Total Maximum Daily Load

Evaluation

for

Twenty-Eight Stream Segments

in the

Flint River Basin

For

Fecal coliform

Submitted to:

The U.S. Environmental Protection Agency
Region 4
Atlanta, Georgia

Submitted by:
The Georgia Department of Natural Resources
Environmental Protection Division
Atlanta, Georgia

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Table of Contents

List of Tables

List of Figures

Appendix

EXECUTIVE SUMMARY

The State of Georgia assesses its water bodies for compliance with water quality standards criteria established for their designated uses as required by the Federal Clean Water Act (CWA). Assessed water bodies are placed into three categories, supporting, partially supporting, or not supporting their designated uses, depending on water quality assessment results. These water bodies are found on Georgia's 305(b) list as required by that section of the CWA that defines the assessment process, and are published in *Water Quality in Georgia* every two years.

Some of the 305(b) partially and not supporting water bodies are also assigned to Georgia's 303(d) list, also named after that section of the CWA. Water bodies on the 303(d) list are required to have a Total Maximum Daily Load (TMDL) evaluation for the water quality constituent(s) in violation of the water quality standard. The TMDL process establishes the allowable pollutant loadings or other quantifiable parameters for a water body based on the relationship between pollutant sources and in-stream water quality conditions. This allows water quality-based controls to be developed to reduce pollution and restore and maintain water quality.

The State of Georgia has identified twenty-eight (28) stream segments located in the Flint River Basin as water quality limited due to fecal coliform. A stream is placed on the partial support list if more than 10% of the samples exceed the fecal coliform criteria and on the not support list if more than 25% of the samples exceed the standard. Water quality samples collected within a 30-day period that have a geometric mean in excess of 200 counts per 100 milliliters during the period May through October, or in excess of 1000 counts per 100 milliliters during the period November through April are in violation of the bacteria water quality standard. In addition, a single sample in excess of 4000 counts per 100 milliliters during the period November through April can also provide a basis for adding a stream segment to the 303(d) listing. The water use classifications of all of the impacted streams are Fishing, Recreation, and Drinking Water.

An important part of the TMDL analysis is the identification of potential source categories. Sources are broadly classified as either point or nonpoint sources. A point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Nonpoint sources are diffuse, and generally, but not always, involve accumulation of fecal coliform bacteria on land surfaces that washoff as a result of storm events.

The process of developing fecal coliform TMDLs for the Flint River Basin listed segments includes the determination of the following:

- The current critical fecal coliform load to the stream under current conditions;
- The TMDL for similar conditions under which the current load was determined; and
- The percent reduction in the current critical fecal coliform load necessary to achieve the TMDL.

The calculation of the fecal coliform load at any point in a stream requires the fecal coliform concentration and stream flow. The availability of water quality and flow data varies considerably among the listed segments. Two different approaches were used depending on data availability: Loading Curve Approach and Equivalent Site Approach. The fecal coliform loads and required reductions for each of the listed segments are summarized in the table below.

Fecal Loads and Required Fecal Load Reductions

Stream Segment	Current Load (cnts/30 days)	TMDL Components					Percent Reduction
		WLA (cnts/30 days)	WLAsw (cnts/30 days)	LA (cnts/30 days)	MOS (cnts/30 days)	TMDL (cnts/30 days)	
Beaver Creek	2.46E+13	9.97E+09		2.30E+12	2.57E+11	2.57E+12	90%
Bell Creek	1.54E+11			8.32E+10	9.24E+09	9.24E+10	40%
Big Slough	4.64E+12	Plant closed		3.98E+12	4.43E+11	4.43E+12	5%
Camp Creek	8.18E+11		1.54E+11	3.38E+11	5.46E+10	5.46E+11	33%
Cooleewahee Creek	2.36E+11			1.21E+11	1.34E+10	1.34E+11	43%
Elkins Creek	2.85E+12	0.00E+00		1.68E+12	1.87E+11	1.87E+12	34%
Flint River - Upstream Hartsfield Airport	2.91E+12		1.07E+12	7.70E+11	2.04E+11	2.04E+12	30%
Flint River - Hartsfield Airport to Hwy 138	3.57E+12		1.23E+12	8.38E+11	2.30E+11	2.3E+12	36%
Flint River - Hwy 138 to N. Hampton Road	3.16E+12		5.69E+11	1.50E+12	2.30E+11	2.3E+12	27%
Flint River - Woolsey Rd. to Horton Creek	7.02E+12	8.65E+10	8.61E+11	4.62E+12	6.19E+11	6.19E+12	12%
Fowltown Creek	4.74E+13			1.65E+13	1.83E+12	1.83E+13	61%
Gum Creek	2.83E+12	3.78E+11		9.72E+11	1.50E+11	1.5E+12	47%
Lanahassee Creek	3.13E+12			1.33E+12	1.48E+11	1.48E+12	53%
Lime Creek	1.15E+12			8.75E+11	9.72E+10	9.72E+11	15%
Muckaloochee Creek	1.81E+12	9.10E+09		5.65E+11	6.38E+10	6.38E+11	65%
Mud Creek	7.28E+13		5.32+12	3.13E+12	9.39E+11	9.39E+12	87%
Patsiliga Creek	3.24E+12			1.92E+12	2.13E+11	2.13E+12	34%
Potato Creek	3.46E+12	2.74E+11		5.91E+11	9.61E+10	9.61E+11	72%
Red Oak Creek	3.58E+12			1.78E+12	1.98E+11	1.98E+12	45%
Sullivan Creek	2.43E+12		2.67E+11	1.54E+11	4.67E+10	4.67E+11	81%
Swift Creek - Tobler Creek to Flint River	1.06E+12			7.50E+11	8.33E+10	8.33E+11	21%
Swift Creek -U/S Lake Blackshear	1.46E+12			6.84E+11	7.60E+10	7.6E+11	48%
Tributary to Flint River	8.67E+12		1.70E+11	1.23E+11	3.26E+10	3.26E+11	96%
Turkey Creek	1.78E+12	3.30E+09		5.21E+11	5.83E+10	5.83E+11	67%
Ulcohatchee Creek	1.36E+11			1.21E+11	1.34E+10	1.34E+11	1%
Whitewater Creek - Big Whitewater Creek to Cedar Creek	2.5E+13			1.25E+13	1.39E+12	1.39E+13	44%
Whitewater Creek -Cedar Creek to Flint River	3.78E+13			3.38E+13	3.75E+12	3.75E+13	1%
Wildcat Creek	8.23E+11			3.19E+11	3.54E+10	3.54E+11	57%

Management practices that may be used to help reduce and/or maintain the average annual sediment loads include:

- Compliance with NPDES permit limits and requirements
- Adoption of NRCS Conservation Practices
- Application of Best Management Practices (BMPs) appropriate to agricultural or urban land uses, whichever applies

The amount of fecal coliform delivered to a stream is difficult to determine. However, by requiring and monitoring the implementation of these management practices, their effects will improve stream water quality, and represent a beneficial measure of TMDL implementation.

1.0 INTRODUCTION

1.1 Background

The State of Georgia assesses its water bodies for compliance with water quality standards criteria established for their designated uses as required by the Federal Clean Water Act (CWA). Assessed water bodies are placed into three categories, supporting, partially supporting, or not supporting their designated uses depending on water quality assessment results. These water bodies are found on Georgia's 305(b) list as required by that section of the CWA that addresses the assessment process, and are published in *Water Quality in Georgia* every two years.

Some of the 305(b) partially and not supporting water bodies are also assigned to Georgia's 303(d) list, also named after that section of the CWA. Water bodies on the 303(d) list are required to have a Total Maximum Daily Load (TMDL) evaluation for the water quality constituent(s) in violation of the water quality standard. The TMDL process establishes the allowable loading of pollutants or other quantifiable parameters for a water body based on the relationship between pollution sources and in-stream water quality conditions. This allows water quality based controls to be developed to reduce pollution and restore and maintain water quality.

EPA Region 4 approved Georgia's final 2002 303(d) list on April 30, 2002. The list identifies the waterbodies as either not supporting or partially supporting designated use classifications, due to exceedances of water quality standards for fecal coliform bacteria. Fecal coliform bacteria are used as an indicator of the potential presence of pathogens in a stream. Table 1 presents the streams of the Flint River Basin included on the 303(d) list for exceedances of the fecal coliform standard criteria. A total of 15 stream segments were listed as partially supporting the designated use, and 13 stream segments were listed as not supporting their designated use.

1.2 Watershed Description

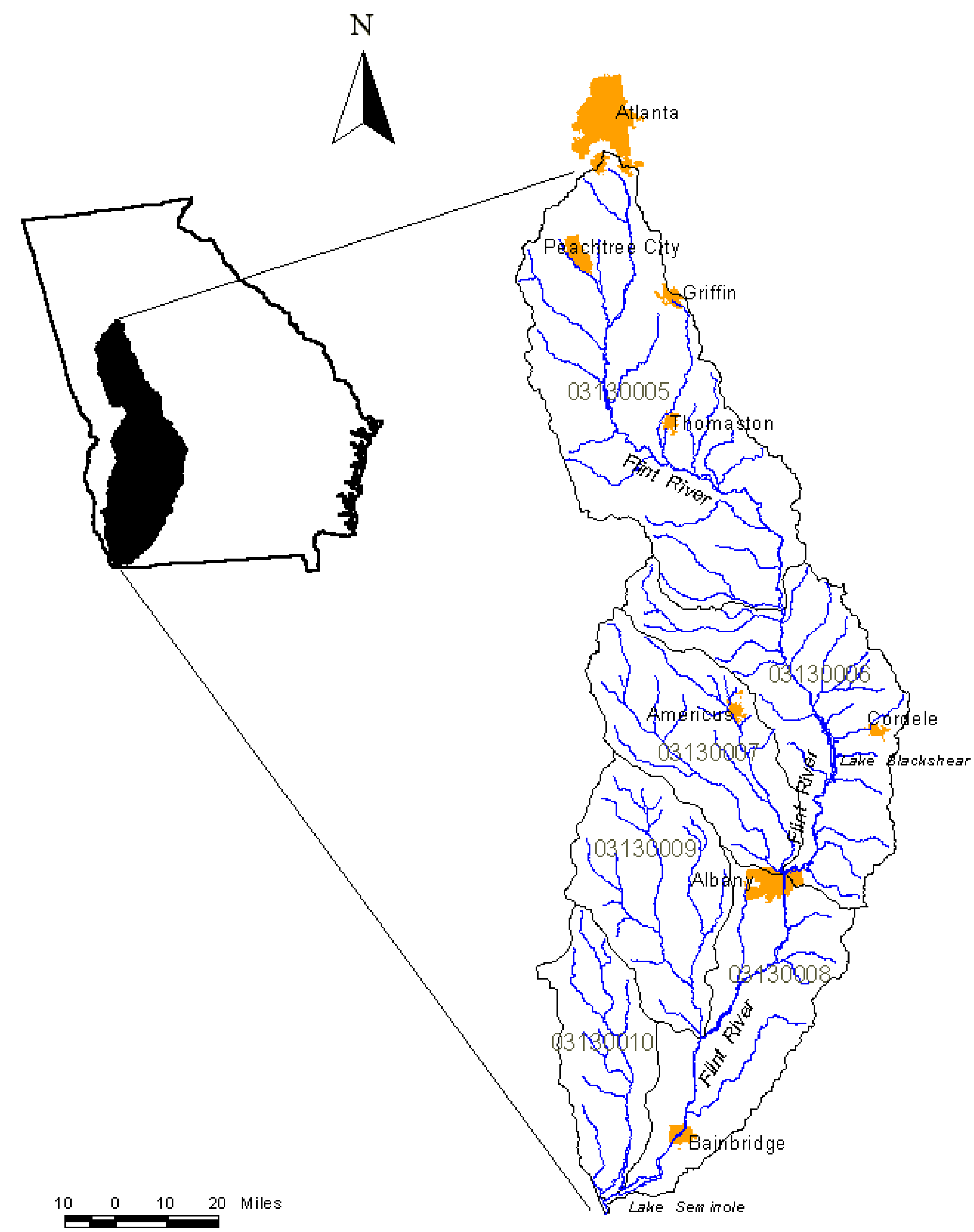
The Flint River originates in the south side of Fulton County, in metropolitan Atlanta, by Hartsfield International Airport (Figure 1). The river flows south to Lake Blackshear to Lake Seminole. At this point, the Flint converges with the Chattahoochee River in Lake Seminole at the Georgia-Florida border. The outflow from Lake Seminole forms the Apalachicola River in Florida, which ultimately discharges to the Gulf of Mexico. The Flint River Basin contains parts of the Piedmont and Coastal Plain physiographic provinces that extend throughout the southeastern United States.

The USGS has divided the Flint basin into four sub-basins, or Hydrologic Unit Codes (HUCs). Figure 1 shows the location of these sub-basins and the associated counties within each sub-basin.

Table 1. Waterbodies Listed for Fecal Coliform Bacteria in the Flint River Basin

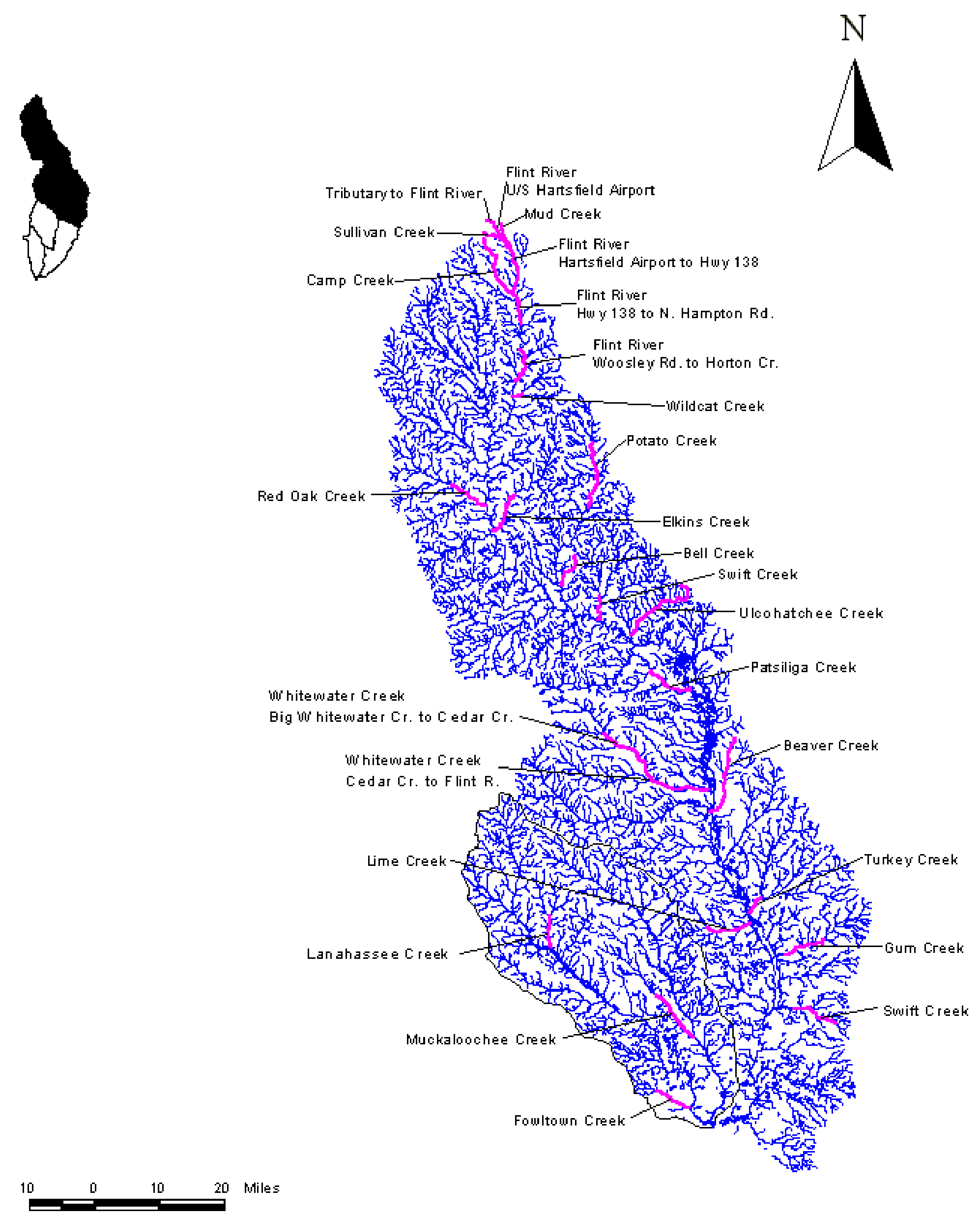
Stream Segment	Location	Segment Length (miles)	Designated Use	Listing
Beaver Creek	Spring Hill Creek to Flint River (Macon Co.)	4	Fishing	NS
Bell Creek	Headwaters, d/s Thomaston, to Potato Creek (Upson Co.)	4	Fishing	PS
Big Slough	Near Pelham (Mitchell Co.)	4	Fishing	NS
Camp Creek	Headwaters to Flint River (Clayton Co.)	9	Fishing	PS
Cooleewahee Creek	Piney Woods Branch to Flint River near Newton, (Dougherty/Baker Co.)	16	Fishing	PS
Elkins Creek	Bull Creek to Flint River near Molena (Pike/Upson Co.)	11	Fishing	NS
Flint River	Upstream Hartsfield Airport (Clayton Co.)	1	Fishing	NS
Flint River	Hartsfield Airport to Hwy 138 (Clayton Co.)	8	Fishing	PS
Flint River	Hwy 138 to N. Hampton Road (Clayton Co.)	8	Fishing	PS
Flint River	Road S1058/Woolsey Rd. to Horton Creek (Clayton/Fayette/Spalding Co.)	9	Drinking Water/ Fishing	PS
Fowltown Creek	D/S Armena Rd. To Kinchafoonee Creek (Lee Co.)	6	Fishing	PS
Gum Creek	Downstream Cordele to Lake Blackshear (Crisp Co.)	4	Fishing	NS
Lanahassee Creek	W. Fork Lanahassee Creek to Kinchafoonee Creek (Webster Co.)	6	Fishing	PS
Lime Creek	Lime Creek to Lake Blackshear (Sumter Co.)	5	Fishing	PS
Muckaloochee Creek	Smithville Pond (aka Wells Mill Pond) to Muckalee Creek (Lee Co.)	10	Fishing	NS
Mud Creek	Downstream Hapeville (Fulton/Clayton Co.)	5	Fishing	NS
Patsiliga Creek	Beaver Cr. to Flint River, Butler (Taylor Co.)	6	Fishing	PS
Potato Creek	U.S. Hwy. 333 to Upson Co. Line (Lamar Co.)	11	Fishing	NS
Red Oak Creek	Little Red Oak Creek to Flint River near Imlac (Meriwether Co.)	8	Fishing	PS
Sullivan Creek	Clayton County	5	Fishing	PS
Swift Creek	Tobler Creek to Flint River (Upson Co.)	5	Fishing	PS
Swift Creek	U/S Lake Blackshear (Turner/Crisp Co.)	7	Fishing	PS
Tributary to Flint River	River College Park (Clayton Co.)	1	Fishing	NS
Turkey Creek	Newnan to Reese Lake (Coweta Co.)	4	Fishing	NS
Ulcohatchee Creek	Headwaters to Auchumpkee Creek (Crawford Co.)	16	Fishing	PS
Whitewater Creek	Big Whitewater Creek to Cedar Creek (Taylor/Macon Co.)	17	Fishing	NS
Whitewater Creek	Cedar Creek to Flint River (Macon Co.)	13	Fishing	NS
Wildcat Creek	Heads Creek to Flint River (Spalding Co.)	2	Fishing	NS

Notes:
PS = Partially Supporting designated uses
NS = Not Supporting designated uses



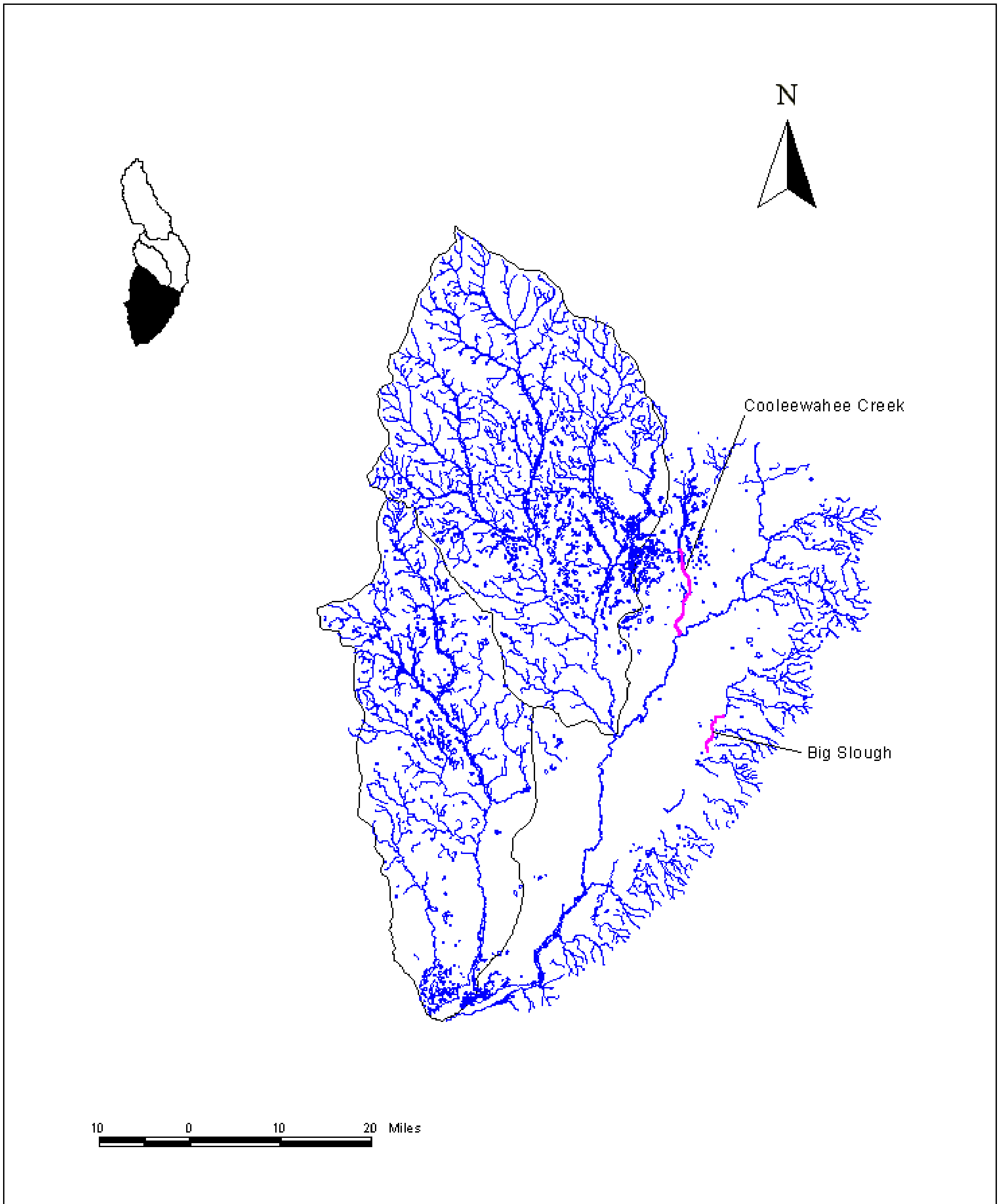
TMDL Evaluation - Fecal Coliform
Flint River Basin

Figure 1. Location of Flint River Basin



TMDL Evaluation - Fecal Coliform
Flint River Basin

Figure 2. HUCs 03130005 through 03130007
303(d) Listed Streams



TMDL Evaluation - Fecal Coliform
Chattahoochee River Basin

Figure 3. HUCs 03130008 through 03130010
303(d) Listed Streams

The land use characteristics of the Flint River Basin watersheds were determined using data from Georgia's Multiple Resolution Land Coverage (MRLC). This coverage was produced from Landsat Thematic Mapper digital images developed in 1995. For the thirteen metro Atlanta counties, the Atlanta Regional Commission (ARC) Landuse Coverage was used, which was derived from digital images developed in 2000. Landuse classification is based on a modified Anderson level one and two system. Table 2 lists the land use distribution of the 28 watersheds on the 303(d) list.

1.3 Water Quality Standard

The water use classification for the listed watersheds in the Flint River Basin is Drinking Water and Fishing. The criterion violated is listed as fecal coliform. The potential cause(s) listed include urban runoff, nonpoint sources, unknown sources, and combine sewer overflows. The use classification water quality standards for fecal coliform bacteria as stated in Georgia's Rules and Regulations for Water Quality Control Chapter 391-3-6-.03(6)(a) and 391-3-6-.03(6)(c) is:

(a) Drinking Water Supplies: Those waters approved as a source for public drinking water systems permitted or to be permitted by the Environmental Protection Division. Waters classified for drinking water supplies will also support the fishing use and any other use requiring water of a lower quality.

(i) Bacteria: For the months of May through October, when water contact recreation activities are expected to occur, fecal coliform not to exceed a geometric mean of 200 per 100 ml based on at least four samples collected from a given sampling site over a 30-day period at intervals not less than 24 hours. Should water quality and sanitary studies show fecal coliform levels from non-human sources exceed 200/100 ml (geometric mean) occasionally, then the allowable geometric mean fecal coliform shall not exceed 300 per 100 ml in lakes and reservoirs and 500 per 100 ml in free flowing freshwater streams. For the months of November through April, fecal coliform not to exceed a geometric mean of 1,000 per 100 ml based on at least four samples collected from a given sampling site over a 30-day period at intervals not less than 24 hours and not to exceed a maximum of 4,000 per 100 ml for any sample. The State does not encourage swimming in surface waters since a number of factors which are beyond the control of any State regulatory agency contribute to elevated levels of fecal coliform.

(c) Fishing: Propagation of Fish, Shellfish, Game and Other Aquatic Life; secondary contact recreation in and on the water; or for any other use requiring water of a lower quality:

(iii) Bacteria: For the months of May through October, when water contact recreation activities are expected to occur, fecal coliform not to exceed a geometric mean of 200 per 100 ml based on at least four samples collected from a given sampling site over a 30-day period at intervals not less than 24 hours. Should water quality and sanitary studies show fecal coliform levels from non-human sources exceed 200/100 ml (geometric mean) occasionally, then the allowable geometric mean fecal coliform shall not exceed 300 per 100 ml in lakes and reservoirs and 500 per 100 ml in free flowing freshwater streams. For the months of November through April, fecal coliform not to exceed a geometric mean of 1,000 per 100 ml based on at least four samples collected from a given sampling site over a 30-day period at intervals not less than 24 hours and not to exceed a maximum of 4,000 per 100 ml for any sample. The State does not encourage swimming in surface waters since a number of factors which are beyond the control of any State regulatory agency contribute to elevated levels of fecal coliform. For waters designated as approved shellfish harvesting waters by the appropriate State agencies, the requirements will be consistent with those established by the State and Federal agencies responsible for the National Shellfish Sanitation Program. The requirements are found in the National Shellfish Sanitation Program Manual of Operation, Revised 1988, Interstate Shellfish Sanitation Conference, U. S. Department of Health and Human Services (PHS/FDA), and the Center for Food Safety and Applied Nutrition. Streams designated as generally supporting shellfish are listed in Paragraph 391-3-6-.03(14).

