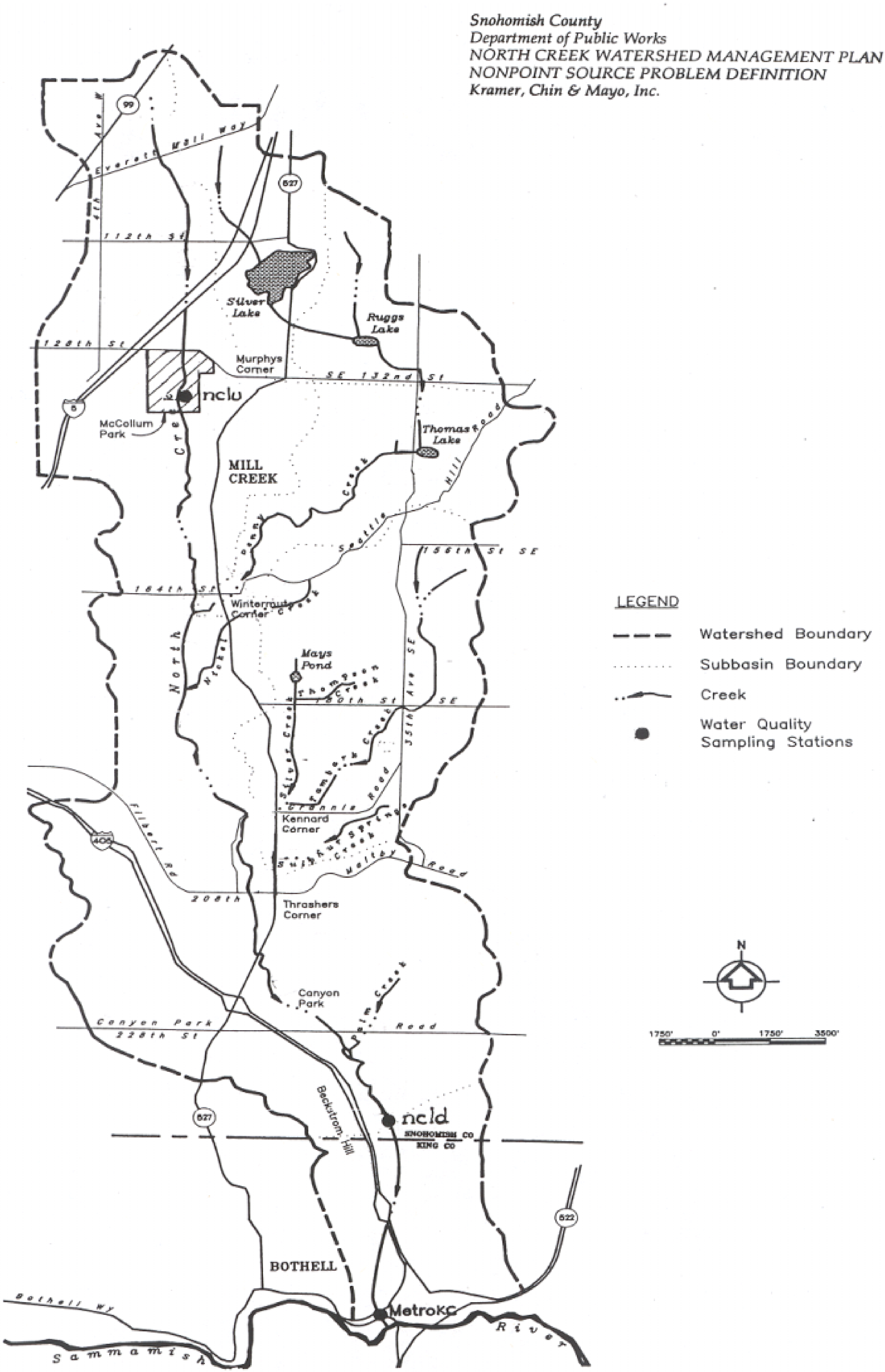

Figure 4. Long-term Monitoring Stations

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The geometric mean of all wet season concentrations at each of the three stations exceeded 110 colonies/100 mL, while dry season concentrations exceeded 230 colonies/100 mL. Both parts of the water quality standard were violated. Thus, the data reviewed for this report support the 303(d) listing for fecal coliform bacteria. Figures 5-7 show box plots of the distribution of the fecal coliform data.

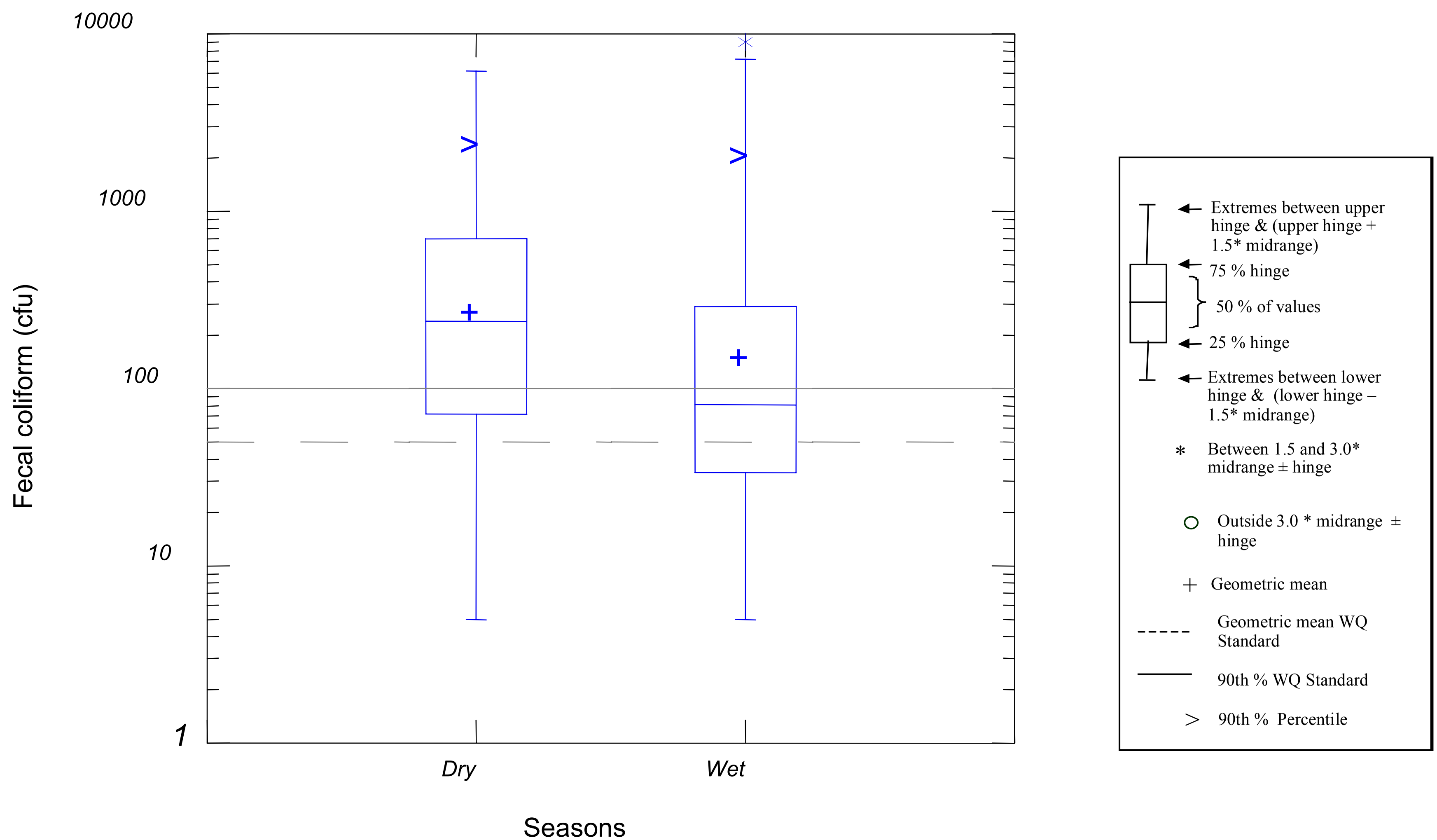

Figure 5. North Creek dry and wet season fecal coliform data. Snohomish County sampling station (nclu) at McCollum Park.

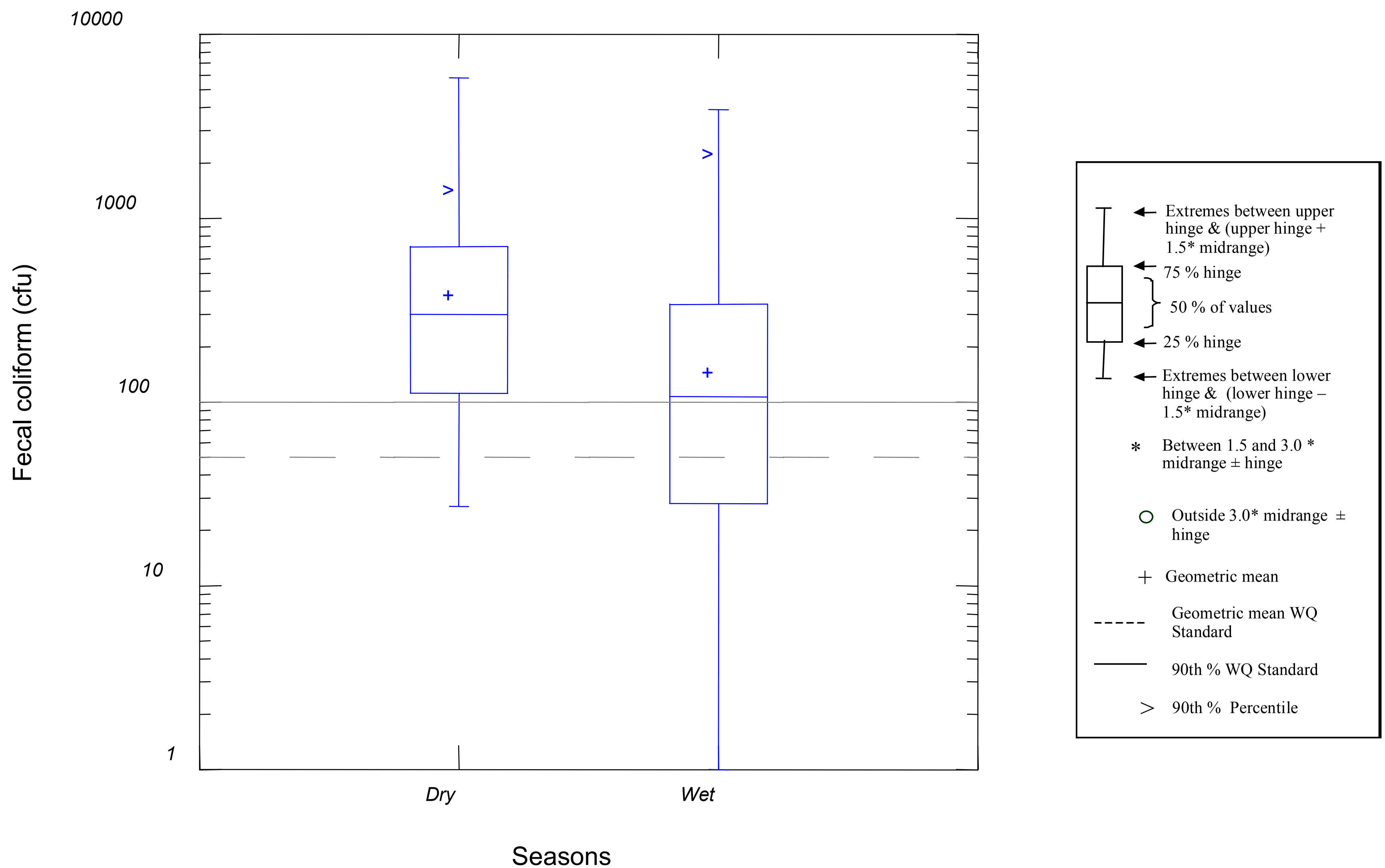

Figure 6. North Creek dry and wet season fecal coliform data. Snohomish County sampling station (ncld) at county line.

