A Department of Ecology Report

WASHINGTON STATE DEPARTMENT OF ECOLOGY

Effectiveness Monitoring for Fecal Coliform Total Maximum Daily Loads in Pipers Creek

Abstract

The Washington State Department of Ecology is required, under Section 303(d) of the federal Clean Water Act and U.S. Environmental Protection Agency regulations, to develop and implement Total Maximum Daily Loads (TMDLs) for impaired waters, and evaluate the effectiveness of the water clean-up plan to achieve the needed improvement in water quality.

When the TMDL was established, Pipers Creek was neither listed on Washington State's list of impaired waters nor on the water-quality-limited list. Nevertheless, a fecal coliform TMDL was developed for Pipers Creek based on a detailed Watershed Action Plan document that outlined control of nonpoint sources of pollution to improve water quality. The goal is to meet the fecal coliform water quality standard in Pipers Creek which is 50 colonies /100 ml. Evaluation of available monitoring data indicated non-compliance with the criterion.

by George Onwumere
June 2003

Publication No. 03-03-027
Waterbody WA-08-1000

Publication Information

This report is available on the Department of Ecology home page on the World Wide Web at http://www.ecy.wa.gov/biblio/0303027.html

For a printed copy of this report, contact the Department of Ecology Publications Distribution Office and ask for publication number 03-03-027.

E-mail: ecypub@ecy.wa.gov
Phone: (360) 407-7472
Address: PO Box 47600, Olympia WA 98504-7600

Author: George Onwumere, Ph.D.
Washington State Department of Ecology
Environmental Assessment Program
Email: ogeo461@ecy.wa.gov
Phone: (360) 407-6730
Address: PO Box 47600, Olympia WA 98504-7600

Introduction

The Washington State Department of Ecology (Ecology) is required, under Section 303(d) of the federal Clean Water Act (CWA) and U.S. Environmental Protection Agency's (EPA) implementing regulations, to:

- Periodically assemble the list of water bodies that are out of compliance with the state water quality standards.
- Develop and implement Total Maximum Daily Loads (TMDLs) for these watersheds.
- Evaluate the effectiveness of the clean-up plan to achieve the needed improvement in water quality.

Currently, over 40 percent of the Nation's and most states' assessed waters still do not meet the water quality standards. In Washington State, there are approximately 398 EPA-approved TMDLs addressing water quality impairments that include pathogens, metals, conventional pollutants, priority pollutants, and exotic biological species (U.S. Environmental Protection Agency, 2002).

The TMDL is a tool for implementing water quality standards under the CWA and is based on the relationship between pollution sources and in-stream or lake water quality conditions. It is a summation of the individual waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources, including natural background conditions.

This report presents an assessment of the effectiveness of fecal coliform (FC) TMDL implementation programs in the Pipers Creek watershed. Pipers Creek watershed, located within the City of Seattle, is an urban drainage basin of approximately 3.5 mi^2. The watershed is highly developed in the upper plateau with residential homes, shopping malls, and commercial buildings. The lower watershed has contrasting land uses that include a park, cemetery, and other open spaces (Shapiro and Associates, Inc., 1989). Typical of the urban stream setting, Pipers Creek has a drainage network that includes a tributary stream, storm drain pipes, and drainage ditches. These drainage network systems convey stormwater runoff events and their associated pollutants, including fecal coliform, into the creek and eventually into the Puget Sound. The deterioration in water quality and pollutant loading into Puget Sound were the motivation for constructing a Pipers' Creek TMDL.

The purpose of this report is to assess the effectiveness of past TMDL implementation programs outlined in the Watershed Action plans and to suggest where water quality improvements can be made in the Pipers Creek watershed. TMDL effectiveness monitoring is a fundamental, but often neglected, component of any TMDL implementation activity. It is a measure of how well recommended improvements outlined in the TMDL promoted compliance with state water quality standards. The benefits of TMDL effectiveness evaluation include:

- A measure of progress toward water quality improvements (i.e. how much watershed restoration has been achieved, how much more effort is required).
- More efficient allocation of funding and optimization in planning/decision-making.

- Technical feedback to refine the initial TMDL model, best management practices (BMPs), nonpoint source (NPS) plans, and permits.

The overall goal is attainment of the FC water quality standard in receiving water for the protection of human and aquatic life.
This report includes the following:

- Background information and a summary of FC criteria
- TMDL summary
- Results and discussion
- Conclusion

Background

The Association of State and Interstate Water Pollution Control Administrators (ASIWPCA, 1986) defined pathogens as disease-causing organisms which include bacteria and viruses. Bacteriological indicators have been used to determine the health of surface waters and their suitability for drinking, human contact recreation, and shellfish harvesting. For example, fecal coliform (FC), total coliform (TC), and, fecal streptococci (FS) are frequently used as indicator bacteria in testing for the presence of pathogenic bacterial contamination. Washington State's water quality criterion for bacteriological pollutants is currently based on fecal coliform as an indicator organism for human or other warm-blooded animal contamination.

Research to date has shown that there are high levels of this indicator micro-organism in urban stormwater runoff. Researchers have found that significant amounts of intermittent bacterial contamination in receiving waters are attributable to urban stormwater runoff (Dutka and Rybakowski, 1978; Field and Pitt, 1990). Fecal coliform densities of 190,000 colonies/100 ml were recorded in urban runoff from Ontario, Canada streams. The sources of bacterial contamination in urban settings like Pipers Creek include failing onsite sewage systems, leakage from old sewer lines, combined sewer overflows (CSOs), and forestry and agricultural practices (Pipers Creek Watershed Management Committee, 1990).

Effects to humans of bacteriological contamination include: gastrointestinal distress, respiratory, and infection symptoms such as skin irritations (from contact recreation). Environmental impacts include commercial and recreational shellfish beach closures. In fact, high levels of fecal coliform bacteria have been measured in the Pipers Creek watershed by the City of Seattle and King County Department of Natural Resources that have prompted the following actions:

- King County beach closures to avoid contact recreation.
- Recommendations to limit harvest and consumption of seaweed, crab, shellfish, and bottomfish from King County beaches (Pipers Creek Watershed Management Committee, 1990).

Pipers Creek is a Class AA (extraordinary) waterbody and has a fecal coliform bacteria limit not to exceed a geometric mean value of 50 colonies/100 ml (freshwater) and 14 colonies/100 ml (marine water) – part 1 of the water quality standard, and not to have more than 10% of all samples used for calculating the geometric mean exceeding 100 colonies/100 ml (freshwater); and 43 colonies/100 ml (marine water) – part 2 of the water quality standard. Other relevant criteria for this creek are: temperature (16 degrees Celsius), pH (6.5 to 8.5), turbidity (5 NTU), and dissolved oxygen (9.5 mg/L) (Washington State Department of Ecology, 1997).

TMDL Summary

Potential sources of bacterial contamination to the creek were identified as pet wastes, combined sewer overflows at the treatment facility and North Beach Pump Station, leaking sewer pipes, failing septic tank systems, and a local duck pond (Pipers Creek Watershed Management Committee, 1990). Difficulties in dealing with nonpoint source pollution encouraged public education as an early implementation element from the Watershed Action Plan.

The Watershed Action Plan supposition stressed that storm event-driven nonpoint sources are primary causes of pollution problems and that limiting stormwater impacts would curtail fecal coliform loading.

