INSTREAM BIOLOGICAL ASSESSMENT OF NPDES POINT SOURCE DISCHARGES AT THE SAVANNAH RIVER SITE, 2000

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Executive Summary

Fish and macroinvertebrates were collected at unimpacted reference locations and downstream of NPDES discharges in Upper Three Runs and its tributaries, Fourmile Branch, Pen Branch/Indian Grave Branch, and Steel Creek/Meyers Branch to determine if the receiving streams have been impacted by the NPDES discharges. The results of the macroinvertebrate and fish surveys conducted during this study were generally in close agreement. Both indicated that most SRS streams were characterized by high biotic integrity and unaffected by SRS NPDES discharges. Possible exceptions included Crouch Branch, McQueen Branch, and Tims Branch, all of which are tributaries of Upper Three Runs. The fish data indicated that these three streams did not differ significantly from the control, while the macroinvertebrate data indicated possible impairment. Of the three, only Crouch Branch was identified as degraded in the earlier (1997-1998) survey. Subsequent investigations in Crouch Branch identified elevated concentrations of copper from the H-02 outfall as the primary cause of the degradation, although habitat degradation resulting from stormwater runoff also is a factor in the midreaches of the stream. In Tims Branch, a series of beaver dams that have been constructed just upstream from the sampling location subsequent to the 1997-1998 biological survey appear to be responsible for the perturbation. Dissolved oxygen levels below the dams are low enough to stress many species of aquatic biota. The source of perturbation in McQueen Branch is unknown, but may be due to habitat degradation that resulted during the construction of the Defense Waste Processing Facility (DWPF) in the late 1980's. In 2000, the sampling location in McQueen Branch was moved approximately 1 km upstream from the original sampling location, due to inundation of the 1997 sampling location by beaver dams. Stream habitat at the new location is somewhat degraded, due to channel erosion and scouring. However, this location is also closer than the original sampling location to the two NPDES outfalls that discharge to the stream, so impacts due to NPDES discharges cannot be ruled out. Biological impairment was also observed in upper Fourmile Branch and upper Steel Creek. Neither of these locations are downstream from NPDES discharges. Depressed biotic integrity in upper Fourmile Branch was related to factors other than NPDES discharges including low dissolved oxygen and elevated concentrations of iron. Fish sampling indicated that biotic integrity decreased in upper Steel Creek between 1997 and 2000, but this trend was not seen in the macroinvertebrate data. Reasons for the change in fish biotic integrity are unclear but may include reservoir impoundment related effects and naturally occurring habitat factors. Any impacts in Steel Creek are unrelated to NPDES discharges, since there have been no effluent discharges to this reach of Steel Creek since 1998.

1.0 Introduction

The Savannah River Site (SRS) currently has 31 NPDES outfalls that that have been permitted by the South Carolina Department of Health and Environmental Control (SCDHEC) to discharge to SRS streams and the Savannah River. In order to determine the cumulative impacts of these discharges to the receiving streams, a study plan was developed to perform in-stream assessments of the fish assemblages, macroinvertebrate assemblages, and habitats of the receiving streams. These studies were designed to detect biological impacts due to point source discharges. Sampling was initially conducted between November 1997 and July 1998 and was repeated in

the summer and fall of 2000. A total of 18 locations were sampled (Table 1, Figure 1). Sampling locations for fish and macroinvertebrates were generally the same. However, different locations were sampled for fish (Road A-2) and macroinvertebrates (Road C) in the lower portion of Upper Three Runs, to avoid interference with ongoing fisheries studies at Road C. Also, fish were sampled in Fourmile Branch at Road 4 rather than at Road F because the stream at Road F was too narrow and shallow to support many fish. Sampling locations and parameters are detailed in Sections 2 and 3 of this report. In general, sampling locations were selected that would permit comparisons upstream and downstream of NPDES outfalls. In instances where this approach was not feasible because effluents discharge into the headwaters of a stream, appropriate unimpacted reference were used for comparison purposes. This report summarizes the results of

Table 1. Sampling Locations for NPDES Biological Monitoring

LOCATION	SITE #	STATUS
Upper Three Runs Watershed		
Upper Three Runs, Road 8-1	3	Reference
Upper Three Runs, Road C (macroinvertebrates only)	2	Downstream from all discharges
Upper Three Runs, near Road A-2 (fish only)	18	Downstream from all discharges
Tims Branch near Road 2	1	Downstream from all discharges
Mill Creek, at Telephone Cable Crossing	4	Reference
McQueen Branch at Road F*	5	Downstream from all discharges
Crouch Branch, Road 4	6	Downstream from all discharges
Fourmile Branch Watershed		
Fourmile Branch, Road F (macroinvertebrates only)	7	Reference
Fourmile Branch, Road C	8	Downstream from F/H Areas
Fourmile Branch, Road A-6*	9	Downstream from all discharges but C-Area
Fourmile Branch, Road A	16	Downstream from all discharges
Pen Branch Watershed		
Pen Branch, Road C	10	Reference
Pen Branch, Road B	11	Reference
Indian Grave Br. near cooling tower	12	Downstream from all discharges
Pen Branch, Road A (macroinvertebrates only)	13	Downstream from all discharges
Pen Branch Road A13.2 (fish only)		Downstream from all discharges
Steel Creek Watershed		
Steel Creek, near Road C	14	Downstream from P-Area; upstream from L Lake
Meyers Branch, Old Dunbarton Rd.	15	Reference

*Location changed from 1997-1998 sampling program

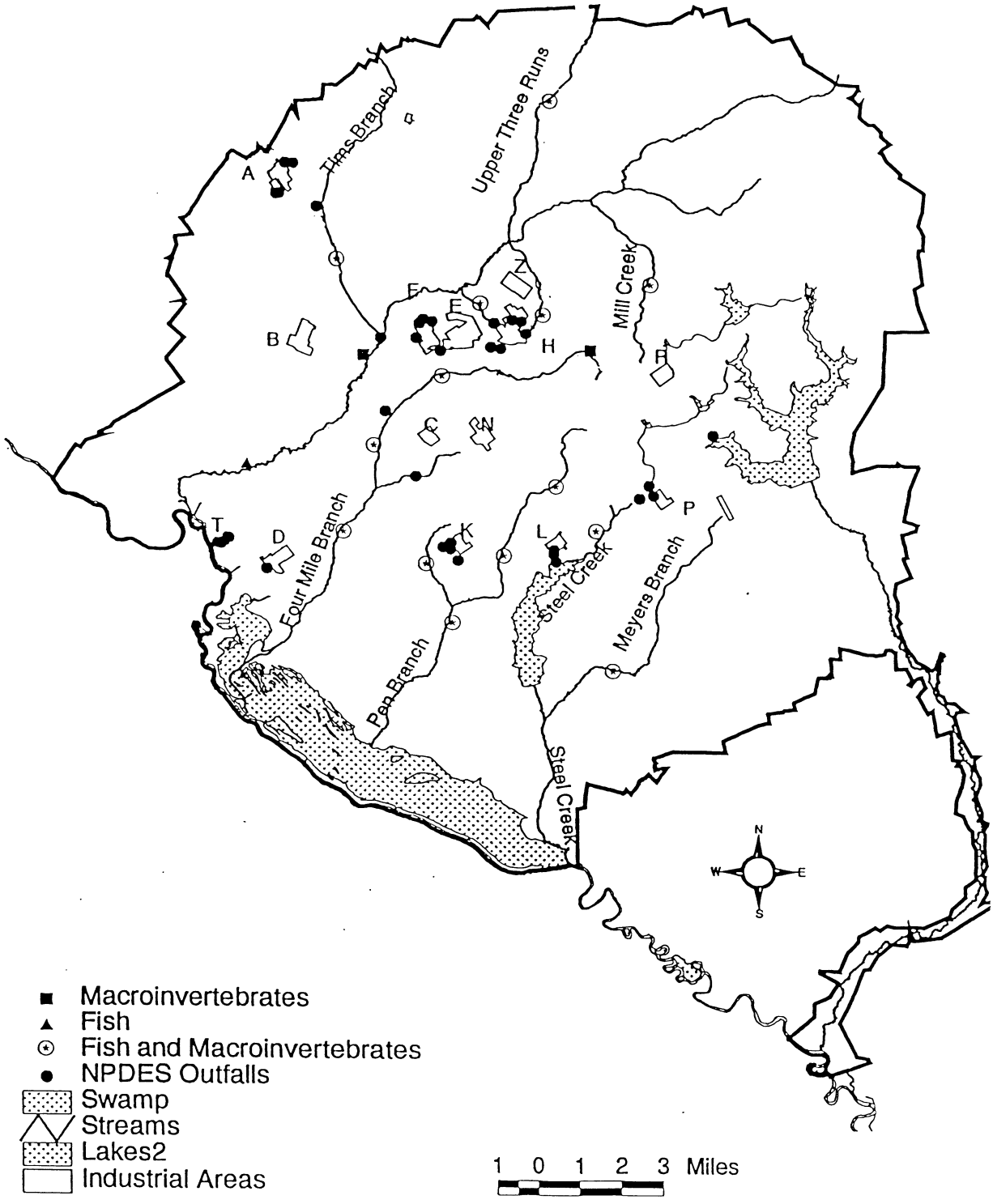

Figure 1. Map of the Savannah River Site showing sampling stations for fish and macroinvertebrates

the sampling that was conducted in 2000 and also compares these data to the data that were collected in 1997 and 1998.

1.1 Changes in NPDES Outfalls, 1997-1998 vs. 2000

Two NPDES outfalls have been eliminated from the SRS inventory since completion of the 1997-1998 biological survey: M-04, which discharged process wastewater from the Liquid Effluent Treatment Facility in M-Area to Tims Branch via the A-11 outfall and L-08, which discharged cooling water and stream water from L Area to L Lake.

2.0 Descriptions of Streams, Effluents, and Sampling Locations.

2.1 Upper Three Runs/Tributaries

Upper Three Runs is a fifth order stream that originates approximately 12 km north of the northern boundary of SRS and flows generally south, entering the Savannah River at River Mile (RM) 157.2 (Figure 1). Tributaries of Upper Three Runs that enter the stream along its flow path from north to south through the Savannah River Site include Tinker Creek, with its major tributaries of Mill Creek, Reedy Branch and McQueen Branch; Crouch Branch; and Tims Branch. With the exception of McQueen Branch, which enters Tinker Creek just before its confluence with Upper Three Runs, Tinker Creek and its tributaries have been largely uninfluenced by SRS activities, and these streams receive no NPDES discharges.

McQueen Branch originates just east of H-Area and flows generally northwest for about 4 km to its confluence with Tinker Creek. As shown in Table 2, McQueen Branch receives the discharge from the H-07 and S-04 NPDES discharges. These discharges consist primarily of neutralized wastewater, cooling water and storm water. McQueen Branch was also impacted by scouring and siltation during construction of the DWPF during the 1980's and early 1990's. Between 1987 and 1991 mean annual total suspended solids concentrations in the creek during high rain events (>1 cm in 24 hours) ranged between 159 and 256 mg/l, as compared to pre- and post-construction concentrations of 11 to 59 mg/l (Savannah River Ecology Laboratory, 1995) .

Crouch Branch is a small tributary of Upper Three Runs that originates just northwest of H-Area and flows northwest for about 2 km to Upper Three Runs. Crouch Branch receives NPDES discharges from the H-02 and H-04 outfalls, which primarily contain cooling water, steam condensate, Consolidated Incinerator Facility (CIF) treated wastewater, and stormwater. Crouch Branch was also impacted by scouring and siltation during construction of the DWPF. Between 1987 and 1991 mean annual total suspended solids concentrations during high rain events ranged between 120 and 401 mg/l, as compared to baseline levels of <15 mg/l (Savannah River Ecology Laboratory, 1995)

Tims Branch originates near A Area and flows southeast for about 8 km, entering Upper Three Runs just upstream from the Road C bridge. Tims Branch is the receiving stream for 4 NPDES outfalls (A-01, A-01A, A-11, and M-05), and a large portion of the flow in Tims Branch is comprised of NPDES effluents. These effluents include cooling water condensates, and water from lab drains, floor drains, two air strippers, an effluent

Table 2. SRS NPDES Outfalls, Receiving Streams and Contributing Waste Streams

Outfall	Receiving Stream	Inputs
Upper Three Runs Watershed (UTR)		
A-01	Tims Branch	cooling water, lab drains, air stripper effluent from A-01A, steam & A/C condensates
A-01A	Tims Branch via A-01	air stripper
A-11	Tims Branch	floor drains, condensate. Well flush water, cooling water, treated wastewater from M-04 and M-05
M-05	Tims Branch via A-11	air stripper effluent
F-01	UTR tributary	cooling water, blowdown, storm water
F-02	UTR tributary	cooling water, blowdown, storm water
F-03	UTR tributary	cooling water, steam condensate, blowdown, process water
F-05	UTR tributary	cooling water, steam condensate, storm water
H-02	Crouch Branch	cooling water, storm water
H-04	Crouch Branch	cooling water, storm water, Consolidated Incineration Facility wastewater, steam condensate
H-07	McQueen Branch	cooling water, blowdown, storm water
S-04	McQueen Br. tributary	neutralization waste water, cooling water, storm water
H-16	UTR	F/H Effluent Treatment Facility
Beaver Dam Creek Watershed (BDC)		
D-01A	BDC via D-01	sanitary effluent
Fourmile Branch Watershed (FMB)		
F-08	FMB tributary	cooling water, steam condensate, process wastewater, laundry effluent, water tank overflow, storm water
G-10	FMB	sanitary
H-08	FMB tributary	cooling water, steam condensate, ash basin, lab drains, storm water
H-12	FMB tributary	cooling water, In-Tank Precipitation Facility neutralized flush water, storm water
Pen Branch (PB)/Indian Grave Branch (IGB) Watershed		
K-06	IGB tributary	cooling water, blowdown, powerhouse waste, storm water
K-10	IBG	Infrequent diversion from K-18
K-12	IGB via K-18	sanitary
K-18	IGB	reactor cooling water basins, cooling water, sanitary from K-12
Steel Creek Watershed (SC)		
L-07	L-Lake	sanitary from L-07A, 186 basins, floor drains, storm water
L-07A	L-Lake via L-07	sanitary
Lower Three Runs Watershed (LTR)		
PP-01	Par Pond	rinse water and backwash from drinking water filter system
Savannah River (SR)		
X-04	SR swamp	welding quench sink water, steam condensate, storm water
X-08	SR	cooling water, sanitary from X-08A, process water, TNX Effluent Treatment Plant effluent from X-08B, air stripper effluent from X-08C
X-08A	SR via X-08	sanitary
X-08B	SR via X-08	TNX Effluent Treatment Plant effluent
X-08C	SR via X-08	air stripper effluent
X-19	SR	treated groundwater

treatment facility, and various other sources (see Table 2). Tims Branch also received inputs of metals from M Area during its early years of operation, and some of the metals (primarily aluminum, nickel, and uranium) are present in elevated concentrations in the depositional areas of Tims Branch.

Four NPDES discharges from F-Area (F-01, F-02, F-03 and F-05), consisting mainly of noncontact cooling water, blowdown, and steam condensate are discharged to flow paths that lead to Upper Three Runs. The H-16 outfall, which is the effluent from the F/H Effluent Treatment Facility (ETF) is the only NPDES outfall that discharges directly into Upper Three Runs. H-16 enters the stream just downstream from the Road C bridge. All NPDES effluents enter the portion of Upper Three Runs between its confluence with Tinker Creek and just downstream from the Road C bridge. In all, 13 NPDES outfalls enter the Upper Three Runs watershed (see Table 2). The upstream reference location in Upper Three Runs was the Road 8-1 bridge. Sampling locations downstream from SRS discharges include the Road C bridge (macroinvertebrates only), which is just downstream from the most-downstream NPDES discharge (H-16) as well as just downstream from Tims Branch, the most downstream tributary that contains NPDES discharges (Figure 1, Table 2) and near Road A-2 (fish only). Fish were sampled near Road A-2 instead of Road C because fish are routinely collected at Road C by the Environmental Monitoring Section (EMS) of WSRC, which may alter the community structure of the fish community at this location. Also sampled were Crouch Branch at Road 4, Tims Branch near Road 2, and McQueen Branch at Road F. In the 1997-1998 sampling program, McQueen Branch was sampled at Road Z. Since that time, beaver activity in the vicinity of Road Z has resulted in the formation of beaver ponds that provide aquatic habitat that is substantially different from that of the reference stream (Mill Creek); therefore the sampling location in McQueen Branch was moved upstream to Road F. Upstream reference locations for Crouch, McQueen, and Tims Branches were not available, since effluents discharge into the headwaters of all three of these tributaries. Mill Creek, an unimpacted tributary of Upper Three Runs, was sampled as a reference location for the tributaries of Upper Three Runs. However, Mill Creek is somewhat larger than the 3 streams that receive NPDES discharges.