Table 2. Flint River Basin Landuse

Stream/Segment	Landuse Categories - Acres (Percent)														
	Open Water	Low Intensity Residential	High Intensity Residential	High Intensity Commercial, Industrial, Transportation	Bare Rock, Sand, Clay	Quarries, Strip Mines, Gravel Pits	Transitional	Forest	Row Crops	Pasture, Hay	Other Grasses (Urban, recreational; e.g. parks, lawns)	Woody Wetlands	Emergent Herbaceous Wetlands	Total	Landuse Source
Beaver Creek	177	0	412	156	5	0	165	8352	12623	4854	97	4162	181	31184	MRLC
	(0.6)	(0.0)	(1.3)	(0.5)	(0.0)	(0.0)	(0.5)	(26.8)	(40.5)	(15.6)	(0.3)	(13.3)	(0.6)		
Bell Creek	33	0	1032	328	0	0	1	3702	259	429	196	209	7	6196	MRLC
	(0.5)	(0.0)	(16.7)	(5.3)	(0.0)	(0.0)	(0.0)	(59.7)	(4.2)	(6.9)	(3.2)	(3.4)	(0.1)		
Big Slough	96	742	216	308	40	2	2895	17359	34984	10106	229	3113	508	70598	MRLC
	(0.1)	(1.1)	(0.3)	(0.4)	(0.1)	(0.0)	(4.1)	(24.6)	(49.6)	(14.3)	(0.3)	(4.4)	(0.7)		
Camp Creek	79	56	7096	538	931	0	0	152	2532	793	14	92	539	12742	ARC
	(0.6)	(0.4)	(55.7)	(4.2)	(7.3)	(0.0)	(0.0)	(1.2)	(19.9)	(6.2)	(0.1)	(0.7)	(4.2)		
Cooleewahee Creek	1496	0	1559	346	9	2	2802	36420	26122	10363	313	17452	2753	99637	MRLC
	(1.5)	(0.0)	(1.6)	(0.3)	(0.0)	(0.0)	(2.8)	(36.6)	(26.2)	(10.4)	(0.3)	(17.5)	(2.8)		
Elkins Creek	461	0	262	223	0	0	142	40201	4045	13866	205	5708	66	65179	MRLC
	(0.7)	(0.0)	(0.4)	(0.3)	(0.0)	(0.0)	(0.2)	(61.7)	(6.2)	(21.3)	(0.3)	(8.8)	(0.1)		
Flint River	5	991	281	1222	0	14	42	396	1	0	30	135	0	3116	ARC
U/S Hartsfield Airport	(0.1)	(31.8)	(9.0)	(39.2)	(0.0)	(0.5)	(1.3)	(12.7)	(0.0)	(0.0)	(1.0)	(4.3)	(0.0)		
Flint River	31	6308	2118	12249	0	373	281	2920	5	0	176	875	0	25336	ARC
Hartsfield Airport to Hwy 138	(0.1)	(24.9)	(8.4)	(48.3)	(0.0)	(1.5)	(1.1)	(11.5)	(0.0)	(0.0)	(0.7)	(3.5)	(0.0)		
Flint River	302	28998	3842	17814	0	504	1627	17504	5701	23	831	4712	0	81860	ARC
Hwy 138 to N. Hampton Rd	(0.4)	(35.4)	(4.7)	(21.8)	(0.0)	(0.6)	(2.0)	(21.4)	(7.0)	(0.0)	(1.0)	(5.8)	(0.0)		
Flint River	1880	44707	4318	22061	0	504	2452	36647	17093	48	1747	8411	0	139868	ARC
Woolsey Rd to Horton Ck	(1.3)	(32.0)	(3.1)	(15.8)	(0.0)	(0.4)	(1.8)	(26.2)	(12.2)	(0.0)	(1.2)	(6.0)	(0.0)		
Fowltown Creek	241	0	14	28	0	0	1472	9121	5927	4333	12	1621	234	23003	MRLC
	(1.0)	(0.0)	(0.1)	(0.1)	(0.0)	(0.0)	(6.4)	(39.7)	(25.8)	(18.8)	(0.1)	(7.0)	(1.0)		
Gum Creek	191	0	1110	1147	55	195	4471	17976	17413	7725	318	2838	29	53468	MRLC
	(0.4)	(0.0)	(2.1)	(2.1)	(0.1)	(0.4)	(8.4)	(33.6)	(32.6)	(14.4)	(0.6)	(5.3)	(0.1)		
Lanahassee Creek	85	0	8	55	0	0	2032	29130	758	889	1	2008	31	34997	MRLC
	(0.2)	(0.0)	(0.0)	(0.2)	(0.0)	(0.0)	(5.8)	(83.2)	(2.2)	(2.5)	(0.0)	(5.7)	(0.1)		
Lime Creek	227	0	9	17	2	0	1220	12439	15112	7462	21	4632	279	3364	MRLC
	(0.5)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(2.9)	(30.0)	(36.5)	(18.0)	(0.1)	(11.2)	(0.7)		

Stream/Segment	Landuse Categories - Acres (Percent)														
	Open Water	Low Intensity Residential	High Intensity Residential	High Intensity Commercial, Industrial, Transportation	Bare Rock, Sand, Clay	Quarries, Strip Mines, Gravel Pits	Transitional	Forest	Row Crops	Pasture, Hay	Other Grasses (Urban, recreational; e.g. parks, lawns)	Woody Wetlands	Emergent Herbaceous Wetlands	Total	Landuse Source
Muckaloochee Creek	308	0	60	75	1	0	1454	17468	11078	8017	74	4927	161	43623	MRLC
	(0.7)	(0.0)	(0.1)	(0.2)	(0.0)	(0.0)	(3.3)	(40.0)	(25.4)	(18.4)	(0.2)	(11.3)	(0.4)		
Mud Creek	0	9	28	2880	0	86	26	252	0	0	0	83	0	3364	ARC
	(0.0)	(0.3)	(0.8)	(85.6)	(0.0)	(2.6)	(0.8)	(7.5)	(0.0)	(0.0)	(0.0)	(2.5)	(0.0)		
Patsiliga Creek	644	0	183	260	7	808	4364	58597	8824	3932	73	7520	342	85554	MRLC
	(0.8)	(0.0)	(0.2)	(0.3)	(0.0)	(0.9)	(5.1)	(68.5)	(10.3)	(4.6)	(0.1)	(8.8)	(0.4)		
Potato Creek	734	0	1536	1038	0	119	477	43638	4486	15437	560	4284	63	72371	MRLC
	(1.0)	(0.0)	(2.1)	(1.4)	(0.0)	(0.2)	(0.7)	(60.3)	(6.2)	(21.3)	(0.8)	(5.9)	(0.1)		
Red Oak Creek	473	0	288	160	0	0	2950	69967	3693	8947	153	6117	88	92835	MRLC
	(0.5)	(0.0)	(0.3)	(0.2)	(0.0)	(0.0)	(3.2)	(75.4)	(4.0)	(9.6)	(0.2)	(6.6)	(0.1)		
Sullivan Creek	4	482	443	2199	0	204	11	345	0	0	0	0	0	3688	ARC
	(0.1)	(13.1)	(12.0)	(59.6)	(0.0)	(5.5)	(0.3)	(9.4)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)		
Swift Creek	346	0	386	253	2	0	2343	52722	3314	9458	212	1964	12	71012	MRLC
Tobler Creek to Flint River	(0.5)	(0.0)	(0.5)	(0.4)	(0.0)	(0.0)	(3.3)	(74.2)	(4.7)	(13.3)	(0.3)	(2.8)	(0.0)		
Swift Creek	591	0	143	70	34	0	2813	11767	16052	8319	7	2808	76	42680	MRLC
U/S Lake Blackshear	(1.4)	(0.0)	(0.3)	(0.2)	(0.1)	(0.0)	(6.6)	(27.6)	(37.6)	(19.5)	(0.0)	(6.6)	(0.2)		
Tributary to Flint River	2	509	144	627	0	7	21	203	0	0	15	69	0	1600	ARC
	(0.1)	(31.8)	(9.0)	(39.2)	(0.0)	(0.5)	(1.3)	(12.7)	(0.0)	(0.0)	(1.0)	(4.3)	(0.0)		
Turkey Creek	48.7	516.9	56.8	363.3	0.0	0.0	152.3	1682.0	348.0	0.0	256.7	113.3	0.0	3538	ARC
	(1.4)	(14.6)	(1.6)	(10.3)	(0.0)	(0.0)	(4.3)	(47.5)	(9.8)	(0.0)	(7.3)	(3.2)	(0.0)		
Ulcohatchee Creek	85	0	8	55	0	0	2032	29130	758	889	1	2008	31	34997	MRLC
	(0.2)	(0.0)	(0.0)	(0.2)	(0.0)	(0.0)	(5.8)	(83.2)	(2.2)	(2.5)	(0.0)	(5.7)	(0.1)		
Whitewater Creek	248	0	10	390	1	488	1773	52108	8859	1586	13	3974	169	69619	MRLC
Big Whitewater Ck to Cedar Ck	(0.4)	(0.0)	(0.0)	(0.6)	(0.0)	(0.7)	(2.5)	(74.8)	(12.7)	(2.3)	(0.0)	(5.7)	(0.2)		
Whitewater Creek	463	0	40	442	6	488	5249	108137	19132	4903	34	7432	235	146561	MRLC
Cedar Creek to Flint River	(0.3)	(0.0)	(0.0)	(0.3)	(0.0)	(0.3)	(3.6)	(73.8)	(13.1)	(3.3)	(0.0)	(5.1)	(0.2)		
Wildcat Creek	440	0	1649	617	0	0	14	19066	1814	5157	502	1266	19	30544	ARC
	(1.4)	(0.0)	(5.4)	(2.0)	(0.0)	(0.0)	(0.0)	(62.4)	(5.9)	(16.9)	(1.6)	(4.1)	(0.1)		

2.0 WATER QUALITY ASSESSMENT

Stream segments are placed on the 303(d) list as partially supporting or not supporting their water use classification based on water quality sampling data. A stream is placed on the partial support list if more than 10% of the samples exceed the fecal coliform criteria and on the not support list if more than 25% of the samples exceed the standard. Water quality samples collected within a 30-day period that have a geometric mean in excess of 200 counts per 100 milliliters during the period May through October, or in excess of 1000 counts per 100 milliliters during the period November through April are in violation of the bacteria water quality standard. In addition, a single sample in excess of 4000 counts per 100 milliliters during the period November through April can also provide a basis for adding a stream segment to the 303(d) listing.

Fecal coliform data were collected during calendar years 2000 and 2001. Sources of these data including the following:

- USGS basin water quality data, 2000 and 2001.
- EPD Trend Monitoring data, 2000 and 2001
- EPD special studies sampling data, 2000.
- City of Atlanta water quality data, 2000 and 2001
- Clayton County water quality data, 2000 and 2001

These sources had eenough information to calculate a 30-day geometric mean and the data used for these TMDLs are presented in Appendix A.

For a number of listed stream segments, available data were not sufficient to calculate a 30-day geometric mean. Many of these stream segments had been placed on the 303(d) list as a result of data collected prior to 2000. These data were assembled from a variety of sources, which included:

- Atlanta Region Commission storm water sampling data
- Chattahoochee River Management Project, 1993 – 1996
- Cobb County Spills data, 1993; water quality sampling data, 1990 - 2002
- DeKalb County spills data, 1992 - 1993; water quality data, 1994 – 1995
- Columbus, GA. spills data, 1992 - 1993; water quality data, 1993 – 1994
- City of Gainesville water quality data, (1999-2001)
- Lake Sidney Lanier Clean Lakes Study
- NAWQUA water quality data
- Sanitary Survey sampling data, 1993

Summaries of these data are presented in Appendix B.

3.0 SOURCE ASSESSMENT

An important part of the TMDL analysis is the identification of potential source categories. Sources are broadly classified as either point or nonpoint sources. A point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Nonpoint sources are diffuse, and generally, but not always, involve accumulation of fecal coliform bacteria on land surfaces that washoff as a result of storm events.

3.1 Point Source Assessment

Title IV of the Clean Water Act establishes the National Pollutant Discharge Elimination System (NPDES) permit program. Basically, there are two categories of NPDES permits: 1) municipal and industrial wastewater treatment facilities and 2) regulated storm water discharges.

3.1.1 Wastewater Treatment Facilities

In general, industrial and municipal wastewater treatment facilities have NPDES permits with effluent limits. These permit limits are either based on federal and state effluent guidelines (technology-based limits) or water quality standards (water quality-based limits).

EPA has developed technology-based guidelines, which establish a minimum standard of pollution control for municipal and industrial discharges without regard for the quality of the receiving waters. These are based on Best Practical Control Technology Current Available (BPT), Best Conventional Control Technology (BCT), and Best Available Technology Economically Achievable (BAT). The level of control required by each facility depends on the type of discharge and the pollutant.

EPA and states have also developed numeric and narrative water quality standards. Typically, these standards are based on the results of aquatic toxicity tests and/or human health criteria and include a margin of safety. Water quality-based effluent limits are set to protect the receiving stream. These limits are based on water quality standards that have been established for a stream based on its intended use and the prescribed biological and chemical conditions that must be met to sustain that use.

Municipal and industrial wastewater treatment facilities discharges may contribute fecal coliform to receiving waters. There are 53 NPDES permitted discharges with effluent limits for fecal coliform bacteria identified in the Flint River Basin Watershed upstream from the listed segments. Table 3 provides the monthly average discharge flows and fecal coliform concentrations for the municipal and industrial treatment facilities, obtained from calendar year 2000 Discharge Monitoring Report (DMR) data. The permitted flow and fecal coliform concentrations for these facilities are also included in this table.

Combined sewer systems convey a mixture of raw sewage and storm water in the same conveyance structure to the wastewater treatment plant. These are considered a component of municipal wastewater treatment facilities. When the combined sewage exceeds the capacity of the wastewater treatment plant, the excess is diverted to a combined sewage overflow (CSO) discharge point.

Table 3. NPDES Facilities Discharging Fecal Coliform in the Flint River Basin

Facility Name	NPDES Permit No.	Receiving Stream	Actual 2000 Discharge: Average Flow (MGD)	Actual 2000 Discharge: Geo Mean (No./ 100 mL)	NPDES Permit Limits: Average Monthly Flow (MGD)	NPDES Permit Limits: Geo Mean (No./ 100 mL)	Number. of Violations July 1998- June 2001
Albany Joshua Road	GA0037222	Flint River	19.08	2.0	32.0	200	0
Americus Mill Cr	GA0047767	Mill Creek	2.80	49.3	4.4	200	0
Arlington Pond #1	GA0026204	Perry Creek Trib to Spring Creek	0.03	fecal added to permit on 6/6/01	0.1	200	0
Baconton WPCP	GA0037737	Flint River	0.05	160.3	0.1	200	2
Bainbridge WPCP	GA0024678	Flint River	1.22	28.1	2.5	200	0
Blakely Pond A	GA0031968	Blue Creek Trib to Dry Creek	0.01	fecal added to permit on 7/31/01	0.12	200	0
Blakely Pond B	GA0031976	Breastworks Branch to Dry Creek	0.00	fecal added to permit on 7/31/01	0.12	200	0
Blakely WPCP	GA0025585	Baptist Branch Tributary	0.65	16.3	1.315	200	3
Buena Vista WPCP	GA0023710	Oochee Creek	0.25	112.9	0.5	200	0
Butler Pond	GA0021083	Town Branch Tributary	0.26	Discharged to LAS in 2000	0.5	200	0
Byromville Pond	GA0025623	Turkey Creek	0.01	no fecal limit	0.104	no fecal limit	0
Camilla WPCP	GA0020362	Big Slough Creek	June 2000 Plant Closed		3.0	200	0
Colquitt WPCP	GA0047252	Spring Creek	0.18	0.0	0.4	200	0
Concord South #1	GA0025470	Elkins Creek	0.04	no fecal limit	0.1	no fecal limit	0
Cordele WPCP	GA0024503	Gum Creek	2.12	51.2	5.0	200	0
Coweta Co Shenandoah WPCP	GA0034614	White Oak Creek	0.50	11.0	0.89	200	0
Cuthbert	GA0037249	Town Branch-Carter Creek	0.43	8.3	0.6	200	0
Cuthbert Pond	GA0050083	Town Branch-Flint River	0.43	16.2	0.41	200	0
Dawson WPCP	GA0021326	Brantley Creek	1.24	80.4	2.5	200	1
Decatur Co Ind Airpark	GA0033511	Flint River	0.39	169.2	1.5	200	1
Donalsonville WPCP	GA0026123	Fish Pond Drain	0.34	5.7	0.4	200	0
Edison	GA0037427	Bay Branch of Pachitla Creek	0.09	no fecal in permit	0.25	no fecal limit	0
Edison Pond	GA0020494	Bay Branch	0.09	no fecal in permit	0.154	no fecal limit	0

Facility Name	NPDES Permit No.	Receiving Stream	Actual 2000 Discharge		NPDES Permit Limits		Number. of Violations July 1998-June 2001
			Average Flow (MGD)	Geo Mean (No./ 100 mL)	Average Monthly Flow (MGD)	Geo Mean (No./ 100 mL)	
Ellaville Pond	GA0050105	Unnamed Trib to Little Muckalee Ck	0.11	no fecal in permit	0.2	no fecal limit reporting required 7/31/01	0
Fayetteville Whitewater	GA0035807	Whitewater Creek-Line Creek	1.71	8.9	3.75	200	0
Greenville Kennel Creek	GA0047813	Kennel Creek Tributary	0.14	45.0	0.25	200	1
Griffin Potato Cr WPCP	GA0030791	Potato Creek	1.34	5.8	2.0	200	1
Griffin Shoal Cr	GA0047040	Shoal Creek Trib To Flint River	Pond discharges to sprayfields		1.5	no fecal limit	0
Hampton WPCP	GA0020320	Bear Creek	0.38	21.0	0.5	200	0
Leary WPCP	GA0026212	Keel Creek	0.03	36.7	0.1	200	0
Lee County	GA0026603	Kinchafoonee Creek	0.23	144.0	**0.25**	200	0
Leesburg	GA0026638	Kinchafoonee Creek	0.29	5,199.8	**0.45**	no fecal limit reporting required 11/14/00	0
Marshallville WPCP	GA0047431	Spring Hill Creek	0.03	no fecal in permit	0.12	200	0
Montezuma WPCP #1	GA0021288	Spring Creek	0.47	23.0	0.84	200	0
Montezuma WPCP #2	GA0020486	Spring Creek	0.32	3.2	1.95	200	4
Oglethorpe	GA0036919	Flint River	0.20	fecal added to permit on 4/6/01	0.45	200	0
Peachtree City Flat Creek WPCP	GA0020371	Flat Creek Trib To Line Creek	0.56	16.1	0.9	200	10
Peachtree City Line Creek WPCP	GA0035777	Line Creek-Whitewater Creek	1.45	19.8	2.0	200	5
Peachtree City Rockaway WPCP	GA0046655	Line Creek Tribuartay	1.33	8.8	2.0	200	0
Plains WPCP	GA0020931	Passell Ck Trib/Kinchafoonee Ck	0.08	20.0	0.12	200	0
Reynolds Pond	GA0020729	Patsiliga Creek	0.06	no fecal in permit	0.16	no fecal limits reporting required 6/5/01	0
Richland Pond	GA0021539	Bear Creek Tributary	0.76	no fecal in permit	0.3	no fecal limits	0
Roberta WPCP	GA0020834	Culpepper Creek Tributary	0.14	131.9	0.44	200	0
Shellman WPCP	GA0032361	Ichawaynotchaway Creek Tributary	0.03	36.7	0.15	200	3
Smithville Pond	GA0047422	Muckaloochee Creek	0.04	no fecal in permit	0.12	no fecal limits	0
South Hampton MHP	GA0025305	Unnamed Trib To Thomason Creek	0.03	2.7	0.1	200	0

Facility Name	NPDES Permit No.	Receiving Stream	Actual 2000 Discharge		NPDES Permit Limits		Number. of Violations July 1998-June 2001
			Average Flow (MGD)	Geo Mean (No./ 100 mL)	Average Monthly Flow (MGD)	Geo Mean (No./ 100 mL)	
Talbotton WCPC	GA0047805	Edwards Creek Tributary	0.11	195.2	0.1	200	1
Taylor County Bd of Comm (Potterville WPCP)	GA0000302	Horse Creek	No discharge	no fecal in permit	0.12	no fecal limits	0
Thomaston Bell Creek	GA0020079	Potato Creek	0.92	5.3	2.0	200	0
Thomaston Town Branch	GA0030121	Potato Creek	0.82	4.5	2.0	200	0
Tyson Foods Inc	GA0000817	Muckalee Creek	1.28	19.3		400	0
Warm Springs WPCP	GA0001601	Warm Springs Branch	0.16	26.5	0.4	200	0
Zebulon WPCP	GA0049476	Town Branch Tributary	0.11	no fecal in permit	0.29	no fecal limit reporting required 5/1/01	0

Source: EPA PCS Website, 2001 and EPD Regional Offices

Six CSOs outfalls, included under a single NPDES permit, are located in the City of Albany (see Table 4). The CSOs are designed to discharge directly into the Flint River only under high flow conditions with the WPCP facilities operating at full capacity. No CSO discharge events have occurred since July 1998.

Table 4. Permitted Combined Sewer Overflows (CSOs) in Flint River Basin

Municipality/County	Permit No.	Facility Name	Receiving Stream
Albany/Dougherty Co.	GA0036854	Albany Joshua Road	Flint River
Albany/Dougherty Co	GA0036854	Lift Station 27 Bypass	Flint River
Albany/Dougherty Co	GA0036854	Lift Station 25 Bypass	Flint River
Albany/Dougherty Co	GA0036854	Whitney Avenue	Flint River
Albany/Dougherty Co	GA0036854	Highland Avenue	Flint River
Albany/Dougherty Co	GA0036854	Ogelthorpe Avenue	Flint River

Source: Permitting and Compliance Program, Environmental Protection Division, GA EPD, 2001

3.1.2 Regulated Storm Water Discharges

Some storm water runoff is covered under the NPDES Permit Program. It is considered a diffuse source of pollution. Unlike other NPDES permits that establish end-of-pipe limits, storm water NPDES permits establish controls “to the maximum extent practicable” (MEP). Currently, regulated storm water discharges that may include discharges with fecal coliform bacteria consist of those associated with industrial activities including construction sites five acres or greater, and large and medium municipal separate storm sewer systems (MS4s) that serve populations of 100,000 or more.

Storm water discharges associated with industrial activities are currently covered under a General Storm Water Permit NPDES permit. This permit requires visual monitoring of storm water discharges, site inspections, implementation of Best Management Practices (BMPs), and record keeping.

Storm water discharges from MS4s are very diverse in pollutant loadings and frequency of discharge. At present, all cities and counties within the state of Georgia that had a population of greater than 100,000 at the time of the 1990 Census, are permitted for their storm water discharge. This includes 60 permittees, with about 45 located in the greater Atlanta metro area (see Table 5).

Table 5. Permitted MS4s in Flint River Basin

Name	Permit No.	Watershed
Atlanta	GAS000100	Flint, Chattahoochee
Clayton County	GAS000107	Flint, Ocmulgee
College Park	GAS000109	Flint, Chattahoochee
East Point	GAS000114	Flint, Chattahoochee, Ocmulgee
Fairburn	GAS000115	Flint, Chattahoochee
Forest Park	GAS000116	Flint, Chattahoochee, Ocmulgee
Fulton County	GAS000117	Flint, Chattahoochee, Ocmulgee, Coosa
Hapeville	GAS000119	Flint, Ocmulgee
Jonesboro	GAS000120	Flint, Ocmulgee
Lake City	GAS000141	Flint, Ocmulgee
Lovejoy	GAS000142	Flint, Ocmulgee
Morrow	GAS000126	Flint, Ocmulgee
Palmetto	GAS000128	Flint, Chattahoochee
Riverdale	GAS000130	Flint
Union City	GAS000136	Flint, Chattahoochee

Source: Nonpoint Source Permitting Program, GA DNR, 2001

MS4 permits require the prohibition on non-storm water discharges (i.e., illicit discharges) into the storm sewer systems, and controls to reduce the discharge of pollutants to the maximum extent practicable, including the use of management practices, control techniques and systems, design and engineering methods (Federal Register, 1990). A site-specific Storm Water Management Plan (SWMP) outlining appropriate controls is required by and referenced in the permit.

In March 2003, small MS4s serving urbanized areas will be required to obtain a storm water permit under the Phase II storm water regulations. An urbanized area is defined as an entity with a residential population of at least 50,000 people and an overall population density of at least 1,000 people per square mile. It is estimated that approximately 60 communities may be permitted under the Phase II regulations, which will also require site-specific SWMPs.

3.1.2 Confined Animal Feeding Operations

Confined livestock and confined animal feeding operations (CAFOs) are characterized by high animal densities. This result in large quantities of fecal material contained within a limited area. Processed agricultural manure from confined hog, dairy cattle and some poultry operations is generally collected in lagoons and applied to pastureland and cropland as a fertilizer during the growing season, at rates which often vary on a monthly basis.

In 1990, the State of Georgia began registering CAFOs. Many of the CAFOs have been issued land application permits for treatment of wastewaters generated from their operations. Table 6 presents the swine and non-swine (primarily dairies) CAFOs located in the Flint River Basin that are registered or have land application permits.

Table 6. Registered CAFOs in the Flint River Basin

Name	County	Type	Total No. of Animals
Atkinson	Miller	Swine	1830
Aurora Dairy – Georgia LC	Mitchell	Dairy	4250
Bud Butcher Dairy Farm	Coweta	Dairy	320
Camilla Floor	Mitchell	Swine	1800
Cox	Miller	Swine	1350
Grady Ranch	Grady	Dairy	675
Green Valley Farms	Pike	Dairy	285
Haygood Farms	Upson	Dairy	400
Higgenbotham Dairy	Talbot	Dairy	300
Holton Floor	Mitchell	Swine	2460
New Milk Company	Macon	Dairy	3400
Oak Hill Farms	Lee	Dairy	1800
Peacot Swine	Mitchell	Swine	2400
Pinecliff Farm	Mitchell	Swine	2400
Powell Farms	Sumter	Dairy	1000
Providence Dairy	Decatur	Dairy	660
Roger's Floor	Mitchell	Swine	2080
Ruck's Dairy Farm	Spalding	Dairy	350
Stephenson Hog Farm	Dooly	Swine	1500
Westhaven Farm	Mitchell	Dairy	600

Source: Permitting and Compliance Program, Environmental Protection Division, GA EPD, 2001

3.2 Nonpoint Source Assessments

In general, nonpoint sources cannot be identified as entering a waterbody through a discrete conveyance at a single location. Typical nonpoint sources of fecal coliform bacteria include:

- Wildlife
- Agricultural Livestock
    - Animal grazing
    - Animal access to streams
    - Application of manure to crop and pasture land

- Urban Development
    - Leaking septic systems
    - Land Application Systems
    - Landfills

In urban areas, a large portion of storm water runoff may be collected to storm sewer systems and discharged through distinct outlet structures. For large urban areas, these storm sewer discharge points may be regulated as described in Section 3.1.2.

3.2.1 Wildlife

The importance of wildlife as a source of fecal coliform bacteria in streams varies considerably, depending on the animal species present in the subwatersheds. Based on information provided by the Wildlife Resources Division (WRD) of DNR, the animals that spend a large proportion of their time in or around aquatic habitats are considered to be the most important wildlife sources of fecal coliform. Waterfowl, most notably ducks and geese, are considered to potentially be the greatest contributors of fecal coliform. This is because they are typically found on the water surface, often in large numbers, and deposit their feces directly into the water. Other potentially important animals, regularly found around aquatic environments, include racoon, beaver, muskrat, and to a lesser extent, river otter and mink. Population estimates of these animal species in Georgia are currently not available.

White-tailed deer have a significant presence throughout the Flint River Basin. The 2000 deer census for counties in the Flint River Basin is presented in Table 7. Fecal coliform bacteria contributions from deer to water bodies are generally considered less significant than that of waterfowl, racoon, and beaver. This is because a greater portion of their time is spent in terrestrial habitats. However, feces deposited on the land surface can result in the introduction of fecal coliform to streams during runoff events. It should be noted that between storm events, considerable decomposition of the fecal matter might occur, resulting in a decrease in the associated fecal coliform numbers. This is especially true in warm, humid environments typical of the southeast. This also holds true for other terrestrial mammals such as squirrel and rabbit, and terrestrial birds (WRD, personal communication).

3.2.2 Agricultural Livestock

Agricultural livestock are a potential source of fecal coliform to streams in the Flint River Basin. The animals grazing on pasture land deposit their feces onto land surfaces where it can be transported during storm events to nearby streams. Animal access to pasture land varies monthly, resulting in varying fecal coliform loading rates throughout the year. Beef cattle spend all of their time in pastures, while dairy cattle and hogs are confined periodically. Agricultural livestock also often have direct access to streams that pass through pastures, and as such can impact water quality in a more direct manner. (Personal communication, EPA, Georgia Agribusiness Council, NRCS, University of Georgia, et. al.).

Table 8, provides the estimated number of beef cattle per USGS 12-digit HUC. The number of dairy cattle, swine, sheep, goats and horses reported by county are presented in Table 9. These data were provided by the Natural Resources Conservation Service (NRCS) and are based on 2000 data.

Table 7. 2000 Deer Census Data by County in the Flint River Basin

County	Deer Density (number/sq mile)
Baker	35
Calhoun	35
Clayton	35
Colquitt	35
Crawford	50
Crisp	35
Decatur	35
Dooly	35
Dougherty	35
Fayette	50
Grady	35
Houston	45
Lamar	50
Lee	35
Macon	35
Marion	35
Mitchell	35
Peach	45
Pike	50
Schley	35
Spaulding	50
Sumter	35
Talbot	50
Terrell	35
Upson	50
Webster	35
Worth	35

Source: Wildlife Resource Division, GA DNR, 2000

Table 8. Estimated Beef Cattle Population in Flint River Basin

HUC	Beef Cattle
31300010401	1,726
31300010402	2,230
31300010403	1,842
31300010404	1,102
31300010501	13
31300010502	821
31300010503	622
31300010504	903
31300010505	1,248
31300010601	1,044
31300010602	880
31300010603	877
31300010604	169
31300010701	802
31300010702	747
31300010703	617
31300010704	241
31300010705	120
31300010801	417
31300010802	433
31300010803	551
31300010804	824
31300010805	755
31300010806	398
31300010807	99
31300010808	507
31300010809	448
31300010901	513
31300010902	779
31300010903	534
31300010904	120
31300010905	434
31300010906	348
31300010907	26
31300011001	1,827
31300011002	1,281
31300011003	49
31300011004	259
31300011101	9
31300011102	40
31300011104	12
31300011105	13
31300011203	107

Source: NRCS, 2000

Table 9. Estimated Agricultural Livestock Populations in the Flint River Basin

County	Livestock						
	Dairy Cattle	Swine	Sheep	Horse	Goats	Chickens Layers	Chickens-Broilers Sold
Baker		400	0	60	300	160018	4071500
Calhoun		450	0	0	300	0	5096000
Clayton		-	0	0	50	0	0
Colquitt	1127	420	25	220	335	0	7763000
Crawford	263	10	0	40	150	0	2380500
Crisp		3400	0	55	500	0	3928000
Decatur		133	0	0	200	0	0
Dooly	320	1100	0	40	250	0	3605700
Dougherty		-	0	400	0	0	0
Fayette		-	50	1000	150	0	0
Grady	1250	3450	50	335	625	117066	2816870
Houston	833	-	0	250	300	0	4618401
Lamar	1200	1000	150	250	450	0	4930000
Lee	1633	-	0	650	0	172	0
Macon	283	175	20	180	50	0	13711000
Marion	283	175	20	180	50	0	5858000
Mitchell	4333	11600	15	610	100	0	31355778
Peach	1217	-	0	400	150	0	0
Pike	433	-	100	400	500	0	6871561
Schley		300	0	0	0	0	2749000
Spaulding	625	700	0	650	100	0	0
Sumter	1585	-	0	300	0	0	6456100
Talbot	362	-	0	134	75	0	0
Terrell		30	20	941	200	0	0
Upson	600	-	60	0	800	0	3510400
Webster		200	0	80	150	0	0
Worth	483	100	0	50	150	0	1963654

Source: NRCS, 2000

3.2.3 Urban Development

Fecal coliform from urban areas are attributable to multiple sources including: domestic animals, leaks and overflows from sanitary sewer systems, illicit discharges of sanitary waste, leaking septic systems, runoff from improper disposal of waste materials, and leachate from operating and closed landfills.