The TMDL required that adequate monitoring be conducted to assess progress in achieving both the TMDL and Watershed Action Plan's goals. Water quality sampling was conducted bi-weekly or monthly by both City of Seattle and King County in the Pipers Creek watershed from 1993 to the present. However, only the data from 1993 to 2002 was used in the evaluation, as indicated in Figure 1 and Table 1. The Pipers Creek TMDL was limited to freshwater issues. Freshwater monitoring results from the four sites (KTHA01, KTHA02, KTHA03, and KSHZ06) are used in this analysis (Table 1).

Results and Discussion

Table 2 reports the annual geometric mean calculated from fecal coliform results for all sites beginning 1993 to 2002. Fecal coliform data from January to June was used in the 2002 geometric mean calculation. The data indicate a variation in annual fecal coliform concentration ranging from 50 colonies/100 ml in 1997 (KTHA03 site) to 533 colonies/100 ml in 1999 (KTHA02 site). These results indicate that fecal coliform concentrations exceeded the criterion each year (Figure 2), except for 1997 at the KTHA03 (mouth of Venema Creek) site. Table 2 also presents the 90th percentile values and percent of samples exceeding part 2 of the water quality standard in brackets.

The main channel sites (KTHA02 and KSHZ06) below the Waste Treatment Facility have consistently higher fecal coliform concentrations than the upstream (KTHA01) site (Figure 3). Fecal coliform concentrations are lowest at the KTHA03 site (Freshwater station at the mouth of Venema Creek), except in 1999 (Figure 2). The lower Venema Creek (KTHA03) site still does not meet the fecal coliform water criterion. It appears there are sources of fecal coliform contribution to Pipers Creek from the Venema Creek tributary to the downstream (KSHZ06) site (Figure 3). The nonpoint source control programs implemented over the past years appear ineffective in bringing Pipers Creek water quality into compliance with state standards.

Table 1. Pipers Creek Watershed Sampling Locations

Site	Latitude & Longitude	Site description	Monitoring Period
ITCarkeekP	47 42 45 122 22 45	Marine water beach station at Carkeek Park that is north of Pipers' Creek mouth, away from the creek's influence.	2000 - 2001
KSHZ03	47 42 45 122 22 46	Marine water beach station at Carkeek Park that is at the mouth of Pipers Creek.	1993 - 2002
KTHA01	47 42 41 122 22 27	Freshwater Pipers Creek station upstream from the Treatment Facility.	1993 - 2002
KTHA02	47 42 39 122 22 18	Freshwater Pipers Creek station, main channel.	1993 - 2002
KTHA03	47 42 39.8 122 22 18	Freshwater station at the mouth of Venema Creek.	1993 - 2002
KSHZ06	47 42 42 122 22 46	Freshwater Pipers Creek station, main channel	1993 - 2002

Table 2. Upstream to Downstream Annual Geometric Mean for Fecal Coliform Data for Pipers Creek sites (#/100 mL).

	KTHA01		KTHA02		KTHA03		KSHZ06	
Year	Geo-mean	90th Percentile	Geo-mean	90th Percentile	Geo-mean	90th Percentile	Geo-mean	90th Percentile
1993	122	559 (**67**)	138	892 (**60**)	68	270 (**46**)	126	389 (**50**)
1994	151	558 (**67**)	197	1,520 (**69**)	51	148 (**42**)	93	382 (**50**)
1995	179	600 (**67**)	297	1,750 (**77**)	105	332 (**58**)	303	1,630 (**83**)
1996	261	587 (**92**)	300	806 (**83**)	145	569 (**50**)	280	654 (**77**)
1997	255	645 (**83**)	425	5,540 (**77**)	***50***	140 (**23**)	218	852 (**67**)
1998	197	899 (**67**)	263	860 (**73**)	124	879 (**40**)	259	1,241 (**60**)
1999	175	600 (**67**)	***553***	11,270 (**83**)	214	1,310 (**57**)	297	1,730 (**92**)
2000	208	529 (**83**)	294	760 (**82**)	122	590 (**46**)	248	420 (**83**)
2001	100	312 (**50**)	255	5,528 (**62**)	56	87 (8)	231	1,690 (**70**)
2002	87	430 (**20**)	228	354 (**100**)	67	147 (**20**)	117	268 (**40**)

Note:
1) Bold numbers in brackets are percent of samples exceeding water quality standard **part 2.**
2) Part 1 - geometric mean value (GMV) shall not exceed 50 colonies/100mL.
Part 2 - not more than 10% of the samples used for calculating the GMV shall exceed 100 colonies/100mL
3) For geometric mean calculation, the minimum sample number/year/site = 11, except for year 2002 with the minimum sample number/year/site = 5