2.2 Fourmile Branch

Fourmile Branch is a third order stream that originates southeast of H-Area and flows generally west and southwest for about 25 km, entering the Savannah River at RM 150.6, just across the river from the Vogtle Nuclear Power Plant. The first five km of the stream receive no NPDES discharges. Four NPDES outfalls (F-08, G-10, H-08 and H-12) discharge to Fourmile Branch and all of the discharges are to the portion of the stream located between just upstream from Road 4 to approximately 1 km upstream from Road A-7. NPDES discharges to the stream include cooling water, ash basin overflows, treated sanitary wastewater from the new central sanitary treatment plant, storm water and other miscellaneous sources (see Table 2). Fourmile Branch also receives inputs from the F/H seepline, which is primarily encompassed by the area between Roads 4 and C-4. Shallow groundwater from the old F/H seepage basins and the old Burial Ground outcrops near this section of Fourmile Branch. This water contains elevated levels of tritium, as well as above-background concentrations of some metals and other contaminants. The portion of Fourmile Branch from

approximately 0.5 km downstream from Road 3 to the Savannah River was subject to very high temperatures and flows until 1984, when the operation of C Reactor was discontinued. The habitat of the post-thermal streams still differs substantially from the habitat in streams that were not exposed to high temperatures and flows, primarily with respect to canopy cover, the composition of stream substrate, in-stream structure (size and amount of woody debris, etc.), and riparian vegetation. These habitat differences have had lasting influence on the biotic communities of the post-thermal streams.

Sampling locations in Fourmile Branch included Road F (macroinvertebrates only), which is upstream from all SRS discharges; Road C, which is downstream from the H-Area discharges; Road A-6 which is downstream from the F-Area outfall and sanitary treatment plant, but upstream of where the C-Area outfalls previously entered Fourmile Branch, and Road A, which is downstream from all SRS discharges, and is a post-thermal location. In the 1997-1998 round of sampling, macroinvertebrates were sampled at Road A-7, and fish were sampled at Road A-6 because there was better access. For consistency, in this round of sampling both fish and macroinvertebrates were sampled at Road A-6. Road A-6 is located approximately 300 m upstream from Road A-7 and contains similar habitat. In 1997-1998 fish were sampled near Road 4 (located between Road F and Road C). However, this location was not sampled in 2000 because it had been impounded by beavers and converted into a series of ponds and swamps. The IBI used on the SRS was developed for free flowing streams and would not be expected to produce accurate results for standing waters (Paller et al. 1996).

2.3 Pen Branch/Indian Grave Branch

Pen Branch is a third order stream that originates near the intersection of Roads F and 6 and flows generally southwest for approximately 17 km to the Savannah River swamp, exiting the swamp to the Savannah River via Steel Creek. Indian Grave Branch is a small tributary of Pen Branch that is located just west of K Area. It is about 4 km long and flows generally south, merging with Pen Branch approximately one km upstream of Road A. Four NPDES discharges (K-06, K-10, K-12, and K-18) enter Indian Grave Branch from K Area (Table 2); no effluents discharge directly to Pen Branch. The discharges to Indian Grave Branch consist primarily of cooling water, powerhouse wastewater, storm water, and a small quantity of treated sanitary effluent. Indian Grave Branch was also the receiving stream for the thermal discharge from K Reactor, which operated until 1988. Like Fourmile Branch, Indian Grave Branch and the portion of Pen Branch that was impacted by thermal discharge have very different habitat than the non-thermal streams. These habitat differences need to be considered when interpreting biological data from the post-thermal streams.

Sampling locations in Pen Branch and Indian Grave Branch included Pen Branch at Roads C and B, which are both upstream from all SRS discharges, Pen Branch at Road A (macroinvertebrates only), which is downstream from Indian Grave Branch and all SRS discharges, and Indian Grave Branch near the cooling tower, which is downstream of all existing K-Area NPDES discharges to this tributary. Fish were sampled near Road A in 1997-1998 but not during 2000 because beavers had impounded the stream near Road A converting it to a pond-like environment unsuitable for analysis with the IBI. During 2000, fish samples were instead collected near Road

A13.2, which is located downstream of Road A. Because effluents discharge into the headwaters of the stream, no upstream reference location could be sampled in Indian Grave Branch.

2.4 Steel Creek/Meyers Branch

Steel Creek is a third order stream that originates west of P Reactor and flows south for about 18 km, entering the Savannah River at RM 141.6. A portion of Steel Creek was impounded in 1985 to form L Lake, a 1000 acre cooling reservoir. The lake has not received thermal discharges since 1988. Meyers Branch is a major tributary of Steel Creek that originates east of P Reactor and flows generally southwest for about 12 km, merging with Steel Creek approximately one km downstream from the L-Lake dam. Steel Creek is the receiving stream for two NPDES outfalls (L-07 and L-07A; Table 2). The discharges consist primarily of cooling water, building drains, stormwater, and a small volume of treated sanitary effluent. In the past, the upper reach of Steel Creek upstream from L Lake received NPDES discharges from several outfalls in P Area, but this portion of Steel Creek has received no NPDES discharges since January 1998. However, during the fall of 2000, water from the Savannah River was diverted to L Lake via the P-19 outfall during an extended pumping outage that prevented pumping river water to L Lake via the L-07 outfall. Meyers Branch has been largely unimpacted by SRS activities.

Sampling locations in Steel Creek and Meyers Branch included Steel Creek near Road C, which is downstream from the P-Area discharges into Steel Creek but upstream from L Lake and Meyers Branch at old Dunbarton Road. Two NPDES outfalls from L Area discharge to L Lake, which is located downstream from the sampling location in Steel Creek. However, the volume of the discharges is small and would be diluted by the entire volume of L Lake prior to discharging into lower Steel Creek. Lower Steel Creek was not sampled because previous studies indicated that the stream community was influenced by the lentic community of L Lake, and it would be impossible to distinguish between possible outfall impacts and the greater influence of L Lake discharges into the stream. Meyers Branch at old Dunbarton Road was sampled as a reference location for Steel Creek and some of the other sampling locations.

2.5 Other Water Bodies/NPDES Discharges

A number of NPDES outfalls discharge to other locations on the SRS (Table 2). Outfall D-01A consists of treated sanitary discharge that is discharged to the D-01 outfall. Outfall PP-01 consists of a very small amount of backwash water from a drinking water filter system at the Par Pond laboratory that discharges to Par Pond. However, neither Beaver Dam Creek nor Par Pond/Lower Three Runs were included in the permit condition that requires biological sampling. Six outfalls from TNX discharge indirectly to the Savannah River. Due to the small volume of effluent in relation to the large dilution factor provided by the river, and because previous studies have not detected any impact from SRS operations to the Savannah River, studies in the Savannah River were not included in this study, but a discussion of previous biological studies conducted on the Savannah River is presented in Section 4.5.

3.0 Methods

3.1 Habitat Evaluation/Water Chemistry

Physical habitat data were collected from each fish assemblage sample site to assist in the interpretation of the biological data. These data were collected from transects running across the stream perpendicular to the direction of water flow. Except at the sample sites in Upper Three Runs, there were three transects evenly spaced within each 50 m section for a total of nine habitat transects per site. Because of the difficulty in obtaining habitat data from Upper Three Runs, which was comparatively deep and wide, there were only two evenly spaced habitat transects per site in this stream. The following habitat data were collected at each transect:

1) Stream width (distance from waters edge to waters edge).
2) Depth of the stream (nearest 0.01 m) at a minimum of approximately 20%, 40%, 60%, and 80% of the distance from the left bank to the right bank.
3) Current velocity (cm/s) at each point where depth was measured. Where depth equaled or exceeded 0.6 m, two current velocity measurements were taken, one at 0.2 times the depth and one at 0.8 times the depth. Where the depth was less than 0.6 m, only one measurement was taken at 0.6 times the distance from the surface.
4) Predominant substrate types (mud, sand, gravel, rocks) in the vicinity of the transect (i.e., 3 m upstream from the transect and 3 m downstream from the transect). Visual estimate.
5) Bottom area (nearest 5%) covered by debris (detritus and leaves). Visual estimate.
6) Number of logs (i.e., recumbent wood in excess of 6 cm in diameter) in the vicinity of the transect.
7) Number of stumps in the vicinity of the transect.
8) Number of cypress knees in the vicinity of the transect.
9) Bottom area (nearest 5%) covered by fibrous root systems. Visual estimate.
10) Bottom area (nearest 5%) covered by brush piles/log jams. Visual estimate.
11) Aquatic macrophyte cover (nearest 5%) and the predominant types (submerged, emergent, floating) in the vicinity of the transect. Visual estimate.
12) Amount of stream surface (nearest 5%) overhung by low growing riparian vegetation (e.g. shrubs, grasses, and small trees) in the vicinity of the transect. Visual estimate.
13) Canopy cover (nearest 5%) and the predominant canopy types (cypress/tupelo forest, hardwood forest, pine forest) in the vicinity of the transect. Visual estimate.
14) Bank erosion on a scale of zero (none) to severe (three). Visual Estimate.

To maintain consistency and facilitate comparisons among sample reaches, all habitat variables requiring visual estimation (i.e., 4, 5, 8, 9, 10, 11, and 12) were recorded by the same person.

Physical and chemical data collected in conjunction with the biological data included water temperature, dissolved oxygen, pH and specific conductance. These data were collected by ETT Environmental, Greenville, SC (SCDHEC Certification # 23104) at the time that the multiplate samples were retrieved. Temperature was measured to the nearest degree using a mercury thermometer, dissolved oxygen was measured using a YSI Model 51B dissolved oxygen meter, pH was measured using a Fisher Model 1001

pH meter, and specific conductance was measured using a VWR Model 604 conductivity meter.

3.2 Macroinvertebrates

3.2.1 Sampling Methods

Sampling and identification of macroinvertebrates for this sampling program were performed by ETT Environmental (SCDHEC Certification # 23104). At each sampling location, five replicate Hester-Dendy multiplate samplers (Figure 2), each having a surface area of 0.179 m^2 were deployed and allowed to colonize for 28 days. The samplers were retrieved and returned to the laboratory for processing. In the laboratory, the samplers were disassembled and organisms gently removed from the plates using a soft brush or a stream of water from a wash bottle. Organisms were preserved in 70% ethanol until identified to the lowest practical taxon (usually genus).

Although multiplate samplers provide a uniform substrate for macroinvertebrate sampling, the species composition and relative abundance of macroinvertebrate assemblages collected from multiplate samplers differ from natural substrates. Some taxa are over-represented on multiplate samplers, while other taxa are under-represented or completely absent. In order to perform a thorough assessment of the macroinvertebrate community at each sampling site, qualitative sampling of natural substrates was also performed. At the time that the multiplates were retrieved, sampling of natural substrates (leaf packs, snags, root mats, woody debris, etc.) present at the sampling site was performed for one man hour per sampling station, and macroinvertebrates present on the substrates were collected, preserved, and returned to the laboratory for identification.

3.2.2 Data Analysis

Descriptive Parameters - The multiplate data were analyzed for the parameters listed in Table 3. In addition, SCDHEC's Bioclassification of Streams Procedure (SCDHEC, 1998) was performed on both the quantitative and qualitative data. This procedure assigns numerical scores to North Carolina biotic index values (Lenat, 1993) and EPT taxa richness values. The two scores are then averaged to obtain a Bioclassification score, which ranges from 5 (excellent) to 1 (poor). The scores of sampling sites located downstream from NPDES discharges are then compared to the scores of reference sites, using the following decreases in Bioclassification scores to assess the level of impairment:

Level of Impairment	Decrease in Bioassessment Score
Unimpaired	≤0.4
Slightly impaired	0.6 - 1.4
Moderately impaired	1.6 - 2.4
Severely impaired	≥2.6

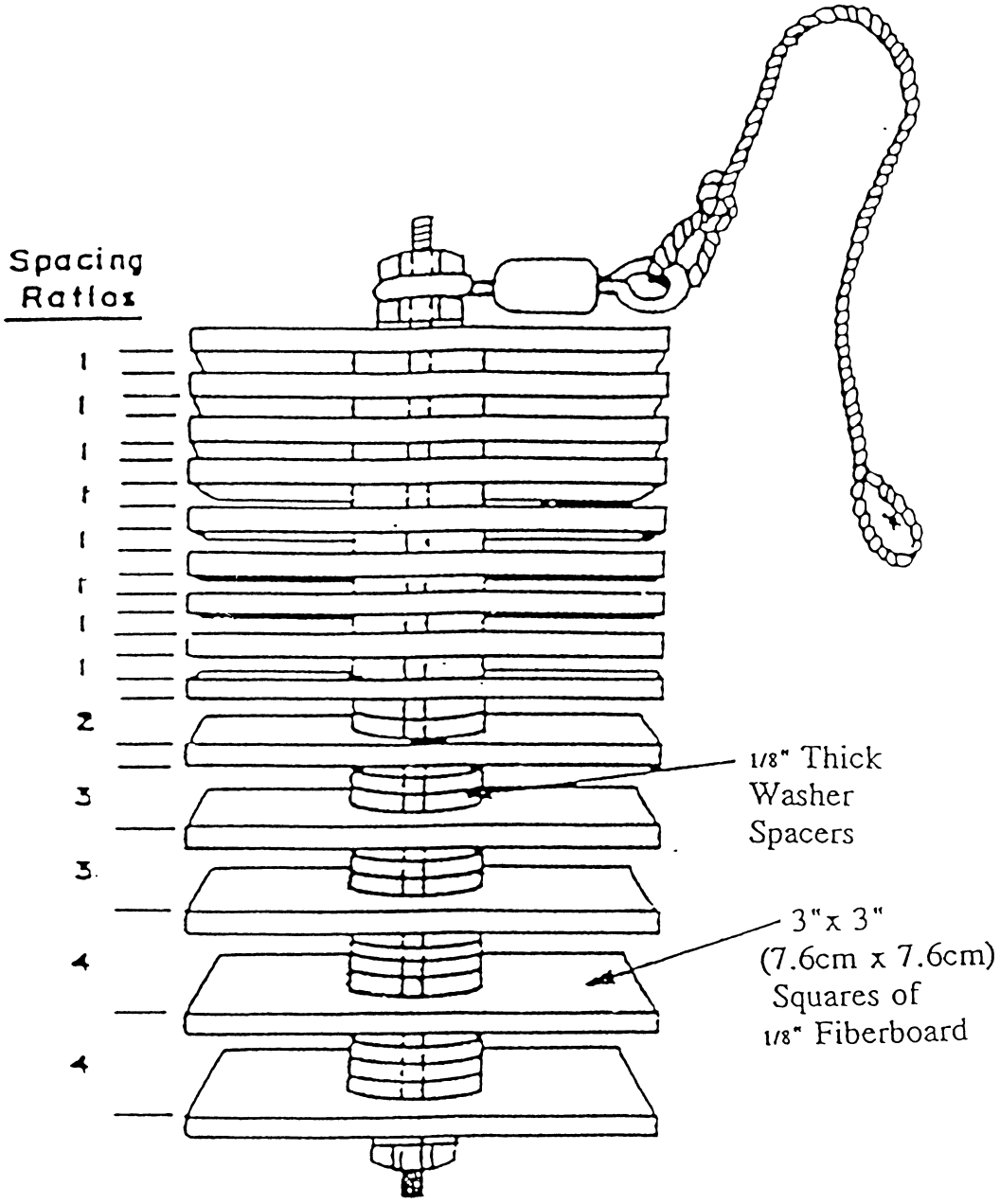

Figure 2. Hester-Dendy Multiplate Sampler

Table 3. Metrics for Macroinvertebrate Multiplate and Qualitative Data

Quantitative (Multiplate) Data
Total number of taxa
Mean Number of taxa/sampler
Mean density of organisms (number/m^2)
Biomass (g ash-free dry weight/m^2)
Total number of EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa
Relative abundance (%) of major taxonomic groups
Relative abundance (%) of functional feeding groups
Relative abundance (%) of functional feeding group biomass
Listing of dominant taxa (>5% abundance)
North Carolina Biotic Index (NCBI; Lenat, 1993)

Qualitative Data
Total number of taxa
Total number of EPT taxa
North Carolina Biotic Index (NCBI)

3.3 Fish

3.3.1 Sampling Methods

Fish assemblages were sampled at 15 sites. Five of these (one in Mill Creek, one in Meyers Branch, two in Pen Branch, and one in Upper Three Runs) were located upstream from SRS NPDES outfalls (Figure 1). The other sites were located downstream from SRS NPDES discharges. With the exception of the uppermost portion of Fourmile Creek, all stream reaches sampled for macroinvertebrates were also sampled for fish; although, in some cases, the exact locations sampled differed slightly (Figure 1).

Three 50 m stream segments were electrofished at each sample site. All sites except for those in Upper Three Runs were sampled with a Coffelt backpack electrofisher powered by a generator, a Smith-Root backpack electrofisher powered by a battery, or a Smith-Root backpack electrofisher powered by a generator. A single pass was made through each 50 m segment at each site while moving upstream. All microhabitats were carefully sampled in an effort to obtain as many species and individuals as possible by collecting them with dip nets after they had been stunned by DC current. At relatively narrow sites (under 4-5 m) we used one backpack electrofisher and a two or three person crew. At wider sites, two back pack electrofishers and two crews were used, with a crew covering each bank as both moved upstream simultaneously. To sample Upper Three Runs, the widest (up to 20 m in the sample areas) and deepest stream (up to 2.1 m), a 4.5 m boat with a boat mounted generator and a Smith-Root electrofisher was used. Each bank was sampled separately in Upper Three Runs using the previously described protocol. All fish were identified to species and released.