Urban runoff can contain high concentrations of fecal coliform from domestic animals and urban wildlife. Fecal coliform enter streams by direct washoff from the land surface, or the runoff may be diverted to a storm water collection system and discharged through a discrete outlet structure. For larger urban areas (population greater than 100,000), the storm water outlets are regulated under MS4 permits (see Section 3.1.2). For smaller urban areas, the storm water discharge outlets currently remain unregulated.

In addition urban animal sources of fecal coliform, there may be illicit sanitary sewer connections to the storm sewer system. As part of the MS4 permitting program, municipal are required to conduct dry-weather monitoring to identify and then eliminate these illicit discharges. Fecal coliform may also enter streams from leaky sewer pipes or during storm events when the combine sewer overflows discharge.

3.2.3.1 Leaking Septic Systems

Some fecal coliform in the Flint River Basin may be attributed to failure of septic systems and illicit discharges of raw sewage. Table 10 presents the number of septic systems in each county of the Flint River Basin existing in 1990 based on U.S. 1990 Census Data, and the number existing in 2000 based on Georgia Department of Human Resources, Division of Public Health data. In addition, an estimate of the number of septic systems repaired during the ten-year period form 1990 to 2000 is given.

3.2.4.2 Land Application Systems

Many smaller communities use land application systems (LAS) for treatment of their sanitary wastewaters. These facilities are required through LAS permits to treat all their wastewater by land application and have zero discharge. However, runoff during storm events may carry surface residual containing fecal coliform bacteria to nearby streams. Some of these facilities may also exceed the ground percolation rate when applying the wastewater, resulting in surface runoff from the field. If not properly bermed, this runoff, which likely contains fecal coliform bacteria, may discharge to nearby surface waters. There are nineteen permitted LAS systems located in the Flint River Basin and they are listed in Table 11.

3.2.4.3 Landfills

Leachate from landfills may contain fecal coliform bacteria and may at some point discharge into surface waters. Sanitary (or municipal) landfills are the most likely type of landfills to serve as a source of fecal coliform bacteria. These receive household wastes, animal manure, offal, hatchery and poultry processing plant wastes, dead animals, and other types of wastes. Older sanitary landfills were not lined and have been closed. Those that remain active and have not been lined operate as construction/demolition landfills. Currently active sanitary landfills are lined and have leachate collection systems. All landfills, except inert landfills, are now required to install environmental monitoring systems for groundwater sampling and methane. There are 75 known landfills in the Flint River Basin (Table 12). Of these, four are active landfills, and 71 are landfills that are inactive or closed. As shown in the Table 12, many of the older, inactive landfills were never permitted.

Table 10. Number of Septic Systems by County in the Flint River Basin

County	Total Septic Systems	No. of Septic Systems Installed 1990 to 2000	No. of Septic Systems Repaired 1990 to 2000
Baker	1366	1751	150
Calhoun	847	1027	150
Clayton	10658	17408	480
Colquitt	7359	9898	176
Crawford	2714	5247	227
Crisp	3817	6117	80
Decatur	6066	11393	1059
Dooly	1914	2964	30
Dougherty	7412	9537	215
Fayette	12295	19825	3331
Grady	4399	7530	378
Houston	9058	16549	327
Lamar	2714	3252	170
Lee	3938	7968	401
Macon	4898	8477	156
Marion	4898	8477	156
Mitchell	3635	5780	402
Peach	3268	5279	303
Pike	3024	5969	100
Schley	714	1064	15
Spaulding	10243	15553	1579
Sumter	4765	6865	50
Talbot	1917	2742	30
Terrell	1715	4715	330
Upson	5942	9943	26
Webster	715	1015	15
Worth	5044	15018	1250

Source: 1990 Census Data, Georgia Department of Human Resources, Division of Public Health, 2000

Table 11. Permitted Land Application Systems in the Flint River Basin

LAS Name	County	Permit No	Type
Butler LAS	Taylor	GAU020074	Municipal
Cagles, Inc.	Henry	GAU010423	Industrial
Camilla LAS	Mitchell	GAU020088	Municipal
City of Vienna	Dooly	GAU020167	Municipal
City of Vienna	Dooly	GAU020244	Municipal
Clayton Co. Shoal Creek	Clayton	GAU020236	Municipal
Fayette Co. Board of Education	Fayette	GAU030898	Municipal
Hampton Industrial Park	Henry	GAU020125	Municipal
Henry Co. Water & Sewer	Henry	GAU020095	Municipal
Lee Correctional Institution	Lee	GAU020284	Municipal
Masonite Corporation	Crisp	GAU010376	Industrial
Mitchell Co. Board of Commissioners	Mitchell	GAU030740	Municipal
Oak Hill Farms	Lee	GAU010455	Industrial
Progressive Dairies	Macon	GAU010409	Industrial
Southern Mills	Upson	GAU010578	Industrial
Southern Mills Inc.	Fulton	GAU010578	Industrial
Tyson Foods	Macon	GAU010457	Industrial

Source: Permitting and Compliance Program, Environmental Protection Division, GA EPD, 2000

Table 12. Landfills in the Flint River Basin

Name	County	Permit No.	Type	Status
WMI - Rolling Hills	Clayton	031-017d	Sanitary Landfill	Closed
Forest Park - Jones Rd. Ext.	Clayton	031-023d	Dry Trash Landfill	Closed
Forest Park - Jones Rd PH3	Clayton	031-031d	Sanitary Landfill	Closed
Fountain School	Clayton		Municipal Solid Waste Landfill	Active
Forest Park	Clayton	031-012d	Dry Trash Landfill	Ceased Accepting Waste
CR 49 – Roberta	Crawford	039-005d	Sanitary Landfill	Closed
Crawford Co. - Co. Rd. 48 - S, PH.1	Crawford		Sanitary Landfill	Ceased Accepting Waste
Crisp Co. US 41S Site 2	Crisp	040-008d	Municipal Solid Waste Landfill	Ceased Accepting Waste
Cordele - US 41S PH2	Crisp	040-004d	Dry Trash Landfill	Closed
Cordele - US 41S PH2	Crisp	040-002d	Sanitary Landfill	Closed
Cordele	Crisp		Sanitary Landfill	Closed
Arabi	Crisp		Sanitary Landfill	Ceased Accepting Waste
US 41	Dooly	046-001d	Municipal Solid Waste Landfill	Active
CR 101	Dooly	046-006d	Not Applicable	No Record
Vienna	Dooly		Municipal Solid Waste Landfill	Permit Issued
Maple Hill Landfill, Inc.	Dougherty	047-018d	Sanitary Landfill	Closed
Marine Corps Logistics Base	Dougherty	047-012d	Not Applicable	No Record
Oxford Const. Co.	Dougherty	047-011d	Dry Trash Landfill	Closed
Acree Ga. Landfill	Dougherty		Sanitary Landfill	Closed
Blakely - Howell St. - Pitt Rd.	Early	049-002d	Sanitary Landfill	No Record
Damascus	Early		Sanitary Landfill	Ceased Accepting Waste
BFI Roberts Rd. PH2	Fayette	056-012d	Sanitary Landfill	Closed
B.F.I., Inc. Roberts Rd.	Fayette	056-004d	Sanitary Landfill	Closed
Peachtree City	Fayette		Dry Trash Landfill	Closed
No Name	Fayette		Municipal Solid Waste Landfill	Active
No Name	Fayette		Sanitary Landfill	Closed
Fayette Co. - Dixon Bridge Rd.	Fayette		Sanitary Landfill	Closed
B.F.I., Inc. Roberts Rd.	Fayette	056-011d	Sanitary Landfill	No Record
B.F.I., Inc. Roberts Rd.	Fayette	056-008d	Sanitary Landfill	Ceased Accepting Waste
Grove St. Ext. (Old Milner Rd.)	Lamar	085-004d	Sanitary Landfill	Closed
Lamar County - Regional Solid Waste Authority	Lamar	085-007d	Municipal Solid Waste Landfill	Closed
Prison Farm, Jordan Rd.	Lee	088-001d	Sanitary Landfill	Closed
Smithville	Lee		Dry Trash Landfill	Closed
Middle Georgia SMWA Regional	Macon	094-009d	Municipal Solid Waste Landfill	Permit Issued
SR 49N No. 3	Macon	094-005d	Sanitary Landfill	No Record
Macon Co.	Macon		Not Applicable	No Record

Name	County	Permit No.	Type	Status
Macon Co. (Montezuma)	Macon		Not Applicable	No Record
Greenville	Meriwether		Not Applicable	No Record
SR 91	Miller	100-002d	Sanitary Landfill	No Record
Donalsonville - SR 39N	Miller	100-005d	Dry Trash Landfill	No Record
CR 37 - Sheffield	Miller	100-004d	Sanitary Landfill	No Record
Colquitt	Miller		Not Applicable	No Record
Donalsonville Rd.	Miller		Not Applicable	No Record
Boykin	Miller		Not Applicable	No Record
Mitchell Co S1643	Mitchell	101-002d	Sanitary Landfill	No Record
Mitchell County SR 3a	Mitchell	101-004d	Sanitary Landfill	No Record
County Farm Rd.	Pike	114-007d	Sanitary Landfill	No Record
County Farm Rd.	Pike	114-009d	Dry Trash Landfill	No Record
Meansville	Pike		Not Applicable	No Record
Molena	Pike		Not Applicable	No Record
SR 26 E PH1	Schley	123-002d	Sanitary Landfill	No Record
Ellaville	Schley		Not Applicable	No Record
Donalsonville	Seminole		Not Applicable	No Record
Andersonville - Freeman St.	Sumter	129-010d	Dry Trash Landfill	No Record
Andersonville (City)	Sumter		Not Applicable	No Record
Andersonville (County)	Sumter		Not Applicable	No Record
So. Ga. Tech. & Voc. School	Sumter		Not Applicable	No Record
District Rd. (County)	Sumter		Not Applicable	No Record
Plains	Sumter		Not Applicable	No Record
Dominy Branch (County)	Sumter		Not Applicable	No Record
New Era (County)	Sumter		Not Applicable	No Record
Steel Bridge Rd. (County)	Sumter		Not Applicable	No Record
Andersonville - Freeman St.	Sumter	129-001d	Sanitary Landfill	No Record
Allied Services, LLC Sr90/Sr137 Charring	Taylor	133-003d	Municipal Solid Waste Landfill	No Record
SR 137 N Butler	Taylor	133-002d	Sanitary Landfill	No Record
Reynolds	Taylor		Not Applicable	No Record
Terrell Co. Us 82 E Dawson	Terrell	135-005d	Not Applicable	No Record
City Of Dawson Sanitary Landfill	Terrell	135-004D	Sanitary Landfill	No Record
Kersey - Firetower Rd./Jeff Davis Rd.	Upson	145-007d	Dry Trash Landfill	No Record
Thomaston - Zorn St. PH2&3	Upson	145-005d	Sanitary Landfill	No Record
Yatesville Rd.	Upson		Not Applicable	No Record
Upson Co. - Zorn St., Thomaston	Upson	145-003d	Sanitary Landfill	No Record
Kendrick - Waymonville Rd.	Upson		Not Applicable	No Record
Webster Co. SR 41 Reston	Webster	152-001d	Sanitary Landfill	No Record
Preston	Webster		Not Applicable	No Record

Source: Land Protection Branch, GA DNR, 1999

4.0 ANALYTICAL APPROACH

The process of developing fecal coliform TMDLs for the Flint River Basin listed segments includes the determination of the following:

- The current critical fecal coliform load to the stream under current conditions;
- The TMDL for similar conditions under which the current load was determined; and
- The percent reduction in the current critical fecal coliform load necessary to achieve the TMDL.

The calculation of the fecal coliform load at any point in a stream requires the fecal coliform concentration and stream flow. The availability of water quality and flow data varies considerably among the listed segments. A discussion of the available monitoring data was presented in Section 2.0. For the majority of listed segments, fecal coliform sampling data were sufficient to calculate at least one 30-day geometric mean to compare with the regulatory criteria (see Appendix A). Fecal coliform data for the remaining segments were limited (see Appendix B). Depending on the nature and availability of water quality data, different approaches were used to determine the current critical loads and TMDLs for the listed segments. These different approaches are outlined below.

4.1 Loading Curve Approach

For those segments in which sufficient water quality data were collected to calculate at least one 30-day geometric mean that was above the regulatory standard, the loading curve approach was used. The method involves comparing the current critical load to summer and winter seasonal TMDL curves.

As mentioned in Section 2.0, the USGS monitored many of the listed segments and collected stream flow information concurrently with water quality samples. Stream depths were measured and used to determine stream flows, based on rating curves developed by the USGS for each sampling location.

In cases where no stream flow measurements were available, flow on the day the fecal coliform samples were collected was estimated using data from a nearby gaged stream. The nearby stream had to have relatively similar watershed characteristics, including landuse, slope, and drainage area. The stream flows were estimated by multiplying the gaged flow by the ratio of the listed stream drainage area to the gaged stream drainage area. Table 13 listed those segments in which no flow data was available and the gaged station that was used to estimate the flow. If a gage stream was available within the same watershed, it was used.

The current critical loads were determined using fecal coliform data collected within a 30-day period to calculated the geometric means, and multiplying these values by the arithmetic mean of the flows measured at the time the water quality samples were collected. Georgia's instream fecal coliform standards are based on a geometric mean of samples collected over a 30-day period, each samples is at least 24 hours apart. To reflect this in the load calculation, the fecal coliform loads are expressed as 30-day accumulation loads with units of counts per 30 days. This is described by the equation below:

$$L_{critical} = C_{geomean} * Q_{mean}$$

Table 13. Monitoring Stations with No Flow Data and USGS Gaging Stations used to Estimate the Flow

Stream Name	USGS Station Name	Station No.
Flint River - Hartsfield Airport to Hwy 138	Flint River near Lovejoy, GA	02334350
Fowltown Creek	Mucalee Creek near Leesburger, GA	02351890
Lanahassee Creek	Kinchafoonee Creek At Hwy 41 near Preston, GA	02350600
Muckaloochee Creek	Mucalee Creek near Leesburger, GA	02351890
Mud Creek	Flint River near Lovejoy, GA	02334350
Sullivan Creek	Flint River near Lovejoy, GA	02334350
Tributary to Flint River	Flint River near Lovejoy, GA	02334350

Where:
$L_{critical}$ = current critical fecal coliform load
$C_{geomean}$= fecal coliform concentration as a30-day geometric mean
Q_{mean} = stream flow as arithmetic mean

The current critical load is dependent on the fecal coliform concentrations and stream flows measured during the sampling events. The number of events sampled is usually 16 events per year. Thus, it does not represent the full range of flow conditions or loading rates that can occur. Therefore, it must be kept in mind that the current critical loads used only represent the worst-case scenario that the occurred during the time periods sampled.

The maximum fecal load at which the instream fecal coliform criteria will be met can be determined using a variation of the equation above. By setting C equal to the seasonal instream fecal coliform standards, the load will equal the TMDL. However, the TMDL is dependent on stream flow. Figures in Appendix A graphically illustrates that the TMDL is a continuum for the range of flows (Q) that can occur in the stream over time. There are two TMDL lines. One representing the summer TMDL for the period from May through October when the 30-day geometric mean standard is 200 counts/ 100 mL. The second line represents the winter TMDL for the period from November through April when the 30-day geometric mean standard is 1000 counts/ 100 mL. The equations for these two TMDL lines are given below.

$$TMDL_{summer} = 200 \text{ counts (as a 30-day geometric mean)/100 mL} * Q$$

$$TMDL_{winter} = 1000 \text{ counts (as a 30-day geometric mean)/100 mL} * Q$$

The graph shows the relationship between the current critical load ($L_{critical}$) and the TMDL. The TMDL for a given stream segment is the load for the mean flow corresponding to the current critical load. This is the point where the current load most exceeds the TMDL curve. This critical TMDL can be represented by the following equation:

$$TMDL_{critical} = C_{standard} * Q_{mean}$$

Where:
$TMDL_{critical}$ = critical fecal coliform TMDL load
$C_{standard}$ = seasonal fecal coliform standard as 30-day geometric mean
summer - 200 counts/100 mL
winter - 1000 counts/ 100 mL
Q_{mean} = stream flow as arithmetic mean (same as used for $L_{critical}$)

A 30-day geometric mean load that plots above the respective seasonal TMDL curve, represents an exceedance of the instream fecal coliform standard. The difference between the current critical load and the TMDL curve represents the load reduction required for the stream segment to meet the appropriate instream fecal coliform standard. The load reduction can thus be expressed as follows:

$$\text{Load Reduction} = \frac{L_{critical} - TMDL_{critical}}{L_{critical}} * 100$$

4.2 Equivalent Site Approach

TMDLs must be developed for a number of listed segments for which sufficient data are not available to calculate the 30-day geometric mean fecal coliform concentrations. Although there may be sampling data for many of these streams, there are not enough data within a 30-day period to directly calculate geometric means. Therefore, an equivalent site approach is used to estimate the current and TMDL loads. This approach involves calculating loads for the stream segments that lack sufficient data based on a relationship to other, similar, equivalent site(s) that have data. This method provides estimates that can be refined in the future as additional data are collected.

Development of loads using the equivalent site approach addresses three key issues:

1. Site-specific monitoring data should be used, even if it is insufficient for direct estimation of geometric means. The site-specific and equivalent site monitoring data should be combined in a weighted approach that reflects the relative accuracy of information provided by each data source.

2. Equivalent site selection has a potential impact on the resulting load estimates. In the case where a TMDL has already been prepared for a downstream segment within the same watershed, the equivalent site selection is obvious. For other segments, multiple sites within the same general region may be available for use.

3. Different landuses result in different fecal coliform concentrations. An equivalent site with a perfect landuse match is unlikely to be available. Differences in landuses among watersheds should be addressed through use of a regionalization model that identifies the extent to which variability in fecal coliform concentrations can be explained by changes in landuse.

In translating data from an equivalent site to a listed segment, it is important to account for changes in fecal coliform runoff concentrations associated with different landuses, and for changes in flow associated with different drainage areas. The critical load at site *i* can be estimated in relations to the calculated critical loads at other sites using the following equation:

$$\text{Load}_{\text{critical}} = \frac{1}{n}\sum_{j=1}^{n}\left[A_{ij}\cdot C_j \cdot Q_{crit,j}\cdot\frac{DA_i}{DA_j}\right]$$

Where:

$L_{critical}$ = estimated critical fecal coliform load) at site *i*
n = number of equivalent sites
A_{ij} = translation factor
C_j = fecal coliform concentration as 30-day geometric mean at site(s) *j*
Q_j = stream flow as arithmetic mean at site(s) *j*
DA_i = drainage area above site *i*
DA_j = drainage area above site *j*

The A_{ij} factor relates the geometric mean fecal coliform concentration at site *i* to that at site(s) *j*. It is expressed in log space, since a geometric mean is used. It is expected that this factor will vary with landuse, but may exhibit strong site-specific characteristics. For example, a given site might exhibit higher fecal coliform concentrations relative to an equivalent site than are expected from land use differences alone.

A method is needed that provides an appropriate weighing between limited site-specific data and a landuse based regression of equivalent sites. An empirical Bayes analysis is the mathematical technique ideally suited for this circumstance. This analysis combines two important concepts: maximum likelihood techniques for combining data sources, and hierarchical regionalization techniques. The data combination step assumes that both equivalent site data and site-specific data provide information the true local geometric mean. The two data sources are weighted in accordance with their degree of precision or accuracy. The regionalization step assumes that the true mean at any site is a result of random variability and a regional regression model on land use. Empirical Bayes techniques provide statistically optimal methods for computing both the data combination and regionalization steps from observed data.

In the empirical Bayes analysis, it is assumed that the long-term geometric mean fecal coliform concentration at a given site is a function of watershed landuse and site-specific factors that are represented by random noise. A sample realization of the geometric mean at site *i*, X_i, is assumed to be normally distributed about a true mean Θ_i, with standard error of the estimate given by σ_ι. In statistical notation:

$$X_i \sim N(\Theta_i, \sigma_\iota^2)$$

The desired translation factor is then: $A_c = \Theta_I / \Theta_j$. Full technical details on the implementation of the empirical Bayes approach are provided in Appendix C. Table 14 list the equivalent sites used for the listed segments that did not have sufficient data to calculate a 30-day geometric mean.

The estimated TMDL for the stream segments with insufficient data can be calculated using the following equation:

$$TMDL = \frac{1}{n}\sum_{j=1}^{n}\left[C_{s\tan dard} \bullet Q_j \bullet \frac{DA_i}{DA_j}\right]$$

Where:
TMDL = fecal coliform TMDL load at site *i*
n = number of equivalent sites
$C_{standard}$ = seasonal fecal coliform standard as 30-day geometric mean
summer - 200 counts/100 mL
winter - 1000 counts/ 100 mL *j*
Q_j = stream flow as arithmetic mean at site(s) *j* (cfs)
DA_i = drainage area above site *i* (acres)
DA_j = drainage area above site *j* (acres)

Table 14. List of Equivalent Sites

Site	Equivalent Sites
Big Slough	Pataula Creek
Turkey Creek	New River Crawfish Creek Mobley Creek

The DA_i / DA_j ratio, as mentioned in the previous section, adjusts the flow from site *j* to site *i*. In the case where flow data are available, the actual arithmetic mean flow associated with the estimated 30-day geometric mean fecal coliform concentration can be used.

As in the loading curve approach, the estimated percent load reduction needed at site *i* can be expressed as follows:

$$\text{Load Reduction} = \frac{L_{critical} - TMDL}{L_{critical}} * 100$$

5.0 TOTAL MAXIMUM DAILY LOAD

A Total Maximum Daily Load (TMDL) is the amount of a pollutant that can be assimilated by the receiving waterbody without exceeding the applicable water quality standard; in this case the seasonal fecal coliform standards. A TMDL is the sum of the individual waste load allocations (WLAs) and load allocations (LAs) for nonpoint sources and natural background (40 CFR 130.2) for a given waterbody. The TMDL must also include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the water quality response of the receiving water body. TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measures. For fecal coliform bacteria, the TMDLs are expressed as counts per 30 days as a geometric mean.

A TMDL is expressed as follows:

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

The TMDL calculates the WLAs and LAs with margins of safety to meet the stream's water quality standards. The allocations are based on estimates that use the best available data and provide the basis to establish or modify existing controls so that water quality standards can be achieved. In developing a TMDL, it is important to consider if adequate data is available to identify the sources, fate, and transport of the pollutant to be controlled.

TMDLs may be developed using a phased approach. Under a phased approach, the TMDL includes: 1) WLAs that confirm existing limits and controls or lead to new limits and 2) LAs that confirm existing controls or include implementing new controls (EPA TMDL Guidelines). A phased TMDL requires additional data be collected to determine if load reductions required by the TMDL lead to the attainment of water quality standards.

The TMDL Implementation Plan will establishes a schedule or timetable for the installation and evaluation of point and nonpoint source control measures, data collection, assessment of water quality standard attainment, and if needed, additional modeling. Future monitoring of the listed segment water quality will then be used to evaluate this phase of the TMDL, and if necessary reallocate the loads.

The fecal coliform loads calculated for each listed stream segment include the sum of the total loads from all point and nonpoint sources for the segment. The load contributions to the listed segment from unlisted upstream segments are represented in the background loads, unless the unlisted segment contained point sources that had permit violations for fecal coliform. In these cases, the upstream point sources are included in the wasteload allocations for the listed segment. In cases where two or more adjacent segments are listed, the fecal coliform loads to each segment are individually evaluated on a localized watershed basis. Point source loads originating in upstream segments are included in the background loads of the downstream segment. The following sections describe the various fecal coliform TMDL components.

5.1 Waste Load Allocations

The waste load allocation is the portion of the receiving water's loading capacity that is allocated to existing or future point sources. Waste load allocations (WLA) are provided to the point sources from municipal and industrial wastewater treatment systems that have NPDES effluent limits. There are 8 active NPDES permitted facilities with fecal coliform permit limits in the Flint River Basin watershed that discharge into listed segments. The maximum allocated fecal coliform loads for these municipal wastewater treatment facilities facilities are given in Table 15. The WLA loads were calculated based on the permitted or design flows and average monthly permitted fecal coliform concentrations or a fecal coliform concentration of 200 counts/ 100 mL (as a geometric mean). If a facility expands its capacity and the permitted flow increases, the wasteload allocation for the facility would increase in proportion to the flow. These were expressed as accumulated loads over a 30-day period, presented as units of counts per 30 days.

Table 15. WLA for Flint River Basin

Facility Name	Permit No.	Receiving Stream	Listed Watershed	WLA
Byromville Pond	GA0025623	Turkey Creek	Turkey Creek	2.37E+10
Camilla WPCP	GA0020362	Big Slough Creek	Big Slough	Plant closed
Concord South #1	GA0025470	Elkins Creek	Elkins Creek	2.28E+11
Cordele WPCP	GA0024503	Gum Creek	Gum Creek	1.14E+12
Griffin Potato Cr WPCP	GA0030791	Potato Creek	Potato Creek	4.55E+11
Hampton WPCP	GA0020320	Bear Creek	Flint River - SR1058	4.55E+11
Marshallville WPCP	GA0047431	Spring Hill Creek	Beaver Creek - Spring Hill	2.73E+10
Smithville Pond	GA0047422	Muckaloochee Creek	Muckaloochee Creek	2.73E+10
South Hampton MHP	GA0025305	Unnamed Trib To Thomason Creek	Flint River - SR1058	2.28+10

State and Federal Rules define storm water discharges covered by NPDES permits as point sources. However, storm water discharges are from diffuse sources and there are multiple storm water outfalls. Storm water sources (point and nonpoint) are different than traditional NPDES permitted sources in four respects: (1) they do not produce a continuous (pollutant loading) discharge; (2) their pollutant loading depends on the intensity, duration, and frequency of rainfall events, over which the permittee has no control; (3) the activities contributing to the pollutant loading may include various allowable activities of others, and control of these activities is not solely within the discretion of the permittee; and (4) they do not have wastewater treatment plants that control specific pollutants to meet numerical limits.

The intent of storm water NPDES permits is not to treat the water after collection, but to reduce the exposure of storm water to pollutants by implementing various controls. It would be infeasible and prohibitively expensive to try to control pollutant discharges from each storm water outfall. Therefore, storm water NPDES permits require the establishment of controls or BMPs to reduce pollutants entering the environment.

The waste load allocations from storm water discharges associated with MS4s (WLAsw) are estimated based on the percentage of urban landuse in each watershed covered by the MS4 storm water permit. At this time, the portion of each watershed that goes directly to the permitted storm sewer and that goes through non-permitted point sources or is sheet flow or agricultural runoff has not been clearly defined. Thus, it is assumed that approximately 70 percent of the storm water runoff from the regulated urban area is collected by the municipal separate storm sewer systems.

There are twenty permitted CAFOs in the Flint River Basin. These facilities have no discharge. Therefore, they are not provided a WLA.

This TMDL will use an iterative approach. Future phases of the TMDL development will attempt to further define the sources of pollutants and the portion that enters the permitted storm sewer systems. As more information is collected and these TMDLs are implemented, it will become clearer, which BMPs are needed, and how the water quality standards can be achieved.

5.2 Load Allocations

The load allocation (LA) is the portion of the receiving water's loading capacity that is attributed to existing or future nonpoint sources or to natural background sources. Nonpoint sources are identified in 40 CFR 130.6 as follows:

- Residual waste
- Land disposal
- Agricultural and silvicultural
- Mines
- Construction
- Saltwater intrusion
- Urban storm water (non-permitted)

The LA is calculated as the remaining portion of the TMDL load available after allocating the WLA and the MOS and was determined by the following equation:

$$\Sigma \text{LA} = \text{TMDL} - (\Sigma \text{WLA} + \Sigma \text{WLAsw} + \Sigma \text{MOS})$$

As described above, there are two types of load allocations: loads to the stream independent of precipitation including sources such as failing septic systems, leachate from landfills, animals in the stream, and leaking sewer system collection lines or background loads; and loads associated with fecal coliform accumulation on land surfaces that is washed off during storm events including runoff from saturated LAS fields. At this time, it is not possible to partition of the various sources of load allocations. Table 16 presents the total load allocation expressed as counts per 30 days for the 303(d) listed streams located in the Flint River Basin for the current critical condition. In the future, with additional data, it may be possible to partition the load allocation by source.

Evaluation of the relationship between in-stream water quality and the potential sources of pollutant loading is an important component of TMDL development, and is the basis for later implementation of corrective measures and BMPs. For the current TMDLs, the association between fecal coliform loads and the potential sources occurring within the subwatersheds of each segment was examined on a qualitative basis. The most probable sources were identified in Section 3.0.

5.3 Seasonal Variation

The Georgia fecal coliform criteria are seasonal. One set applies to the summer season, while a different set applies to the winter season. To account for seasonal variations, the critical loads for each listed segment were determined from sampling data obtained during both summer and winter seasons, when possible. However, in some cases, the available data was limited to a single season for the calculation of the critical load. The TMDL and percent reduction given in Table 16 for each listed segment was based on the season in which the critical load occurred. The TMDLs for each season, for any given flow, are presented as equations in Section 5.5.

Analyses of the available fecal coliform data and corresponding flows were performed to determine if the fecal coliform violations occurred during wet weather (high flow) or dry weather (low flow) conditions. The flow data from each sampling site were normalized by dividing the measured flow by the product of the average annual runoff (cfs/ sq mile), published in Open-File Report 82-577, and the appropriate drainage area (Carter, 1982). Plots of the normalized flows (Q/Qo) versus fecal coliform are shown in Appendix D. The plots do not show a consistent relationship between fecal coliform concentrations and flow. The summer and winter plots show that the fecal coliform violations occur during both high (wet weather) and low (dry weather) flow conditions.

5.4 Margin of Safety

The MOS is a required component of TMDL development. There are two basic methods for incorporating the MOS: 1) Implicitly incorporate the MOS using conservative assumptions to develop allocations; or 2) Explicitly specify a portion of the TMDL as the MOS and using the remainder for allocations. For this TMDL, an explicit MOS of 10 percent of the TMDL was use. The MOS values are presented in Table 16.