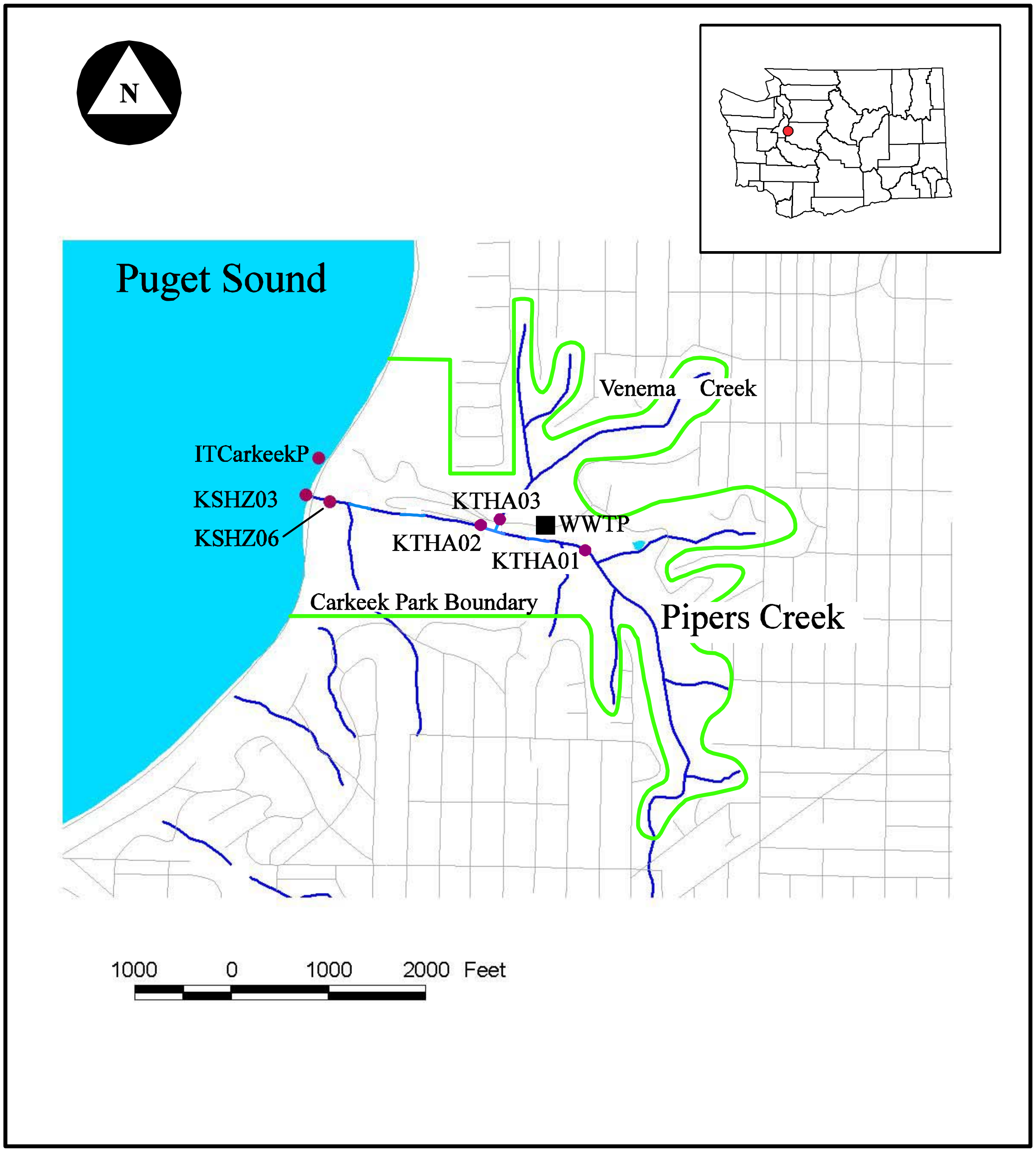

Figure 1. Pipers Creek Water Quality Sampling Locations.

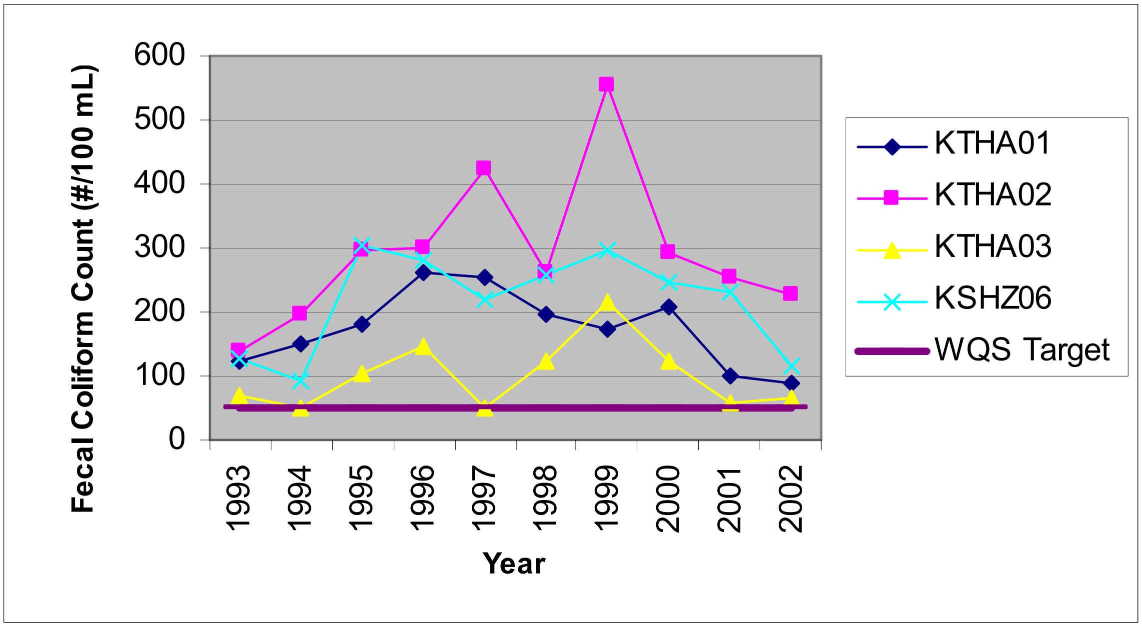

Figure 2. Annual Geometric Mean Fecal Coliform Comparison to Water Quality Standard Target for Pipers Creek Freshwater sites from 1993 to 2002.

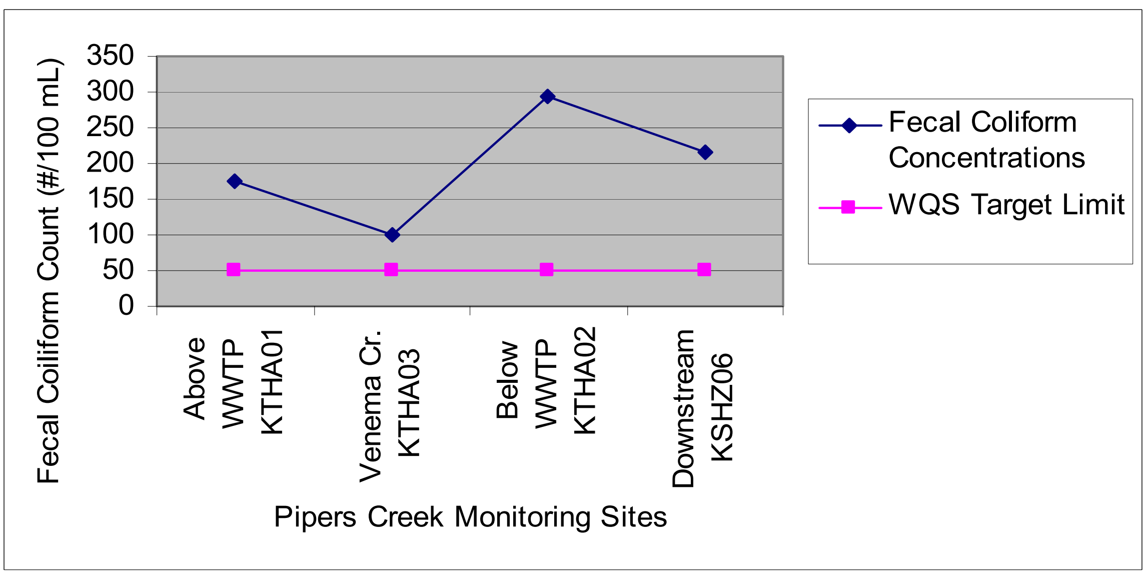

Figure 3. Upstream to Downstream Fecal Coliform Concentration Pattern at the Pipers Creek Watershed.

Fecal coliform concentrations are higher during the dry non-winter period (April – October) than during the wet winter (November – March) at all sites (Figure 4). The lower fecal coliform concentration observed during the wet winter months could be due to the following.

- High precipitation events that lead to concentration dilution.
- Reduction in domestic animal presence, especially pet wastes.

As usual, the two main channel sites below the treatment facility, KTHA02 and KSHZ06, show the most variation in fecal coliform concentration compared to other locations in the creek (Figure 4).