3.3.2 Data Analysis

Fish assemblage data were analyzed using the Index of Biotic Integrity (IBI). The IBI is a bioassessment method used to assess the biotic integrity of streams. Biotic integrity is the ability of a stream to support a self sustaining biological community and ecological processes typical of undisturbed, natural conditions (Angermeier and Karr 1994). The IBI uses fish assemblage data to assess biotic integrity. It is composed of a number of community, population, and organism level variables that are ecologically important and sensitive to environmental disturbances of various types. These variables are measured at assessment sites, compared to those in a range of similar but undisturbed benchmark sites, and the results summarized in a single number that reflects the extent to which the assessment site resembles the benchmark. The IBI has been endorsed by the USEPA (Plafkin et al. 1989) and has been adapted for use throughout the United States and in a number of foreign countries. It has been modified for use in SRS streams where it accurately discriminated undisturbed sites from sites affected by physical habitat alterations and chemical pollution (Paller et al. 1996).

The IBI was calculated using methods presented in Paller et al. 1996 and Paller and Dyer 1997. IBI metrics and scoring criteria for the metrics are listed in Table 4. This methodology adjusts for differences in stream size and sample area making it possible to directly compare IBI values from streams and sample areas of different size. The highest IBI value that can be obtained is 50. The IBI was calculated for each 50 m segment at each location. The statistical significance of differences between the average IBI at the undisturbed sample sites and the average IBI at the sample site receiving NPDES discharges was assessed with the Kruskal-Wallis test ($P \leq 0.05$), although results must be treated with caution because of small sample sizes. In addition, the average IBI at each sample site was compared to IBI values at 29 undisturbed locations sampled during previous sampling programs. These data (hereafter referred to as historical data) are described more fully in Paller and Dyer (1997).

4.0 Results

A master species list, containing all of the macroinvertebrate taxa collected from both quantitative and qualitative sampling can be found in Table 5. A list of dominant species, which included any species that comprised 5% or more of the organisms collected from quantitative or qualitative sampling of natural substrates can be found in Table 6. The remaining macroinvertebrate data are organized into three tables, by watershed (Upper Three Runs; Fourmile Branch; Pen Branch/Indian Grave Branch, and Steel Creek/Meyers Branch). Also included are summary data from the 1997 survey, for comparison.

4.1 Upper Three Runs Watershed

4.1.1 Macroinvertebrates - Upper Three Runs and Tributaries

As discussed in Section 2.1, sampling was performed at two locations in Upper Three Runs: Road 8-1, which is upstream from all NPDES discharges to the stream and just downstream from Road C, which is downstream from all NPDES discharges and tributaries that receive

Table 4. Metrics and scoring criteria used in the Index of Biotic Integrity (IBI) as modified by Paller et al (1996). The modified IBI is calculated by summing the scores for the individual metrics.

Metrics	Scoring criteria 1	3	5
Species richness			
Adjusted number species[a]	<70	70-90	>90
Adjusted number cyprinid species[a]	<55	55-80	>80
Adjusted number piscivorous species[a]	<65	65-85	>85
Number darter species	0	1-2	≥3
Number madtom species	0	1	≥2
Number intolerant species	0	1	≥2
Species composition			
Percent tolerant species	>15	5-15	<5
Percent sunfish species	>45	25-45	<25
Trophic composition			
Percent insectivorous cyprinids	<20	20-35	>35
Percent generalized insectivores	>75	50-75	<50
Fish abundance (Number/100 m^2)			
Stream orders 1-3, ≥4 passes	<25		≥25
Stream orders 1-3, 1 pass	<10		≥10
Stream order 4, ≥4 passes	<5		≥5
Stream order 4, 1 pass		<2	
Fish condition			
Percent with disease or anomalies	>5	>2-5	0-2

[a] Species number expressed as a percentage of the number of species expected in an unimpacted stream after adjusting for the effects of sample area, stream order, and sampling effort (Paller et al. 1996). Maximum percentage equals 100.

discharges. With respect to most of the parameters that were measured, Upper Three Runs at Road 8-1 and Road C were fairly similar (Table 7). Slightly more taxa were collected at Road C than at Road 8-1 in the quantitative sampling (33 vs. 29), but the reverse was seen for the qualitative data (52 at Road C; 56 at Road 8-1) and for qualitative and quantitative data combined (64 at Road C; 70 at Road 8-1). Eleven EPT taxa were collected at Road C; nine were collected at Road 8-1. The North Carolina biotic index was 5.78 at Road C, and was slightly lower (better) at Road 8-1 (5.53). By far, the most dominant group of taxa at both locations were dipteran midges (about 80% at both locations), with Orthocladiinae being the most dominant group of midges 51.9% at Road 8-1; 67.3% at Road C. Tanytarsini and Chironomini midges

Table 5. Master Species List for Quantitative/Qualitative Sampling Combined, November 2000

	Upper Three Runs System						Fourmile Branch System				Pen Branch System				Steel Cr. Sys.	
	Upper Three Runs Rd. 8-1	Upper Three Runs Rd. C	Mill Creek	Tims Branch Rd. 2	McQueens Branch Rd F	Crouch Branch Rd. 4	Fourmile Branch Rd. E	Fourmile Branch Rd. C	Fourmile Br. Rd. A-6	Fourmile Branch Rd. A	Pen Branch Rd. C	Pen Branch Rd. B	Pen Branch Rd. A	Indian Grave Branch	Steel Cr. near Rd. C	Meyers Branch
ORDER EPHEMEROPTERA (mayflies)																
Acerpenna pygmaea	x															
Baetis dubium		x														
Baetis frondalis	x									x					x	x
Baetis intercalaris			x					x		x	x	x	x	x		
Baetis nr. punctiventris	x									x			x			
Baetis propinquus												x	x			
Caenis diminuta	x	x	x	x										x		x
Dannella simplex													x			
Ephemerella catawba/inconstans				x								x	x		x	
Ephemerella nr. doris									x							
Eurylophella		x	x							x					x	
Hexagenia	x	x	x													
Isonychia		x								x					x	
Leptophlebia			x					x			x					
Neoephemera youngi		x							x				x			
Paraleptophlebia	x	x	x						x							x
Stenonema modestum/smithae	x	x	x	x				x	x	x	x	x	x	x	x	x
ORDER PLECOPTERA (stoneflies)																
Acroneuria abnormis	x	x											x			
Allocapnia	x	x	x		x			x		x	x	x	x	x	x	x
Clioperla clio			x								x	x	x		x	
Eccoptura xanthenes			x													
Haploperla brevis									x							
Isoperla bilineata															x	
Isoperla dicala		x	x									x	x			
Paragnetina fumosa	x	x											x			
Perlesta placida	x	x	x									x	x		x	
Pteronarcys	x	x														
Taeniopteryx		x	x						x	x	x	x	x	x		
Taeniopteryx nr. metequi		x	x										x			
ORDER TRICHOPTERA (caddisflies)																
Agarodes libalis	x															
Anisocentropus pyraloides			x													
Brachycentrus nigrosoma	x	x											x			
Brachycentrus numerosus		x														

Table 5. Master Species List for Quantitative/Qualitative Sampling Combined, November 2000

	Upper Three Runs System						Fourmile Branch System				Pen Branch System				Steel Cr. Sys.	
	Upper Three Runs Rd. 8-1	Upper Three Runs Rd. C	Mill Creek	Tims Branch Rd. 2	McQueens Branch Rd F	Crouch Branch Rd. 4	Fourmile Branch Rd. E	Fourmile Branch Rd. C	Fourmile Br. Rd. A-6	Fourmile Branch Rd. A	Pen Branch Rd. C	Pen Branch Rd. B	Pen Branch Rd. A	Indian Grave Branch	Steel Cr. near Rd. C	Meyers Branch
ORDER TRICHOPTERA (cont.)																
Cernotina									x	x				x		x
Cheumatopsyche		x	x		x	x			x	x	x	x	x	x	x	x
Chimarra aterrima		x	x							x				x	x	x
Chimarra socia													x			
Diplectrona modesta	x															
Heteroplectron americanum											x					
Hydropsyche betteni										x				x	x	
Hydropsyche elissoma	x	x														
Hydropsyche nr. venularis													x			
Hydroptila														x		
Lepidostoma		x														
Limnephilidae										x						
Lype diversa			x				x		x			x			x	
Macrostemum carolina	x															
Micrasema rusticum																x
Micrasema wataga	x	x														
Neureclipsis		x														
Oecetis sp.			x						x						x	
Oxyethira			x					x	x					x		
Oxyethira janella													x			
Phylocentropus	x		x									x				x
Polycentropus		x														
Ptilostomis							x									x
Pycnopsyche															x	
Triaenodes			x									x				x
ORDER ODONATA (dragonflies)																
Aeshna umbrosa							x									
Anax junius	x															
Anax longipes							x									
Argia sedula	x					x		x	x	x				x		
Argia sp			x							x		x				
Boyeria vinosa	x	x	x					x				x			x	
Calopteryx dimidiata	x	x						x	x		x	x	x		x	
Cordulegaster maculata			x		x	x										x
Enallagma divagans							x	x	x	x		x		x	x	x
Enallagma traviatum			x													

Table 5. Master Species List for Quantitative/Qualitative Sampling Combined, November 2000

	Upper Three Runs System						Fourmile Branch System				Pen Branch System				Steel Cr. Sys.	
	Upper Three Runs Rd. 8-1	Upper Three Runs Rd. C	Mill Creek	Tims Branch Rd. 2	McQueens Branch Rd F	Crouch Branch Rd. 4	Fourmile Branch Rd. E	Fourmile Branch Rd. C	Fourmile Br. Rd. A-6	Fourmile Branch Rd. A	Pen Branch Rd. C	Pen Branch Rd. B	Pen Branch Rd. A	Indian Grave Branch	Steel Cr. near Rd. C	Meyers Branch
ORDER ODONATA (cont.)																
Erythrodiplax connata																x
Gomphus lividus			x					x	x			x				x
Hagenius brevistylus		x														
Libellula sp.	x													x		x
Macromia sp.			x												x	x
Neurocordulia virginiensis	x	x								x						
Ophiogomphus mainensis											x					
Progomphus		x	x								x					
ORDER HETEROPTERA (true bugs)																
Corixidae																x
Mesovelia mulsanti									x	x	x				x	
Metrobates hesperius									x	x						
Ranatra															x	
Rhagovelia obesa	x	x			x											
Trepobates											x					
O. MEGALOPTERA (hellgrammites)																
Sialis	x	x							x							
Corydalus cornutus						x		x								
Nigronia serricornis	x	x						x								
ORDER COLEOPTERA (beetles)																
Agabus/Ilybius				x			x									
Anchytarsus bicolor						x						x				
Ancyronyx variegatus		x	x	x				x			x					
Berosus sp.									x							
Coptotomus sp.							x									
Curculionidae														x		
Dineutus discolor	x															
Dineutus sp.							x		x							
Dubiraphia bivittata								x								x
Dubiraphia sp.	x															
Ectopria sp.	x		x													
Hydrochus sp.													x			
Hydroporus sp.			x	x			x	x			x	x				x
Hydroporus sp. 2	x															

Table 5. Master Species List for Quantitative/Qualitative Sampling Combined, November 2000

	Upper Three Runs System						Fourmile Branch System				Pen Branch System				Steel Cr. Sys.	
	Upper Three Runs Rd. 8-1	Upper Three Runs Rd. C	Mill Creek	Tims Branch Rd. 2	McQueens Branch Rd F	Crouch Branch Rd. 4	Fourmile Branch Rd. E	Fourmile Branch Rd. C	Fourmile Br. Rd. A-6	Fourmile Branch Rd. A	Pen Branch Rd. C	Pen Branch Rd. B	Pen Branch Rd. A	Indian Grave Branch	Steel Cr. near Rd. C	Meyers Branch
ORDER COLEOPTERA (cont.)																
Macronychus glabratus		x	x						x	x	x	x	x			
Microcylloepus pusillus			x					x		x			x			
Optioservus sp.		x													x	
Oulimnius sp.	x												x	x		
Peltodytes sexmaculatus						x										x
Peltodytes sp.																
Rhantus callidus		x														
Sperchopsis tessellatus		x														
Stenelmis crenata								x								
Stenelmis sinuata		x	x	x	x			x	x	x		x	x			x
Stenelmis sp.																
ORDER DIPTERA - other than midges																
Antocha sp.				x									x			
Bezzia sp.		x									x				x	
Chaoborus sp.																
Chelifera sp.	x															
Culex sp.	x						x			x						
Ectemnia invenusta	x	x														
Hemerodromia	x		x	x		x			x			x				
Hexatoma		x	x		x											x
Limoninae										x						
Palpomyia			x									x				
Probezzia																x
Prosimulium														x		
Simulium jonesi			x													
Simulium nr. tuberosum	x	x	x		x					x		x	x		x	x
Simulium nr. venustum	x	x	x							x		x		x		x
Simulium sp.									x							
Tipula (Yamatotipula)			x										x			
Tipula (Nippotipula)					x								x			
ORDER DIPTERA - (Tanypodinae)																
Ablabesmyia janta gp.						x										
Ablabesmyia mallochi	x		x					x	x	x		x	x	x	x	x
Ablabesmyia nr. monilis														x		
Clinotanypus pinguis	x	x							x					x		

Table 5. Master Species List for Quantitative/Qualitative Sampling Combined, November 2000

	Upper Three Runs System						Fourmile Branch System				Pen Branch System				Steel Cr. Sys.	
	Upper Three Runs Rd. 8-1	Upper Three Runs Rd. C	Mill Creek	Tims Branch Rd. 2	McQueens Branch Rd F	Crouch Branch Rd. 4	Fourmile Branch Rd. E	Fourmile Branch Rd. C	Fourmile Br. Rd. A-6	Fourmile Branch Rd. A	Pen Branch Rd. C	Pen Branch Rd. B	Pen Branch Rd. A	Indian Grave Branch	Steel Cr. near Rd. C	Meyers Branch
Tanypodinae (cont.)																
Conchapelopia/Meropelopia	x		x			x		x	x	x		x	x			x
Helopelopia sp.																x
Labrundinia pilosella	x		x	x		x		x		x	x	x	x	x	x	x
Paramerina sp.	x					x										
Procladius sp.									x				x			
Zavrelimyia			x							x	x			x		x
ORDER DIPTERA - (Orthocladiinae)																
Brillia flavifrons	x	x	x									x				x
Corynoneura nr. taris		x	x	x	x	x		x	x	x	x		x		x	x
Corynoneura sp. 4			x			x			x			x		x	x	x
Cricotopus bicinctus	x	x				x		x	x	x		x	x	x	x	x
Cricotopus/ Orthocladius annectens	x														x	
Diamesinae - Potthastia longimana	x											x	x	x	x	
Eukiefferiella													x			
Genus nr. Paracladius													x			
Nanocladius					x			x					x	x	x	x
Orthocladius (Euorthocladius) sp.										x			x	x		
Orthocladius obumbratus										x						
Orthocladius sp.															x	
Parakiefferiella sp.		x	x				x	x	x	x					x	x
Parametriocnemus lundbecki	x	x	x	x	x	x			x	x	x	x	x	x	x	x
Psectrocladius sp.														x		x
Rheocricotopus robacki	x	x	x	x	x			x	x	x		x	x	x		x
Rheocricotopus tuberculatus				x							x					
Rheosmittia sp.																x
Synorthocladius semivirens	x	x												x		
Thienemanniella fusca gp.	x	x	x		x					x			x			x
Thienemanniella xena gp.	x	x	x		x			x	x	x		x	x	x	x	x
Tvetenia discoloripes gp.	x	x	x							x		x	x	x		x
Tvetenia paucunca gp.		x			x							x	x		x	
Unniella multivirga	x		x								x	x			x	x
ORDER DIPTERA - (Chironomini)																
Chironomus sp.				x	x	x	x	x	x		x				x	
Cladopelma sp.																x
Cryptochironomus fulvus gp.						x		x							x	

Table 5. Master Species List for Quantitative/Qualitative Sampling Combined, November 2000

	Upper Three Runs System						Fourmile Branch System				Pen Branch System				Steel Cr. Sys.	
	Upper Three Runs Rd. 8-1	Upper Three Runs Rd. C	Mill Creek	Tims Branch Rd. 2	McQueens Branch Rd F	Crouch Branch Rd. 4	Fourmile Branch Rd. E	Fourmile Branch Rd. C	Fourmile Br. Rd. A-6	Fourmile Branch Rd. A	Pen Branch Rd. C	Pen Branch Rd. B	Pen Branch Rd. A	Indian Grave Branch	Steel Cr. near Rd. C	**Meyers Branch**
Chironomini (cont.)																
Dicrotendipes nr neomodestus								x	x	x			x	x		x
Dicrotendipes simpsoni											x					
Microtendipes nr. rydalensis	x	x														
Microtendipes pedellus			x						x		x	x				x
Phaenopsectra flavipes	x		x			x		x	x		x	x				x
Polypedilum aviceps	x	x	x		x							x	x	x	x	
Polypedilum fallax	x				x	x			x		x	x				x
Polypedilum halterale								x		x		x		x		
Polypedilum illinoense	x	x	x		x		x		x	x	x				x	x
Stenochironomus			x													
Tribelos jucundum	x		x		x			x							x	
ORDER DIPTERA - (Tanytarsini)																
Cladotanytarsus	x		x													
Paratanytarsus	x						x									
Rheotanytarsus distinctissimus gp.	x	x	x	x	x			x	x	x	x	x	x	x	x	x
Tanytarsus	x	x	x		x			x	x	x	x	x	x	x	x	x
Tanytarsus sp. 2																x
Zavrelia															x	x
PHYLUM ANNELIDA (worms,leeches)																x
Naididae				x												
Nais sp.							x							x		
Tubificidae (w/o cap. setae)	x								x		x					
PHYLUM MOLLUSCA (clams, snails)																
Amnicola	x		x													
Campeloma decisum	x		x								x	x		x		x
Corbicula fluminea			x						x	x		x	x	x	x	
Ferrissia sp.																x
Physella								x	x						x	
Planorbella trivolvis										x				x		x
Sphaerium							x		x							x
CLASS CRUSTACEA/MISCELLANEOUS																
ACARI- Hydracarina			x							x			x	x		x
Cambarinae (female)		x	x		x			x			x	x	x	x		x