5.5 Total Fecal Coliform Load

The fecal coliform TMDL for the listed stream segment is dependent on the time of year and the stream flow. The maximum seasonal fecal loads are given below.

$$TMDL_{summer} = 200 \text{ counts (as a 30-day geometric mean)/100 mL} * Q$$

$$TMDL_{winter} = 1000 \text{ counts (as a 30-day geometric mean)/100 mL} * Q$$

For purposes of determining necessary load reductions required to meet the instream water quality criteria, the current critical TMDL was determined. This load is the product of the applicable seasonal fecal coliform standard and the mean flow used to calculate the current critical load. It represents the sum of the allocated loads from point and nonpoint sources located within the immediate drainage area of the listed segment, the NPDES-permitted point discharges with recorded fecal coliform violations from the nearest upstream subwatersheds, and a margin of safety (MOS). The current critical loads and corresponding TMDLs, WLAs, LAs, MOSs, and percent load reductions for the Flint River Basin 303(d) listed streams are presented in Table 16.

The relationships of the current critical loads to the current critical TMDLs are shown graphically in Appendix A. The vertical distance between the two values represents the load reductions necessary to achieve the TMDLs. As a consequence of the localized nature of the load evaluations, the calculated fecal load reductions pertain to point and nonpoint sources occurring within the immediate drainage area of the listed segment. These current critical values represent a worst-case scenario for the limited set of data. Thus, the load reductions required are conservative estimates, and should be sufficient to prevent exceedances of the instream fecal coliform standard for a wide range of conditions.

Table 16. Fecal Loads and Required Fecal Load Reductions

Stream Segment	Current Load (cnts/30 days)	TMDL Components					Percent Reduction
		WLA (cnts/30 days)	WLAsw (cnts/30 days)	LA (cnts/30 days)	MOS (cnts/30 days)	TMDL (cnts/30 days)	
Beaver Creek	2.46E+13	9.97E+09		2.30E+12	2.57E+11	2.57E+12	90%
Bell Creek	1.54E+11			8.32E+10	9.24E+09	9.24E+10	40%
Big Slough	4.64E+12	Plant closed		3.98E+12	4.43E+11	4.43E+12	5%
Camp Creek	8.18E+11		1.54E+11	3.38E+11	5.46E+10	5.46E+11	33%
Cooleewahee Creek	2.36E+11			1.21E+11	1.34E+10	1.34E+11	43%
Elkins Creek	2.85E+12	0.00E+00		1.68E+12	1.87E+11	1.87E+12	34%
Flint River - Upstream Hartsfield Airport	2.91E+12		1.07E+12	7.70E+11	2.04E+11	2.04E+12	30%
Flint River - Hartsfield Airport to Hwy 138	3.57E+12		1.23E+12	8.38E+11	2.30E+11	2.3E+12	36%
Flint River - Hwy 138 to N. Hampton Road	3.16E+12		5.69E+11	1.50E+12	2.30E+11	2.3E+12	27%
Flint River - Woolsey Rd. to Horton Creek	7.02E+12	8.65E+10	8.61E+11	4.62E+12	6.19E+11	6.19E+12	12%
Fowltown Creek	4.74E+13			1.65E+13	1.83E+12	1.83E+13	61%
Gum Creek	2.83E+12	3.78E+11		9.72E+11	1.50E+11	1.5E+12	47%
Lanahassee Creek	3.13E+12			1.33E+12	1.48E+11	1.48E+12	53%
Lime Creek	1.15E+12			8.75E+11	9.72E+10	9.72E+11	15%
Muckaloochee Creek	1.81E+12	9.10E+09		5.65E+11	6.38E+10	6.38E+11	65%
Mud Creek	7.28E+13		5.32+12	3.13E+12	9.39E+11	9.39E+12	87%
Patsiliga Creek	3.24E+12			1.92E+12	2.13E+11	2.13E+12	34%
Potato Creek	3.46E+12	2.74E+11		5.91E+11	9.61E+10	9.61E+11	72%
Red Oak Creek	3.58E+12			1.78E+12	1.98E+11	1.98E+12	45%
Sullivan Creek	2.43E+12		2.67E+11	1.54E+11	4.67E+10	4.67E+11	81%
Swift Creek - Tobler Creek to Flint River	1.06E+12			7.50E+11	8.33E+10	8.33E+11	21%
Swift Creek -U/S Lake Blackshear	1.46E+12			6.84E+11	7.60E+10	7.6E+11	48%
Tributary to Flint River	8.67E+12		1.70E+11	1.23E+11	3.26E+10	3.26E+11	96%
Turkey Creek	1.78E+12	3.30E+09		5.21E+11	5.83E+10	5.83E+11	67%
Ulcohatchee Creek	1.36E+11			1.21E+11	1.34E+10	1.34E+11	1%
Whitewater Creek - Big Whitewater Creek to Cedar Creek	2.5E+13			1.25E+13	1.39E+12	1.39E+13	44%
Whitewater Creek -Cedar Creek to Flint River	3.78E+13			3.38E+13	3.75E+12	3.75E+13	1%
Wildcat Creek	8.23E+11			3.19E+11	3.54E+10	3.54E+11	57%

6.0 RECOMMENDATIONS

The TMDL process consists of an evaluation of the 303(d) listed stream segments subwatersheds to identify, as best as possible, the sources of the fecal coliform loads causing the stream to exceed instream standard criteria. The TMDL analysis was performed using the best available data to specify WLAs and LAs that will meet fecal coliform water quality criteria so as to support the use classification specified for each listed segments.

This TMDL represents the first phase of a long-term process to reduce fecal coliform loading to meet water quality standards in the Flint River Basin. Implementation strategies will be reviewed and the TMDLs will be refined as necessary in the next phase (next five-year cycle). The phased approach will support progress toward water quality standards attainment in the future. In accordance with USEPA TMDL guidance, these TMDLs may be revised based on results of future monitoring and source characterization data efforts The following recommendations target further source identification and involve the collection of data to support the current allocations and subsequent source reductions.

6.1 Monitoring

Water quality monitoring is conducted at a number of locations across the State each year. GAEPD has adopted a basin approach to water quality management that divides Georgia's major river basins into five groups. This approach provides for additional sampling work to be focused on one of the five basin groups each year and offers a five-year planning and assessment cycle. The Chattahoochee and Flint River Basins were the subjects of focused monitoring in 2000 and will again receive focused monitoring in 2005.

The TMDL Implementation Plan will outline an appropriate water-quality sampling program for the listed streams in the Flint River Basin. The monitoring program will be developed to help identify the various fecal coliform sources. The sampling program will be used to verify the 303(d) stream segment listings. This will be especially valuable for those segments where no data, old data, or spill data resulted in the listing. In addition, scheduled quarterly geometric mean sampling will be performed to evaluate 303(d) listed waters and determine if there has been improvement in the water quality of the listed stream segments.

6.2 Fecal coliform Management Practices

Based on the findings of the source assessment, NPDES point fecal coliform loads from wastewater treatment facilities do not significantly contribute to the impairment of the listed stream segments. This is because discharges from these facilities are required to treat to levels corresponding to instream water quality criteria. Fecal coliform loads from NPDES permitted MS4 areas may be significant. But these sources cannot be easily segregated from other storm water runoff. Other sources of fecal coliform in urban areas include wastes are attributable to domestic animals, leaks and overflows from sanitary sewer systems, illicit discharges of sanitary waste, leaking septic systems, runoff from improper disposal of waste materials, and leachate from operating and closed landfills. In agricultural areas, potential sources of fecal coliform may include CAFOs; animals grazing in pastures; dry manure storage facilities and lagoons; chicken litter storage areas, and direct access of livestock to streams. Wildlife and waterfowl can be an important source of fecal coliform bacteria.

Management practices are recommended to reduce fecal coliform source loads to the listed 303(d) stream segments, with the result of achieving the instream fecal coliform standard criteria. These recommended management practices include:

- Compliance with NPDES permit limits and requirements
- Adoption of NRCS Conservation Practices
- Application of Best Management Practices (BMPs) appropriate to agricultural or urban land uses, whichever applies.

6.2.1 Point Source Approaches

Point sources are defined as discharges of treated wastewater or storm water into rivers and streams at discrete locations. The NPDES permit program provides a basis for municipal, industrial and storm water permits, monitoring and compliance with limitations, and appropriate enforcement actions for violations.

In accordance with GAEPD rules and regulations, all discharges from point source facilities are required to be in compliance with the conditions of their NPDES permit at all times. In the future, all municipal and industrial wastewater treatment facilities with the potential for the occurrence of fecal coliform in their discharge will be given end-of-pipe limits equivalent to the water quality standard of 200 counts/100 ml or less.

6.2.2 Nonpoint Source Approaches

The Georgia EPD is responsible for administering and enforcing laws to protect the waters of the State. EPD is the lead agency for implementing the State's Nonpoint Source Management Program. Regulatory responsibilities that have a bearing on nonpoint source pollution include establishing water quality standards and use classifications, assessing and reporting water quality conditions, and regulating land-use activities, which may affect water quality. Georgia is working with local governments, agricultural, and forestry agencies such as the Natural Resources Conservation Service, the Georgia Soil and Water Conservation Commission, and the Georgia Forestry Commission to foster the implementation of Best Management Practices (BMPs) that address nonpoint source pollution. In addition, public education efforts are being targeted to individual stakeholders to provide information regarding the use of BMPs to protect water quality. The following sections describe, in more detail, recommendations to reduce nonpoint source loads of fecal coliform bacteria in Georgia's surface waters.

6.2.2.1 Agricultural Sources

The Georgia Environmental Protection Division (EPD) should coordinate with other agencies that are responsible for agricultural activities in the state to address issues concerning fecal coliform loading from agricultural lands. It is recommended that information (e.g., livestock populations by subwatershed, animal access to streams, manure storage and application practices, etc.) be periodically reviewed so that watershed evaluations can be updated to reflect current conditions. It is also recommended that BMPs be utilized to reduce the amount of fecal coliform bacteria transported to surface waters from agricultural sources to the maximum extent practicable.

The following three organizations have primary responsibility for working with farmers to promote soil and water conservation, and to protect water quality:

- The University of Georgia - Cooperative Extension Service
- Georgia Soil and Water Conservation Commission
- Natural Resources Conservation Service

The University of Georgia (UGA) has faculty, County Cooperative Extension Agents, and technical specialists who provide services in several key areas relating to agricultural impacts on water quality.

The Georgia EPD designated the GSWCC as the lead agency for agricultural Nonpoint Source Management in the State. The GSWCC develops nonpoint source management programs and conducts educational activities to promote conservation and protection of land and water devoted to agricultural uses.

The Natural Resources Conservation Service (NRCS) works with Federal, State, and local governments to provide financial and technical assistance to farmers. NRCS develops standards and specifications for BMPs that are to be used to improve, protect, or maintain our State's natural resources. In addition, every five years, the NRCS conducts the National Resources Inventory (NRI). The NRI is a statistically based sample of land use and natural resource conditions and trends that covers non-federal land in the United States.

NRCS is also providing technical assistance to the GSWCC and the Georgia Environmental Protection Division with the Georgia River Basin Planning Program. Planning activities associated with this program will describe conditions of the agricultural natural resource base once every five years. It is recommended that the GSWCC and the NRCS continue to encourage BMP implementation, education efforts, and river basin surveys with regard to River Basin Planning.

6.2.2.2 Urban Sources

Both point and nonpoint sources of fecal coliform bacteria can be significant in the Flint River Basin urban areas. Urban sources of fecal coliform can best be addressed using a strategy that involves public participation and intergovernmental coordination to reduce the discharge of pollutants to the maximum extent practicable. Management practices, control techniques, public education, and other appropriate methods and provisions may be employed. In addition to water quality monitoring programs, discussed in Section 6.1, the following activities and programs conducted by cities, counties, and state agencies are recommended:

- Uphold requirements that all new and replacement sanitary sewage systems be designed to minimize discharges from the system into storm sewer systems;

- Further develop and streamline mechanisms for reporting and correcting illicit connections, breaks, surcharges, and general sanitary sewer system problems;

- Sustained compliance with storm water NPDES permit requirements.

- Continue efforts to increase public awareness and education towards the impact of mans activities in urban settings on water quality, ranging from the consequences of industrial and municipal discharges down to activities of the individual in residential neighborhoods.

6.3 Reasonable Assurance

Permitted discharges will be regulated through the NPDES permitting process described in this report. Georgia is working federal and state agencies such as the NRCS and the GSWCC, and with local governments to foster the implementation of best management practices to address nonpoint sources. In addition, public education efforts will be targeted to individual stakeholders to provide information regarding the use of best management practices to protect water quality.

6.4 Public Participation

A thirty-day public notice was provided for this TMDL. During this time the availability of the TMDL was public noticed, a copy of the TMDL was provided as requested, and the public was invited to provide comments on the TMDL.

7.0 INITIAL TMDL IMPLEMENTATION PLAN

EPD has coordinated with EPA to prepare this Initial TMDL Implementation Plan for this TMDL. EPD has also established a plan and schedule for development of a more comprehensive implementation plan after this TMDL is established. EPD and EPA have executed a Memorandum of Understanding that documents the schedule for developing the more comprehensive plans. This Initial TMDL Implementation Plan includes a list of best management practices and provides for an initial implementation demonstration project to address one of the major sources of pollutants identified in this TMDL while State and/or local agencies work with local stakeholders to develop a revised TMDL implementation plan. It also includes a process whereby EPD and/or Regional Development Centers (RDCs) or other EPD contractors (hereinafter, "EPD Contractors") will develop expanded plans (hereinafter, "Revised TMDL Implementation Plans").

This Initial TMDL Implementation Plan, written by EPD and for which EPD and/or the EPD Contractor are responsible, contains the following elements.

1. EPA has identified a number of management strategies for the control of nonpoint sources of pollutants, representing some best management practices. The "Management Measure Selector Table" shown below identifies these management strategies by source category and pollutant. Nonpoint sources are the primary cause of excessive pollutant loading in most cases. Any wasteload allocations for wastewater treatment plant facilities will be implemented in the form of water-quality based effluent limitations in NPDES permits. Any wasteload allocations for regulated storm water will be implemented in the form of best management practices in the NPDES permits. NPDES permit discharges are a secondary source of excessive pollutant loading, where they are a factor, in most cases.

2. EPD and the EPD Contractor will select and implement one or more best management practice (BMP) demonstration projects for each River Basin. The purpose of the demonstration projects will be to evaluate by River Basin and pollutant parameter the site-specific effectiveness of one or more of the BMPs chosen. EPD intends that the BMP demonstration project be completed before the Revised TMDL Implementation Plan is issued. The BMP demonstration project will address the major category of contribution of the pollutant(s) of concern for the respective River Basin as identified in the TMDLs of the watersheds in the River Basin. The demonstration project need not be of a large scale, and may consist of one or more measures from the Table or equivalent BMP measures proposed by the EPD Contractor and approved by EPD. Other such measures may include those found in EPA's "Best Management Practices Handbook", the "NRCS National Handbook of Conservation Practices, or any similar reference, or measures that the volunteers, etc., devise that EPD approves. If for any reason the EPD Contractor does not complete the BMP demonstration project, EPD will take responsibility for doing so.

3. As part of the Initial TMDL Implementation Plan the EPD brochure entitled "Watershed Wisdom -- Georgia's TMDL Program" will be distributed by EPD to the EPD Contractor for use with appropriate stakeholders for this TMDL, and a copy of the video of that same title will be provided to the EPD Contractor for its

use in making presentations to appropriate stakeholders, on TMDL Implementation plan development.

4. If for any reason an EPD Contractor does not complete one or more elements of a Revised TMDL Implementation Plan, EPD will be responsible for getting that (those) element(s) completed, either directly or through another contractor.

5. The deadline for development of a Revised TMDL Implementation Plan, is the end of August, 2004.

6. The EPD Contractor helping to develop the Revised TMDL Implementation Plan, in coordination with EPD, will work on the following tasks involved in converting the Initial TMDL Implementation Plan to a Revised TMDL Implementation Plan:
   A. Generally characterize the watershed;
   B. Identify stakeholders;
   C. Verify the present problem to the extent feasible and appropriate, (e.g., local monitoring);
   D. Identify probable sources of pollutant(s);
   E. For the purpose of assisting in the implementation of the load allocations of this TMDL, identify potential regulatory or voluntary actions to control pollutant(s) from the relevant nonpoint sources;
   F. Determine measurable milestones of progress;
   G. Develop monitoring plan, taking into account available resources, to measure effectiveness; and
   H. Complete and submit to EPD the Revised TMDL Implementation Plan.

7. The public will be provided an opportunity to participate in the development of the Revised TMDL Implementation Plan and to comment on it before it is finalized.

8. The Revised TMDL Implementation Plan will supersede this Initial TMDL Implementation Plan when the Revised TMDL Implementation Plan is approved by EPD.

Management Measure Selector Table

Land Use	Management Measures	Fecal Coliform	Dissolved Oxygen	pH	Sediment	Temperature	Toxicity	Mercury	Metals (copper, lead, zinc, cadmium)	PCBs, toxaphene
Agriculture	1. Sediment & Erosion Control	_	_		_	_				
	2. Confined Animal Facilities	_	_							
	3. Nutrient Management	_	_							
	4. Pesticide Management		_							
	5. Livestock Grazing	_	_		_	_				
	6. Irrigation		_		_	_				
Forestry	1. Preharvest Planning				_	_				
	2. Streamside Management Areas	_	_		_	_				
	3. Road Construction &Reconstruction		_		_	_				
	4. Road Management		_		_	_				
	5. Timber Harvesting		_		_	_				
	6. Site Preparation & Forest Regeneration		_		_	_				
	7. Fire Management	_	_	_	_	_				
	8. Revegetation of Disturbed Areas	_	_	_	_	_				
	9. Forest Chemical Management		_			_				
	10. Wetlands Forest Management	_	_	_		_		_		

Land Use	Management Measures	Fecal Coliform	Dissolved Oxygen	pH	Sediment	Temperature	Toxicity	Mercury	Metals (copper, lead, zinc, cadmium)	PCBs, toxaphene
Urban	1. New Development	—	—		—	—			—	
	2. Watershed Protection & Site Development	—	—		—	—		—	—	
	3. Construction Site Erosion and Sediment Control		—		—	—				
	4. Construction Site Chemical Control		—							
	5. Existing Developments	—	—		—	—			—	
	6. Residential and Commercial Pollution Prevention	—	—							
Onsite Wastewater	1. New Onsite Wastewater Disposal Systems	—	—							
	2. Operating Existing Onsite Wastewater Disposal Systems	—	—							
Roads, Highways and Bridges	1. Siting New Roads, Highways & Bridges	—	—		—	—			—	
	2. Construction Projects for Roads, Highways and Bridges		—		—	—				
	3. Construction Site Chemical Control for Roads, Highways and Bridges		—							
	4. Operation and Maintenance-Roads, Highways and Bridges	—	—			—			—	

REFERENCES

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Appendix A

30-day Geometric Mean Fecal coliform Monitoring Data

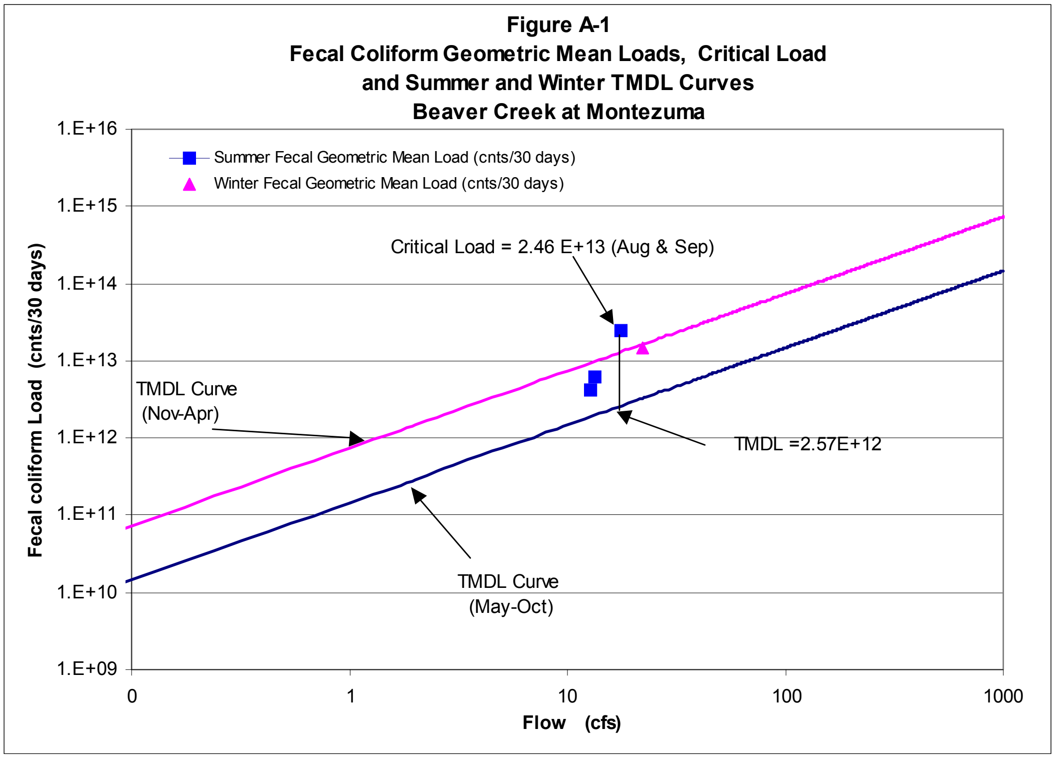

Table A-1. Data for Figure A -1, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
24-Feb-00	490	22.00	7.91E+12			
2-Mar-00	70	23.00	1.18E+12			
9-Mar-00	24000	20.00	3.52E+14			
16-Mar-00	790	23.00	1.33E+13	898	22.00	1.45E+13
18-May-00	790	13.00	7.53E+12			
25-May-00	80	13.00	7.63E+11			
8-Jun-00	790	13.00	7.53E+12			
14-Jun-00	790	12.00	6.95E+12	446	12.75	4.17E+12
17-Aug-00	16000	12.00	1.41E+14			
31-Aug-00	1100	14.00	1.13E+13			
7-Sep-00	700	29.00	1.49E+13			
13-Sep-00	1100	15.00	1.21E+13	1,919	17.50	2.46E+13
13-Sep-00	1100	15.00	1.21E+13			
21-Sep-00	20	9.80	1.44E+11			
5-Oct-00	2800	14.00	2.88E+13			
12-Oct-00	2400	14.00	2.46E+13	620	13.45	6.12E+12

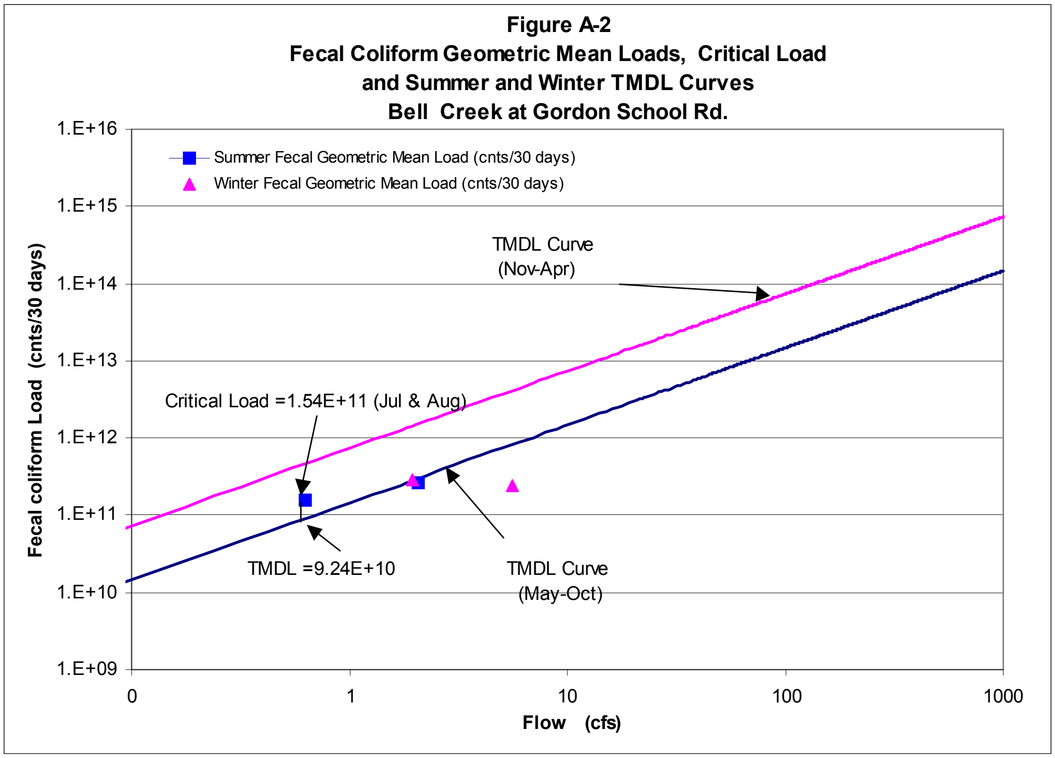

Table A-2. Data for Figure A-2, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
22-Feb-00	20	5.30	7.78E+10			
29-Feb-00	110	5.00	4.03E+11			
6-Mar-00	130	5.90	5.63E+11			
15-Mar-00	80	6.20	3.64E+11	69	5.60	2.84E+11
15-May-00	130	2.30	2.19E+11			
23-May-00	170	2.30	2.87E+11			
1-Jun-00	330	2.10	5.08E+11			
12-Jun-00	130	1.60	1.53E+11	175	2.08	2.67E+11
25-Jul-00	1300	1.40	1.34E+12			
1-Aug-00	80	0.51	2.99E+10			
8-Aug-00	700	0.43	2.21E+11			
15-Aug-00	170	0.18	2.24E+10	334	0.63	1.54E+11
6-Nov-00	330	1.70	4.12E+11			
13-Nov-00	80	2.10	1.23E+11			
27-Nov-00	230	0.00	0.00E+00			
5-Dec-00	140	4.00	4.11E+11	171	1.95	2.44E+11

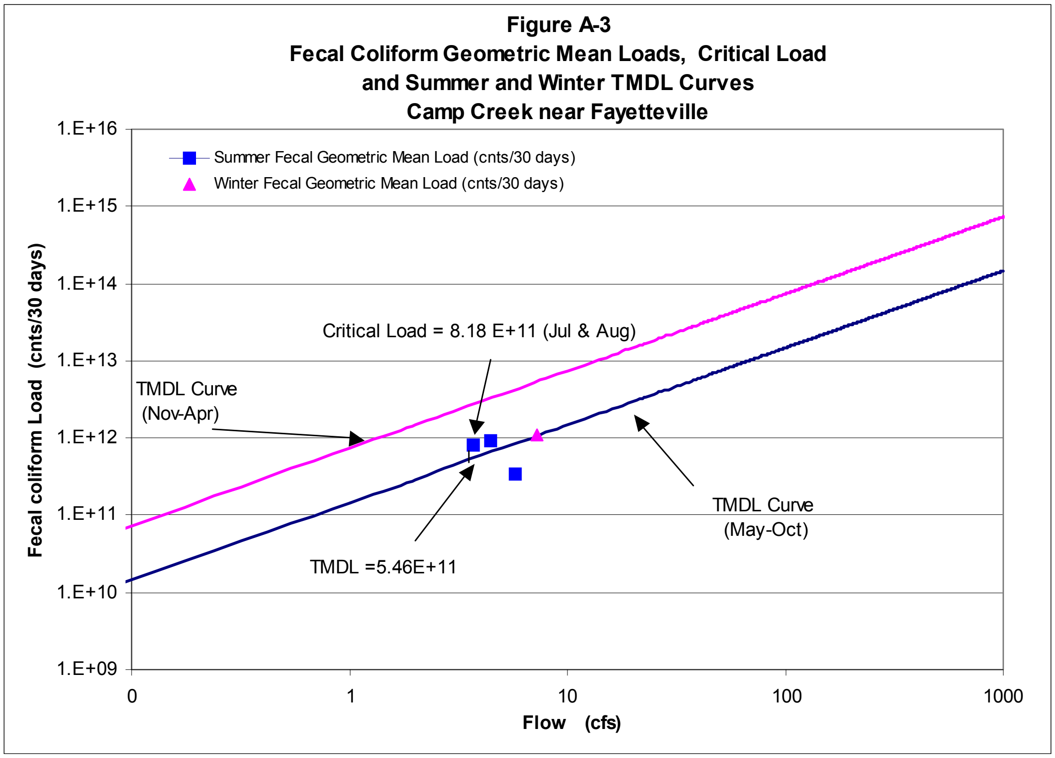

Table A-3. Data for Figure A-3, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
14-Mar-00	210	9.40	1.45E+12			
21-Mar-00	70	6.50	3.34E+11			
28-Mar-00	110	7.30	5.89E+11			
4-Apr-00	1100	5.60	4.52E+12	205	7.20	1.08E+12
30-May-00	50	6.10	2.24E+11			
12-Jun-00	80	6.40	3.76E+11			
19-Jun-00	230	5.70	9.62E+11			
26-Jun-00	50	4.80	1.76E+11	82	5.75	3.47E+11
19-Jul-00	230	3.50	5.90E+11			
2-Aug-00	460	3.10	1.05E+12			
7-Aug-00	230	3.80	6.41E+11			
14-Aug-00	330	4.50	1.09E+12	299	3.73	8.18E+11
18-Sep-00	700	4.40	2.26E+12			
27-Sep-00	330	4.30	1.04E+12			
10-Oct-00	330	4.10	9.92E+11			
12-Oct-00	80	5.00	2.93E+11	279	4.45	9.12E+11