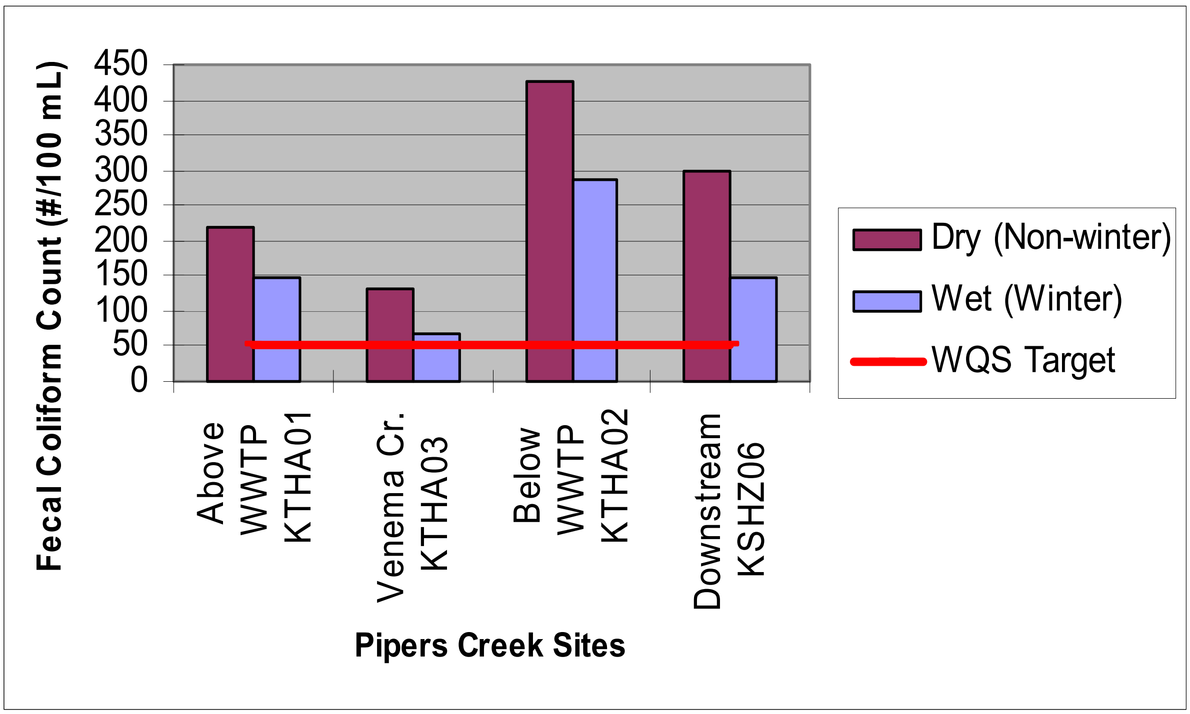

Figure 4. Seasonal Variations in Mean Fecal Coliform Concentration at Pipers Creek sites from 1993 to 2002.

There were less observable trends in fecal coliform concentrations at these sites, KTHA01 and KSHZ06, (Figures 5 and 8) compared to an increasing trend observed at the two middle sites, KTHA02 and KTHA03, (Figures 6 and 7).

Similarly, there were less observable trends in seasonal fecal coliform concentrations at the two sites, KTHA01 and KSHZ06, (Figures 13, 14, 15, and 16) compared to an increasing seasonal trend observed at the two middle sites, KTHA02 and KTHA03, (Figures 9, 10, 11, and 12).

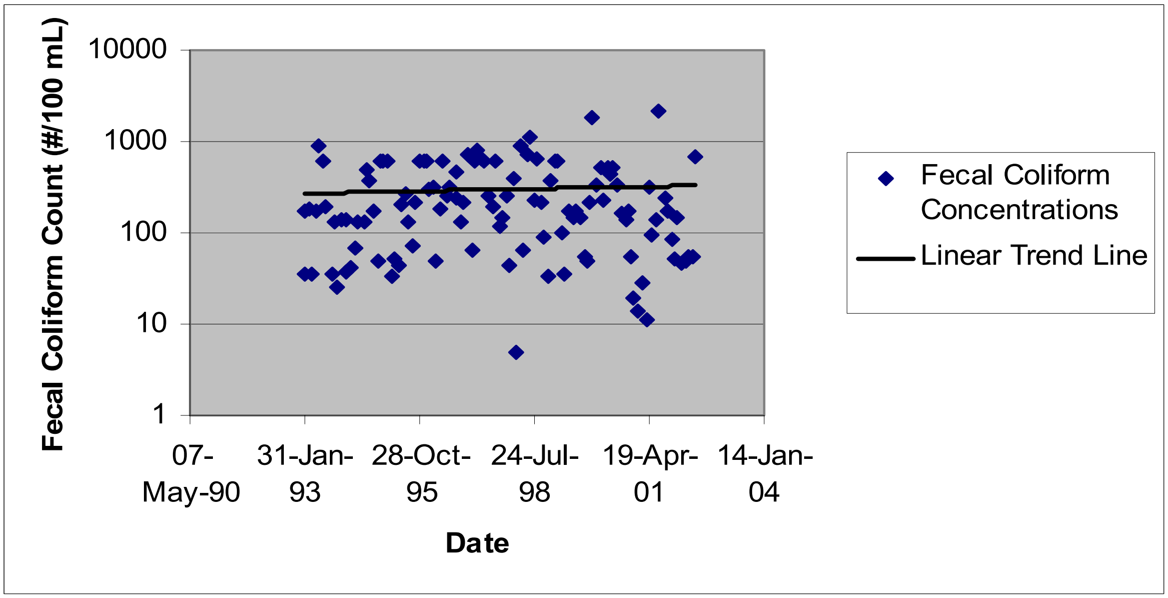

Figure 5. Trend Analysis for the Upstream (KTHA01) Site above the Treatment Facility from 1993 to 2002.

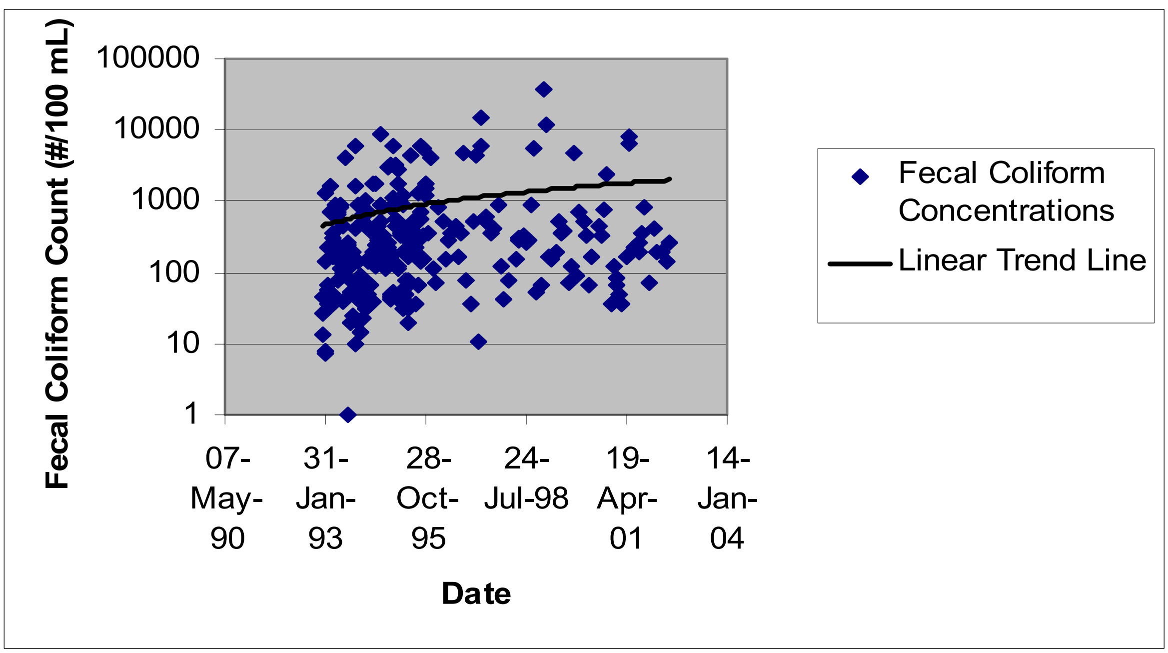

Figure 6. Trend Analysis for the Middle Stream (KTHA02) Site, Main Channel from 1993 to 2002.

