UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
841 Chestnut Building
Philadelphia, Pennsylvania 19107-4431

February 20, 1998

RECEIVED
FEB 23 1998
WATER RESOURCE SECTION

Barbara Taylor, Chief
OWR, WV Division of Environmental Protection
1201 Greenbrier Street
Charleston, West Virginia 25311-1088

RE: Final Total Maximum Daily Loads (TMDLs) for the Upper Blackwater River, South Fork South Branch Potomac, South Branch Potomac River including Lunice Creek, Mill Creek, North Fork and Anderson Run, West Virginia

Dear Ms. Taylor:

According to paragraph 18 of the Consent Decree in the case OVEC, Inc. et al. v. Browner et al., C.A. No. 2:95-0529 and 2:96-0091, EPA is providing copies of the seven final TMDLs in West Virginia. Item 1 below satisfies the Consent Decree and the deadline that was agreed to in the plantiffs' letter of November 25, 1997 extending the deadline to February 20, 1998 for development of seven TMDLs in West Virginia.

Enclosed items:

1. the final TMDL reports for the Upper Blackwater River, South Fork South Branch Potomac, South Branch Potomac River including Lunice Creek, Mill Creek, North Fork and Anderson Run, West Virginia.

2. responsiveness summaries that address comments EPA and the West Virginia Division of Environmental Protection received on the proposed TMDLs.

Please contact Tom Henry of my staff (215) 566-5752, if you have any question regarding the enclosed materials.

Sincerely,

Joseph Piotrowski

Joseph Piotrowski, Associate Director
Office of Watersheds

Enclosures (2)

Fecal Coliform Total Maximum Daily Loads for the South Fork South Branch Potomac River, South Branch Potomac River including Lunice Creek, Mill Creek and North Fork and Anderson Run, West Virginia

Established by the U.S. Environmental Protection Agency Region III

Developed in cooperation with the West Virginia Division of Environmental Protection

February 20, 1998

Established by:

W. Michael McCabe
Regional Administrator
EPA Region III

2/20/98
Date

Fecal Coliform Total Maximum Daily Load South Branch Potomac River including Lunice Creek, Mill Creek , and North Fork, West Virginia

Established by the U.S. Environmental Protection Agency Region III

Developed in cooperation with the West Virginia Division of Environmental Protection

February 20, 1998

Executive Summary: Fecal Coliform TMDL for South Branch Potomac River including Lunice Creek, Mill Creek, and North Fork, West Virginia

The Clean Water Act at Section 303(d) and its implementing regulations at 40CFR Part 130 require the states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not or not expected to meet designated uses under technology-based controls or waterbodies that are considered threatened. The TMDLs documented in this report were developed by Tetra Tech, Inc under close oversight from EPA. The funding for this study was provided through EPA contract # 68-C3-0303, work assignment #4-116.

Total Maximum Daily Load (TMDL) analyses have been performed for fecal coliform in four West Virginia stream segments on the 1996 303(d) list of water quality impaired waterbodies. The four segments listed are (1) South Branch form Moorefield to Upper Tract, (2) Lunice Creek, (3) Mill Creek, and (4) North Fork South Branch Potomac River. The U.S. EPA Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) system (US EPA, 1996) and the Nonpoint Source Model (NPSM) were used to predict the significance of fecal coliform bacteria sources and fecal coliform bacteria levels in the South Branch watershed. BASINS is a multipurpose environmental analysis system for use in performing watershed and water quality-based studies. The NPSM simulates nonpoint source runoff from selected watersheds, as well as the transport and flow of pollutants through stream reaches. Since Lunice Creek, Mill Creek, and North Fork are all confluent with the South Branch, a nested approach was used to develop a watershed model for the TMDL analysis for these waters. A TMDL was first developed for the South Branch by dividing the main stem into 11 subwatersheds. This allowed the analyst to address the relative contribution of sources within each subwatershed to different segments of the river. Both point and nonpoint sources were represented in the model. Septic system discharges for the watershed were included in the model as a point source. The three major nonpoint source categories that were addressed in the study were: forest land, agricultural land, and urban areas. To account for the fecal coliform loadings from Lunice Creek, Mill Creek and the North Fork, three additional watersheds were included. Separate detailed models were constructed and TMDLs developed for Lunice Creek, Mill Creek, and North Fork watersheds.

The output from the NPSM indicated a number a violations of the 200 cfu/100mL geometric mean standard in the various parts of the subject watersheds for the existing condition covering a representative hydrologic year (October 1990 through September 1991). After applying the load allocations, the NPSM indicated that all sub-watersheds did not exceed the fecal coliform bacteria standard of 200 cfu/100mL geometric mean. The relative contribution of wildlife and septic systems did not appear in the model to be as significant of a source of fecal coliform during the critical condition of high flow in the watershed. The model analysis shows that water quality standards will be achieved if Best Management Practices (BMPs) are implemented in the agricultural areas to reduce fecal coliform runoff by the amount indicated in the table below.

TMDL Allocations for Watersheds in the South Branch Potomac River

Watershed	Reduction in Agriculture Fecal Coliform Loading Required to Meet Water Quality Standards
South Branch Potomac River	50.6 %
Lunice Creek	40.6 %
Mill Creek	37.7 %
North Fork South Branch Potomac River	36.1 %

A long-term study recommendation would be for sampling of fecal coliform, fecal streptococci, and enterococci bacteria at demonstration sites both with and without BMPs have been implemented. This is necessary to determine the effectiveness of BMPs implemented under the TMDL for pathogen control.

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ACKNOWLEDGMENTS

Funding for this study was provided through the U.S. Environmental Protection Agency, EPA contract #68-C3-0303, Work Assignment #4-116. The EPA TMDL Coordinator was Mr. Chris Laabs of EPA AWPD/Watershed Branch. EPA Regional Coordinator was Mr. Tom Henry of EPA Region III. EPA Region III Work Assignment Manager was Ms. Carol Ann Davis. TMDL Coordinator for West Virginia DEP was Mr. Stephen J. Stutler.

1.0 INTRODUCTION

1.1 Background

Levels of fecal coliform bacteria can become elevated in waterbodies as a result of both point and nonpoint sources of pollution. Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not meeting designated uses under technology-based controls. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water-quality based controls to reduce pollution from both point and nonpoint sources and restore and maintain the quality of their water resources (USEPA 1991b).

The South Branch Potomac River above Moorefield, West Virginia, lies in the Potomac Headwaters and traverses Hardy County, Pendleton County, and Grant County, West Virginia, as well as a portion of Highland County, Virginia (Figure 1.1). The land area of the South Branch watershed above Moorefield is approximately 575,000 acres. Runoff from the South Branch watershed flows by way of the Potomac River to the Chesapeake Bay. The primary industry in the watershed is agriculture with poultry and beef cattle leading the gross revenues. Most of the poultry produced in the watershed and adjacent areas is processed in Moorefield, West Virginia. The primary land uses in the watershed are forest, agricultural land, and the three largest urban areas are the towns of Moorefield, Petersburg, and Franklin.

1.2 Purpose of the Study

The objective of this study was to identify the background information and framework needed for developing a TMDL for South Branch, Lunice Creek, Mill Creek, and North Fork. The West Virginia Division of Environmental Protection (DEP) has identified these waters as being impacted by fecal coliform bacteria as reported in the 1996 303(d) list of water quality limited waters (see Table 1.1). The determination for impairment and inclusion on the West Virginia 303(d) list was based on water quality surveys performed by the U.S. Geological Survey (USGS) in 1994-95 in which samples were collected at a monthly frequency at a several stations in these watersheds (PHIWQO 1996). The results of the USGS study indicated elevated fecal coliform levels above 200 cfu/100 mL at a number of the stations in the study area. Based on these data and the state's water quality standard for fecal coliform bacteria, South Branch, Lunice Creek, Mill Creek, and North Fork were placed on the 1996 303(d) list. The West Virginia state standard specifies that the maximum allowable level of fecal coliform for primary contact recreation shall not exceed 200 cfu/100 mL as a monthly geometric mean (based on not less than 5 samples per month. The fecal coliform content also shall not exceed 400 cfu/100 mL in more than 10 percent of all samples taken during any one month (PVSCD, 1995). The data collected during the 1994-1995 USGS study do not allow a direct comparison to the state standard of 200 cfu/100 mL as a monthly geometric mean because there is an insufficient quantity of samples. However, when fewer than five samples are collected per month, the applicable standard becomes 400 cfu/100 mL.

Table 1.1 Water Quality Limited Waters from West Virginia 1996 303(d) Stream List

Priority Ranking	Stream Name	Stream Code	Miles Affected	Sources	Pollutant of Concern
17	Lunice Creek	PSB-26	7.50	Undetermined	Fecal Coliform
19	Mill Creek	PSB-25	2.36	Undetermined	Fecal Coliform
32	N. Fork So. Br. Potomac River	PSB-28	45.77	Undetermined	Fecal Coliform
46	South Branch Potomac River	P-21	36.00	Undetermined	Fecal Coliform

1.3 Nested Watershed Modeling Approach

Since Lunice Creek, Mill Creek, and North Fork are all confluent with the South Branch, a nested approach was used to develop the watershed model for the TMDL analysis of these four listed waters. A TMDL was first developed for the South Branch by dividing the main stem above Moorefield into 11 sub-watersheds. Three additional sub-watersheds were also included in the South Branch model to account for fecal coliform loads from Lunice Creek, Mill Creek, and North Fork. Separate detailed models were then constructed for the Lunice Creek, Mill Creek, and North Fork watersheds and individual TMDLs were developed for those watersheds as well. In this report, the South Branch modeling is described in Chapter 2, Lunice Creek is detailed in Chapter 3, Mill Creek is described in Chapter 4, and the North Fork is reported in Chapter 5. The summary and recommendations for all of the watersheds can be found in Chapter 6.

1.4 Selection of a TMDL Endpoint

One of the major components of a TMDL is the establishment of instream numeric endpoints that are used to evaluate the attainment of acceptable water quality. Instream numeric endpoints therefore represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. The endpoints allow for a comparison between predicted instream conditions and conditions that are expected to restore beneficial uses; the endpoints are usually based on either the narrative or numeric criteria available in state water quality standards. For the South Branch TMDL, the applicable endpoints and associated target values can be determined directly from the West Virginia standard for waters designated as primary contact recreation. That is, the allocation of loads will be distributed such that the fecal coliform levels in any of the modeled stream reached will not exceed 200 cfu/100 mL as a monthly geometric mean. The fecal coliform content also shall not exceed 400 cfu/100 mL in more than 10 percent of all samples taken during any one month (PVSCD 1995).

1.5 Phased TMDL Approach

Under a phased TMDL approach, load allocations are calculated with margins of safety to meet water quality standards because of uncertainty in the available data or due to lack of certain key information. This study is the first part of a phased TMDL for the study watersheds. The allocations derived herein are based on estimates which use available data and information, however, monitoring for additional new data is required to ensure that any implemented nonpoint source controls are achieving their expected load reductions. The TMDL analysis in this study is based on the 1990-91 hydrologic year but also uses fecal coliform bacteria monitoring data from the 1994-97 period for "calibrating" the nonpoint source runoff model. It is important to understand that any BMPs implemented since 1991 are not explicitly accounted for in the model since their impact on loading rates is not known due to lack of "before and after" monitoring. Since the model does not reflect certain BMPs which may be reducing nonpoint source loads, the overall load allocation reductions computed in this analysis may be overestimated and can be considered as part of the margin of safety for this phased TMDL.

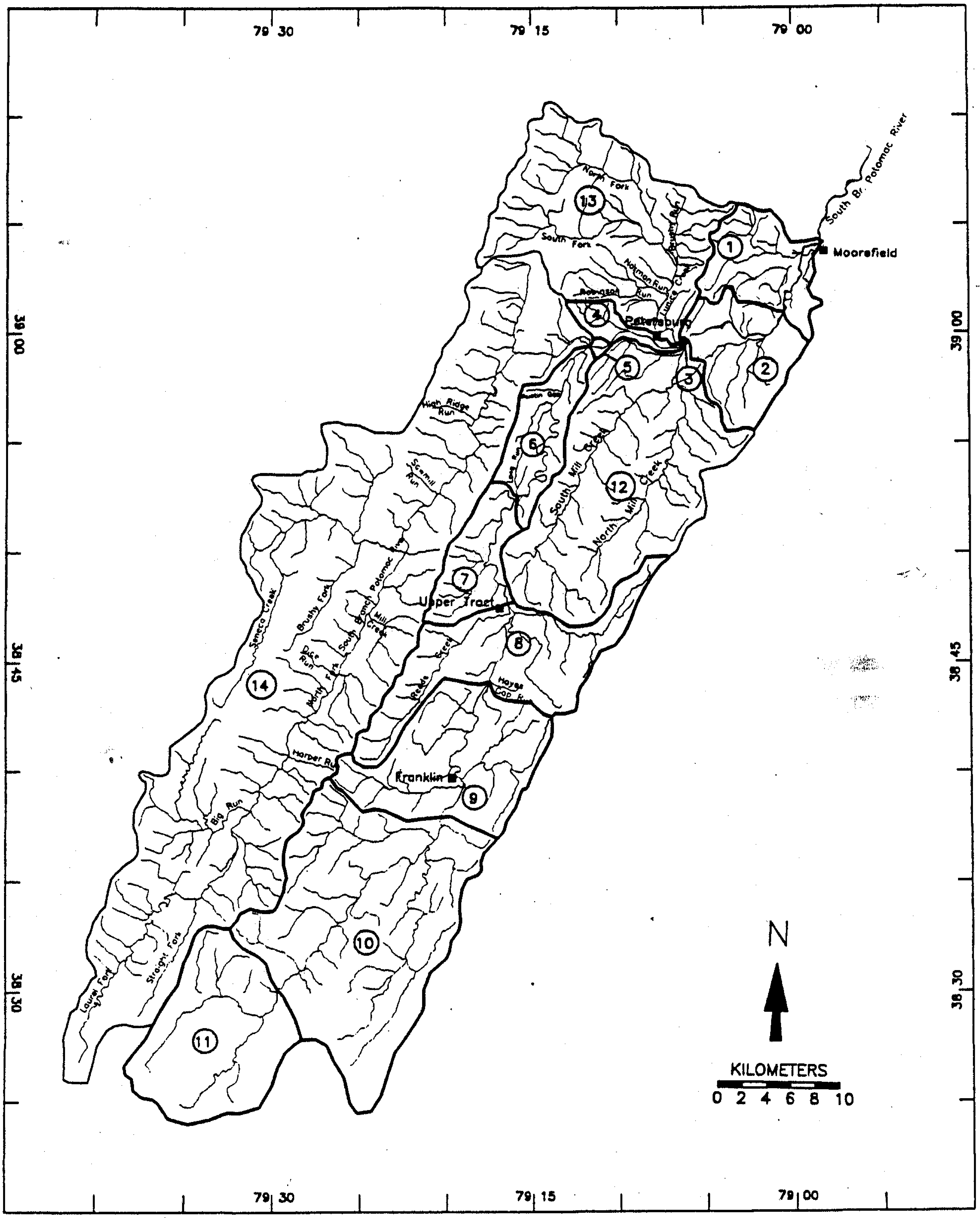

Figure 1.1 Study area: South Branch Potomac River watershed above Moorefield, West Virginia.

2.0 SOUTH BRANCH POTOMAC RIVER WATERSHED

This chapter describes the development of a TMDL for the South Branch Potomac River above Moorefield, West Virginia. The West Virginia 303(d) stream list indicates that 36.00 miles of the South Branch are impacted by fecal coliform bacteria from Moorefield to Upper Tract. The total land area of the watershed is about 575,000 acres.

2.1 SOURCE ASSESSMENT (SOUTH BRANCH)

This section presents an overview of the instream water quality monitoring data available for South Branch and then discusses the type, magnitude, and location of potential point and nonpoint sources of fecal coliform loading. In general, potential sources of fecal coliform bacteria are numerous, and often occur in combination. Potential point sources include poorly treated municipal sewages, urban storm water runoff, sanitary sewer overflows, combined sewer overflows (CSOs), and untreated domestic sewage. Potential nonpoint sources include poor management and handling of animal waste from feedlots, poor management and handling of poultry litter, failing or ill-sited septic systems, poor management of pasture lands, excess application of manure or municipal sludge in cropland and other agricultural areas, and natural background loadings from wildlife.

2.1.1 Instream Water Quality Monitoring Data (South Branch)

Periodic monitoring for fecal coliform bacteria at a number of locations in the South Branch has been conducted over the years. Locations of the monitoring sites from the special study conducted by the U.S. Geological Survey from March 1994 to August 1995 for the Potomac Headwaters study (PHIWQO 1996) are shown in Figure 2.1.1. The USGS stations were sampled approximately once per month throughout the study period. Time-series plots of the fecal coliform data for the station USGS stations are shown in Figures 2.1.2-2.1.9. From these figure it is apparent that individual sample points are occasionally higher than the state water quality standards of 200 and 400 cfu/100 mL. However, because only one data value was collected per month, it was not possible to make a direct comparison to the 200 cfu/100 mL state standard (which requires a geometric mean of at least 5 samples per month). When fewer than 5 samples are collected per month, the applicable standard becomes 400 cfu/100 mL.

In support of the development of this fecal coliform bacteria TMDL analysis, the West Virginia Division of Environmental Protection (DEP) has begun a monitoring program in the South Branch watershed in which numerous sites are sampled during a single field excursion. As of the date of this report, three intensive sampling runs have been completed in August 1996, June 1997, and August 1997. The locations of the monitoring stations are shown in Figure 2.1.1. The June 1997 sampling date coincided with a high-flow event whereas the August 1996 and August 1997 dates occurred during low-flow periods.

The 1994-95 USGS reconnaissance survey provided the best long-term multi-year data set of fecal coliform bacteria for South Branch. West Virginia DEP used the results of the USGS survey to determine whether a stream segment should be added to the 303(d) list of water quality limited streams. Since the sample frequency was less than 5 per month, it was not possible to determine whether a stream segment was in compliance with the 200 cfu/100 mL State standard for fecal coliform bacteria. Instead, if more than 25% of the samples were greater than 200 cfu/100 mL, the stream segment was considered threatened and placed on the 303(d) list as needing a TMDL for fecal coliform bacteria. A summary of the USGS bacteria data for the monitoring stations on South Branch is given in Table 2.1.1. Stations USGS#8 (at Upper Tract), USGS#14 (near Moorefield), and USGS#15 (above Moorefield) indicate greater than 25% of the samples were above the 200 cfu/100 mL level which is the reason South Branch was placed on the 303(d) list.

Table 2.1.1 Summary of Fecal Indicator Bacteria from 1994-95 USGS Study.

		Fecal Coliform Bacteria (cfu/100 mL)					Fecal Streptococci	
Station	n	Min	Median	Max	percent greater than 200	percent greater than 400	Median (cfu/100 mL)	FC/FS median ratio
USGS#5	11	1	45	130	0.0	0.0	195	0.2
USGS#6	12	13	71	520	16.7	8.3	350	0.2
USGS#7	12	5	58	140	0.0	0.0	220	0.1
USGS#8	15	12	145	3,400	26.7	13.3	890	0.3
USGS#14	18	15	305	4,500	55.6	38.8	795	0.4
USGS#15	11	18	67	460	27.2	9.1	240	0.6
USGS#17	10	5	140	340	20.0	0.0	140	0.5
USGS#18	11	4	30	350	9.1	0.0	76	0.3

Both fecal coliform (FC) and fecal streptococci (FS) were measured during the 1994-95 USGS survey. The ratio of fecal coliform to fecal streptococci can indicate possible sources of bacterial contamination. Each warm-blooded species has a unique bacteria ratio of fecal coliform to fecal streptococci in the intestinal tract. In humans, this ratio is generally greater than 4.0 whereas in animals the ratio is usually less than 0.7. Therefore, ratios greater than 4.0 in stream-water samples indicate that the source of bacterial contamination is likely human waste. Conversely, ratios of less than 0.7 indicate a bacterial source which is non-human. Intermediate ratios indicate mixed or undetermined sources of bacterial contamination (PHIWQO 1996). All of the USGS stations on the South Branch have FC/FS ratios of 0.6 or less indicating the likely source of bacterial contamination is from animal waste (APHA, 1985).

2.1.2 Assessment of Point Sources (South Branch)

The greatest potential source of human fecal coliform from point sources is raw sewage. Raw sewage typically has a total coliform count of 10^7 to 10^9 mpn[1]/100 mL (Novotny and Olem, 1994), along with significant concentrations of fecal coliform bacteria, viruses, protozoans, and other parasites. Typical treatment in a municipal plant reduces the total coliform count in effluent by about 3 orders of magnitude, to the range of 10^4 to 10^6 mpn/100 mL. Raw sewage, while usually not discharged intentionally, may reach waterbodies through leaks in sanitary sewer systems, overflows from surcharged sanitary sewers (non-combined sewers), illicit connections of sanitary sewers to storm sewer collection systems, or unidentified broken sanitary sewer lines.

There are 12 permitted point source discharges in the South Branch watershed (see Figure 2.1.10 and Table 2.2.1 in the next section) of which 7 indicate fecal coliform concentrations in their effluent. The two largest discharges in the watershed are the City of Petersburg POTW (1.3 MGD) and the Town of Franklin POTW (0.155 MGD).

2.1.3 Assessment of Nonpoint Sources (South Branch)

Nonpoint sources of fecal coliform bacteria are typically separated into urban and rural components. In urban or suburban settings with high amounts of paved impervious area, important sources of loading are surface storm flow, failing septic tanks, and leakage of sanitary sewer systems. In rural settings, the amount of impervious area is usually much lower, and sources of fecal coliform may include runoff of animal wastes associated with the erosion of sediments, runoff from concentrated animal operations, contributions from wildlife, and failing septic tanks.

The primary tributaries to the South Branch above Moorefield are Lunice Creek, Mill Creek, and North Fork. The main stem of the South Branch was divided into 11 reaches or sub-watersheds for modeling purposes and the peripheral tributaries added three additional sub-watersheds to the model for a total of 14 sub-watersheds (see Figure 2.1).

The U.S. GeoData 1:250,000 scale land use and land cover data (U.S. GeoData 1986) were used to determine land uses in the South Branch watershed. The land uses consist primarily of forested, agricultural, and urban areas. The various land uses for each of the 14 sub-watersheds are

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[1] MPN stands for Most Probable Number (of colony forming units).

listed in Table 2.1.2. The West Virginia Soil Conservation Agency (WVSCA) maintains a geographic information system (GIS) with the locations of poultry houses, feedlots, and other agricultural-related information. The delineations of the sub-watersheds for the South Branch Fork were provided to WVSCA and they in turn estimated the number of poultry houses and animal feedlots within each of the sub-watersheds with the exception of those in Pendleton County. For the sub-watersheds in Pendleton County, the GIS maps in the Potomac Headwaters Report (PVSCD 1995) were used to estimate the number of poultry houses and feedlots. Estimates of total head of cattle in each sub-watershed were also provided by WVSCA (see Table 2.1.3).

The West Virginia Division of Natural Resources (DNR) provided estimates of the numbers of geese and ducks within the South Branch region typical of July 1 of any given year. The numbers of birds may vary with season because of migratory patterns as well as birds moving in and out of the watershed. The DNR estimated an upper bound of 650 for the migratory goose population and 195 for the migratory duck population in the South Branch watershed. In addition, deer population was estimated from the Big Game Bulletin (DNR 1996). The total deer population can be estimated as about 10 times the number of buck killed during hunting season. Animal population estimates for the South Branch watershed are given in Table 2.1.4.

Table 2.1.2 Land Use Distributions in the South Branch Sub-watersheds

Subbasin Number	Stream Name Location	Total Area (acres)	Urban (acres)	Agricultural (acres)	Forest (acres)	Septic Population
1	Moorefield to Rig	17,327	63	7,536	9,728	869
2	Rig to Mill Creek	17,730	202	5,651	11,877	917
3	Mill Creek to Lunice Creek	73	0	31	42	3
4	Lunice Creek to USGS gage	4,096	331	3,174	591	845
5	USGS gage to North Fork	594	1	285	308	35
6	North Fork to Long Run	14,044	0	1,431	12,613	19
7	Long Run to Reeds Creek	13,569	57	1,370	12,142	179
8	Reeds Creek to Hayes Gap Run	33,961	95	9,741	24,125	534
9	Hayes Gap Run to Franklin	35,071	422	7,772	26,877	1,043
10	Franklin to Virginia State Line	76,283	95	17,381	58,807	1,201
11	Upstream of Virginia State Line	31,817	219	17,795	13,803	200
12	Mill Creek watershed	66,860	732	19,035	47,093	2,348
13	Lunice Creek watershed	57,575	432	19,707	37,436	2,280
14	North Fork watershed	205,802	710	29,991	175,101	3,333
	Totals	574,802	3,359	140,900	430,543	10,473

Table 2.1.3 Inventory of Poultry Houses and Cattle Feedlots in South Branch Watershed.

Subbasin	South Branch Segment	Poultry Houses Broiler	Poultry Houses Breeder	Poultry Houses Turkey	Feedlots	Head Cattle	Poultry Litter Storage
1	Moorefield to Rig	13	30	0	11	1100	3
2	Rig to Mill Creek	36	17	0	15	650	1
3	Mill Creek to Lunice Creek	0	0	0	0	0	0
4	Lunice Creek to USGS gage	0	5	0	2	300	2
5	USGS gage to North Fork	0	0	0	1	50	0
6	North Fork to Long Run	0	0	0	0	0	0
7	Long Run to Reeds Creek	1	0	0	2	100	0
8	Reeds Creek to Hayes Gap Run	35	0	0	22	1100	0
9	Hayes Gap Run to Franklin	4	0	0	6	300	0
10	Franklin to Virginia State Line	24	0	0	16	800	0
11	Upstream of Virginia State Line	0	0	0	0	0	0
12	Mill Creek watershed	38	2	0	24	740	2
13	Lunice Creek watershed	36	17	6	21	1,650	0
14	North Fork watershed	12	1	0	27	1,300	2
	Totals	199	72	6	147	8,090	10

Table 2.1.4 Population Estimates of Farm and Wild Animals in South Branch Watershed.

Subbasin Number	Stream Name Location	Number Chickens Broilers	Number Chickens Breeders	Number Turkeys	Head Cattle	Number Migratory Ducks	Number Migratory Geese	Number Deer
1	Moorefield to Rig	364,000	270,000	0	1100	14	46	498
2	Rig to Mill Creek	1,008,000	153,000	0	650	14	47	609
3	Mill Creek to Lunice Creek	0	0	0	0	0	0	2
4	Lunice Creek to USGS gage	0	45,000	0	300	3	11	30
5	USGS gage to North Fork	0	0	0	50	0	2	16
6	North Fork to Long Run	0	0	0	0	11	37	646
7	Long Run to Reeds Creek	28,000	0	0	100	11	36	622
8	Reeds Creek to Hayes Gap Run	980,000	0	0	1100	27	90	1,236
9	Hayes Gap Run to Franklin	112,000	0	0	300	28	93	1,377
10	Franklin to Virginia State Line	672,000	0	0	800	61	203	3,013
11	Upstream of Virginia State Line	0	0	0	0	25	85	707
12	Mill Creek watershed	1,064,000	18,000	0	740	30	60	2,547
13	Lunice Creek watershed	1,008,000	153,000	90,000	1,650	30	80	2,739
14	North Fork watershed	336,000	9,000	0	1,300	50	90	8,187
	Totals	5,572,000	648,000	90,000	8,090	305	880	22,231

Onsite septic systems are the predominant form of waste water treatment in the South Branch watershed. No information was readily available on the specific locations of septic systems, septic tank densities, or failure rates. However, WVDEP provided estimates of the percent of the population for each county which used septic systems. For Hardy County, it was estimated that 80% of the population of 11,000 residents used septic systems. In Pendleton County, about 90% of the 8,000 residents are on septic systems. A septic system failure rate of about 2.5% was estimated for Hardy County (NSFC 1993) and it was assumed this rate was also applicable to the South Branch watershed. It was further assumed that 100% of the fecal coliform load from the failed systems reached the receiving waters at a concentration of 1×10^4 cfu/100 mL for raw sewage (Metcalf & Eddy 1991). The assumed septic system waste flow rate was computed based on a typical value of 70 gallons per capita per day (Horsely & Whitten 1996).

As previously mentioned, the 1994-95 USGS monitoring data suggest that the source of bacterial contamination in South Branch is from animal sources based on the fecal coliform to fecal streptococci ratios of 0.6 or less. For this study, it was assumed that manure from poultry operations was applied to agricultural land within the sub-watershed in which the poultry house was situated. In practice, poultry manure may be transported to or imported from other sub-watersheds; or it may be moved completely out of the South Branch watershed. No information was available as to the specific manure management practices. A list of sites for the land application of municipal and industrial sludge in the South Branch watershed was provided by WVDEP (Aug 5, 1997) and is given in Table 2.1.5. Since the amount of sludge applied to the land areas is not known at this time, no attempt was made to incorporate these sites as a possible source of fecal coliform bacteria into the TMDL analysis.

Table 2.1.5 Land Application Sites in South Branch Watershed

Generator	Type	Farm	Acres	Drainage Area/Location
Hester Ind.	Ind.	Island	25	South Branch/South Fork confluence
Hester Ind.	Ind.	Old Fields Farm	65	UT-South Branch, one mile north of Old Fields Bridge
Wampler-Longacre	Ind.	Warner Farm	105	South Br., River Road north of Fisher bridge
Wampler-Longacre	Ind.	Tom Hawse	56	South Br., River Road south of Fisher
Wampler-Longacre	Ind.	Alan Crites	100	South Br., River Road south of Fisher
Wampler-Longacre	Ind.	Bob Moran	65	South Br., River Road south of Fisher
Wampler-Longacre	Ind.	Bill Keplinger*		Dumpling Run
Wampler-Longacre	Ind.	H.L. Wilson	67	Fort Run
Wampler-Longacre	Ind.	H.L. Wilson*	50	Fort Run/South Br.
Wampler-Longacre	Ind.	Holly Martin*	47	UT-South Br., on CR1 near Old Fields bridge
Wampler-Longacre	Ind.	Charlie Williams*		Dumpling Run
A&S Septic	Septage	Alt	4	Hinkle Run of South Mill Creek near Dorcas
A&S Septic	Septage	Jeff Thorne	12	North Mill Creek, between 1st & 2nd bridge on N. Mill Creek Rd.
A&S Septic	Septage	Iman Farm**	3	North Mill Creek, between 1st & 2nd bridge on N. Mill Creek Rd.
Petersburg	Sludge	Roy Hyre	80	South Br., 1 mile below North Fork confluence on CR220/2
Petersburg	Sludge	Bruce Hyre	60	Johnson Run near headwaters
Petersburg	Sludge	Bruce Hyre	100	UT-Lunice Creek, near intersection of CR220/1 and 220/9

UT = unnamed tributary

Ind. = sludge from chicken processing facility

** This farm has not been used as of Aug 4, 1997

* These farms have not been used since 1994

Using the available information for poultry houses, head of cattle, and wildlife estimates, the daily fecal coliform loads were computed for each sub-watershed. The average fecal coliform loading rates for the various animal species used for the total potential load calculation are given in Table 2.1.6.

Table 2.1.6 Estimated Fecal Coliform Production Rates.

Animal	Fecal Coliform Production Rate	Reference
beef cow	5.40×10^9 cfu/day	Metcalf & Eddy, 1991
chicken	0.24×10^9 cfu/day	Metcalf & Eddy, 1991
turkey	0.13×10^9 cfu/day	Metcalf & Eddy, 1991
duck	11.0×10^9 cfu/day	Metcalf & Eddy, 1991
goose	49.0×10^9 cfu/day	LIRPB, 1982
deer	0.50×10^9 cfu/day	BPJ estimate

The average number of birds for each type of poultry house was based on information obtained from WVDEP (1997) as follows: 15,000 Turkeys; 9,000 Breeders; and 28,000 Broilers. The total potential fecal coliform production per subwatershed for each of the animal categories is given in Table 2.1.7. Poultry makes up 86% of the potential nonpoint source fecal coliform load in the watershed followed by cattle with about 7% of the load. It is important to understand that the values in Table 2.1.7 are the "potential" fecal coliform loads from various nonpoint sources and not necessarily the loads which reach the receiving waters in the watershed (with the exception of the septic load which is the estimated load reaching the stream). Various attenuation processes and agricultural management practices will reduce these loads before they reach the stream.