Table 5. Master Species List for Quantitative/Qualitative Sampling Combined, November 2000

	Upper Three Runs System						Fourmile Branch System				Pen Branch System				Steel Cr. Sys.	
	Upper Three Runs Rd. 8-1	Upper Three Runs Rd. C	Mill Creek	Tims Branch Rd. 2	McQueens Branch Rd F	Crouch Branch Rd. 4	Fourmile Branch Rd. F	Fourmile Branch Rd. C	Fourmile Br. Rd. A-6	Fourmile Branch Rd. A	Pen Branch Rd. C	Pen Branch Rd. B	Pen Branch Rd. A	Indian Grave Branch	Steel Cr. near Rd. C	Meyers Branch
CRUSTACEA/MISC. (cont.)																
Hyallela azteca				x				x	x	x			x	x	x	x
Palaemonetes paludosus	x	x	x							x	x	x	x			x
COLLEMBOLA																x
LEPIDOPTERA - *Parapoynx obscuralis*	x	x	x													
TOTAL NUMBER OF TAXA	70	64	72	18	23	19	16	38	48	50	35	50	56	46	49	66

Table 6. Dominant Taxa Collected on Multiplate Samplers (Quantitative) and from Qualitative Sampling of Natural Substrates, November 2000

	Upper Three Runs System						Fourmile Branch System				Pen Branch System				teel Cr. Syste	
	Upper Three Runs Road 8-1	Upper Three Runs Road C	Mill Creek at Telephone Cable Crossing	Tims Branch Road 2	McQueens Branch Road F	Crouch Branch Road 4	Fourmile Branch Road F	Fourmile Branch Road C	Fourmile Branch Road A-6	Fourmile Branch Road A	Pen Branch Road C	Pen Branch Road B	Pen Branch Road A	Indian Grave Branch Road B	Steel Creek east of Road C	Meyers Branch at Old Dunbarton Rd.
Annelida																
Naididae				ql												
Nais sp.							qn									
Crustacea																
Cambarinae											ql					
Hyalella azteca				ql						ql				qn ql	ql	
Palaemonetes paludosus											ql					
Mollusca																
Corbicula fluminea									ql	ql		ql				
Campeloma decisum											ql					
Sphaerium sp.							ql									
Ephemeroptera																
Baetis intercalaris										ql			qn			
Ephemerella catawba/inconstans															qn	
Ephemerella sp.				qn												
Leptophlebia sp.											qn					
Neoephemera sp.		ql														
Stenonema modestum/smithae			qn	qn							qn	qn			qn	
Plecoptera																
Acroneuria abnormis	ql															
Allocapnia sp.											qn	qn			ql	
Perlesta placida	ql											qn				
Trichoptera																
Brachycentrus nigrosoma	ql															
Cheumatopsyche spp.		ql			ql	ql							qn ql	ql		
Hydropsyche betteni														ql		
Hydropsyche elissoma	ql	ql														
Odonata																
Aeshna umbrosa							ql									
Anax longipes							ql									
Boyeria vinosa								ql								
Enallagma divagans								ql	ql							ql
Progomphus sp.											ql					

Table 6. Dominant Taxa Collected on Multiplate Samplers (Quantitative) and from Qualitative Sampling of Natural Substrates, November 2000

	Upper Three Runs System						Fourmile Branch System				Pen Branch System				Steel Cr. System	
	Upper Three Runs Road 8-1	Upper Three Runs Road C	Mill Creek at Telephone Cable Crossing	Tims Branch Road 2	McQueens Branch Road F	Crouch Branch Road 4	Fourmile Branch Road F	Fourmile Branch Road C	Fourmile Branch Road A-6	Fourmile Branch Road A	Pen Branch Road C	Pen Branch Road B	Pen Branch Road A	Indian Grave Branch Road B	Steel Creek east of Road C	Meyers Branch at Old Dunbarton Rd.
Heteroptera																
Mesovelia mulsanti											ql					
Coleoptera																
Ancyronyx variegatus				ql												
Dubiraphia bibittata																ql
Hydroporus sp.				ql			qn									
Stenelmis sp.				ql	qn			ql								
Non-Chironomid Dipterans																
Bezzia sp.											ql					
Culex sp.							ql									
Hemerodromia sp.				qn												
Simulium nr. tuberosum			ql										ql			
Simulium nr. venustum														ql		
Tipula sp.					qn											
Chironomidae																
Chironomini																
Chironomus sp.				qn			qn ql									
Dicrotendipes nr. neomodestus																qn ql
Microtendipes nr. rydalensis	qn															
Phaenopsectra flavipes											qn					
Polypedilum aviceps			qn ql		qn ql							ql	ql	ql	qn ql	
Polypedilum illinoense			qn		qn						ql					ql
Orthocladiinae																
Corynoneura nr. taris	qn	qn			qn	ql		qn			qn					
Corynoneura sp. 4						qn						qn ql				
Cricotopus bicinctus										ql			ql	qn		
Cricotopus/Orthocladius annectens	ql														ql	
Parametriocnemus lundbecki	qn ql										qn	qn ql	qn			qn
Rheocricotopus robacki	qn	qn			ql											
Rheocricotopus tuberculatus				ql												
Thienemanniella xena gp.	qn	qn						qn								
Tvetenia discoloripes gp.														ql		
Tvetenia paucuna gp..												ql				
Unniella multivirga															ql	

Table 6. Dominant Taxa Collected on Multiplate Samplers (Quantitative) and from Qualitative Sampling of Natural Substrates, November 2000

	Upper Three Runs System						Fourmile Branch System				Pen Branch System				Steel Cr. System	
	Upper Three Runs Road 8-1	Upper Three Runs Road C	Mill Creek at Telephone Cable Crossing	Tims Branch Road 2	McQueens Branch Road F	Crouch Branch Road 4	Fourmile Branch Road F	Fourmile Branch Road C	Fourmile Branch Road A-6	Fourmile Branch Road A	Pen Branch Road C	Pen Branch Road B	Pen Branch Road A	Indian Grave Branch Road B	Steel Creek east of Road C	Meyers Branch at Old Dunbarton Rd.
Tanypodinae																
Ablabesmyia mallochi									ql					qn		
Conchapelopia/Meropelopia						ql										
Labrundinia pilosella				ql												
Zavrelimyia											qn					
Tanytarsini																
Paratanytarsus							qn									
Rheotanytarsus distinctissimus gp.	qn	qn		qn				qn		qn		ql	qn ql	qn ql	ql	
Tanytarsus	qn ql		qn		ql			qn ql	qn ql	qn ql	qn ql	qn ql	qn ql	qn	ql	qn ql
qn - dominant (>5%) in quantitative (multiplate) samples																
ql - dominant (>5%) in qualitative sampling of natural substrates																

Table 7. Macroinvertebrate Data for Upper Three Runs/Tributaries, November 2000

	Upper Three Runs Creek System					
	Upper Three Runs at Rd. 8-1	Upper Three Runs at Rd. C	Mill Creek at Telephone Cable Crossing	Tims Branch at Road 2	McQueen Branch at Road F	Crouch Branch at Road 4
Parameter	MULTIPLATE (QUANTITATIVE DATA)					
Total # of Species	29	33	43	12	9	13
Mean Species per Replicate	13.4	14	15.4	4	2.4	6
EPT Index	9	11	15	3	0	0
Density (organisms/m^2)	1550.0	2241.7	1550.0	225.0	133.3	6800.0
Total Biomass (g)	0.1509	0.4055	0.0413	0.0039	0.0020	0.0212
NC Biotic Index	5.53	5.78	5.69	7.77	7.28	5.4
Relative Abundance of Major Taxonomic Groups						
Annelida (worms)	0	0.0	0.0	0.0	0.0	0.0
Mollusca (clams, snails)	0	0.0	0.0	0.0	0.0	0.0
Crustacea	0	0.0	0.0	3.7	0.0	0.0
Ephemeroptera	5.4	1.5	18.3	18.5	0.0	0.0
Plecoptera	7.0	10.4	12.4	0.0	0.0	0.0
Trichoptera	0.5	2.6	5.9	0.0	0.0	0.0
Megaloptera	0.5	0.4	0.0	0.0	0.0	0.0
Odonata	0.5	0.0	1.6	0.0	0.0	0.2
Heteroptera	0	0.0	0.0	0.0	0.0	0.0
Coleoptera	0	0.7	2.7	3.7	25.0	0.1
Diptera (excluding midges)	6.5	3.0	3.2	11.1	12.5	0.1
Diptera (midges)	79.6	81.4	55.9	63.0	62.5	99.5
Tanypodinae	1.6	1.5	4.8	0.0	0.0	2.5
Orthocladiinae	51.9	67.3	7.5	11.1	18.8	95.1
Chironomini	10.3	4.5	28.5	33.3	37.5	2.0
Tanytarsini	16.1	8.2	15.1	18.5	6.3	0.0
Relative Abundance of Functional Feeding Groups						
Collector-gatherers	58.9	69.1	32.5	40.7	43.8	96.0
Collector-filterers	21.0	11.9	22.6	18.5	6.3	0.0
Predators	10.8	9.7	15.1	11.1	0.0	3.5
Scrapers	2.4	1.1	10.2	9.3	12.5	0.0
Shredders	7.0	8.2	19.6	20.4	37.5	1.5
Relative Abundance of Functional Feeding Group Biomass						
Collector-gatherers	2.9	1.7	16.5	56.4	45.0	59.0
Collector-filterers	1.6	1.3	8.5	<0.1	<0.1	0.0
Predators	95.5	28.9	56.4	2.6	0.0	24.1
Scrapers	<0.1	0.3	11.1	20.5	45.0	0.0
Shredders	<0.1	67.8	7.5	20.5	10.0	17.0
	QUALITATIVE DATA					
Total # species	56	52	50	8	20	12
EPT Index	16	22	16	0	2	1
NC Biotic Index	4.94	4.38	4.99	6.95	6.25	8.17
QUALITATIVE AND QUANTITATIVE DATA COMBINED						
Total # species	**70**	64	72	18	23	19

were also abundant, comprising 4.5 to 16.1% of the organisms collected at the two locations. Plecoptera was the second most abundant group at both locations (7% at Road 8-1; 10.4% at Road C). Ephemeroptera were somewhat more abundant at Road 8-1 (5.4% than at Road C (1.5%). Dominant species collected included orthoclads (*Corynoneura* nr. *taris, Rheocricotopus robacki,* and *Thienemanniella xena* gp.) at both locations, as well as midges from other groups, including *Rheotanytarsus distinctissimus* gp., *Microtendipes*, and *Tanytarsus* (Table 6). The most abundant Plecoptera were *Acroneuria* and *Pteronarcys*. The most commonly collected Ephemeroptera was *Stenonema*. Both the density of organisms and total biomass were considerably higher at Road C than at Road 8-1 (Table 7). Density at Road C averaged 2241.7 organisms/m^2, as compared to 1550 at Road 8-1. Biomass at Road C averaged about 0.4 g/m^2, as compared to 0.15 g/m^2 at Road 8-1. With respect to functional feeding groups, collector-gatherers were the most abundant functional feeding group at both locations 59 to 69%, followed by collector filterers (12 to 21%) and predators (10 to 11%). Functional group biomass in Upper Three Runs was skewed in favor of shredders and predators, due primarily to the collection of a few large shredders, such as *Pteronarcys*, and a few large predators, such as *Acroneuria* (Plecoptera), and *Nigronia* (Megaloptera).

A few more taxa were collected by qualitative sampling of natural substrates at Road 8-1 than at Road C (56 vs. 52), but more EPT taxa were collected at Road C than at Road 8-1 (22 vs. 16), and Road C had a somewhat lower (better) biotic index (4.38 vs. 4.94 at Road 8-1; Table 7). The most common taxa collected from natural substrates included the midges *Cricotopus/Orthocladius annectens, Parametriocnemus lunbecki*, and *Tanytarsus*; the mayfly, *Neoephemera*;, the *stoneflies Acroneuria abnormis*, and *Perlesta placida*, and the caddisflies *Cheumatopsyche* and *Hydropsyche* (Table 6). In all, the macroinvertebrate data collected at Roads 8-1, which is upstream from all SRS discharges and Road C, which is downstream of all SRS discharges to the stream and all tributaries that contain NPDES discharges indicate that the two locations are very similar with respect to most of the parameters that were measured. The Bioclassification scores for Upper Three Runs indicate that the score for qualitative data for Road C was slightly higher (better) than Road 8-1 (4.5 vs. 4.0), while the scores for quantitative data were identical (4.0; Table 8). Therefore, there is no indication in the macroinvertebrate data that Upper Three Runs is being impacted by NPDES discharges to Upper Three Runs or its tributaries.

Tributaries of Upper Three Runs that were sampled include McQueen Branch, Crouch Branch, Tims Branch, and Mill Creek. Of these, only Mill Creek receives no NPDES discharges. Mill Creek is a high quality stream, and has a drainage area that is fairly similar to the size of the Tims Branch watershed, but is considerably larger than the watersheds of McQueen Branch and Crouch Branch. Since taxonomic richness generally increases with stream size, McQueen Branch and Crouch Branch would not be expected to have macroinvertebrate communities that are quite as diverse as Mill Creek. The macroinvertebrate data for these tributaries of Upper Three Runs are summarized in Table 7. The data from most of the parameters that were measured indicate that Mill Creek supports a much richer macroinvertebrate community than the three tributaries than receive NPDES discharges. A total of 43 taxa were collected from the multiplate samplers in Mill Creek, as compared to 12 in Tims Branch, 9 in McQueen Branch and 13 in Crouch Branch. For qualitative and quantitative combined,

Table 8. SCDHEC Bioclassification Scores for SRS Qualitative and Quantitative Data

	Qualitative Data				Quantitative Data			
Location	NCBI	EPT	Mean	Rating	NCBI	EPT	Mean	Rating
UTR Rd. 8-1	5	3	4.0	good	4	2	3.0	good/fair
UTR Rd. C	5	4	4.5	good/excellent	4	2	3.0	good/fair
Mill Creek	5	3	4.0	good	4	3	3.5	good -
Tims Branch	2	1	1.5	fair/poor	1.4	1	1.2	poor +
McQueen Br.	3	1	2.0	fair	2	1	1.5	fair/poor
Crouch Br.**	1	1	1.0	poor	5*	1*	3.0	good/fair
FMB Rd. F	1	1	1.0	poor	1	1	1.0	poor
FMB Rd. C	2	1	1.5	fair/poor	3	1	2.0	fair
FMB Rd. A-6	2	1	1.5	fair/poor	3	2	2.5	fair +
FMB Rd. A	2	1	1.5	fair/poor	3	2	2.5	fair +
Pen Br. Rd. C**	2	1	1.5	fair/poor	4	2	3.0	good/fair
Pen Br. Rd. B	4.6*	1.4*	3.0	good/fair	5*	2*	3.5	good -
Pen Br. Rd. A	3	2	2.5	fair +	4	3	3.5	good -
Indian Gr. Br.	2.6	1.6	2.1	fair	2	2	2.0	fair
Steel Creek	5*	2*	3.5	good	5*	2*	3.5	good -
Meyers Br.	2	2	2.0	fair	3	1.4	2.2	fair +

*Disparity of >2 units between NCBI and EPT scores
**disparity of >1 unit between Qualitative and Quantitative scores

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72 taxa were collected from Mill Creek, 18 from Tims Branch, 23 from McQueen Branch, and 19 from Crouch Branch. More EPT taxa were also collected from multiplates in Mill Creek (15) than the other tributaries (0 to 3). The density of organisms on the multiplates averaged 1550 organisms/m^2 in Mill Creek, as compared to 225 in Tims Branch, 133.3 in McQueen Branch and 6800 organisms/m^2 in Crouch Branch. The community of Mill Creek was dominated by Ephemeroptera (18.3%; primarily *Stenonema;* Table 6), Plecoptera (12.4%) and Chironomini and Tanytarsini midges (28.5 and 15.1%). *Polypedilum* was the most abundant Chironomini midge in Mill Creek, while *Tanytarsus* was the most common Tanytarsini. Tims Branch was also dominated by these same groups, except that no Plecoptera were collected. Common mayflies in Tims Branch were *Ephemerella* and *Stenonema*; common midges were *Chironomus* and *Rheotanytarsus*. Dominant groups in McQueen Branch were Coleoptera (25%; primarily *Stenelmis*), and Chironomini (mostly *Polypedilum*) and Orthocladiinae (mostly *Corynoneura*) midges (37.5 and 18.8%). In Crouch Branch, midges accounted for 99.5% of the organisms collected from the multiplates. Most of the midges were the orthoclad, *Corynoneura*. Macroinvertebrate biomass in Mill Creek was higher (0.04 g/m^2) that in the tributaries that receive NPDES discharges (0.002 to 0.02 g/m^2). With respect to functional feeding groups, Mill Creek, Tims Branch and McQueen Branch were fairly similar, with collector-gatherers comprising 32.5 to 43.8% of the organisms collected, followed by shredders (19.6 to 37.5%) and collector filterers 6.3 to 22.6%. In Crouch Branch, 96% of the organisms collected were collector-gatherers. This was because almost all of the organisms collected from Crouch Branch were a single species of midge (*Corynoneura*). For the qualitative data, 50 species were collected from Mill Creek, 18 were collected from Tims Branch, 23 from McQueen

Branch, and 19 were collected in Crouch Branch (Table 7). More EPT taxa were collected in the qualitative samples from Mill Creek (16) than from the tributaries that receive NPDES discharges (0 to 2). The Bioclassification scores for Mill Creek were 4.0 and 3.5 for qualitative and quantitative sampling, respectively (Table 8). When compared to Mill Creek, the decreases in scores for the three tributaries that receive NPDES discharges are:

	Qualitative Data		Quantitative Data	
Stream	Decrease in Score	Level of Impairment	Decrease in Score	Level of Impairment
Mill Creek	Reference Stream			
Tims Branch	2.5	Moderate	2.3	Moderate
McQueen Br.	2.0	Moderate	2.0	Moderate
Crouch Br.	3.0	Severe	0.5	Slight

When compared to Mill Creek, the results of the qualitative and quantitative Bioclassification scores for Tims Branch and McQueen Branch concur that the streams are moderately impaired. The qualitative data for Crouch indicates severe impairment, while the quantitative data indicates slight impairment. This difference is a result of a low (good) biotic index value for the quantitative data for Crouch Branch. A large number of a single species of orthoclad midge (*Corynoneura*) were collected on the multiplate samplers. Lenat(1993) assigns a relatively good biotic index value (6.2) to this genus, which resulted in a good overall biotic index score. However, Geckler et al., 1976) reported that Orthocladiini chironomids are quite tolerant to copper, which may explain their abundance in Crouch Branch. The almost complete absence of EPT taxa and domination by a single taxon of orthoclad in the quantitative data, as well as a very low Bioclassification score for the qualitative data, all indicate that Crouch Branch is still impaired.