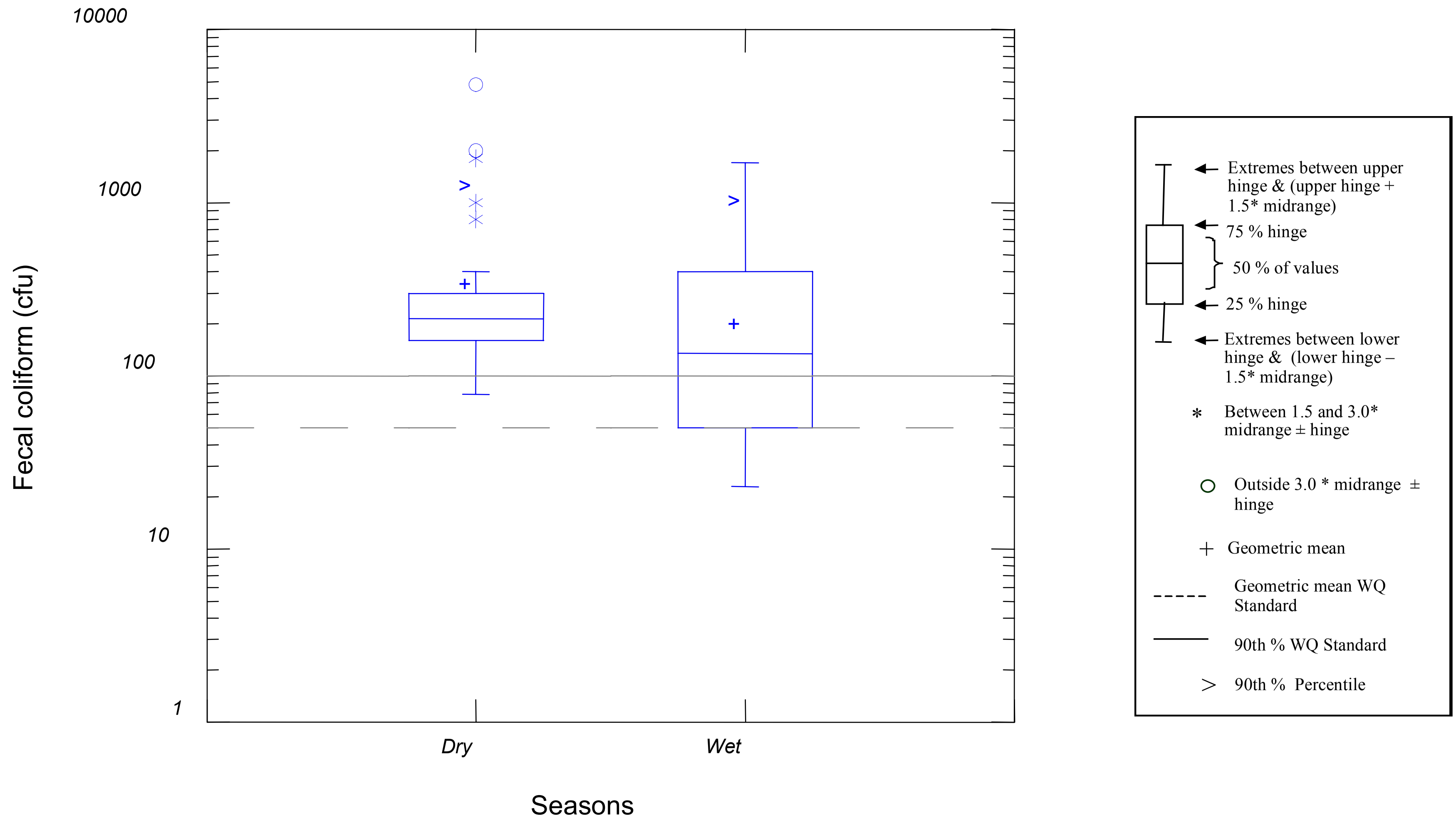

Figure 7. North Creek dry and wet season fecal coliform data. MetroKC sampling station in Bothell (near mouth of creek)

Sources of Pollution

Bacterial pollution in the basin is from diffuse sources. The predominant sources can be grouped into the categories of agriculture, on-site disposal (septic) systems, and post-development activities attributable to urban development (e.g., domesticated animals*)*. Agricultural inputs include animal waste from pasture and concentrated animal areas, waste storage facilities, land application, and stream access. Animals with access to the creeks contribute both fecal coliform bacteria and oxygen-demanding organic matter. The local conservation district does not keep records of agricultural activity in the basin. However, a windshield survey indicated that numerous hobby farms, small ranches, and livestock pastures still operate in the basin. Data for fecal coliform bacteria and nutrients indicate that animal access is a major source of diffuse pollution caused by poor management practices.

Septic systems, when improperly located, not maintained, or failing, can contribute bacterial contamination to streams through surface or groundwater flows. As shown in Figure 8 (Figure 3-3 from the *Technical Supplement;* Snohomish County, 1994*)*, extensive areas of the watershed remain unsewered. In addition, even though sewer service is provided in many areas, there may be a substantial number of homes that use on-site disposal systems, because hookup is not always required when a new sewer line is installed. The *Technical Supplement* states on page 2-10 that, "Most of the soils in the North Creek watershed are unsuitable for septic systems, because they are poorly drained with an underlying hardpan."

The field survey confirmed that animal-keeping operations and failing septic tanks are possible sources of elevated fecal coliform counts. Several key findings from the assessment monitoring (Thornburgh, 1994) related to potential sources were:

- Both large-animal wastes and on-site disposal systems are potential sources of bacteria (and nutrients) in the hobby farming areas.
- Residential reaches are primarily served by sewer, but are downstream of an area with septic systems.
- Very high levels of bacteria were measured at a site where Penny Creek enters the city of Mill Creek. This site is downstream of several potential sources of bacteria, including Pacific Topsoils, a buffalo farm, and an area served by on-site disposal systems.

Stormwater runoff, while not an original source, must be factored in as a pathway under post-development activities. As development continues, stormwater runoff from ever-expanding impervious areas has become more pronounced. Pets and waterfowl are primary sources of bacteria conveyed by stormwater runoff in urbanized areas. By EPA dictate, stormwater within the North Creek watershed that is located in the unincorporated areas of Snohomish and King counties is classified as a point source and is regulated by Ecology's National Pollutant Discharge Elimination System (NPDES) Municipal Phase I Stormwater Management Program. Stormwater generated by industrial sites and by construction sites clearing greater than five acres are point sources permitted by Ecology's General Stormwater Permit Program.

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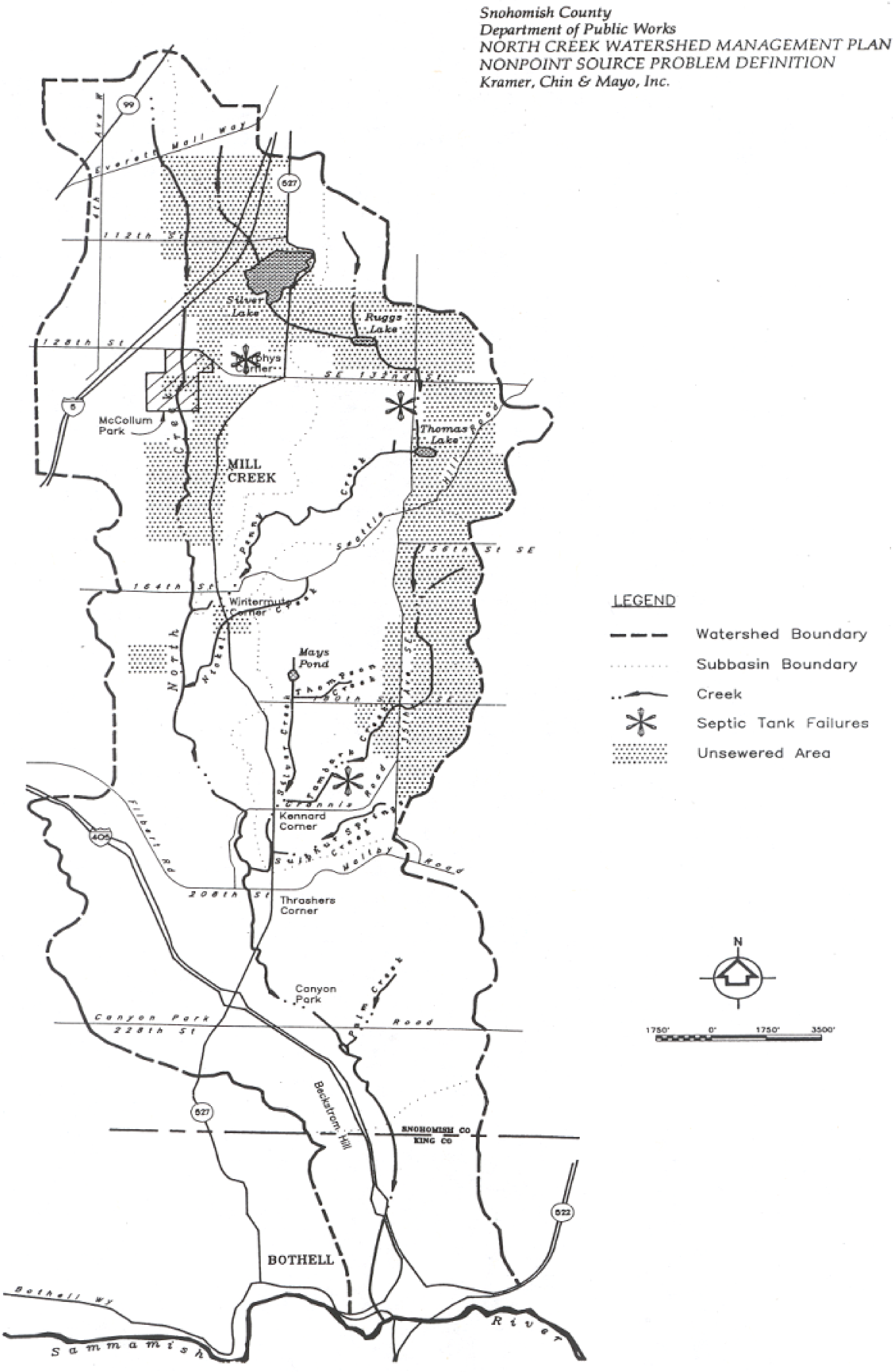

Figure 8. Unsewered Areas in the North Creek Watershed

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Total Maximum Daily Load Analysis

The federal Clean Water Act requires states to establish a Total Maximum Daily Load (TMDL) for each pollutant violating state water quality standards. In the simplest terms, a TMDL process determines the sum of all point and nonpoint source loads that a waterbody can receive and still meet water quality standards. Loads are measured in mass/time units such as pounds/day or colonies/day. The quality of the water itself (i.e., the way it directly affects organisms, including humans) depends on the concentration of pollutants, measured in mass/volume units such as mg/L or colonies/100 mL.

This report recommends a two-pronged approach for addressing the 303(d) listings for fecal coliform and dissolved oxygen. A TMDL is established for bacteria control measures. Most of the sources of bacteria are also sources affecting dissolved oxygen. After the bacteria control measures are implemented, the follow-up monitoring will also determine if dissolved oxygen is in compliance with the standard, or if a separate TMDL for dissolved oxygen will be necessary.

Loading Capacity for Fecal Coliform Bacteria

The loading capacity for North Creek is presented in three parts: The total amount of pollutant that can pass by each of the three permanent monitoring stations without causing violations of the standard. Each station provides a reference for calculating the amount of pollutant reduction needed.

The nature of bacteria loading is too dynamic to assign fixed allocations for wasteloads and nonpoint loads. Instead, water quality based allocations are recommended that reflect the expected reduction of bacteria under defined flow conditions. This TMDL, involving diffuse sources and a high percentage of impervious surfaces, addresses loading capacity in terms of concentration. The loading capacity at each of the three monitoring stations for each season is the concentration needed to meet the two, separate and distinct, parts of the Class AA fecal coliform bacteria criterion:

- "Fecal coliform organism levels shall not exceed a geometric mean value of 50 colonies/100 mL.
- "….shall not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 100 colonies/100 mL."

The approach used on North Creek was to first calculate a *percent reduction needed* for: (1) both parts of the fecal coliform criterion, (2) both the wet and dry seasons, and (3) each of the three monitoring stations. Next, t*arget percent reduction* values were established by selecting the more restrictive of the percent reductions needed for the two parts of the criterion. Finally, a *target geometric mean* was calculated for each site and season. The target geometric mean of future fecal coliform data for each season from each monitoring station must be equal to or less than the appropriate target value to ensure meeting both parts of the water quality criterion.

The Statistical Theory of Rollback was used to calculate target percent reductions and target geometric means for the North Creek TMDL (Ott, 1995). Table 2 summarizes the pertinent results. Appendix D contains the raw fecal coliform data grouped by wet and dry season within each monitoring station, as well as results from each step involved in the Statistical Theory of Rollback.

Target percent reduction values ranged from 86 to 96 percent; target geometric mean values ranged from 19 to 45. It is apparent that substantial reductions in fecal coliform bacteria concentrations are needed. The target geometric mean values, driven by part two of the criterion, are well below the part one (50 colonies/100 mL) criterion.

Load and Wasteload Allocations

An allocation is defined as the portion of a receiving water's loading capacity that is attributed to one of its existing or future sources of pollution or to natural background sources. The pollutant loading allocation assigned to a particular point source is called a wasteload allocation, and that assigned to a nonpoint source is called a load allocation. The diffuse sources of bacteria in North Creek would ordinarily be considered nonpoint sources. However, because stormwater runoff in Snohomish and King counties falls under the jurisdiction of the counties' respective stormwater NPDES permits, stormwater runoff to North Creek from unincorporated areas is considered point-source loading and is given a wasteload allocation.

Estimating urban stormwater loads is complicated by a lack of data and high variability in available monitoring data. Because of the nature of stormwater runoff, general stormwater NPDES permits do not typically establish numeric loading limits. Instead, EPA has defined an approach wherein narrative *effluent limitations* may be set (in lieu of *numeric limitations*) for water quality-based permit requirements for stormwater (EPA, 1996). Effluent limitations may be expressed either as numerical restrictions on pollutant discharges or as best management practices (BMPs) when numerical limitations are infeasible (40 CFR 122.44(k)). The narrative limitations are most appropriate when there are numerous diffuse, non-continuous sources and when individual contributions are difficult to identify and model, such as in the North Creek watershed.

Under this approach, EPA suggests that the narrative limitations should require the implementation of BMPs, monitoring, and adaptive management. The monitoring would be in the form of follow-up monitoring to evaluate the effectiveness of the pollution control measures employed in the watershed. Adaptive management will call for BMP modification if monitoring shows that standards are not being met. In addition, adaptive management includes a contingency to sample stormwater outfalls and evaluate stormwater wasteload in terms of mass loading, in the event that North Creek does not attain water quality standards within five years. Consistent with this approach, the fecal coliform wasteload allocation for stormwater runoff in North Creek is inherent in the target geometric mean at each station on North Creek (Table 2) and is a loading such that stream concentrations do not exceed water quality standards for fecal coliform.