Table 2.1.7 Potential Nonpoint Source Fecal Coliform Production in South Branch Watershed.

Subbasin Number	Stream Name Location	Total Load (cfu/day)	Poultry (cfu/day)	Cattle (cfu/day)	Ducks (cfu/day)	Geese (cfu/day)	Deer (cfu/day)	Septic (cfu/day)
1	Moorefield to Rig	1.608E+14	1.522E+14	5.940E+12	1.520E+11	2.257E+12	2.492E+11	5.756E+08
2	Rig to Mill Creek	2.849E+14	2.786E+14	3.510E+12	1.555E+11	2.309E+12	3.043E+11	6.074E+08
3	Mill Creek to Lunice Creek	1.901E+12	0.000E+00	0.000E+00	6.403E+08	9.507E+09	1.076E+09	1.987E+06
4	Lunice Creek to USGS gage	1.193E+13	1.080E+13	1.620E+12	3.592E+10	5.334E+11	1.514E+10	5.597E+08
5	USGS gage to North Fork	3.605E+11	0.000E+00	2.700E+11	5.210E+09	7.736E+10	7.891E+09	2.318E+07
6	North Fork to Long Run	2.275E+12	0.000E+00	0.000E+00	1.232E+11	1.829E+12	3.231E+11	1.259E+07
7	Long Run to Reeds Creek	9.457E+12	6.720E+12	5.400E+11	1.190E+11	1.767E+12	3.111E+11	1.186E+08
8	Reeds Creek to Hayes Gap Run	2.465E+14	2.352E+14	5.940E+12	2.979E+11	4.423E+12	6.181E+11	3.537E+08
9	Hayes Gap Run to Franklin	3.406E+13	2.688E+13	1.620E+12	3.076E+11	4.567E+12	6.886E+11	6.909E+08
10	Franklin to Virginia State Line	1.777E+14	1.613E+14	4.320E+12	6.691E+11	9.934E+12	1.507E+12	7.955E+08
11	Upstream of Virginia State Line	4.776E+12	0.000E+00	0.000E+00	2.791E+11	4.144E+12	3.536E+11	1.325E+08
12	Mill Creek watershed	2.682E+14	2.597E+14	3.996E+12	3.300E+11	2.940E+12	1.274E+12	1.555E+09
13	Lunice Creek watershed	3.049E+14	2.903E+14	8.910E+12	3.300E+11	3.920E+12	1.370E+12	1.304E+09
14	North Fork watershed	9.592E+13	8.280E+13	7.020E+12	5.500E+11	1.459E+12	4.093E+12	2.208E+09
	Totals	1.603E+15	1.505E+15	4.369E+13	3.355E+12	4.017E+13	1.112E+13	8.939E+09
	Percent of total	100.00%	86.32%	7.32%	0.57%	1.52%	4.27%	0.00%

2.1.4 Critical Conditions (South Branch)

Based on the available fecal coliform stream monitoring data, it was apparent that the highest concentrations of fecal coliform bacteria measured in the stream occurred during high-flow periods. Thus, it is the high-flow, storm event conditions which are most likely to induce violations of the State water quality standards for fecal coliform bacteria due to nonpoint source runoff. However, point source discharges, due to their continuous nature of discharge, may cause elevated fecal coliform levels during low-flow periods as well.

To develop a TMDL, it is necessary to consider a range of flow conditions to represent the bacterial loading phenomenon occurring within the watershed. During storm events, runoff from urban and agricultural land uses will cause large concentrations of fecal coliform bacteria to occur in the receiving waters. During dry periods, little or no land-based runoff will occur, and elevated bacteria levels in the stream may be due to point sources. A continuous simulation model is necessary to capture the buildup and washoff of pollutants due to nonpoint sources. For this study, an average hydrologic year was selected for the continuous simulation period. The period 1984 to 1992 was used as the initial screening period. The 1991 water year, from October 1990 through September 1991, was selected as the most representative of an average meteorologic year for the South Branch watershed from within the screening period. Two USGS long-term flow gaging stations on the South Branch (#01605500 at Franklin and #01606500 at Petersburg) were used to calibrate the hydrologic flows computed by the nonpoint source runoff model.

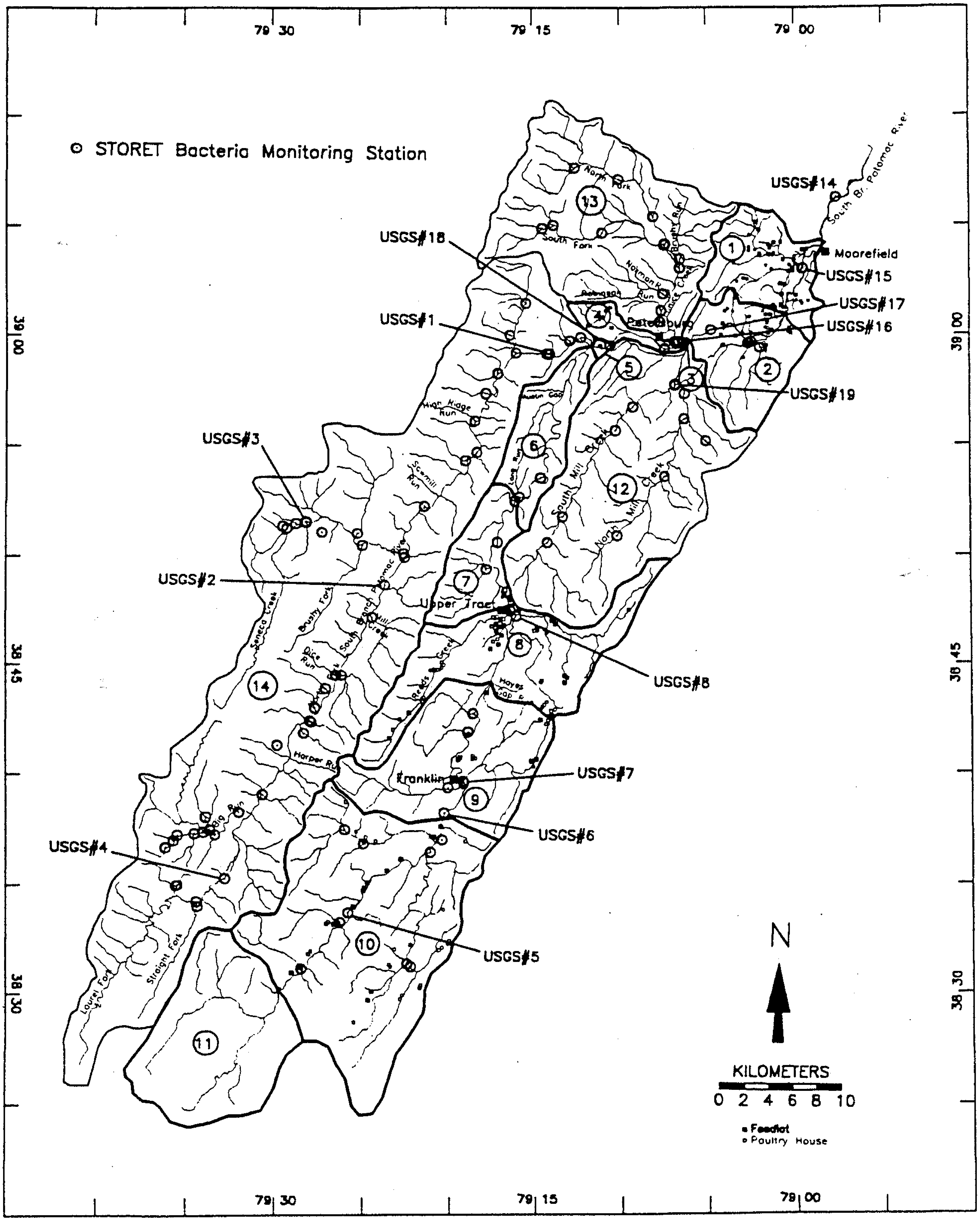


Figure 2.1.1 STORET bacteria monitoring stations.

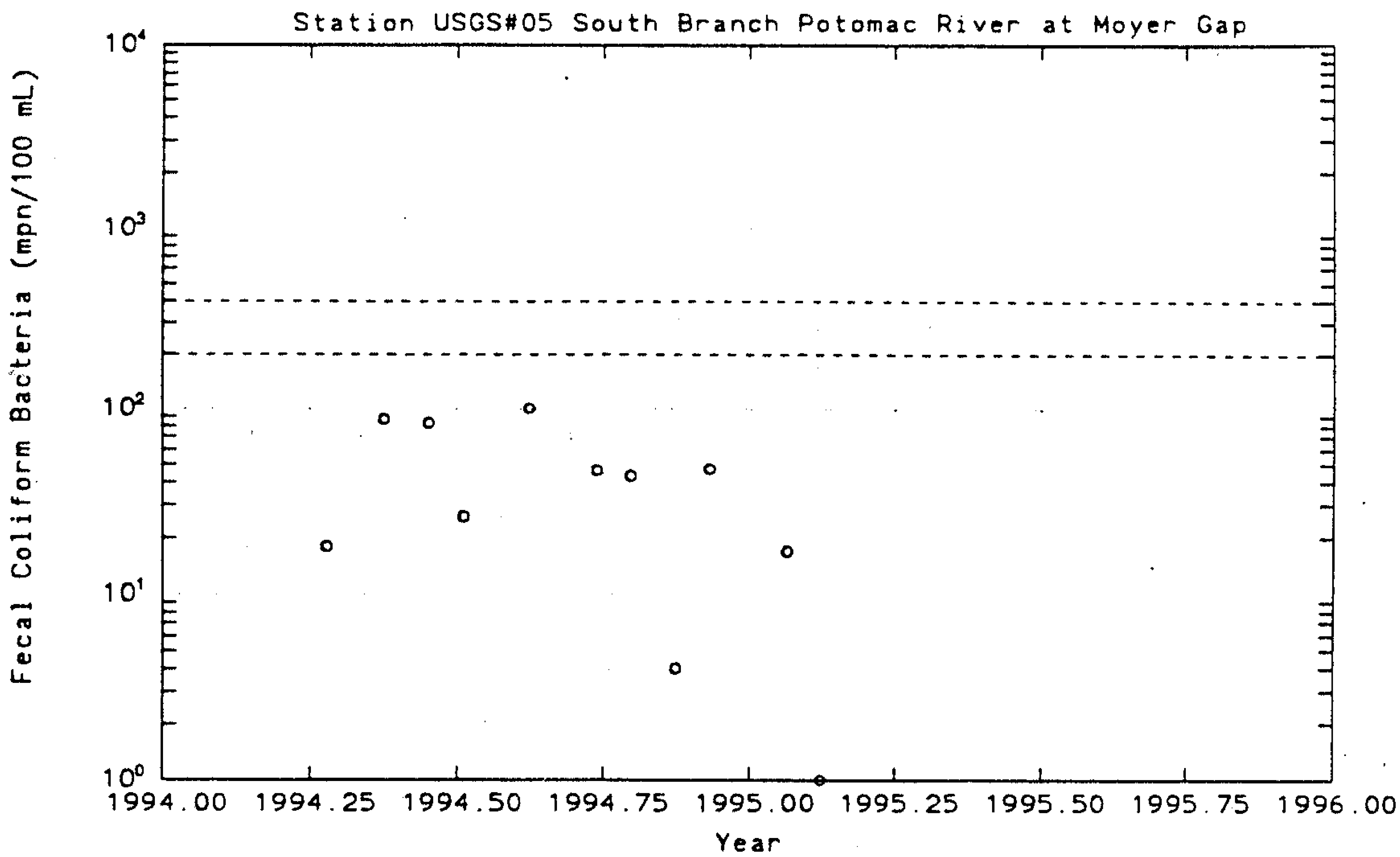


Figure 2.1.2 Time-series of fecal coliform bacteria data for USGS Station #5.

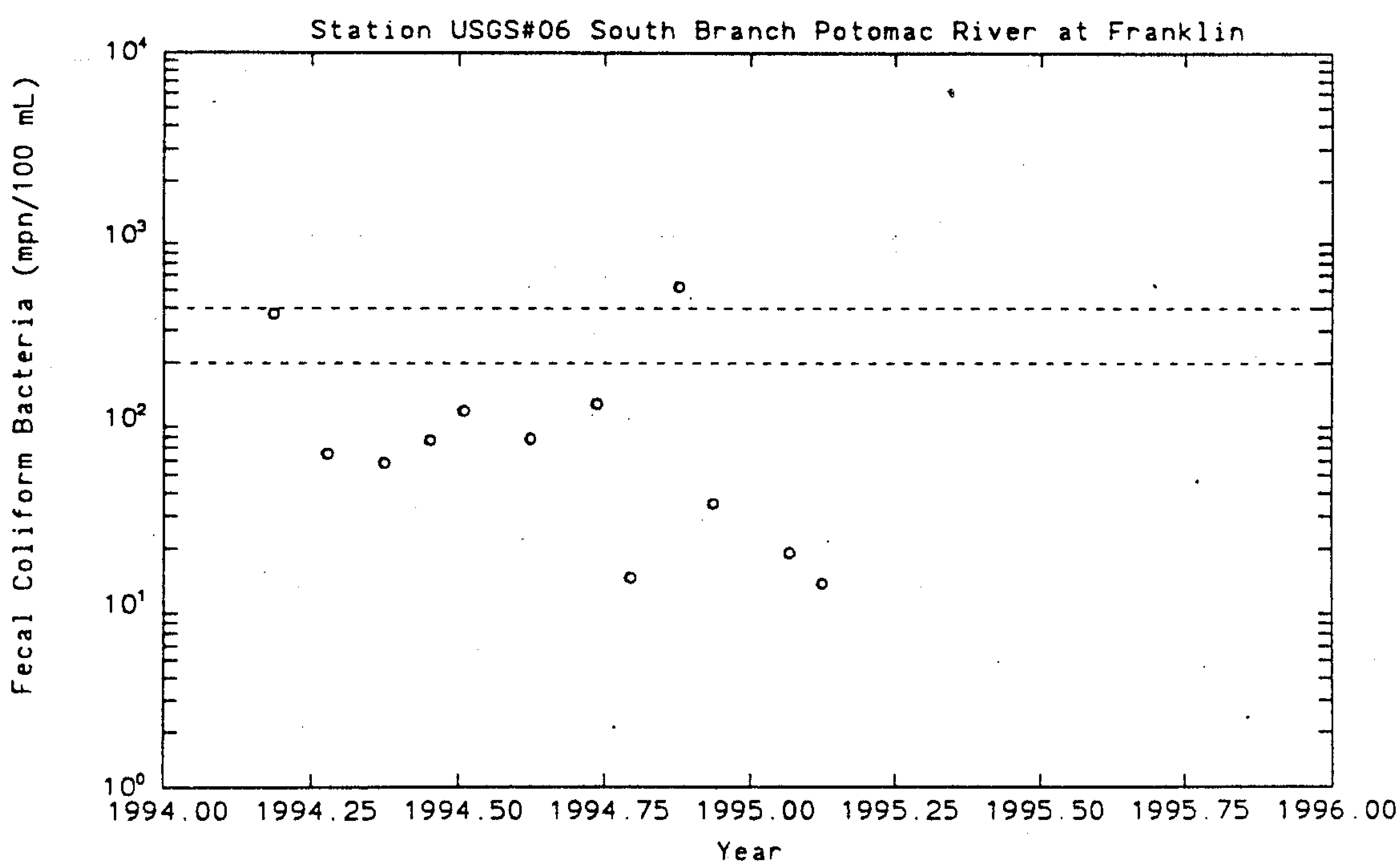


Figure 2.1.3 Time-series of fecal coliform bacteria data for USGS Station #6.

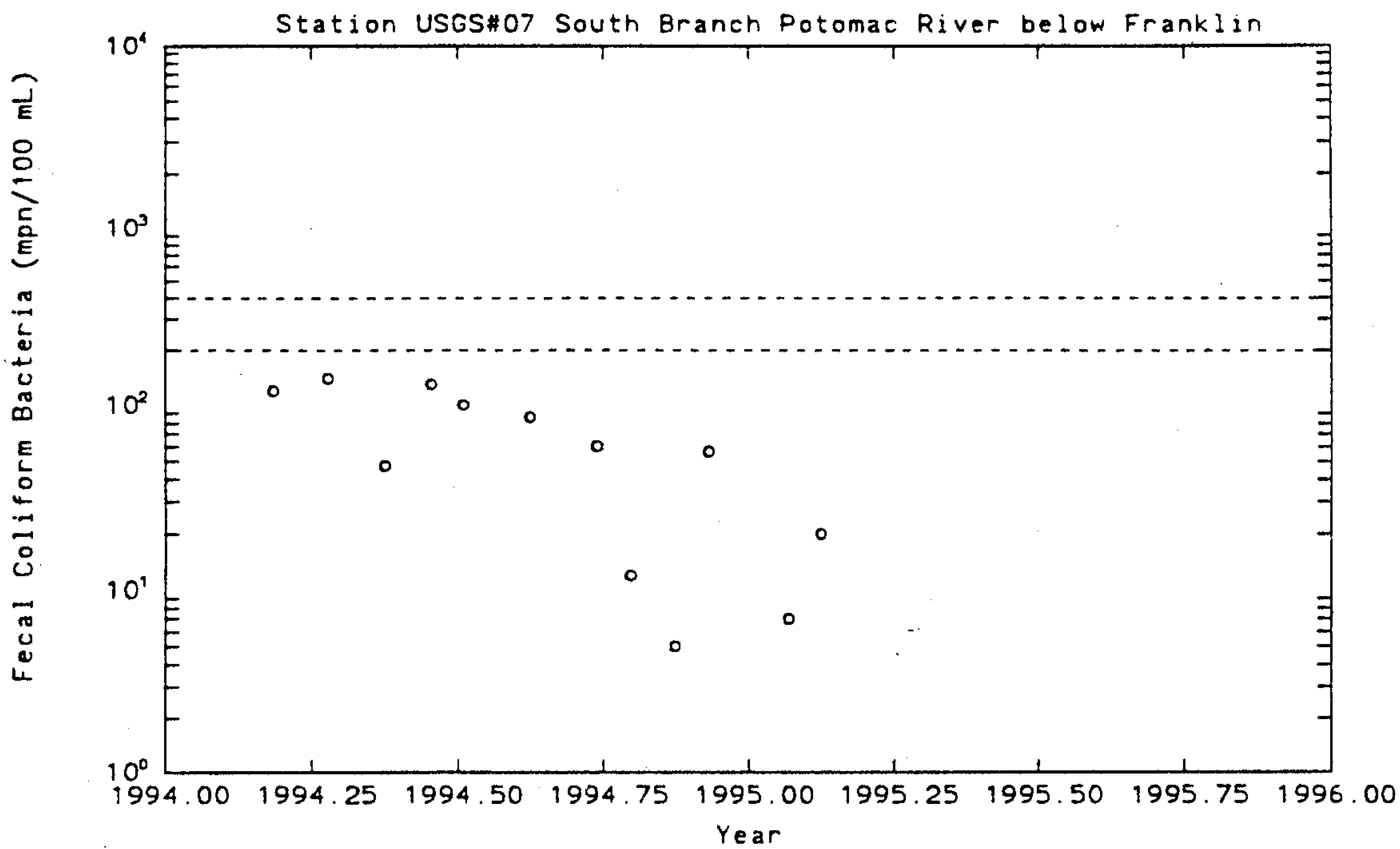


Figure 2.1.4 Time-series of fecal coliform bacteria data for USGS Station #7.

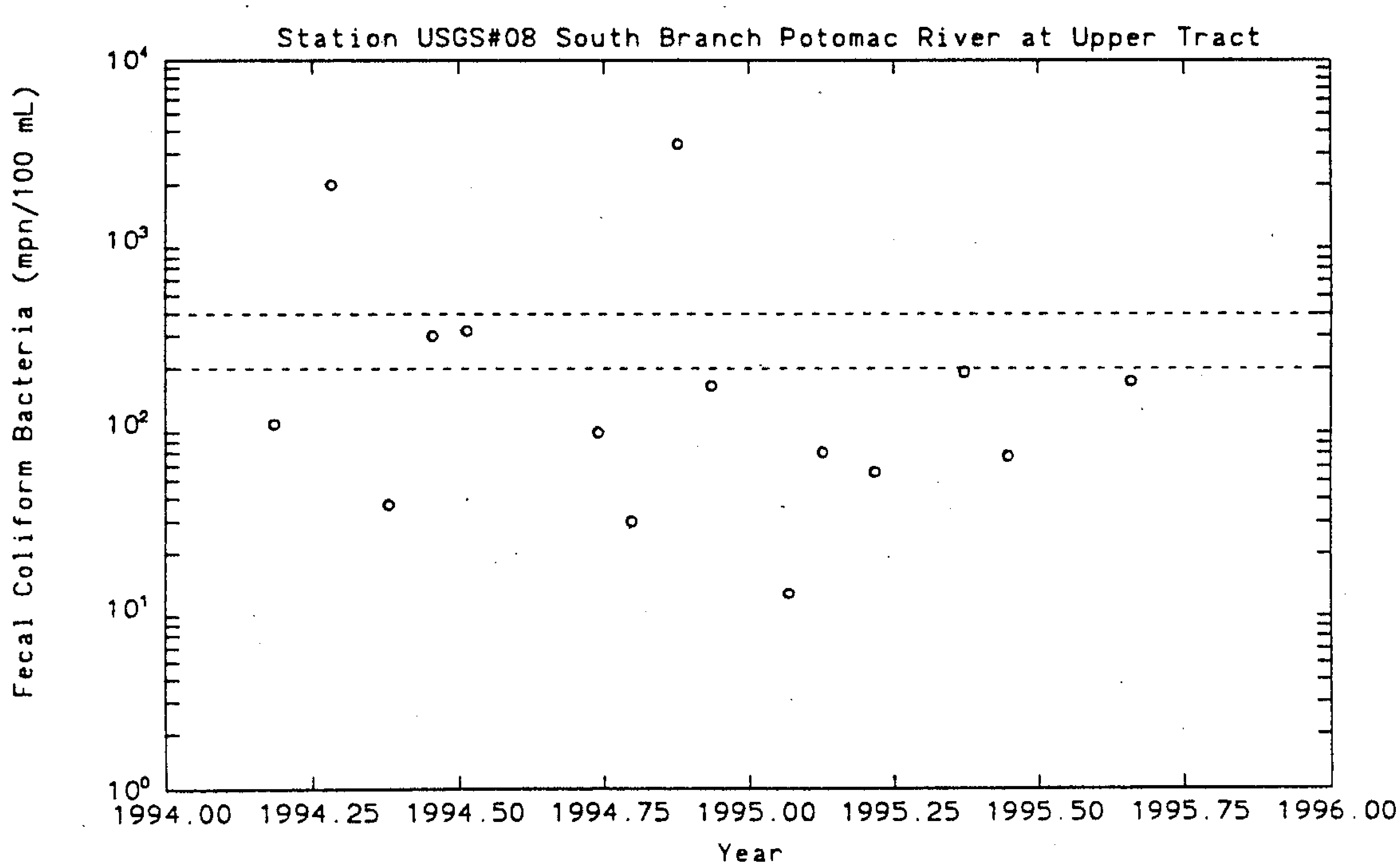


Figure 2.1.5 Time-series of fecal coliform bacteria data for USGS Station #8.

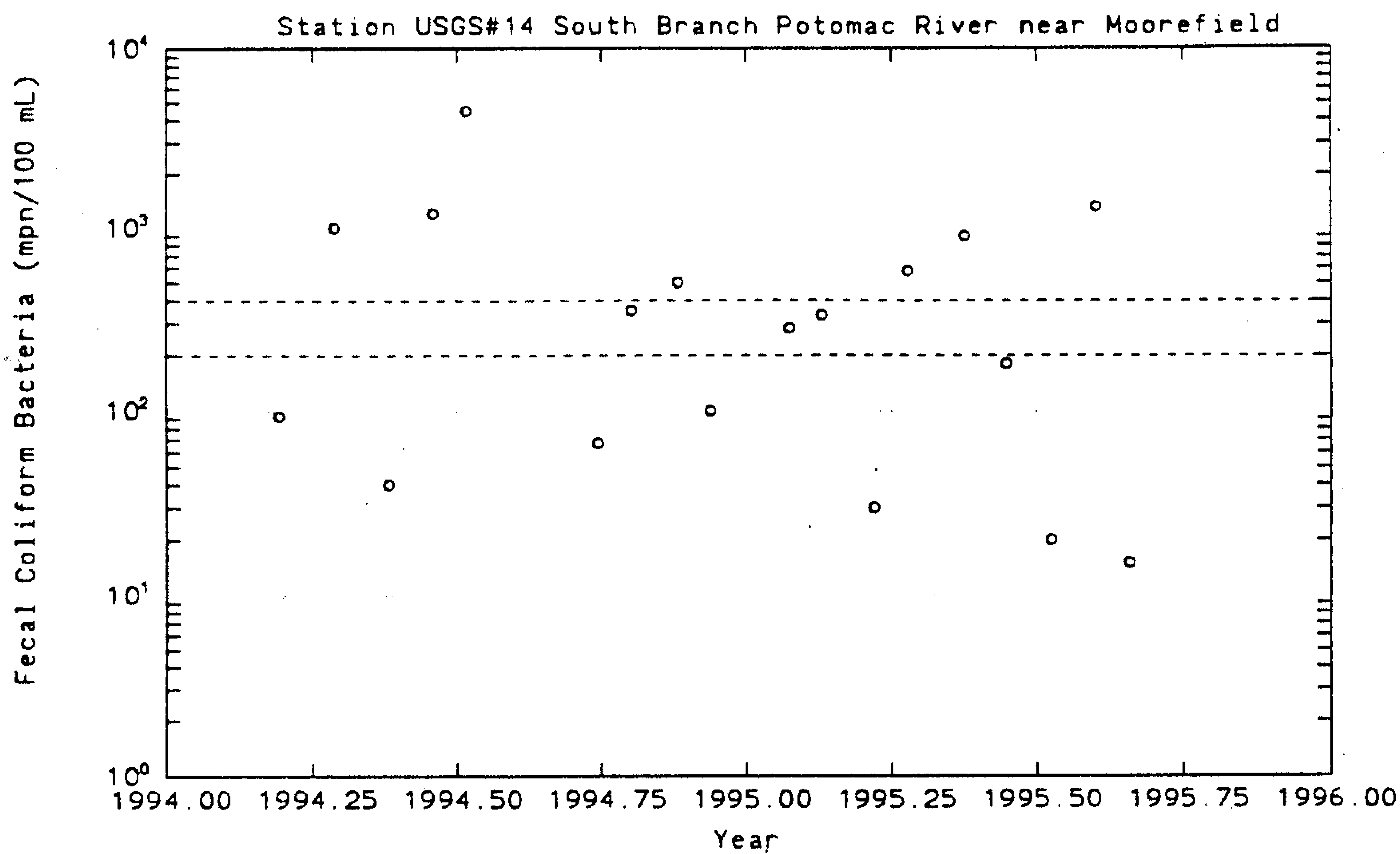


Figure 2.1.6 Time-series of fecal coliform bacteria data for USGS Station #14.

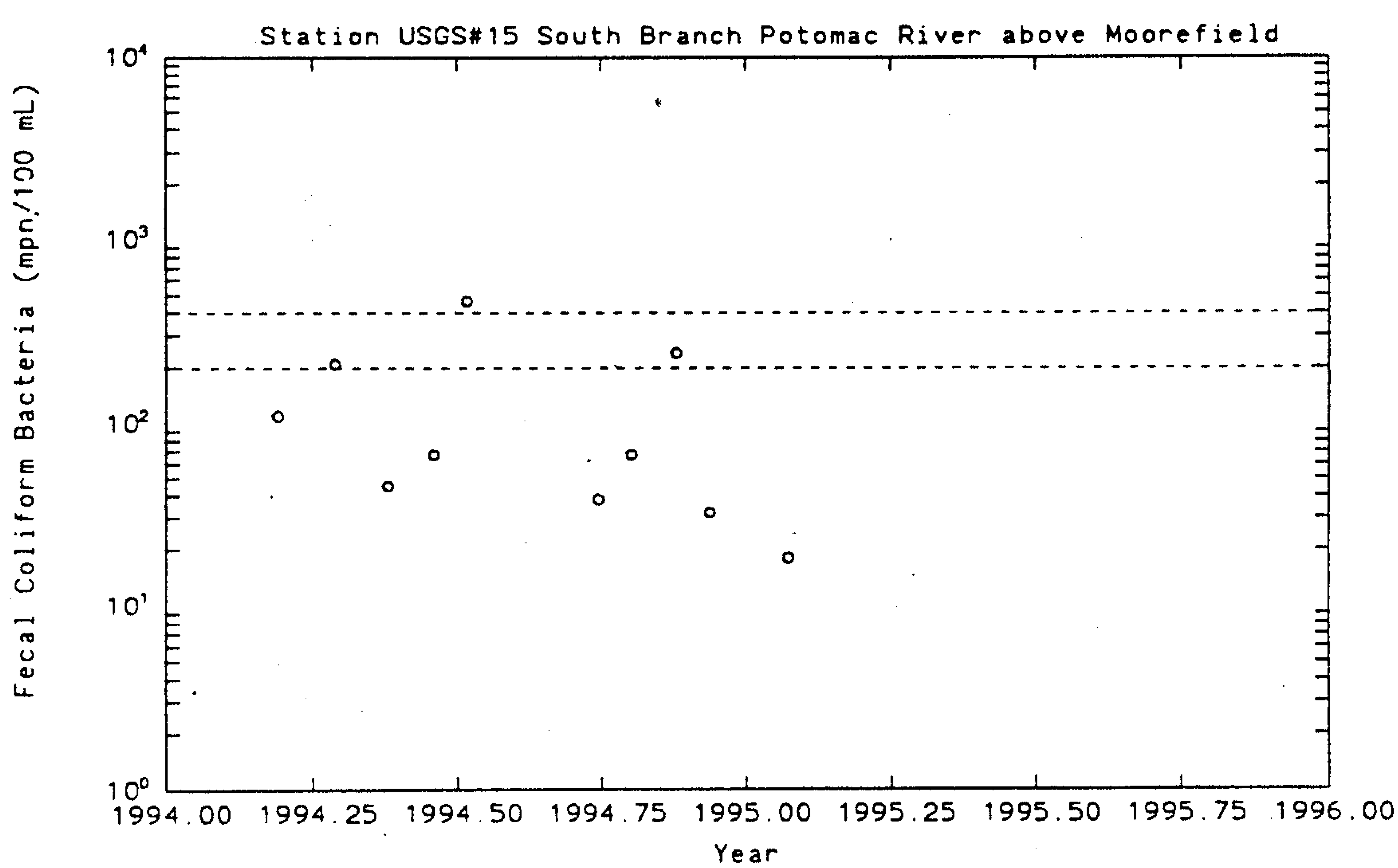


Figure 2.1.7 Time-series of fecal coliform bacteria data for USGS Station #15.