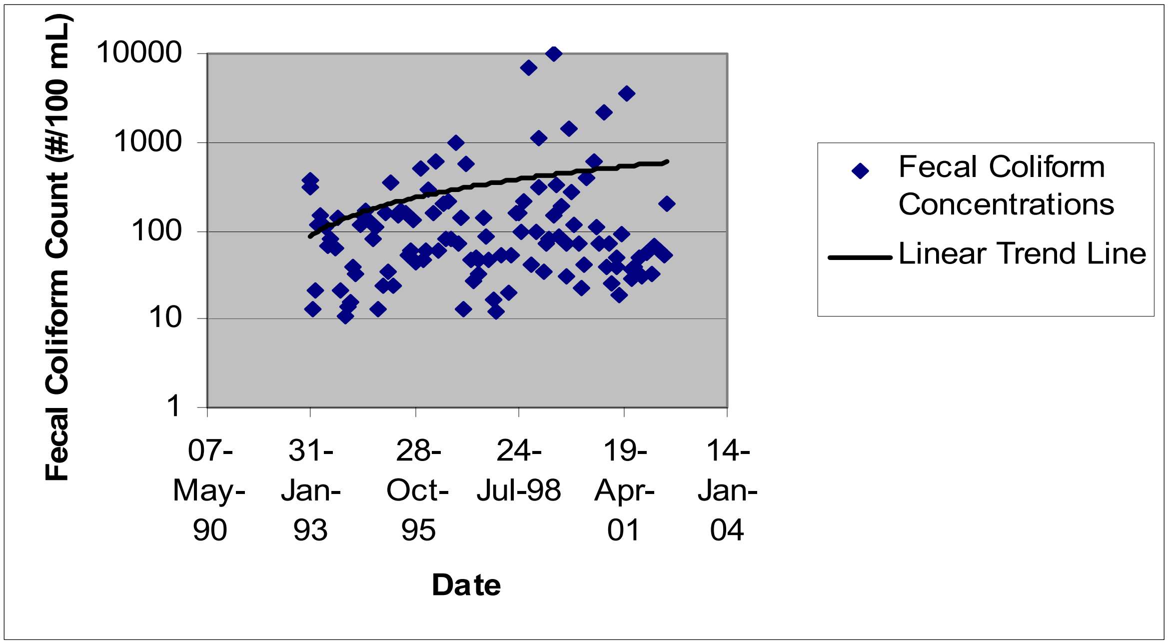

Figure 7. Trend Analysis for the KTHA03 Site, Mouth of Venema Creek from 1993 to 2002.

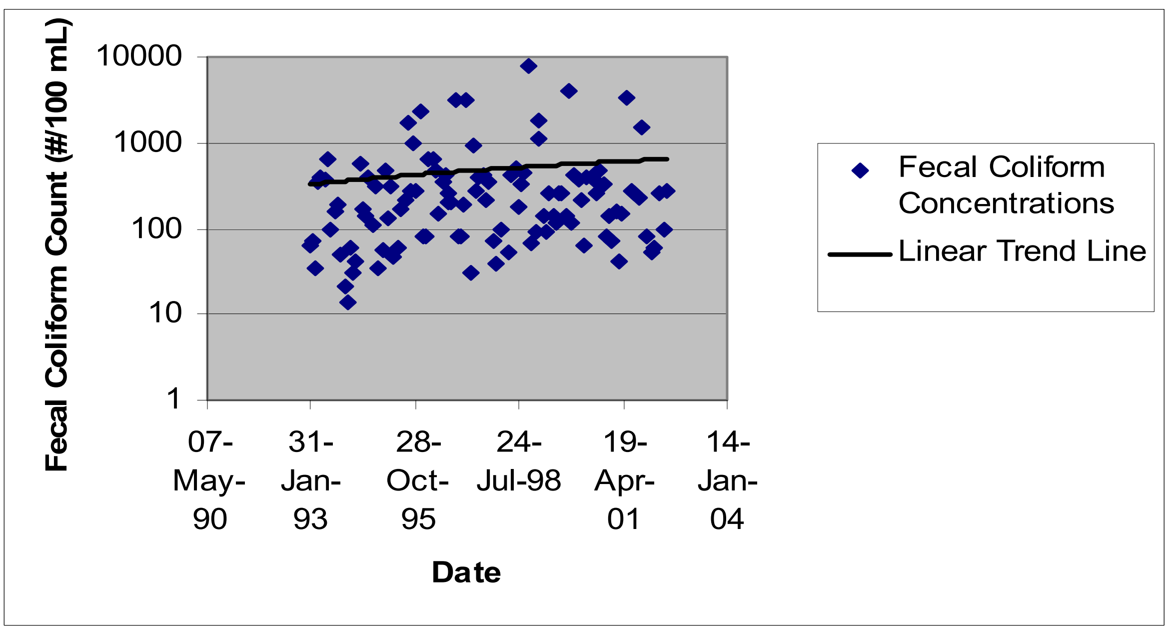

Figure 8. Trend Analysis for the Downstream (KSHZ06) Site, Main Channel from 1993 to 2002.

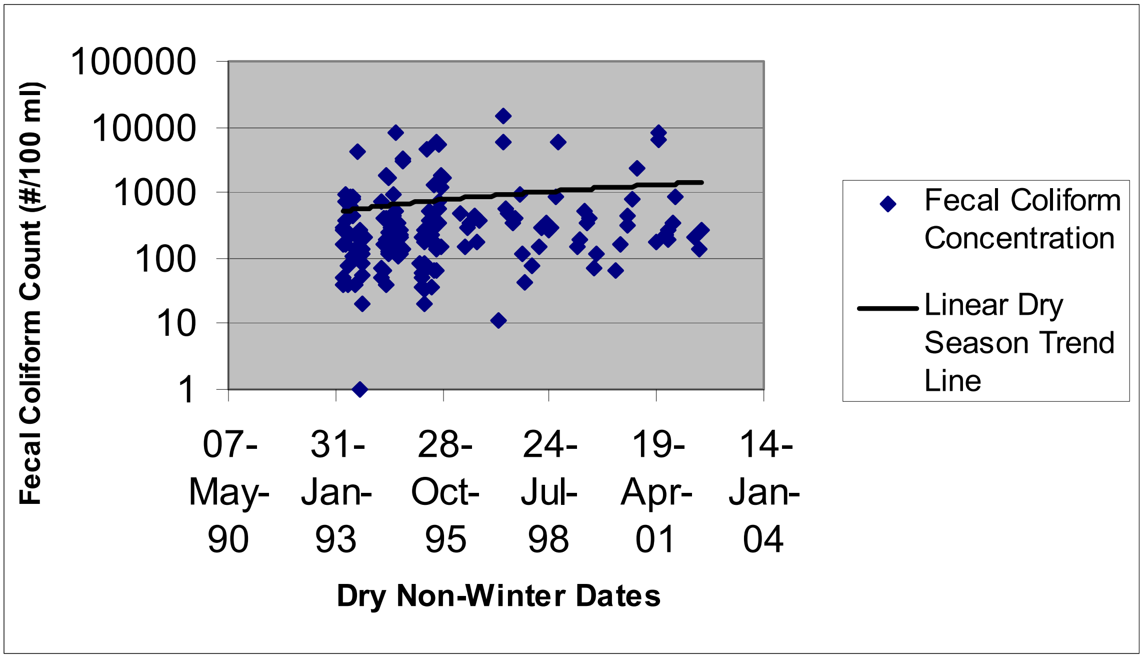

Figure 9. Dry Season Trend Analysis for the Middle Stream (KTHA02) Site, Main Channel from 1993 to 2002.