Table 2. North Creek drainage wet and dry season fecal coliform geometric means, 90th percentiles, and target levels.

Code Name of Sampling Station	**First Criterion Geometric Mean < 50**				**Second Criterion 90% of Samples < 100**				**Target Levels**			
	Existing Geometric Mean		Percent Reduction Needed		Existing Upper Tenth Percentile		Percent Reduction Needed		Target Percent Reduction		Target Geometric Mean	
	Wet Season col/100mL	Dry Season col/100mL	Wet Season	Dry Season	Wet Season col/100mL	Dry Season col/100mL	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season col/100mL	Dry Season col/100mL
nclu (McCollum Park)	128	230	61	78	1241	2366	92	96	92	96	23	25
ncld (county line)	111	292	55	83	1497	1532	93	93	93	93	19	35
MetroKC (mouth)	155	264	68	81	722	861	86	88	86	88	34	45

Seasonal Variation

Seasonal variation is addressed in this TMDL study by establishing target geometric means and percent reductions for both a wet and dry season.

Three key findings from the one year of assessment monitoring (Thornburgh, 1994) were:

1. Fecal coliform levels are significantly higher during the dry season than during the wet season.
2. High dry season fecal coliform levels may be due, in large measure, to extreme low flows and little dilution.
3. There was a pattern of higher fecal coliform levels at the residential sites than at the hobby farm sites, especially during the wet season.

The plotted results in Figures 5, 6, and 7 substantiate point No. 1 above. Factoring in the plotted flow results in Figure 3 suggests that the pollution loading is continuous and steady because concentration and flow are inversely related. This substantiates point No. 2 above, that concentrations are relatively high during the dry season, while flows and associated dilution effects are dramatically lower.

The possible influence of storm events on fecal coliform concentrations was examined. The values in Table 2 under the heading *Existing Upper Tenth Percentile* are extraordinarily high. (Ten percent of all monthly sampling results are above these values). Dry season values higher than those in the wet season suggest that the continuous, steady pollution loading is amplified when sampling events coincide with the "first-flush" of storms, whether wet or dry season storms. It appears that there is no significant seasonal variation in pollutant loading, just dramatic fluctuations in flows; there is a storm-related component to the loading.

Margin of Safety

The target geometric mean values in Table 2 are conservative. The extraordinarily high values in Table 2 under *Existing Upper Tenth Percentile* means that the geometric means of all future results for the three monitoring stations must, in turn, be extraordinarily low in order to meet the part two (100 colonies/100 mL) criterion in the water quality standard. Because body contact recreation is minimal during storms, this approach provides a significant margin of safety.

Additional margins of safety may be incorporated during the public process for acceptance of the TMDL. For example, additional margins of safety may be established by (1) subtracting a portion of the proposed load allocations or (2) increasing an allocation designated as the margin of safety.

Adaptive Management

The adaptive management approach for the North Creek TMDL calls for evaluating within five years of TMDL initiation whether BMPs are effective at causing North Creek to attain water quality standards. If BMPs are not proven to make sufficient progress toward meeting water quality standards within five years, then BMPs shall be made more stringent or revised in such a way as to improve water quality toward meeting standards. In addition, adaptive management for the North Creek TMDL includes a contingency to sample stormwater outfalls and evaluate stormwater wasteload in terms of mass loading, in the event that North Creek does not attain water quality standards within five years.

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Conclusions and Recommendations

- Land use within the watershed has changed drastically in the last 30 years. The trend toward small ranches and hobby farms has been replaced by a trend toward large residential developments and mobile home communities, interspersed with large shopping centers, many small businesses, and supporting facilities.

- North Creek violates the Class AA water quality standards for fecal coliform bacteria and dissolved oxygen.

- Pollution in the basin is due to diffuse sources. The predominant source categories are agriculture, on-site disposal (septic) systems, and post-development activities attributable to urban development (e.g., domesticated animals).

- Dry season (base flow) fecal coliform concentrations higher than those in the wet season suggest that there is a continuous, steady component to the pollution loading. Since concentrations are relatively high during the wet season and flows are dramatically higher, there is also a storm-related component to the loading.

- The recommended TMDL load allocations are established in the form of fecal coliform target percent reductions and target geometric means for both dry and wet seasons, as presented in Table 2.

- Improvements in dissolved oxygen concentrations should accompany implementation of control measures for fecal coliform bacteria and the concomitant reduction in inputs of organic matter.

- Even though sewer service is provided in many areas, there may be a substantial number of homes that use on-site disposal systems, because hookup is not always required when a new sewer line is installed. Strategies to prevent additional fecal coliform pollution from these sources should be investigated in the development of the Water Cleanup Plan for this TMDL project.

- The best approach when developing control measures for diffuse sources is to maintain or even increase flow rates throughout the dry season and decrease peak flows during the wet season, while focusing on lowering concentrations in the water. Flow attenuation can be achieved with detention ponds, establishing or restoring wetlands, and managing riparian corridors.

- Sampling stations on one or both of the two major tributaries downstream from known land use types is recommended.

- A long-term monitoring strategy is essential to track and evaluate the effectiveness of the source control measures in the North Creek watershed.

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Appendices

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Appendix A

Water Quality Standards for Freshwater Class AA Waters

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Appendix A

Water Quality Standards for Freshwater Class AA Waters

WAC 173-201A-030 General water use and criteria classes. The following criteria shall apply to the various classes of surface waters in the state of Washington:

(1) **Class AA (extraordinary).**

(a) General characteristic. Water quality of this class shall markedly and uniformly exceed the requirements for all or substantially all uses.

(b) Characteristic uses. Characteristic uses shall include, but not be limited to, the following:
- (i) Water supply (domestic, industrial, agricultural).
- (ii) Stock watering.
- (iii) Fish and shellfish:
  - Salmonid migration, rearing, spawning, and harvesting.
  - Other fish migration, rearing, spawning, and harvesting.
  - Clam, oyster, and mussel rearing, spawning, and harvesting.
  - Crustaceans and other shellfish (crabs, shrimp, crayfish, scallops, etc.) rearing, spawning, and harvesting.
- (iv) Wildlife habitat.
- (v) Recreation (primary contact recreation, sport fishing, boating, and aesthetic enjoyment).
- (vi) Commerce and navigation.

(c) Water quality criteria:
- (i) Fecal coliform organisms:
  - (A) Freshwater - fecal coliform organism levels shall both not exceed a geometric mean value of 50 colonies/100 mL and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 100 colonies/100 mL.
- (ii) Dissolved oxygen:
  - (A) Freshwater - dissolved oxygen shall exceed 9.5 mg/L.
- (iii) Total dissolved gas shall not exceed 110 percent of saturation at any point of sample collection.
- (iv) Temperature shall not exceed 16.0ºC (freshwater) due to human activities. When natural conditions exceed 16.0ºC (freshwater), no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3ºC.

  Incremental temperature increases resulting from point source activities shall not, at anytime, exceed $t=23/(T+5)$ (freshwater). Incremental temperature increases resulting from nonpoint source activities shall not exceed 2.8ºC.

For purposes hereof, "t" represents the maximum permissible temperature increase measured at a mixing zone boundary; and "T" represents the background temperature as measured at a point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge.

(v) pH shall be within the range of 6.5 to 8.5 (freshwater) or 7.0 to 8.5 (marine water) with a human-caused variation within the above range of less than 0.2 units.

(vi) Turbidity shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10 percent increase in turbidity when the background turbidity is more than 50 NTU.

(vii) Toxic, radioactive, or deleterious material concentrations shall be below those which have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent upon those waters, or adversely affect public health, as determined by the department (see WAC 173-201A-040 and 173-201A-050).

(viii) Aesthetic values shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.

Appendix B

Water Quality Data

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Appendix B. Site nclu - North Creek Water Quality Data from McCollum Park.

SITE	DATE	TIME	Temp	D.O.	pH	Conduct.	Fecal Col.	Hardness	Nitrate-nitrite	Total Phosphorus	Total Suspended Solids	Copper	Lead	Zinc
			Celsius	mg/l		ıos/cm	ɔol/100ml	mg/L (as CaCO3)	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
nclu	5/12/92	10:05:00	9.1	11.10	8.10	151	200	52	0.360	0.019	1	0.0010	0.0005	
nclu	6/10/92	09:30:00	14.1	4.65	7.30	221	380	110	0.420	0.024	25	0.0210	0.0060	
nclu	7/7/92	11:15:00	14.5	7.84	7.40	101	240	51	0.320	0.070	1	0.0130	0.0040	
nclu	8/12/92	11:00:00	17.3	2.77	6.80	142	162	80	0.170	0.047	31	0.0010	0.0020	
nclu	9/9/92	10:30:00	11.6	7.46	6.90	90	75	110	0.250	0.050	14	0.0020	0.0020	
nclu	10/13/92	10:30:00	9.3	4.69	6.50	132	1,120	61	0.320	0.020	10	0.0010	0.0005	
nclu	11/2/92	10:30:00	9.5	6.38	7.40	72	6	38	0.073	0.034	1	0.0190	0.0030	
nclu	11/30/92	11:15:00	6.3	7.94	6.70	72	33	36	0.450	0.035	7	0.0130	0.0080	
nclu	1/11/93	11:15:00	1.4	9.14	7.20	115	22	95	1.100	0.010	2	0.0810	0.0030	
nclu	2/3/93	13:00:00	4.4	8.72	7.40	90	5	77	1.000	0.016	0	0.0010	0.0005	
nclu	3/2/93	10:15:00	4.6	8.58	7.10	91	820	69	0.460	0.035	6	0.0010	0.0005	
nclu	4/7/93	10:15:00	8.1	6.60	7.80	77	205	47	0.440	0.030	3	0.0010	0.0020	
nclu	5/3/93	10:50:00	10.6	5.24	7.40	104	280	53	0.620	0.027	3	0.0010	0.0020	
nclu	6/7/93	10:30:00	14.0	9.52	7.70	81	2,000	45	0.740	0.056	8	0.0010	0.0060	
nclu	7/6/93	10:00:00	13.6	10.37	7.80	157	69	77	0.630	0.027	0	0.0010	0.0020	
nclu	8/3/93	10:45:00	17.0	5.64	7.80	150	164	73	0.740	0.064	5	0.0010	0.0010	
nclu	9/8/93	10:00:00	14.9	3.88	7.30	200	21	100	1.600	0.270	22	0.0090	0.0020	
nclu	10/5/93	10:15:00	11.9	3.31	7.50	209	5	110	0.086	0.029	1	0.0030	0.0005	
nclu	11/9/93	10:15:00	5.3	5.28	7.50	175	22	92	0.280	0.016	1	0.0010	0.0010	
nclu	12/8/93	10:20:00	5.3	13.53	7.50	85	260	59	0.910	0.041	3	0.0030	0.0060	
nclu	1/10/94	11:15:00	6.7	9.34	7.80	120	52	66	1.300	0.019	3	0.0010	0.0040	
nclu	2/8/94	09:45:00	0.2	11.81	6.80	154	32	79	1.100	0.020	25	0.0010	0.0050	
nclu	3/8/94	10:30:00	5.5	12.75	7.20	127	49	63	1.800	0.019	5	0.0040	0.0010	
nclu	4/11/94	10:15:00	9.5	10.56	7.20	96	33	130	0.810	0.018	1	0.0110	0.0005	
nclu	5/17/94	09:00:00	11.5	10.01	7.10	128	2,000	34	0.400	0.050	4	0.0020	0.0034	
nclu	6/6/94	09:00:00	12.5	6.51	7.50	75	1,100	47	0.760	0.050	3	0.0038	0.0030	0.0350
nclu	7/12/94	21:20:00	14.6	4.54	7.00	116	8	84	0.530	0.110	24	0.0079	0.0110	0.0500
nclu	8/3/94	09:30:00	17.1	2.35	7.60	131	4,400	76	0.045	0.036	8	0.0011	0.0021	0.0130
nclu	9/15/94	09:45:00	15.4	8.07	7.10	52	164	50	0.094	0.058	8	0.0280	0.0005	0.0025
nclu	10/10/94	10:30:00	11.1	3.58	7.30	132	480	120	0.022	0.055	31	0.0022	0.0005	0.0730
nclu	11/8/94	8:45	7.0	11.61	6.50	69	151	38	0.260	0.041	2	0.0020	0.0005	0.0150
nclu	12/6/94	10:00	1.9	14.12	7.00	70	74	55	0.720	0.011	0	0.0019	0.0015	0.0270
nclu	1/11/95	10:00	5.4	13.22	7.00	50	300	35	0.720	0.024	2	0.0038	0.0014	0.0220
nclu	2/6/95	9:45	8.1	10.57	7.30	71	200	49	1.400	0.014	2	0.0017	0.0014	0.0120
nclu	3/7/95	10:40	4.7	12.35	7.40	72	220	55	0.570	0.081	7	0.0016	0.0014	0.0140
nclu	4/5/95	10:25	8.6	11.71	7.10		310	45	0.350	0.018	8	0.0017	0.0012	0.0095
nclu	5/4/95	10:50	10.7	10.71	7.31		510		0.290	0.024	2	0.0024	0.0017	0.0025
nclu	6/7/95	9:50	11.5	9.70	6.90		31		0.310	0.016	11	0.0059	0.0005	0.0025
nclu	7/13/95	9:30	14.9	4.39	6.89		740		0.170	0.023	5	0.0014	0.0005	0.0093
nclu	8/10/95	9:40	14.5	8.68	7.02	133	627		0.310	0.035	5	0.0028	0.0005	0.0067
nclu	9/21/95	9:20	12.8	3.58	6.74	249	19		0.078	0.018	0	0.0017	0.0005	0.0089
nclu	10/3/95	8:15	12.8	9.61	6.32	49	6,200		0.360	0.040	17	0.0028	0.0027	0.0200
nclu	11/8/95	8:20	10.9	10.07	6.65	69	3,000		0.320	0.048	9	0.0021	0.0005	0.0200
nclu	12/11/95	8:30	7.2	11.20	6.70	67	1,700		0.880	0.078	35	0.0036	0.0057	0.0380
nclu	1/2/96	8:15	7.9	10.92	7.19	142	30		1.100	0.027	6	0.0016	0.0005	0.0150
nclu	2/5/96	8:10	2.1	14.04	6.92	168	800		0.550	0.028	19	0.0045	0.0066	0.0260
nclu	3/5/96	8:05	5.3	12.22	7.22	175	38		0.810	0.012	1	0.0014	0.0009	0.0097
nclu	4/1/96	10:39	8.4	11.39	7.13	87	7,200		0.300	0.058	20	0.0037	0.0030	0.0280
nclu	5/7/96	8:30	8.9	11.68	7.04	136	9,000		0.385	0.056	19	0.0078	0.0080	0.0475
nclu	6/5/96	9:30	12.3	9.80	7.04	173	181		0.457	0.016	1	0.0013	0.0005	0.0067
nclu	7/17/96	7:25	14.0	6.12	6.58	215	56		0.498	0.018	1	0.0017	0.0004	0.0139
nclu	8/5/96	9:05	14.3	9.52	6.50	84	320		0.379	0.053	5	0.0028	0.0029	0.0149
nclu	9/11/96	10:30	13.7	8.16	6.77	164	660		0.285	0.020	1	0.0012	0.0011	0.0057
nclu	10/8/96	8:45	12.0	8.98	6.59	134	190		0.388	0.013	1	0.0016	0.0002	0.0026
nclu	11/4/96	9:30	7.8	11.60	6.69	152	81		0.368	0.006	0	0.0017	0.0011	0.0087
nclu	12/5/96	10:25	5.6	12.54	6.72	109	20		1.260	0.024	5	0.0026	0.0015	0.0236
nclu	1/7/97	10:15	6.1	12.54	6.24	120	27		0.927	0.029	5	0.0023	0.0013	0.0345
nclu	2/11/97	10:10	4.2	9.68	6.89	156	72		0.751	0.021	2	0.0013	0.0000	0.0153
nclu	3/5/97	8:00	5.2	13.08		125	157		0.620	0.014	2	0.0021	0.0008	0.0126
nclu	4/8/97	8:00	8.6	11.30	7.62		40		0.297	0.054	1	0.0021	0.0002	0.0159
nclu	5/6/97	7:45	10.9	10.63	7.20	119	190		0.313	0.021	1	0.0023	0.0007	0.0130
nclu	6/2/97	7:40	14.2	9.96	6.82	112	450		0.350	0.022	2	0.0021	0.0002	0.0096
nclu	7/8/97	8:00	16.5	9.35	6.99	111	2,110		0.266	0.038	5	0.0021	0.0009	0.0134
nclu	10/6/97	7:45	12.0	10.23	6.13	99			0.409	0.012	0	5.0000	0.0025	0.0004
nclu	11/3/97	7:30	10.3	10.80	5.97	139	51		0.495	0.008	1	0.0025	0.0002	0.0067
nclu	12/1/97	8:00	6.8	11.85	6.66	115	34		0.540	0.005	0	0.0018	0.0003	0.0108
nclu	1/7/98	8:00	5.6	13.50	6.17	90			#####	0.887	0	8.0000	0.0033	0.0038
nclu	4/13/98	11:50	8.6	11.20	7.43	133	49		0.360	0.014	2	0.0027	0.0006	0.0069
nclu	5/4/98	10:42	12.6	8.67	7.38	168								