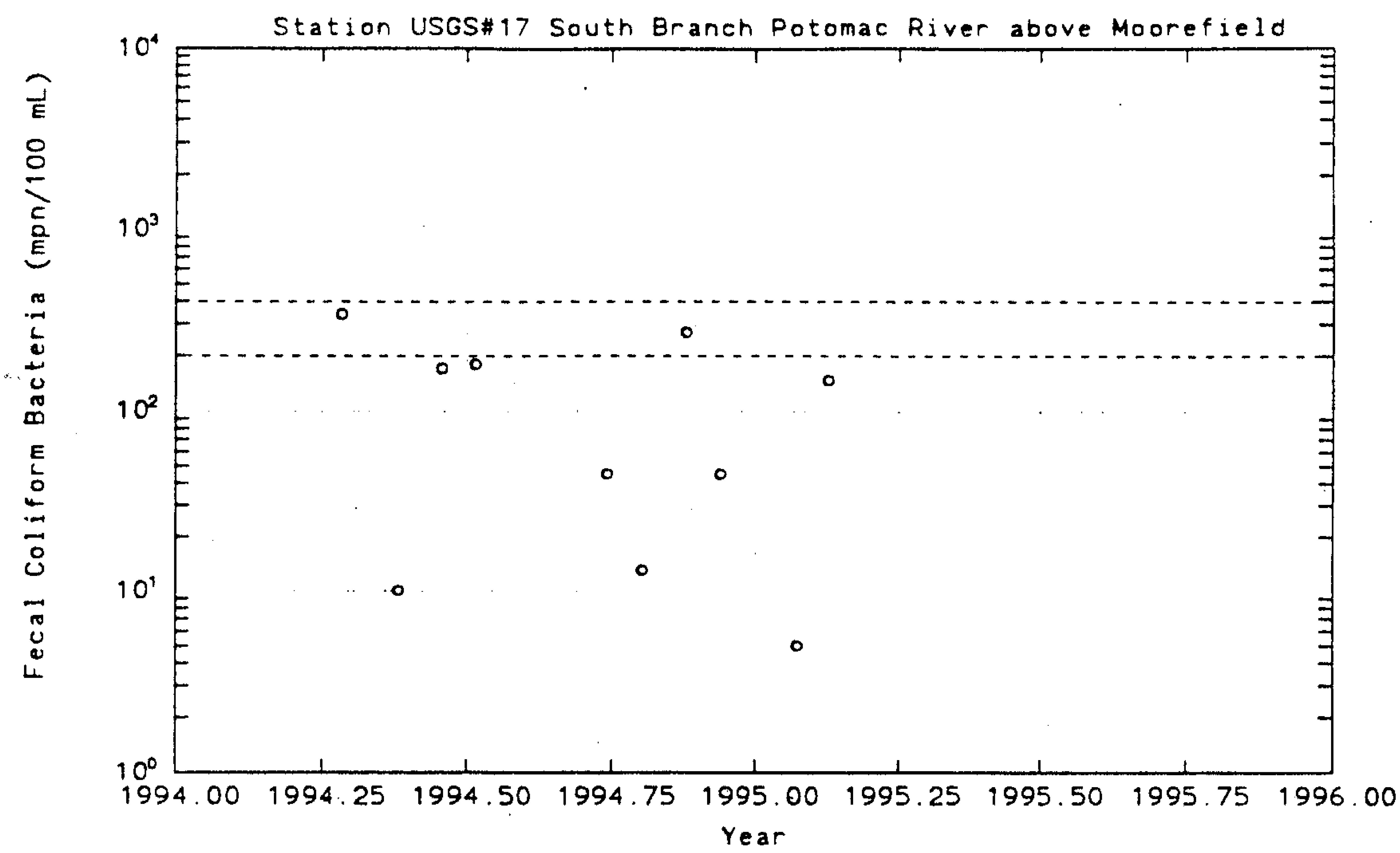


Figure 2.1.8 Time-series of fecal coliform bacteria data for USGS Station #17.

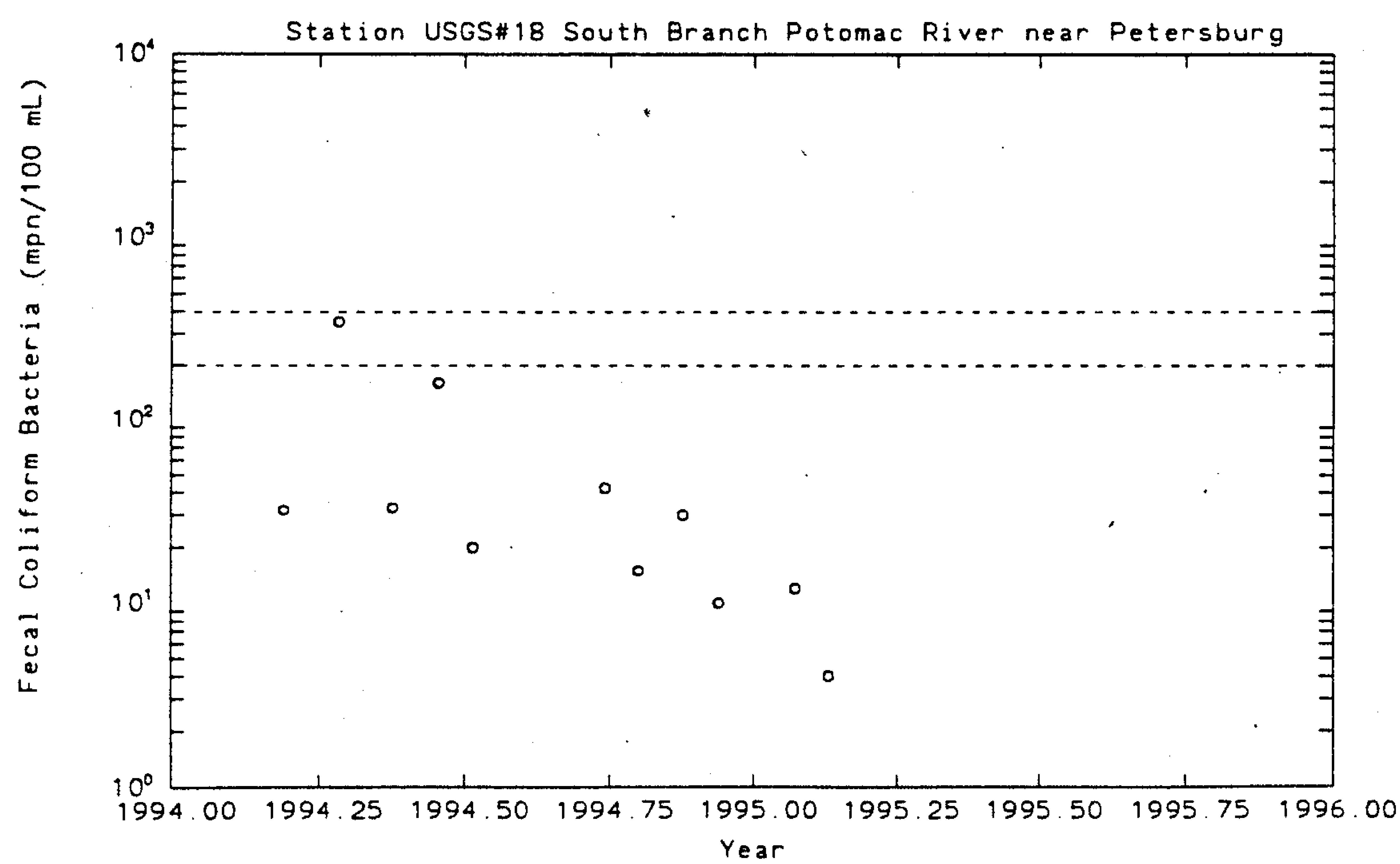


Figure 2.1.9 Time-series of fecal coliform bacteria data for USGS Station #18.

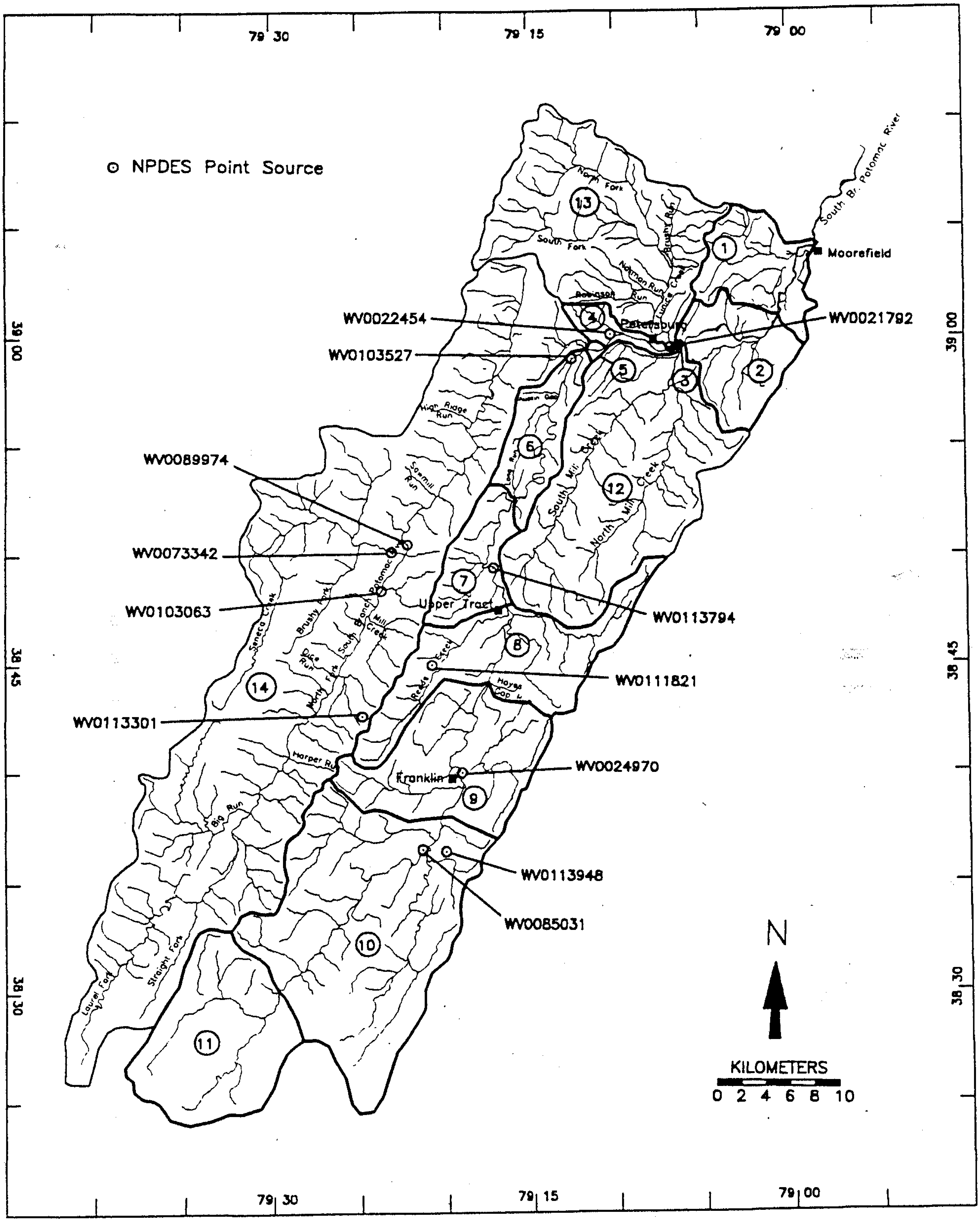


Figure 2.1.10 Locations of point source dischargers in South Branch watershed.

2.2 MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Establishing the relationship between the instream water quality target and the source loadings is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired source load reductions. The link can be established through a range of techniques, from qualitative assumptions based on sound scientific principles to sophisticated modeling techniques. Ideally, the linkage will be supported by monitoring data that allow the TMDL developer to associate certain waterbody responses to flow and loading conditions.

2.2.1 Modeling Framework Selection

The U.S. EPA Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) system (USEPA 1996) and the Nonpoint Source Model (NPSM) were used to predict the significance of fecal coliform sources and fecal coliform levels in the South Branch watershed. BASINS is a multipurpose environmental analysis system for use in performing watershed and water quality-based studies. A geographic information system (GIS) provides the integrating framework for BASINS and allows for the display and analysis of a wide variety of landscape information (e.g., land uses, monitoring stations, point source dischargers). The NPSM simulates nonpoint source runoff from selected watersheds, as well as the transport and flow of the pollutants through stream reaches. A key criteria for using BASINS as the modeling framework is its ability to integrate both point and nonpoint source simulation, as well as its ability to assess instream water quality response.

2.2.2 Model Set-Up (South Branch)

To obtain a spatial variation of the concentration of bacteria along the South Branch , the watershed was subdivided into 14 sub-watersheds. This allowed analysts to address the relative contribution of sources within each sub-watershed to the different segments of the river. The watershed subdivision was based on a number of factors, including the nesting of additional waterbodies present on the 303(d) list within the South Branch watershed, locations of flow monitoring stations, the locations of stream sampling stations, the locations of feedlots and poultry houses, the reach network, and the land use coverage. Watersheds 12, 13, and 14 represent the Mill Creek, Lunice Creek, and North Fork South Branch Potomac River Watersheds, respectively, and have been listed as separate waterbodies on the 303(d) list.

2.2.3 Source Representation (South Branch)

Both point and nonpoint sources were represented in the model. The point source dischargers that were used are shown in Table 2.2.1. Flow rates and fecal coliform concentrations were obtained from the EPA PCS database for major facilities. In the absence of flow rates and fecal coliform concentrations for minor sources, either typical values for facilities with similar SIC codes were used or facilities were excluded from the modeling. In the model, flow rates were based on average flow rates from facilities rather than permitted flows. Septic system discharges for the South Branch watershed were also represented as point sources in the model. The three major nonpoint source categories that were addressed in this study were: forest land, agricultural land, and urban areas. To better represent these three categories, they were further divided into more refined land use types. This breakdown was based on additional information regarding the distribution of feedlots, poultry houses, and wildlife. A variety of parameters needed for predicting runoff and fecal coliform loadings were then estimated for each of the land uses within these 14 sub-watersheds.

Table 2.2.1 Modeled values for municipal and industrial dischargers in the South Branch watershed

NPDES No.	Facility Name	SIC codes	Flow (gpd)	cfu/100 mL
WV0089974	Pendleton County Board of Education	8211	1,300	459
WV0103063	Woodedge Mobile Home Park	6515	3,000	357
WV0113301	Mountain State Fish Hatchery		NA	NA
WV0073342	Hinkle Trucking Car Wash		NA	NA
WV0103527	Allen's Mobile Home Park	6515	6,450	452
WV0022454	USDA Forest Service - Potomac Adm. Site	4952	400	1
WV0021792	City of Petersburg		1,343,429	53
WV0085031	Pendleton Industries, Inc. - Hanover Shoes	6512	12,923	3730
WV0024970	Town of Franklin	4952	155,000	901
WV0111821	Division of Natural Resources		NA	NA
WV0113794	Pendleton County PSD		NA	NA
WV0113948	Franklin Town WTP		NA	NA

Septic system discharges were quantified based on the following information: the population distribution within each of the 14 sub-watersheds based on 1990 Census Data (WVDEP 1996), an assumed average daily discharge of 70 gallons per person per day (Horsley & Whitten 1996), an assumed septic effluent concentration of 10^4 cfu/100 ml of effluent (Horsley & Whitten 1996), and a 2.5% failure rate (NSFC 1993). The entire population outside the City of Petersburg and the Town of Franklin (which both contain water treatment plants) was assumed to use septic systems.

The initial default values for the fecal coliform loading parameters needed for each land use were based on either general literature values or a variety of available site-specific information. Loading parameters for urban land uses were based on literature values (USEPA 1988).

Fecal coliform loading parameters for forest land uses were based on the wildlife population within the study area. As described in earlier sections, duck and geese populations for the watershed were readily available as were deer population densities (in Hardy, Grant, and Pendleton Counties). Separate loading rates were calculated for each of three counties situated within the 14 subwatersheds. These rates were based on those described earlier for various animal species (Metcalf and Eddy 1991).

A similar analysis was performed to estimate fecal coliform loading rates for agriculture landuses in each of the 14 subwatersheds. Estimates were made of the number and type of poultry houses and cattle in each subwatershed (WVSCA 1997 and PHIWQO 1986). Cattle densities and poultry densities (based on the type of poultry house) were determined for each subwatershed. Each agricultural land use in the 14 subwatersheds was assigned a different fecal coliform loading rate based on these densities and typical fecal coliform loading rates for the cattle and poultry species (Metcalf and Eddy 1991). All waste generated by poultry and cattle was assumed to be applied directly to the land surface within the agricultural land use of the respective watershed.

BMPs were not represented explicitly in the model. However, BMPs already in place during the representative period 10/1/1990 - 9/30/1991 are implicitly represented in the model. That is, calibration of the model for the representative period inherently requires consideration of everything present in the watershed (BMPs included).

2.2.4 Stream Characteristics (South Branch)

The channel geometry of the South Branch in the vicinity of Moorefield (i.e., reach #1) was defined from a Corps of Engineers HEC-2 flood model which contained a number of cross-section surveys of the South Branch. Channel geometries for the remaining 13 reaches in the South Branch model were derived from WVDEP cross-section measurements made during stream flow sampling runs (where available) and by interpolation.

2.2.5 Selection of Representative Modeling Period (South Branch)

The hydrologic conditions in the South Branch watershed consist of relatively random successions of dry, average, and wet rainfall years. Since it was determined that bacteria contamination in the South Branch is critical during high flow conditions, the selection of a hydrologically representative time period was necessary. In addition, the amount of bacteria loading is most likely to increase in response to both the magnitude and intensity of storm events, which can occur in both dry and wet years. It should also be noted that frequent small storms or individual large storms can lead to excessive fecal coliform loading. To represent the hydrological regime, an average rainfall year was selected based on a review of annual rainfall. The period 1984 to 1992 was used as the initial screening period and the 1991 water year (October 1990 through September 1991) was selected as the most representative meteorologic year. Additionally, the modeled flow best-matched the USGS flow data for this year, once hydrologic calibration was performed.

2.2.6 Model Calibration Process (South Branch)

To develop a representative linkage between the sources and the instream water quality response in the 14 reaches of the South Branch, model parameters were adjusted to the extent possible for both hydrology and bacteria loading. Hydrologic calibration required a comparison of the modeled overall water balance and stream flows for the portion of the watershed upstream from USGS gage #01605500 to the actual water balance and flows for 10/1/1990 - 9/30/1991. A variety of hydrologic parameters relating to surface water runoff, water balance, and groundwater flows were adjusted within their reasonable range of values until the predicted flows adequately matched observed values. Some of these parameters represent groundwater storage, evapotranspiration, infiltration capacity of the soil, interflow inflow, and length of assumed overland flow. Once the model was calibrated for the subwatersheds contributing to stream flow at gage station #01605500, the results were validated using flow data at gage station #01606500, which is located downstream and encompasses a larger drainage area. Based on this validation and a verification that parameter values were reasonable, it was decided that the model was adequately representing hydrology of the South Branch.

Parameters related to fecal coliform surface loading as well as background concentrations in the reaches were adjusted by comparing the modeled in-stream concentrations to available observed data. This process was limited by the absence of data for high flow and storm flow conditions. The loading rate and background concentration parameters for the forested land were set to values similar to those in the South Fork watershed. These values were adjusted based on the data for the Hawes Run drainage area (which consists of primarily undisturbed forest land). The loading parameters for urban runoff were primarily based on literature values, however, the background concentration values were adjusted to match the available background (i.e., low flow) data from the 1994 and 1995 USGS data and the 1996 and 1997 DEP monitoring data. Background concentration parameters for the agricultural landuses in the 14 subwatersheds were also adjusted to match available low flow data. Loading parameters for the agricultural land uses were adjusted until modeled water quality most closely matched the observed data. Parameter values were changed within a range of acceptable values, in a manner which retained consistency between relative contributions from the agricultural landuse categories in the 14 subwatersheds.

2.2.7 Existing Loadings (South Branch)

The model was run for the hydrologically representative period (October 1990 through September 1991). The modeling run represents the existing condition of bacteria concentrations and loadings at various reaches of the South Branch. For the existing conditions, the overall fecal coliform bacteria loadings by land-use category for the South Branch watershed are given in Table 2.2.2. A summary of the existing point source loading estimates, including the septic system contribution, is given in Table 2.2.3.

Table 2.2.2 Annual Nonpoint Source Fecal Coliform Bacteria Loading Factors.

Land Use Category	Annual Fecal Coliform Loading
Agriculture and Pasture	1.0357×10^{16} cfu
Forest Land	2.6399×10^{14} cfu
Urban	7.8389×10^{13} cfu

Table 2.2:3 Existing Annual Fecal Coliform Bacteria Point Source Loads for the South Branch Watershed.

Point Source Facility Name	Annual Fecal Coliform Loading (cfu)	Flow Rate (cfs)	Effluent Concentration cfu/100 mL
Pendleton County Board of Education	8.2422×10^{9}	0.002	459
Woodedge Mobile Home Park	1.4598×10^{10}	0.005	357
Mountain State Fish Hatchery	NA	NA	NA
Hinkle Trucking Car Wash	NA	NA	NA
Allen's Mobile Home Park	4.0259×10^{10}	0.010	452
USDA Forest Service - Potomac Adm. Site	3.6614×10^{o}	0.001	1
City of Petersburg	9.8245×10^{11}	2.084	53
Pendleton Industries, Inc. - Hanover Shoes	6.6602×10^{11}	0.020	3730
Town of Franklin	1.9294×10^{12}	0.240	901
Division of Natural Resources	NA	NA	NA
Pendleton County PSD	NA	NA	NA
Franklin Town WTP	NA	NA	NA
Failed Septic Systems	3.3382×10^{12}	0.038	10,000

A summary of West Virginia water quality standard violations for the selected hydrologically representative period is given in Table 2.2.4. All 14 reaches (consisting of the same numerical representation as the subwatersheds) and information relating to violation of the 200 cfu/100 mL geometric mean standard are presented. It is apparent from Table 2.2.4 that reaches in subwatersheds 1, 2, 3, 4, 5, 6, 7, 8, 12, 13, and 14 are in violation of the 200 cfu/100 mL standard. Appendix A also contains plots of the 30-day geometric mean for fecal coliform bacteria for each of the 14 reaches.

Table 2.2.4 Existing Conditions - Summary of Violations of 200 cfu/100 mL Standard.

Reach No. (Subwatershed)	No. of Exceedances	Max No. of Days in an Exceedance	Min No. of Days in an Exceedance	Total No. of Exceedance Days	Exceedance Percentage
1	6	15	2	38	10.41%
2	5	14	3	31	8.49%
3	3	7	1	14	3.84%
4	3	4	1	8	2.19%
5	2	4	2	6	1.64%
6	2	4	1	5	1.37%
7	1	2	2	2	0.55%
8	1	1	1	1	0.27%
9	0	0	0	0	0.00%
10	0	0	0	0	0.00%
11	0	0	0	0	0.00%
12	2	3	1	4	1.10%
13	2	7	3	10	2.74%
14	1	2	2	2	0.55%

2.3 ALLOCATION (SOUTH BRANCH)

Total maximum daily loads (TMDLs) are comprised of the sum of individual waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relation between pollutant loads and the quality of the receiving water body. Conceptually, this definition is denoted by the equation:

$$\text{TMDL} = \Sigma\,\text{WLAs} + \Sigma\,\text{LAs} + \text{MOS}$$

The TMDL is the total amount of a pollutant that can be assimilated by the receiving water while still achieving water quality standards.

For some pollutants, TMDLs are expressed on a mass loading basis (e.g., pounds per day). For bacteria, however, TMDLs can be expressed in terms of organism counts (or resulting concentration), in accordance with 40 CFR 130.2(I).

2.3.1 Incorporating a Margin of Safety (South Branch)

The margin of safety (MOS) is part of the TMDL development process. There are two basic methods for incorporating the MOS (USEPA 1991b):

- Implicitly incorporate the MOS using conservative model assumptions to develop allocations,

  or

- Explicitly specify a portion of the total TMDL as the MOS; use the remainder for allocations.

The MOS is incorporated implicitly into the modeling process by running a dynamic simulation to calculate the daily instream fecal coliform values. Other margins of safety for this TMDL analysis include the following:

- The discharge rates from the point sources were assumed to flow at a constant rate throughout the year. If this flow rate varies based on facility operations, the fecal coliform load may be substantially different from those used in the model.

- It is assumed that all fecal coliform bacteria discharged from the septic system reaches the stream. In reality, it is likely that only a small portion of the bacteria will reach the stream after being filtered through the soil. Additionally, these septic system discharges are assumed to be constant throughout the year, while in reality septic system failures are likely to occur less frequently.

- The baseline year for calibrating NPSM for this TMDL analysis was 1990-91. Any BMPs which have been implemented in the watershed since 1991 are not explicitly included in the model and the resulting allocation reductions should be adjusted in the next phase of this TMDL to reflect the effectiveness of these BMPs.

2.3.2 Assessing Alternatives (South Branch)

For the allocation runs, the model was run for the same hydrologically representative period (October 1990 through September 1991) as used for the existing conditions calibration run. The overall nonpoint source fecal coliform bacteria loadings by landuse category for the South Branch watershed are given in Table 2.3.1. An allocation of 50.6% was applied to all agriculture and pasture lands in the South Branch Watershed for this phase of the TMDL. No reductions were applied to the urban and forest lands. Additionally, no reductions were applied to septic system discharges or other point sources in the watershed. The nonpoint source load allocations reduce the instream concentrations of fecal coliform bacteria sufficiently for the representative year so that no violations of the 200 cfu/100 mL state water quality standards occur.

Table 2.3.1 Fecal Coliform Bacteria Nonpoint Source Allocations for South Branch Watershed.

Land Use	Annual Loading for Existing Run	Annual Loading for Allocation Run	Percent Reduction
Agriculture and Pasture	1.0357×10^{16} cfu	5.1150×10^{15} cfu	50.6%
Urban	7.8389×10^{13} cfu	7.8389×10^{13} cfu	0.0%
Forest	2.6399×10^{14} cfu	2.6399×10^{14} cfu	0.0%

While the overall nonpoint source fecal reduction for the agricultural landuse is presented as a single value, each of the 14 sub-watersheds requires a unique reduction. These unique reductions are required for sub-watersheds 12, 13, and 14, the Mill Creek, Lunice Creek, and North Fork watersheds, respectively, in order to complete TMDLs for these additional waterbodies listed on the 303(d) list. Table 2.3.2 presents the required reductions by watershed to meet the overall reduction of 50.6% and hence the 200 cfu/100 mL water quality standard. Note that sub-watersheds 3, 6, 8, and 11 require no reduction. This is a result of the absence of poultry houses and cattle on agricultural land in these watersheds. An average fecal coliform bacteria loading for forested land was applied to agricultural landuses in these watersheds.

Table 2.3.2 Allocated Fecal Coliform Load Reductions by Sub-watershed for Agricultural Landuses.

Watershed Number	Segment Name	Percent Reduction
1	Moorefield to Rig	71%
2	Rig to Mill Creek	72%
3	Mill Creek to Lunice Creek	0%
4	Lunice Creek to USGS Gage	35%
5	USGS Gage to North Fork	35%
6	North Fork to Long Run	0%
7	Long Run to Reeds Creek	35%
8	Reeds Creek to Hayes Gap Run	71%
9	Hayes Gap Run to Franklin	35%
10	Franklin to Virginia State Line	35%
11	Upstream of Virginia State Line	0%
12	Mill Creek	37%
13	Lunice Creek	40%
14	North Fork	35%

3.0 LUNICE CREEK WATERSHED

This chapter describes the development of a fecal coliform bacteria TMDL for the Lunice Creek watershed. The West Virginia 303(d) stream list indicates that 7.50 miles of Lunice Creek is impacted by fecal coliform bacteria. The Lunice Creek watershed was included as subwatershed #13 in the NPSM model of the South Branch (see Section 2.0). A more detailed model of the Lunice Creek watershed is presented in this section in which the basin is divided into 9 subwatersheds.

3.1 SOURCE ASSESSMENT (LUNICE CREEK)

This section presents an overview of the instream water quality monitoring data available for Lunice Creek and then discusses the type, magnitude, and location of potential point and nonpoint sources of fecal coliform loading.

3.1.1 Instream Water Quality Monitoring Data (Lunice Creek)

Periodic monitoring for fecal coliform bacteria at a number of locations in the Lunice Creek has been conducted over the years. Locations of the monitoring sites are shown in Figure 3.1.1 and the station labeled USGS#16 is from the special study conducted by the U.S. Geological Survey from March 1994 to August 1995 for the Potomac Headwaters study (PHIWQO 1996). The USGS station was sampled approximately once per month throughout the study period. Time-series plots of the fecal coliform data for the USGS station is shown in Figure 3.1.2. The data in this figure indicate that individual sample points are occasionally higher than the state water quality standards of 200 and 400 cfu/100 mL.

In support of the development of this fecal coliform bacteria TMDL analysis, the West Virginia Division of Environmental Protection (DEP) has begun a monitoring program in the Lunice Creek watershed in which numerous sites are sampled during a single field excursion. As of the date of this report, three intensive sampling runs have been completed in August 1996, June 1997, and August 1997. The locations of the monitoring stations are shown in Figure 3.1.1. The June 1997 sampling date coincided with a high-flow event whereas the August 1996 and August 1997 dates occurred during low-flow periods.

The 1994-95 USGS reconnaissance survey provided the best long-term multi-year data set of fecal coliform bacteria for Lunice Creek. West Virginia DEP used the results of the USGS survey to determine whether a stream segment should be added to the 303(d) list of water quality limited streams. Since the sample frequency was less than 5 per month, it was not possible to determine whether a stream segment was in compliance with the 200 cfu/100 mL State standard for fecal coliform bacteria. Instead, if more than 25% of the samples were greater than 200 cfu/100 mL, the stream segment was considered threatened and placed on the 303(d) list as needing a TMDL for fecal coliform bacteria. A summary of the USGS bacteria data for monitoring station USGS#16 on Lunice Creek is given in Table 3.1.1. These data indicate greater than 25% of the samples were above the 200 cfu/100 mL level which is the reason Lunice Creek was placed on the 303(d) list.

Table 3.1.1 Summary of Fecal Indicator Bacteria from 1994-95 USGS Study for Lunice Creek.

		Fecal Coliform Bacteria (cfu/100 mL)					Fecal Streptococci	
Station	n	Min	Median	Max	percent greater than 200	percent greater than 400	Median (cfu/100 mL)	FC/FS median ratio
USGS#16	15	38	495	16,000	60.0	53.3	680	1.0

Both fecal coliform (FC) and fecal streptococci (FS) were measured during the 1994-95 USGS survey. The ratio of fecal coliform to fecal streptococci can indicate possible sources of bacterial contamination. Each warm-blooded species has a unique bacteria ratio of fecal coliform to fecal streptococci in the intestinal tract. In humans, this ratio is generally greater than 4.0 whereas in animals the ratio is usually less than 0.7. Therefore, ratios greater than 4.0 in stream-water samples indicate that the source of bacterial contamination is likely human waste. Conversely, ratios of less than 0.7 indicate a bacterial source which is non-human. Intermediate ratios indicate mixed or undetermined sources of bacterial contamination (PHIWQO 1996). The USGS station on Lunice Creek has a FC/FS ratio of 1.0 indicating the likely source of bacterial contamination is from animal waste (APHA, 1985).

3.1.2 Assessment of Point Sources (Lunice Creek)

There are no point sources permitted for fecal coliform bacteria discharges in the Lunice Creek watershed. The City of Petersburg lies mostly within the watershed, however, the municipal POTW discharges to South Branch Potomac River.

3.1.3 Assessment of Nonpoint Sources (Lunice Creek)

The primary tributaries to the Lunice Creek are Robinson Run, Norman Run, Brushy Run, North Fork Lunice Creek, and South Fork Lunice Creek. Inadequate long-term monitoring data were available to characterize the flow and bacteria loading from each of these peripheral tributaries. The watershed was divided into 9 subwatersheds based on tributary location, land use, poultry house and feedlot density, and the locations of bacteria monitoring stations (see Figure 3.1.2).