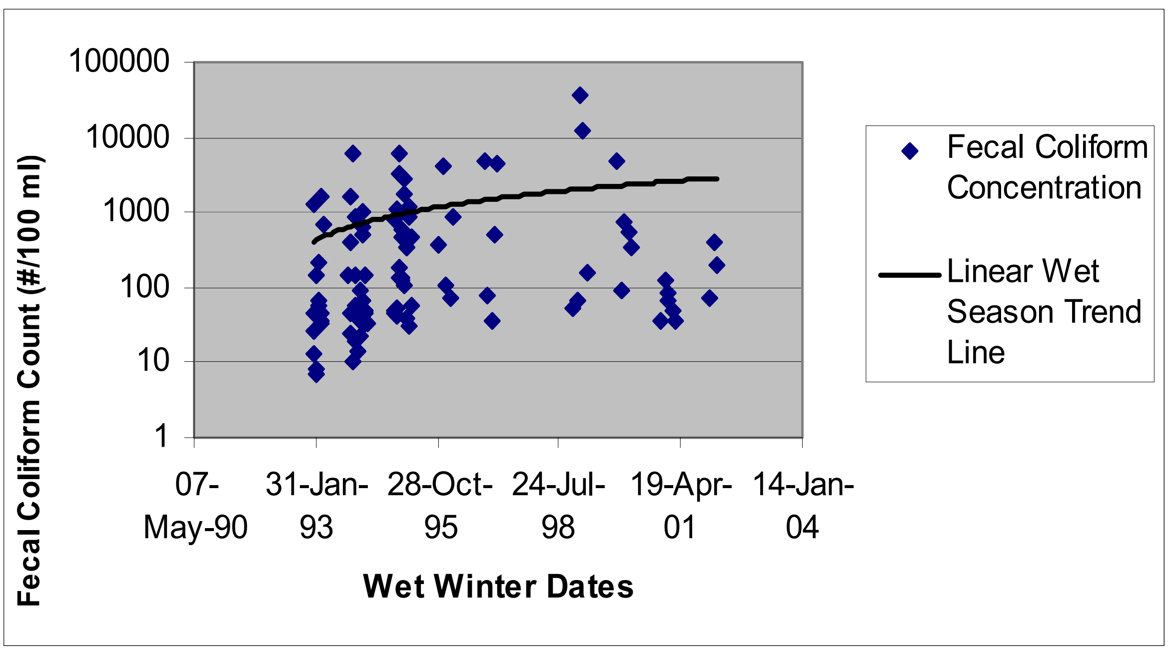

Figure 10. Wet Season Trend Analysis for the Middle Stream (KTHA02) Site, Main Channel from 1993 to 2002.

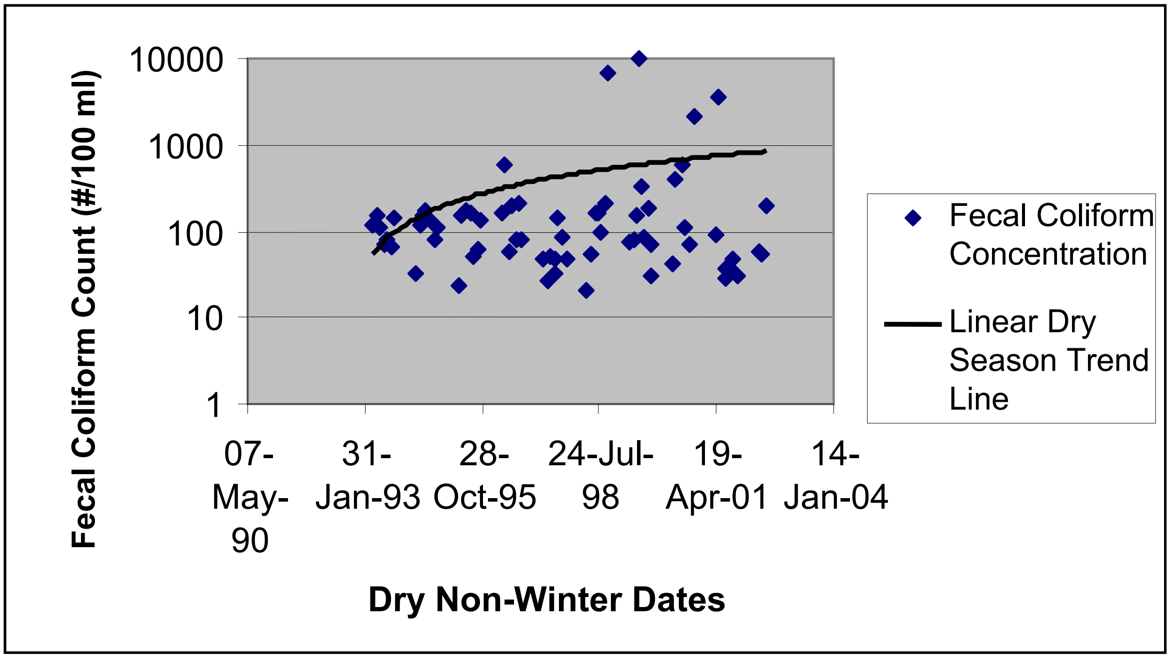

Figure 11. Dry Season Trend Analysis for the KTHA03 Site, Mouth of Venema Creek from 1993 to 2002.

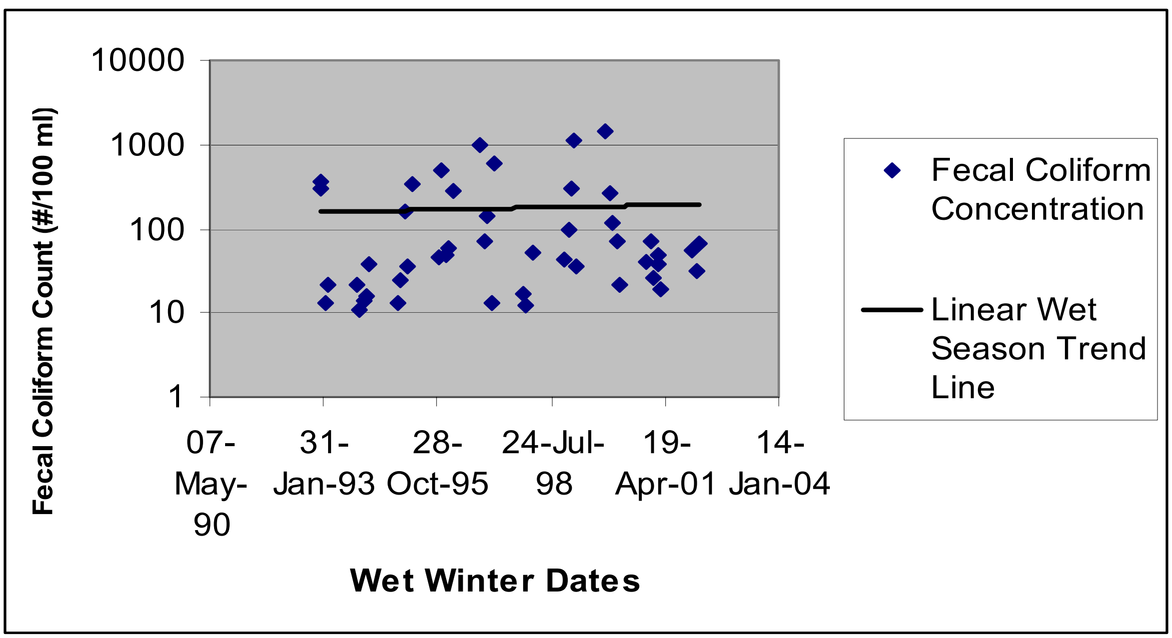

Figure 12. Wet Season Trend Analysis for the KTHA03 Site, Mouth of Venema Creek from 1993 to 2002.