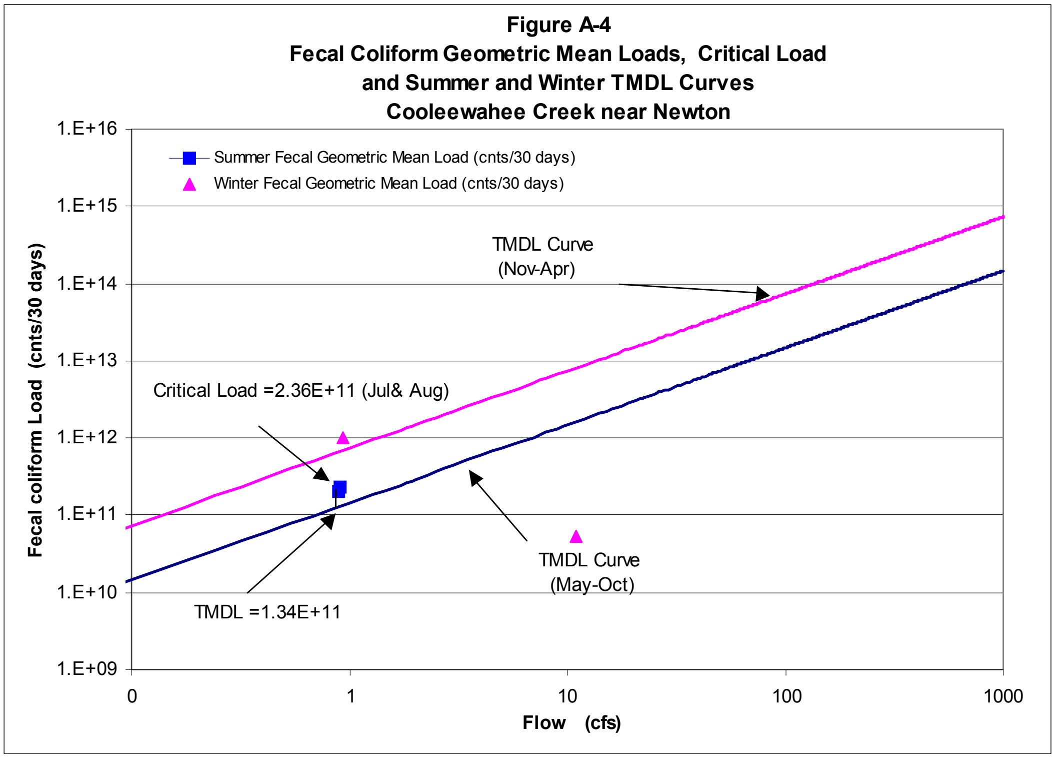

Table A-4. Data for Figure A-4, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
24-Jan-00	330	11.00	2.66E+12			
3-Feb-00	330	5.40	1.31E+12			
10-Feb-00	20	3.70	5.43E+10			
17-Feb-00	110	24.00	1.94E+12	124	11.03	1.01E+12
11-May-00	400	1.20	3.52E+11			
17-May-00	110	0.94	7.58E+10			
24-May-00	1700	0.86	1.07E+12			
8-Jun-00	130	0.58	5.53E+10	314	0.90	2.06E+11
20-Jul-00	3500	0.99	2.54E+12			
27-Jul-00	130	0.94	8.96E+10			
3-Aug-00	490	0.99	3.56E+11			
17-Aug-00	70	0.72	3.70E+10	353	0.91	2.36E+11
8-Nov-00	170	0.82	1.02E+11			
14-Nov-00	40	0.82	2.41E+10			
20-Nov-00	70	0.49	2.52E+10			
7-Dec-00	80	1.60	9.39E+10	79	0.93	5.37E+10

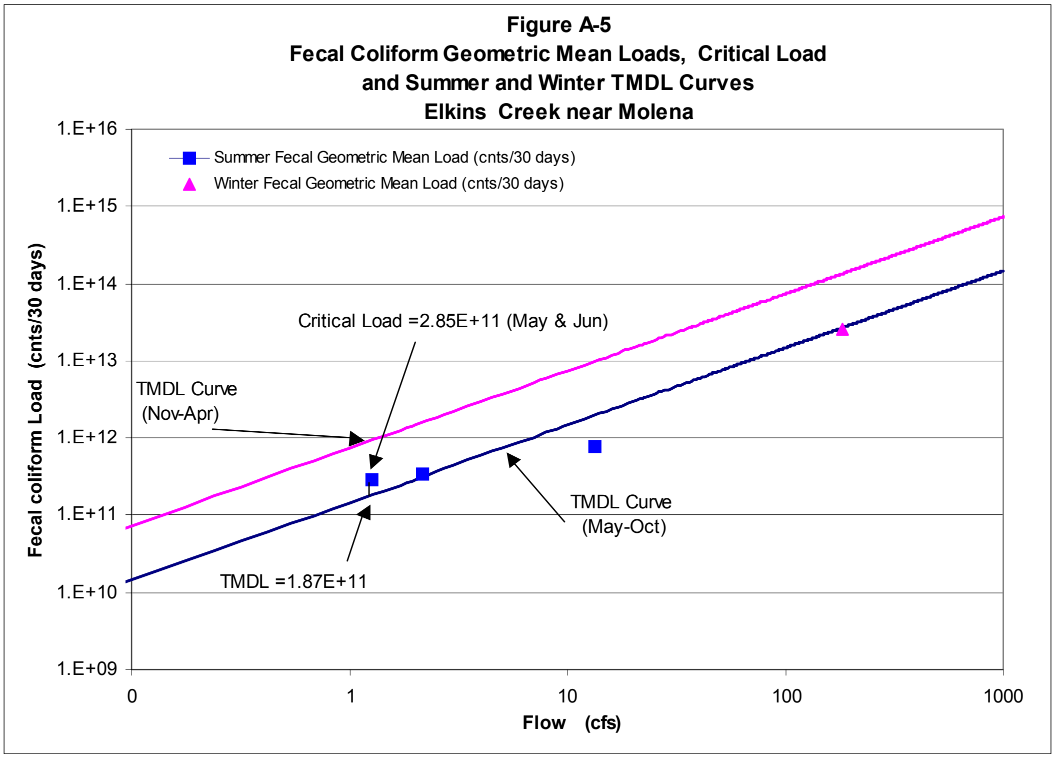

Table A-5. Data for Figure A-5, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
28-Feb-00	330	53.00	1.28E+13			
1-Mar-00	80	45.00	2.64E+12			
16-Mar-00	50	112.00	4.11E+12			
21-Mar-00	1100	519.00	4.19E+14	195	182.25	2.61E+13
30-May-00	230	0.00	0.00E+00			
12-Jun-00	700	1.20	6.16E+11			
19-Jun-00	490	0.50	1.80E+11			
26-Jun-00	110	3.40	2.74E+11	305	1.28	2.85E+11
6-Jul-00	80	2.00	1.17E+11			
10-Jul-00	330	1.80	4.36E+11			
20-Jul-00	490	1.80	6.47E+11			
3-Aug-00	170	3.00	3.74E+11	217	2.15	3.42E+11
7-Sep-00	110	34.00	2.74E+12			
11-Sep-00	130	13.00	1.24E+12			
13-Sep-00	130	6.00	5.72E+11			
2-Oct-00	20	0.60	8.80E+09	78	13.40	7.68E+11

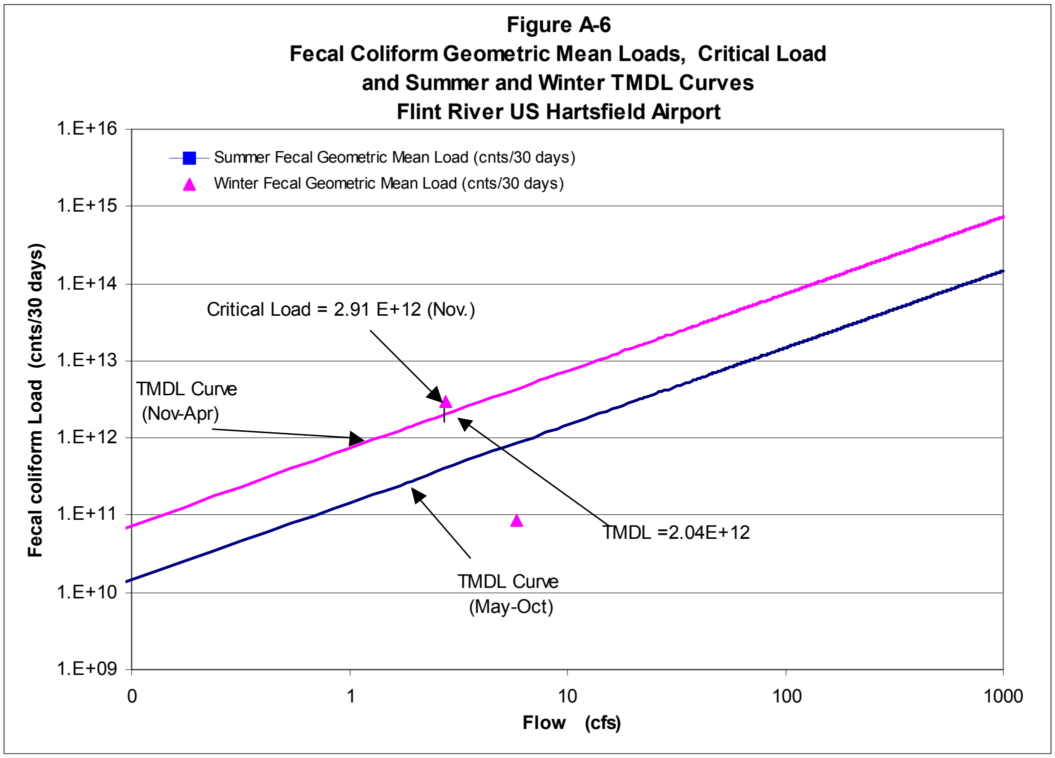

Table A-6. Data for Figure A-6, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
0-Jan-00	0	0.00	0.00E+00			
2-Nov-99	4000	5.55	1.63E+13			
11-Nov-99	360	1.60	4.23E+11			
18-Nov-99	2000	1.21	1.78E+12	1,423	2.79	2.91E+12
4-Jan-00	1	2.15	1.58E+09			
10-Jan-00	630	13.91	6.43E+12			
18-Jan-00	1	3.05	2.23E+09			
27-Jan-00	270	4.34	8.59E+11	20	5.86	8.73E+10

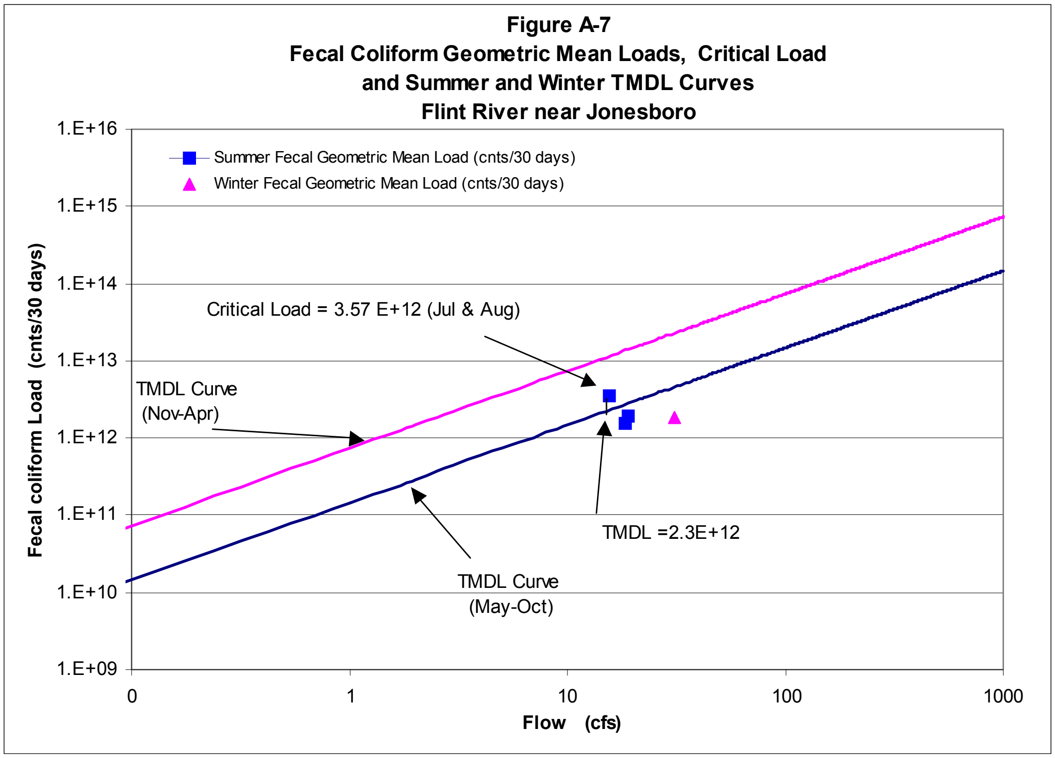

Table A-7. Data for Figure A-7, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
25-Jan-00	330	43.00	1.04E+13			
7-Feb-00	20	24.00	3.52E+11			
15-Feb-00	310	36.00	8.19E+12			
24-Feb-00	20	22.00	3.23E+11	80	31.25	1.83E+12
2-May-00	50	20.00	7.34E+11			
8-May-00	140	19.00	1.95E+12			
11-May-00	220	19.00	3.07E+12			
1-Jun-00	110	16.00	1.29E+12	114	18.50	1.55E+12
13-Jul-00	790	26.00	1.51E+13			
20-Jul-00	330	6.60	1.60E+12			
27-Jul-00	210	15.00	2.31E+12			
3-Aug-00	170	15.00	1.87E+12	311	15.65	3.57E+12
12-Sep-00	50	17.00	6.24E+11			
14-Sep-00	790	19.00	1.10E+13			
20-Sep-00	20	16.00	2.35E+11			
10-Oct-00	490	24.00	8.63E+12	140	19.00	1.95E+12

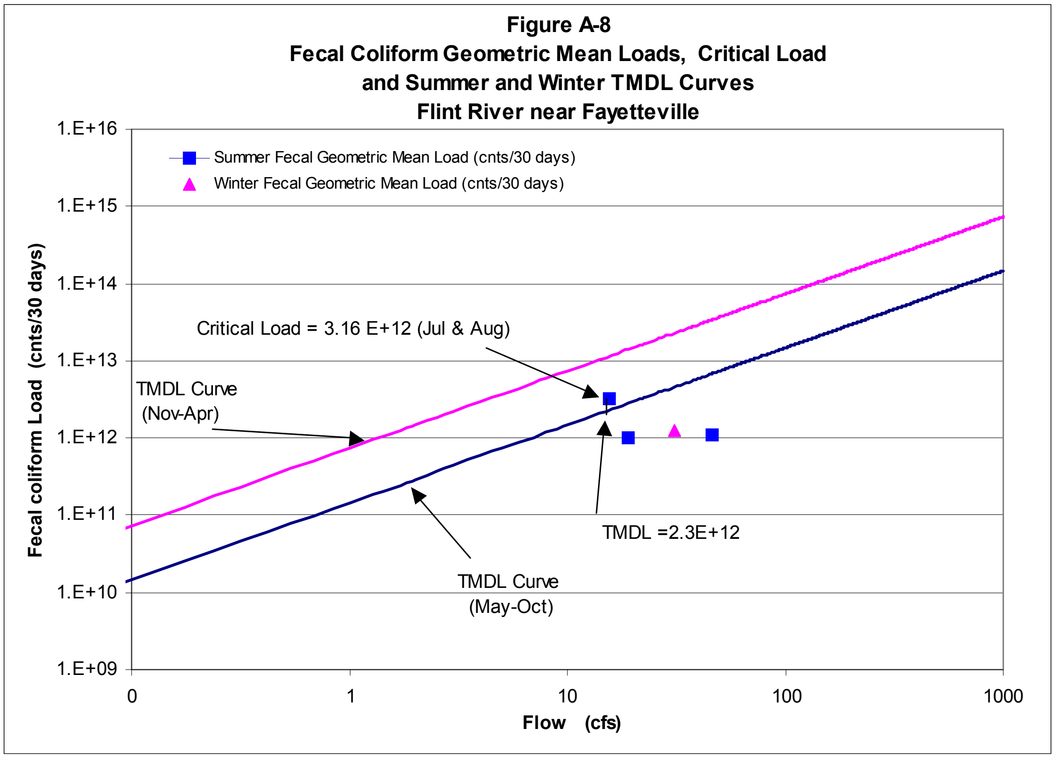

Table A-8. Data for Figure A-8, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
25-Jan-00	70	43.00	2.21E+12			
7-Feb-00	20	24.00	3.52E+11			
15-Feb-00	330	36.00	8.71E+12			
24-Feb-00	20	22.00	3.23E+11	55	31.25	1.26E+12
2-May-00	20	20.00	2.93E+11			
8-May-00	20	129.00	1.89E+12			
11-May-00	50	19.00	6.97E+11			
1-Jun-00	60	16.00	7.04E+11	33	46.00	1.12E+12
13-Jul-00	790	26.00	1.51E+13			
20-Jul-00	170	6.60	8.23E+11			
27-Jul-00	330	15.00	3.63E+12			
3-Aug-00	130	15.00	1.43E+12	276	15.65	3.16E+12
12-Sep-00	700	17.00	8.73E+12			
14-Sep-00	40	19.00	5.57E+11			
20-Sep-00	20	16.00	2.35E+11			
10-Oct-00	50	24.00	8.80E+11	73	19.00	1.01E+12

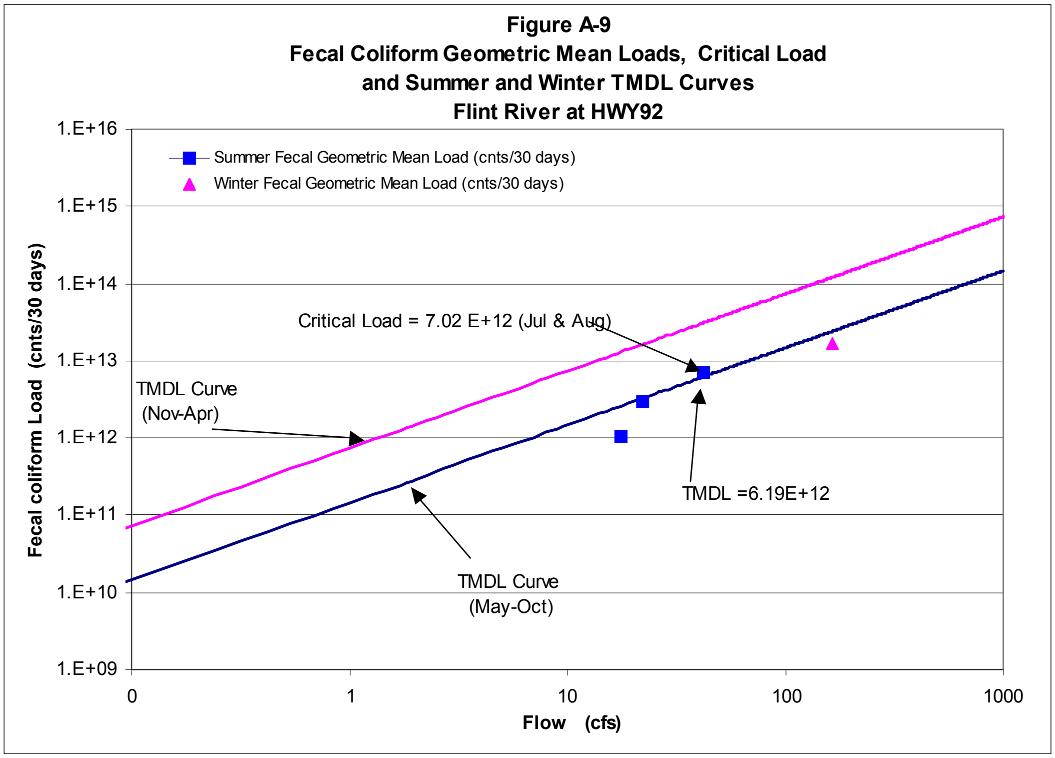

Table A-9. Data for Figure A-9, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
26-Jan-00	110	291.00	2.35E+13			
16-Feb-00	210	249.00	3.84E+13			
23-Feb-00	70	62.00	3.18E+12			
24-Feb-00	230	57.00	9.62E+12	139	164.75	1.68E+13
31-May-00	80	30.00	1.76E+12			
13-Jun-00	110	9.20	7.42E+11			
27-Jun-00	230	17.00	2.87E+12			
29-Jun-00	490	33.00	1.19E+13	177	22.30	2.90E+12
11-Jul-00	80	8.90	5.22E+11			
18-Jul-00	50	13.00	4.77E+11			
26-Jul-00	940	110.00	7.58E+13			
1-Aug-00	700	37.00	1.90E+13	227	42.23	7.02E+12
26-Sep-00	330	50.00	1.21E+13			
17-Oct-00	170	8.90	1.11E+12			
19-Oct-00	20	3.40	4.99E+10			
23-Oct-00	40	8.60	2.52E+11	82	17.73	1.06E+12

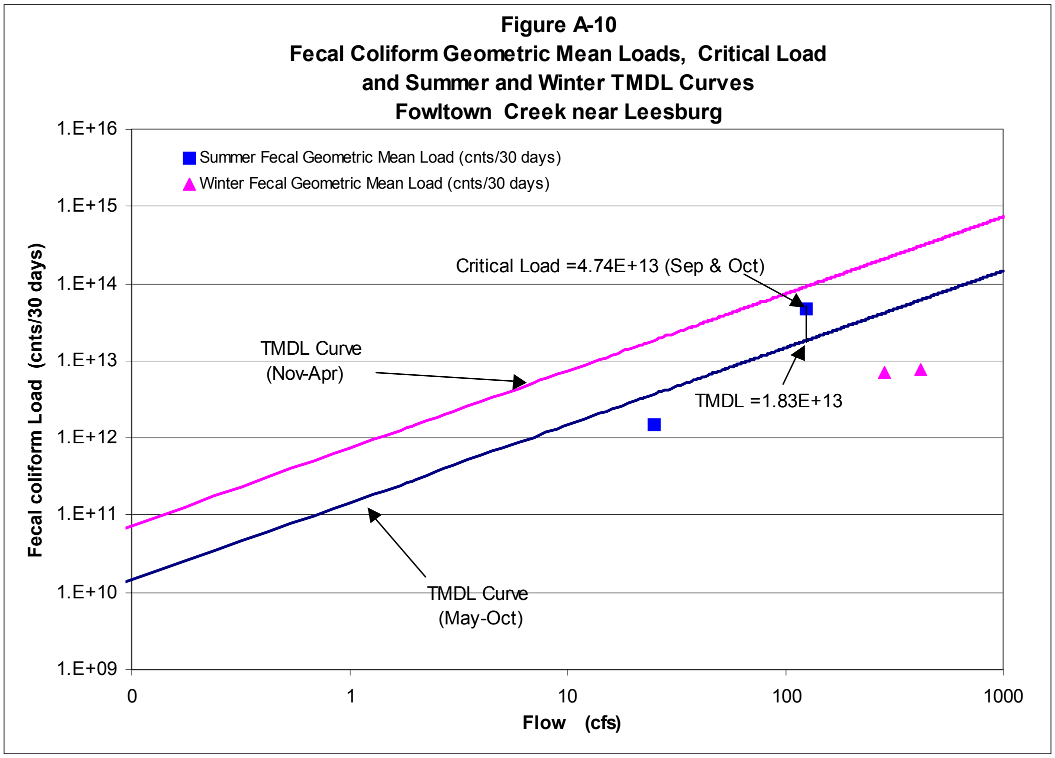

Table A-10. Data for Figure A-10, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
23-Feb-00	20	199.00	2.92E+12			
8-Mar-00	70	238.00	1.22E+13			
15-Mar-00	20	334.00	4.90E+12			
22-Mar-00	50	363.00	1.33E+13	34	283.50	7.15E+12
22-Mar-00	50	1,070.00	3.92E+13			
4-Apr-00	20	233.00	3.42E+12			
12-Apr-00	20	247.00	3.62E+12			
19-Apr-00	20	129.00	1.89E+12	25	419.75	7.74E+12
14-Jun-00	20	13.00	1.91E+11			
20-Jun-00	330	30.00	7.26E+12			
27-Jun-00	80	34.00	2.00E+12			
12-Jul-00	80	23.00	1.35E+12	81	25.00	1.48E+12
20-Sep-00	700	71.00	3.65E+13			
25-Sep-00	330	62.00	1.50E+13			
3-Oct-00	940	280.00	1.93E+14			
18-Oct-00	330	87.00	2.11E+13	517	125.00	4.74E+13

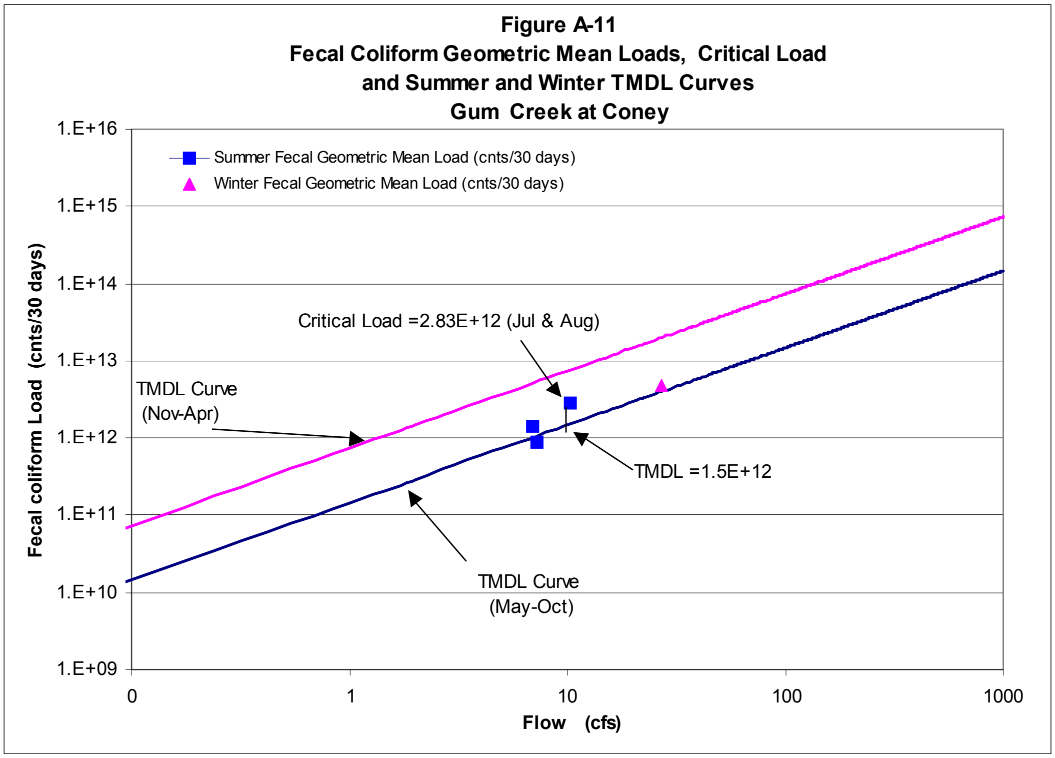

Table A-11. Data for Figure A-11, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
28-Feb-00	170	26.00	3.24E+12			
1-Mar-00	490	34.00	1.22E+13			
16-Mar-00	170	22.00	2.74E+12			
21-Mar-00	230	26.00	4.39E+12	239	27.00	4.73E+12
30-May-00	490	7.60	2.73E+12			
12-Jun-00	170	8.60	1.07E+12			
19-Jun-00	230	5.80	9.79E+11			
26-Jun-00	330	5.60	1.36E+12	282	6.90	1.43E+12
6-Jul-00	220	10.00	1.61E+12			
10-Jul-00	490	7.80	2.80E+12			
20-Jul-00	1700	16.00	2.00E+13			
3-Aug-00	110	7.20	5.81E+11	377	10.25	2.83E+12
7-Sep-00	110	7.20	5.81E+11			
11-Sep-00	790	6.80	3.94E+12			
13-Sep-00	20	7.40	1.09E+11			
2-Oct-00	460	7.80	2.63E+12	168	7.30	9.00E+11

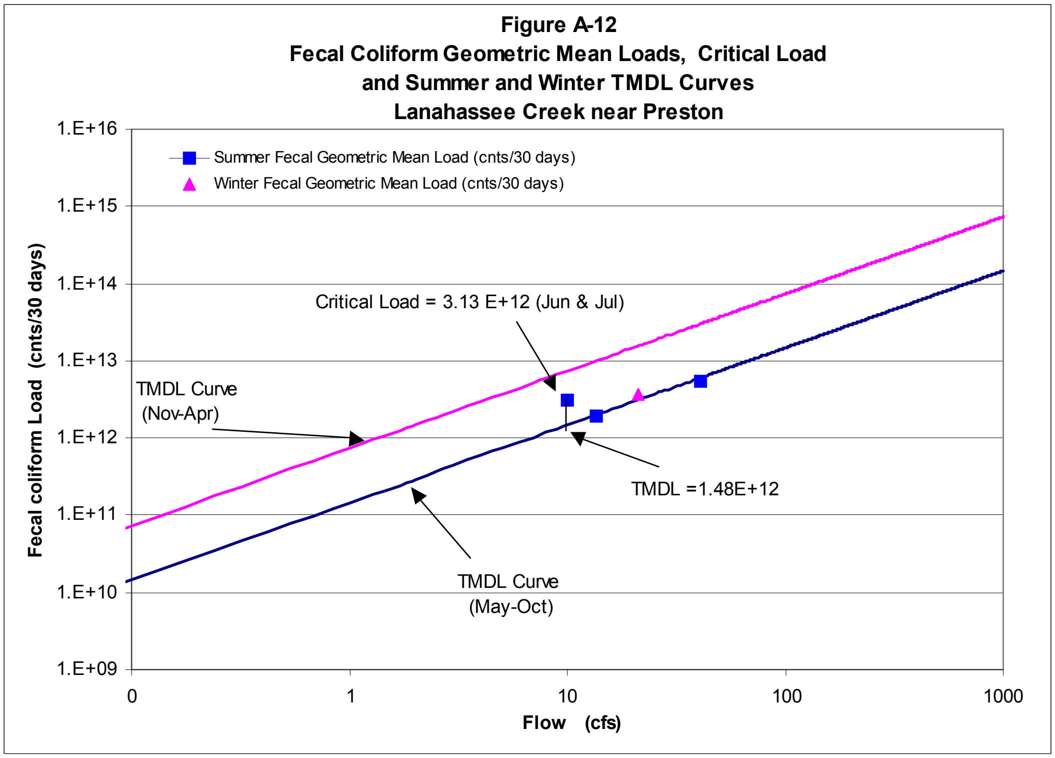

Table A-12. Data for Figure A-12, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
24-Feb-00	130	25.18	2.40E+12			
9-Mar-00	220	24.08	3.89E+12			
16-Mar-00	460	35.31	1.19E+13			
23-Mar-00	0	0.00	0.00E+00	236	21.14	3.66E+12
5-Apr-00	230	57.20	9.65E+12			
6-Apr-00	490	48.99	1.76E+13			
12-Apr-00	140	32.02	3.29E+12			
20-Apr-00	70	25.18	1.29E+12	182	40.85	5.46E+12
15-Jun-00	130	5.47	5.22E+11			
20-Jun-00	1100	7.12	5.22E+11			
27-Jun-00	490	21.62	5.74E+12			
13-Jul-00	460	6.02	7.77E+12	424	10.06	3.13E+12
21-Sep-00	20	8.21	2.03E+12			
25-Sep-00	490	30.65	1.20E+11			
3-Oct-00	790	9.58	1.10E+13			
19-Oct-00	170	8.21	5.55E+12	190	13.62	1.90E+12