The U.S. GeoData 1:250,000 scale land use and land cover data (U.S. GeoData 1986) were used to determine land uses in the Lunice Creek watershed. The land uses consist primarily of forested, agricultural, and urban areas. The various land uses for each of the 9 sub-watersheds are listed in Table 3.1.2 and are shown in the color map for Lunice Creek in Appendix A. The West Virginia Soil Conservation Agency (WVSCA) maintains a geographic information system (GIS) with the locations of poultry houses, feedlots, and other agricultural-related information. The delineations of the sub-watersheds for the South Branch Fork were provided to WVSCA and they in turn estimated the number of poultry houses and animal feedlots within each of the sub-watersheds. Estimates of total head of cattle in each sub-watershed were also provided by WVSCA (see Table 3.1.3).

The West Virginia Division of Natural Resources (DNR) provided estimates of the numbers of geese and ducks within the South Branch region typical of July 1 of any given year. The numbers of birds may vary with season because of migratory patterns as well as birds moving in and out of the watershed. The DNR estimated an upper bound of 650 for the migratory goose population and 195 for the migratory duck population in the Lunice Creek watershed. In addition, deer population was estimated from the Big Game Bulletin (DNR 1996). The total deer population can be estimated as about 10 times the number of buck killed during hunting season. Animal population estimates for the Lunice Creek watershed are given in Table 3.1.4.

Table 3.1.2 Land Use Distributions in the Lunice Creek Subwatersheds

Subbasin Number	Stream Name Location	Total Area (acres)	Urban (acres)	Agricultural (acres)	Forest (acres)	Septic Population
1	Lower Lunice Creek	12,580	0	2,853	9,727	364
2	Robinson Run	10,518	0	1,709	8,809	323
3	Norman Run	4,890	68	1,807	3,015	205
4	Brushy Run	5,812	0	2,943	2,869	226
5	Upper Lunice Creek	3,804	349	1,795	1,660	16
6	South Fork Lunice Cr.	7,157	0	1,606	5,551	318
7	South Fork Lunice Cr.	5,320	0	2,517	2,803	160
8	North Fork Lunice Cr.	641	0	338	303	357
9	North Fork Lunice Cr.	6,597	0	4,033	2,564	311
	Totals	57,319	417	19,601	37,301	2,280

Table 3.1.3 Inventory of Poultry Houses and Cattle Feedlots in Lunice Creek Watershed.

Subbasin	Stream Name	Poultry Houses Broiler	Poultry Houses Breeder	Poultry Houses Turkey	Feedlots	Head Cattle	Litter Storage
1	Lower Lunice Creek	0	0	0	2	300	0
2	Robinson Run	0	3	1	3	100	0
3	Norman Run	9	5	2	9	400	0
4	Brushy Run	2	2	1	3	100	0
5	Upper Lunice Creek	3	0	0	0	50	0
6	South Fork Lunice Cr.	7	3	1	3	400	0
7	South Fork Lunice Cr.	0	0	1	0	50	0
8	North Fork Lunice Cr.	9	4	0	1	150	0
9	North Fork Lunice Cr.	6	0	0	0	100	0
	Totals	36	17	6	21	1,650	0

Table 3.1.4 Population Estimates of Farm and Wild Animals in Lunice Creek Watershed.

Subbasin Number	Stream Name Location	Number Chickens Broilers	Number Chickens Breeders	Number Turkeys	Head Cattle	Number Migratory Ducks	Number Migratory Geese	Number Deer
1	Lower Lunice Creek	0	0	0	300	2	5	714
2	Robinson Run	0	27,000	15,000	100	3	8	647
3	Norman Run	252,000	45,000	30,000	400	4	9	221
4	Brushy Run	56,000	18,000	15,000	100	4	10	211
5	Upper Lunice Creek	84,000	0	0	50	0	1	122
6	South Fork Lunice Cr.	196,000	27,000	15,000	400	3	7	408
7	South Fork Lunice Cr.	0	0	15,000	50	5	15	206
8	North Fork Lunice Cr.	252,000	36,000	0	150	3	7	22
9	North Fork Lunice Cr.	168,000	0	0	100	7	17	188
	Totals	1,008,000	153,000	90,000	1,650	30	80	2,739

Onsite septic systems are the predominant form of waste water treatment in the Lunice Creek watershed. No information was readily available on the specific locations of septic systems, septic tank densities, or failure rates. However, WVDEP provided estimates of the percent of the population for each county which used septic systems. For Hardy County, it was estimated that 80% of the population of 11,000 residents used septic systems. A septic system failure rate of about 2.5% was estimated for Hardy County (NSFC 1993) and it was assumed this rate was also applicable to the Lunice Creek watershed. It was further assumed that 100% of the fecal coliform load from the failed systems reached the receiving waters at a concentration of $1x10^4$ cfu/100 mL for raw sewage (Metcalf & Eddy 1991). The assumed septic system waste flow rate was computed based on a typical value of 70 gallons per capita per day (Horsely & Whitten 1996).

As previously mentioned, the 1994-95 USGS monitoring data suggest that the source of bacterial contamination in Lunice Creek is from animal sources based on the fecal coliform to fecal streptococci ratio of 1.0 at station USGS#16. For this study, it was assumed that manure from poultry operations was applied to agricultural land within the sub-watershed in which the poultry house was situated. In practice, poultry manure may be transported to or imported from other sub-watersheds; or it may be moved completely out of the Lunice Creek watershed. No information was available as to the specific manure management practices. A list of sites for the land application of municipal and industrial sludge in the study area watershed was provided by WVDEP (Aug 5, 1997) and is the only site in the Lunice Creek watershed is indicated in Table 3.1.5. Since the amount of sludge applied to the land areas is not known at this time, no attempt was made to incorporate these sites as a possible source of fecal coliform bacteria into the TMDL analysis.

Table 3.1.5 Land Application Site in Lunice Creek Watershed

Generator	Type	Farm	Acres	Drainage Area/Location
Petersburg	Sludge	Bruce Hyre	100	UT-Lunice Creek, near intersection of CR220/1 and 220/9

UT = unnamed tributary

Using the available information for poultry houses, head of cattle, and wildlife estimates, the daily fecal coliform loads were computed for each sub-watershed. The average fecal coliform loading rates for the various animal species used for the total potential load calculation were previously given in Table 2.1.6. The average number of birds for each type of poultry house was based on information obtained from WVDEP (1997) as follows: 15,000 Turkeys; 9,000 Breeders; and 28,000 Broilers. The total potential fecal coliform production per subwatershed for each of the animal categories is given in Table 3.1.6. Poultry makes up 86% of the potential nonpoint source fecal coliform load in the watershed followed by cattle with about 7% of the load. It is important to understand that the values in Table 3.1.6 are the "potential" fecal coliform loads from various nonpoint sources and not necessarily the loads which reach the receiving waters in the watershed (with the exception of the septic load which is the estimated load reaching the stream). Various attenuation processes and agricultural management practices will reduce these loads before they reach the stream.

Table 3.1.6 Potential Nonpoint Source Fecal Coliform Production in Lunice Creek Watershed.

Subbasin Number	Stream Name Location	Total Load (cfu/day)	Poultry (cfu/day)	Cattle (cfu/day)	Ducks (cfu/day)	Geese (cfu/day)	Deer (cfu/day)	Septic (cfu/day)
1	Lower Lunice Creek	2.259E+12	0.000E+00	1.620E+12	2.184E+10	2.594E+11	3.572E+11	2.411E+08
2	Robinson Run	9.725E+12	8.430E+12	5.400E+11	3.348E+10	3.977E+11	3.235E+11	2.139E+08
3	Norman Run	7.795E+13	7.518E+13	2.160E+12	3.873E+10	4.600E+11	1.107E+11	1.358E+08
4	Brushy Run	2.089E+13	1.971E+13	5.400E+11	4.171E+10	4.955E+11	1.053E+11	1.497E+08
5	Upper Lunice Creek	2.053E+13	2.016E+13	2.700E+11	2.809E+09	3.336E+10	6.095E+10	1.060E+07
6	South Fork Lunice Cr.	5.823E+13	5.547E+13	2.160E+12	3.047E+10	3.619E+11	2.038E+11	2.106E+08
7	South Fork Lunice Cr.	3.097E+12	1.950E+12	2.700E+11	6.010E+10	7.139E+11	1.029E+11	1.060E+08
8	North Fork Lunice Cr.	7.031E+13	6.912E+13	8.100E+11	2.889E+10	3.432E+11	1.113E+10	2.365E+08
9	North Fork Lunice Cr.	4.188E+13	4.032E+13	5.400E+11	7.197E+10	8.549E+11	9.415E+10	2.060E+08
	Totals	3.049E+14	2.903E+14	8.910E+12	3.300E+11	3.920E+12	1.370E+12	1.304E+09
	Percent of total	100.00%	95.23%	2.92%	0.11%	1.29%	0.45%	0.00%

3.1.4 Critical Conditions (Lunice Creek)

For this study, an average hydrologic year was selected for the continuous simulation period. The period 1984 to 1992 was used as the initial screening period. The 1991 water year, from October 1990 through September 1991, was selected as the most representative of an average meteorologic year for the Lunice Creek watershed from within the screening period. There were no long-term flow gaging stations in the watershed which could be used to calibrate the hydrologic flows computed by the nonpoint source runoff model. The time-series of computed flows at the downstream-most reach of the watershed is shown in Figure 3.1.3.

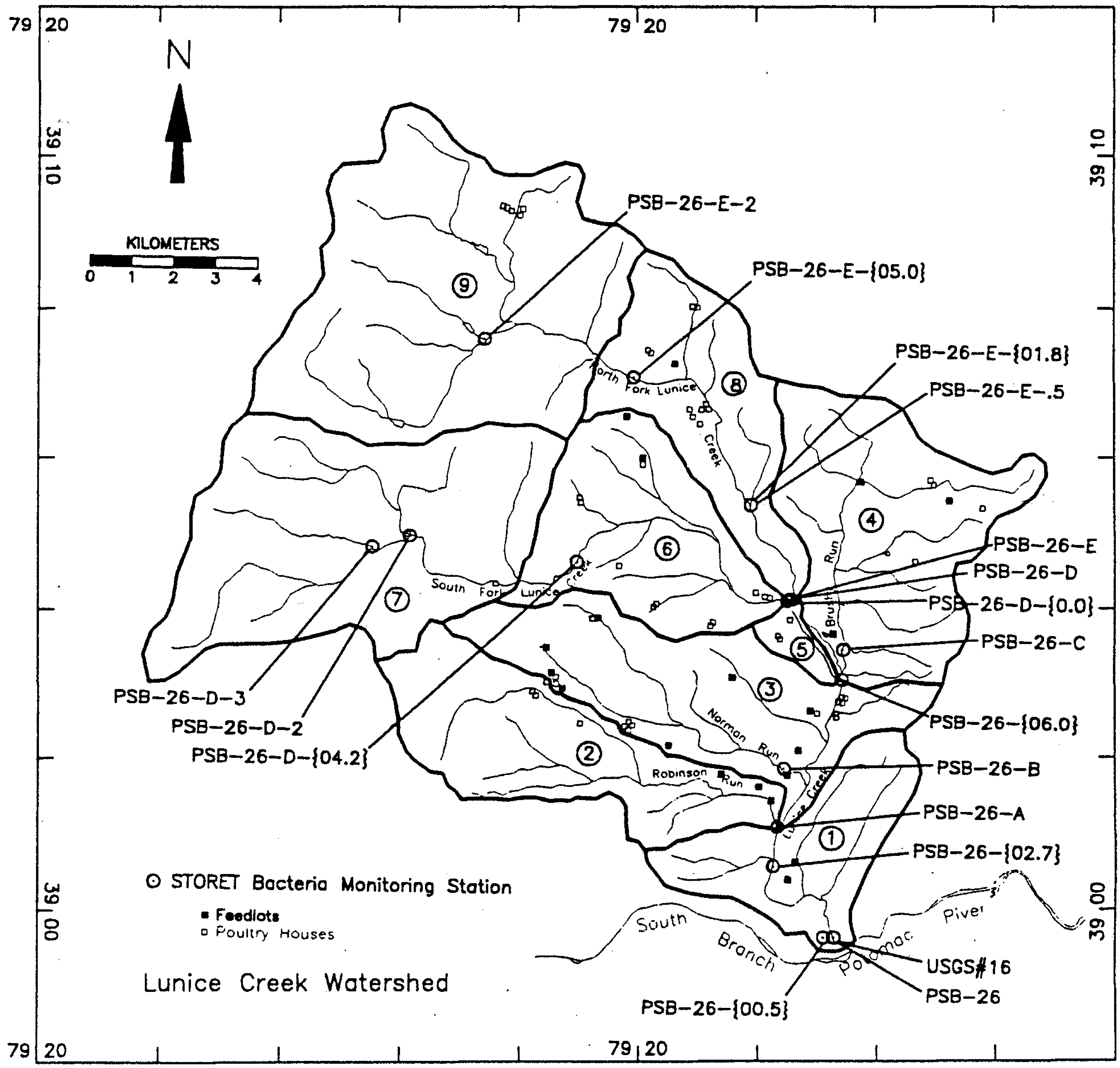


Figure 3.1.1 STORET bacteria monitoring stations in Lunice Creek watershed.

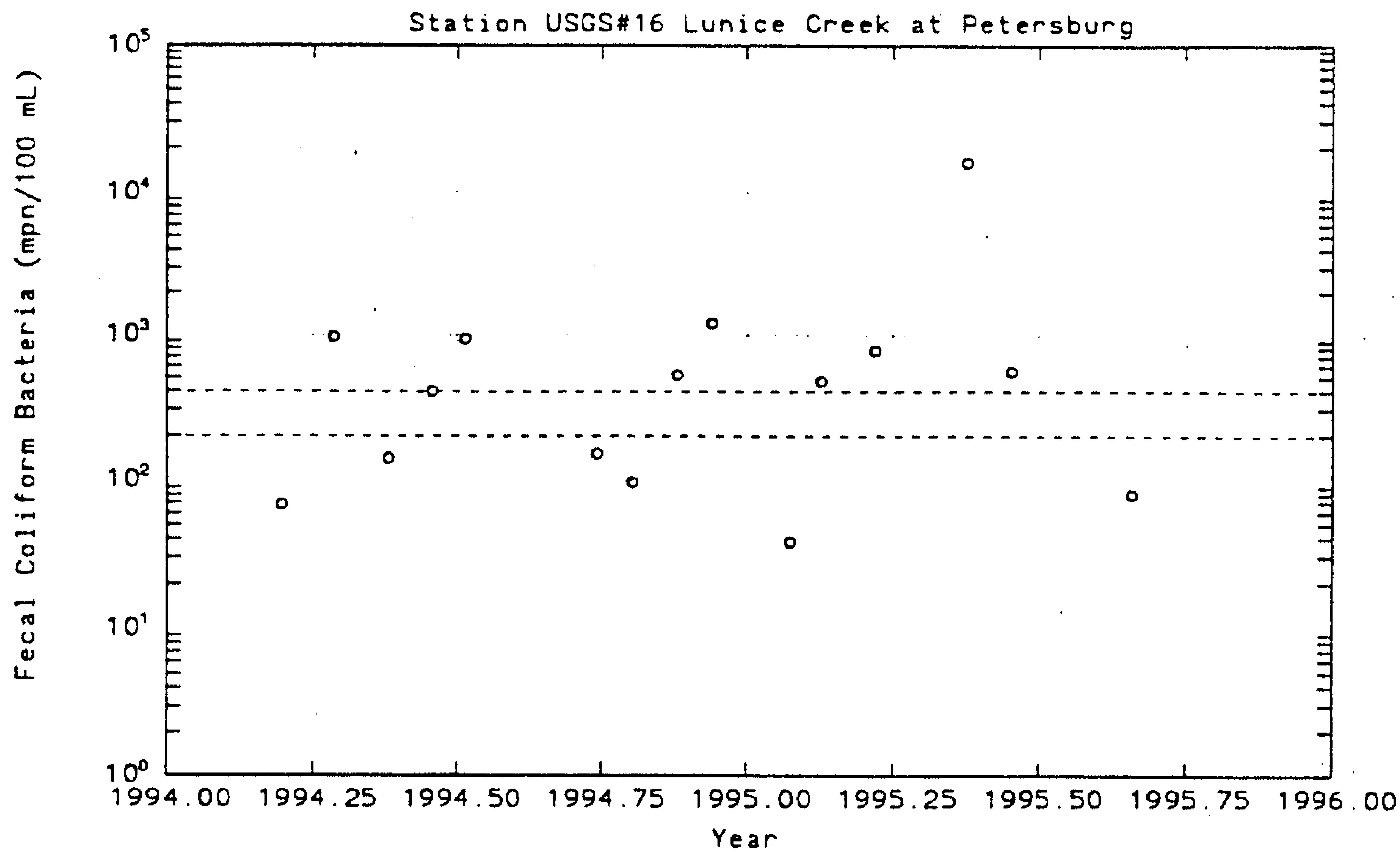


Figure 3.1.2 Time-series of fecal coliform bacteria for USGS station #16.

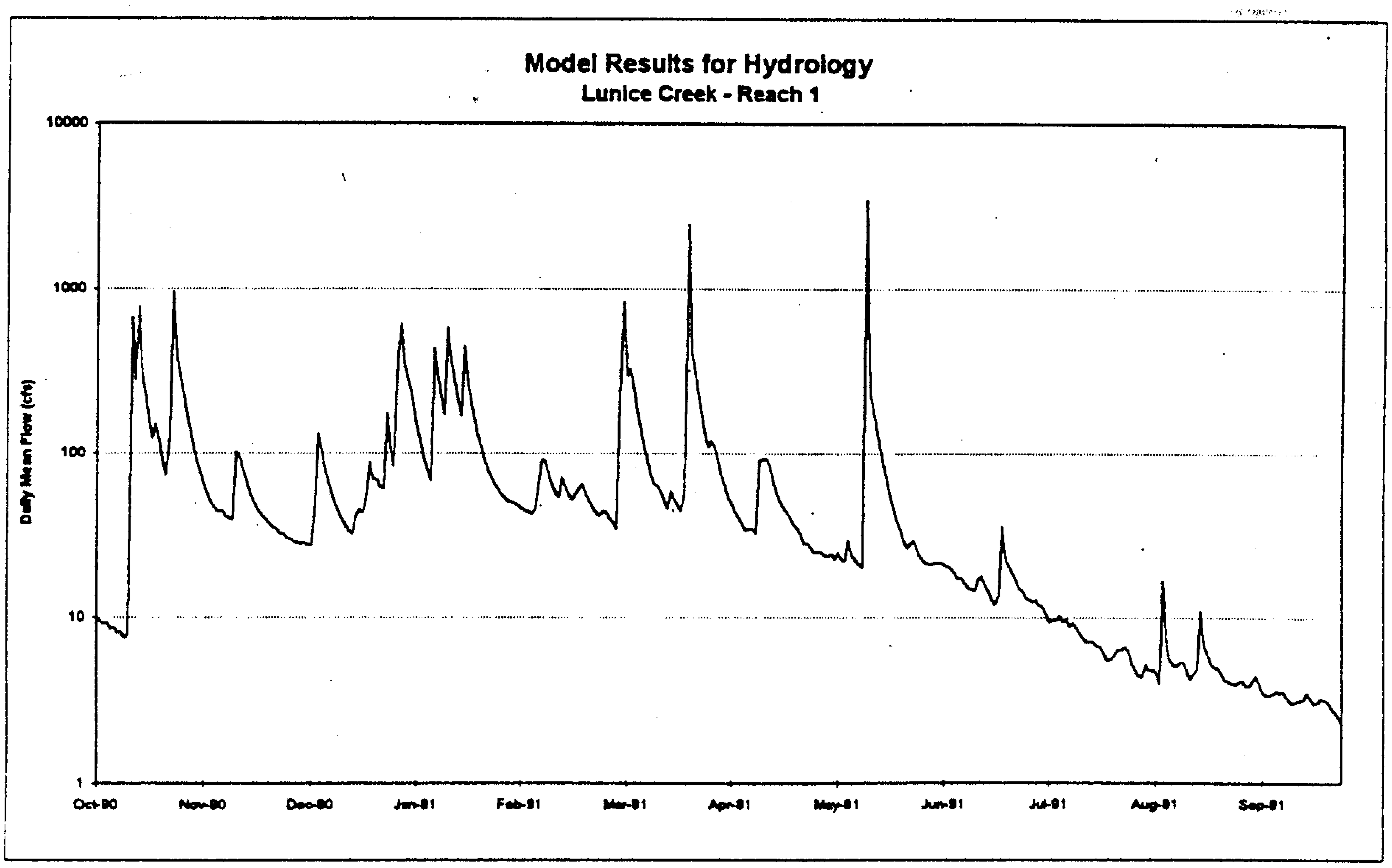


Figure 3.1.3 Model flow time series for 1990-91 hydrologic year at Lunice Creek.

3.2 MODEL SET-UP (LUNICE CREEK)

Although the required percent reduction of fecal coliform bacteria loading for the Lunice Creek watershed was known as a result of the South Branch allocation, it was necessary to perform a more in-depth analysis and modeling of the area. In modeling the large South Branch watershed, it was necessary to represent the Lunice Creek watershed as a single watershed. After arriving at a target allocation value for Lunice Creek, which meets the water quality standard in the South Branch Potomac River, it was necessary to further segment the watershed and arrive at a more refined loading reduction. To obtain a spatial variation of the concentration of bacteria along Lunice Creek, the watershed was subdivided into 9 sub-watersheds. This allowed analysts to address the relative contribution of sources within each sub-watershed to the different segments of the river. The watershed subdivision was based on a number of factors, including the locations of flow monitoring stations, the locations of stream sampling stations, the locations of feedlots and poultry houses, and the reach network and land use coverage.

3.2.1 Source Representation (Lunice Creek)

Both point and nonpoint sources were represented in the model. Septic system discharges for the Lunice Creek watershed were the only point sources represented in the model, because no permitted point sources are located in the watershed. The three major nonpoint source categories that were addressed in this study were: forest land, agricultural land, and urban areas. To better represent these three categories, they were further divided into more refined land use types. This breakdown was based on additional information regarding the distribution of feedlots, poultry houses, and wildlife. A variety of parameters needed for predicting runoff and fecal coliform loadings were then estimated for each of the land uses within these 9 sub-watersheds.

Septic system discharges were quantified based on the following information: the population distribution within each of the 9 sub-watersheds based on 1990 Census Data (WVDEP 1996), an assumed average daily discharge of 70 gallons per person per day (Horsley & Whitten 1996), an assumed septic effluent concentration of 10^4 cfu/100 ml of effluent (Horsley & Whitten 1996), and a 2.5% failure rate (NSFC 1993). The entire population outside the City of Petersburg, which contains a water treatment plant, was assumed to use septic systems.

The initial default values for the fecal coliform loading parameters needed for each land use were based on either general literature values or a variety of available site-specific information. Loading parameters for urban land uses were based on literature values (USEPA 1988).

Fecal coliform loading parameters for forest land uses were based on the wildlife population within the study area. As described in earlier sections, duck and geese populations for the watershed were readily available as was the deer population density (in Grant County). A specific loading rate was calculated for forested land in the Lunice Creek watershed. The rate was based on fecal coliform contributions described earlier for various animal species (Metcalf and Eddy 1991).

A similar analysis was performed to estimate fecal coliform loading rates for agriculture landuses in each of the 9 subwatersheds. Information was available on the number and type of poultry houses and cattle in each subwatershed (WVSCA 1997 and PHIWQO 1986). Cattle densities and poultry densities (based on the type of poultry house) were determined for each subwatershed. Each agricultural land use in the 9 subwatersheds was assigned a different fecal coliform loading rate based on these densities and typical fecal coliform loading rates for the cattle and poultry species (Metcalf and Eddy 1991). All waste generated by poultry and cattle was assumed to be applied directly to the land surface within the agricultural land use of the respective watershed.

BMPs were not represented explicitly in the model. However, BMPs already in place during the representative period 10/1/1990 - 9/30/1991 are implicitly represented in the model. That is, calibration of the model for the representative period inherently requires consideration of everything present in the watershed (BMPs included).

3.2.2 Stream Characteristics (Lunice Creek)

Channel geometries for the reaches in Lunice Creek were determined from cross-section surveys performed by WVDEP during stream flow monitoring activities in June 1997 at several sampling locations.

3.2.3 Selection of Representative Modeling Period (Lunice Creek)

The hydrologic conditions in the Lunice Creek watershed consist of relatively random successions of dry, average, and wet rainfall years. Since it was determined that bacteria contamination in Lunice Creek is critical during high flow conditions, the selection of a hydrologically representative time period was necessary. In addition, the amount of bacteria loading is most likely to increase in response to both the magnitude and intensity of storm events, which can occur in both dry and wet years. It should also be noted that frequent small storms or individual large storms can lead to excessive fecal coliform loading. To represent the hydrological regime, an average rainfall year was selected based on a review of annual rainfall. The period 1984 to 1992 was used as the initial screening period and the 1991 water year (October 1990 through September 1991) was selected as the most representative meteorologic year.

3.2.4 Model Calibration Process (Lunice Creek)

To develop a representative linkage between the sources and the instream water quality response in the 9 reaches of Lunice Creek, model parameters were adjusted to the extent possible for both hydrology and bacteria loading. Hydrologic parameters used in calibration of NPSM for the South Branch watershed, which contains Lunice Creek, were applied to the Lunice Creek watershed. Hydrologic parameters which were set for the model relate to surface water runoff, water balance, and groundwater flows. Some of these parameters represented groundwater storage, evapotranspiration, infiltration capacity of the soil, interflow inflow, and length of assumed overland flow. Based on the calibration, validation, and a verification of the model for the South Branch watershed, it was decided that the model was adequately representing hydrology of Lunice Creek.

Parameters related to fecal coliform surface loading as well as background concentrations in the reaches were adjusted by comparing the modeled in-stream concentrations to available observed data. This process was limited by the absence of data for high flow and storm flow conditions. The loading rate and background concentration parameters for the forested land were set to values similar to those in the South Fork watershed. These values were adjusted based on the data for the Hawes Run drainage area (which consists of primarily undisturbed forest land). The loading parameters for urban runoff were primarily based on literature values and the background concentration values were adjusted to match the available background (i.e., low flow) data from the 1996 and 1997 DEP monitoring data. Background concentration parameters for the 9 different agricultural landuses were also adjusted to match available low flow data. Loading parameters for the agricultural land uses were adjusted until modeled water quality most closely matched the observed data. Parameter values were changed within a range of acceptable values, in a manner which retained consistency between relative contributions from the 9 different agricultural landuse categories.

3.2.5 Existing Loadings (Lunice Creek)

The model was run for the hydrologically representative period (October 1990 through September 1991). The modeling run represents the existing condition of bacteria concentrations and loadings at various reaches of Lunice Creek. For the existing conditions, the fecal coliform bacteria loading from the septic systems was 5.5129×10^{11} cfu/yr. The overall fecal coliform bacteria loadings by land-use category for Lunice Creek watershed are given in Table 3.2.1.

Table 3.2.1 Annual Nonpoint Source Fecal Coliform Bacteria Loading Factors.

Land Use Category	Annual Fecal Coliform Loading
Agriculture and Pasture	1.6835×10^{15} cfu
Forest Land	3.5917×10^{13} cfu
Urban	8.9122×10^{12} cfu

A summary of West Virginia water quality standard violations for the selected hydrologically representative period is given in Table 3.2.2. All 9 reaches (consisting of the same numerical representation as the subwatersheds) and information relating to violation of the 200 cfu/100 mL geometric mean standard are presented. It is apparent from Table 3.2.2 that reaches in subwatersheds 1, 3, 4, and 8 are in violation of the 200 cfu/100 mL standard. Appendix A also contains plots of the 30-day geometric mean for fecal coliform bacteria for each of the 9 reaches.

Table 3.2.2 Existing Conditions - Summary of Violations of 200 cfu/100 mL Standard.

Reach No. (Subwatershed)	No. of Exceedances	Max No. of Days in an Exceedance	Min No. of Days in an Exceedance	Total No. of Exceedance Days	Exceedance Percentage
1	2	7	2	9	2.47%
2	0	0	0	0	0.00%
3	2	7	3	10	2.74%
4	2	3	1	4	1.10%
5	0	0	0	0	0.00%
6	0	0	0	0	0.00%
7	0	0	0	0	0.00%
8	2	6	2	8	2.19%
9	0	0	0	0	0.00%

3.3 ALLOCATION (LUNICE CREEK)

For the allocation runs, the model was run for the same hydrologically representative period (October 1990 through September 1991) as used for the existing conditions calibration run. From the South Branch watershed allocation, Lunice Creek requires a 40% reduction in fecal coliform bacteria loading from the agricultural land, in order to meet the 200 cfu/100 mL state water quality standard in the South Branch Potomac River. The allocation run for Lunice Creek must meet this requirement, however, the distribution of loading reductions among the sub-watersheds can potentially vary. The refined overall nonpoint source fecal coliform bacteria loadings by landuse category for the Lunice Creek watershed are given in Table 3.3.1. An allocation of 40.6% was applied to all agriculture and pasture lands in the Lunice Creek watershed for this phase of the TMDL. No reductions were applied to the urban and forest lands. Additionally, no reductions were applied to septic system discharges in the watershed. These nonpoint source load allocations reduce the instream concentrations of fecal coliform bacteria sufficiently for the representative year so that no violations of the 200 cfu/100 mL state water quality standards occur.

Table 3.3.1 Fecal Coliform Bacteria Nonpoint Source Allocations for the Lunice Creek Watershed..

Land Use	Annual Loading for Existing Run	Annual Loading for Allocation Run	Percent Reduction
Agriculture and Pasture	1.6835×10^{15} cfu	9.9996×10^{14} cfu	40.6%
Urban	8.9122×10^{12} cfu	8.9122×10^{12} cfu	0.0%
Forest	3.5917×10^{13} cfu	3.5917×10^{13} cfu	0.0%

4.0 MILL CREEK WATERSHED

This chapter describes the development of a fecal coliform bacteria TMDL for the Lunice Creek watershed. The West Virginia 303(d) stream list indicates that 2.36 miles of Mill Creek is impacted by fecal coliform bacteria. The Mill Creek watershed was included as subwatershed #12 in the NPSM model of the South Branch (see Section 2.0). A more detailed model of the Mill Creek watershed is presented in this section in which the basin is divided into 8 subwatersheds.

4.1 SOURCE ASSESSMENT (MILL CREEK)

This section presents an overview of the instream water quality monitoring data available for Mill Creek and then discusses the type, magnitude, and location of potential point and nonpoint sources of fecal coliform loading.

4.1.1 Instream Water Quality Monitoring Data (Mill Creek)

Periodic monitoring for fecal coliform bacteria at a number of locations in the MillCreek has been conducted over the years. Locations of the monitoring sites are shown in Figure 4.1.1 and the station labeled USGS#19 is from the special study conducted by the U.S. Geological Survey from March 1994 to August 1995 for the Potomac Headwaters study (PHIWQO 1996). The USGS station was sampled approximately once per month throughout the study period. Time-series plots of the fecal coliform data for the USGS station is shown in Figure 4.1.2. The data in this figure indicate that individual sample points are occasionally higher than the state water quality standards of 200 and 400 cfu/100 mL.

In support of the development of this fecal coliform bacteria TMDL analysis, the West Virginia Division of Environmental Protection (DEP) has begun a monitoring program in the Mill Creek watershed in which numerous sites are sampled during a single field excursion. As of the date of this report, three intensive sampling runs have been completed in August 1996, June 1997, and August 1997. The locations of the monitoring stations are shown in Figure 4.1.1. The June 1997 sampling date coincided with a high-flow event whereas the August 1996 and August 1997 dates occurred during low-flow periods.

The 1994-95 USGS reconnaissance survey provided the best long-term multi-year data set of fecal coliform bacteria for Mill Creek. West Virginia DEP used the results of the USGS survey to determine whether a stream segment should be added to the 303(d) list of water quality limited streams. Since the sample frequency was less than 5 per month, it was not possible to determine whether a stream segment was in compliance with the 200 cfu/100 mL State standard for fecal coliform bacteria. Instead, if more than 25% of the samples were greater than 200 cfu/100 mL, the stream segment was considered threatened and placed on the 303(d) list as needing a TMDL for fecal coliform bacteria. A summary of the USGS bacteria data for monitoring station USGS#19 on Mill Creek is given in Table 4.1.1. These data indicate greater than 25% of the samples were above the 200 cfu/100 mL level which is the reason Mill Creek was placed on the 303(d) list.