Appendix B (cont.). Site ncld - North Creek Water Quality Data from county line.

SITE	DATE	TIME	Temp	D.O.	pH	Conduct.	Fecal Col.	Hardness	Nitrate-nitrite	Total Phosphorus	Total Suspended Solids	Copper	Lead	Zinc
			Celsius	mg/l		ıos/cm	ɔol/100ml	mg/L (as CaCO3)	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
ncld	5/12/92	10:55:00	10.4	11.45	8.10	168	2,600	73	0.570	0.064	3	0.0010	0.0005	
ncld	6/10/92	11:00:00	14.8	8.44	7.90	178	162	77	0.650	0.056	4	0.0170	0.0060	
ncld	7/7/92	14:05:00	15.8	9.14	7.60	130	219	62	0.650	0.100	3	0.0080	0.0050	
ncld	8/12/92	11:45:00	17.4	8.55	7.30	148	200	82	0.750	0.074	7	0.0010	0.0005	
ncld	9/9/92	11:30:00	12.7	9.93	7.50	136	112	90	0.590	0.062	1	0.0010	0.0005	
ncld	10/13/92	11:45:00	9.8	6.00	6.80	146	112	82	0.850	0.056	2	0.0010	0.0010	
ncld	11/2/92	13:00:00	9.9	6.78	7.60	195	6	69	0.540	0.087	1	0.0130	0.0040	
ncld	11/30/92	14:00:00	6.9	7.59	7.30	113	116	57	0.750	0.066	4	0.0120	0.0020	
ncld	1/11/93	13:45:00	0.8	10.14	7.40	99	37	82	1.200	0.053	7	0.0440	0.0030	
ncld	2/3/93	14:00:00	4.7	9.62	7.60	85	14	72	1.100	0.055	4	0.0010	0.0005	
ncld	3/2/93	13:00:00	7.0	9.10	8.60	93	21	65	0.850	0.052	0	0.0010	0.0005	
ncld	4/7/93	12:15:00	9.2	6.56	8.00	80	99	55	0.570	0.056	5	0.0010	0.0010	
ncld	5/3/93	12:15:00	11.1	5.14	7.60	111	107	59	0.730	0.058	4	0.0010	0.0020	
ncld	6/7/93	12:15:00	14.0	9.40	7.70	106	1,100	56	0.640	0.093	9	0.0010	0.0040	
ncld	7/6/93	12:00:00	15.0	11.57	7.90	137	37	85	0.840	0.085	3	0.0010	0.0010	
ncld	8/3/93	13:15:00	19.3	10.77	8.00	138	340	75	0.370	0.037	2	0.0010	0.0005	
ncld	9/8/93	12:15:00	16.2	11.87	7.80	131	90	66	0.860	0.067	8	0.0040	0.0010	
ncld	10/5/93	12:30:00	12.1	11.32	7.80	155	62	77	0.950	0.093	5	0.0040	0.0005	
ncld	11/9/93	11:30:00	5.4	14.06	7.70	117	49	76	0.980	0.076	4	0.0010	0.0010	
ncld	12/8/93	12:40:00	5.8	12.62	7.30	127	28	59	1.000	0.062	19	0.0050	0.0040	
ncld	1/10/94	14:10:00	7.3	9.03	7.30	120	27	72	1.300	0.058	3	0.0010	0.0020	
ncld	2/8/94	14:30:00	2.3	11.07	7.10	129	60	74	1.300	0.061	5	0.0010	0.0030	
ncld	3/8/94	14:00:00	7.7	11.54	7.20	115	22	73	1.400	0.051	6	0.0010	0.0005	
ncld	4/11/94	13:30:00	11.7	10.58	8.20	158	52	65	0.790	0.051	2	0.0010	0.0005	
ncld	5/17/94	12:05:00	12.1	10.06	7.10	168	200	40	0.690	0.050	6	0.0018	0.0024	
ncld	6/6/94	13:30:00	14.1	7.84	8.10	91	280	41	0.600	0.050	0	0.0005	0.0005	0.0200
ncld	7/12/94	13:45:00	18.2	10.48	7.60	95	35	65	0.660	0.095	5	0.0005	0.0017	0.0025
ncld	8/3/94	13:40:00	18.2	9.34	8.10	95	860	54	0.500	0.099	2	0.0005	0.0005	0.0100
ncld	9/15/94	14:00:00	15.4	10.29	7.20	69	991	74	0.520	0.088	3	0.0005	0.0005	0.0025
ncld	10/10/94	14:45:00	11.2	10.57	4.60	87	540	73	0.760	0.053	3	0.0022	0.0005	0.0260
ncld	11/8/94	12:35	8.4	11.38	7.40	85	0	65	0.580	0.080	5	0.0013	0.0012	0.0430
ncld	12/6/94	14:00	3.7	13.09	7.30	63	120	61	0.700	0.062	4	0.0005	0.0005	0.0025
ncld	1/11/95	13:45	5.3	13.71	7.00	41	450	42	0.910	0.055	5	0.0037	0.0005	0.0072
ncld	2/6/95	13:50	8.6	10.19	7.10	31	1,254	49	1.200	0.046	4	0.0014	0.0012	0.0025
ncld	3/7/95	14:20	7.3	11.82	7.40	82	85	60	0.840	0.054	3	0.0005	0.0005	0.0025
ncld	4/5/95	13:40	10.2	11.49	7.40		190	54	0.600	0.046	4	0.0011	0.0005	0.0025
ncld	5/4/95	14:30	13.3	10.39	7.45		310		0.530	0.037	4	0.0017	0.0017	0.0025
ncld	6/7/95	13:35	14.8	11.83	7.79		200		0.870	0.091	7	0.0005	0.0005	0.0025
ncld	7/13/95	14:18	16.1	10.74	7.82		27		0.830	0.080	5	0.0005	0.0005	0.0025
ncld	8/10/95	12:00	14.3	9.87	6.99	188	240		0.950	0.089	8	0.0013	0.0012	0.0025
ncld	9/21/95	13:05	14.0	9.88	7.59	182	88		0.900	0.077	3	0.0014	0.0005	0.0025
ncld	10/3/95	11:25	12.8	9.03	6.61	105	5,800	0	0.680	0.120	35	0.0018	0.0120	
ncld	11/8/95	11:55	10.9	9.86	6.81	148			0.670	0.095	11	0.0005	0.0005	0.0120
ncld	12/11/95	13:35	7.5	11.12	6.66	77	1,600		1.200	0.071	22	0.0022	0.0020	0.0076
ncld	1/2/96	11:50	8.3	11.13	7.11	132	3,900		1.100	0.052	8	0.0005	0.0005	0.0056
ncld	2/5/96	12:20	3.1	13.84	7.02	121	1,200		0.710	0.035	99	0.0062	0.0076	0.0160
ncld	3/5/96	11:05	6.2	11.37	7.20	153	145		1.100	0.043	4	0.0014	0.0004	0.0016
ncld	4/1/96	14:24	9.6	10.95	7.23	124	1,900		0.650	0.097	10	0.0017	0.0000	0.0100
ncld	5/7/96	11:15	9.6	10.44	7.03	150	3,800		0.709	0.064	25	0.0025	0.0034	0.0089
ncld	6/5/96	13:05	15.2	10.57	7.44	167	450		0.764	0.070	5	0.0008	0.0007	0.0066
ncld	7/17/96	10:20	14.2	8.90	7.35	181	700		1.000	0.115	17	0.0035	0.0012	0.0035
ncld	8/5/96	11:35	14.3	11.31	7.00	180	700		0.744	0.097	25	0.0020	0.0033	0.0054
ncld	9/11/96	15:05	14.7	9.90	7.30	190	350		0.843	0.075	28	0.0006	0.0009	0.0014
ncld	10/8/96	11:55	12.0	10.03	7.02	183	700		0.858	0.060	3	0.0011	0.0023	0.0008
ncld	11/4/96	13:45	8.9	10.92	7.07	168	1,300		0.687	0.058	130	0.0067	0.0029	0.0207
ncld	12/5/96	13:05	6.0	11.85	6.81	117	20		1.190	0.051	9	0.0018	0.0014	0.0106
ncld	1/7/97	15:10	6.4	11.89	7.00	117	340		1.050	0.046	6	0.0018	0.0012	0.0069
ncld	2/11/97	12:20	5.0	12.18	6.77	147			1.020	0.047	8	0.0008	0.0000	0.0050
ncld	3/5/97	11:15	6.4	12.18		140			0.955	0.039	4	0.0020	0.0003	0.0042
ncld	4/8/97	11:40	9.9	11.30	7.71		39		0.841	0.011	4	0.0015	0.0005	0.0054
ncld	5/6/97	11:00	12.0	10.40	7.54	139	140		0.521	0.050	3	0.0021	0.0006	0.0069
ncld	6/2/97	11:15	14.9	9.45	7.49	149	1,090		0.613	0.074	5	0.0021	0.0001	0.0037
ncld	7/8/97	11:15	15.4	9.15	7.32	152	320		0.507	0.102	14	0.0011	0.0006	0.0058
ncld	10/6/97	11:40	12.3	9.55	7.03	149	2,700		0.691	0.035	5	0.0026	0.0006	0.0040
ncld	11/3/97	10:45	10.3	9.68	7.29	158	157		0.871	0.033	5	0.0011	0.0005	0.0011
ncld	12/1/97	11:10	7.1	10.93	7.38	144	77		0.964	0.028	5	0.0018	0.0007	0.0172
ncld	1/7/98	11:15	6.1	11.50	6.60	109	0		1.200	0.029	8	0.0018	0.0005	0.0126
ncld	4/13/98	13:10	10.8	11.42	7.40	159	27		0.835	0.051	0	0.0026	0.0006	0.0062
ncld	5/4/98	15:45	15.5	10.80	8.09	174								