As discussed in Section 2.1, Mill Creek is considerably larger than Tims, Crouch and McQueen Branches. Therefore, The Bioclassification Scores of these tributaries were also compared to scores from Pen Branch at Road C. Although in a different watershed, this reach of Pen Branch is more comparable in size to these tributaries than is Mill Creek.

	Qualitative Data		Quantitative Data	
Stream	Decrease in Score	Level of Impairment	Decrease in Score	Level of Impairment
Pen Br. Rd. C	Reference Stream			
Tims Branch	0	Unimpaired	1.8	Moderately impaired
McQueen Br.	0	Unimpaired	1.5	Slight to moderately impaired
Crouch Br.	0.5	Very slightly impaired	0	Unimpaired

When compared to Pen Branch at Road C, the qualitative data indicates little impairment, while the quantitative data indicates no impairment for Crouch Branch, slight/moderate impairment for McQueen Branch, and moderate impairment for Tims Branch.

The data for the Upper Three Runs tributaries indicates that none of the tributaries that receive NPDES discharges support macroinvertebrate communities that are of the quality of that found in Mill Creek. However, the differences may be due, at least in part, to Mill Creek being a somewhat larger stream than the other three tributaries and also to habitat alterations. When compared to Pen Branch at Road C, the bioclassification scores indicate no impairment to slight impairment for all of the data except the Tims Branch quantitative data, which indicated moderate impairment. The location that was sampled in Tims Branch is located just downstream from the old Steeds Pond dam. Although the dam no longer impounds what was Steeds Pond, the portion of the stream that flows through the old pond bed of Steeds Pond is braided and has little canopy. Earlier macroinvertebrate surveys that were conducted in McQueen Branch in 1993 and 1994 (Specht, 1995a; Specht and Paller, 1995) both indicated that the macroinvertebrate community of the stream was more perturbed than was found in this study. As described in Section 2.1, both McQueen Branch and Crouch Branch were subject to high total suspended solids levels during construction of the DWPF (Savannah River Ecology Laboratory, 1995) and increased stormwater inputs. These conditions resulted in intense scouring and siltation, which have resulted in channel erosion and long-term habitat degradation. Other factors that may have affected the benthic communities in Tims, McQueen, and Crouch Branches are discussed in the Temporal Changes section that follows.

Temporal Changes in Upper Three Runs and Its Tributaries between 1997 and 2000 - The quality of the macroinvertebrate communities of both Tims Branch and McQueen Branch declined between the first macroinvertebrate survey that was conducted in 1997 (Table 9) and the survey that was conducted in November 2000 (Table 7). A significant change in the Tims Branch watershed was the construction of a wetland treatment system approximately 3 km upstream from the sampling location. The treatment system was constructed in 2000 to remove copper from NPDES outfall A-01. Although total suspended solids (TSS) levels were sometime elevated just downstream from the wetland during construction, most of the soil particles were trapped in two natural wetlands that are located between the constructed wetland and the macroinvertebrate sampling location in Tims Branch. Therefore, construction of the wetland is not believed to be the source of the perturbation in Tims Branch. Rather, the changes appear to be due to the construction of a series of beaver dams in the old pond bed of Steeds Pond, which is located just upstream from the sampling location. At the time of sampling, the water flowing out of the old pond bed appeared to contain an iron hydroxide floc, which suggests that the beaver ponds are probably producing anoxic conditions that are releasing ferrous iron from the pond sediments. Dissolved oxygen was only 64% of saturation (6.67 mg/l at a temperature of 13.3 °C), which suggests that during the warmer months, dissolved oxygen levels are probably too low to support most species of macroinvertebrates. In the past, similar conditions have been seen in areas downstream from beaver dams in Fourmile Branch and McQueen Branch. Beaver dams are usually transient, and the macroinvertebrate communities rebound when the beaver impoundments are no longer present. The permitted

Table 9. Macroinvertebrate Data for Upper Three Runs/Tributaries, November 1997

	Upper Three Runs at Rd. 8-1	Upper Three Runs at Rd. C	Mill Creek at Telephone Cable Crossing	Tims Branch Rd. 2	McQueen Br. near Z Area	Crouch Br. Rd. 4
	Site 3	Site 2	Site 4	Site 1	Site 5	Site 6
MULTIPLATE (QUANTITATIVE DATA)						
Total # species	27	37	20	17	11	5
Mean # species/replicate	5.4	7.4	4.0	3.4	2.2	1.0
EPT Index	15	16	9	3	5	0
Density (organisms/m^2)	93.3	232.0	112.0	73.3	53.3	8.9
Total biomass (g/m^2)	0.2590	0.2582	0.0518	1.0685	0.0317	0.0006
NC Biotic Index	3.70	4.84	4.87	6.72	5.18	8.88
Relative Abundance of Major Taxonomic Groups						
Annelida (worms)	0.0	0.5	0.0	25.8	0.0	0.0
Mollusca (clams, snails)	0.0	0.0	0.0	0.0	0.0	0.0
Crustacea	0.0	0.0	0.0	0.0	0.0	0.0
Ephemeroptera	10.7	11.0	55.4	1.5	64.6	0.0
Plecoptera	34.5	18.2	21.8	0.0	8.3	0.0
Trichoptera	23.8	9.6	5.0	9.1	10.4	0.0
Odonata	1.2	0.0	1.0	0.0	0.0	25.0
Heteroptera	0.0	0.0	0.0	0.0	0.0	0.0
Coleoptera	2.4	1.9	1.0	0.0	0.0	0.0
Diptera (excluding midges)	8.3	1.0	0.0	22.7	0.0	0.0
Diptera (midges)	16.7	57.9	12.9	39.4	12.5	75.0
Chironomini	3.6	6.2	8.9	1.5	0.0	62.5
Orthocladiinae	3.6	45.9	2.0	12.1	12.5	0.0
Tanypodinae	1.2	0.0	2.0	10.6	0.0	12.5
Tanytarsini	8.3	5.7	0.0	15.2	0.0	0.0
Other	2.4	0.0	2.9	1.5	4.2	0.0
Relative Abundance of Functional Feeding Groups						
Collector-gatherers	10.7	40.0	36.6	37.1	52.1	25.0
Collector-filterers	32.7	11.0	0.0	45.5	2.1	0.0
Predators	15.5	11.5	12.9	12.1	6.3	37.5
Scrapers	5.4	6.0	28.2	0.8	32.3	0.0
Shredders	35.7	32.3	24.3	4.5	7.3	37.5
Relative Abundance of Functional Feeding Group Biomass						
Collector-gatherers	0.3	7.8	22.6	0.3	26.4	<0.1
Collector-filterers	3.3	4.9	<0.1	0.8	2.0	<0.1
Predators	94.5	54.3	50.8	98.9	42.3	100.0
Scrapers	1.6	6.8	22.6	<0.1	26.4	<0.1
Shredders	0.3	26.2	4.1	<0.1	2.9	<0.1
QUALITATIVE DATA						
total # species	41	61	39	33	33	3
EPT Index	18	20	9	3	12	0
NC Biotic Index	4.76	4.45	5.62	6.37	5.39	7.6
QUALITATIVE AND QUANTITATIVE DATA COMBINED						
total # species	51	81	50	41	38	8

chemical constituents in the outfalls that discharge to Tims Branch (A-01 and A-11) are primarily metals. In addition, the old pond bed of Steeds Pond contains elevated concentrations of several metals (primarily nickel, aluminum, and uranium). In order to determine if the perturbation in Tims Branch was due to metals, on November 2, a water sample was collected from just downstream from the old Steeds Pond dam and analyzed for the metals most likely to be present in NPDES outfalls and in Steeds Pond sediments. This sample was collected at the same location that biological sampling had been performed.

Metal	Total (µg/l)	Dissolved (µg/l)
Copper	<10	<10
Zinc	19	9
Chromium	<20	<20
Nickel	26	15
Iron	3620	268
Aluminum	1620	<50
Manganese	67	<5
Uranium	<50	<50

The results indicate that total iron and aluminum were high (3620 and 1620 µg/l, respectively), but that none of the other metals that were measured, including dissolved iron, exceeded EPA water quality criteria. High total iron and aluminum are usually indicative of suspended soil particles in the water column, which probably occurs as water pours over the old spillway of the dam. Therefore, it does not appear that metals from NPDES outfalls are the source of the perturbation, and we conclude that low dissolved oxygen concentrations resulting from beaver impoundments are the most likely source of the perturbation in Tims Branch.

In McQueen Branch, the sampling location in 1997 was located near Z Area. This site has since be inundated by the pool of a beaver dam, so the sampling location for 2000 was moved upstream to Road F. The location that was sampled was impacted by high total suspended solids levels and increased flows during construction of the Defense Waste Processing Facility (DWPF) in the 1980's (Savannah River Ecology Laboratory, 1995) and as a result, has somewhat poorer habitat than the sampling location near Z Area. Substrate is primarily shifting sand or clay, and few leaf packs or root mats are present. The total absence of EPT taxa in the multiplate samples from McQueen Branch and relatively low Bioclassification scores for both the quantitative and qualitative data indicate possible impact. However, it is not known if the impact is due to poor habitat or NPDES discharges.

Results of biological sampling in 1997 indicated that Crouch Branch was severely impaired. Subsequent investigations found that the H-02 outfall, which discharges to Crouch Branch less than 50 m upstream from the Road 4 sampling location, contained elevated levels of copper (Specht, 1999). Source reductions of copper contributions to the H-02 outfall have reduced copper concentrations in the stream. Crouch Branch has improved considerably since it was sampled in 1997, but it is still moderately impaired. The number of taxa collected on multiplate samplers increased from 5 to 13; the number of taxa collected from natural substrates increased from 3 to 12, and the total

number of taxa collected from quantitative and qualitative samples combined increased from 8 to 19 (Tables 7 and 8). A macroinvertebrate survey performed at four locations in Crouch Branch in 1999 showed that the quality of the macroinvertebrate community improved with increasing distance from the outfall, and that the lower portions of the stream contained a reasonably diverse macroinvertebrate community. Near the creek mouth, 44 taxa were collected during qualitative sampling, including 11 EPT taxa (Specht, 1999).

Mill Creek, which is the unperturbed reference stream to which Tims, Crouch, and McQueen data were compared showed substantial increases in both species richness and density of organisms between 1997 and 2000 (Tables 7 and 8). The number of taxa collected from multiplate samplers increased from 20 to 43, the number of taxa collected during qualitative sampling increased from 39 to 50, and the total number of taxa collected in the quantitative and qualitative sampling combined increased from 50 to 72. The density of organisms on the multiplate samplers was 112 in 1997 and 1550 in 2000. No changes are known to have occurred in Mill Creek that would have improved conditions in the stream. The differences are probably attributable to normal temporal variations or sampling differences attributable to the relatively small number of samples that were collected. Both sets of samples were collected and identified by the same taxonomists (ETT Environmental, SCDHEC Certification # 23104), so the sampling techniques employed and level of taxonomic resolution should have been similar between the two studies.

The data from Upper Three Runs collected in 1997 and 2000 (Tables 7 and 8) are fairly similar, except that like Mill Creek, macroinvertebrate densities on multiplate samplers were about an order of magnitude higher in 2000 than in 1997 (93.3 and 232 organisms/m^2 in 1997 vs. 1550 and 2242 in 2000). In addition, the relative abundance of Ephemeroptera, Plecoptera and Trichoptera all decreased between 1997 and 2000. However, the net number of organisms in these groups actually increased somewhat. Their relative abundances were lower, because of the much higher numbers of midges that were collected in 2000. These differences are probably due to normal temporal variations in the stream.

4.1.2 Fish - Upper Three Runs and Tributaries

Fish assemblages in the Upper Three Runs Creek drainage were sampled at Upper Three Runs near Road 8-1, Upper Three Runs near Road A.2, Crouch Branch, McQueen Branch, Tims Branch, and Mill Creek. The sample stations at Upper Three Runs near Road A.2, Crouch Branch, Tims Branch and McQueen Branch were located downstream from NPDES outfalls (Figure 1). Because Mill Creek does not receive NPDES discharges and is largely undisturbed, it was considered a control site and was pooled with the other control sites for statistical comparisons. The sample station at Upper Three Runs near Road 8-1 was located upstream from the SRS NPDES outfalls but, as discussed below, was not pooled with the other control sites because it may have been influenced by offsite pollution and was difficult to effectively sample. These sample locations corresponded to the macroinvertebrate sampling locations except that the fish assemblage samples from the portion of Upper Three Runs potentially affected by NPDES discharges were collected near Road A.2 rather than near Road C. Road A.2 is approximately 9 km downstream from Road C. Fish assemblages were not

sampled near Road C to avoid interfering with other fish sampling programs being conducted in that area.

There were two changes in sampling locations between 1997 and 2000. The upstream sample station in Upper Three Runs was moved from Tyler Bridge Road to Road 8-1 because boat access was no longer possible near Tyler Bridge Road. The McQueen Branch sample station was moved from Z area to Road F because the stream reach near Z area was impounded by beaver dams. The IBI was designed for use in free flowing stream reaches and would not be expected to produce accurate results in standing water habitats.

The number of individual fish and number of species, respectively, collected from each site in the Upper Three Runs drainage were 367 and 15 for Mill Creek, 156 and 5 for McQueen Branch, 115 and 12 for Tims Branch, 58 and 9 for Crouch Branch, 268 and 19 for Upper Three Runs near Road A.2, and 217 and 10 for Upper Three Runs near Road 8-1. The most abundant species in the smaller tributaries, including Mill Creek, Crouch Branch, and McQueen Branch were yellowfin shiner, bluehead chub, pirate perch and various other smaller species as is typical of smaller streams on the SRS (Paller 1994). Tims Branch, the remaining small tributary, had fewer shiners and was numerically dominated by pirate perch. Upper Three Runs near Road A.2 supported a diverse assemblage numerically dominated by a variety of shiner and sunfish species. The assemblage at Upper Three Runs near Road 8-1 included fewer species and was numerically dominated by dusky, sailfin, and yellowfin shiners.

Average IBIs in Upper Three Runs were 42.0 near Road A.2 and 36.7 near Road 8-1. (Table 10). Neither value was significantly different from the IBIs at the four control sites, and both were within the range of IBIs for unimpacted sites in the historical data set (Figure 3). However, the IBI at Road 8-1 was substantially lower than the IBIs at the control sites (46-48) despite the fact that it, like the control sites, was upstream of all NPDES discharges. Sampling was difficult near Road 8-1 because of relatively deep water, strong currents, and extensive overhanging brush (Table 11), raising the possibility that reduced sampling efficiency may have depressed the IBI. Another possibility is that offsite point or nonpoint discharges may have affected fish assemblages near Road 8-1, although macroinvertebrate assemblages appeared healthy at this site.