Table 4.1.1 Summary of Fecal Indicator Bacteria from 1994-95 USGS Study for Mill Creek.

		Fecal Coliform Bacteria (cfu/100 mL)					Fecal Streptococci	
Station	n	Min	Median	Max	percent greater than 200	percent greater than 400	Median (cfu/100 mL)	FC/FS median ratio
USGS#19	14	110	580	31,000	85.7	64.2	1,100	0.8

Both fecal coliform (FC) and fecal streptococci (FS) were measured during the 1994-95 USGS survey. The ratio of fecal coliform to fecal streptococci can indicate possible sources of bacterial contamination. Each warm-blooded species has a unique bacteria ratio of fecal coliform to fecal streptococci in the intestinal tract. In humans, this ratio is generally greater than 4.0 whereas in animals the ratio is usually less than 0.7. Therefore, ratios greater than 4.0 in stream-water samples indicate that the source of bacterial contamination is likely human waste. Conversely, ratios of less than 0.7 indicate a bacterial source which is non-human. Intermediate ratios indicate mixed or undetermined sources of bacterial contamination (PHIWQO 1996). The USGS station on MillCreek has a FC/FS ratio of 0.8 indicating the likely source of bacterial contamination is from animal waste (APHA, 1985).

4.1.2 Assessment of Point Sources (Mill Creek)

There are no point source discharges permitted for fecal coliform bacteria in the Mill Creek watershed.

4.1.3 Assessment of Nonpoint Sources (Mill Creek)

The primary tributaries to Mill Creek are Johnson Run, North Mill Creek, and South Mill Creek. Inadequate long-term monitoring data were available to characterize the flow and bacteria loading from these peripheral tributaries. The watershed was divided into 8 subwatersheds based on tributary location, land use, poultry house and feedlot density, and the locations of bacteria monitoring stations.

The U.S. GeoData 1:250,000 scale land use and land cover data (U.S. GeoData 1986) were used to determine land uses in the Mill Creek watershed. The land uses consist primarily of forested, agricultural, and urban areas. The various land uses for each of the 8 sub-watersheds are listed in Table 4.1.2 and are shown in the color map for Mill Creek in Appendix A. The West Virginia Soil Conservation Agency (WVSCA) maintains a geographic information system (GIS) with the locations of poultry houses, feedlots, and other agricultural-related information. The delineations of the sub-watersheds for Mill Creek were provided to WVSCA and they in turn estimated the number of poultry houses and animal feedlots within each of the sub-watersheds. Estimates of total head of cattle in each sub-watershed were also provided by WVSCA (see Table 4.1.3).

The West Virginia Division of Natural Resources (DNR) provided estimates of the numbers of geese and ducks within the South Branch region typical of July 1 of any given year. The numbers of birds may vary with season because of migratory patterns as well as birds moving in and out of the watershed. The DNR estimated an upper bound of 60 for the migratory goose population and 30 for the migratory duck population in the Mill Creek watershed. In addition, deer population was estimated from the Big Game Bulletin (DNR 1996). The total deer population can be estimated as about 10 times the number of buck killed during hunting season. Animal population estimates for the Lunice Creek watershed are given in Table 4.1.4.

Table 4.1.2 Land Use Distributions in the Mill Creek Subwatersheds

Subbasin Number	Stream Name Location	Total Area (acres)	Urban (acres)	Agricultural (acres)	Forest (acres)	Septic Population
1	Lower Mill Creek	7,293	163	3,648	3,482	686
2	North Mill Creek	8,203	65	2,436	5,702	388
3	North Mill Creek	9,632	60	2,498	7,074	96
4	North Mill Creek	5,370	24	1,186	4,160	80
5	North Mill Creek	5,306	20	1,125	4,161	528
6	South Mill Creek	11,840	9	2,267	9,564	333
7	South Mill Creek	12,004	43	4,024	7,937	179
8	South Mill Creek	6,772	0	1,984	4,788	58
	Totals	66,420	384	19,168	46,868	2,348

Table 4.1.3 Inventory of Poultry Houses and Cattle Feedlots in Mill Creek Watershed.

Subbasin	Stream Name	Poultry Houses Broiler	Poultry Houses Breeder	Poultry Houses Turkey	Feedlots	Head Cattle	Poultry Litter Storage
1	Lower Mill Creek	6	0	0	8	100	1
2	North Mill Creek	1	1	0	3	50	0
3	North Mill Creek	0	1	0	4	100	0
4	North Mill Creek	0	0	0	1	50	0
5	North Mill Creek	7	0	0	4	200	0
6	South Mill Creek	14	0	0	2	100	0
7	South Mill Creek	3	0	0	0	40	1
8	South Mill Creek	7	0	0	2	100	0
	Totals	38	2	0	24	740	2

Table 4.1.4 Population Estimates of Farm and Wild Animals in Mill Creek Watershed.

Subbasin Number	Stream Name Location	Number Chickens Broilers	Number Chickens Breeders	Number Turkeys	Head Cattle	Number Migratory Ducks	Number Migratory Geese	Number Deer
1	Lower Mill Creek	168,000	0	0	100	3	6	280
2	North Mill Creek	28,000	9,000	0	50	4	7	315
3	North Mill Creek	0	9,000	0	100	2	5	369
4	North Mill Creek	0	0	0	50	2	5	206
5	North Mill Creek	196,000	0	0	200	5	11	204
6	South Mill Creek	392,000	0	0	100	5	9	454
7	South Mill Creek	84,000	0	0	40	5	11	460
8	South Mill Creek	196,000	0	0	100	3	6	260
	Totals	1,064,000	18,000	0	740	30	60	2,547

Onsite septic systems are the predominant form of waste water treatment in the Mill Creek watershed. No information was readily available on the specific locations of septic systems, septic tank densities, or failure rates. However, WVDEP provided estimates of the percent of the population for each county which used septic systems. For Hardy County, it was estimated that 80% of the population of 11,000 residents used septic systems. A septic system failure rate of about 2.5% was estimated for Hardy County (NSFC 1993) and it was assumed this rate was also applicable to the Mill Creek watershed. It was further assumed that 100% of the fecal coliform load from the failed systems reached the receiving waters at a concentration of $1x10^4$ cfu/100 mL for raw sewage (Metcalf & Eddy 1991). The assumed septic system waste flow rate was computed based on a typical value of 70 gallons per capita per day (Horsely & Whitten 1996).

As previously mentioned, the 1994-95 USGS monitoring data suggest that the source of bacterial contamination in Mill Creek is from animal sources based on the fecal coliform to fecal streptococci ratio of 0.8 at station USGS#19. For this study, it was assumed that manure from poultry operations was applied to agricultural land within the sub-watershed in which the poultry house was situated. In practice, poultry manure may be transported to or imported from other sub-watersheds; or it may be moved completely out of the Mill Creek watershed. No information was available as to the specific manure management practices. A list of sites for the land application of municipal and industrial sludge in the study area watershed was provided by WVDEP (Aug 5, 1997) and is the only site in the Mill Creek watershed is indicated in Table 4.1.5. Since the amount of sludge applied to the land areas is not known at this time, no attempt was made to incorporate these sites as a possible source of fecal coliform bacteria into the TMDL analysis.

Table 4.1.5 Land Application Site in Mill Creek Watershed

Generator	Type	Farm	Acres	Drainage Area/Location
A&S Septic	Septage	Alt	4	Hinkle Run of South Mill Creek near Dorcas
A&S Septic	Septage	Jeff Thorne	12	North Mill Creek, between 1st & 2nd bridge on N. Mill Creek Rd.
A&S Septic	Septage	Iman Farm**	3	North Mill Creek, between 1st & 2nd bridge on N. Mill Creek Rd.
Petersburg	Sludge	Bruce Hyre	60	Johnson Run near headwaters

** This farm has not been used as of Aug 4, 1997

Using the available information for poultry houses, head of cattle, and wildlife estimates, the daily fecal coliform loads were computed for each sub-watershed. The average fecal coliform loading rates for the various animal species used for the total potential load calculation were previously given in Table 2.1.6. The average number of birds for each type of poultry house was based on information obtained from WVDEP (1997) as follows: 15,000 Turkeys; 9,000 Breeders; and 28,000 Broilers. The total potential fecal coliform production per subwatershed for each of the animal categories is given in Table 4.1.6. Poultry makes up 86% of the potential nonpoint source fecal coliform load in the watershed followed by cattle with about 7% of the load. It is important to understand that the values in Table 4.1.6 are the "potential" fecal coliform loads from various nonpoint sources and not necessarily the loads which reach the receiving waters in the watershed (with the exception of the septic load which is the estimated load reaching the stream). Various attenuation processes and agricultural management practices will reduce these loads before they reach the stream.

Table 4.1.6 Potential Nonpoint Source Fecal Coliform Production in Mill Creek Watershed.

Subbasin Number	Stream Name Location	Total Load (cfu/day)	Poultry (cfu/day)	Cattle (cfu/day)	Ducks (cfu/day)	Geese (cfu/day)	Deer (cfu/day)	Septic (cfu/day)
1	Lower Mill Creek	4.132E+13	4.032E+13	5.400E+11	3.250E+10	2.895E+11	1.399E+11	4.544E+08
2	North Mill Creek	9.712E+12	8.880E+12	2.700E+11	4.079E+10	3.634E+11	1.573E+11	2.570E+08
3	North Mill Creek	3.145E+12	2.160E+12	5.400E+11	2.623E+10	2.337E+11	1.847E+11	6.359E+07
4	North Mill Creek	6.367E+11	0.000E+00	2.700E+11	2.661E+10	2.371E+11	1.030E+11	5.299E+07
5	North Mill Creek	4.881E+13	4.704E+13	1.080E+12	5.957E+10	5.307E+11	1.018E+11	3.497E+08
6	South Mill Creek	9.536E+13	9.408E+13	5.400E+11	5.190E+10	4.624E+11	2.271E+11	2.206E+08
7	South Mill Creek	2.119E+13	2.016E+13	2.160E+11	5.912E+10	5.267E+11	2.302E+11	1.186E+08
8	South Mill Creek	4.804E+13	4.704E+13	5.400E+11	3.327E+10	2.964E+11	1.299E+11	3.842E+07
	Totals	2.682E-14	2.597E-14	3.996E-12	3.300E-11	2.940E-12	1.274E-12	1.555E+09
	Percent of total	100.00%	96.82%	1.49%	0.12%	1.10%	0.47%	0.00%

4.1.4 Critical Conditions (Mill Creek)

For this study, an average hydrologic year was selected for the continuous simulation period. The period 1984 to 1992 was used as the initial screening period. The 1991 water year, from October 1990 through September 1991, was selected as the most representative of an average meteorologic year for the

Mill Creek watershed from within the screening period. There were no long-term flow gaging stations in the watershed which could be used to calibrate the hydrologic flows computed by the nonpoint source runoff model. The time-series of computed flows at the downstream-most reach of the watershed is shown in Figure 4.1.3.

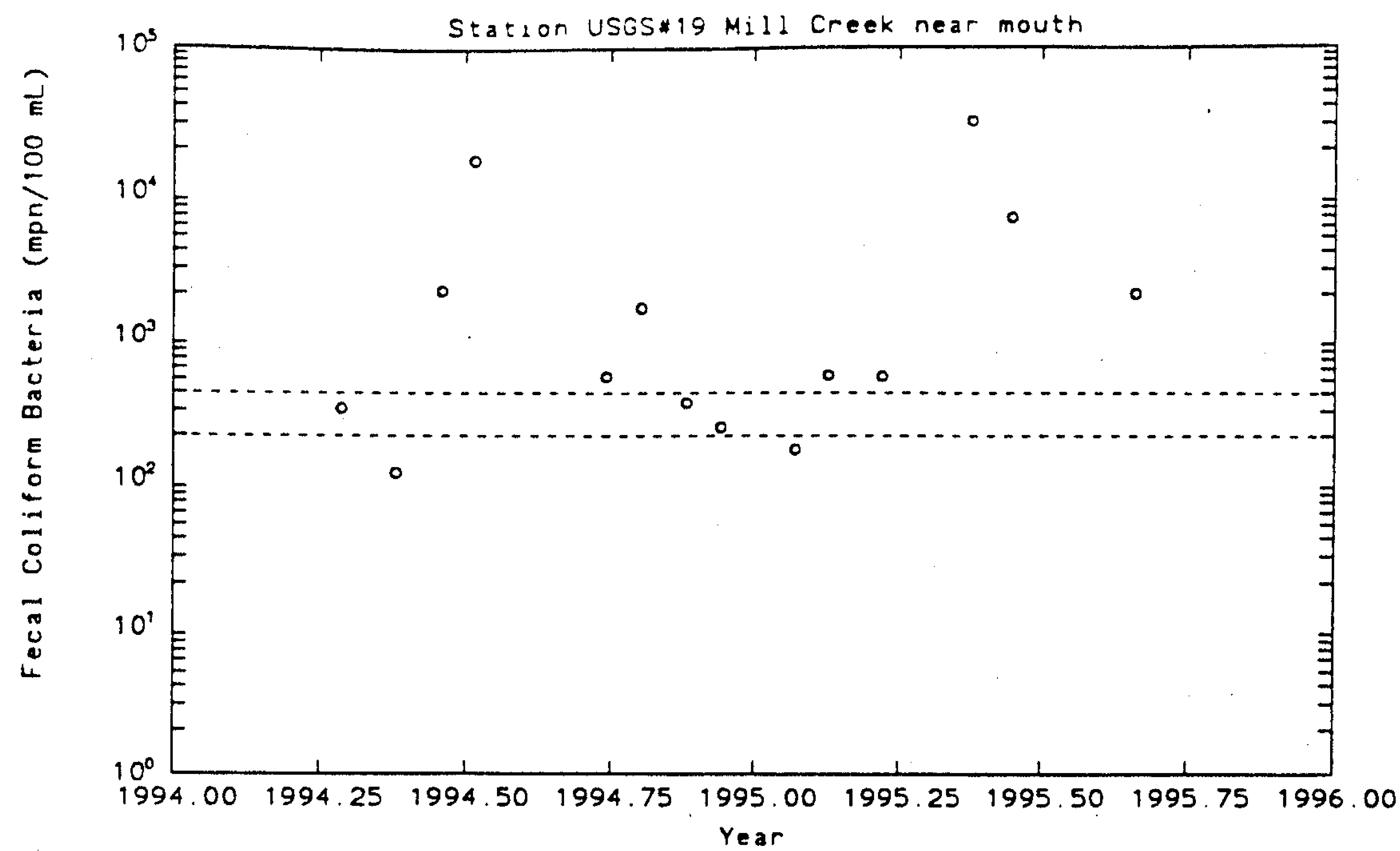


Figure 4.1.2 Time-series of fecal coliform bacteria for USGS station #19.

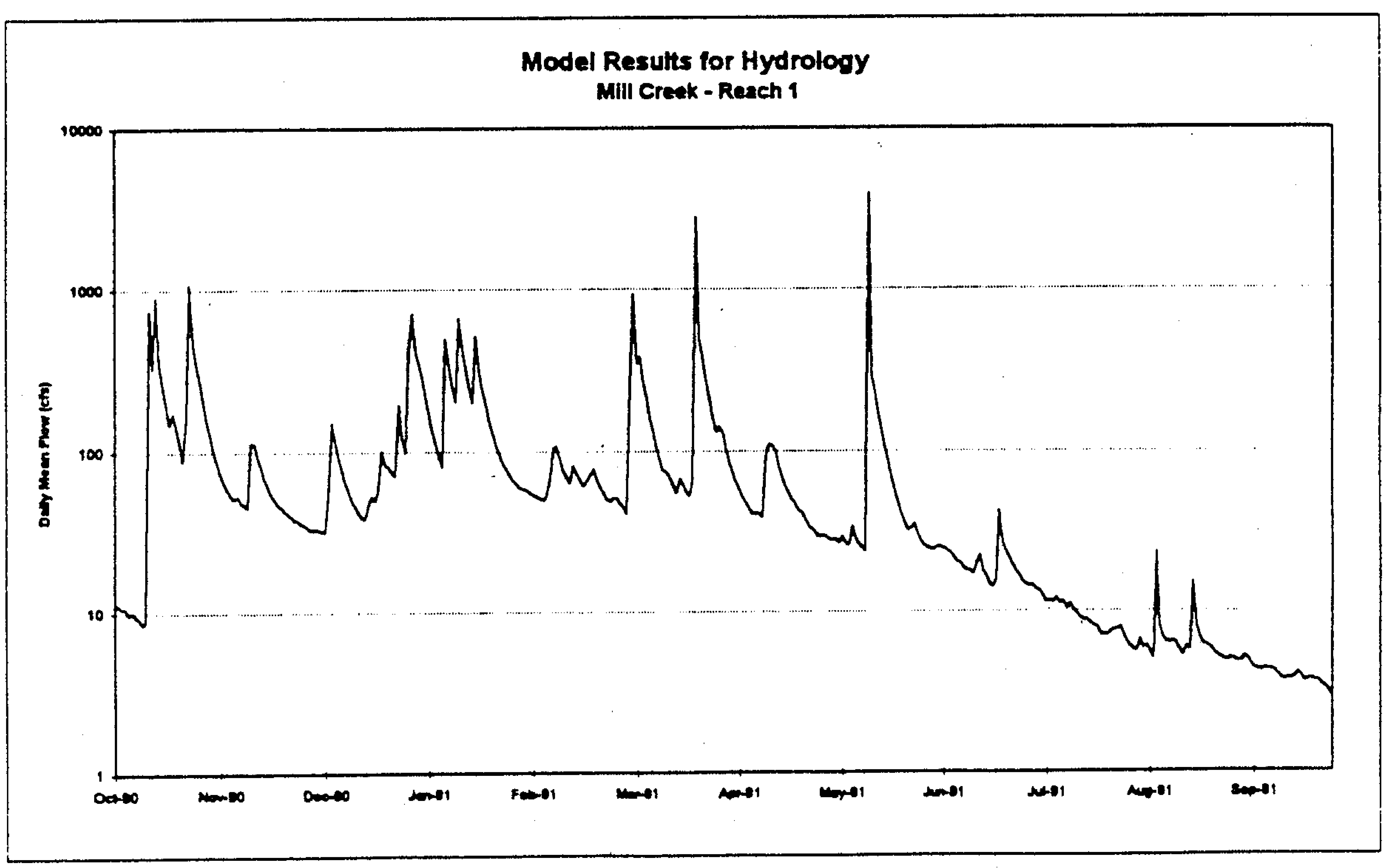


Figure 4.1.3 Model flow time series for 1990-91 hydrologic year at Mill Creek.

4.2 MODEL SET-UP (MILL CREEK)

Although the required percent reduction of fecal coliform bacteria loading for the Mill Creek watershed was known as a result of the South Branch allocation, it was necessary to perform a more in-depth analysis and modeling of the area. In modeling the large South Branch watershed, it was necessary to represent the Mill Creek watershed as a single watershed. After arriving at a target allocation value for Mill Creek, which meets the water quality standard in the South Branch Potomac River, it was necessary to further segment the watershed and arrive at a more refined loading reduction. To obtain a spatial variation of the concentration of bacteria along Mill Creek, the watershed was subdivided into 8 sub-watersheds. This allowed analysts to address the relative contribution of sources within each sub-watershed to the different segments of the river. The watershed subdivision was based on a number of factors, including the locations of flow monitoring stations, the locations of stream sampling stations, the locations of feedlots and poultry houses, and the reach network and land use coverage.

4.2.1 Source Representation (Mill Creek)

Both point and nonpoint sources were represented in the model. Septic system discharges for the Mill Creek watershed were the only point sources represented in the model, because no permitted point sources are located in the watershed. The three major nonpoint source categories that were addressed in this study were: forest land, agricultural land, and urban areas. To better represent these three categories, they were further divided into more refined land use types. This breakdown was based on additional information regarding the distribution of feedlots, poultry houses, and wildlife. A variety of parameters needed for predicting runoff and fecal coliform loadings were then estimated for each of the land uses within these 8 sub-watersheds.

Septic system discharges were quantified based on the following information: the population distribution within each of the 8 sub-watersheds based on 1990 Census Data (WVDEP 1996), an assumed average daily discharge of 70 gallons per person per day (Horsley & Whitten 1996), an assumed septic effluent concentration of 10^4 FC/100 ml of effluent (Horsley & Whitten 1996), and a 2.5% failure rate (NSFC 1993). The entire population outside the City of Petersburg, which contains a water treatment plant, was assumed to use septic systems.

The initial default values for the fecal coliform loading parameters needed for each land use were based on either general literature values or a variety of available site-specific information. Loading parameters for urban land uses were based on literature values (USEPA 1988).

Fecal coliform loading parameters for forest land uses were based on the wildlife population within the study area. As described in earlier sections, duck and geese populations for the watershed were readily available as was the deer population density (in Grant and Pendleton Counties). A specific loading rate was calculated for forested land in the Mill Creek watershed. The rate was based on fecal coliform contributions described earlier for various animal species (Metcalf and Eddy 1991).

A similar analysis was performed to estimate fecal coliform loading rates for agriculture landuses in each of the 8 subwatersheds. Information was available on the number and type of poultry houses and cattle in each subwatershed (WVSCA 1997 and PHIWQO 1986). Cattle densities and poultry densities (based on the type of poultry house) were determined for each subwatershed. Each agricultural land use in the 8 subwatersheds was assigned a different fecal coliform loading rate based on these densities and typical fecal coliform loading rates for the cattle and poultry species (Metcalf and Eddy 1991). All waste generated by poultry and cattle was assumed to be applied directly to the land surface within the agricultural land use of the respective watershed.

BMPs were not represented explicitly in the model. However, BMPs already in place during the representative period 10/1/1990 - 9/30/1991 are implicitly represented in the model. That is, calibration of the model for the representative period inherently requires consideration of everything present in the watershed (BMPs included).

4.2.2 Stream Characteristics (Mill Creek)

Channel geometies for the reaches in the Mill Creek model were determined from cross-section surveys performed by WVDEP during stream flow monitoring activities in June 1997 at several sampling locations.

4.2.3 Selection of Representative Modeling Period (Mill Creek)

The hydrologic conditions in the Mill Creek watershed consist of relatively random successions of dry, average, and wet rainfall years. Since it was determined that bacteria contamination in Mill Creek is critical during high flow conditions, the selection of a hydrologically representative time period was necessary. In addition, the amount of bacteria loading is most likely to increase in response to both the magnitude and intensity of storm events, which can occur in both dry and wet years. It should also be noted that frequent small storms or individual large storms can lead to excessive fecal coliform loading. To represent the hydrological regime, an average rainfall year was selected based on a review of annual rainfall. The period 1984 to 1992 was used as the initial screening period and the 1991 water year (October 1990 through September 1991) was selected as the most representative meteorologic year.

4.2.4 Model Calibration Process (Mill Creek)

To develop a representative linkage between the sources and the instream water quality response in the 8 reaches of Mill Creek, model parameters were adjusted to the extent possible for both hydrology and bacteria loading. Hydrologic parameters used in calibration of NPSM for the South Branch watershed, which contains Mill Creek, were applied to the Mill Creek watershed. Hydrologic parameters which were set for the model relate to surface water runoff, water balance, and groundwater flows. Some of these parameters represented groundwater storage, evapotranspiration, infiltration capacity of the soil, interflow inflow, and length of assumed overland flow. Based on the calibration, validation, and a verification of the model for the South Branch watershed, it was decided that the model was adequately representing hydrology of Mill Creek.

Parameters related to fecal coliform surface loading as well as background concentrations in the reaches were adjusted by comparing the modeled in-stream concentrations to available observed data. This process was limited by the absence of data for high flow and storm flow conditions. The loading rate and background concentration parameters for the forested land were set to values similar to those in the South Fork watershed. These values were adjusted based on the data for the Hawes Run drainage area (which consists of primarily undisturbed forest land). The loading parameters for urban runoff were primarily based on literature values and the background concentration values were adjusted to match the available background (i.e., low flow) data from the 1996 and 1997 DEP monitoring data. Background concentration parameters for the 8 different agricultural landuses were also adjusted to match available low flow data. Loading parameters for the agricultural land uses were adjusted until modeled water quality most closely matched the observed data. Parameter values were changed within a range of acceptable values, in a manner which retained consistency between relative contributions from the 8 different agricultural landuse categories.

4.2.5 Existing Loadings (Mill Creek)

The model was run for the hydrologically representative period (October 1990 through September 1991). The modeling run represents the existing condition of bacteria concentrations and loadings at various reaches of Mill Creek. For the existing conditions, the fecal coliform bacteria loading from the septic systems was 5.6773×10^{11} cfu/yr. The overall fecal coliform bacteria loadings by land-use category for Mill Creek watershed are given in Table 4.2.1.

Table 4.2.1 Annual Nonpoint Source Fe[illegible]liform Bacteria Loading Factors.

Land Use Category	Annual Fecal Coliform Loading
Agriculture and Pasture	1.4737×10^{15} cfu
Forest Land	4.3364×10^{13} cfu
Urban	1.6429×10^{12} cfu

A summary of West Virginia water quality standard violations for the selected hydrologically representative period is given in Table 4.2.2. All 8 reaches (consisting of the same numerical representation as the subwatersheds) and information relating to violation of the 200 cfu/100 mL geometric mean standard are presented. It is apparent from Table 4.2.2 that reaches in subwatersheds 1, 6, and 8 are in violation of the 200 cfu/100 mL standard. Appendix A also contains plots of the 30-day geometric mean for fecal coliform bacteria for each of the 8 reaches.

Table 4.2.2 Existing Conditions - Summary of Violations of 200 cfu/100 mL Standard.

Reach No. (Subwatershed)	No. of Exceedances	Max No. of Days in an Exceedance	Min No. of Days in an Exceedance	Total No. of Exceedance Days	Exceedance Percentage
1	2	4	2	6	1.64%
2	0	0	0	0	0.00%
3	0	0	0	0	0.00%
4	0	0	0	0	0.00%
5	0	0	0	0	0.00%
6	2	7	2	9	2.47%
7	0	0	0	0	0.00%
8	2	6	3	9	2.47%

4.3 ALLOCATION (MILL CREEK)

For the allocation runs, the model was run for the same hydrologically representative period (October 1990 through September 1991) as used for the existing conditions calibration run. From the South Branch watershed allocation, Mill Creek requires a 37% reduction in fecal coliform bacteria loading from the agricultural land, in order to meet the 200 cfu/100 mL state water quality standard in the South Branch Potomac River. The allocation run for Mill Creek must meet this requirement, however, the distribution of loading reductions among the sub-watersheds can potentially vary. The refined overall nonpoint source fecal coliform bacteria loadings by landuse category for the Mill Creek watershed are given in Table 4.3.1. An allocation of 37.7% was applied to all agriculture and pasture lands in the Mill Creek watershed for this phase of the TMDL. No reductions were applied to the urban and forest lands. Additionally, no reductions were applied to septic system discharges in the watershed. These nonpoint source load allocations reduce the instream concentrations of fecal coliform bacteria sufficiently for the representative year so that no violations of the 200 cfu/100 mL state water quality standards occur.

Table 4.3.1 Fecal Coliform Bacteria Nonpoint Source Allocations for Mill Creek Watershed..

Land Use	Annual Loading for Existing Run	Annual Loading for Allocation Run	Percent Reduction
Agriculture and Pasture	1.4737×10^{15} cfu	9.1869×10^{14} cfu	37.7%
Urban	1.6429×10^{12} cfu	1.6429×10^{12} cfu	0.0%
Forest	4.3364×10^{13} cfu	4.3364×10^{13} cfu	0.0%

5.0 NORTH FORK WATERSHED

This chapter describes the development of a fecal coliform bacteria TMDL for the North Fork South Branch Potomac River ("North Fork") watershed. The West Virginia 303(d) stream list indicates that 45.77 miles of North Fork is impacted by fecal coliform bacteria. The North Fork watershed was included as subwatershed #14 in the NPSM model of the South Branch (see Section 2.0). A more detailed model of the Mill Creek watershed is presented in this section in which the basin is divided into 7 subwatersheds.

5.1 SOURCE ASSESSMENT (NORTH FORK)

This section presents an overview of the instream water quality monitoring data available for North Fork and then discusses the type, magnitude, and location of potential point and nonpoint sources of fecal coliform loading.

5.1.1 Instream Water Quality Monitoring Data (North Fork)

Periodic monitoring for fecal coliform bacteria at a number of locations in the North Fork has been conducted over the years. Locations of the monitoring sites are shown in Figure 5.1.1 and the stations labeled USGS#1 through USGS#4 are from the special study conducted by the U.S. Geological Survey from March 1994 to August 1995 for the Potomac Headwaters study (PHIWQO 1996). The USGS stations were sampled approximately once per month throughout the study period. Time-series plots of the fecal coliform data for the USGS stations are shown in Figures 5.1.2 through 5.1.5. The data in these figures indicate that individual sample points are occasionally higher than the state water quality standards of 200 and 400 cfu/100 mL.

In support of the development of this fecal coliform bacteria TMDL analysis, the West Virginia Division of Environmental Protection (DEP) has begun a monitoring program in the North Fork watershed in which numerous sites are sampled during a single field excursion. As of the date of this report, three intensive sampling runs have been completed in August 1996, June 1997, and August 1997. The locations of the monitoring stations are shown in Figure 5.1.1. The June 1997 sampling date coincided with a high-flow event whereas the August 1996 and August 1997 dates occurred during low-flow periods.

The 1994-95 USGS reconnaissance survey provided the best long-term multi-year data set of fecal coliform bacteria for North Fork. West Virginia DEP used the results of the USGS survey to determine whether a stream segment should be added to the 303(d) list of water quality limited streams. Since the sample frequency was less than 5 per month, it was not possible to determine whether a stream segment was in compliance with the 200 cfu/100 mL State standard for fecal coliform bacteria. Instead, if more than 25% of the samples were greater than 200 cfu/100 mL, the stream segment was considered threatened and placed on the 303(d) list as needing a TMDL for fecal coliform bacteria. A summary of the USGS bacteria data for the monitoring stations on North Fork is given in Table 5.1.1. Data at stations USGS#2 and USGS#4 indicate greater than 25% of the samples were above the 200 cfu/100 mL level which is the reason North Fork was placed on the 303(d) list.

Table 5.1.1 Summary of Fecal Indicator Bacteria from 1994-95 USGS Study for North Fork.

		Fecal Coliform Bacteria (cfu/100 mL)					Fecal Streptococci	
Station	n	Min	Median	Max	percent greater than 200	percent greater than 400	Median (cfu/100 mL)	FC/FS median ratio
USGS$1	11	5	18	540	9.1	9.1	150	0.2
USGS#2	14	6	91	2,000	21.4	21.4	360	0.3
USGS#3	16	1	5	87	0.0	0.0	160	<0.1
USGS#4	11	2	56	550	27.2	9.1	255	0.3

Both fecal coliform (FC) and fecal streptococci (FS) were measured during the 1994-95 USGS survey. The ratio of fecal coliform to fecal streptococci can indicate possible sources of bacterial contamination. Each warm-blooded species has a unique bacteria ratio of fecal coliform to fecal streptococci in the intestinal tract. In humans, this ratio is generally greater than 4.0 whereas in animals the ratio is usually less than 0.7. Therefore, ratios greater than 4.0 in stream-water samples indicate that the source of bacterial contamination is likely human waste. Conversely, ratios of less than 0.7 indicate a bacterial source which is non-human. Intermediate ratios indicate mixed or undetermined sources of bacterial contamination (PHIWQO 1996). The USGS stations on the North fork have FC/FS ratios of 0.3 or less indicating the likely source of bacterial contamination is from animal waste (APHA, 1985).

5.1.2 Assessment of Point Sources (North Fork)

There are 4 permitted point source discharges in the South Branch watershed (see Figure 5.1.7 and Table 5.2.1 in the next section). Only two of the point source discharges are permitted for fecal coliform bacteria concentrations. These two point sources are very small discharges having flow rates of 3,000 gallons per day or less.