Appendix B (cont.). Site MetroKC - North Creek Water Quality Data from Bothell.

locator	collect date	SAMPLE START TIME	NON-STORM or STORM	AMBIENT AIR TEMP. °C	SAMPLE TEMP. °C	DISCHARGE RATE cfs	ENTEROCOCCUS CFU/10	FECAL COLIFORM CFU/100	D. O. (WINKLER) mg/l	CONDUCTIVITY umhos	TOTAL SUSPENDED SOLIDS mg/l	TURBIDITY NTU	AMMONIA NITROGEN mg/l	NITRITE + NITRATE NITROGEN mg/l	ORTHO PHOSPHORUS mg/l	TOTAL PHOSPHORUS mg/l
474	13-Jan-97	1100	N	3.5	2.1		22	40	13.0	137	7	4	0.10	1.19	0.033	0.068
474	18-Mar-97	1215	S	11.3	8.5		410	800	11.1	103	23	8	0.10	0.77	0.023	0.095
474	10-Feb-97	1045	N	6.3	4.7		10	30	12.3	142	3	2	0.05	1.16	0.029	0.054
474	10-Mar-97	1015	N	7.4	7.1		58	97	11.5	145	10	4	0.04	0.96	0.049	0.088
474	7-Apr-97	1130	N	13.0	8.5		17	30	11.9	158	4	2	0.03	0.92	0.042	0.052
474	10-May-93	1008	N	17.2	13.0		130	140	9.8		5	2		0.63	0.045	0.057
474	12-May-97	1045	N	20.7	14.0		41	150	10.2	162	4	3	0.03	0.85	0.051	0.079
474	9-Jun-97	1150	N	19.1						139	3	1	0.03	0.89	0.049	0.078
474	9-Jun-97	1025	N	16.6	13.3		74	130		147	3	5	0.04	0.93	0.060	0.091
474	7-Jul-97	1120	N	22.0	16.1		46	140		168	4	3	0.02	0.74	0.067	0.087
474	11-Aug-97	1040	N	23.1	16.3		32	210		177	4	4		0.87	0.060	0.062
474	8-Sep-97	1030	N	22.0	15.9		90	160		177	5	2	0.02	0.84	0.059	0.078
474	25-Aug-97	1245	N	23.0												
474	13-Oct-97	1013	N	13.2	10.7		50	100		157	4	4	0.05	0.77	0.097	0.081
474	2-Oct-97	1100	S	13.5	13.1		1,800	800		131	18	8	0.04	0.48	0.094	0.135
474	20-Jan-93	1030	S	7.0	4.0		5,700	760	12.0	120	46	18	0.14	0.80	0.033	0.260
474	29-Oct-97	1045	S	11.6	10.6		1,500	2,000		126	50	25	0.06	0.60	0.151	0.262
474	12-Nov-97	1030	N	5.6	6.4		46	50		164	3	2	0.07	0.88	0.048	0.067
474	16-Dec-97	1210	S	13.0	7.7		320	400		135	34	15	0.06	0.77	0.117	0.185
474	8-Dec-97	1040	N	8.3	6.1		140	38		145	6	3	0.07	0.92	0.042	0.073
474	5-Jan-98	1120	S	6.3	5.4		320	300		123	12	9	0.03	0.97	0.035	0.119
474	9-Feb-98	1002	N	10.3	7.6		33	73		150	7	4	0.03	1.01	0.029	0.071
474	14-Jan-98	1100	S	6.3	4.2		500	600		82.3	44	17	0.07	0.88	0.041	0.215
474	14-Jun-93	925	N	17.0	11.0		40	110	9.1	150	4	2	0.01	0.56	0.031	0.082
474	9-Mar-98	1015	N	7.1	7.3		32			233	5	3	0.03	1.23	0.026	0.078
474	11-Mar-98						170	140								
474	13-Apr-98	1050	N	9.2	9.0		21	70		167	3	3		0.87	0.030	0.065
474	11-May-98	1100	N	11.6	12.0		36	310		180	3	2		1.01	0.039	0.072
474	13-Jul-98	1130	N	21.0	15.9		48	220		186	3	2		0.82	0.039	0.057
474	10-Aug-98						150			196	5	4	0.01	0.83	0.044	0.065
474	12-Jul-93	935	N	15.0	13.0		90	220	10.0	180	3	2	0.01	0.83	0.051	0.075
474	11-Aug-93	808	N	16.0	14.0		310	200	9.4	180	4	3		0.82	0.046	0.081
474	25-Aug-93	1210	N													
474	20-Sep-93	956	N	11.0	11.0		2,500	1,800	9.5	180	22	7		0.90	0.072	0.089
474	11-Oct-93	1015	N	14.0	10.5		120	170	10.0	180	4	4		0.68	0.065	0.100
474	13-Dec-93	1135	S	10.0	7.0		380	320	11.0	120	7	3	0.04	1.60	0.039	0.064
474	15-Nov-93	940	N	8.0	6.8		130	43	11.0	180	4	2	0.09	0.84	0.053	0.070
474	20-Dec-93	1020	N	2.0	2.2		68	60	13.0	160	8	4	0.06	1.20	0.029	0.058

Appendix B (cont.). Site MetroKC **-** North Creek Water Quality Data from Bothell.

locator	collect date	SAMPLE START TIME	STORM/NON-STORM	AMBIENT AIR TEMP. °C	SAMPLE TEMPERATURE °C	DISCHARGE RATE cfs	ENTEROCOCCUS CFU/10	FECAL COLIFORM CFU/100	DISSOLVED OXYGEN (WINKLER) mg/l	CONDUCTIVITY umhos	TOTAL SUSPENDED SOLIDS mg/l	TURBIDITY NTU	AMMONIA NITROGEN mg/l	NITRITE + NITRATE NITROGEN mg/l	ORTHO PHOSPHORUS mg/l	TOTAL PHOSPHORUS mg/l
474	15-Feb-94	1000	S	8.0	6.5		910	140	11.0	140	8	5	0.04	1.00	0.044	0.064
474	18-Jan-94	1000		3.0	5.0		34	39	12.0	170	7	3	0.04	1.00	0.044	0.061
474	22-Feb-94	1030	N	10.0	5.8		38	100	12.0	130	6	4	0.06	1.40	0.033	0.071
474	11-Jan-93	1050	N	-2.0	0.5		50	23	14.0	180	3	3	0.05	1.20	0.027	0.066
474	14-Mar-94	1014	N	9.5	9.5		26	50	11.0	150	6	2		1.10	0.037	0.058
474	11-Apr-94	1000	N	9.0	9.0		47	39	11.0	120	3	2		0.67	0.032	0.050
474	16-May-94	953	S	12.1	11.5		560	1,700	10.0	170	11	5	0.03	0.82	0.053	0.092
474	20-Jun-94	1120	N	18.6	14.7		130	240	10.0	160	5	2		1.55	0.039	0.088
474	22-Mar-93	1045	S	13.0	9.0		350	220	11.0	150	12	3		0.57	0.019	0.084
474	11-Jul-94	945	N	18.6	14.8		60	180	9.5	240	3	2		0.79	0.063	0.098
474	10-Aug-94	937	N	18.7	15.2		170	260	9.6	180	2	1		0.82	0.053	0.102
474	23-Aug-94	1530	N	21.0												
474	19-Sep-94	1007	N	15.0	13.5		150	100	9.6	180	5	2		0.72	0.028	0.103
474	10-Oct-94	1020	N	15.0	11.1		130	240	9.9	180	2	2	0.02	0.73	0.021	0.098
474	26-Oct-94	1115	S	11.0	11.6		5,900	1,000	9.0	150	27	7		0.61	0.057	0.205
474	31-Oct-94	1125	S	13.0	9.6		1,900	400	9.7	140	12	5		0.60	0.036	0.120
474	7-Nov-94	1010	N	9.0	6.8		70	61	11.0	160	3	3		0.67	0.031	0.061
474	30-Nov-94	1120	S	10.0	8.3		3,500	450	9.4	120	29	10	0.02	0.66	0.041	0.170
474	16-Feb-93	945	S	0.0	3.0		29	39	14.0	170	5	3	0.01	1.10	0.026	0.062
474	12-Dec-94	1040	N	6.0	4.3		91	40	12.0	170	3	2	0.04	0.86	0.034	0.071
474	9-Jan-95	1005	N	9.0	4.0		240	460	12.0	130	3	3	0.07	1.09	0.028	0.073
474	30-Jan-95	1220	S	12.0	7.8		560	1,000	11.0	96	45	15	0.02	0.74	0.027	0.151
474	14-Feb-95		N	0.0	1.2		23	58	13.0	160	8	3	0.04	1.06	0.048	0.114
474	9-Mar-95	1100	S	12.0	7.4		540	170	11.0	120	16	6		0.69	0.024	0.115
474	13-Mar-95	945	N	10.0	7.8		450	360	11.0	120	7	3		1.00	0.021	0.060
474	10-Apr-95	1030	N	10.0	8.6		70	360	11.0	140	3	2		0.79	0.024	0.068
474	2-May-95	1100	S	13.0	10.9		1,100	1,700	9.8	140	58	5	0.04	0.69	0.032	0.188
474	8-May-95	945	N	13.0	11.8		690	100	11.0	160	4	1	0.02	0.86	0.043	0.085
474	12-Jun-95	940	N	21.0	13.2		190	300	10.0	160	6	3		0.73	0.043	0.104
474	8-Mar-93	950	N	9.0	7.5		42	43	12.0	160	3	2		0.82	0.024	0.060
474	17-Jul-95	858	N	21.5	16.2		420	160	9.4	170	5	3		0.86	0.049	0.103
474	14-Aug-95	917	N	17.5	12.8		170	200	9.9	160	3	3		0.66	0.042	0.088
474	15-Aug-95	1012	S	14.5	13.8			4,800	8.6	100	48	13	0.03	0.66	0.077	0.296
474	18-Sep-95	1024	N	16.4	14.3		60	150	9.8	175	3	1		0.90	0.056	0.095
474	12-Sep-95	1245	N	21.0												
474	16-Oct-95	10.15	S	12.6	12.2		1,400	300	9.4	153	4	2	0.03	0.66	0.045	0.099
474	17-Oct-95	1105	S	12.0	12.2		370	260	9.2	123	5	3		0.45	0.038	0.068
474	1-Dec-95	1255	S	12.0	9.6		280	80	10.0	120	7	3	0.05	1.19	0.042	0.086
474	13-Nov-95	1010	N	10.0	9.0		52	120	10.0	138	4	3	0.03	0.96	0.030	0.076
474	11-Dec-95	1031	N	12.0	7.2		2,600	800	10.8	79	28	11	0.03	1.08	0.048	0.187
474	8-Jan-96	1000	N	8.0	8.0		1,700	300	10.2	114	5	3	0.03	1.31	0.034	0.069
474	12-Feb-96	1015	N	12.0	5.0		21	40	12.2	111	5	4	0.05	1.53	0.039	0.061
474	11-Mar-96	1030	N	13.0	10.1		240	500	10.6	150	13	4	0.04	0.88	0.032	0.092
474	12-Apr-93	830	N	7.0	8.2		380	340	10.0	120	8	2		0.90	0.230	0.051
474	15-Apr-96	1023	N	13.0	11.3		80	110	10.7	163	4	2	0.04	0.78	0.031	0.063
474	1-Apr-96	1010	S	9.0	8.4		410	460	10.7	123	13	6	0.04	0.72	0.037	0.105
474	16-Apr-96	1020	S	11.9	11.2		1,500	1,100	10.1	126	25	6	0.05	0.61	0.032	0.133
474	15-May-96	1000	N	13.1	11.3		520	1,200	10.2	135	2	3	0.07	0.62	0.038	0.077
474	10-Jun-96	1010	N	13.0	12.7		58	160	11.6	168	3	2	0.02	0.80	0.045	0.076
474	15-Jul-96	945	N	20.4	17.4		250	320	8.4	189	4	2	0.04	0.90	0.060	0.124
474	12-Aug-96	1120	N	23.0	15.7		110	250	10.4	187	4	2		0.91	0.058	0.088
474	26-Aug-96	1220	N	26.0												
474	9-Sep-96	1030	N	16.0	13.6		190	160	10.0	183	3	2	0.02	0.84	0.070	0.102
474	7-Oct-96	1041	N	15.0	12.2		130	78	9.8	172	4	3	0.05	0.78	0.052	0.114
474	12-Nov-96	1030	N	13.0	10.5		160	130	10.6	172	8	4	0.04	0.70	0.047	0.096
474	9-Dec-96	1100	N	7.0	6.0		42	82	11.4	123	5	4	0.05	1.39	0.048	0.081

Appendix C

Stream Survey of North Creek and Tributaries

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APPENDIX C

STREAM SURVEY OF NORTH CREEK

AND TRIBUTARIES

Prepared by

WATER Environmental Services, Inc.
May 8, 1991

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NORTHCREEK WATERSHED MANAGEMENT PLAN

STREAM SURVEY OF NORTH CREEK AND TRIBUTARIES

INTRODUCTION

As part of the water quality assessment task, a field survey was conducted on selected segments of the North Creek Watershed during April, 1991 to characterize the existing physical, chemical and biological conditions of the main stem and tributaries. The stream survey provided firsthand data on current stream bank conditions, water quality, riparian and instream vegetation, aquatic biota, fisheries and wildlife habitat. Major findings of the survey are summarized below for each stream segment.