The average IBI at Mill Creek, a control stream without NPDES outfalls, was the second highest recorded at any site (47.3) (Table 10). The average IBI in Crouch Branch, which receives NPDES discharges was nearly comparable, averaging 44.0. The average IBIs at McQueen Branch and Tims Branch, both of which receive NPDES discharges, were lower, averaging 38.0 and 35.3, respectively, although neither IBI significantly differed from the control sites. These moderately depressed IBIs indicate that Tims Branch and McQueen Branch do not possess the environmental quality characteristic of the reference streams. Large amounts of iron floc on the stream bed of Tims Branch suggest that habitat quality may have been diminished by the release of anoxic water from beaver ponds located upstream of the sample site (as described more fully in the preceding section). The situation in McQueen Branch was less clear. The narrow and shallow reach sampled in this stream (Table 11) offered comparatively poor habitat compared with the reference sites and undoubtedly reduced the IBI at this site.

Table 10. IBI values from stream sites receiving NPDES discharges (Y) and sites unaffected by NPDES discharges (N) during 1997 and 2000.

Sample site	NPDES	Rep. 1	Rep. 2	Rep. 3	Average	St. error
		1997				
Fourmile Branch Rd. 4	Y	18	26	22	22.0	2.3
Fourmile Branch Rd. C	Y	36	46		41.0	5.0
Fourmile Branch Rd. A.6	Y	42	48	38	42.7	2.9
Fourmile Branch Rd. A	Y	42	40	50	44.0	3.1
Steel Creek	Y	38	30	30	32.7	2.7
Pen Branch Rd. B	N	46	48	48	47.3	0.7
Pen Branch Rd. C	N	50	50	46	48.7	1.3
McQueen Branch	Y	44	42	30	38.7	4.4
Tims Branch	Y	40	38	38	38.7	0.7
Pen Branch Rd. A	Y	44	46	46	45.3	0.7
Indian Grave Branch	Y	44	46	44	44.7	0.7
Meyers Branch	N	44	46	46	45.3	0.7
Crouch Branch	Y	28	36	24	29.3	3.5
Upper Three Runs Rd. A2	Y	40	42	30	37.3	3.7
Upper Three Runs Tyler Br.	N	22	30	30	27.3	2.7
Mill Creek	Y	44	44	40	42.7	1.3
		2000				
Fourmile Branch Rd. C	Y	44	36	46	42.0	3.1
Fourmile Branch Rd. A.6	Y	46	44	48	46.0	1.2
Fourmile Branch Rd. A	Y	50	34		42.0	6.5
Steel Creek	Y	24	18	28	23.3	2.9
Pen Branch Rd. B	N	46	44	48	46.0	1.2
Pen Branch Rd. C	N	48	46	50	48.0	1.2
McQueen Branch	Y	38	38	38	38.0	0.0
Tims Branch	Y	40	30	36	35.3	2.9
Pen Branch Rd. A13.2	Y	50	46	50	48.7	1.3
Indian Grave Branch	Y	48	48	46	47.3	0.7
Meyers Branch	N	50	46	44	46.7	1.8
Crouch Branch	Y	46	42	44	44.0	1.2
Upper Three Runs Rd. A2	Y	48	40	38	42.0	3.1
Upper Three Runs Rd. 8-1	N	34	38	38	36.7	1.3
Mill Creek	Y	48	46	48	47.3	0.7

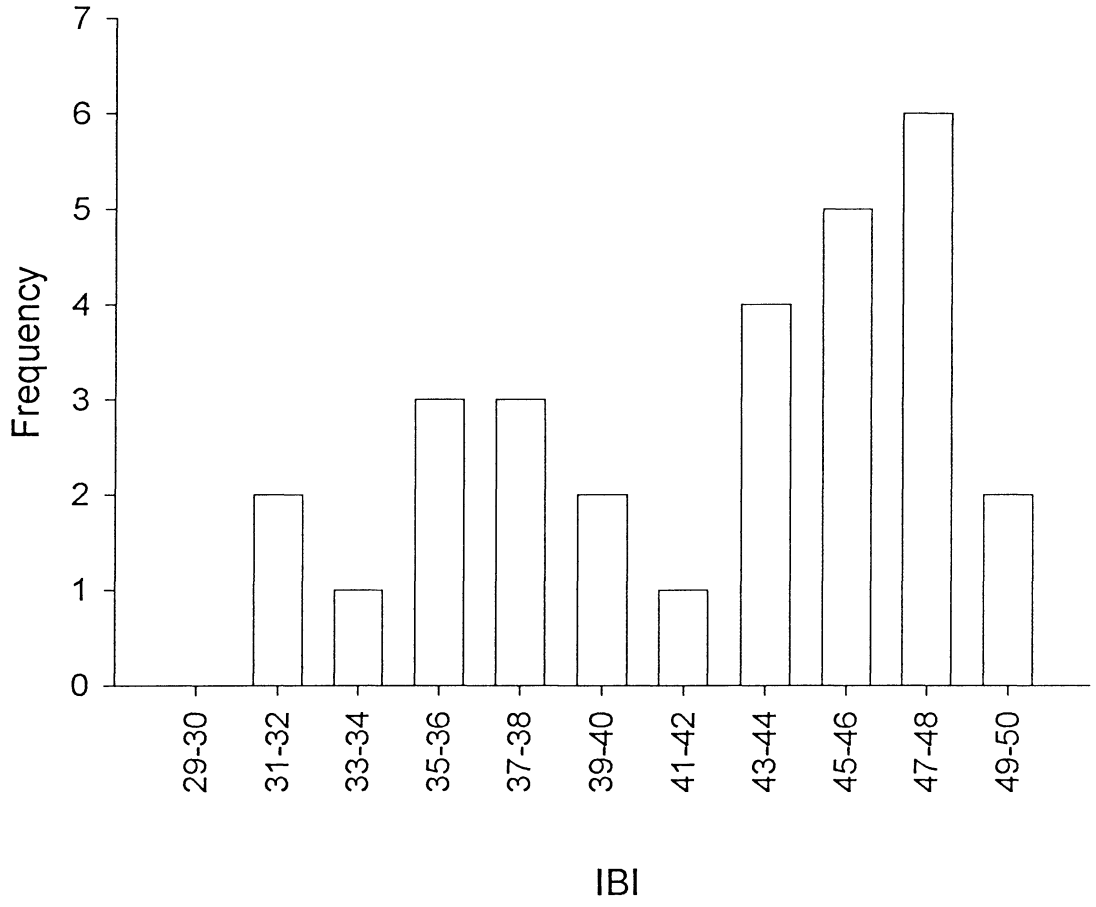

Figure 3. IBI values from undisturbed streams on and near the SRS sampled during previous studies.

Table 11. Means for Habitat Variables. Variables were measured at nine transects at each sample station except at Upper Three Runs Road 8-1 and Upper Three Runs Road A-2, where variables were measured at six transects

Variable	Tims Branch	Upper Three Runs Road 8-1	Upper Three Runs Road A.2	Mill Creek	McQueens Branch	Crouch Branch	Four Mile Creek Road C	Four Mile Creek Road A-6	Four Mile Creek Road A	Pen Branch Road C	Pen Branch Road B	Indian Grave Branch	Pen Branch Road A	Steel Creek	Meyers Branch
Width (m)	1.4	11.9	14.6	4.0	1.6	2.0	7.3	5.2	5.8	1.6	3.6	4.9	6.0	2.3	2.9
Depth (cm)	11.0	46.1	102.3	21.9	10.9	4.4	19.1	44.4	47.8	14.3	11.7	30.7	37.6	12.1	15.6
Current velocity (m/s)	0.33	0.37	0.45	0.50	0.17	0.65	0.35	0.38	0.48	0.03	0.10	0.16	0.36	0.31	0.25
Wood debris and leaves (%)*	7	10	13	16	4	4	11	16	5	51	4	6	4	3	10
Number logs and stumps**	0.9	1.5	4.1	3.0	1.8	2.1	7.4	2.4	2.1	2.3	1.7	3.1	1.0	1.2	2.3
Brush piles (%)*	6	15	18	4	7	4	11	6	8	9	8	9	7	7	14
Root masses (%)*	17	3	0.8	6	8	5	6	8	2	8	4	2.2	1	11	4
Macrophytes (%)*	1	24.2	0	0	0	0	3	19	13	0	0	10	10	0	0
Overhanging bank vegetation (%)*	3	26.9	2	4	1	3	6	13	13	2	7	17.4	20	6	3
Bank overhang (%)*	2	0.3	0	2	12	3	1	4	1	10	2	2.2	0	5	3
Canopy cover (%)*	91	49	75	84	95	92	88	54	42	95	87	58	28	91	97
Bank erosion***	0.7	0	0	0.6	1.9	1.3	0.8	1.1	0.0	0.1	0.3	0.6	0.0	1.9	0.3

* Percent variables refer to percent of stream bottom area covered by or overhung by the indicated variable

** Number of logs and stumps within a 3m band on either side of the transect (6 m in total).

*** Estimated on a scale of 0-3 with 3 most severe

Temporal changes between 1997 and 2000 - IBIs in Upper Three Runs were higher in 2000 than in 1997 (Table 10). The average IBI increased from 37.3 to 42.0 downstream from the NPDES discharges (Road A.2) and increased from 27.3 to 36.7 upstream from the NPDES discharges (Road 8-1). The latter increase may be attributable to a change in sample locations from Tyler Bridge Road in 1997 to Road 8-1 in 2000. The Road 8-1 site was easier to sample than the Tyler Bridge site because there was less overhanging brush, possibly resulting in the collection of more fish and more fish species. Whatever the cause, increases in the IBI both upstream and downstream from the NPDES discharges indicate that environmental quality has certainly not diminished, and may have improved, in Upper Three Runs.

The IBI in Crouch Branch increased substantially from an average of 29.3 in 1997 to 44.0 in 2000 (Table 10). Reductions in copper concentrations in discharges from the H-02 outfall probably contributed to this improvement. Improvement in the IBI, which is based on fish assemblage data, paralleled improvements in the macroinvertebrate assemblages collected from Crouch Branch. However, macroinvertebrate data still suggest moderate impairment in Crouch Branch in contrast to the IBI, which suggested that Crouch Branch was fully recovered by 2000. Differences in recovery rates indicated by fish and macroinvertebrates have been reported by other researchers (Yoder and Rankin 1995), and fish and macroinvertebrate results from Crouch Branch may become more congruent in the future.

Like the macroinvertebrate results, the IBI suggested that conditions in Tims Branch deteriorated slightly between 1997 and 2000. As previously described, this change was probably caused by the release of anoxic water from recently constructed beaver ponds located just upstream from the Tims Branch sample site. The most obvious manifestation of this perturbation was thick deposits of iron floc covering the stream bottom within the sample area.

4.2 Fourmile Branch Watershed

4.2.1 Macroinvertebrates - Fourmile Branch

As described in Section 2.2, macroinvertebrates were collected from four locations in Fourmile Branch. Road F is located upstream from all SRS discharges, Road A is located downstream from all NPDES outfalls, and Roads C and A-6 are located intermediately (Figure 1). All of the parameters that were measured indicate that the quality of Fourmile Branch's macroinvertebrate community improves in a downstream direction, and that the location in Fourmile Branch that is upstream from all NPDES discharges (Road F) is the most perturbed location that was sampled (Table 12). For the multiplate data, a total of 10 taxa were collected at Road F, 26 were collected at Road C, 30 were collected at Road A-6 and 35 were collected at Road A. Two EPT were collected at Road F, 5 were found at Road C, 9 at Road A-6 and 10 at Road A. The density of organisms on the multiplate samplers was also lowest at Road F (283.3 organisms/m^2, increasing to 1008.3 at Road C, 2608.3 at Road A-6, and 7366.7 at Road A. Macroinvertebrate biomass was relatively low at Road F (0.0056 g/m^2) and Road A-6 (0.0173 g/m^2), and much higher at Roads C and A (0.2227 and 0.2452 g/m^2). The biotic index was highest at Road F (8.81) and very similar at the other three locations (6.52 to 6.56). The qualitative data showed similar patterns, with 9 species

Table 12. Macroinvertebrate Data for Fourmile Branch, November 2000

	Road F	Road C	Road A-6	Road A
Parameter	MULTIPLATE (QUANTITATIVE DATA)			
Total # of Species	10	26	30	35
Mean Species per Replicate	4	9.6	10.8	17.2
EPT Index	2	5	9	10
Density (organisms/m^2)	283.3	1008.3	2608.3	7366.7
Total Biomass (g)	0.0056	0.2227	0.0173	0.2452
NC Biotic Index	8.81	6.52	6.56	6.55
Relative Abundance of Major Taxonomic Groups				
Annelida (worms)	5.9	0.0	0.0	0.0
Mollusca (clams, snails)	0.0	0.0	0.3	0.0
Crustacea	0.0	0.8	0.0	3.2
Ephemeroptera	0.0	5.0	2.6	5.4
Plecoptera	0.0	2.5	1.0	0.2
Trichoptera	5.9	1.7	4.2	2.5
Megaloptera	0.0	1.7	0.0	0.0
Odonata	0.0	0.0	0.0	0.8
Heteroptera	0.0	0.0	0.0	0.0
Coleoptera	32.4	5.0	0.6	0.1
Diptera (excluding midges)	2.9	0.0	1.0	1.8
Diptera (midges)	52.9	83.5	90.4	86.0
Tanypodinae	0	5.0	2.6	1.5
Orthocladiinae	2.9	23.1	9.6	9.8
Chironomini	44.1	5.0	5.1	0.9
Tanytarsini	5.9	50.4	73.2	73.8
Relative Abundance of Functional Feeding Groups				
Collector-gatherers	26.5	31.0	12.3	14.5
Collector-filterers	5.9	50.4	76.0	77.9
Predators	33.8	9.9	5.0	2.3
Scrapers	2.9	3.7	1.9	2.7
Shredders	30.9	5.0	4.8	2.5
Relative Abundance of Functional Feeding Group Biomass				
Collector-gatherers	8.9	32.4	27.7	39.6
Collector-filterers	0.0	0.9	45.7	11.9
Predators	16.1	66.2	10.4	10.0
Scrapers	<0.1	0.5	16.2	37.7
Shredders	75.0	0.1	<0.1	0.8
	QUALITATIVE DATA			
Total # species	9	15	27	31
EPT Index	0	0	2	5
NC Biotic Index	9.23	6.79	7.35	7.57
QUALITATIVE AND QUANTITATIVE DATA				
Total # species	16	38	48	50

collected at Road F, 15 at Road C, 27 at Road A-6, and 31 at Road A. No EPT were found at Roads F or C; 2 were collected Road A-6 and 5 at Road A. The biotic index values for the qualitative data were highest at Road F (9.23), lowest (but still high) at Road C (6.79) and intermediate at Roads A-6 and A (7.35 and 7.57). For both the qualitative and quantitative sampling combined, a total of 16 taxa were collected at Road F, 38 at Road C, 48 at Road A-6, and 50 at Road A. Dipterans (55.8%), Coleoptera (mostly *Hydroporus*; 32.4%), annelids (*Nais*; 5.9%), and Trichoptera (5.9%) were the only taxa collected at Road F. *Chironomus* was by far the most abundant midge at Road F, accounting for 44% of the organisms collected. *Chironomus* is considered to be a very pollution-tolerant taxon (Lenat, 1993) and it is particularly tolerant of low concentrations of dissolved oxygen. In contrast, the most common midge collected at the other three sampling locations was *Tanytarsus*. The community at Road C was dominated by midges (83.5%), Coleoptera (5%), and Ephemeroptera (5%). Midges were also the most abundant group collected at Road A-6 (90.4%), followed by Trichoptera (4.2%) and Ephemeroptera (2.6%). At Road A, the community was dominated by midges (86%) followed by mayflies (5.4%), Crustacea (*Hyalella*; 3.2%), and Trichoptera (2.5%).

Bioclassification scores for both the qualitative and quantitative data (Table 8) both indicate that Fourmile Branch at Road F was the most impaired location in the stream, with scores of 1.0 for both data sets. The qualitative data indicate that the quality of the other three locations was slightly better, with scores of 1.5 at all three locations. The quantitative data indicate more improvement at the downstream locations, with a score of 2.0 (fair) at Road C, and 2.5 at Roads A-6 and A.

The macroinvertebrate data clearly indicate that the region of Fourmile Branch that is upstream from all NPDES discharges is severely perturbed due to naturally occurring conditions and that the quality of the stream increases in a downstream direction. The portion of Fourmile Branch just upstream from Road F is a shallow stagnant marshy area. Dissolved oxygen in the stream at Road F was 4.85 mg/l in November (Table 13), which was only 45% saturation (based on a water temperature of 11.9 °C). During the summer months, oxygen concentrations of <1 mg/l have been measured at this location (Specht, 1995a). Numerous areas of Fourmile Branch that are downstream from Road F have been impounded by beaver dams, and it is likely that these dams result in low dissolved oxygen concentrations downstream from the impounded areas during the summer months. If the macroinvertebrate community is subjected to low dissolved oxygen concentrations periodically, it is likely that the community does not have time to recover completely during the cooler months.

Other studies conducted in Fourmile Branch at Road F indicate that *Ceriodaphnia dubia* does poorly when cultured in water from Fourmile Branch (Specht 1995b). During an investigation conducted for 12 months during 1994, water collected from this location was always either acutely or chronically toxic to *Ceriodaphnia*. In 1995, a Toxicity Identification Evaluation was performed to determine the cause of the toxicity (ETT Environmental, 1995a, 1995b). The results of the TIE indicated that naturally occurring iron was responsible for the observed toxicity. The iron is believed to leach from wetland soils, as a result of the low pH of the water.