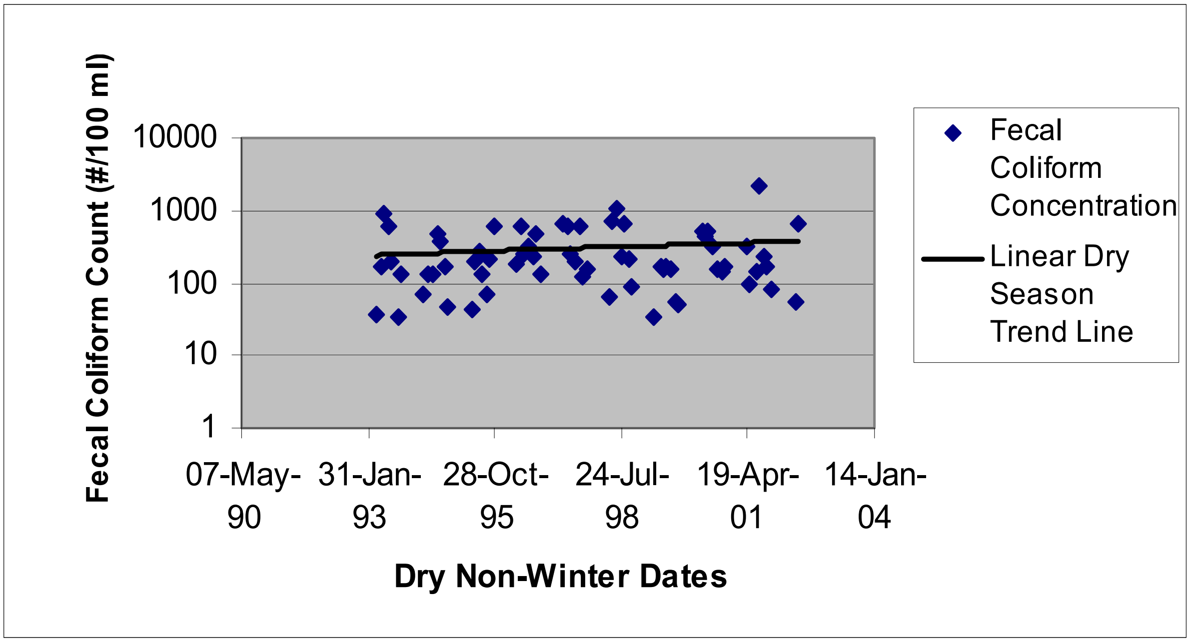

Figure 13. Dry Season Trend Analysis for the Upstream (KTHA01) Site above the Treatment Facility from 1993 to 2002.

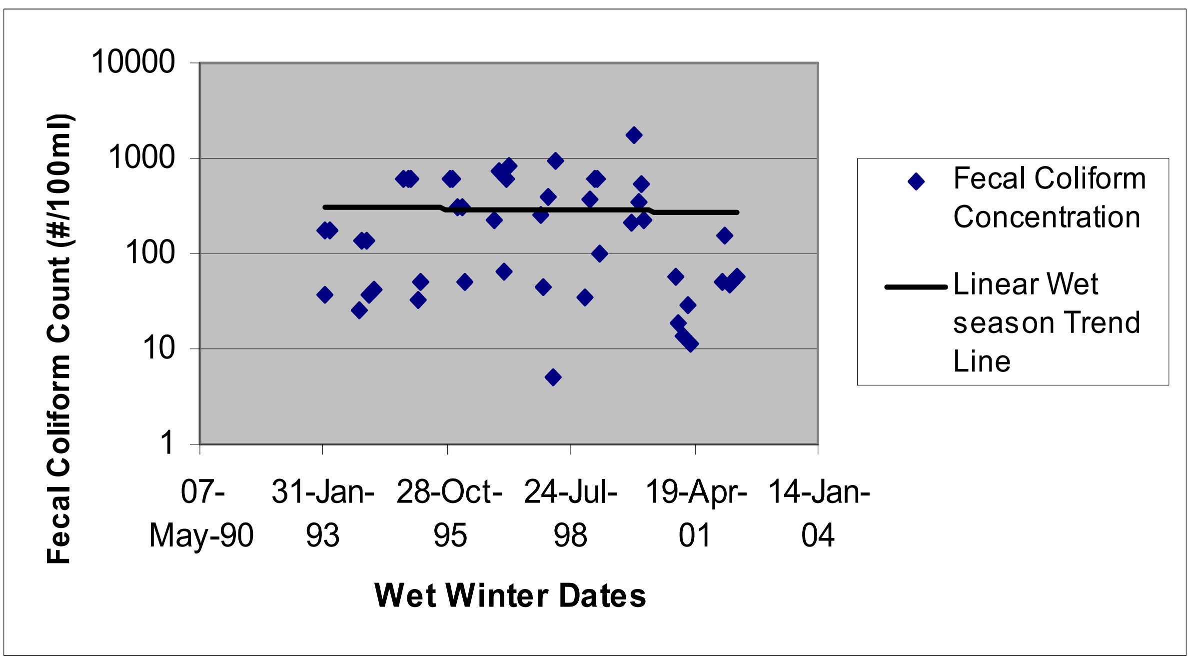

Figure 14. Wet Season Trend Analysis for the Upstream (KTHA01) Site above the Treatment Facility from 1993 to 2002.