Segment 1: North Creek
McCollum Park

This segment lies in the northern part of the watershed within McCollum Park, extending from the day use area to below the wooden bridge (Cedar Grove). The stream is relatively shallow and narrow, the low bank vegetated mostly with grasses, ferns, and shrubs providing about 25-50% stream cover. Deciduous trees (e.g., red alder) are common with conifers (Douglas fir, red cedar) occasionally present. Streambed is typically composed of small cobbles and gravel, but silted bottom was evident in low flow areas. At the time of the survey, the stream was carrying a heavy sediment load as a result of recent heavy rains, and woody debris cluttered sections of the stream. Aquatic biota was not well developed. Samples taken at three points along the segment showed the benthic invertebrate community composed of primarily chironomids and oligochaetes, with only a few caddisfly (Tricoptera) larvae observed. Fisheries habitat is negatively affected by excessive sediment loading, eroded stream banks, and low flow conditions. This segment of North Creek historically dries up during the summer months, a condition that results in a serious impediment to local fisheries. The stream showed evidence of recreational use impacts (eg. stream banks were collapsed or eroded at points along the segment), and possible nonpoint source impacts from nearby residential area (site 2). Healthy filamentous algal growth was observed growing in a small side stream (influenced by ground water) that empties into the main channel at this site; residential property bordering this side channel may be a possible source of nonpoint inputs of organics (compost piles), nutrients (neighborhood septic systems, fertilizers), sediment and possible toxic compounds (pesticides/herbicides).

Segment 1 (cont.)

Recommendations:

- **provide streambank stabilization**
- **control upstream flow fluctuations and sediment loading**
- **investigate possible nonpoint source inputs (residential) at site 2.**

Segment 2: North Creek Headwaters

South of Everett Mall Way

Segment occurs in a multi-family residential area at the edge of a large commercial zone. This segment is bordered on the upper edge by a fenced biofiltration unit that does not appear to be functioning optimally (flooded, presence of debris, little meander). Stream here is narrow, shallow with low gradient. Bank vegetation consists of riparian grasses, shrubs, deciduous trees (young red alder) that provide about 50-75% stream cover. Woody and other debris observed in stream, as well as in small roadside drainage swales emptying into the creek. Stream substrate composed primarily of silt and clays, with some sand and gravel present. Conditions of low flow, water column turbidity due to heavy sediment load, and presence of litter and woody debris in stream suggest poor habitat potential for fisheries and other aquatic biota. Impairment to this portion of North Creek is most likely due to urban influence in the form of runoff from multi-family complexes, roadways and adjacent commercial areas.

Recommendations:

- remove debris/litter from stream and roadside drainage swales; regular maintenance
- clean up biofiltration unit, suggest restructuring unit by adding more meander to lengthen flow-through to increase treatment effectiveness.

Segment 3: North Creek Headwaters

Drainage from Everett Mall Way

Segment originates as outfall drainage from Everett Mall commercial center that passes through a short constructed settling pond and large diameter culvert into a brushy channel that constitutes headwater source for North Creek. The stream is severely disturbed in the vicinity of the outfall, the upper portion littered with debris (eg. shopping cart), highly turbid with sediment, and covered with surface scum and foam. Channel substrate is mostly silt, suggesting low-quality habitat potential for invertebrates and fish. Stream degradation is most likely occurring as a result of the form of commercial runoff in the form of organic enrichment, sediment and inorganic loading, and possible toxicant inputs.

Recommendations:

- clean up outfall and settling pond area

Segment 4: North Creek

Midway Between Headwaters & McCollum Park

Segment flows through a single-family residential area, and receives drainage from swale-pond system serving residential area (see Slide 33). This portion of the stream segment is narrow, shallow, with a low gradient, and a short stretch passes through a culvert under roadway. Natural streamside vegetation has been largely removed and consists predominantly of grasses and shrubs, providing coverage of greater than 50%. Stream shows evidence of moderate-to-severe degradation. Sections of bank were severely eroded/washed out by heavy flows, and water column turbidity was excessive as a result of silt/sediment loading. Attached filamentous and periphyticalgal growth was evident, and woody debris littered the stream as well. Stream bottom was mostly silty-mud with little evidence of larger diameter cobbles and rocks, offering low biotic habitat potential. Inspection of in-stream rocks revealed only a few chironomids and oligochaetes, generally considered to be more pollution-tolerant taxa. Impairment to this segment appears to be largely due to urbanization effects resulting in bank destabilization, excessive runoff and sedimentation.

Recommendations:

- clean debris out of stream channel
- reconstruct collapsed streambanks, consider adding biofiltratiion component in downstream portion of reach.

Segment 5: North Creek

Proposed Detention Facility

This segment passes through a rural agricultural area in the mid portion of the watershed, and is the proposed site for the North Creek Detention Facility. A low grassy berm has been constructed to form the eastern stream bank, separating the creek from a vast wetland (ponded at time of survey) that has supported pastured livestock. The western bank exhibits denser plant growth in the form of gasses, sedges, shrubs and mostly red alder trees, but conifers are occasionally present. Stream cover is at best roughly 25%. The channel segment is narrow (average width 9-10 feet), shallow, and flows on a relatively straight coursee with no observable pool formation. At the time of the survey, water column turbidity was high as a result of substantial sediment loading following heavy rains, and woody debris cluttered most of the channel reach. The base substrate for much of the segment was composed of gravel and cobbles, but in many areas there was evidence of build up of silt and fines, especially around debris piles. This portion of North Creek has been used by cutthroat trout, winter-run steelhead, and fall chinook and coho salmon, and thus offers considerable fisheries potential, but habitat is currently limited by flow regime (lack of pools) and sparse vegetative cover. Examination of in-stream rocks not only revealed the presence of oligochaetes and chironomids, but also some mayflies (Ephemeroptera: Bactidae) on the high bank, which suggests the potential for favorable invertebrate habitat may exist along this segment. However, the stream is impaired. Cattle access to the stream has resulted in physical damage to stream banks, as well as providing a source of organic (and inorganic) enrichment to the creek. Also, recent construction activity by the local beaver population has caused a server breach in the berm, resulting in a bifurcation of channel flow.

<u>Recommendations:</u>

- repair damage to berm , increase streamside vegetative growth
- modify channel to create pools to enhance salmonid fisheries habitat.

Segment 6: Mouth of Penny Creek

(tributary of North Creek)

Segment is along a wooded lower reach of Penny Creek before it passes beneath a roadway prior to emptying into North Creek (just south of Mill Creek). Stream channel here is relatively narrow (average width 10 feet), shallow and courses along a moderately steep gradient. Streamside vegetative cover on moderately steep banks is quite substantial (>75%), consisting of grasses, sedges, and brushy understory plants as well as large deciduous trees occasionally interspersed with conifers. Stream bottom is composed primarily of gravel and sand with some silting in evident in lower flow areas. At the time of the survey, the stream was somewhat turbid and colored as a result of sediment loading from recent heavy rains. However, this reach of Penny Creek does offer a high quality habitat potential for aquatic biota. Stream benthos samples showed a high degree of diversity and abundance in invertebrate species, with Plecoptera (stoneflies), Ephemeroptera (mayflies) and Trichoptera (caddisflies) taxa well-represented, in addition to occurrence of Amphipods (freshwater shrimp), Coleopterans (beetles), and chironomids (midges). Relative to the other selected segments surveyed on the main stem and tributaries of North Creek, this segment shows a lesser degree of impairment. This is most likely a result of biofiltration effects of upstream wetlands, as well as less intensive development along the upper reach, which translates into better upstream water quality. Nevertheless, some impacts to the stream may result from urban runoff from upstream sources (single-family homes), and also to agricultural runoff from pastured livestock (buffalo) with direct access much further upstream.

<u>Recommendations:</u>

- control upstream sources of organic and nutrient enrichment to the creek
- consider a fish pass at barrier dam
- maintain riparian vegetative cover

Segment *7:* North Creek

Mill Creek Business Park

Segment skirts perimeter of extensive commercial complex at Mill Creek. The area also supports single and multi-family residential development. The stream corridor is fairly narrow (average width 8 feet), shallow, and the stream gradient low. Bank vegetation abutting the business park boundary was mostly turfgrass with some woody shrubs, apparently providing a small park-like access complete with streamside paths and benches. In fact, several animal feces deposits (most likely from domestic pets) were observed along the grassy shoreline near the pathways. The opposite bank is vegetated with grasses, sedges, shrubs, deciduous trees and some conifers, providing greater than 50% stream cover. This reach of the stream showed various signs of disturbance in the form of bank sloughing/erosion, high turbidity and color due to heavy sediment load (probably exascerbated by recent storms), and woody debris piles obstructing flow. Large areas of the stream bed were of a cobbly-gravel composition, but silting-in was evident along most of this reach, most likely due to bank instability as well as to urban/ commercial runoff. The benthic invertebra!e community was somewhat developed, showing low-moderate abundance and species diversity. In addition to chironomids, members of the Plecoptera, Ephemeroptera, and Trichoptera taxa were found in benthos samples, suggesting the potential for good benthic habitat may exist in this segment that could be enhanced through clean up.

<u>Recommendations:</u>

- remove debris and stabilize collapsed stream banks
- control nonpoint runoff from commercial and urban sources near stream

Segment 8: Silver Creek

Rehab site adjacent to Highway 527 at Alpine Industries location

Segment includes a rehabilitated section of Silver Creek (at Alpine industries location on Highway 527), extending a short way downstream to hobby farm boundary. This section of Silver Creek was restored and reconstructed about 4 years ago to enhance salmonid fisheries, and is still in a transitional/recovery period. The restored segment originates at a culvert beneath the highway, which flows over a series of riffles and pools (created by several log weirs), makes a right angle turn and is routed along a further course of riffles and pools through another culvert under drive to Alpine Industries, continuing in a very slight meander through an area of hobby farms. The stream corridor is narrow (average width riffles=8 ft; average width pools=6ft), with an approximately even mix of riffles and pools. Several small detention ponds occur near the stream, supporting dense macrophytic growth and surface algal growth at the time of the survey. Bank vegetation consisted of some grasses, rushes, invading scotch broom and small planted redcedar (1-2 ft tall), offering minimal streamside cover (0-25%). The stream bed was composed of mostly cobbles, gravel and boulders in the riffle zones, with pool bottoms showing more sand and silt buildup. At the right-angle turn in the stream, the armored banks showed signs of erosion and collapse of the uniformly-sized rock armor, rock pieces deposited in the downstream direction. Gravel depositional areas were observed building up at leading edge of several blunt-ended in-stream logs. Juvenile coho and recent spawning redds (steelhead) were sited in pools within this rehab site. An abundance of pools and riffles offer good potential habitat for benthic invertebrates. To avoid disturbing fish, no kick samples were taken, but examination of individual rocks revealed the presence of mayfly larvae (Ephemeropten) and caddisfly larvae (Trichoptera), indicating the likelihood of a healthy benthic invertebrate community. Drainage from a detention area abutting the drive to Alpine Industries enters Silver Creek via culvert in the downstream portion of this segment; the drainage water was colored, turbid, with an oily surface scum, suggesting poor water quality. Of note is the location of an auto wrecking yard further upstream along this drainage inflow, which may also be a contributing source of nonpoint pollutants. Impairment of this stream segment is primarily in the form of physical breakdown (bank instability, sedimentation/gravel bar formation, lack of sufficient vegetative cover), as well as probable nonpoint source loading from roads and commercial complex. In addition, a nearby dog kennel operation may be a source of organic and inorganic loading to the stream.

Segment 8 (cont.)

Recommendations:

- repair and stabilize stream banks
  - upgrade and increase streamside vegetation to provide more cover and stability
  - eroded uniformly-sized cobble and boulder piles should be replaced with larger expanses of mixed-sized rock material,

- enhance riffles/pools by creating more or deeper notches in log weirs,

- taper blunt-ended in-stream logs to reduce tendency for sedimentation and gravel bar development in the channel,

- control nonpoint pollutant loading from nearby industrial complexes, roads

Segment 9: Silver Creek-North Creek confluence

At TWir Creeks Mobile Home Park (Filbert Rd)

Segment includes vicinity above and below mouth of Silver Creek as it flows into North Creek (Note: this is a Snohomish County water quality sampling site). The reach is located in a residential area of single- and multi-family homes. Silver Creek channel is narrow (average depth 18 inches), with a low gradient of flow. Bank vegetation is mostly turfgrass, with low bank sedges, grasses and Ranunculus, patchy occurrence of shrubs and deciduous trees and an occasional conifer, providing stream cover of less than 25%. Stream banks are armored in places with intermixed cobble/boulder, but there is evidence of bank collapse due to uprooted trees and bank sloughing. The ratio of riffles/pools is about 4:1, and the channel bottom consists of a high proportion of cobbles and gravel with lesser areas of silt and sand and some boulders, indicating good invertebrate habitat potential. However, benthos samples of Silver Creek revealed lower than expected numbers of caddisflies, mayflies, and chironomids, and a few oligochaetes, beetles, and amphipods (*Gummarus* sp). Also, given the flow regime and good quality substrate, the lack of any stoneflies in this reach suggests the possibility that high organic loading from residential areas may be limiting biotic growth. Benthos samples on North Creek above and below the mouth of Silver Creek (sites 2, 3) also showed a poorly-developed invertebrate community with even lesser species abuncance and diversity. Attached filamentous and periphytic algal growth was observed in both creeks. Impairment in this segment is most likely due to influences in the form of residential runoff and streamside landscaping activities.