Table 13. Physical/Chemical Data for SRS Sampling Locations, November 2000

Location	D.O. (mg/L)	Temperature (°C)	pH (s.u.)	Conductivity µmhos/cm
Upper Three Runs Creek at 8-1	9.18	16.0	5.04	20.0
Upper Three Runs Creek at Rd C	9.17	17.0	5.50	26.0
Mill Creek at Telephone Cable Rd.	9.01	12.5	6.50	109.0
Tims Branch at Road 2	6.67	13.3	5.78	53.0
McQueen Branch at Road F	9.06	13.0	6.33	65.0
Crouch Branch at Road 4	8.90	16.3	6.81	174.0
Fourmile Branch at Road F	4.85	11.9	3.78	118.0
Fourmile Branch at Road C	7.93	20.5	5.58	52.0
Fourmile Branch at Road A-6	8.42	18.5	6.26	173.0
Fourmile Branch at Road A	7.83	13.7	6.00	73.0
Pen Branch at Road C	7.36	16.8	6.52	86.0
Pen Branch at Road B	8.09	17.8	6.28	66.0
Pen Branch at Road A	9.46	15.3	6.18	80.0
Indian Grave Branch at Road B	8.20	19.3	6.29	105.0
Steel Creek	10.12	11.3	6.77	36.0
Meyers Branch at Old Dunbarton Rd.	7.70	17.4	6.08	56.0

In conclusion, the macroinvertebrate data from Fourmile Branch indicated that the upstream portions of Fourmile Branch are perturbed, but the perturbation is not related to SRS discharges, since the most upstream station, which is above all discharges to the stream, is the most perturbed. The impacts are most likely due to periodically low levels of dissolved oxygen, and possibly elevated concentrations of naturally occurring iron.

Temporal Changes in Fourmile Branch between 1997 and 2000 - The 1997 data also showed that the headwaters of Fourmile Branch were impaired due to naturally occurring conditions, and that the macroinvertebrate community of the stream improved markedly in a downstream direction (Specht and Paller, 1998). Overall, more taxa were collected, more EPT taxa were collected, and densities of organisms on multiplate samplers were considerably higher at all locations in 2000 (Table 12) than in 1997 (Table 14). A similar pattern was observed at most locations in the Upper Three Runs drainage (see Section 4.1.1), which suggests that the differences are due to natural temporal variability. The macroinvertebrate data from Fourmile Branch show no indications that SRS NPDES discharges are having an adverse effect on the macroinvertebrate community of the stream.

4.2.2 Fish - Fourmile Branch

Fish sampling station locations in Fourmile Branch differed slightly from macroinvertebrate sampling locations. Both fish and macroinvertebrate surveys were conducted near Road C, Road A-6, and Road A (Figure 1).

Table 14. Macroinvertebrate Data for Fourmile Branch, November 1997

	Road F	Road C	Road A-7	Road A
MULTIPLATE (QUANTITATIVE DATA)				
Total # species	5	11	26	29
Mean # species/replicate	1.0	2.2	5.2	5.8
EPT Index	0	1	9	7
Density (organisms/m^2)	5.6	17.8	341.0	229.0
Total biomass (g/m^2)	0.0061	0.0054	0.1226	0.0315
NC Biotic index	8.15	7.15	6.40	5.95
Relative Abundance of Major Taxonomic Groups				
Annelida (worms)	20.0	12.5	0.0	0.0
Mollusca (clams, snails)	20.0	0.0	1.0	1.9
Crustacea	0.0	0.0	0.0	1.5
Ephemeroptera	0.0	0.0	11.1	32.5
Plecoptera	0.0	6.3	2.9	0.5
Trichoptera	0.0	0.0	69.1	2.4
Odonata	0.0	6.3	0.0	0.5
Heteroptera	0.0	0.0	0.0	0.0
Coleoptera	0.0	12.5	2.3	0.5
Diptera (excluding midges)	20.0	0.0	7.2	0.0
Diptera (midges)	40.0	62.5	6.2	59.7
Chironomini	0.0	12.5	2.9	2.4
Orthocladiinae	20.0	6.3	3.3	37.9
Tanypodinae	0.0	6.3	0.0	1.0
Tanytarsini	20.0	37.5	0.0	18.4
Other	0.0	0.0	0.0	0.5
Relative Abundance of Functional Feeding Groups				
Collector-gatherers	40.0	28.1	11.1	58.0
Collector-filterers	20.0	37.5	74.9	20.4
Predators	20.0	18.8	1.0	2.4
Scrapers	20.0	3.1	7.7	14.8
Shredders	0.0	12.5	5.4	4.6
Relative Abundance of Functional Feeding Group Biomass				
Collector-gatherers	<0.1	9.3	7.4	42.5
Collector-filterers	<0.1	<0.1	63.1	5.4
Predators	100.0	81.5	15.9	7.0
Scrapers	<0.1	9.3	11.7	45.1
Shredders	<0.1	<0.1	1.9	<0.1
QUALITATIVE DATA				
Total # species	15	11	20	27
EPT Index	0	1	6	6
NC Biotic index	7.47	6.63	6.56	5.95
QUALITATIVE AND QUANTITATIVE DATA COMBINED				
Total # species	18	19	36	41

Macroinvertebrate surveys were also conducted near Road F (upstream from all NPDES discharges); however, fish surveys were not because the stream was too shallow and narrow (except in beaver ponds) to support many fish. The control sites used for statistical analysis of the Fourmile Branch sampling stations were the four in Pen Branch, Meyers Branch, and Mill Creek.

Numbers of fish and fish species, respectively, collected from the Fourmile Branch sample stations were 145 and 13 near Road C, 182 and 17 near Road A-6, and 221 and 17 near Road A. The most abundant species near Road C were yellowfin shiner, spotted sunfish, dusky shiner, and pirate perch. Dusky shiner, yellowfin shiner, redbreast sunfish, and pirate perch predominated near Road A-6, and yellowfin shiner, dusky shiner, bluehead chub, redbreast sunfish, and tesselated darter were most abundant near Road A.

The IBI at the Fourmile Branch sampling stations averaged 42.0 at Road A, 46.0 at Road A-6, and 42.0 at Road C (Table 10). None of these values differed significantly from the IBIs at the control sites. These results were generally similar to the macroinvertebrate results, which indicated that the mid and lower reaches of Fourmile Branch (Roads A-6 and A) were generally comparable to the reference sites. However the macroinvertebrate samples at Road C and Road F indicated significant degradation in the upper reaches of Fourmile Branch attributable to the release of anoxic water from beaver impoundments and iron leached from wetland soils. Fish samples taken from the Road 4 area in 1997 also indicated degradation in the upper reaches of Fourmile Branch, although this area was not sampled in 2000. The only substantial difference between the fish and macroinvertebrate samples was at Road C where the IBI indicated no degradation and the macroinvertebrate samples indicated the opposite. This difference may have resulted from more rapid recovery of the fish assemblage along the recovery gradient stretching from the degraded upstream to the comparatively undegraded downstream reaches of Fourmile Branch.

Temporal changes between 1997 and 2000 - IBIs at the sample sites near Roads C, A6, and A were similar between 1997 and 2000, indicating acceptable and relatively stable environmental quality in the mid and lower reaches of Fourmile Branch (Table 10). Temporal comparisons involving the IBI cannot be made for the upper portion of Fourmile Creek because this area was impounded by beavers by 2000. The beaver dam converted the stream reach near Road 4 into a comparatively large and deep pond which would not be expected to support the same species found in a free flowing stream and, therefore, could not be accurately analyzed using the IBI.

4.3 Pen Branch Watershed

4.3.1 Macroinvertebrates - Pen Branch/Indian Grave Branch

Macroinvertebrates were collected at four locations in the Pen Branch watershed: Pen Branch at Road C and Road B, both of which are upstream from all SRS discharges; Indian Grave Branch just downstream from the new cooling tower, which is downstream from all NPDES discharges from K Area; and Pen Branch at Road A, which is downstream from the confluence of Indian Grave Branch with Pen Branch, and

therefore downstream from all NPDES discharges to Pen Branch. Pen Branch at Road C is a small (second order) stream, with a dense canopy. No upstream reference location could be sampled on Indian Grave Branch, since the discharges from K Area enter the headwaters of the stream.

The macroinvertebrate data collected from the three locations in Pen Branch and from one location in Indian Grave Branch indicate that the locations were fairly similar with respect to many of the metrics that were measured (Table 15). Fewer taxa (24) were collected from multiplate samplers at the headwater station in Pen Branch (Road C) than at the other two locations in Pen Branch (34). A similar pattern was seen for the qualitative data, with 17 taxa collected at Road C, 28 at Road B, and 45 at Road A. For qualitative and quantitative sampling combined, the total number of taxa collected ranged from 35 at Road C to 56 at Road A. The number of EPT taxa collected in the quantitative and qualitative samples also both increased in a downstream direction (from 8 to 15 on the multiplates and from 2 to 12 in the qualitative samples The density of organisms collected from the multiplates also increased in a downstream direction, from 1191.7 organisms/m^2 at Road C to 5616.7 organisms/m^2 at Road A. Biomass showed a similar pattern, increasing from 0.0381 g/m^2 at Road C to 0.253 g/m^2 at Road A . Species composition differed among the three locations. The relative abundance of mayflies and stoneflies decreased in a downstream direction, while the abundance of Orthocladiinae and Tanytarsini midges increased, particularly at Road A. Caddisflies (primarily *Cheumatopsyche*) were much more abundant at Road A (13.9%) than at the other two locations (1.4 and 2.8%). These differences in species composition are due to differences in habitat and not effluent effects. Road A is located in the post-thermal portion of Pen Branch, and as such has a much more open canopy and a greater abundance of periphyton and other algae. This difference in habitat is reflected in the relative abundance of functional feeding groups. Collector-filterers (primarily Tanytarsini midges and filter-feeding caddisflies) were much more abundant at Road A (44.2%) than at the other two locations 8.4 and 13.5%). In contrast, Pen Branch at Road C which has a closed canopy, had only 8.4% collector filterers, but a much higher percentage of shredders (27.6%), which feed on inputs of leaf litter to the stream. Indian Grave Branch is the tributary of Pen Branch that receives NPDES effluents from K Area. Indian Grave Branch also is a post-thermal stream and has fairly similar habitat to that of Pen Branch at Road A, although it is somewhat smaller. The number of taxa collected from Indian Grave Branch was slightly lower than from Pen Branch at Road A, but comparable to the upper two Pen Branch stations, which are more similar in size to Indian Grave Branch. In Indian Grave Branch, 28 taxa were collected from multiplates, 35 from natural substrates, and 46 from multiplates and qualitative, combined. Nine EPT taxa were collected from multiplates, and 7 from natural substrates. Tanytarsini midges (primarily *Tanytarsus*) was the most abundant group, accounting for 51.2% of the macroinvertebrates collected from multiplates. Also abundant were orthoclad midges (16.2%; primarily *Cricotopus*) and amphipod crustaceans (*Hyalella azteca*; 10%). Like Pen Branch at Road A, Indian Grave Branch has a relatively open canopy, which has resulted in higher algal production. Filter-feeders comprised 53.5% of the organisms collected from Indian Grave Branch.

Bioclassification scores for Pen Branch and Indian Grave Branch (Table 8) indicate that the most upstream sampling location in Pen Branch (Road C) had the lowest score for both qualitative and quantitative data (1.5 and 3.0, respectively). For the qualitative

Table 15. Macroinvertebrate Data for Pen Branch/Indian Grave Branch and Steel Creek/Meyers Branch, November 2000

	Pen Branch System				Steel Creek Sys.	
	Road C	Road B	Road A	IGB	Steel Cr.	Meyers Branch
Parameter	MULTIPLATE (QUANTITATIVE DATA)					
Total # of Species	24	34	34	28	24	34
Mean # Species/ Replicate	10.2	14.6	19.8	13.8	9.4	19.2
EPT Index	8	10	15	9	11	6
Density (organisms/m^2)	1191.7	2100.0	5616.7	2833.3	983.3	7108.3
Total Biomass (g/m^2)	0.0381	0.0606	0.2530	0.0238	0.1369	0.0237
NC Biotic Index	5.8	4.69	5.87	6.95	5.04	6.46
Relative Abundance of Major Taxonomic Groups						
Annelida (worms)	0.0	0.0	0.0	0.3	0.0	0.0
Mollusca (clams, snails)	2.8	0.0	0.0	0.3	0.8	0.1
Crustacea	0.0	0.4	0.3	10.0	0.0	0.2
Ephemeroptera	24.5	22.2	11.1	2.6	52.5	3.8
Plecoptera	18.2	21.4	5.5	0.6	8.5	0.1
Trichoptera	1.4	2.8	13.9	3.2	12.7	1.3
Megaloptera	0.0	0.0	0.0	0.0	0.0	0.0
Odonata	0.0	1.2	0.0	0.9	0.0	0.0
Heteroptera	0.0	0.0	0.0	0.0	0.0	0.0
Coleoptera	3.5	1.2	1.2	0.0	0.0	0.2
Diptera (excluding midges)	0.0	1.6	0.3	0.3	1.7	0.1
Diptera (midges)	49.7	49.2	67.7	81.8	23.7	94.1
Tanypodinae	6.3	1.6	1.2	8.5	0.0	4.2
Orthocladiinae	16.8	29.0	31.9	16.2	6.8	15.6
Chironomini	19.6	7.5	3.9	5.9	14.4	12.8
Tanytarsini	7.0	11.1	30.7	51.2	2.5	61.5
Relative Abundance of Functional Feeding Groups						
Collector-gatherers	40.2	43.3	38.0	24.1	38.6	23.8
Collector-filterers	8.4	13.5	44.2	53.5	16.1	62.6
Predators	11.2	12.3	3.1	10.6	8.1	4.5
Scrapers	12.6	13.5	6.2	1.6	26.7	1.7
Shredders	27.6	17.5	8.5	10.1	10.6	7.4
Relative Abundance of Functional Feeding Group Biomass						
Collector-gatherers	26.0	29.5	83.4	74.2	32.7	43.5
Collector-filterers	2.1	4.0	9.3	10.5	24.4	41.4
Predators	9.7	26.9	3.4	7.1	2.0	4.2
Scrapers	49.6	29.5	3.1	8.2	39.9	8.0
Shredders	12.6	10.2	0.8	0.0	1.0	3.0
	QUALITATIVE DATA					
Total # species	17	28	45	35	37	46
EPT Index	2	6	12	7	9	9
NC Biotic Index	7.15	5.44	6.38	6.71	5.19	7.51
	QUALITATIVE AND QUANTITATIVE DATA COMBINED					
Total # species	35	50	56	46	49	66

data, Road B, which is also upstream from NPDES discharges, scored higher (3.0) than Road A (2.5), but the scores for the quantitative data were the same (3.5) for Roads B and A. Indian Grave Branch, which receives NPDES discharges from K Area scored lower (2.1 for qualitative; 2.0 for quantitative) than any of the Pen Branch sites. However, the difference is most likely related to habitat alterations that are the result of the long history of thermal discharges to the stream, and not to NPDES discharges.

In summary, the two stations that are downstream from NPDES discharges (Pen Branch at Road A and Indian Grave Branch) differ somewhat from the upstream stations, but the differences are due to habitat differences related to the post-thermal nature of these locations, and not to the effects of NPDES discharges. Species richness was actually highest at Road A, but the species composition differed from that of the upstream locations. However, the shift in species is to filter-feeding species that are utilizing the algae produced in the open-canopy habitat of the post-thermal streams and not to pollution-tolerant species.

Temporal Changes in Pen Branch/Indian Grave Branch - More taxa and more EPT taxa were collected from multiplate samplers at all locations in 2000 than in 1997 (Tables 15 and 16). In 1997 the total number of taxa at the four sampling locations in Pen Branch/Indian Grave Branch ranged from 10 to 23; in 2000 the range was 24 to 34. The number of EPT taxa collected in 1997 ranged from 3 to 7; in 2000 the range was 8 to 15. Macroinvertebrate densities were also much higher in 2000 (1191.7 to 5616.7) than in 1997 (95.6 to 163). The number of taxa collected from qualitative sampling of natural substrates ranged from 25 to 34 in 1997 and from 17 to 45 in 2000, which indicates that the number of taxa collected from natural substrates was fairly similar in both years. The total number of taxa collected from quantitative and qualitative sampling combined was slightly higher at three of the four stations in 2000 and slightly lower (35 vs. 38) at one location (Road C). Ephemeroptera (primarily *Baetis, Stenonema* and *Leptophlebia;* Table 6) comprised a lower percentage of the organisms collected at all Pen Branch locations in 2000 (2.6 to 24.5%) than in 1997 (9.3 to 62.5%). The relative abundances of Plecoptera and Trichoptera were fairly similar between years. The biggest shift in relative abundance occurred in the Tanytarsini midges, which comprised 0.9 to 17.4% of the macroinvertebrate collected from multiplates in 1997, but 7.0 to 51.2% in 2000. The relative abundances of functional feeding groups were very similar in 1997 and 2000.