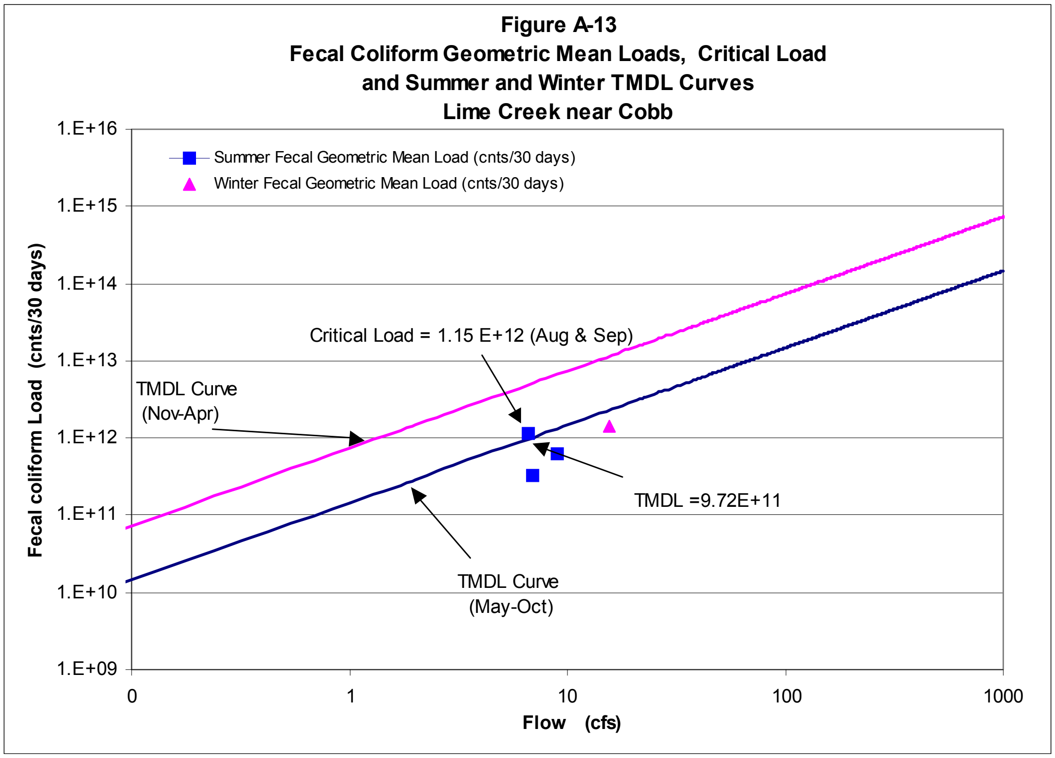

Table A-13. Data for Figure A-13, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
23-Feb-00	130	17.00	1.62E+12			
1-Mar-00	140	16.00	1.64E+12			
8-Mar-00	130	15.00	1.43E+12			
15-Mar-00	110	14.00	1.13E+12	127	15.50	1.44E+12
17-May-00	140	8.90	9.14E+11			
24-May-00	50	6.20	2.27E+11			
7-Jun-00	130	7.40	7.06E+11			
15-Jun-00	20	5.30	7.78E+10	65	6.95	3.33E+11
16-Aug-00	110	4.20	3.39E+11			
30-Aug-00	70	4.30	3.39E+11			
6-Sep-00	1800	8.50	2.21E+11			
12-Sep-00	230	9.50	1.12E+13	238	6.63	1.15E+12
12-Sep-00	230	9.50	1.60E+12			
19-Sep-00	230	8.30	1.60E+12			
4-Oct-00	20	8.60	1.40E+12			
11-Oct-00	80	8.40	1.26E+11	96	8.98	6.31E+11

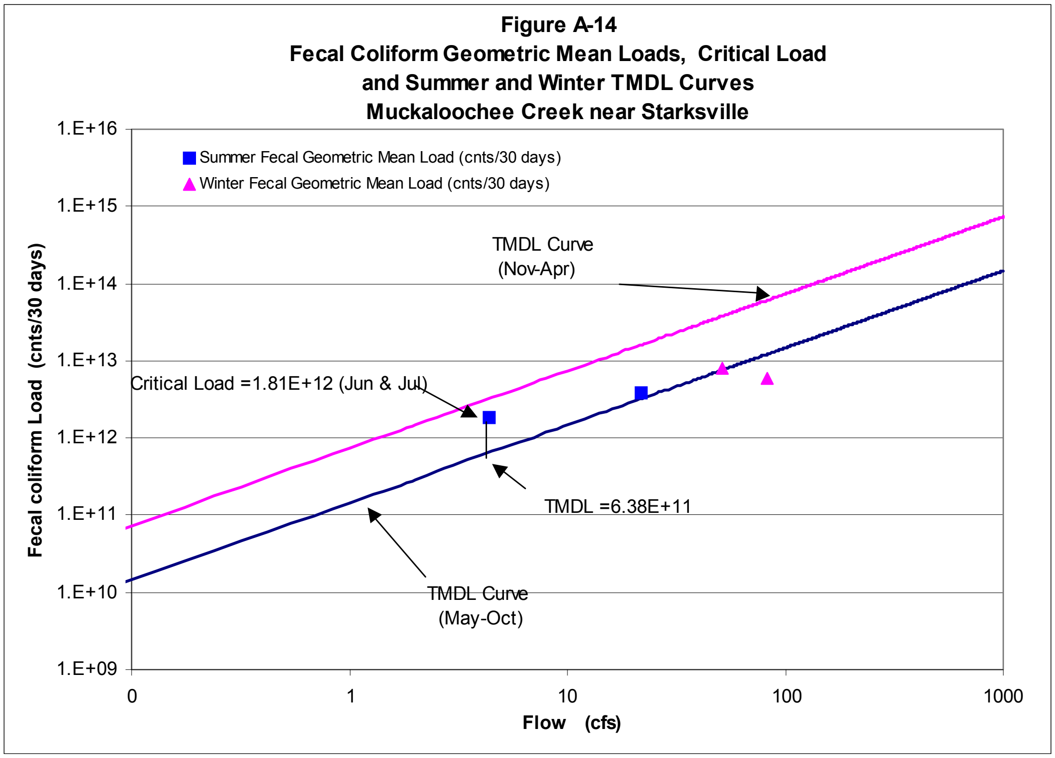

Table A-14. Data for Figure A-14, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
26-Jan-00	330	72.91	1.77E+13			
23-Feb-00	80	34.63	2.03E+12			
8-Mar-00	230	41.42	6.99E+12			
15-Mar-00	330	58.12	1.41E+13	212	51.77	8.03E+12
22-Mar-00	330	63.17	1.53E+13			
4-Apr-00	110	186.20	1.50E+13			
12-Apr-00	50	40.55	1.49E+12			
19-Apr-00	50	42.98	1.58E+12	98	83.22	5.96E+12
14-Jun-00	2800	2.26	4.65E+12			
20-Jun-00	1300	5.22	4.98E+12			
27-Jun-00	130	5.92	5.64E+11			
12-Jul-00	220	4.00	6.46E+11	568	4.35	1.81E+12
20-Sep-00	110	10.79	8.71E+11			
25-Sep-00	310	48.73	1.11E+13			
3-Oct-00	80	15.14	8.88E+11			
18-Oct-00	1300	12.01	1.15E+13	244	21.67	3.88E+12

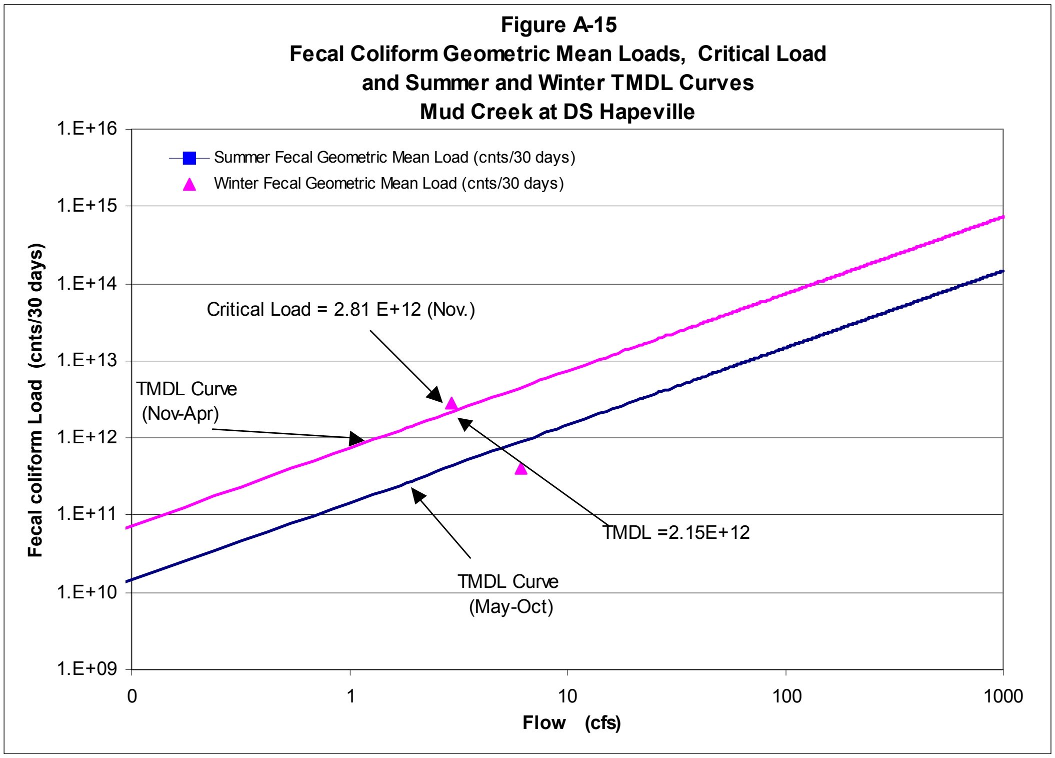

Table A-15. Data for Figure A-15, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
0-Jan-00	0	0.00	0.00E+00			
2-Nov-99	2100	5.82	8.97E+12			
11-Nov-99	630	1.68	7.77E+11			
18-Nov-99	1700	1.27	1.59E+12	1,310	2.93	2.81E+12
4-Jan-00	1	2.26	1.65E+09			
10-Jan-00	2300	14.60	2.46E+13			
18-Jan-00	31000	3.20	7.27E+13			
27-Jan-00	1	4.55	3.34E+09	92	6.15	4.15E+11
0-Jan-00						
0-Jan-00						
0-Jan-00						
0-Jan-00						
0-Jan-00						
0-Jan-00						
0-Jan-00						
0-Jan-00						

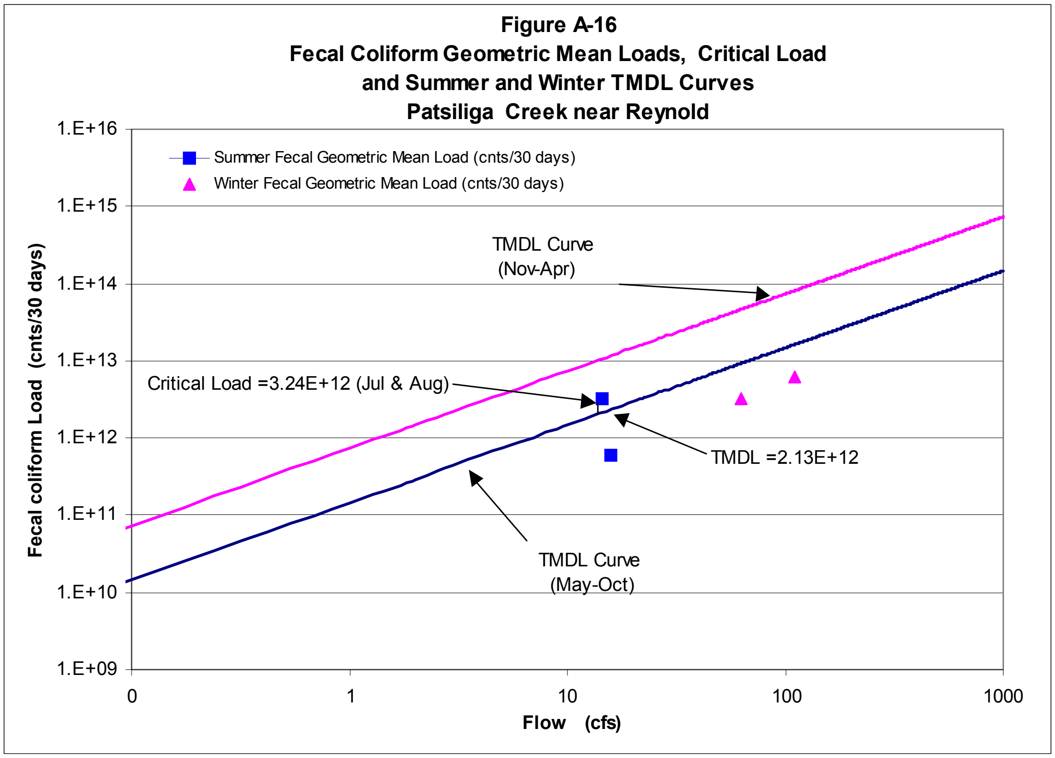

Table A-16. Data for Figure A-16, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
24-Feb-00	50	71.00	2.60E+12			
2-Mar-00	50	69.00	2.53E+12			
8-Mar-00	20	93.00	1.36E+12			
14-Mar-00	50	206.00	7.56E+12	40	109.75	3.20E+12
17-May-00	110	19.00	1.53E+12			
25-May-00	50	17.00	6.24E+11			
31-May-00	20	16.00	2.35E+11			
14-Jun-00	70	11.00	5.65E+11	53	15.75	6.09E+11
27-Jul-00	80	15.00	8.80E+11			
3-Aug-00	490	18.00	6.47E+12			
10-Aug-00	1300	14.00	1.34E+13			
17-Aug-00	170	11.00	1.37E+12	305	14.50	3.24E+12
8-Nov-00	490	36.00	1.29E+13			
15-Nov-00	330	69.00	1.67E+13			
29-Nov-00	20	92.00	1.35E+12			
7-Dec-00	110	53.00	4.28E+12	137	62.50	6.30E+12

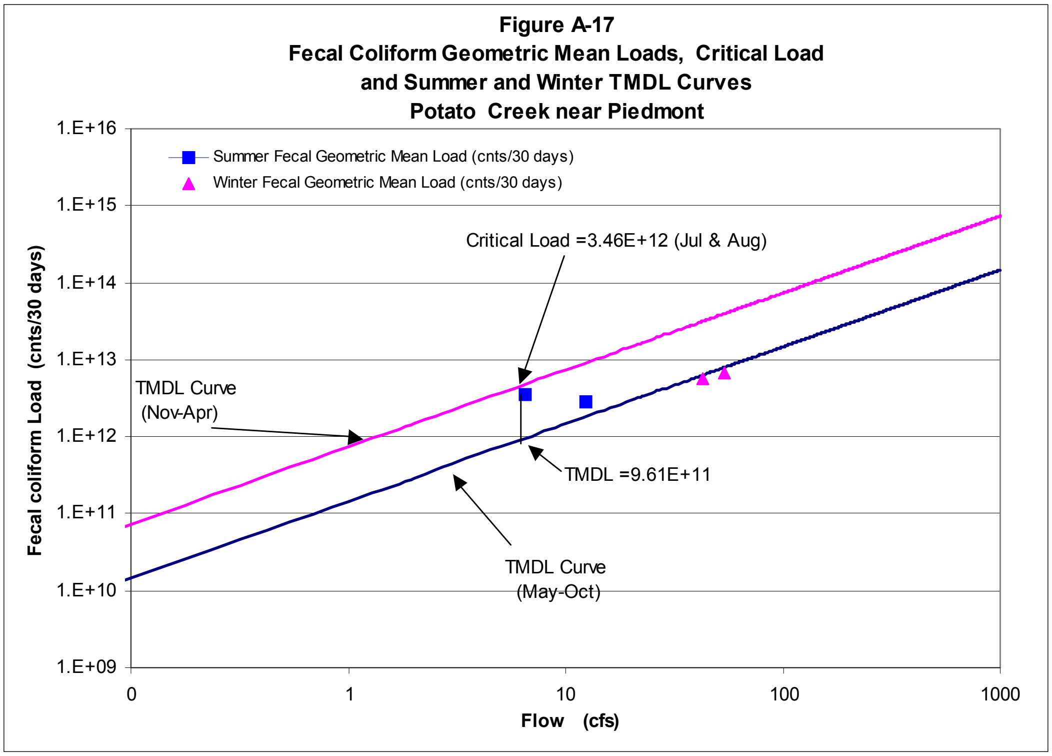

Table A-17. Data for Figure A-17, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
22-Feb-00	140	47.00	4.83E+12			
29-Feb-00	110	54.00	4.36E+12			
6-Mar-00	130	51.00	4.86E+12			
15-Mar-00	230	62.00	1.05E+13	146	53.50	5.75E+12
15-May-00	940	16.00	1.10E+13			
23-May-00	220	14.00	2.26E+12			
31-May-00	230	12.00	2.02E+12			
12-Jun-00	210	7.50	1.16E+12	316	12.38	2.87E+12
25-Jul-00	790	6.20	3.59E+12			
1-Aug-00	330	5.30	1.28E+12			
8-Aug-00	790	10.00	5.79E+12			
15-Aug-00	1300	4.70	4.48E+12	719	6.55	3.46E+12
6-Nov-00	140	5.30	5.44E+11			
13-Nov-00	330	21.00	5.08E+12			
27-Nov-00	230	112.00	1.89E+13			
5-Dec-00	220	32.00	5.16E+12	220	42.58	6.87E+12

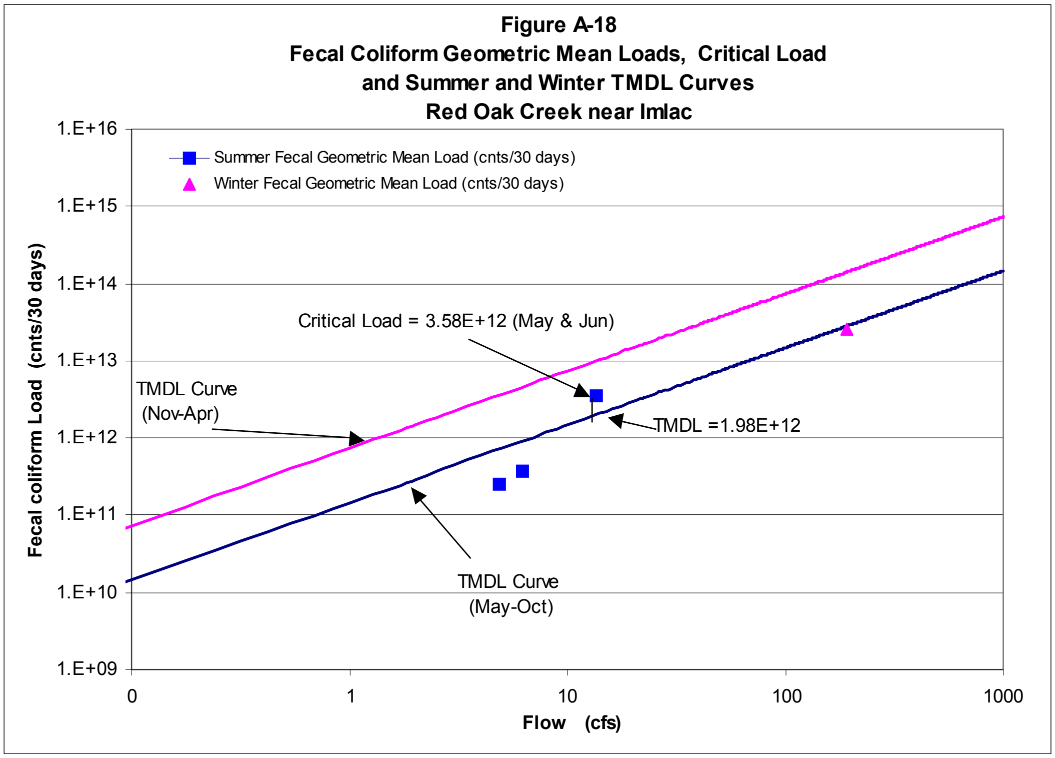

Table A-18. Data for Figure A-18, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
28-Feb-00	220	128.00	2.07E+13			
1-Mar-00	80	92.00	5.40E+12			
16-Mar-00	20	184.00	2.70E+12			
21-Mar-00	3300	366.00	8.86E+14	185	192.50	2.61E+13
30-May-00	170	12.00	1.50E+12			
12-Jun-00	3500	22.00	5.65E+13			
19-Jun-00	220	6.10	9.84E+11			
26-Jun-00	130	14.00	1.34E+12	361	13.53	3.58E+12
6-Jul-00	130	7.60	7.25E+11			
10-Jul-00	20	4.70	6.90E+10			
20-Jul-00	230	3.30	5.57E+11			
3-Aug-00	40	3.80	1.11E+11	70	4.85	2.49E+11
7-Sep-00	50	5.10	1.87E+11			
11-Sep-00	130	5.10	4.86E+11			
13-Sep-00	340	3.60	8.98E+11			
2-Oct-00	20	11.00	1.61E+11	82	6.20	3.71E+11

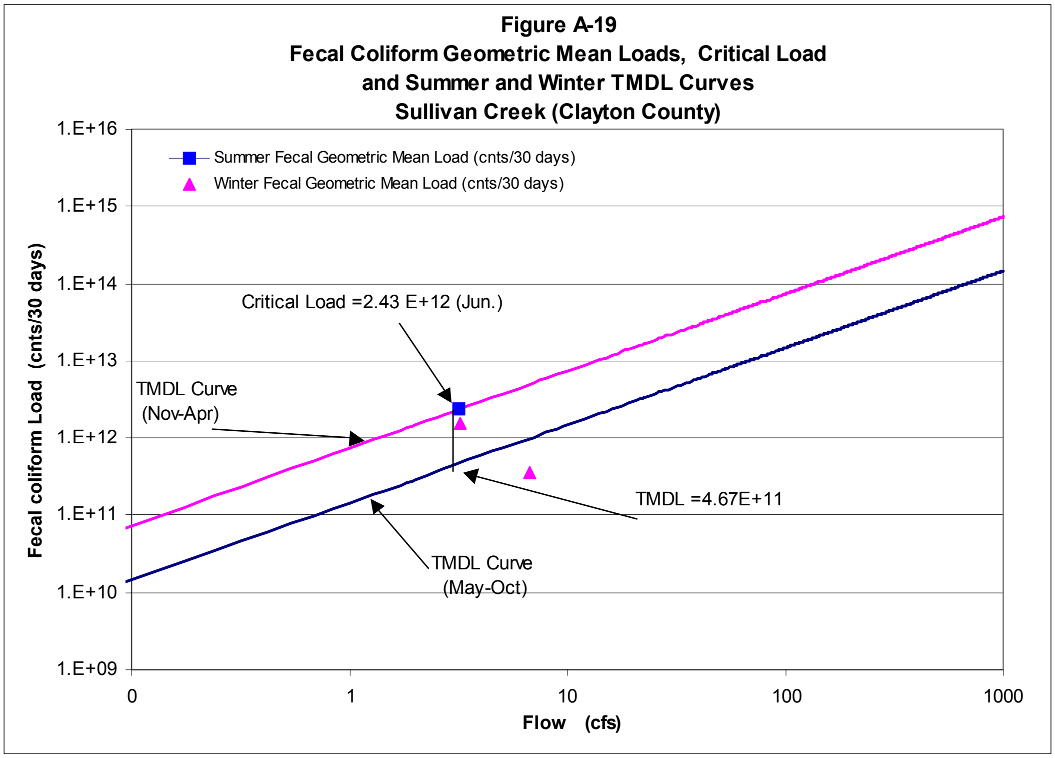

Table A-19. Data for Figure A-19, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
	0	0.00	0.00E+00			
13-Jun-93	3300	4.22	1.02E+13			
21-Jun-93	700	2.15	1.11E+12			
27-Jun-93	490	5.25	1.89E+12	1,042	3.18	2.43E+12
27-Oct-99	0	0.00	0.00E+00			
2-Nov-99	8400	6.37	3.92E+13			
11-Nov-99	360	1.84	4.86E+11			
18-Nov-99	90	1.39	9.18E+10	648	3.20	1.52E+12
4-Jan-00	1	2.47	1.81E+09			
10-Jan-00	180	15.96	2.11E+12			
18-Jan-00	360	3.50	9.24E+11			
27-Jan-00	450	4.98	1.64E+12	73	6.73	3.63E+11

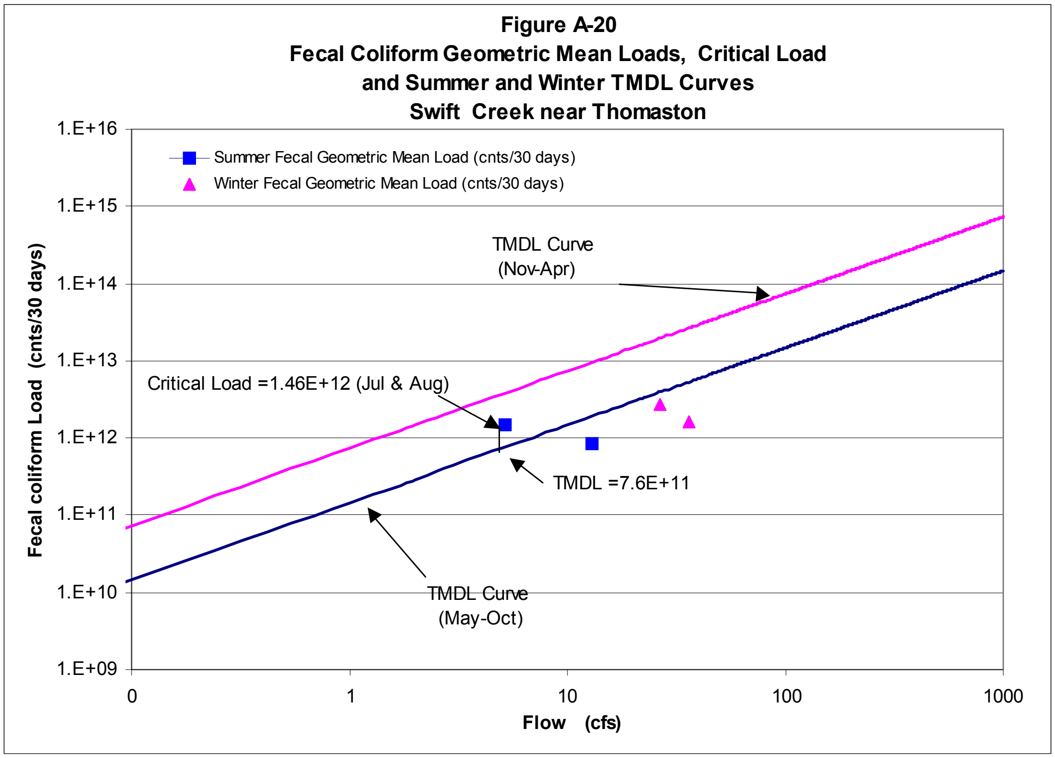

Table A-20. Data for Figure A-20, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
24-Feb-00	80	34.00	2.00E+12			
2-Mar-00	40	33.00	9.68E+11			
8-Mar-00	140	34.00	3.49E+12			
15-Mar-00	230	44.00	7.42E+12	101	36.25	2.68E+12
17-May-00	130	19.00	1.81E+12			
25-May-00	230	17.00	2.87E+12			
31-May-00	20	8.40	1.23E+11			
14-Jun-00	110	7.30	5.89E+11	90	12.93	8.54E+11
27-Jul-00	490	6.30	2.26E+12			
3-Aug-00	1700	8.40	1.05E+13			
10-Aug-00	330	5.80	1.40E+12			
17-Aug-00	80	0.23	1.35E+10	385	5.18	1.46E+12
8-Nov-00	110	18.00	1.45E+12			
15-Nov-00	1100	21.00	1.69E+13			
29-Nov-00	20	39.00	5.72E+11			
7-Dec-00	20	29.00	4.25E+11	83	26.75	1.64E+12