<u>Recommendations:</u>

- repair and stabilize eroded/collapsed banks
- control sources of runoff from residential properties

Segment 10: North Creek

Canyon Park, Industrial Park near Canyon Creek

This segment of North Creek runs through a commercial corridor near Canyon Creek The channel is shallow, somewhat narrow (average width=15 ft) with a moderate gradient. Natural plant cover has been severely degraded and bank vegetation consists mainly of grasses, rushes, sedges, blackberry patches and scattered red alder trees, which afford minimal streamside cover. The reach is badly channeled with no real meander and very little pool formation. Stream substrate consists of gravel/cobbles/silt, but is very slimy as a result of considerable periphytic growth. Filamentous algal growth was also evident in the stream. Some woody debris was observed in the reach at the time of the survey. Habitat potential for fisheries and benthic invertebrates is considered low. Benthos sampling produced a few chironomids and a caddisfly larva, while a couple of mayfly larvae were found on overturned rocks. Channel water column was turbid, probably a result of high sediment loading exascerbated by recent rains. Of particular note was the occurrence of an orange-colored discharge (possibly iron bacteria) into the stream (Picture #20) originating from one of the small detention ponds apparently servicing the adjacent commercial complex, indicating further water quality problems. Impairment of this reach of the stream is in the form of water quality degradation caused by urban, construction site and commercial runoff and habitat limitations caused by poor channelization of stream.

Recommendations:

- control sources of nonpoint runoff
- enhance fisheries habitat potential by rechannelizing to create more pools and riffles.

Segment 11: Silver Creek

Residential Area @ 185th Pl SE and 20th Ave SE

This upstream segment of Silver Creek is very narrow (< 6 ft) and shallow (4-6 in) and flows at low gradient through a residential site. Several constructed cattail marshes are present on either side of this stream segment. A commercial cement plant operation is located just beyond the residential development. Streamside vegetation consists some of grasses, sedges, dense shrubby undergrowth and young deciduous trees with occasional evergreens present along shore, providing about 25-50% stream coverage, although some sections are almost entirely covered by vegetation. Stream shows obvious signs of disturbance. In the more open areas, stream banks are collapsed and degraded from human use, and sediment curtains have been placed along some shoreline sections for protection. The channel is littered in places with garbage and woody debris, as well as clogged in slackwater areas with surface scum and filamentous algal growth. Channel substrate is mostly silt/mud and slimy due to periphytic algal growth, with greater abundance of gravel and cobbles in the upper part of the creek as its exists squash culvert under roadway. Limited number of pools, the low flow and muddy bottom conditions suggest available habitat for fisheries and other aquatic organisms appears to be minimal within this segment of Silver Creek Examination of several overturned rocks in stream produced no invertebrates, and no fish were observed, however, in the constructed marshes adjacent to the stream. Impairment to this stream section appears to be due to human use and urban runoff in the form of loading of sediment, nutrients, and organic matter.

<u>Recommendations:</u>

- this would be good site for stream cleanup project by local residents.

Segment 12: Tambark Creek (tributary of Silver Creek)

(169th Street SE)

An inspection was made of a short segment of Tambark Creek that flows through a culvert under 169th St. SE and south through a fenced wet meadow pasture. Fed by some smaller side streams, the creek is very narrow (<5 ft wide), shallow (6-8 in deep), and meanders slightly through a meadowland pasture vegetated primarily by soft rush *(Juncus effusus*), grasses and an occasional young red alder, which provide essentially no stream cover. Water exiting from culvert under roadway was very cold, indicating substantial groundwater influence, and was colored as a result of humic material most likely originating from peaty area upstream. Stream course is mostly that of riffles/runs with only an occasional pool-like area present. Stream bed is composed of gravel/sand near the mouth of the culvert, grading into finer silt/mud further downstream. Periphytic algal growth was evident on rocks and some filamentous algae also observed. The benthic invertebrate community appeared to be fairly well-developed, showing moderate species abundance and diversity. Kick samples and examination of individual rocks produced larvae of caddisflies, mayflies, chironomids, leeches and a good number of amphipods (*Gammarus* sp.). This segment appears to offer good in-stream habitat potential, but seriously lacks sufficient streamside plant cover, important for fisheries. Impairment to stream is due primarily to the effects of livestock pasturing, consisting of some bank damage, loss of natural streamside vegetation and agriculatural runoff inputs.

<u>Recommendations:</u>

- restrict livestock access to reduce nonpoint inputs
- increase streamside vegetative cover.

Segment 13: Thomas Lake

(At Headwaters Penny Creek)

A cursory inspection of Thomas Lake and adjacent bogs was made (picture #25), with no benthic invertebrate samples taken. The shoreline area of this peat lake is mostly undeveloped forest and bog wetlands, but is surrounded by agricultural lands and some residential areas. The highway abutting the lake (35th Ave SE) was recently washed out due to heavy storm activity and flooding, and has been rebuilt with roadside drainage swales that were full at time of visit. Heavily-used footpaths to and around the lake attest to its popularity as a recreational site. Waterfowl were also observed on the lake, indicating valuable wildlife habitat. From shoreline, water clarity appeared good, and there was no visible evidence of surface scum or algal mats.

Recommendations:

- preservation of this peat lake and surrounding bog lands.

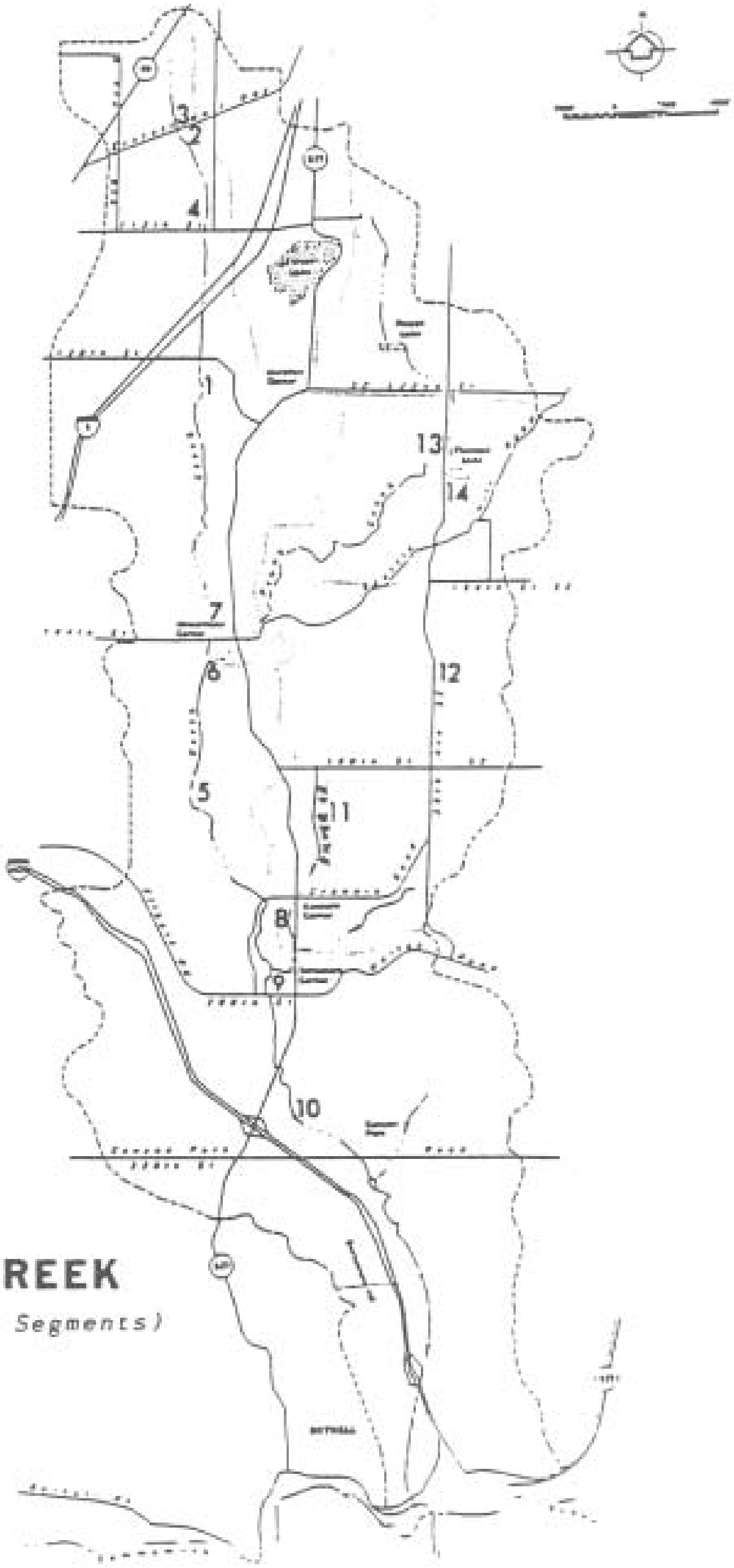
Segment 14: Penny Creek

Site of Buffulo Farm

This segment of Penny Creek flowing through a pasture was not sampled for benthic invertebrates, but viewed from outside the chain-link enclosure (picture #26) . Unvegetated streambanks showed considerable physical damage from direct access by buffalo, and poor water quality resulting from sediment input as well as drainage of organics and nutrients from agricultural lands abutting stream.

Recommendations:

- restricting cattle access, revegetating and restoring streambanks
- explore preservation of site perhaps by establishment of conservation easement



NORTH CREEK

(Stream Survey Segments)

Appendix D

Fecal Coliform Percent Reduction Calculations

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Appendix D. FC percent reduction calculation for wet season at station nclu applying statistical theory of rollback.

Season	Site Code	FC/100 mL	log (FC)
Wet	nclu	22	1.342422681
Wet	nclu	52	1.716003344
Wet	nclu	300	2.477121255
Wet	nclu	30	1.477121255
Wet	nclu	27	1.431363764
Wet	nclu	5	0.698970004
Wet	nclu	32	1.505149978
Wet	nclu	200	2.301029996
Wet	nclu	800	2.903089987
Wet	nclu	72	1.857332496
Wet	nclu	820	2.913813852
Wet	nclu	49	1.69019608
Wet	nclu	220	2.342422681
Wet	nclu	38	1.579783597
Wet	nclu	157	2.195899652
Wet	nclu	205	2.311753861
Wet	nclu	33	1.51851394
Wet	nclu	310	2.491361694
Wet	nclu	7200	3.857332496
Wet	nclu	40	1.602059991
Wet	nclu	49	1.69019608
Wet	nclu	200	2.301029996
Wet	nclu	280	2.447158031
Wet	nclu	2000	3.301029996
Wet	nclu	510	2.707570176
Wet	nclu	9000	3.954242509
Wet	nclu	190	2.278753601
Wet	nclu	6	0.77815125
Wet	nclu	33	1.51851394
Wet	nclu	22	1.342422681
Wet	nclu	151	2.178976947
Wet	nclu	3000	3.477121255
Wet	nclu	81	1.908485019
Wet	nclu	51	1.707570176
Wet	nclu	260	2.414973348
Wet	nclu	74	1.86923172
Wet	nclu	1700	3.230448921
Wet	nclu	20	1.301029996
Wet	nclu	34	1.531478917

A	mean	2.106439158	mean of the log data (= Geometric Mean (GM) of non-log data)
B	std.dev.	0.770414201	standard deviation of the log data
C	90%tile	3.093801998	90% tile of the log data = mean+(1.2816*std.dev.)
D	CV	0.365742442	coefficient of variation of the log data = std.dev./mean
E	log^mean	128	anti-log of mean of the log data = Geometric Mean (GM)
F	log^90%tile	1241	anti-log of 90% tile of the log data
G	reduction(x)	0.193439795	reduction for average (GM of non-log data) to be 50 colonies/100 mL.
H	reduction(%)	0.353546219	reduction for 90%tile of the log data to be 100 colonies/100 mL.
I	reduction(GM)	0.60868108	reduction for GM to be 50 colonies/100 ml.
J	reduction(%)	0.919425429	reduction for anti-log of 90%tile of log data to be 100 colonies/100 ml

Application of the Statistical Theory of Rollback (STR)

K	target mean	1.361715559	average of future log data to ensure meeting both WQ criteria (90%tile is limiting).
L	target std.dev	0.498037173	
M	target 90%tile	2	calculated log of second criterion (90%tile of data not exceed 100 colonies/100 ml.
N	CV	0.365742442	
O	log^mean	23	target GM of future data to ensure meeting both WQ criteria (90%tile is limiting).
P	log^90%tile	100	second criterion

Appendix D (cont.). FC percent reduction calculation for dry season at station nclu applying statistical theory of rollback.