4.3.2 Fish - Pen Branch/Indian Grave Branch

NPDES outfalls within the Pen Branch watershed discharge into Indian Grave Branch, a tributary of Pen Branch (Figure 1). One fish sampling station was located within Indian Grave Branch downstream of the outfalls and one was located in Pen Branch downstream from the confluence of Pen Branch and Indian Grave. Both were potentially subject to impacts from the NPDES outfalls, particularly the Indian Grave Branch station which was closest to the outfalls. There were two additional fish sampling stations in the Pen Branch drainage located above the confluence of Indian Grave Branch and Pen Branch (Pen Branch Rd. B and Pen Branch Rd. C) Because they were located in undisturbed areas and did not receive NPDES discharges, these sampling stations were considered reference sites and grouped with the other two reference sites (Meyers Branch and Mill Creek) for statistical testing.

Table 16. Macroinvertebrate Data for Pen Branch/Indian Grave Branch and Steel Creek/Meyers Branch, November 1997

	Pen Branch System				Steel Creek Sys.	
	Road C	Road B	Road A	IGB	Steel Cr.	Meyers Branch
Parameter	MULTIPLATE (QUANTITATIVE DATA)					
Total # of Species	10	21	22	23	17	18
Mean # Species/ Replicate	2.0	4.2	4.4	4.6	3.4	3.6
EPT Index	7	7	3	4	4	6
Density (organisms/m^2)	124.0	163.0	95.6	101.0	71.1	180.0
Total Biomass (g/m^2)	0.0513	0.0654	0.1356	0.0702	0.0428	0.0221
NC Biotic Index	5.51	5.16	6.54	6.58	5.81	4.81
Relative Abundance of Major Taxonomic Groups						
Annelida (worms)	0.0	0.0	0.0	1.1	0.0	.06
Mollusca (clams, snails)	0.0	0.7	2.3	1.1	3.1	0.0
Crustacea	0.0	0.7	0.0	1.1	0.0	0.0
Ephemeroptera	62.5	46.9	9.3	28.6	35.9	14.2
Plecoptera	15.2	19.7	0.0	0.0	23.4	9.3
Trichoptera	0.0	12.2	3.5	2.2	0.0	2.5
Megaloptera	0.0	0.0	0.0	0.0	0.0	0.0
Odonata	1.8	0.0	3.5	2.2	1.6	0.0
Heteroptera	0.0	0.0	0.0	0.0	0.0	0.0
Coleoptera	0.0	4.8	2.3	3.3	0.0	0.0
Diptera (excluding midges)	0.0	0.0	0.0	0.0	1.6	0.6
Diptera (midges)	20.5	15.0	76.9	60.4	32.8	72.8
Tanypodinae	0.0	7.0	2.3	7.7	3.1	3.1
Orthocladiinae	0.0	10.2	24.4	7.7	9.4	26.5
Chironomini	19.6	2.0	32.6	42.9	17.2	29.6
Tanytarsini	0.9	2.0	17.4	2.2	3.1	13.6
Relative Abundance of Functional Feeding Groups						
Collector-gatherers	42.4	36.4	40.7	46.2	34.4	49.2
Collector-filterers	0.9	15.0	20.9	3.3	4.7	15.4
Predators	3.6	5.4	8.1	12.1	9.4	6.2
Scrapers	29.9	23.1	8.1	16.5	21.1	6.8
Shredders	23.2	20.1	22.1	22.5	30.5	22.2
Relative Abundance of Functional Feeding Group Biomass						
Collector-gatherers	39.2	<0.1	3.3	87.0	23.6	50.7
Collector-filterers	1.4	50.5	0.9	1.1	<0.1	6.8
Predators	14.6	0.9	93	2.6	46.3	10.4
Scrapers	37.8	39.1	2.3	9.3	23.6	29.4
Shredders	7.0	9.5	0.5	<0.1	6.5	2.7
	QUALITATIVE DATA					
Total # species	34	34	30	25	33	40
EPT Index	9	7	7	7	6	17
NC Biotic Index	6.1	6.07	6.82	7.05	6.77	5.68
	QUALITATIVE AND QUANTITATIVE DATA COMBINED					
Total # species	38	44	45	38	41	47

Electrofishing yielded a total of 15 species and 238 individual fish from the Pen Branch reference site near Road C. The other Pen Branch reference site near Road B yielded 15 species and 243 individuals. The most abundant species at both locations were yellowfin shiner, bluehead chub, and pirate perch. Redbreast sunfish, spotted sunfish, and creek chubs were also well represented, especially at the sample site near Road C. The sites located downstream from the NPDES outfalls, Indian Grave Branch and Pen Branch near Road A13.2, supported somewhat more species (22 and 20 respectively) and were numerically dominated by dusky shiner, coastal shiner, spotted sunfish and a variety of other species. These differences in numbers and types of species supported by the reference sites and the other sites, which were located farther downstream, were a consequence of differences in stream size and habitat that naturally occur between the upper and lower reaches of streams (Paller 1994). The IBI takes such natural differences into account and generates a score based only on environmental quality (Paller et al. 1996)

The IBI at the Pen Branch reference sites (Roads C and B) averaged 48.0 and 46.0 (Table 10). IBI values in Indian Grave Branch and at Pen Branch near Road A13.2 were also quite high, averaging 47.3 and 48.7, respectively. These values are close to the maximum IBI value of 50 and reflect the high environmental quality of both the undisturbed upper reaches of Pen Branch and the downstream reaches that receive NPDES discharges. These results were comparable to the macroinvertebrate results, which also indicated high environmental quality at all sample areas in Pen Branch.

Temporal changes between 1997 and 2000 - The average IBI at the Pen Branch reference sites (Road C and Road B) differed little between 1997 and 2000, reflecting high environmental quality and stable conditions at both sites (Table 10). In contrast, IBIs at the Indian Grave Branch and Pen Branch Road A13.2 sites increased slightly between 1997 and 2000, from 44.7 to 47.3 and from 45.3 to 48.7, respectively. These increases reflect the continuation of a recovery trend that began when thermal discharge into these streams was discontinued with the shut down of K-Reactor, permitting recolonization by fishes and restoration of the habitat.

4.4 Steel Creek/Meyers Branch

4.4.1 Macroinvertebrates - Steel Creek/Meyers Branch

Macroinvertebrates were collected from two locations in the Steel Creek watershed: Steel Creek near Road C, which is downstream from all previous P-Area discharges to the stream and approximately one km upstream from the upper end of L Lake; and Meyers Branch at Old Dunbarton Road, which is essentially unimpacted by SRS activities. As discussed in Section 2.4, sampling was not performed farther downstream in Steel Creek, because NPDES discharges enter directly into L Lake, the NPDES discharges into the lake are minimal, and it would not be possible to distinguish between ecosystem changes resulting from the impoundment of Steel Creek and effluent effects. During the time that the multiplates were in Steel Creek, substantial volumes of water from the Savannah River were discharged down Steel Creek to provide water to L Lake. Therefore, both the discharge rate and water velocity were elevated. These factors can influence the kinds of taxa that inhabit the stream, and can also dislodge macroinvertebrates from the substrate. In Steel Creek, 24 taxa were

collected from the multiplate samplers, 37 were collected from qualitative sampling, and 49 were collected in all (Table 15). In Meyers Branch, 34 taxa were collected from the multiplates, 46 were collected during qualitative sampling, and 66 taxa were collected in all. More EPT taxa were collected from multiplates in Steel Creek than in Meyers Branch (11 taxa vs. 6), but an equal number of EPT taxa were collected from both streams in the qualitative sampling (9). The density of organisms on the multiplates was much higher in Meyers Branch (7108.3 organisms/m^2) than in Steel Creek (983.3 organisms/m^2). The lower densities in Steel Creek may have been related to the high flows resulting from river water being pumped to L Lake during the multiplate colonization period. The biotic index values were higher (poorer) in Meyers Branch than Steel Creek for both the multiplate data (6.46 vs. 5.04) and the qualitative sampling (7.51 vs. 5.19). The data indicate that Meyers Branch has a more diverse fauna than Steel Creek, and higher densities of organisms, but the high densities were attributable to a very few species of midges, which resulted in a relatively high biotic index value. The macroinvertebrate community on the multiplate samplers in Steel Creek was dominated by mayflies (52.5%; primarily *Stenonema and Ephemerella*; Table 6), midges (23.7%; primarily *Polypedilum*), caddisflies (12.7%) and stoneflies (8.5%). In Meyers Branch, 94.1% of the organisms collected were midges (primarily *Tanytarsus*, *Parametriocnemus,* and *Microtendipes*), with mayflies accounting for 3.8% of the macroinvertebrates that were collected from multiplates. The collector-gatherer functional feeding group was the most group in Steel Creek (38.6%), followed by scrapers (26.7%) and collector-filterers (16.1%). In Meyers Branch, collector filterers (mostly Tanytarsini midges) were dominant (62.6%), followed by collector gatherers.

The Bioclassification scores for Steel Creek were 3.5 (good) for both the qualitative and quantitative data sets (Table 8), while Meyers Branch, which is a reference site, scored 2.0 for the qualitative data and 2.2 for the quantitative data, which are both ratings of "fair". There is no ready explanation for the relatively low Bioclassification scores for Meyers Branch, since the stream receives no NPDES discharges and there are no other known sources of perturbation to the stream.

The macroinvertebrate communities of Steel Creek and Meyers Branch are quite different, but the differences appear to be due to differences in habitat, rather than to effluent effects. Steel Creek, which received small amounts of NPDES effluents from P Area until 1998, but presently receives no NPDES discharges, had fewer taxa than Meyers Branch, but much higher percentages of EPT taxa. The macroinvertebrate data from Steel Creek look remarkably similar to those of Mill Creek, which is an unperturbed tributary of Upper Three Runs.

Temporal Changes in Steel Creek and Meyers Branch - Like most of the other streams that were sampled, more taxa were collected from Steel Creek and Meyers Branch in 2000 than in 1997 (Tables 15 and 16). In the 2000 sampling of Steel Creek, 24 taxa were collected from multiplates, 37 from qualitative samples and 49 from quantitative combined, as compared to 17, 33 and 41 taxa, respectively, in 1997. In Meyers Branch in 2000, 34 taxa were collected from multiplates, 46 from qualitative sampling, and 66 from qualitative and quantitative combined, as compared to 18, 40, and 47 taxa, respectively, in 1997. The relative abundance of mayflies and caddisflies were considerably higher in Steel Creek in 2000 (52.5% and 12.7%, respectively) than in 1997 (35.9% and 0.0%), but the reverse was seen for stoneflies (8.5% in 2000 and

23.4% in 1997). In Meyers Branch, midges, and particularly Tanytarsini midges, were much more abundant in 2000 than in 1997. Tanytarsini midges made up 61.5% of the organisms collected from multiplates in Meyers Branch in 2000, as compared to just 13.6% in 1997. No explanation for the change is obvious. In Steel Creek, the distribution of organisms in functional feeding groups was fairly consistent between 1997 and 2000. In Meyers Branch, collector-filterers were much more abundant in 2000 (62.6%) than in 1997 (15.4%), while most other functional groups represented a smaller percentage of the organisms collected in 2000 than in 1997. The shift in functional group composition was due primarily to the large number of filter-feeding Tanytarsini midges that were collected in Meyers Branch.

4.4.2 Fish – - Steel Creek/Meyers Branch

Fish were collected from sample stations in the portion of Steel Creek upstream from L Lake (near Road C) and Meyers Branch. The sample station in Steel Creek was located approximately 1.75 km downstream from several former NPDES outfalls. The Meyers Branch station did not receive NPDES discharges and was largely undisturbed. It was considered a reference site and grouped with the other three reference sites for statistical analysis.

The assemblage of fish collected from Meyers Branch was typical of reference sites, consisting of 159 individual fish representing 15 species. The most abundant species were yellowfin shiner, bluehead chub, and creek chubsucker. In contrast, the fish sample from Steel Creek near Road C included only 28 individuals and eight species. It is unlikely that these low numbers were the result of inefficient sampling since sampling conditions at Steel Creek near Road C were good (comparatively shallow and clear water).

The mean IBI value for Steel Creek near Road C was 23.3 (Table 10). This value was significantly lower than the mean IBI for the four control sites. Furthermore, it was below the range of IBI values calculated for undisturbed streams in the historical data base (Figure 3) suggesting that biotic integrity in upper Steel Creek was poor. It is noteworthy that the Steel Creek was electrofished prior to the pumping of large volumes of Savannah River into Steel Creek to recharge L Lake (discussed in the preceding section). Therefore, this perturbation was not responsible for the low IBI in Steel Creek. Furthermore, Steel Creek has not received NPDES discharges since January 1988, indicating that poor biotic integrity in Steel Creek near Road C is unrelated to NPDES outfalls.

The low IBI from Steel Creek near Road C contrasts with the macroinvertebrate data from this site which do not indicate significant degradation. Reasons for this difference are unclear. Fish were collected in July and macroinvertebrates in November; however, there were no known changes in Steel Creek preceding or during this period that would account for the differences between the fish and macroinvertebrate results. It is important to consider that fish and macroinvertebrate bioassessments do not always agree because fish and macroinvertebrates respond differently to some environmental disturbances. Mount et al (1984) observed that fish were more sensitive to metal pollution than were macroinvertebrates, but macroinvertebrates were more sensitive to organic pollution than were fish. Yoder and Rankin (1995) observed differences in the rates of recovery of fish and

macroinvertebrates from the combined effects of several types of disturbance. Berkman et al. (1986) found that stream fish and invertebrate communities often responded differently to sedimentation and that invertebrates seemed more sensitive to this type of disturbance. The Ohio Department of Natural Resources samples both fish and macroinvertebrates and determines the level of impact based on the number of taxonomic groups that are degraded (Yoder and Rankin 1999). Based on this logic, a low IBI from Steel Creek indicates environmental degradation, although not as severe as if both fish and macroinvertebrate assemblages were degraded.

The low IBI in Steel Creek may be at least partly habitat related. The banks of Steel Creek were severely eroded (Table 11). The stream channel was cut more deeply than is typical of most SRS streams and bank collapse was evident in a number of areas raising the possibility of intermittent siltation and habitat instability. However, it cannot be definitively stated that habitat degradation was the sole cause of the low IBI observed in Steel Creek.

Temporal changes between 1997 and 2000 - The IBI in Steel Creek near Road C declined markedly between 1997 and 2000, from 32.7 to 23.3 (Table 10). Steel Creek near Road C was the only sample site to exhibit such a strong decrease in the IBI between years. The cause of this decrease is unknown.

4.5 Savannah River

All discharges from SRS NPDES outfalls ultimately flow into the Savannah River because all SRS streams are tributaries of the Savannah River. However, NPDES outfalls on SRS streams discharge into the upper or midreaches of these streams (Table 2), resulting in a long flow path to the Savannah River and considerable dilution of the effluents before they reach the river. Biological sampling has demonstrated that most of these outfalls have not affected their receiving streams. In the few cases where possible effects were observed (e.g., Crouch Branch), they were confined to headwaters and did not persist downstream. Therefore, it is reasonable to conclude that NPDES outfalls located on SRS streams have not affected the Savannah River.

Unlike the majority of the SRS NPDES outfalls, which discharge into tributary streams, there are six NPDES outfalls (Table 2) that are located near the Savannah River. Effluents from these outfalls are discharged into the Savannah River Swamp or flow directly into the Savannah River through a relatively short ditch. Upon entering the river, all effluents are highly diluted by mixing with Savannah River water. Previous biological surveys (1983 to 1985) indicated the presence of diverse and healthy fish and macroinvertebrate communities in the Savannah River with no evidence of impacts related to SRS NPDES discharges (Specht 1987).

5.0 Conclusions

The results of the macroinvertebrate and fish surveys conducted during this study were generally in close agreement. Both indicated that most SRS streams were characterized by high biotic integrity and unaffected by SRS NPDES discharges. Possible exceptions include Crouch Branch, McQueen Branch and Tims Branch. For Crouch Branch, the fish data indicate no impairment, while the macroinvertebrate data indicates possible impairment. Investigations conducted in Crouch Branch subsequent

to the 1997-1998 biological survey indicated that elevated concentrations of copper contributed by the H-02 outfall are responsible for much of the degradation, although erosion and scouring by stormwater runoff have also degraded habitat in the midreaches of Crouch Branch. Sampling conducted during 2000 indicated the fish community in Crouch Branch has fully recovered and the macroinvertebrate community has improved considerably. For Tims Branch, the fish data is not significantly different from the control, but the macroinvertebrate data indicates some impairment. Since 1997, several beaver dams have been constructed just upstream from the sampling location in Tims Branch. Dissolved oxygen concentrations below the dams are low, and this appears to be the cause of the perturbation in Tims Branch. For McQueen Branch, the fish data was not significantly different from the control, but the macroinvertebrate data indicates some impairment. For the sampling conducted in 2000, the sampling location in McQueen Branch was moved approximately 1 km upstream from the 1997 sampling location, due to inundation of this location by beaver dams. Stream habitat at the new location is somewhat degraded, due to channel scouring in the 1980's. However, this location is also closer to two NPDES discharges than the original sampling location, so impacts due to NPDES discharges cannot be ruled out. Degradation was also observed in upper Fourmile Branch and upper Steel Creek, neither of which presently receive NPDES discharges. Depressed biotic integrity in upper Fourmile Branch was related to factors other than NPDES discharges including low dissolved oxygen and elevated concentrations of iron. The IBI indicated that biotic integrity decreased in upper Steel Creek between 1997 and 2000. Reasons for this change are unclear but may include reservoir impoundment related effects and naturally occurring habitat factors.

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