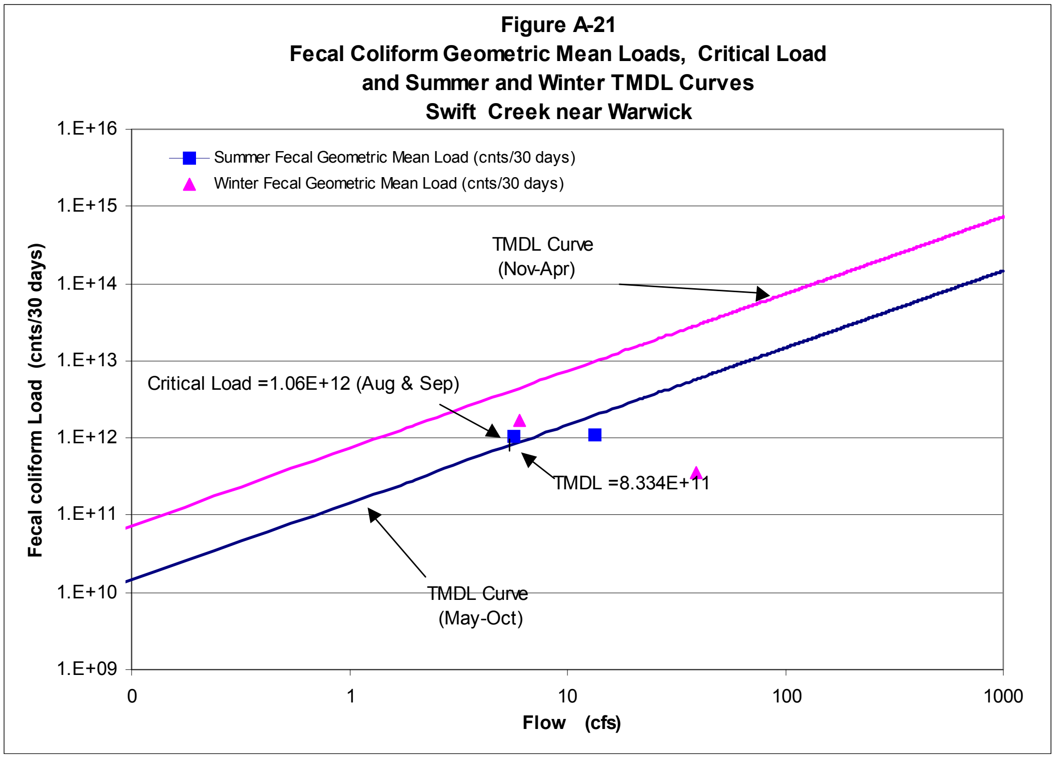

Table A-21. Data for Figure A-21, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
23-Feb-00	20	40.00	5.87E+11			
1-Mar-00	70	47.00	2.41E+12			
8-Mar-00	70	31.00	1.59E+12			
15-Mar-00	130	37.00	3.53E+12	60	38.75	1.70E+12
24-May-00	170	19.00	2.37E+12			
7-Jun-00	70	14.00	7.19E+11			
15-Jun-00	170	12.00	1.50E+12			
12-Jul-00	80	8.20	4.81E+11	113	13.30	1.10E+12
16-Aug-00	70	5.50	2.82E+11			
30-Aug-00	130	5.20	4.96E+11			
6-Sep-00	1400	5.70	5.85E+12			
12-Sep-00	330	6.30	1.53E+12	255	5.68	1.06E+12
12-Sep-00	330	6.30	1.53E+12			
19-Sep-00	130	6.30	6.01E+11			
4-Oct-00	20	5.90	8.66E+10			
11-Oct-00	50	5.70	2.09E+11	81	6.05	3.59E+11

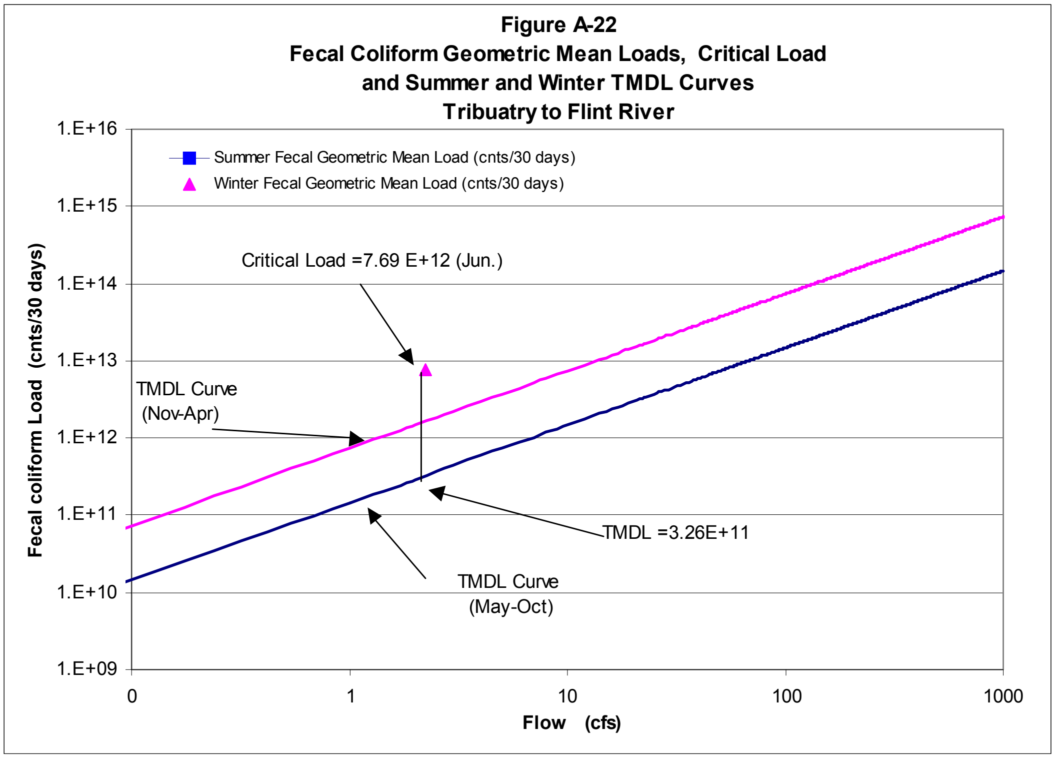

Table A-22. Data for Figure A-22, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
7-Jun-93	4900	1.11	3.95E+16			
13-Jun-93	11000	3.67	2.96E+13			
21-Jun-93	2800	1.88	3.85E+12			
27-Jun-93	3300	4.57	1.11E+13	4,724	2.22	7.69E+12

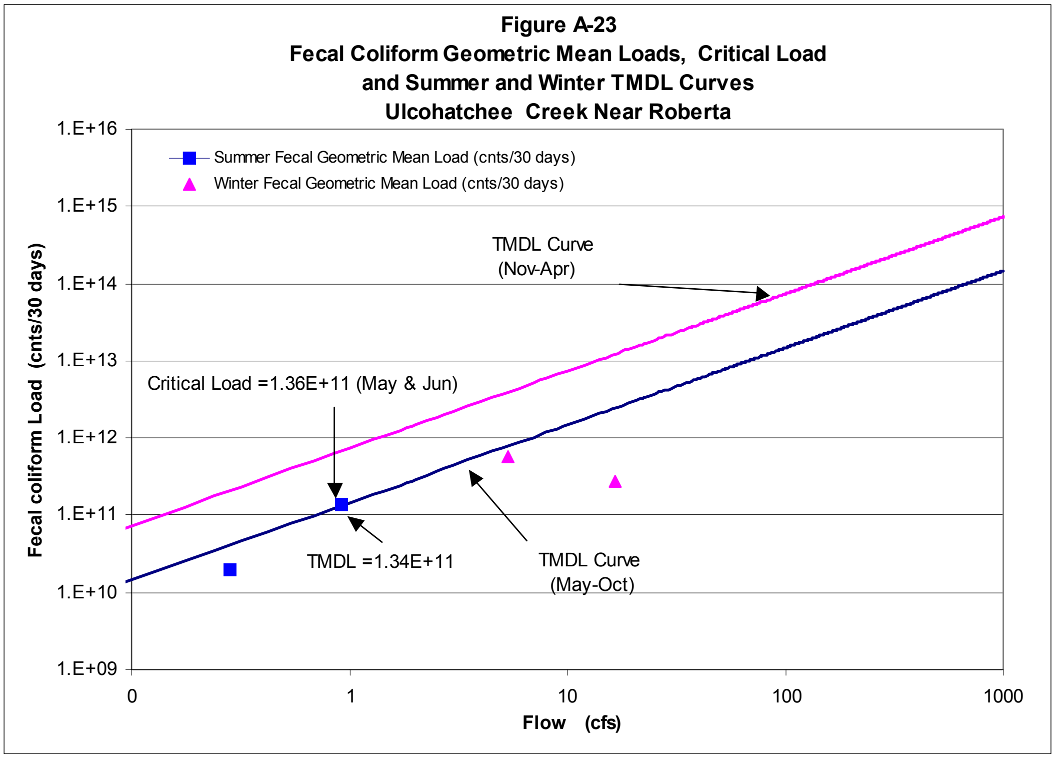

Table A-23. Data for Figure A-23, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
24-Feb-00	20	12.00	1.76E+11			
2-Mar-00	70	11.00	5.65E+11			
8-Mar-00	70	16.00	8.22E+11			
15-Mar-00	50	27.00	9.90E+11	47	16.50	5.69E+11
17-May-00	220	2.00	3.23E+11			
25-May-00	490	1.30	4.67E+11			
31-May-00	310	0.12	2.73E+10			
14-Jun-00	50	0.24	8.80E+09	202	0.92	1.36E+11
27-Jul-00	50	0.22	8.07E+09			
3-Aug-00	130	0.55	5.24E+10			
10-Aug-00	330	0.27	6.54E+10			
17-Aug-00	40	0.09	2.64E+09	96	0.28	1.99E+10
8-Nov-00	110	0.78	6.29E+10			
15-Nov-00	20	1.90	2.79E+10			
29-Nov-00	170	14.00	1.75E+12			
7-Dec-00	70	4.60	2.36E+11	72	5.32	2.79E+11

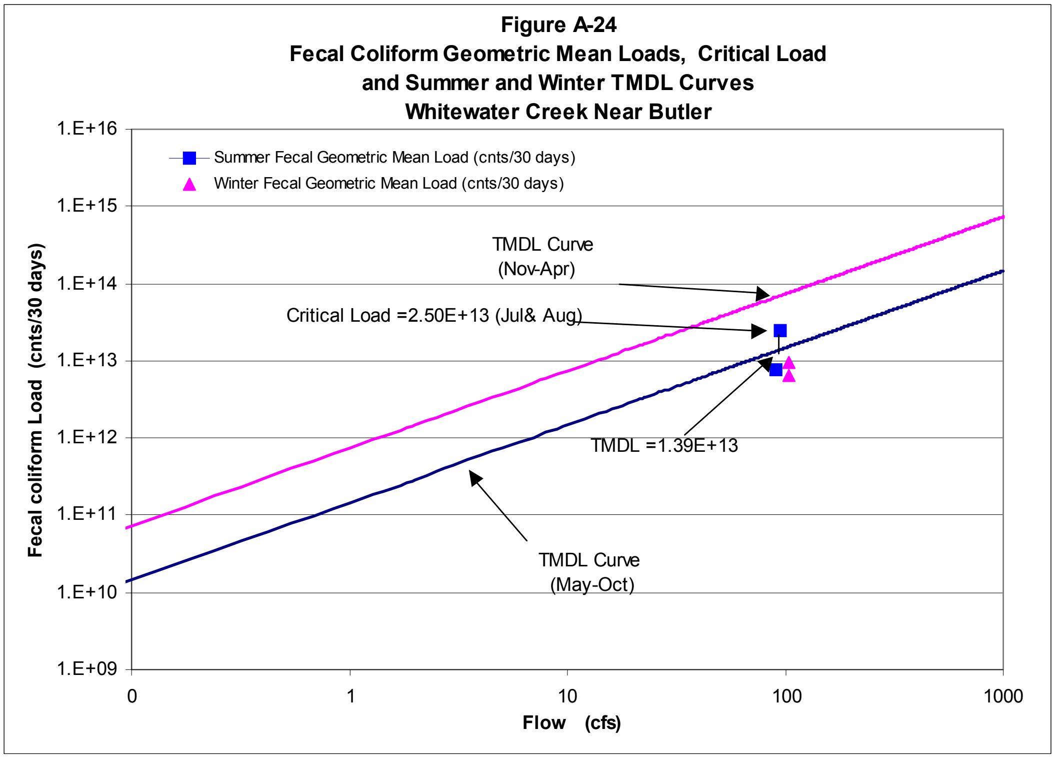

Table A24. Data for Figure A-24, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
23-Feb-00	80	102.00	5.99E+12			
1-Mar-00	80	101.00	5.93E+12			
7-Mar-00	50	103.00	3.78E+12			
14-Mar-00	170	109.00	1.36E+13	86	103.75	6.54E+12
16-May-00	50	92.00	3.37E+12			
24-May-00	140	93.00	9.55E+12			
31-May-00	70	89.00	4.57E+12			
13-Jun-00	330	89.00	2.15E+13	113	90.75	7.51E+12
26-Jul-00	490	101.00	3.63E+13			
2-Aug-00	130	99.00	9.44E+12			
9-Aug-00	330	93.00	2.25E+13			
16-Aug-00	790	87.00	5.04E+13	359	95.00	2.50E+13
14-Nov-00	330	108.00	2.61E+13			
16-Nov-00	110	102.00	8.23E+12			
28-Nov-00	80	107.00	6.28E+12			
6-Dec-00	80	101.00	5.93E+12	123	104.50	9.46E+12

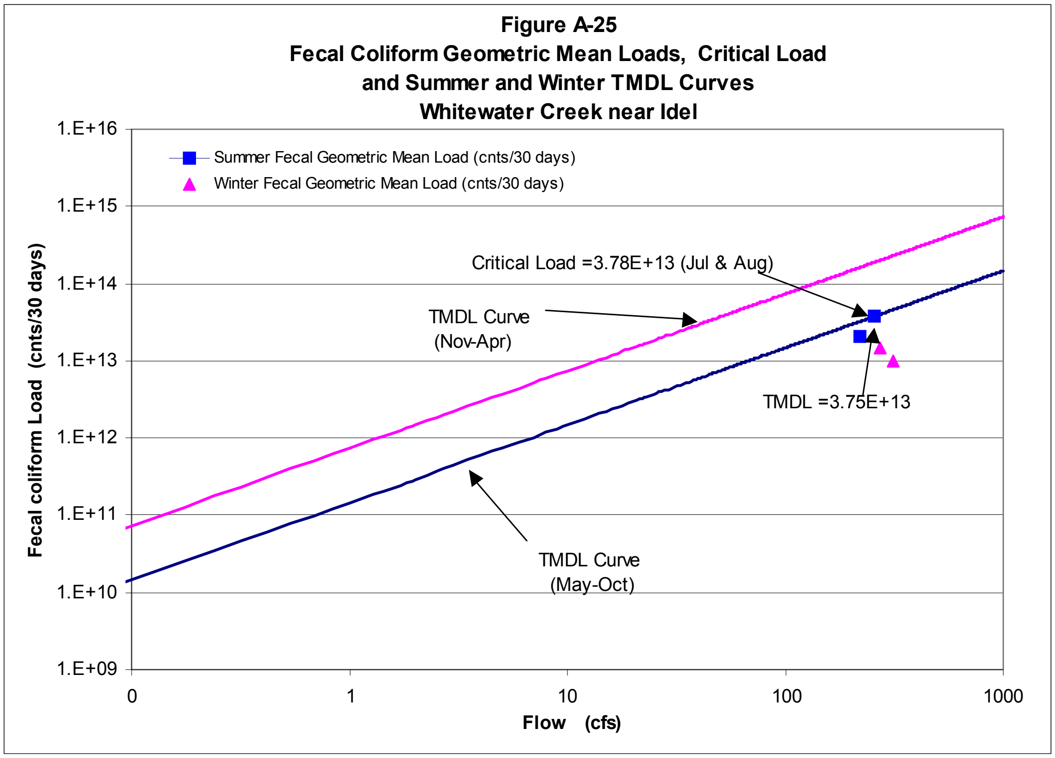

Table A-25. Data for Figure A-25, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
23-Feb-00	20	294.00	4.31E+12			
1-Mar-00	50	290.00	1.06E+13			
7-Mar-00	140	313.00	3.21E+13			
14-Mar-00	110	353.00	2.85E+13	63	312.50	1.44E+13
16-May-00	330	226.00	5.47E+13			
24-May-00	130	234.00	2.23E+13			
31-May-00	80	222.00	1.30E+13			
13-Jun-00	80	199.00	1.17E+13	129	220.25	2.08E+13
26-Jul-00	490	305.00	1.10E+14			
2-Aug-00	170	287.00	3.58E+13			
9-Aug-00	220	232.00	3.74E+13			
16-Aug-00	90	198.00	1.31E+13	202	255.50	3.78E+13
14-Nov-00	50	278.00	1.02E+13			
16-Nov-00	130	266.00	2.54E+13			
28-Nov-00	20	288.00	4.23E+12			
6-Dec-00	50	263.00	9.65E+12	50	273.75	1.01E+13

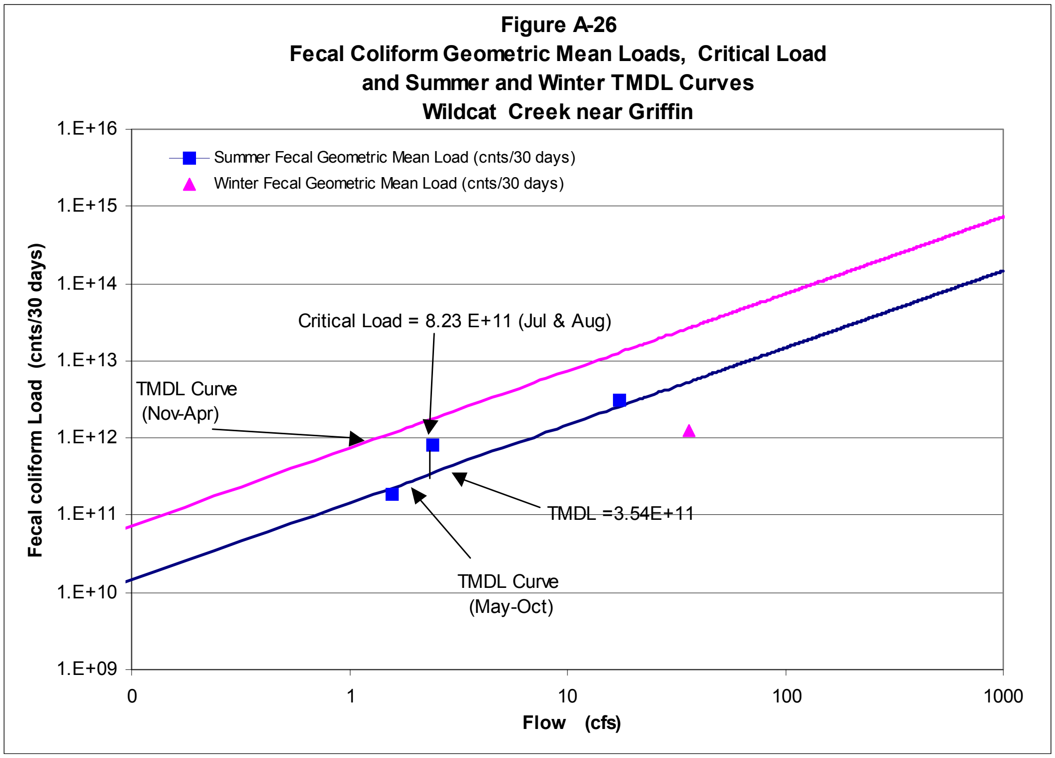

Table A-26. Data for Figure A-26, including: observed fecal coliform, instantaneous flow fecal coliform load, fecal coliform geometric mean, mean flow, fecal coliform geometric mean load.

Date	Observed Fecal Coliform (counts/100 ml)	Estimated Instantaneous Flow On Sample Day (cfs)	Estimated Fecal Coliform Loading on Sample Day (cnts/30 days)	Geometric Mean (cnts/100 ml)	Mean Flow (cfs)	Geometric Mean Fecal Coliform Loading (cnts/30 days)
26-Jan-00	40	46.00	1.35E+12			
16-Feb-00	50	41.00	1.50E+12			
23-Feb-00	20	29.00	4.25E+11			
24-Feb-00	130	29.00	2.77E+12	48	36.25	1.27E+12
31-May-00	110	2.30	1.86E+11			
13-Jun-00	230	1.20	2.02E+11			
27-Jun-00	330	1.20	2.90E+11			
29-Jun-00	80	1.60	9.39E+10	161	1.58	1.86E+11
11-Jul-00	80	0.41	2.41E+10			
18-Jul-00	130	0.21	2.00E+10			
26-Jul-00	9200	0.82	5.53E+12			
1-Aug-00	490	8.20	2.95E+12	465	2.41	8.23E+11
26-Sep-00	2400	19.00	3.34E+13			
17-Oct-00	80	15.00	8.80E+11			
19-Oct-00	110	14.00	1.13E+12			
23-Oct-00	170	21.00	2.62E+12	245	17.25	3.10E+12

Appendix B

Summary of Limited Fecal Coliform Monitoring Data

Summary of Limited Fecal Coliform Monitoring Data

Listed Segment	Number of Observations	Total Geometric Mean (counts/100 mL)	Data Source
Big Slough	4	75.86	River Basin 95, WRDB
Turkey Creek			

Appendix C

Technical Details for Calculating TMDLs for Limited-Data Sites

Conceptual Approach

The approach to estimating fecal coliform bacteria TMDLs for the waterbodies lacking geometric mean data relies on a relationship to other similar or "equivalent" waterbodies that do have data. This provides an estimated TMDL that can be refined in future as additional site-specific data are collected.

Development of the TMDLs via an "equivalent" site approach needed to address three important issues:

1. Any site-specific monitoring data for a waterbody should also be incorporated, even if it is not sufficient for direct estimation of geometric means.

2. Differences in land use will result in different fecal coliform bacteria concentrations, an equivalent waterbody that provides a perfect match in landuse to a subject site is unlikely to be available.

3. The selection of an equivalent waterbody is likely to have a strong impact on the resulting TMDL estimates for a subject waterbody

Consideration of these three issues led to a corresponding set of objectives for the approach:

1. Site-specific and equivalent site data should be combined in a weighted approach that reflects the relative accuracy of information provided by each data source.

2. Differences in land use among watersheds should be addressed through use of a regionalization model that identifies the extent to which changes in geometric mean fecal coliform concentrations can be explained by changes in land use.

3. The influence of equivalent waterbody selection should be minimized through the use of multiple equivalent waterbodies for each subject waterbody.

These three objectives may be met through use of an Empirical Bayes regionalization analysis. This method combines two important concepts: Bayesian maximum likelihood techniques for combining sources of data (local and regional), and hierarchical regionalization techniques. The data combination step assumes that both the regional or equivalent site information and the available site-specific data provide information on the true local geometric mean. The two sources of data should be combined or weighted in accordance with the degree of precision or accuracy in each source. The regionalization step assumes that the true mean at any site is a result of random variability and a regression model on land use. Empirical Bayes techniques provide statistically optimal methods for computing both the data combination and regionalization steps from observed data.

Technical Basis

In the TMDL Curve method, the needed reductions for a given waterbody, and thus the allocations, are determined by the ratio

$$\text{Reduction} = \frac{\text{TMDL Curve Point}}{\text{Critical Load}} \qquad (1)$$

where the critical load is the estimated 30-day fecal coliform load most exceeding the TMDL curve, and the TMDL curve point is calculated as the geometric mean water quality standard for fecal coliform bacteria times the 30-day average flow corresponding to the critical load estimate. Both the numerator and denominator of this equation can be written in terms of a critical geometric mean, C_{crit} and a corresponding critical flow, $Q_{crit:}$

$$\text{TMDL Curve Point} = WQS \cdot Q_{crit} \qquad (2)$$
$$\text{Critical Load} = C_{crit} \cdot Q_{crit}$$

For sites for which sufficient 30-day geometric means have not been collected, an estimate of C_{crit} is not available. For many waterbodies, some to many scattered observations are available, even though 30-day geometric means cannot be estimated. For other waterbodies, no site-specific data are available. In most cases, site-specific flow gaging is also not available. The approach estimates the TMDL for the sites without geometric mean data by adjusting the critical load, and thus the reduction estimate, from one or more equivalent sites that do have data.

In translating from an equivalent site to a subject site, it is important to account for changes in runoff concentrations associated with differences in land use, and for changes in flow associated with different basin size. The critical load at site *i* can be estimated in relation to calculated critical loads at *n* other sites through

$$\text{Critical Load}_{\text{i}} = \frac{1}{n}\sum_{j=1}^{n}\left[A_{ij} \cdot C_j \cdot Q_{crit,j} \cdot \frac{DA_i}{DA_j}\right] \qquad (3)$$

in which A_{ij} is a factor (based on land use) that relates the geometric mean fecal coliform concentration at site *i* to that at site *j*, since a geometric mean is used), and *DA* represents the drainage area above the sample site.

The ratio DA_i/DA_j adjusts the flow from site j to site i. In the case where gage data are available, actual mean flows rather than drainage areas can be used for the ratio. Equation (3) thus translates both the critical geometric mean concentration and the associated critical flow to provide a new estimate of critical load at site *i*. Averaging over estimates obtained from *n* equivalent sites, the estimated reduction needed at site *i* is then, from (1):

$$\text{Reduction}_{\text{i}} = \sum_{\text{j=1}}^{\text{n}} \frac{\left[WQS \cdot Q_{crit,j} \cdot \frac{DA_i}{DA_j}\right]}{\left[A_{ij}\ G_j \cdot Q_{crit,j} \cdot \frac{DA_i}{DA_j}\right]} \qquad (4)$$

The key task for completing this effort is determining the translation factor, A_{ij}, which relates the long term geometric mean at site *i* to that at site *j*. This factor can reasonably be assumed to vary with land use, but also to exhibit strong site-specific characteristics. For instance, a given site might tend to exhibit higher concentrations relative to an equivalent site than are expected from consideration of land use differences alone.

So, what is needed is a method that provides an appropriate weighting between limited site-specific data and a land-used based regression on equivalent sites. This situation is ideally suited for an empirical Bayes analysis (Berger, 1985; Morris, 1983). This is a technique for Bayesian updating that is based entirely in observed data (thus, "empirical").

It is assumed that the long-term geometric mean fecal coliform concentration at a given site (expressed in log space) is a function of underlying properties of land use in the watershed plus site-specific factors that are represented by random noise. A sample realization of the (log-space) geometric mean at site *i*, x_i is assumed to be normally distributed about a true mean, 2_i, with standard error of the estimate given by F_i. In statistical notation:

$$x_i \sim \mathrm{N}\left(\theta_i, \sigma_i^2\right) \tag{5}$$

The desired translation factor for use in Equations (3) and (4) above is then

$$A_{ij} = e^{\theta_i} \big/ e^{\theta_j} \tag{6}$$

In a regional context, we assume that each of the true (but unknown) local site means arises from a regional regression on land characteristics, such that

$$\theta_i = \boldsymbol{y}_i^t \cdot \beta + \varepsilon_i \tag{7}$$

where ***y*** is a vector of land use characteristics, the **ß** are regression coefficients, and g_i is a normally-distributed error term, such that

$$\varepsilon_i \sim \mathrm{N}\left(0, \sigma_\pi^2\right) \tag{8}$$

Equations (7) and (8) constitute a standard linear regression model, written in vector notation. (Note that the vector **ß** includes an intercept value, in addition to coefficients on the regressors, and the first item in the vector ***y*** is a 1 corresponding to the intercept value.) The regionalization is accomplished by estimating **ß** and Φ_B from the data, i.e., across multiple sites. To simplify the mathematics, it is assumed that the F_i are known from the sample data, and uncertainty in the estimation of the F_i is ignored (Berger, 1985).

The desired maximum likelihood estimate of a geometric mean associated with a given site should range between the regression estimate, $\boldsymbol{y}_i^t$ **ß**, and the at-site observed geometric mean, x_i. If there are no monitoring data at a given site, the best estimator is simply the regression estimator. On the other hand, if there are sufficient data at a given site it is appropriate to use the observed geometric mean without regionalization. Weighting between these two end-members depends on the relative magnitudes of F_i and F_B, which express, respectively, the degree of uncertainty associated with the local and regional estimators. In a Bayesian sense, the best estimate is provided by the posterior distribution, incorporating the regional regression (as a prior) and the likelihood function of observed site data.

In a standard Bayes approach, the prior should be independent of the data used to form the likelihood function. Morris (1983) developed Empirical Bayes approximations to the posterior means and variances that take into account the errors introduced by estimating **ß** and F_B from the data. The maximum likelihood Empirical Bayes estimator of 2 is given by :$_i^{EB}$, with variance V_i^{EB}. These are estimated through the equations

$$\mathrm{E}(\theta_i) \;=\; \mu_i^{EB} = \; x_i - \hat{\mathrm{B}}_i \cdot \left(x_i - \boldsymbol{y}_i^t \hat{\beta}\right) \tag{9}$$

and

$$V_i^{EB} = \sigma_i^2 \cdot \left[1 - \frac{\left(p - \hat{l}_i\right)}{p} \hat{\mathrm{B}}_i\right] + \frac{2}{p - l - 2} \hat{\mathrm{B}}_i^2 \left(\frac{\hat{\sigma}_p^2 + \hat{\sigma}_\pi^2}{\sigma_i^2 + \hat{\sigma}_\pi^2}\right) \left(x_i - \boldsymbol{y}_i^t \hat{\beta}\right)^2 \tag{10}$$

In these equations, the parameter B_i is a Bayes factor that weights between the regional and local estimates. The x_I and F_i are, as noted above, the observed mean and variance of the logarithms of fecal coliform concentration data at site *i*. When no observations are available at a site, F_I^2 is assumed to be equal to the mean variance across all sites with data.