5.1.3 Assessment of Nonpoint Sources (North Fork)

The primary tributaries to North Fork are Seneca Creek, Big Run, and Laurel Fork. Inadequate long-term monitoring data were available to characterize the flow and bacteria loading from these peripheral tributaries. The watershed was divided into 7 subwatersheds based on tributary location, land use, poultry house and feedlot density, and the locations of bacteria monitoring stations.

The U.S. GeoData 1:250,000 scale land use and land cover data (U.S. GeoData 1986) were used to determine land uses in the North Fork watershed. The land uses consist primarily of forested, agricultural, and urban areas. The various land uses for each of the 7 sub-watersheds are listed in Table 5.1.2 and are shown in the color map for North Fork in Appendix A. The West Virginia Soil Conservation Agency (WVSCA) maintains a geographic information system (GIS) with the locations of poultry houses, feedlots, and other agricultural-related information. The delineations of the sub-watersheds for North Fork were provided to WVSCA and they in turn estimated the number of poultry houses and animal feedlots within each of the sub-watersheds. Estimates of total head of cattle in each sub-watershed were also provided by WVSCA (see Table 5.1.3).

The West Virginia Division of Natural Resources (DNR) provided estimates of the numbers of geese and ducks within the South Branch region typical of July 1 of any given year. The numbers of birds may vary with season because of migratory patterns as well as birds moving in and out of the watershed. The DNR estimated an upper bound of 90 for the migratory goose population and 50 for the migratory duck population in the Mill Creek watershed. In addition, deer population was estimated from the Big Game Bulletin (DNR 1996). The total deer population can be estimated as about 10 times the number of buck killed during hunting season. Animal population estimates for the North Fork watershed are given in Table 5.1.4.

Table 5.1.2 Land Use Distributions in the North Fork Subwatersheds

Subbasin Number	Stream Name Location	Total Area (acres)	Urban (acres)	Agricultural (acres)	Forest (acres)	Septic Population
1	South Branch to High Ridge Run	26,023	0	1,658	24,365	998
2	High Ridge Run to Seneca Creek	43,570	97	7,663	35,810	358
3	Seneca Creek	17,942	52	3,947	13,943	197
4	Seneca Creek to Dice Run	18,243	220	5,979	12,044	451
5	Dice Run to Harper Run	41,123	54	4,042	37,027	392
6	Harper Run to Laurel Fork	23,904	25	1,952	21,927	737
7	Laurel Fork and Straight Fork	28,043	246	3,870	23,927	200
	Totals	198,848	694	29,111	169,043	3,333

Table 5.1.3 Inventory of Poultry Houses and Cattle Feedlots in North Fork Watershed.

Subbasin	Stream Segment	Poultry Houses Broiler	Poultry Houses Breeder	Poultry Houses Turkey	Feedlots	Head Cattle	Poultry Litter Storage
1	South Branch to High Ridge Run	5	1	0	3	100	2
2	High Ridge Run to Seneca Creek	2	0	0	2	100	0
3	Seneca Creek	0	0	0	2	100	0
4	Seneca Creek to Dice Run	0	0	0	13	650	0
5	Dice Run to Harper Run	4	0	0	5	250	0
6	Harper Run to Laurel Fork	1	0	0	2	100	0
7	Laurel Fork and Straight Fork	0	0	0	0	0	0
	Totals	12	1	0	27	1,300	2

Table 5.1.4 Population Estimates of Farm and Wild Animals in North Fork Watershed.

Subbasin Number	Stream Segment	Number Chickens Broilers	Number Chickens Breeders	Number Turkeys	Head Cattle	Number Migratory Ducks	Number Migratory Geese	Number Deer
1	South Branch to High Ridge Run	140,000	9,000	0	100	7	12	1180
2	High Ridge Run to Seneca Creek	56,000	0	0	100	6	11	1734
3	Seneca Creek	0	0	0	100	11	19	675
4	Seneca Creek to Dice Run	0	0	0	650	4	8	583
5	Dice Run to Harper Run	112,000	0	0	250	4	8	1793
6	Harper Run to Laurel Fork	28,000	0	0	100	11	19	1062
7	Laurel Fork and Straight Fork	0	0	0	0	7	13	1159
	Totals	336,000	9,000	0	1,300	50	90	8,187

Onsite septic systems are the predominant form of waste water treatment in the North Fork watershed. No information was readily available on the specific locations of septic systems, septic tank densities, or failure rates. However, WVDEP provided estimates of the percent of the population for each county which used septic systems. For Hardy County, it was estimated that 80% of the population of 11,000 residents used septic systems. A septic system failure rate of about 2.5% was estimated for Hardy County (NSFC 1993) and it was assumed this rate was also applicable to the North Fork watershed. It was further assumed that 100% of the fecal coliform load from the failed systems reached the receiving waters at a concentration of $1x10^4$ cfu/100 mL for raw sewage (Metcalf & Eddy 1991). The assumed septic system waste flow rate was computed based on a typical value of 70 gallons per capita per day (Horsely & Whitten 1996).

As previously mentioned, the 1994-95 USGS monitoring data suggest that the source of bacterial contamination in North Fork is from animal sources based on the fecal coliform to fecal streptococci ratio of 0.3 or less at the USGS stations. For this study, it was assumed that manure from poultry operations was applied to agricultural land within the sub-watershed in which the poultry house was situated. In practice, poultry manure may be transported to or imported from other sub-watersheds; or it may be moved completely out of the North Fork watershed. No information was available as to the specific manure management practices. A list of sites for the land application of municipal and industrial sludge in the study area watershed was provided by WVDEP (Aug 5, 1997), however, there were no sites listed for the North Fork watershed.

Using the available information for poultry houses, head of cattle, and wildlife estimates, the daily fecal coliform loads were computed for each sub-watershed. The average fecal coliform loading rates for the various animal species used for the total potential load calculation were previously given in Table 2.1.6. The average number of birds for each type of poultry house was based on information obtained from WVDEP (1997) as follows: 15,000 Turkeys; 9,000 Breeders; and 28,000 Broilers. The total potential fecal coliform production per subwatershed for each of the animal categories is given in Table 5.1.5. Poultry makes up 86% of the potential nonpoint source fecal coliform load in the watershed followed by cattle with about 7% of the load. It is important to understand that the values in Table 5.1.5 are the "potential" fecal coliform loads from various nonpoint sources and not necessarily the loads which reach the receiving waters in the watershed (with the exception of the septic load which is the estimated load reaching the stream). Various attenuation processes and agricultural management practices will reduce these loads before they reach the stream.

Table 5.1.5 Potential Nonpoint Source Fecal Coliform Production in North Fork Watershed.

Subbasin Number	Stream Segment	Total Load (cfu/day)	Poultry (cfu/day)	Cattle (cfu/day)	Ducks (cfu/day)	Geese (cfu/day)	Deer (cfu/day)	Septic (cfu/day)
1	South Branch to High Ridge Run	3.757E+13	3.576E+13	5.400E+11	7.535E+10	6.042E+11	5.900E+11	6.611E+08
2	High Ridge Run to Seneca Creek	1.503E+13	1.344E+13	5.400E+11	6.434E+10	1.158E+11	8.671E+11	2.371E+08
3	Seneca Creek	1.210E+12	0.000E+00	5.400E+11	1.186E+11	2.135E+11	3.376E+11	1.305E+08
4	Seneca Creek to Dice Run	3.939E+12	0.000E+00	3.510E+12	4.881E+10	8.787E+10	2.916E+11	2.987E+08
5	Dice Run to Harper Run	2.926E+13	2.688E+13	1.350E+12	4.817E+10	8.670E+10	8.966E+11	2.597E+08
6	Harper Run to Laurel Fork	8.122E+12	6.720E+12	5.400E+11	1.181E+11	2.126E+11	5.310E+11	4.882E+08
7	Laurel Fork and Straight Fork	7.939E+11	0.000E+00	0.000E+00	7.656E+10	1.378E+11	5.794E+11	1.325E+08
	Totals	9.592E+13	8.280E+13	7.020E+12	5.500E+11	1.459E+12	4.093E+12	2.208E+09
	Percent of total	100.00%	86.32%	7.32%	0.57%	1.52%	4.27%	0.00%

5.1.4 Critical Conditions (North Fork)

For this study, an average hydrologic year was selected for the continuous simulation period. The period 1984 to 1992 was used as the initial screening period. The 1991 water year, from October 1990 through September 1991, was selected as the most representative of an average meteorologic year for the

North Fork watershed from within the screening period. There were no long-term flow gaging stations in the watershed which could be used to calibrate the hydrologic flows computed by the nonpoint source runoff model. The time-series of computed flows at the downstream-most reach of the watershed is shown in Figure 5.1.3.

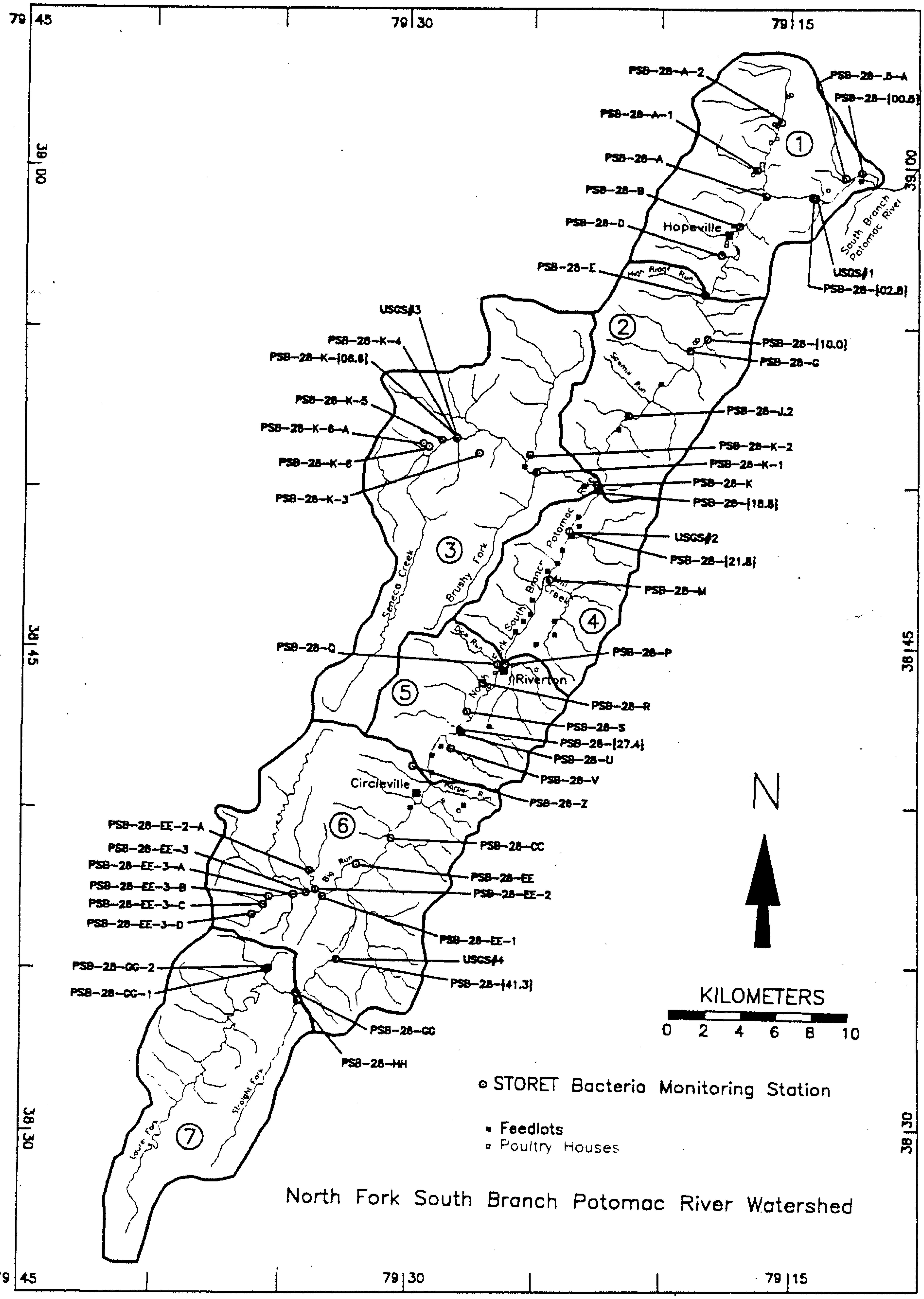


Figure 5.1.1 STORET bacteria monitoring stations in North Fork watershed.

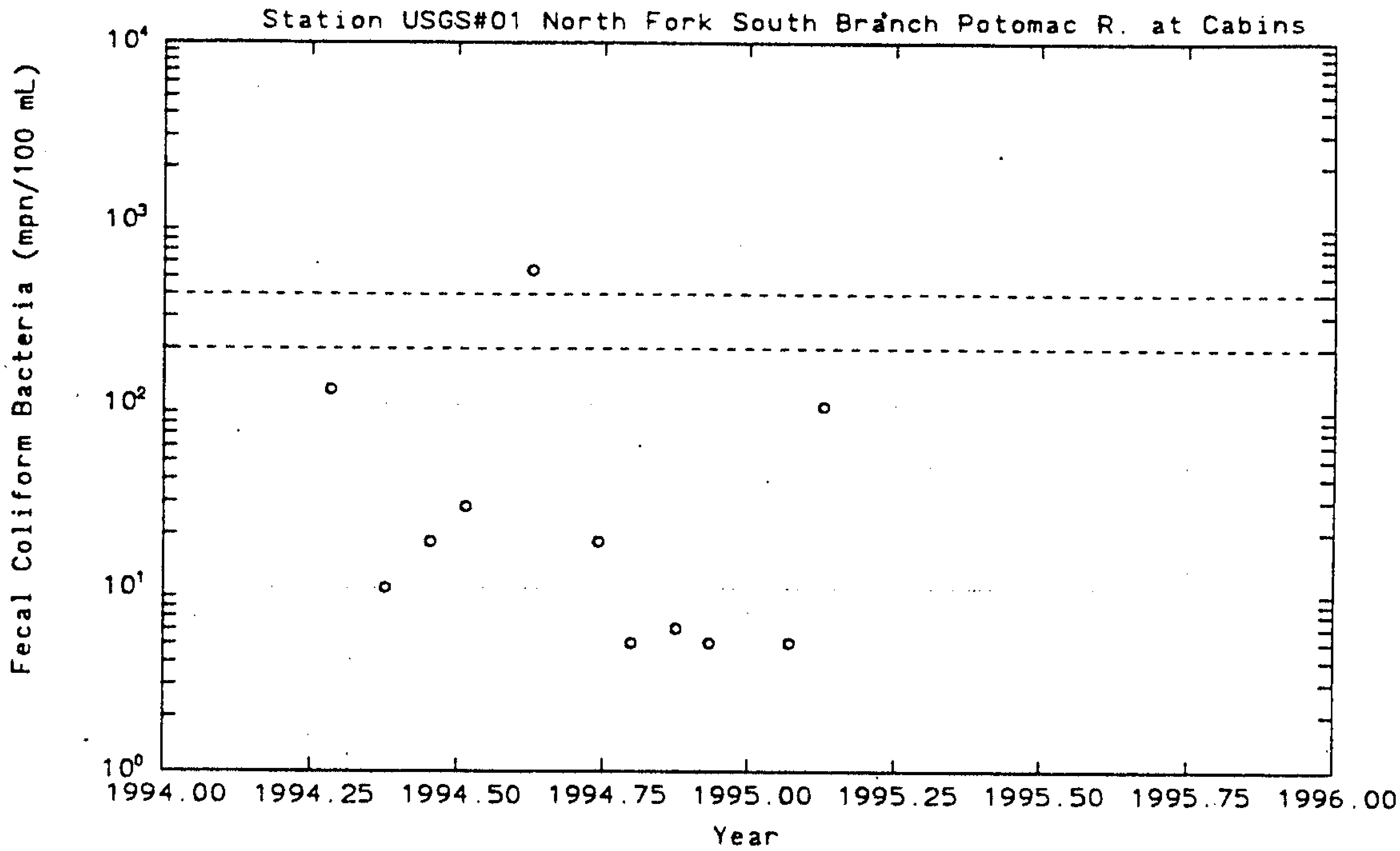


Figure 5.1.2 Time-series of fecal coliform bacteria for USGS station #1.

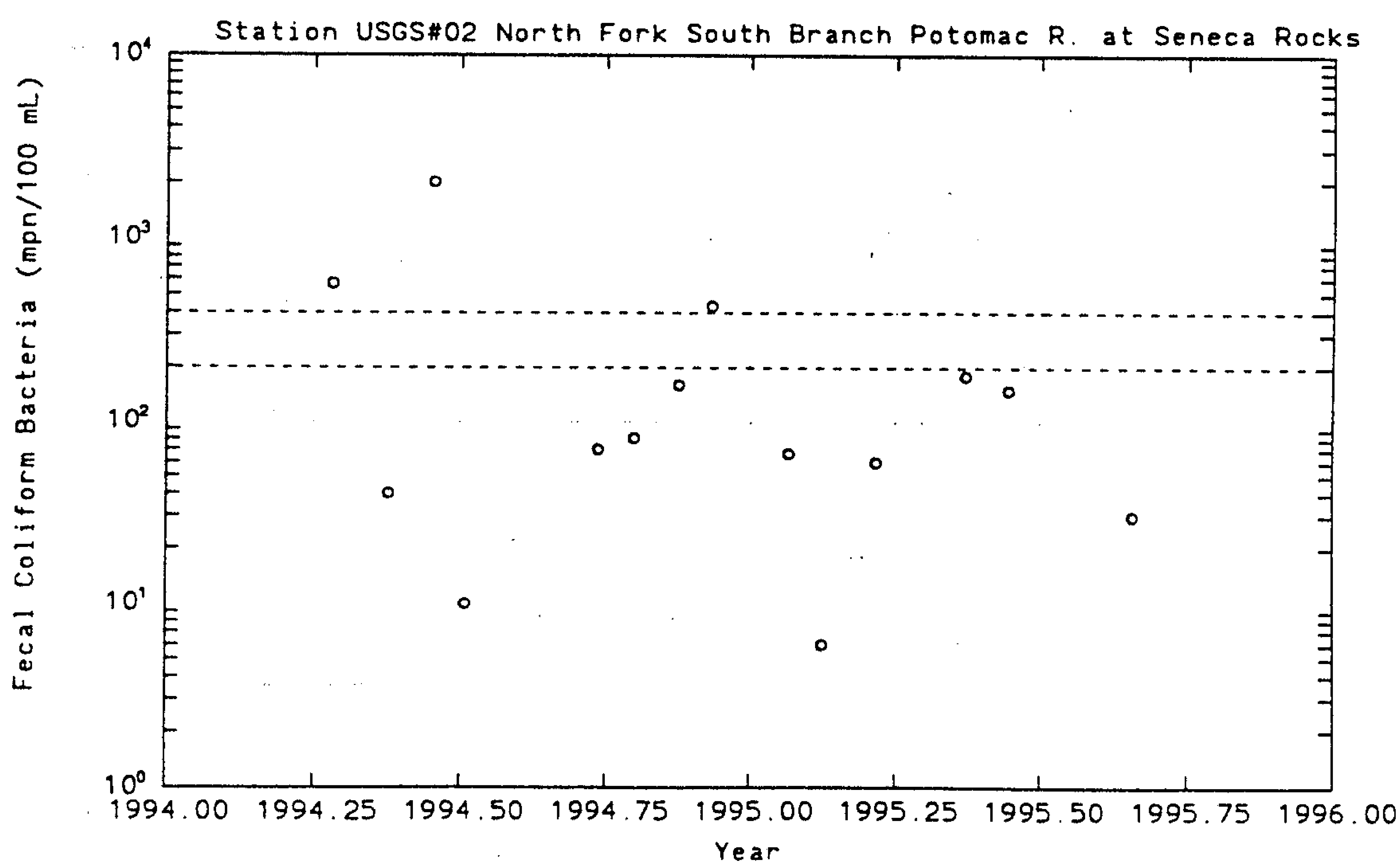


Figure 5.1.3 Time-series of fecal coliform bacteria for USGS station #2.

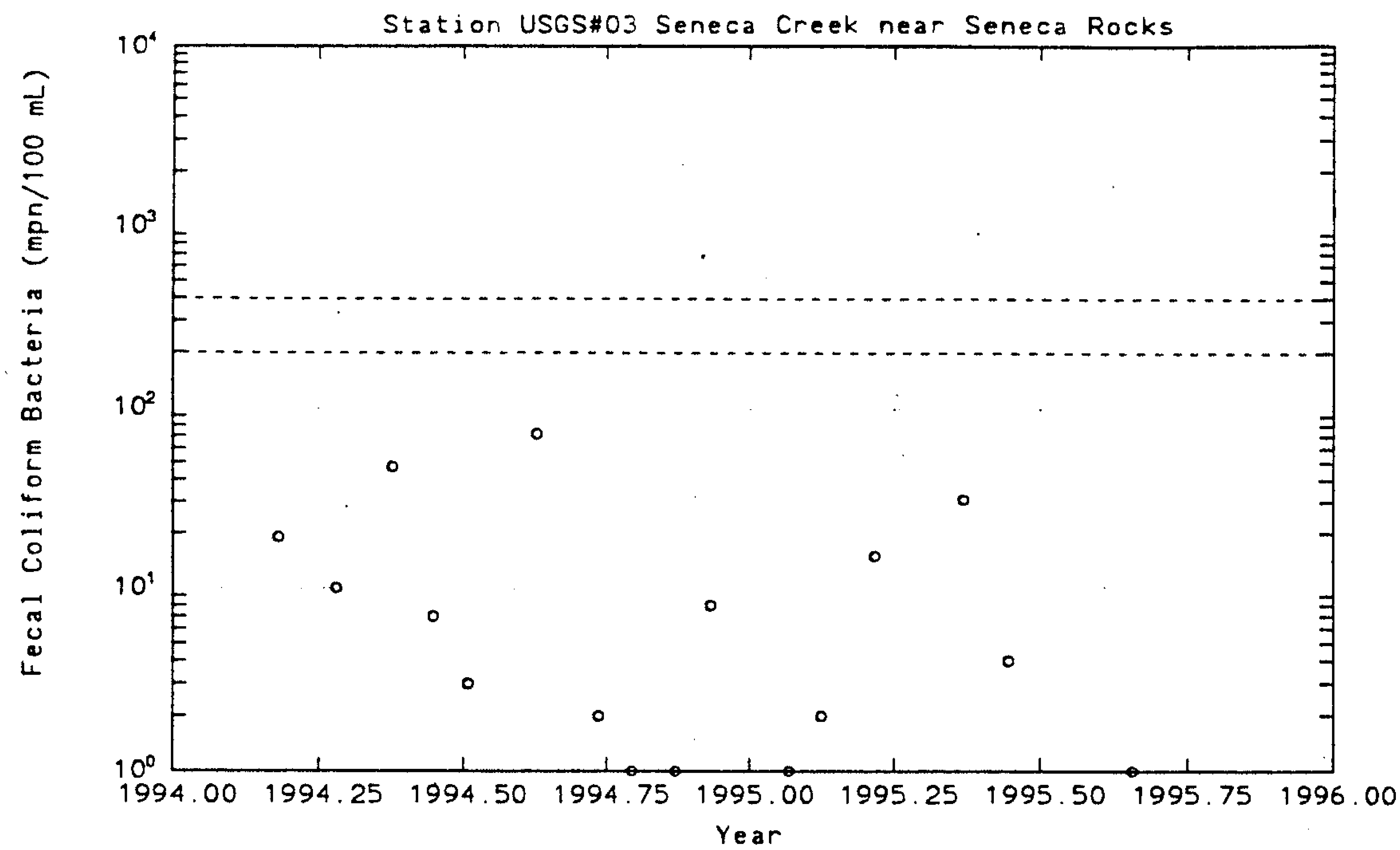


Figure 5.1.4 Time-series of fecal coliform bacteria for USGS station #3.

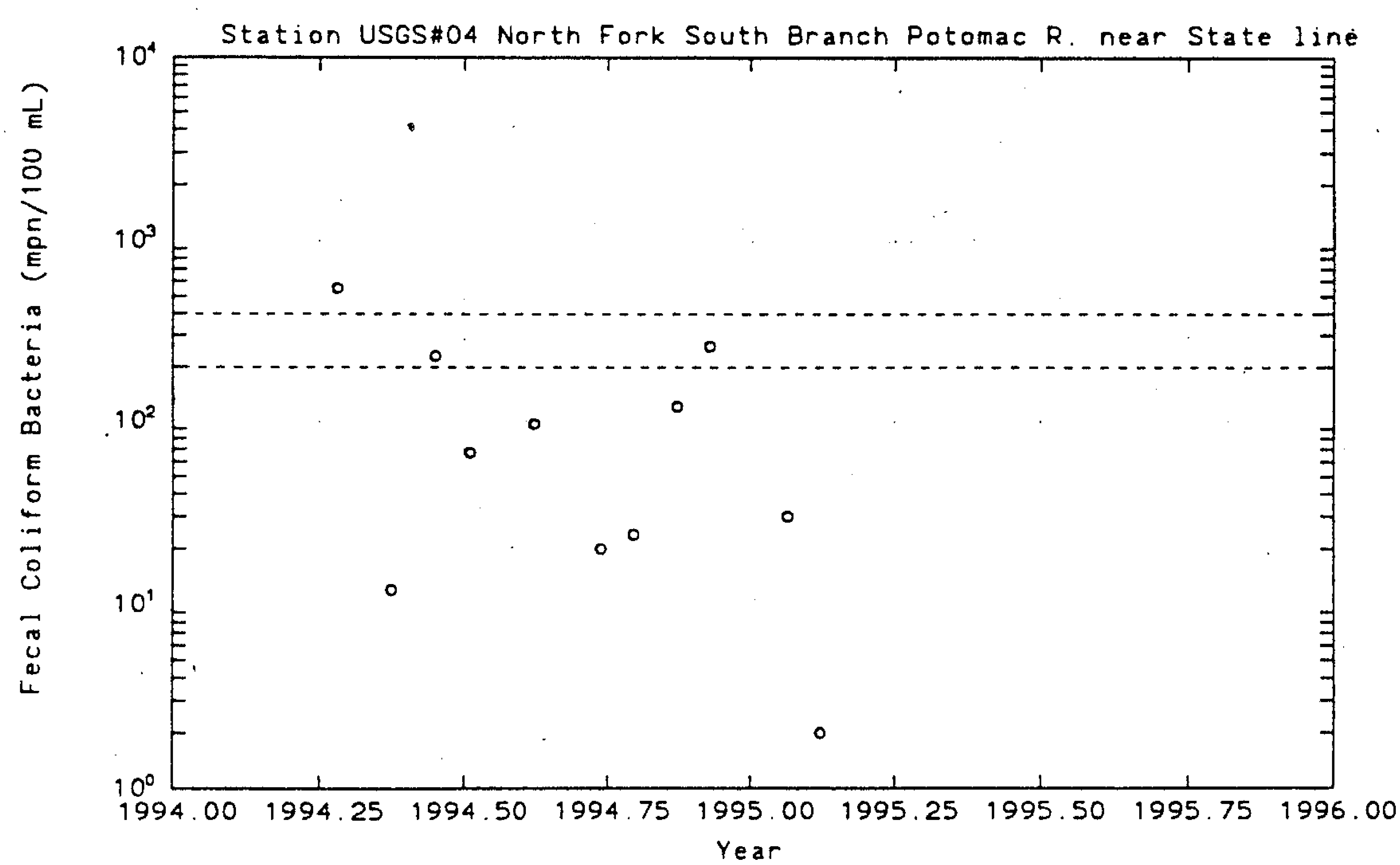


Figure 5.1.5 Time-series of fecal coliform bacteria for USGS station #4.

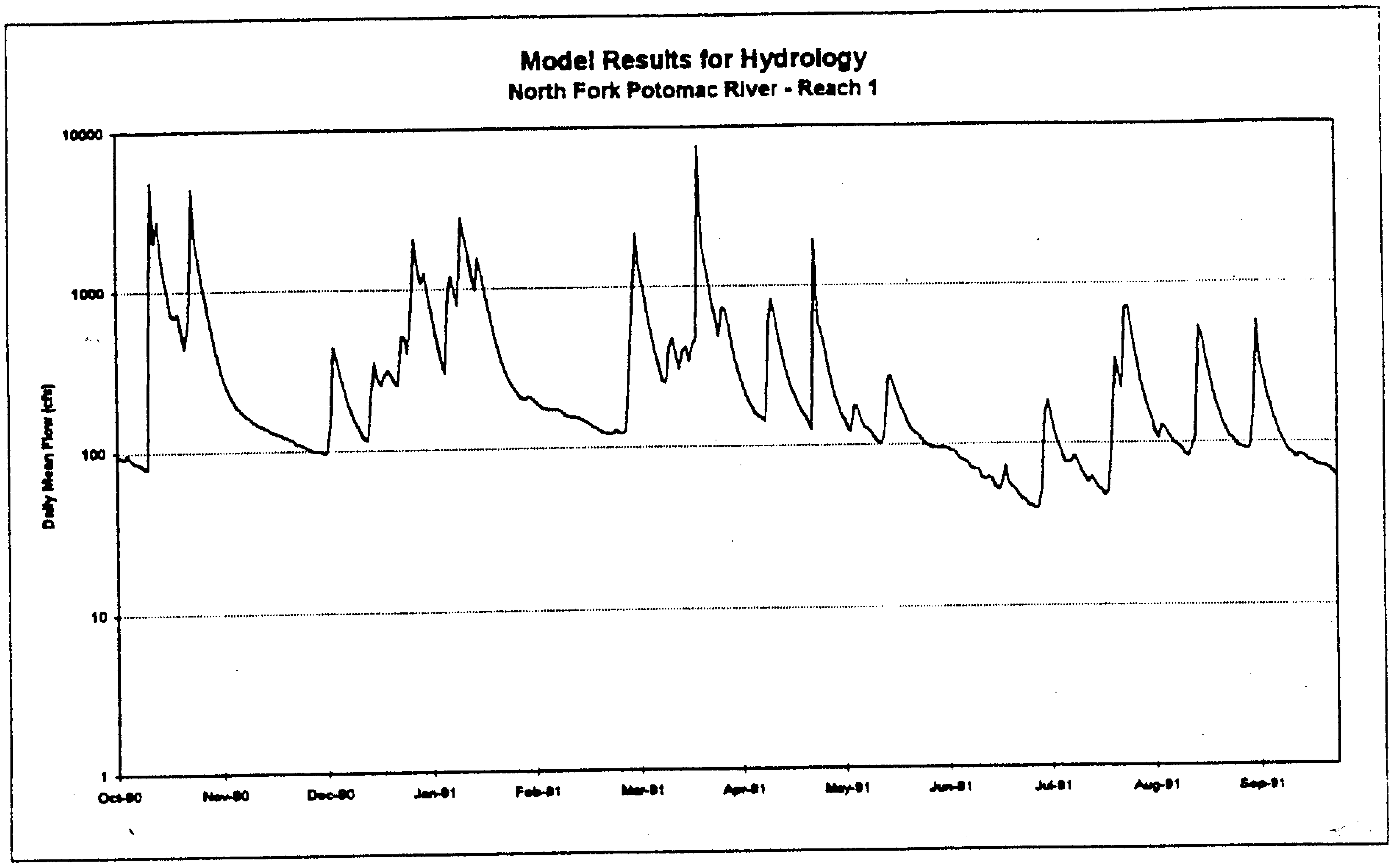


Figure 5.1.6 Model flow time series for 1990-91 hydrologic year for North Fork.