Season	Site Code	FC/100 mL	log (FC)
dry	nclu	380	2.5797836
dry	nclu	2000	3.30103
dry	nclu	1100	3.04139269
dry	nclu	31	1.49136169
dry	nclu	181	2.25767857
dry	nclu	450	2.65321251
dry	nclu	240	2.38021124
dry	nclu	69	1.83884909
dry	nclu	8	0.90308999
dry	nclu	740	2.86923172
dry	nclu	56	1.74818803
dry	nclu	2110	3.32428246
dry	nclu	162	2.20951501
dry	nclu	164	2.21484385
dry	nclu	4400	3.64345268
dry	nclu	627	2.79726754
dry	nclu	320	2.50514998
dry	nclu	75	1.87506126
dry	nclu	21	1.32221929
dry	nclu	164	2.21484385
dry	nclu	19	1.2787536
dry	nclu	660	2.81954394
dry	nclu	1120	3.04921802
dry	nclu	5	0.69897
dry	nclu	480	2.68124124
dry	nclu	6200	3.79239169
dry	nclu	190	2.2787536

A	mean	2.36183471	mean of the log data (= Geometric Mean (GM) of non-log data)
B	std.dev.	0.78982497	standard deviation of the log data
C	90%tile	3.37407439	90% tile of the log data = mean+(1.2816*std.dev.)
D	CV	0.16720581	coefficient of variation = std.dev./mean
E	log^mean	230	anti-log of mean = Geometric Mean (GM)
F	log^90%tile	2366	anti-log of 90% tile
G	reduction(x)	0.28065669	reduction for average (GM of non-log data) to be 50 colonies/100 mL.
H	reduction(%)	0.40724484	reduction for 90%tile of the non-log data to be 100 colonies/100 mL.
I	reduction(GM)	0.78266219	reduction for GM to be 50 colonies/100 ml.
J	reduction(%)	0.95774038	reduction for anti-log of 90%tile of log data to be 100 colonies/100 ml

Application of the Statistical Theory of Rollback (STR)

K	target mean	1.39998971	average of future log data to ensure meeting both WQ criteria (90%tile is limiting).
L	target std.dev	0.46817282	
M	target 90%tile	2	calculated log of second criterion (90%tile of data not exceed 100 colonies/100 ml.
N	CV	0.33441162	
O	log^mean	25	target GM of future data to ensure meeting both WQ criteria (90%tile is limiting).
P	log^90%tile	100	second criterion

Appendix D (cont.). FC percent reduction calculation for wet season at station ncld applying statistical theory of rollback.

Season	Site Code	FC/100 mL	log (FC)
wet	ncld	37	1.5682017
wet	ncld	27	1.4313638
wet	ncld	450	2.6532125
wet	ncld	3900	3.5910646
wet	ncld	340	2.5314789
wet	ncld	1	0
wet	ncld	14	1.146128
wet	ncld	60	1.7781513
wet	ncld	1254	3.0982975
wet	ncld	1200	3.0791812
wet	ncld	21	1.3222193
wet	ncld	22	1.3424227
wet	ncld	85	1.9294189
wet	ncld	145	2.161368
wet	ncld	99	1.9956352
wet	ncld	52	1.7160033
wet	ncld	190	2.2787536
wet	ncld	1900	3.2787536
wet	ncld	39	1.5910646
wet	ncld	27	1.4313638
wet	ncld	2600	3.4149733
wet	ncld	107	2.0293838
wet	ncld	200	2.30103
wet	ncld	310	2.4913617
wet	ncld	3800	3.5797836
wet	ncld	140	2.146128
wet	ncld	6	0.7781513
wet	ncld	116	2.064458
wet	ncld	49	1.6901961
wet	ncld	1	0
wet	ncld	1300	3.1139434
wet	ncld	157	2.1958997
wet	ncld	28	1.447158
wet	ncld	120	2.0791812
wet	ncld	1600	3.20412
wet	ncld	20	1.30103
wet	ncld	77	1.8864907

A	mean	2.0445236	mean of the log data (= Geometric Mean (GM) of non-log data)
B	std.dev.	0.8822471	standard deviation of the log data
C	90%tile	3.1752115	90% tile of the log data = mean+(1.2816*std.dev.)
D	CV	0.4315172	coefficient of variation = std.dev./mean
E	log^mean	111	anti-log of mean = Geometric Mean (GM)
F	log^90%tile	1497	anti-log of 90% tile
G	reduction(x)	0.1690142	reduction for average (GM of non-log data) to be 50 colonies/100 mL.
H	reduction(%)	0.3701207	reduction for 90%tile of the non-log data to be 100 colonies/100 mL.
I	reduction(GM)	0.5487196	reduction for GM to be 50 colonies/100 ml.
J	reduction(%)	0.9331981	reduction for anti-log of 90%tile of log data to be 100 colonies/100 ml

Application of the Statistical Theory of Rollback (STR)

K	target mean	1.2878031	average of future log data to ensure meeting both WQ criteria (90%tile is limiting).
L	target std.dev	0.5557092	
M	target 90%tile	2	calculated log of second criterion (90%tile of data not exceed 100 colonies/100 ml.
N	CV	0.4315172	
O	log^mean	19	target GM of future data to ensure meeting both WQ criteria (90%tile is limiting).
P	log^90%tile	100	second criterion

Appendix D (cont.). FC percent reduction calculation for dry season at station ncld applying statistical theory of rollback.

Season	Site Code	FC/100 mL	log (FC)
dry	ncld	162	2.209515015
dry	ncld	1100	3.041392685
dry	ncld	280	2.447158031
dry	ncld	200	2.301029996
dry	ncld	450	2.653212514
dry	ncld	1090	3.037426498
dry	ncld	219	2.340444115
dry	ncld	37	1.568201724
dry	ncld	35	1.544068044
dry	ncld	27	1.431363764
dry	ncld	700	2.84509804
dry	ncld	320	2.505149978
dry	ncld	200	2.301029996
dry	ncld	340	2.531478917
dry	ncld	860	2.934498451
dry	ncld	240	2.380211242
dry	ncld	700	2.84509804
dry	ncld	112	2.049218023
dry	ncld	90	1.954242509
dry	ncld	991	2.996073654
dry	ncld	88	1.944482672
dry	ncld	350	2.544068044
dry	ncld	112	2.049218023
dry	ncld	62	1.792391689
dry	ncld	540	2.73239376
dry	ncld	5800	3.763427994
dry	ncld	700	2.84509804
dry	ncld	2700	3.431363764

A	mean	2.464941258	mean of the log data (= Geometric Mean (GM) of non-log data)
B	std.dev.	0.561992779	standard deviation of the log data
C	90%tile	3.185191203	90% tile of the log data = mean+(1.2816*std.dev.)
D	CV	0.22799439	coefficient of variation = std.dev./mean
E	log^mean	292	anti-log of mean = Geometric Mean (GM)
F	log^90%tile	1532	anti-log of 90% tile
G	reduction(x)	0.310746252	reduction for average (GM of non-log data) to be 50 colonies/100 mL.
H	reduction(%)	0.37209421	reduction for 90%tile of the non-log data to be 100 colonies/100 mL.
I	reduction(GM)	0.828592924	reduction for GM to be 50 colonies/100 ml.
J	reduction(%)	0.934715693	reduction for anti-log of 90%tile of log data to be 100 colonies/100 ml

Application of the Statistical Theory of Rollback (STR)

K	target mean	1.547750889	average of future log data to ensure meeting both WQ criteria (90%tile is limiting).
L	target std.dev	0.35287852	
M	target 90%tile	2	calculated log of second criterion (90%tile of data not exceed 100 colonies/100 ml.
N	CV	0.22799439	
O	log^mean	35	target GM of future data to ensure meeting both WQ criteria (90%tile is limiting).
P	log^90%tile	100	second criterion

Appendix D (cont.). FC percent reduction calculation for wet season at station MetroKC applying the statistical theory of rollback.

Season	Site Code	FC/100 mL	log (FC)
wet	MetroKC	40	1.60205999
wet	MetroKC	760	2.88081359
wet	MetroKC	300	2.47712125
wet	MetroKC	600	2.77815125
wet	MetroKC	39	1.59106461
wet	MetroKC	23	1.36172784
wet	MetroKC	460	2.66275783
wet	MetroKC	1000	3
wet	MetroKC	300	2.47712125
wet	MetroKC	30	1.47712125
wet	MetroKC	73	1.86332286
wet	MetroKC	140	2.14612804
wet	MetroKC	100	2
wet	MetroKC	39	1.59106461
wet	MetroKC	58	1.76342799
wet	MetroKC	40	1.60205999
wet	MetroKC		#NUM!
wet	MetroKC	800	2.90308999
wet	MetroKC	97	1.98677173
wet	MetroKC	140	2.14612804
wet	MetroKC	50	1.69897
wet	MetroKC	220	2.34242268
wet	MetroKC	170	2.23044892
wet	MetroKC	360	2.5563025
wet	MetroKC	43	1.63346846
wet	MetroKC	500	2.69897
wet	MetroKC	30	1.47712125
wet	MetroKC	70	1.84509804
wet	MetroKC	39	1.59106461
wet	MetroKC	360	2.5563025
wet	MetroKC	340	2.53147892
wet	MetroKC	110	2.04139269
wet	MetroKC	460	2.66275783
wet	MetroKC	1100	3.04139269
wet	MetroKC	140	2.14612804
wet	MetroKC	150	2.17609126
wet	MetroKC	310	2.49136169
wet	MetroKC	1700	3.23044892
wet	MetroKC	1700	3.23044892
wet	MetroKC	100	2
wet	MetroKC	1200	3.07918125
wet	MetroKC	50	1.69897
wet	MetroKC	43	1.63346846
wet	MetroKC	61	1.78532984
wet	MetroKC	450	2.65321251
wet	MetroKC	120	2.07918125
wet	MetroKC	130	2.11394335
wet	MetroKC	400	2.60205999
wet	MetroKC	38	1.5797836
wet	MetroKC	320	2.50514998
wet	MetroKC	60	1.77815125
wet	MetroKC	40	1.60205999
wet	MetroKC	80	1.90308999
wet	MetroKC	800	2.90308999
wet	MetroKC	82	1.91381385

A	mean	2.19114977	mean of the log data (= Geometric Mean (GM) of non-log data)
B	std.dev.	0.52090081	standard deviation of the log data
C	90%tile	2.85873624	90% tile of the log data = average+(1.2816*std.dev.)
D	CV	0.23772944	coefficient of variation = std.dev./mean
E	log^mean	155	anti-log of mean = Geometric Mean (GM)
F	log^90%tile	722	anti-log of 90% tile
G	reduction(x)	0.22462169	reduction for average (GM of non-log data) to be 50 colonies/100 mL.
H	reduction(%)	0.30039016	reduction for 90%tile of the non-log data to be 100 colonies/100 mL.
I	reduction(GM)	0.67802642	reduction for GM to be 50 colonies/100 ml.
J	reduction(%)	0.86155931	reduction for anti-log of 90%tile of log data to be 100 colonies/100 ml

Application of the Statistical Theory of Rollback (STR)

K	target mean	1.53294993	average of future log data to ensure meeting both WQ criteria (90%tile is limiting).
L	target std.dev	0.36442733	
M	target 90%tile	2	calculated log of second criterion (90%tile of data not exceed 100 colonies/100 ml.
N	CV	0.237729441	
O	log^mean	34	target GM of future data to ensure meeting both WQ criteria (90%tile is limiting).
P	log^90%tile	100	second criterion

Appendix D (cont.). FC percent reduction calculation for dry season at station metroKC applying statistical theory of rollback.

Season	Site Code	FC/100 mL	log (FC)
dry	MetroKC	130	2.113943352
dry	MetroKC	110	2.041392685
dry	MetroKC	240	2.380211242
dry	MetroKC	300	2.477121255
dry	MetroKC	160	2.204119983
dry	MetroKC	140	2.146128036
dry	MetroKC	220	2.342422681
dry	MetroKC	220	2.342422681
dry	MetroKC	180	2.255272505
dry	MetroKC	160	2.204119983
dry	MetroKC	320	2.505149978
dry	MetroKC	210	2.322219295
dry	MetroKC		#NUM!
dry	MetroKC	200	2.301029996
dry	MetroKC	260	2.414973348
dry	MetroKC	200	2.301029996
dry	MetroKC	4800	3.681241237
dry	MetroKC	250	2.397940009
dry	MetroKC	160	2.204119983
dry	MetroKC	1800	3.255272505
dry	MetroKC	100	2
dry	MetroKC	150	2.176091259
dry	MetroKC	160	2.204119983
dry	MetroKC	100	2
dry	MetroKC	800	2.903089987
dry	MetroKC	2000	3.301029996
dry	MetroKC	170	2.230448921
dry	MetroKC	240	2.380211242
dry	MetroKC	1000	3
dry	MetroKC	400	2.602059991
dry	MetroKC	300	2.477121255
dry	MetroKC	260	2.414973348
dry	MetroKC	78	1.892094603

A	mean	2.420980354	mean of the log data (= Geometric Mean (GM) of non-log data)
B	std.dev.	0.401102373	standard deviation of the log data
C	90%tile	2.935033155	90% tile of the log data = mean+(1.2816*std.dev.)
D	CV	0.165677665	coefficient of variation = std.dev./mean
E	log^mean	264	anti-log of mean = Geometric Mean (GM)
F	log^90%tile	861	anti-log of 90% tile
G	reduction(x)	0.298230571	reduction for average (GM of non-log data) to be 50 colonies/100 mL.
H	reduction(%)	0.318576693	reduction for 90%tile of the non-log data to be 100 colonies/100 mL.
I	reduction(GM)	0.810333928	reduction for GM to be 50 colonies/100 ml.
J	reduction(%)	0.883864005	reduction for anti-log of 90%tile of log data to be 100 colonies/100 ml

Application of the Statistical Theory of Rollback (STR)

K	target mean	1.64971244	average of future log data to ensure meeting both WQ criteria (90%tile is limiting).
L	target std.dev	0.273320505	
M	target 90%tile	2	calculated log of second criterion (90%tile of data not exceed 100 colonies/100 ml.
N	CV	0.165677665	
O	log^mean	45	target GM of future data to ensure meeting both WQ criteria (90%tile is limiting).
P	log^90%tile	100	second criterion