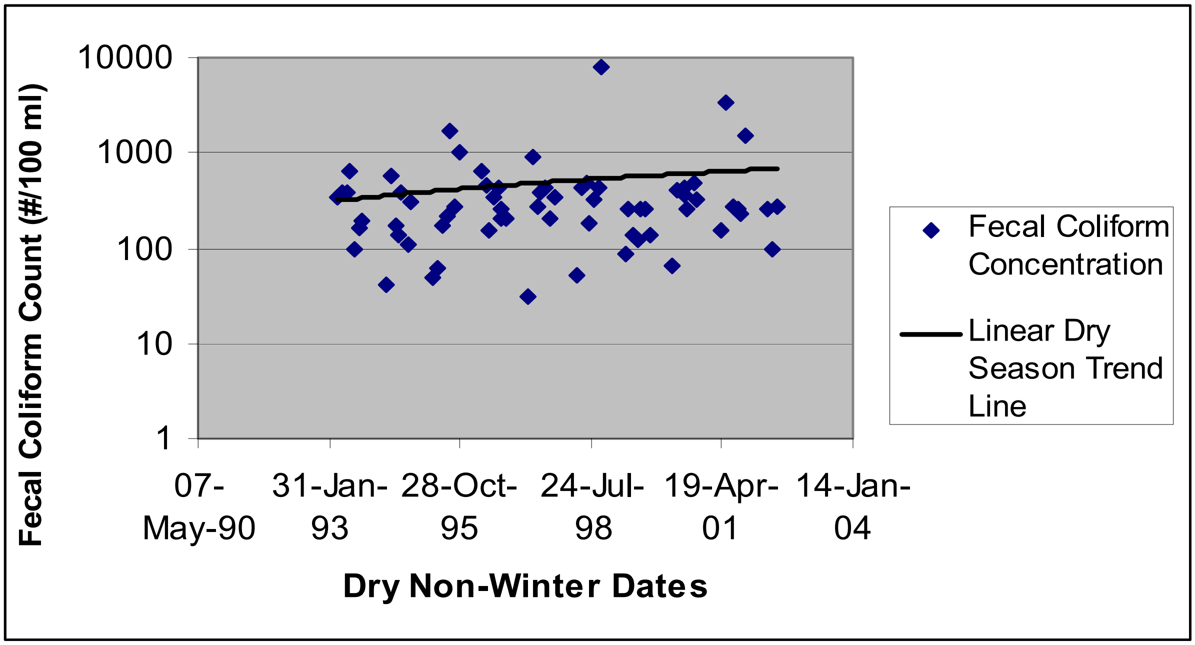

Figure 15. Dry Season Trend Analysis for Downstream (KSHZ06) Site, Main Channel from 1993 to 2002.

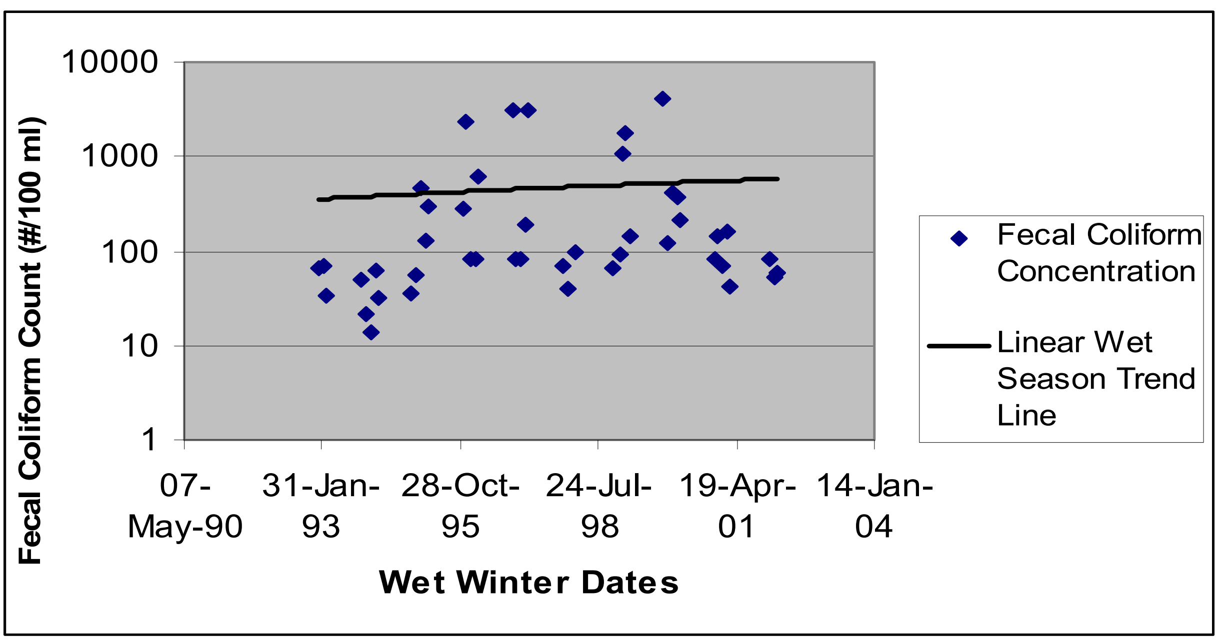

Figure 16. Wet Season Trend Analysis for Downstream (KSHZ06) Site, Main Channel from 1993 to 2002.

The data evaluation suggests that current implementation programs to reduce fecal coliform sources to Pipers Creek have not been effective despite management programs such as public education and outreach. Future programs should target nonpoint source identification and aggressively implement management guidelines to curtail these sources.

Conclusion

Evaluation of available effectiveness monitoring data indicates that fecal coliform concentrations exceed both parts of the water quality criterion at all Pipers Creek sites. Past programs such as flyer dissemination, public education and outreach to bring the creek into compliance with water quality standards have not been effective in curtailing nonpoint sources of fecal coliform bacteria. Reducing fecal coliform levels in this creek should consider:

1) Identifying and reducing potential sources especially during the dry (non-winter) period (April – October).
2) Further reducing the wet (winter) stormwater runoff-related fecal coliform contributions.
3) Targeting specific areas with additional high resolution monitoring.
4) Checking for the presence of human sources, e.g., leaking septic systems and sewers (dye test).
5) Continuing the public education campaign.
6) Aggressive enforcement of local ordinances to deter violators.

Without strategically targeting these sources of fecal coliform, Pipers Creek will continue to experience elevated bacterial concentrations and subsequent risks to human health.

Acknowledgements

The author would like to thank the following people and organizations for their contributions to this report.

- King County, for providing the Pipers Creek data sets. Sally Abella (King County) and Beth Schmoyer (Seattle Public Utilities) for reviewing the draft report.
- Robert W. Plotnikoff, Tony Whiley, Steve Butkus (Department of Ecology), and Lisa Olson (NWRO) for providing the Unit-level review and comments on the report. Special thanks to Robert W. Plotnikoff for editing the final draft report.
- Karol Erickson, Department of Ecology, for providing timely Program-level review.
- Dr. Stephen Smith, Simon Fraser University, Burnaby, Canada, for providing timely external-level review of the draft report.
- Michelle Harper for formatting the report.

References

Association of State and Interstate Water Pollution Control Administrators (ASIWPCA). 1986. Meeting the Challenge of Nonpoint Source Control. Journal WPCF. Vol. 58(7), pp. 730-740.

Dukta, B.J., and Rybakowski, I. 1978. Microbiological Study of some Canadian Stormwater Runoffs at Burlington and Brucewood. Bacteriological Data Collection for the Urban Drainage Subcommittee, Canada-Ontario Agreement on Great Lakes Water Quality, Ontario Ministry of Environment, Toronto, Ontario, Canada, Project No. 75-3-24.

Field, R., and Pitt, R.E. 1990. Urban Storm-induced Discharge Impacts. Water Environ. Technol. Vol. 2(8), pp. 64-67.

Pipers Creek Watershed Management Committee. 1990. Pipers Creek Watershed Action Plan For the Control of Nonpoint Source Pollution. Final Action Plan. Seattle, WA. pp. 92.

Shapiro and Associates, Inc. 1989. Pipers Creek Watershed Action Plan for Nonpoint Source Pollution – Watershed Characterization and Water Quality Assessment. Prepared for City of Seattle Engineering Department, Seattle, WA. pp. 129.

U.S. Environmental Protection Agency. 2002. 1998 Section 303(d) List Fact Sheet for Washington, accessed November 2002, at URL http://oaspub.epa.gov/waters/state_rept.control?p_state=WA

Washington State Department of Ecology. 1997. Water Quality Standards for Surface Waters of the State of Washington. Washington State Department of Ecology, Olympia, WA. pp. 37.