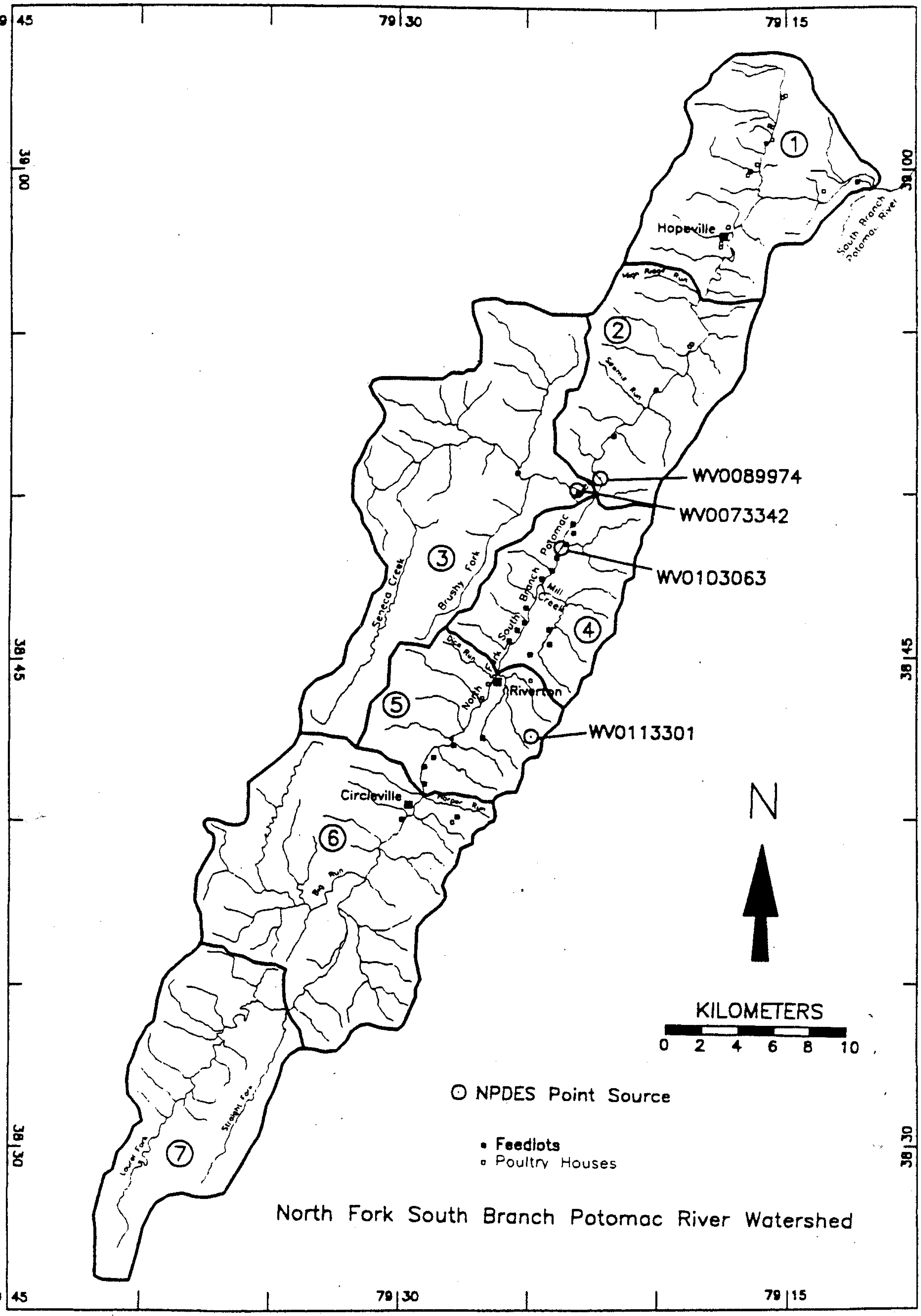


Figure 5.1.7 Locations of point source dischargers in the North Fork watershed.

5.2 MODEL SET-UP (NORTH FORK)

Although the required percent reduction of fecal coliform bacteria loading for the North Fork watershed was known as a result of the South Branch allocation, it was necessary to perform a more in-depth analysis and modeling of the area. In modeling the large South Branch watershed, it was necessary to represent the North Fork watershed as a single watershed. After arriving at a target allocation value for North Fork,which meets the water quality standards in the South Branch Potomac River, it was necessary to further segment the watershed and arrive at a more refined loading reduction. To obtain a spatial variation of the concentration of bacteria along the North Fork, the watershed was subdivided into 7 sub-watersheds. This allowed analysts to address the relative contribution of sources within each sub-watershed to the different segments of the river. The watershed subdivision was based on a number of factors, including the locations of flow monitoring stations, the locations of stream sampling stations, the locations of feedlots and poultry houses, and the reach network and land use coverage.

5.2.1 Source Representation (North Fork)

Both point and nonpoint sources were represented in the model. The point source dischargers that were used are shown in Table 5.2.1. Flow rates and fecal coliform concentrations were obtained from the EPA PCS database for major facilities. In the absence of flow rates and fecal coliform concentrations for minor sources, either typical values for facilities with similar SIC codes were used or facilities were excluded from the modeling. In the model, flow rates were based on average flow rates from facilities rather than permitted flows. Septic system discharges for the North Fork watershed were also represented as point sources in the model. The three major nonpoint source categories that were addressed in this study were: forest land, agricultural land, and urban areas. To better represent these three categories, they were further divided into more refined land use types. This breakdown was based on additional information regarding the distribution of feedlots, poultry houses, and wildlife. A variety of parameters needed for predicting runoff and fecal coliform loadings were then estimated for each of the land uses within these 7 sub-watersheds.

Table 5.2.1 Modeled values for municipal and industrial dischargers in the North Fork watershed

NPDES No.	Facility Name	SIC codes	Flow (gpd)	cfu/100 mL
WV0089974	Pendleton County Board of Education	8211	1,300	459
WV0103063	Woodedge Mobile Home Park	6515	3,000	357
WV0113301	Mountain State Fish Hatchery		NA	NA
WV0073342	Hinkle Trucking Car Wash		NA	NA

Septic system discharges were quantified based on the following information: the population distribution within each of the 7 sub-watersheds based on 1990 Census Data (WVDEP 1996), an assumed average daily discharge of 70 gallons per person per day (Horsley & Whitten 1996), an assumed septic effluent concentration of 10^4 FC/100 ml of effluent (Horsley & Whitten 1996), and a 2.5% failure rate (NSFC 1993). The entire population outside the Town of Franklin, which contains a water treatment plant, was assumed to use septic systems.

The initial default values for the fecal coliform loading parameters needed for each land use were based on either general literature values or a variety of available site-specific information. Loading parameters for urban land uses were based on literature values (USEPA 1988).

Fecal coliform loading parameters for forest land uses were based on the wildlife population within the study area. As described in earlier sections, duck and geese populations for the watershed were readily available as was the deer population density (in Grant and Pendleton Counties). A separate loading rate was calculated for forested landuses in Grant and Pendleton Counties for the North Fork watershed. These rates were based on fecal coliform contributions described earlier for various animal species (Metcalf and Eddy 1991).

A similar analysis was performed to estimate fecal coliform loading rates for agriculture landuses in each of the 7 subwatersheds. Information was available on the number and type of poultry houses and cattle in each subwatershed (WVSCA 1997 and PHIWQO 1986). Cattle densities and poultry densities (based on the type of poultry house) were determined for each subwatershed. Each agricultural land use in the 7 subwatersheds was assigned a different fecal coliform loading rate based on these densities and typical fecal coliform loading rates for the cattle and poultry species (Metcalf and Eddy 1991). All waste generated by poultry and cattle was assumed to be applied directly to the land surface within the agricultural land use of the respective watershed.

BMPs were not represented explicitly in the model. However, BMPs already in place during the representative period 10/1/1990 - 9/30/1991 are implicitly represented in the model. That is, calibration of the model for the representative period inherently requires consideration of everything present in the watershed (BMPs included).

5.2.2 Stream Characteristics (North Fork)

Channel geometries for the stream reaches in the North Fork model were determined from cross-section surveys performed by WVDEP during stream flow monitoring activities in June 1997 at several sampling locations.

5.2.3 Selection of Representative Modeling Period (North Fork)

The hydrologic conditions in the North Fork watershed consist of relatively random successions of dry, average, and wet rainfall years. Since it was determined that bacteria contamination in the North Fork is critical during high flow conditions, the selection of a hydrologically representative time period was necessary. In addition, the amount of bacteria loading is most likely to increase in response to both the magnitude and intensity of storm events, which can occur in both dry and wet years. It should also be noted that frequent small storms or individual large storms can lead to excessive fecal coliform loading. To represent the hydrological regime, an average rainfall year was selected based on a review of annual rainfall. The period 1984 to 1992 was used as the initial screening period and the 1991 water year (October 1990 through September 1991) was selected as the most representative meteorologic year.

5.2.4 Model Calibration Process (North Fork)

To develop a representative linkage between the sources and the instream water quality response in the 7 reaches of the North Fork South Branch, model parameters were adjusted to the extent possible for both hydrology and bacteria loading. Hydrologic parameters used in calibration of NPSM for the South Branch watershed, which contains the North Fork, were applied to the North Fork watershed. Hydrologic parameters which were set for the model relate to surface water runoff, water balance, and groundwater flows. Some of these parameters represented groundwater storage, evapotranspiration, infiltration capacity of the soil, interflow inflow, and length of assumed overland flow. Based on the calibration, validation, and a verification of the model for the South Branch watershed, it was decided that the model was adequately representing hydrology of the North Fork.

Parameters related to fecal coliform surface loading as well as background concentrations in the reaches were adjusted by comparing the modeled in-stream concentrations to available observed data. This process was limited by the absence of data for high flow and storm flow conditions. The loading rate and background concentration parameters for the forested land were set to values similar to those in the South Fork watershed. These values were adjusted based on the data for the Hawes Run drainage area (which consists of primarily undisturbed forest land). The loading parameters for urban runoff were primarily based on literature values and the background concentration values were adjusted to match the available background (i.e., low flow) data from the 1996 and 1997 DEP monitoring data. Background concentration parameters for the 7 different agricultural landuses were also adjusted to match available low flow data. Loading parameters for the agricultural land uses were adjusted until modeled water quality most closely matched the observed data. Parameter values were changed within a range of acceptable values, in a manner which retained consistency between relative contributions from the 7 different agricultural landuse categories.

5.2.5 Existing Loadings (North Fork)

The model was run for the hydrologically representative period (October 1990 through September 1991). The modeling run represents the existing condition of bacteria concentrations and loadings at various reaches of the North Fork. For the existing conditions, the overall fecal coliform bacteria loadings by land-use category for the North Fork watershed are given in Table 5.2.2. A summary of the existing point source loading estimates, including the septic system contribution, is given in Table 5.2.3.

Table 5.2.2 Annual Nonpoint Source Fecal Coliform Bacteria Loading Factors.

Land Use Category	Annual Fecal Coliform Loading
Agriculture and Pasture	3.2631×10^{15} cfu
Forest Land	1.2341×10^{14} cfu
Urban	1.7338×10^{13} cfu

Table 5.2.3 Existing Annual Fecal Coliform Bacteria Point Source Loads for the North Fork Watershed.

Point Source Facility Name	Annual Fecal Coliform Loading (cfu)	Flow Rate (cfs)	Effluent Concentration cfu/100 mL
Pendleton County Board of Education	8.2422×10^{9}	0.002	459
Woodedge Mobile Home Park	1.4598×10^{10}	0.005	357
Mountain State Fish Hatchery	NA	NA	NA
Hinkle Trucking Car Wash	NA	NA	NA
Failed Septic Systems	8.0589×10^{11}	0.009	10000

A summary of West Virginia water quality standard violations for the selected hydrologically representative period is given in Table 5.2.3. All 7 reaches (consisting of the same numerical representation as the subwatersheds) and information relating to violation of the 200 cfu/100 mL geometric mean standard are presented. It is apparent from Table 5.2.3 that only the reach in subwatershed 1 is in violation of the 200 cfu/100 mL standard. Appendix A also contains plots of the 30-day geometric mean for fecal coliform bacteria for each of the 7 reaches.

Table 5.2.4 Existing Conditions - Summary of Violations of 200 cfu/100 mL Standard.

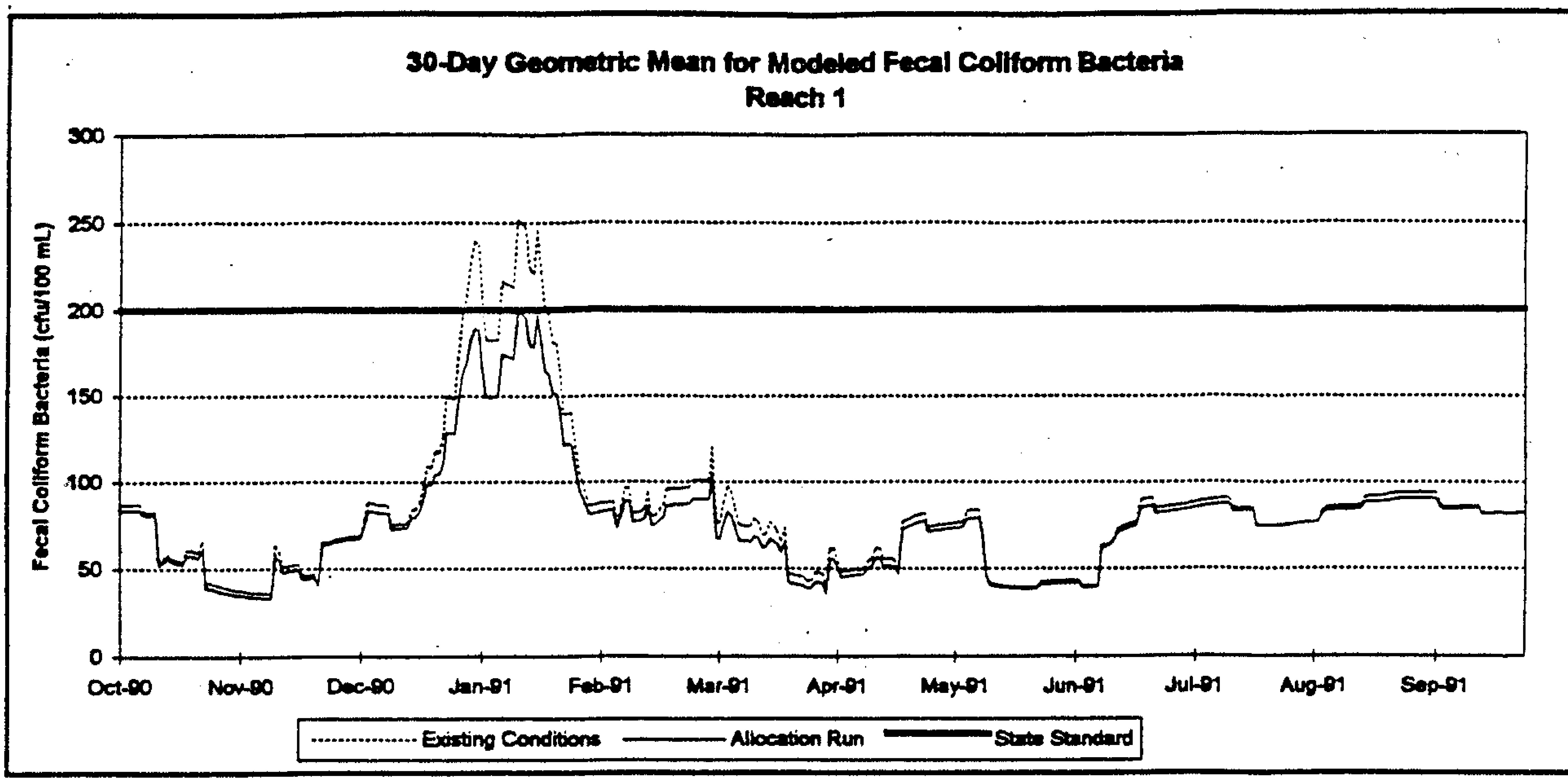
Reach No. (Subwatershed)	No. of Exceedances	Max No. of Days in an Exceedance	Min No. of Days in an Exceedance	Total No. of Exceedance Days	Exceedance Percentage
1	1	2	2	2	0.55%
2	0	0	0	0	0.00%
3	0	0	0	0	0.00%
4	0	0	0	0	0.00%
5	0	0	0	0	0.00%
6	0	0	0	0	0.00%
7	0	0	0	0	0.00%

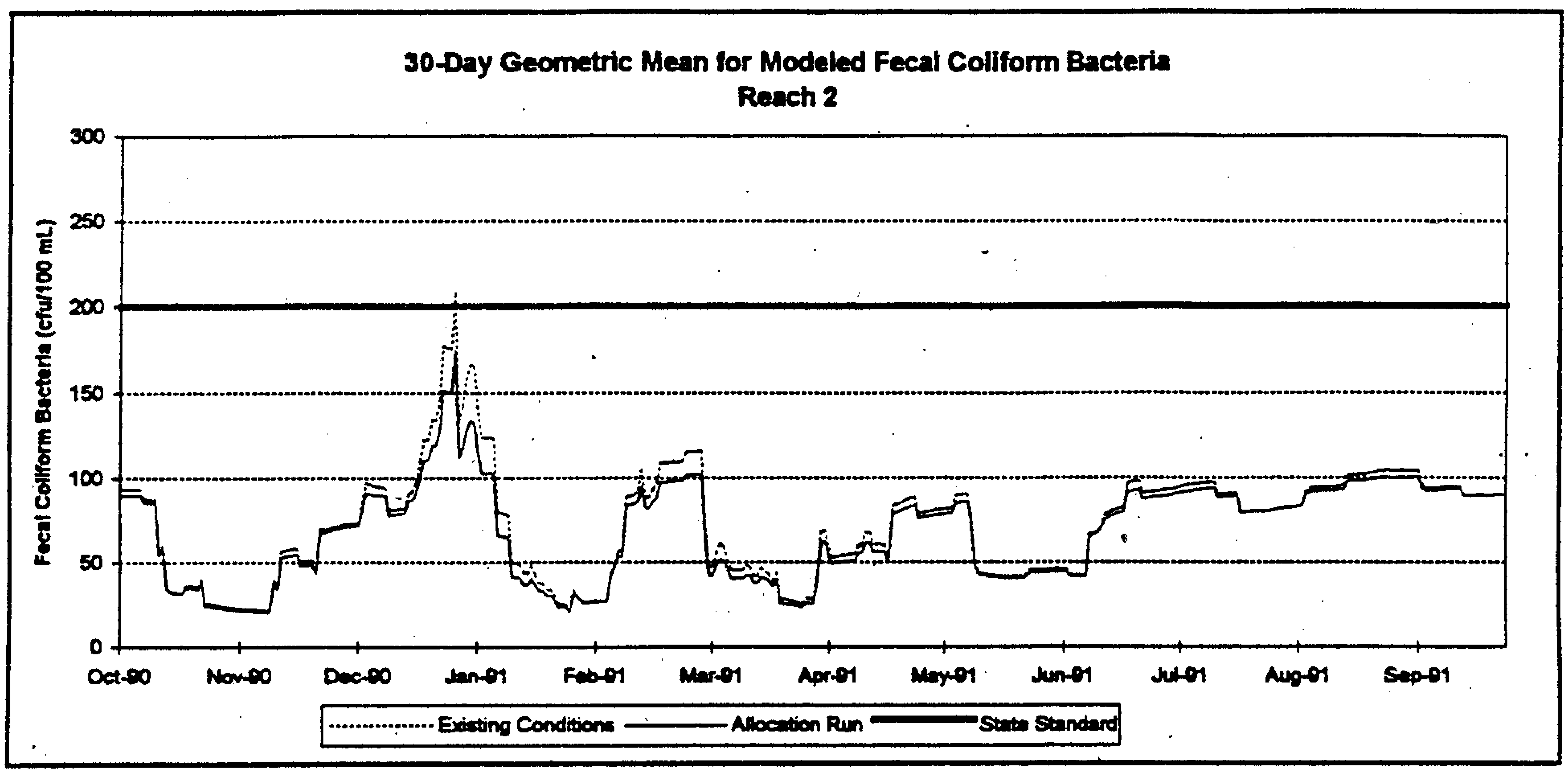
5.3 ALLOCATION (NORTH FORK)

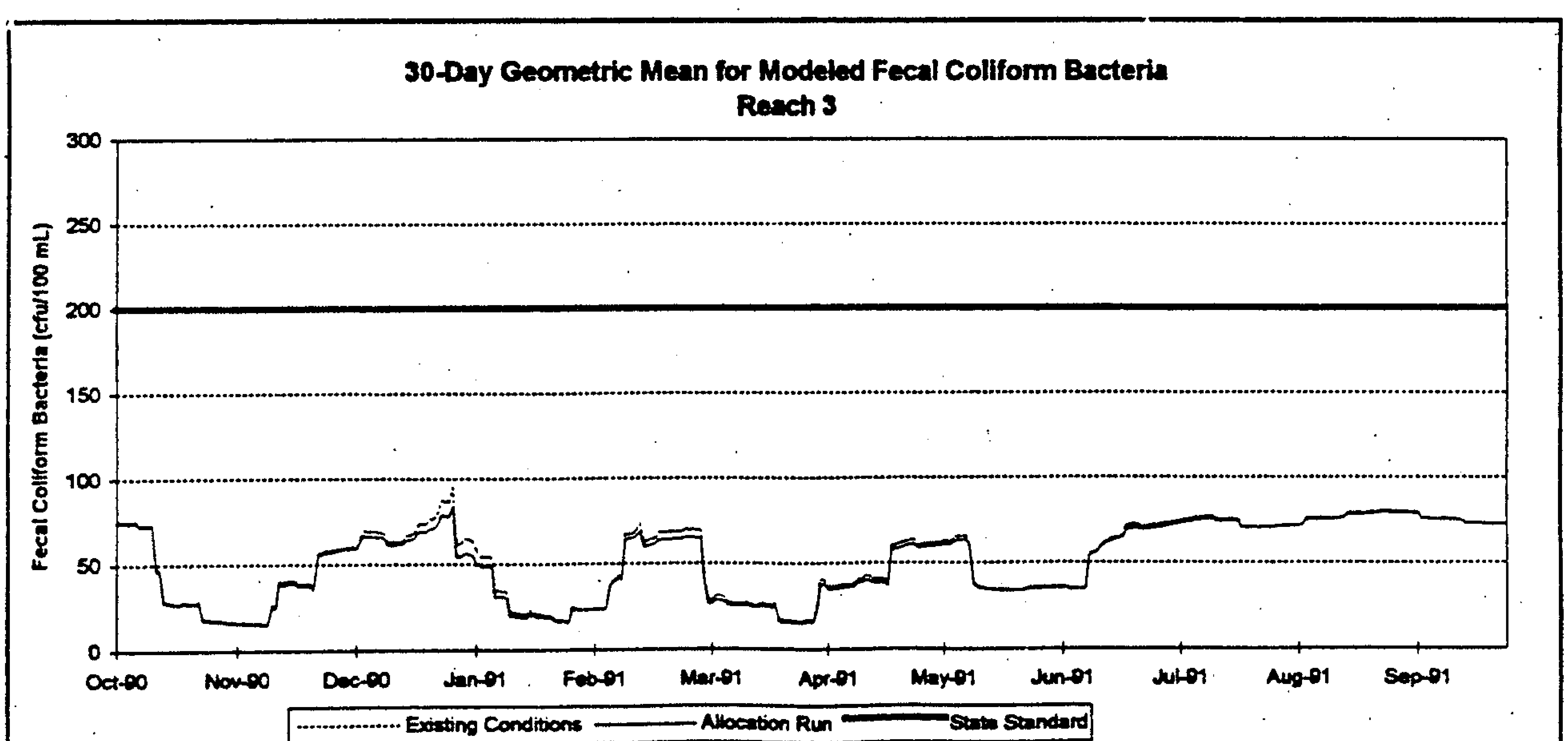
For the allocation runs, the model was run for the same hydrologically representative period (October 1990 through September 1991) as used for the existing conditions calibration run. From the South Branch watershed allocation, the North Fork requires a 35% reduction in fecal coliform bacteria loading from the agricultural land, in order to meet the 200 cfu/100 mL state water quality standard in the South Branch Potomac River. The allocation run for the North Fork must meet this requirement, however, the distribution of loading reductions among the sub-watersheds can potentially vary. The refined overall nonpoint source fecal coliform bacteria loadings by landuse category for the North Fork watershed are given in Table 5.3.1. An allocation of 36.1% was applied to all agriculture and pasture lands in the North Fork Watershed for this phase of the TMDL. No reductions were applied to the urban and forest lands. Additionally, no reductions were applied to septic system discharges or other point sources in the watershed. The nonpoint source load allocations reduce the instream concentrations of fecal coliform bacteria sufficiently for the representative year so that no violations of the 200 cfu/100 mL state water quality standards occur.

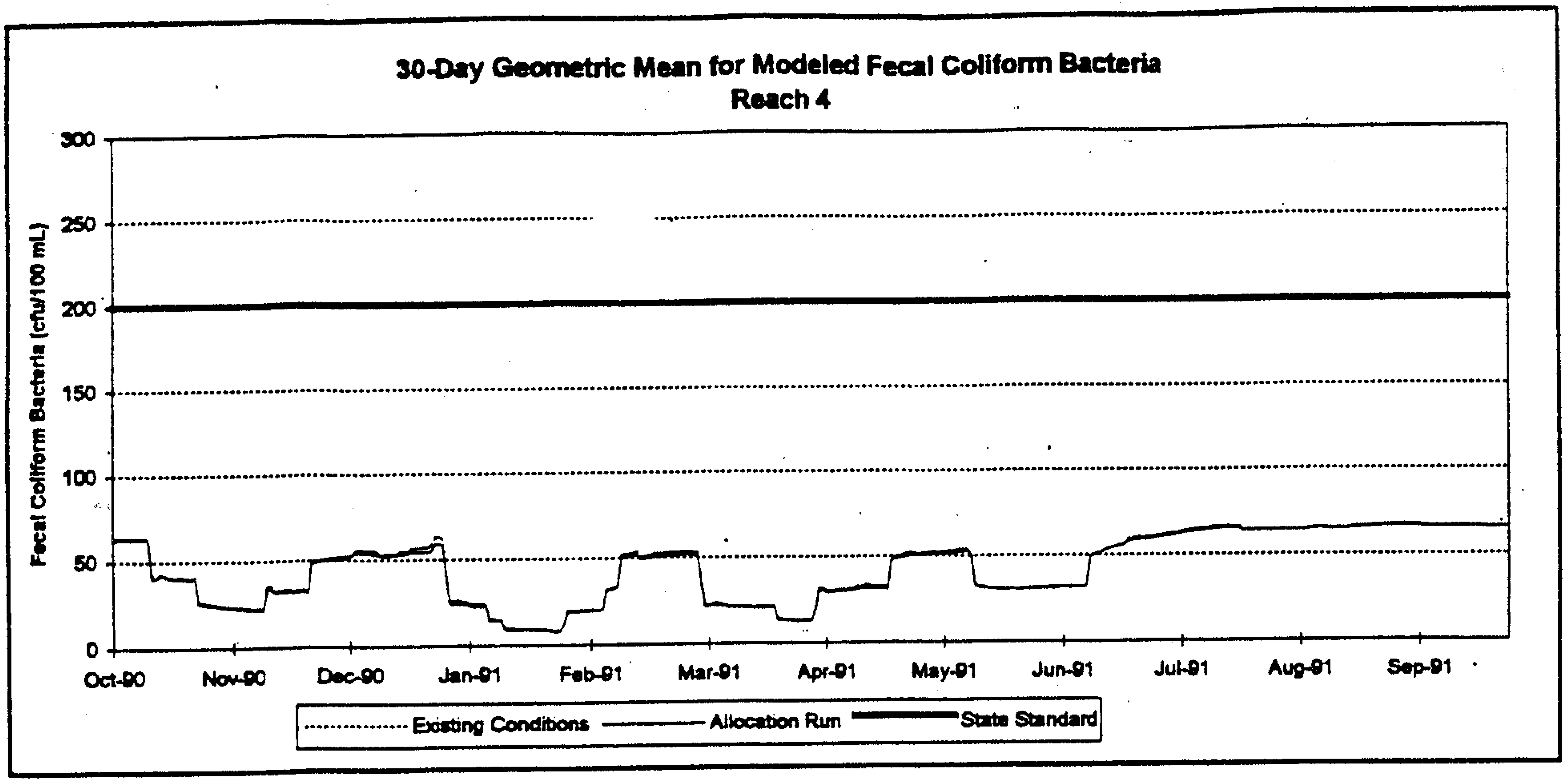
Table 5.3.1 Fecal Coliform Bacteria Nonpoint Source Allocations for the North Fork Watershed..