The vector of regression parameters, **ß**, is estimated by the standard least squares regression equation, written in matrix notation as

$$\hat{\beta} = \left(\boldsymbol{y}^t \boldsymbol{V}^{-1} \boldsymbol{y}\right)^{-1} \left(\boldsymbol{y}^t \boldsymbol{V}^{-1} \boldsymbol{x}\right) \tag{11}$$

where ***y***, representing the observed land characteristics, is a (*p* x *l*) matrix of *l* regressors at *p* sites, ***x*** is the (*p* x 1) vector of observed means at the *p* sites, and ***V*** is a (*p* x *p*) diagonal matrix with diagonal elements $V_{ii} = F_i^2 + F_B^2$. The regional variance is in turn estimated as

$$\hat{\sigma}_\pi^2 = \frac{\sum_{i=1}^{p} \left\{ \left[\left(p / (p - l)\right) \left(x_i - \boldsymbol{y}_i^t \hat{\beta}\right)^2 - \sigma_i^2 \right] / \left[\sigma_i^2 + \hat{\sigma}_\pi^2\right]^2 \right\}}{\sum_{i=1}^{p} \left(\sigma_i^2 + \hat{\sigma}_\pi^2\right)^{-2}} \tag{12}$$

and the remaining factors are

$$\hat{\mathrm{B}}_i = \frac{(p - l - 2)}{(p - l)} \cdot \frac{\sigma_i^2}{\sigma_i^2 + \hat{\sigma}_\pi^2} \tag{13}$$

$$\hat{l}_i = p\left[\boldsymbol{y}\left(\boldsymbol{y}^t \boldsymbol{V}^{-1} \boldsymbol{y}\right)^{-1} \boldsymbol{y}^t\right]_{ii} / \left(\sigma_i^2 + \hat{\sigma}_\pi^2\right) \tag{14}$$

and

$$\hat{\sigma}_p^2 = \frac{\sum_{i=1}^{p} \sigma_i^2 / \left(\sigma_i^2 + \hat{\sigma}_\pi^2\right)}{\sum_{i=1}^{p} 1 / \left(\sigma_i^2 + \hat{\sigma}_\pi^2\right)} \tag{15}$$

These equations do not provide a closed form solution, as **ß** is involved in the equation for F_B, while □□ is required in the equation for **ß**. The equations must thus be solved by iteration: Start with a guess for F_B and use it to calculate **ß**, then use the estimate of **ß** to recalculate F_B. Convergence is usually rapid, with the proviso that, if F_B converges to a negative number, it is replaced by zero. All the necessary calculations have been incorporated into a spreadsheet.

Development of Regionalization Format

The technical approach can be applied to any type of linear regional regression model. Some experimentation was needed to determine the appropriate independent variables for use in the regression equation. Results of Atlanta-area studies such as the Atlanta Regional Stormwater Characterization Study (Quasenbarth, 1993; CDM, 1996; CH2M HILL, 1999) suggested that the most relevant information for urban areas is likely to be percent of the watershed area in residential and commercial/industrial/office land uses.

Data to support the regionalization were obtained from the Georgia Water Resources Database (WRDB), including extensive data from the Chattahoochee River Modeling Project, and supplemented by local (county and municipal) data. Though some of the data sources extend back as far as 1968, the regionalization was restricted to data from the last ten years (1992-2002). Land use data were aggregated to the scale of 12-digit hydrologic unit codes with some further delineation based on reach segments. The smaller sub-watersheds were assigned 13 digit alphanumeric codes. These 12 or 13 digit watersheds will be referred to simply as watersheds in the following discussion.

For each watershed the mean and variance of the fecal coliform data were calculated in log space. The log-space means were then plotted against the fraction of the local watershed in agricultural, rural, urban, or single family residential land use. Single independent variable regressions on fractions in individual land uses had poor explanatory power and high standard errors; however, there was a positive correlation between coliform concentration and both single family residential and urban land uses. Correlation against agricultural land use was weakly negative. Multiple regressions provided better results, and the final exploratory model used fraction of land in single family residential and urban land uses. This model has an adjusted R^2 of 49 percent, as shown in Figure 1, with both coefficients statistically significant.

In sum, the exploratory regression indicates a statistically-significant relationship between the long-term geometric mean of observed fecal coliform data and land use. This model then provides the format for the empirical Bayes regional regression. As expected, the regional regression information provides some useful information, but is not in itself sufficient to provide an accurate estimate of observations. For this reason the weighting of regional and local data based on relative precision, as is done in the Bayes approach, is particularly important.

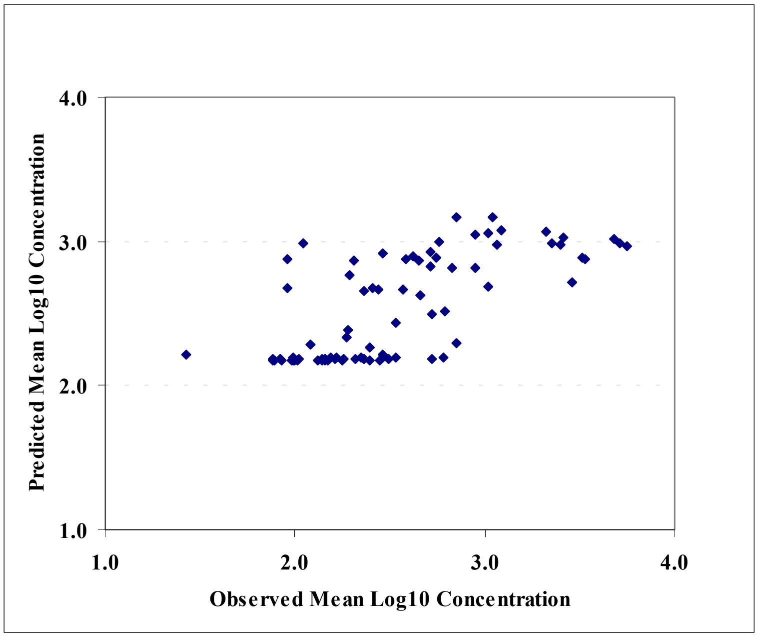

Figure 1. Predicted versus Observed Fecal Coliform Concentrations based on Land Use

Method Implementation

The methods described above were implemented in an Excel spreadsheet, using built-in matrix/array functions. The process consists of two general steps: Determination of the regionalization parameters and combination of site and regional data to estimate individual-site results.

The regionalization problem was broken into two sets. One set included the data from the Atlanta metropolitan area, the other set included sites outside the Atlanta metropolitan area. There are two reasons for taking this approach. First, there are likely to be systematic differences in the sources of bacterial pollution in this highly developed area. Second, the land use coverage in this area is obtained from the Atlanta Regional Commission (ARC) ESDIS coverage, which combines a variety of sources of high-accuracy information, including aerial photography interpretation, and is likely to differ in quality from the satellite imagery-derived MRLC data available for the remainder of the state.

Within the ARC area the regional regression used both fraction urban area and fraction single family residential area as independent variables. Outside the ARC area, the coefficient on single family residential area was not significantly different from zero. Therefore, the regionalization regression for sites in this area uses fraction urban area as a single independent variable. In both cases, only the local land use within the 12+-digit HUC corresponding to the listed segment was used in the regression, and not the entire upstream area land use, as concentrations are believed to be most strongly associated with local inputs. In three cases where the listed segment includes two or more 12+-digit HUCs, the land use distribution in the HUCs associated with the listed segment was combined for the purposes of the regression. The land use fractions associated with each site are shown in Table 1. Site fecal coliform data used

Table 1. Land Use Fractions used in Empirical Bayes Regionalization

Site	Location	HUC	Fraction Urban	Fraction Single Family Residential
Anneewakee Creek	House Creek to Lake Monroe (Douglas Co.)	031300020304A	0.0037	0.3004
Arrow Creek	Atlanta (Fulton Co.)	031300011201B	0.6500	0.3000
Aycocks Creek	Kaney Head Creek to Spring Creek (Miller Co.)	031300100405	0.0003	0.0000
Ball Mill Creek	Fulton/DeKalb Counties	031300010907B	0.0700	0.8500
Balus Creek	Gainesville (Hall Co.)	031300010803C	0.1026	0.0710
Beaver Creek	Spring Hill Creek to Flint River (Macon Co.)	031300060101	0.0100	0.0100
Bell Creek	Headwaters, d/s Thomaston, to Potato Creek (Upson Co.)	031300050908B	0.0800	0.1400
Big Creek	Hwy 400 to Chattahoochee River (Fulton Co.)	031300011004A	0.5600	0.2900
Big Slough	Near Pelham (Mitchell Co.)	031300080505	0.0000	0.0000
Bubbling Creek	DeKalb County	031300011203B	0.6600	0.2900
Buck Creek	Fox Branch to Flint River near Oglethorpe (Schley/Macon Co.)	031300060209	0.0002	0.0002
Bull Creek	Columbus (Muscogee Co.)	031300030104B	0.1800	0.3600
Burnt Fork Creek	DeKalb County	031300011202D	0.3600	0.5700
Buttermilk Creek	Cobb County	031300020208C	0.2000	0.5900
Camp Creek	Fulton County	031300020302	0.0800	0.2900
Camp Creek	Headwaters to Flint River (Clayton Co.)	031300050102	0.1100	0.5800
Centralhatchee Creek	Heard County	031300020407	0.0021	0.0031
Chattahoochee River	Ga. Hwy. 17, Helen to SR255 (White/Habersham Co.)	031300010102	0.0029	0.0012
Chattahoochee River	SR255 to Soquee River (White/Habersham Co.)	031300010106	0.0015	0.0017
Chattahoochee River	Morgan Falls Dam to Peachtree Creek (Fulton/Cobb Co.)	031300011101A	0.3100	0.4300
Chattahoochee River	Headwaters to Chattahoochee River (Cobb Co.)	031300011103A	0.3600	0.1100
Chattahoochee River	Utoy Creek to Pea Creek (Fulton/Douglas Co.)	031300020301	0.2300	0.5800
Chattahoochee River	Pea Creek to Wahoo Creek (Fulton Co.)	031300020307	0.5600	0.2000
Chattahoochee River	Pea Creek to Wahoo Creek (Fulton, Douglas, Coweta, Carroll Co.)	031300020312A	0.0029	0.0034
Chattahoochee River	Pea Creek to Wahoo Creek (Carroll Co.)	031300020401C	0.0300	0.0024
Chattahoochee River	Upatoi Creek to Railroad at Omaha (Chattahoochee/Stewart Co)	031300030606	0.0003	0.0000
Chattahoochee River	Downstream W. F. George, Dam (Clay Co.)	031300040101B	0.0100	0.0300
Cooleewahee Creek	Piney Woods Branch to Flint River near Newton (Dougherty/Baker Co.)	031300080304	0.0014	0.0003
Crawfish Creek	Douglas County	031300020308A	0.0000	0.0000
Crooked Creek	Tributary to Chattahoochee River (Gwinnett Co.)	031300010907C	0.6000	0.2600
Elkins Creek	Bull Creek to Flint River near Molena (Pike/Upson Co.)	031300050603	0.0009	0.0004
Fishpond Drain	U.S. Hwy. 84, Donalsonville to Wash Pond (Seminole Co.)	031300100802	0.0100	0.0100
Flat Creek	Headwaters Gainesville to Lake Lanier (Hall Co.)	031300010803B	0.2200	0.1000
Flat Shoal Creek	West Point (Troup/Harris Co.)	031300021007	0.0030	0.0012
Flint River	Hwy 138 to N. Hampton Road	031300050101A	0.1400	0.4300

Site	Location	HUC	Fraction Urban	Fraction Single Family Residential
Flint River	Road S1058/Woolsey Rd. to Horton Creek	031300050106B	0.0015	0.0034
Fowltown Creek	D/S Armena Rd. To Kinchafoonee Creek (Lee Co.)	031300070604	0.0012	0.0006
Gum Creek	Downstream Cordele to Lake Blackshear	031300060605B	0.0100	0.0100
Hannahatchee Creek	U.S. Hwy. 27 to Lake W.F. George (Stewart Co.)	031300030705	0.0005	0.0007
Hilly Mill Creek	Heard/Coweta Counties	031300020408C	0.0007	0.0002
Johns Creek	Headwaters to Chattahoochee River (Fulton Co.)	031300010906	0.1000	0.6600
Lanahassee Creek	W. Fork Lanahassee Creek to Kinchafoonee Creek (Webster Co.)	031300070203	0.0013	0.0002
Level Creek	Headwaters to Chattahoochee River (Gwinnett Co.)	031300010902B	0.0500	0.4900
Lime Creek	Little Lime Creek to Lake Blackshear (Sumter Co.)	031300060407	0.0000	0.0001
Long Cane Creek	Blue John Creek to Chattahoochee River	031300020912	0.0107	0.0110
Long Island Creek	Headwaters to Chattahoochee River (Fulton Co.)	031300011105B	0.1700	0.7900
Lullwater Creek	DeKalb County	031300011202C	0.1500	0.6700
Marsh Creek	Fulton County	031300011101B	0.2700	0.6100
Mobley Creek	Douglas County	031300020309B	0.0571	0.2857
Mossy Creek	Totherow Rd. near Clermont to Chattahoochee River (White/Hall Co.)	031300010302B	0.0100	0.0036
Mountain Oak Creek	Hamilton (Harris Co.)	031300021104B	0.0100	0.0001
Muckaloochee Creek	Little Muckaloochee Creek to Smithville Pond (Sumter Co.)	031300070903	0.0016	0.0016
Mud Creek	Ga. Hwy. 120 to Noses Creek (Cobb Co.)	031300020206C	0.0200	0.5900
Mulberry Creek	Ossahatchie Creek to Five Points Branch West near Mulberry Grove (Harris Co.)	031300021208B	0.0016	0.0001
Nancy Creek	Headwaters to Peachtree Creek, Atlanta (DeKalb/Fulton Co.)	031300011203A	0.2500	0.6500
New River	Corinth (Heard Co.)	031300020505B	0.0003	0.0001
Nickajack Creek	Headwaters to Chattahoochee River (Cobb Co.)	031300020102	0.1500	0.6100
North Fork Balus Creek	Gainesville (Hall Co.)	031300010803F	0.0500	0.0600
North Fork Peachtree Creek	Headwaters to Peachtree Creek, Gwinnett/DeKalb/Fulton Co.	031300011201C	0.3378	0.5405
Olley Creek	Cobb County	031300020207	0.2300	0.5400
Pataula Creek	Hodchodkee Creek to W.F. George Lake (Quitman/Clay Co.)	031300031508B	0.0002	0.0004
Patsiliga Creek	Beaver Cr. to Flint River, Butler (Taylor Co.)	031300051405	0.0100	0.0040
Pea Creek	Fulton County	031300020305	0.0013	0.1100
Peachtree Creek	I-85 to Chattahoochee River, Atlanta (Fulton Co.)	031300011204A	0.2700	0.6700
Peavine Creek	DeKalb County	031300011202B	0.2200	0.7500
Potato Creek	U.S. Hwy. 333 to Upson Co. Line (Lamar Co.)	031300050904B	0.0100	0.0040
Proctor Creek	Headwaters to Chattahoochee River, Atlanta (Fulton Co.)	031300020101C	0.4100	0.4300
Red Oak Creek	Little Red Oak Creek to Flint River near Imlac (Meriwether Co.)	031300050505	0.0016	0.0010

Site	Location	HUC	Fraction Urban	Fraction Single Family Residential
Rottenwood Creek	Headwaters to Chattahoochee River (Cobb Co.)	031300011104A	0.6700	0.1400
Sandy Creek	I-285 to Chattahoochee River (Fulton Co.)	031300020101B	0.1800	0.6300
Sewell Mill Creek	Cobb County	031300011103D	0.0511	0.8828
Soquee River	Goshen Creek to SR 17, Clarkesville (Habersham Co.)	031300010202	0.0004	0.0005
South Fork Peachtree Creek	Atlanta (Fulton Co.)	031300011202	0.3135	0.5196
Suwanee Creek	Mill Creek to Chattahoochee River (Gwinnett Co.)	031300010904	0.0600	0.0600
Sweetwater Creek	U/S Pine Valley Rd. to Noses Creek (Paulding/Cobb Co.)	031300020208	0.1625	0.4375
Swift Creek	Tobler Creek to Flint River (Upson Co.)	031300060608	0.0000	0.0000
Tesnatee Creek	Cleveland (White Co.)	031300010504	0.0100	0.0100
Turkey Creek	Pennahatchee Creek, NW Cordele to Flint River (Dooley Co.)	031300060507	0.0008	0.0010
Ulcohatchee Creek	Headwaters to Auchumpkee Creek (Crawford Co.)	031300051206	0.0011	0.0003
Utoy Creek	Atlanta (Fulton Co.)	031300020103A	0.1800	0.4200
Ward Creek	Cobb County	031300020205B	0.1300	0.7100
Weracoba Creek	Columbus (Muscogee Co.)	031300030104A	0.2800	0.4000
West Fork Little River	Headwaters to above Lake Lanier (White/Hall Co.)	031300010402A	0.0022	0.0024
White Oak Creek	Fulton County	031300020312B	0.0900	0.1900
Whitewater Creek	Headwaters to Little Whitewater Creek (Taylor Co.)	031300051503	0.0069	0.0001
Whitewater Creek	Big Whitewater Creek to Cedar Creek (Taylor/Macon Co.)	031300051507	0.0014	0.0012
Willeo Creek	Cobb/Fulton Counties	031300011102	0.0500	0.8600

in the regionalization consisted of the post-1992 data collected for the “limited data” TMDL sites, plus data provided by GA EPD for the TMDL Curve sites.

The empirical Bayes implementation yields the regionalization parameters shown in Table 2. These parameters are then used in Equation 9 to maximum likelihood estimates of 2 for each site. This in turn allows calculation of the translation factors through equation 6. The resulting TMDL estimates are provided in the main document.

Table 2. Regional Regression Parameter Estimates to Predict Long-Term Average Log base 10 Fecal Coliform Bacteria Concentration

Area	Intercept	Coefficient on fraction urban area	Coefficient on fraction single family residential
ARC	2.21	1.33	0.457
Outside ARC	2.13	2.73	NA

For both areas, the estimate of Φ_B is zero. This is a common occurrence in the method, and does not interfere with application. The implications are discussed by Berger (1985, p. 177) who states that the presence of a zero estimate of the regional or prior variance does not mean that there is no uncertainty in the estimate of the regional parameters. Rather, it implies a *lack* of information about F_B due to the fact that the likelihood function for F_B is quite flat.

The resulting empirical Bayes estimates of the site statistics are provided in Table 3.

Selection of Equivalent Site

Selection of equivalent sites proceeded with the following rules:

1. In the case where valid geometric mean data are available for a downstream segment within the same watershed, this site (or sites) was used as the equivalent site.

2. The total pool of equivalent sites available consisted of all the sites with completed TMDL estimates provided by GA EPD. Potential equivalent sites for segments within the Atlanta Metropolitan area were selected from other sites in the metro area; the pool for sites outside the metro area was other sites outside the metro area.

3. Where an equivalent site was not already present in a downstream segment, up to 5 equivalent sites were selected from within an approximately 10 mile radius, depending on availability. If the subject site is a headwater basin, preference was given to selection of equivalent sites that were also headwater basins, as these should have similar flow regimes.

4. If no equivalent sites were present within a 10 mile radius of the subject site, 1 or 2 equivalent sites were picked from the general pool of sites that had similar land use and drainage area size.

Selected equivalent sites for each limited-data site are identified in a table in the main report.

Translating Results to TMDLs

When a single equivalent site is used, estimation of the TMDL is straightforward. The procedure is the same as is used for the sites with valid geometric mean data, except that the estimates of critical load and associated flow are obtained from the equivalent site using the methods described in this appendix.

When multiple equivalent sites are used, the situation is somewhat more complicated, as each equivalent site may produce a different estimate of critical load and flow. The Bayes procedure described in this appendix is based, of necessity, on determining the relationship of long-term geometric means between sites. As a result, the primary output of this procedure is an estimate of the needed percent reduction, while the estimates of critical loads are less reliable because the regionalization reflects mean loads rather than critical loads. For this reason, the TMDL table entry for a limited-data site with multiple equivalent sites is filled in starting with the estimated percent reduction as the primary output and working

Table 3. Empirical Bayes Sufficient Statistics for Limited Data Sites (Expressed as Log base 10)

Site Name	HUC ID	μ EB (Equation 9)	V EB (Equation 10)
Atlanta Metro Area (ARC) Sites			
Ball Mill Creek	031300010907B	2.694	0.024
Hog Wallow Creek	031300011004B	2.830	0.358
Foe Killer Creek	031300011004C	2.795	0.350
Marsh Creek	031300011101B	2.898	0.062
Bishop Creek	031300011103B	2.792	0.349
Sewell Mill Creek	031300011103D	2.664	0.026
Foxwood Branch	031300011104C	2.704	0.329
Arrow Creek	031300011201B	3.211	0.018
South Fork Peachtree Creek	031300011202A, E	2.896	0.033
Peavine Creek	031300011202B	2.789	0.069
Lullwater Creek	031300011202C	2.738	0.061
Burnt Fork Creek	031300011202D	2.934	0.033
Bubbling Creek	031300011203B	3.206	0.028
Woodall Creek	031300011204B	3.245	0.462
Tanyard Branch	031300011204C	3.184	0.446
Clear Creek	031300011204D	3.029	0.406
North Utoy Creek	031300020103B	2.652	0.318
South Utoy Creek	031300020103C	2.719	0.333
Cracker Creek	031300020203C	2.670	0.322
Ward Creek	031300020205B	2.631	0.020
Trib to Mud Creek	031300020206B	2.425	0.270
Mud Creek	031300020206C	2.505	0.015
Olley Creek	031300020207	2.721	0.028
Buttermilk Creek	031300020208C	2.741	0.027
Pea Creek	031300020305	2.273	0.014
White Oak Creek	031300020312B	2.259	0.021
Turkey Creek	031300050302B	2.394	0.264
Non-ARC Sites			
Balus Creek	031300010803C, D, G	2.397	0.033
Mud Creek (S Hall)	031300010804B	2.244	0.178
North Fork Balus Creek	031300010803F	2.258	0.017
Hilly Mill Creek	031300020408C	2.132	0.020
Blue John Creek	031300020911A, F	2.305	0.187
Park Branch	031300020911D	2.472	0.213
Tanyard Creek	031300020911E	2.782	0.265
Rocky Branch	031300030101C	2.873	0.282
Weracoba Creek	031300030104A	2.885	0.038
Chattahoochee River	031300040101B	2.129	0.089
Big Slough	031300080505, 031300080506B	2.129	0.162

backward to fill in the other entries. The estimate of the TMDL is set at the average of the TMDL curve points determined in relationship to each of the equivalent sites. The estimate of current critical load is then set to a value such that current load times percent reduction equals the TMDL. When more than one equivalent site is used, this procedure results in an estimate of current critical load that may differ somewhat from the average of the critical load estimates obtained from the equivalent sites, but is within the range of the critical load estimates from the equivalent sites.

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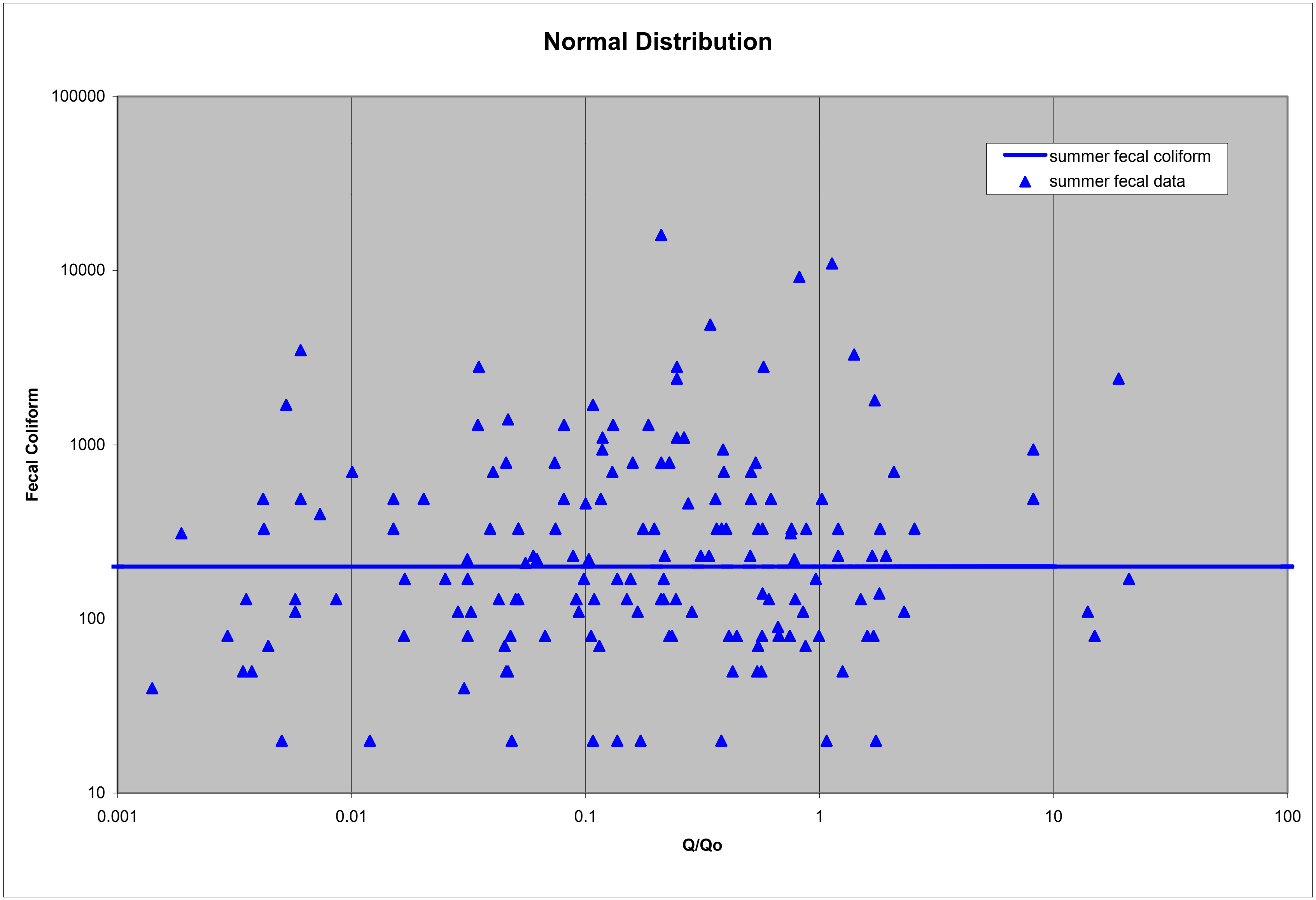
Appendix D

Normalized Flows Versus Fecal Coliform Plots


Normal Distribution
summer fecal coliform
summer fecal data
Fecal Coliform
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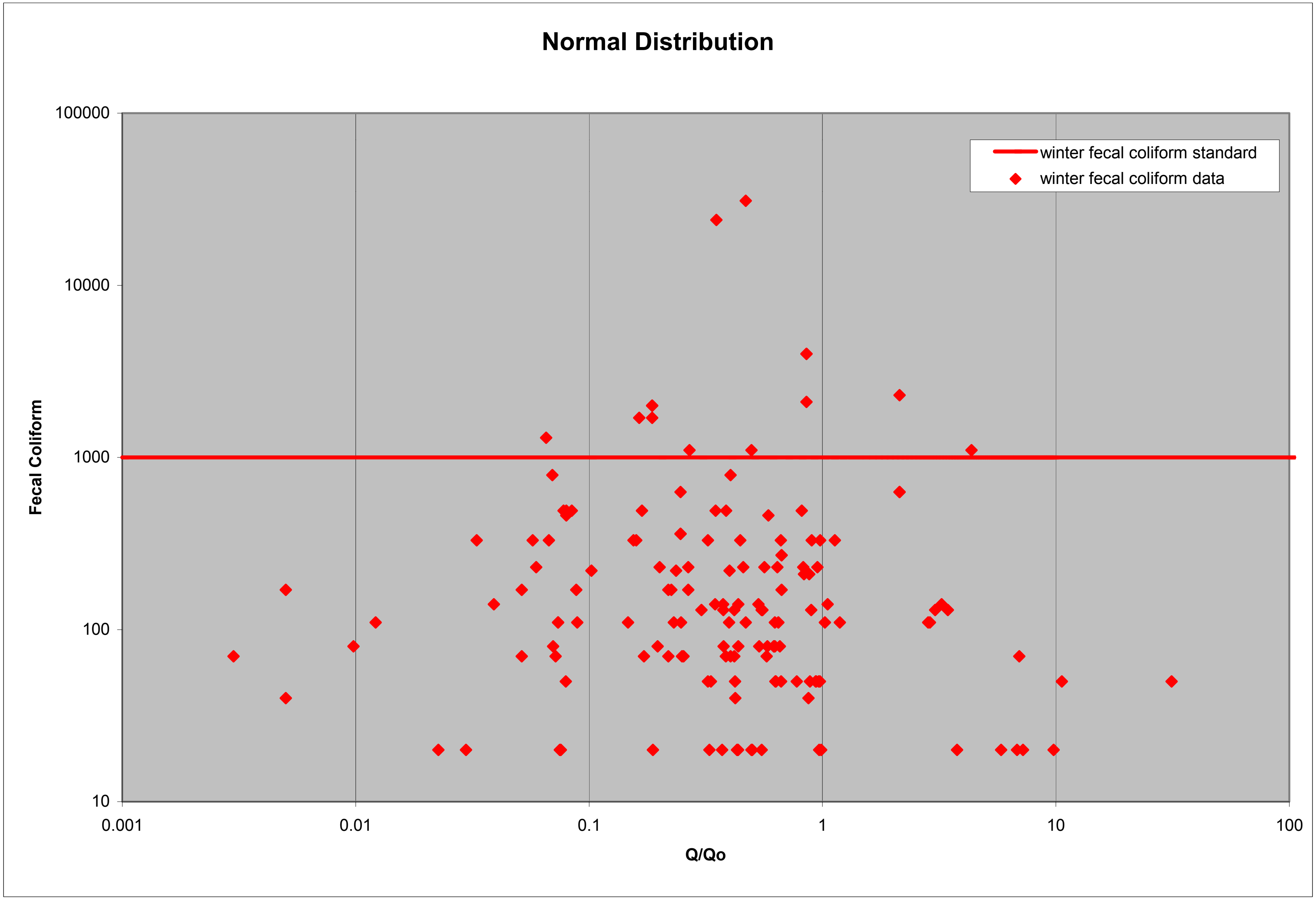
100
10
0.001
0.01
0.1
1
10
100
Q/Qo


Normal Distribution
winter fecal coliform standard
winter fecal coliform data
Fecal Coliform
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1000
100
10
0.001
0.01
0.1
1
10
100
Q/Qo