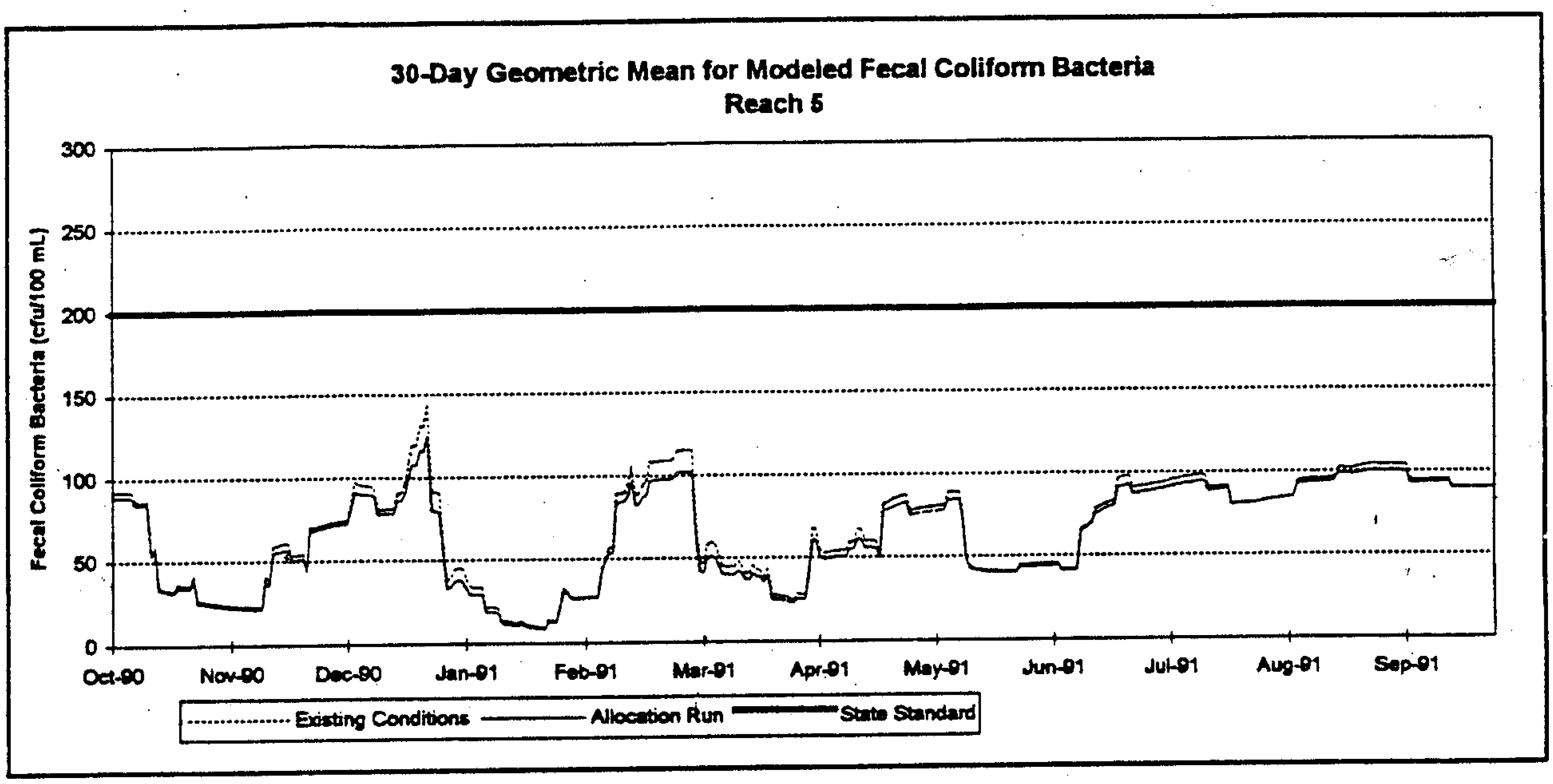
Land Use	Annual Loading for Existing Run	Annual Loading for Allocation Run	Percent Reduction
Agriculture and Pasture	3.2631×10^{15} cfu	2.0867×10^{15} cfu	36.1%
Urban	1.7338×10^{13} cfu	1.7338×10^{13} cfu	0.0%
Forest	1.2341×10^{14} cfu	1.2341×10^{14} cfu	0.0%

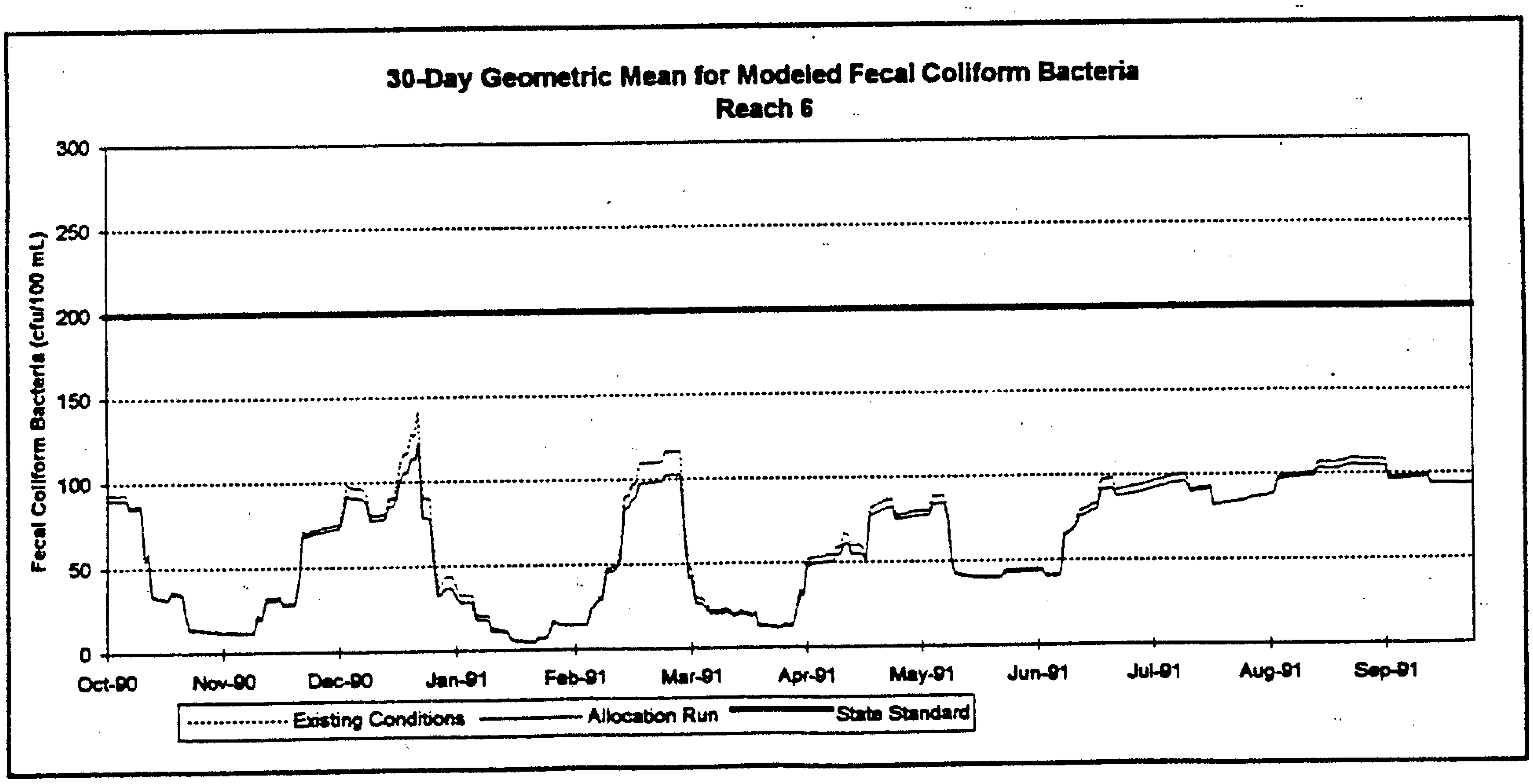

30-Day Geometric Mean for Modeled Fecal Coliform Bacteria
Reach 1
Fecal Coliform Bacteria (cfu/100 mL)
300
250
200
150
100
50
0
Oct-90
Nov-90
Dec-90
Jan-91
Feb-91
Mar-91
Apr-91
May-91
Jun-91
Jul-91
Aug-91
Sep-91
Existing Conditions
Allocation Run
State Standard


30-Day Geometric Mean for Modeled Fecal Coliform Bacteria
Reach 2
Fecal Coliform Bacteria (cfu/100 mL)
300
250
200
150
100
50
0
Oct-90
Nov-90
Dec-90
Jan-91
Feb-91
Mar-91
Apr-91
May-91
Jun-91
Jul-91
Aug-91
Sep-91
Existing Conditions
Allocation Run
State Standard


30-Day Geometric Mean for Modeled Fecal Coliform Bacteria
Reach 3
Fecal Coliform Bacteria (cfu/100 mL)
300
250
200
150
100
50
0
Oct-90
Nov-90
Dec-90
Jan-91
Feb-91
Mar-91
Apr-91
May-91
Jun-91
Jul-91
Aug-91
Sep-91
Existing Conditions
Allocation Run
State Standard


30-Day Geometric Mean for Modeled Fecal Coliform Bacteria
Reach 4
Fecal Coliform Bacteria (cfu/100 mL)
300
250
200
150
100
50
0
Oct-90
Nov-90
Dec-90
Jan-91
Feb-91
Mar-91
Apr-91
May-91
Jun-91
Jul-91
Aug-91
Sep-91
Existing Conditions
Allocation Run
State Standard


30-Day Geometric Mean for Modeled Fecal Coliform Bacteria
Reach 5
Fecal Coliform Bacteria (cfu/100 mL)
300
250
200
150
100
50
0
Oct-90
Nov-90
Dec-90
Jan-91
Feb-91
Mar-91
Apr-91
May-91
Jun-91
Jul-91
Aug-91
Sep-91
Existing Conditions
Allocation Run
State Standard


30-Day Geometric Mean for Modeled Fecal Coliform Bacteria
Reach 6
Fecal Coliform Bacteria (cfu/100 mL)
300
250
200
150
100
50
0
Oct-90
Nov-90
Dec-90
Jan-91
Feb-91
Mar-91
Apr-91
May-91
Jun-91
Jul-91
Aug-91
Sep-91
Existing Conditions
Allocation Run
State Standard

6.0 SUMMARY

Total Maximum Daily Load (TMDL) analyses have been performed for fecal coliform bacteria in four West Virginia stream segments on the 1996 303(d) list of water quality impaired waterbodies. The four listed stream segments are (1) South Branch Potomac River from Moorefield to Upper Tract, (2) Lunice Creek, (3) Mill Creek, and (4) North Fork South Branch Potomac River. The BASINS Nonpoint Source Model (NPSM) was selected as the modeling framework for performing the TMDL allocations. The South Branch TMDL allocation analysis was conducted using a nested watershed approach in which the allocations for the three confluent streams (i.e., Lunice Creek, Mill Creek, and North Fork) were included in the South Branch watershed model. Three additional NPSM models were also developed for a more detailed TMDL analysis of Lunice Creek, Mill Creek, and North Fork.

For these TMDL analyses, load allocations are calculated with margins of safety to meet water quality standards because of uncertainty in the available data or due to lack of certain key information. The uncertainty in the data used for this study is discussed later in this section along with recommendations for improving future TMDL analyses.

6.1 Findings

Output from NPSM indicated a number of violations of the 200 cfu/100 mL geometric mean standard in the various parts of the subject watersheds for the existing conditions covering a representative hydrologic year (Oct 1990 through Sep 1991). After applying the load allocations, the NPSM indicated that all sub-watersheds were in compliance with the fecal coliform bacteria standard of 200 cfu/100 mL geometric mean. The watershed modeling analysis indicates that water quality standards will be achieved if BMPs are implemented in the agriculture areas to reduce fecal coliform runoff by the amounts indicated in Table 6.1.1.

Table 6.1.1 TMDL Allocations for Watersheds in South Branch Potomac River above Moorefield.

Watershed	Reduction in Agriculture Fecal Coliform Loading Required to Meet Water Quality Standards
South Branch Potomac River	50.6%
Lunice Creek	40.6%
Mill Creek	37.7%
North Fork South Branch Potomac River	36.1%

These TMDL analyses are useful for making management decisions such as identifying certain subwatersheds for additional monitoring or for planning the implementation of pollution controls. The subwatersheds which should be targeted for pollution controls are listed in Table 6.1.2. This listing is based on the model results for exceedances of the 200 cfu/100 mL geometric mean standard under the existing conditions scenario.

Table 6.1.2 Candidate Subwatersheds for Fecal Coliform Bacteria Pollution Controls.

Watershed	Candidate Subwatersheds for Pollution Controls
South Branch Potomac River above Moorefield	1, 2, 3 (also 12, 13, 14)
Lunice Creek	1, 3, 4, 8
Mill Creek	1, 6, 8
North Fork South Branch Potomac River	1

6.2 Recommendations

This TMDL analysis was performed with very limited fecal coliform bacteria data for characterizing point and nonpoint sources as well as for characterizing instream water quality conditions. Because of the lack of high-frequency, long-term fecal coliform data sets, the water quality calibration of the NPSM watershed model should be considered to be a "qualitative" calibration only. As additional data become available, they can be incorporated into the model and/or used to determine whether implemented controls are having the intended effect on improving water quality. The remainder of this section is a discussion which includes the key areas of data uncertainty as well as recommendations for filling the data gaps for future TMDL analyses.

6.2.1 Hydrologic Flow Data

The South Branch main stem has two long-term USGS stream gaging stations which were used to calibrate the hydrologic flows from the NPSM watershed model. However, no long-term stream gages were available in Lunice Creek, Mill Creek, or North Fork, which lends uncertainty to flow estimates for these three watersheds. The implementation of a long-term (i.e., multi-season) gaging station in each of these watersheds will improve the certainty of the model results. Once data are obtained from the new gaging stations, a correlation factor can be established with other nearby long-term gages to assist with flow estimates.

6.2.2 Fecal Coliform Monitoring

In general, fecal coliform data in the receiving waters in the South Branch region are monitored infrequently. Shown in Figures 6.1-6.4 are composite time-history plots of the entire fecal coliform bacteria data base in STORET (1960-1997) for each of the four watersheds in this study. The only long-term monitoring study in the area was conducted by the USGS in 1994-95 which collected data once per month at 23 stations over an 18-month period. Since fecal coliform problems in the study area tend to coincide with storm runoff events, sampling at intervals of less than daily will almost certainly miss the highest concentrations since storms tend to be short-term events. The ideal fecal coliform data set would consist of weekly samples collected during dry-weather periods, and daily samples (or more frequent) during storm events. The cost of such an ambitious monitoring program may be prohibitive. In 1996, West Virginia DEP began a sampling program for fecal coliform bacteria in the South Branch area to support this TMDL development effort. It is recommended that sampling program be continued on at least a monthly basis during the spring-to-autumn seasons to develop a long-term data base which will be necessary to (1) provide additional data for future modeling efforts and (2) determine the "before-and-after" impacts of BMPs which are implemented in the study watersheds.

6.2.3 Point Sources

Flow rates and fecal coliform bacteria concentrations from point source discharges in the study area are generally well-documented and reported in EPA's PCS data system or are on file at WVDEP offices. In the model application, it was assumed that point source effluent discharged at a constant flow rate throughout the year. In practice, some industrial flows may be highly variable or intermittent which could impact fecal coliform levels estimated by the model during low-flow periods.

6.2.4 Septic System Information

The assumed failure rate of 2.5% for septic systems as well as the assumption of a fecal coliform concentration of 10^4 cfu/100 mL in the septic overcharge used in this TMDL analysis is a source of some uncertainty. A septic survey should be conducted in the study area to determine whether the assumed failure rate is valid. Failing septic systems which are in close proximity to surface waters have the potential to cause elevated fecal coliform levels especially during low-flow periods.

6.2.5 Agricultural Data

The estimated numbers of feedlots, poultry houses, and poultry litter storage units per subwatershed for Hardy County and Grant County were provided by the West Virginia Soil Conservation Agency and were very useful for developing these TMDLs for fecal coliform bacteria. However, no information was available for the subwatersheds located in Pendleton County. This information should be assembled and incorporated into the watershed models for future TMDL analyses. Also, the upper-most portions of the North Fork and South Branch watersheds lie in Virginia and no agricultural information was incorporated into the watershed models for those subwatersheds. Additional discussion on agriculture-related issues is given in section 6.2.8.

6.2.6 Wildlife Information

Estimates of duck, geese, and deer populations were provided by West Virginia DNR. An attempt was made to estimate the potential fecal coliform contribution from these wildlife species by using literature values of typical daily fecal coliform production based on animal species. No information in the literature was found for daily fecal coliform production by whitetail deer. A value of 0.5×10^9 cfu/day was assumed which is subject to uncertainty. Future TMDL analyses should attempt to refine this loading rate. In addition, it was assumed that all fecal matter produced by deer was deposited in the forested land areas only. In reality, deer are likely to also use agricultural areas for these purposes. Future TMDL analyses should consider performing model sensitivity analyses to determine the impacts of different scenarios of wildlife activity on water quality.

6.2.7 Rainfall Data and Representative Hydrologic Year

The representative hydrologic year used for these initial TMDLs was the 1990-91 water year. The hourly rainfall database available in BASINS for the this project covered the period 1973-1993. The next release of BASINS will include more recent rainfall data through at least 1996. Future modeling should use more recent rainfall records corresponding to a representative hydrologic year which includes the best available concurrent fecal coliform water quality data set (i.e., 1994-97). This will help to improve certainty in the model water quality calibration. Two rain gages, situated at Moorefield and Franklin, were used for the watershed runoff modeling. The use of multiple rain gages helps to improve the flow estimates for localized rain storms. The rain gages were distributed among the various watersheds in the NPSM watershed model as indicated in Table 6.2.1.

Table 6.2.1 Watershed and Rain Gage Cross-Reference.

Watershed	Subwatershed Numbers	Rain Gage Station
South Branch	1-5, 12, 13 6-11, 14	Moorefield Franklin
North Fork	1-7	Franklin
Lunice Creek	1-9	Moorefield
Mill Creek	1-8	Moorefield

6.2.8 General Discussion on Data Needs

This section discusses the types of data that would be useful to support more accurate characterization of source loading for agricultural areas for refinement of the pathogen (bacteria) TMDLs for the South Branch basin. The desired data is organized in two levels to represent the range from simplified (Level I) to more detailed (Level II) TMDL analyses.

Level I data allows for estimates of local and animal concentration but management options cannot be examined in detail. Level II data would provide information needed to evaluate the land area available for disposal of manure, the practices used, the resulting loads, and possible management options. Some of the Level I data were provided by WVSCA for this study for this study (i.e., number of feedlots and poultry houses, head of cattle, litter storage facilities, and county soil survey reports).

Level I Data:

- Location and types of animal facilities (chicken, turkey, cattle feed lots, hogs, etc.)
- Proximity of facilities to stream (i.e., within 1000 ft)
- Number of livestock units (e.g., head of cattle, number of chickens per poultry house, etc.)
- Use of waste storage facilities
- Presence of other waste-management BMPs (such as flow diversions, buffer strips)
- Number of clean-outs per year
- Soil characteristics (hydrologic soil group)
- Long-term daily stream flow measurements at least one location within the watershed for the purpose of calibrating the model hydrologic flows.

Level II Data:

- More detailed information in GIS format on land use, land cover, soils, and topography (land use coverage with crop type/rotation and soil type or hydrologic soil group and land slopes)
- Identification of land areas used for manure disposal
- Practices used in spreading manure and schedules
- Land areas with and without nutrient management programs
- Supplemental information on manure characteristics (bacteria counts)
- Mortality rate and disposal techniques for dead birds

A long-term study recommendation would be for sampling of fecal coliform, fecal streptococci, and enterococci bacteria at demonstration sites both with and without BMPs or before and after BMPs have been implemented. This is necessary to determine the effectiveness of BMPs implemented under the TMDL for pathogen control. Sampling should be performed during low-flow as well as storm periods.

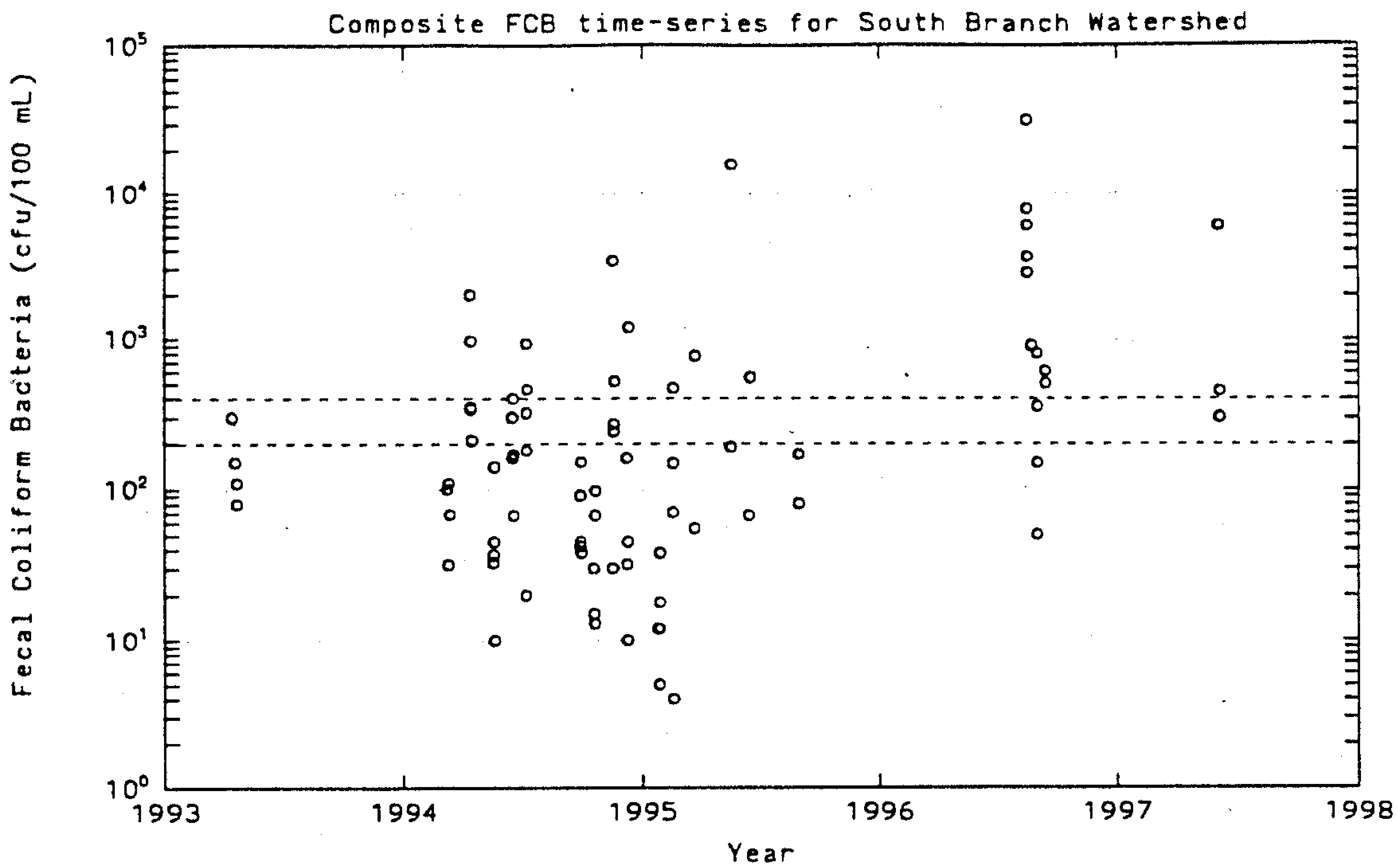


Figure 6.1 Composite time-series of fecal coliform data for all stations in South Branch watershed.

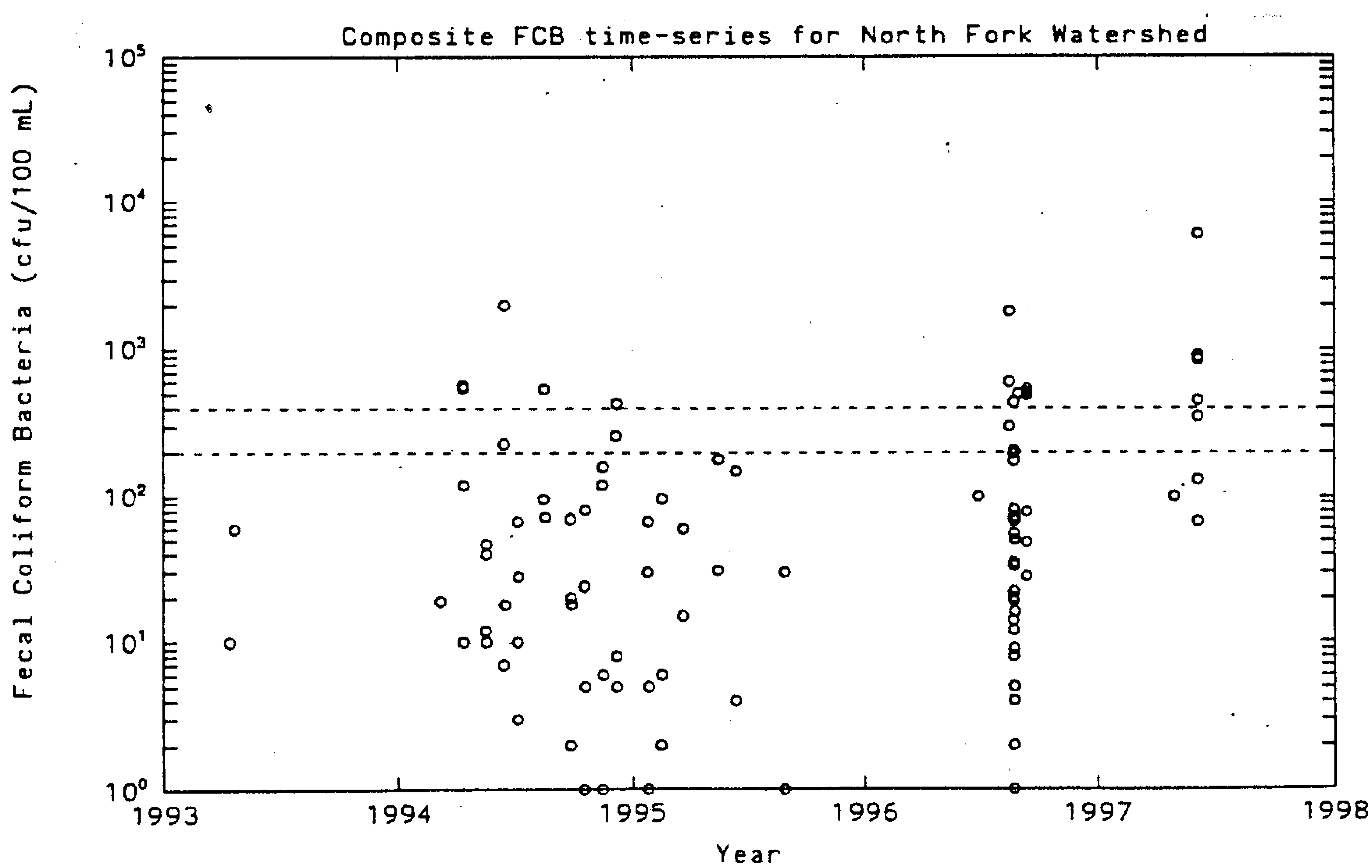


Figure 6.2 Composite time-series of fecal coliform data for all stations in North Fork watershed.

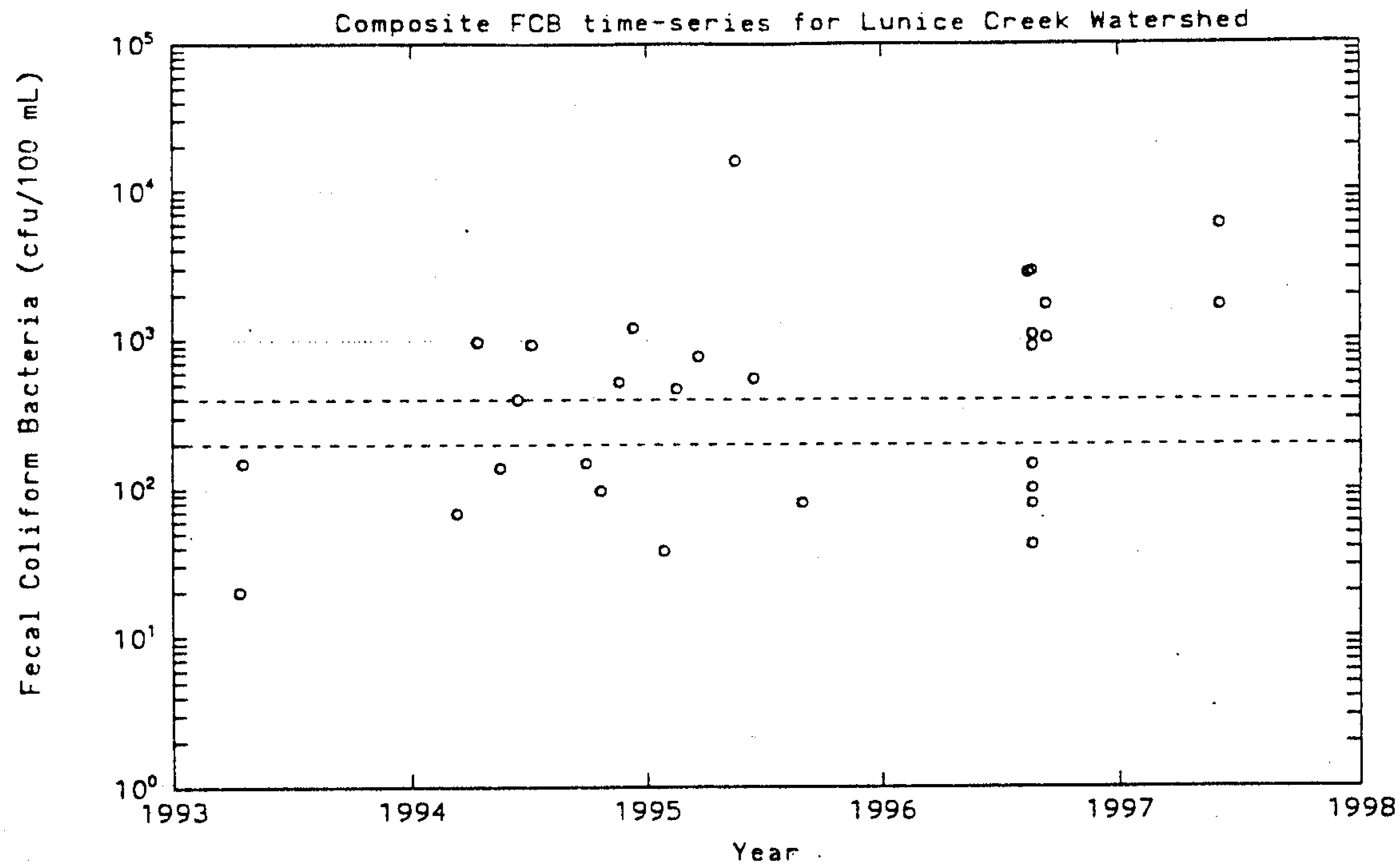


Figure 6.3 Composite time-series of fecal coliform data for all stations in Lunice Creek watershed.

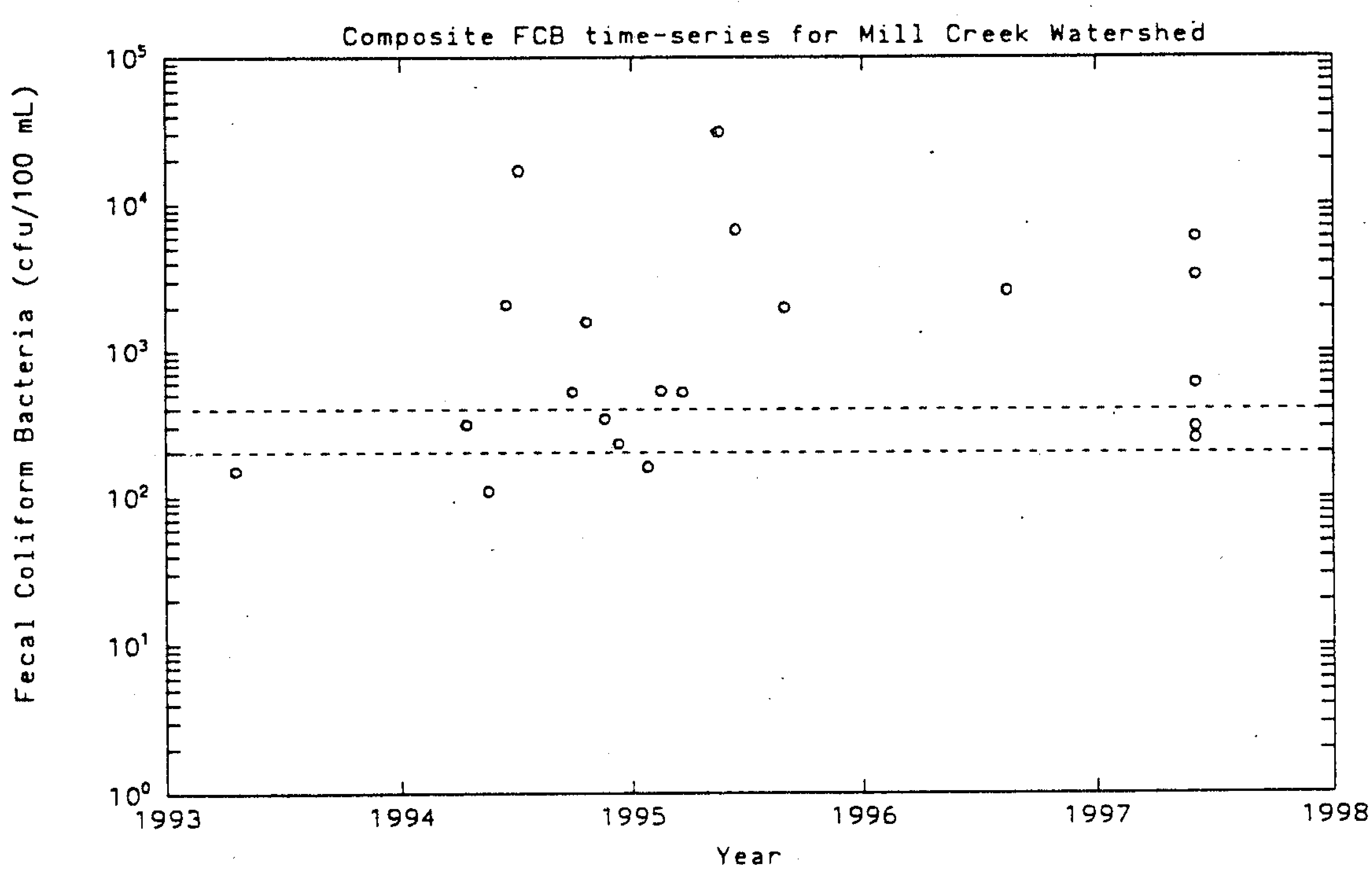


Figure 6.4 Composite time-series of fecal coliform data for all stations in Mill Creek watershed.

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