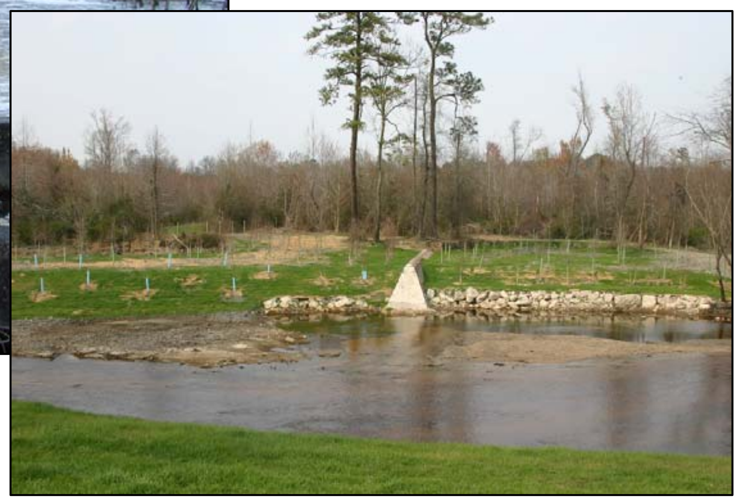
LOWELL MILL DAM-LITTLE RIVER WATERSHED
RESTORATION SITE
2008 Annual Monitoring Report (Year-3)

Johnston County, North Carolina
EEP Project No. D04008-2
Design Firm: Milone and MacBroom, Inc.



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Ecosystem Enhancement PROGRAM

LOWELL MILL DAM-LITTLE RIVER WATERSHED RESTORATION SITE
2008 Annual Monitoring Report (Year-3)

JOHNSTON COUNTY, NORTH CAROLINA

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EXECUTIVE SUMMARY

Introduction

Dam removal projects performed pursuant to the North Carolina Dam Removal Task Force (DRTF) are required to quantitatively demonstrate chemical and biological improvements to the watershed in order to achieve compensatory mitigation credit (DRTF 2001). The following monitoring report documents the latest efforts by Restoration Systems, LLC (RS), on behalf of the N.C. Ecosystem Enhancement Program (NCEEP), to document changes in the study area of the Lowell Mill Dam removal effort. The suite of ecological evaluations performed and described herein establishes new standards for mitigation monitoring. This standard is in keeping with the goal set forth by state and federal agencies to provide functional ecological gains to North Carolina watersheds through the efforts of the NCEEP and its contract partners.

The site of the former Lowell Mill Dam is approximately 0.3 mile downstream (south) of Interstate 95 between the towns of Micro and Kenly (Figure 1, Appendix A) on the Little River, a tributary of the Neuse (Neuse Hydrologic Unit 03020201). Approximately 36,875 linear feet of the Little River and two tributaries (Little Buffalo Creek and an unnamed tributary) were impounded by the dam (Figure 2, Appendix A). Impacts to water quality within the former Site Impoundment (i.e., river and stream reaches formerly impounded by the dam) were manifested in the form of lower dissolved oxygen concentrations, higher temperatures, and increased sedimentation. The character of the aquatic communities shifted from a free-flowing (lotic) river system towards an impounded (lentic) condition following construction of a dam at the site, approximately 200 years ago. Rare and endangered mussel and fish habitat, which depend on free-flowing lotic conditions, was greatly altered or diminished within areas of the Little River impounded by the former dam. The dam also blocked the passage of anadromous fish, extirpating them from upstream reaches.

The dam was removed in a manner that minimized impacts to water resources both upstream and downstream of the dam site. Gradual dewatering began in March of 2004, and dam removal began in December 2005. The dam structure and associated mill works were completely removed by January 18, 2006. For documentation and quantification of the Lowell Dam removal process and associated water quality effects, see Riggsbee et al. (2007a-d).

This report summarizes Year-3 (2008) project monitoring. Monitoring data continue to follow trends displayed during Year-1 (2006) and Year-2 project monitoring. These trends indicate a demonstrably favorable shift towards the restoration of the aquatic community and towards water quality attributes more typical of lotic flow conditions within the former Site Impoundment. In 2006, American shad (*Alosa sapidissima*) were captured within the Little River well upstream of the former dam, confirming the restoration of anadromous fish passage within (and upstream of) the former Site Impoundment.

Monitoring Plan

A monitoring plan was developed in accordance with DRTF guidelines to evaluate success in fulfilling the project's primary success criteria, which include 1) re-colonization of rare and protected aquatic species, 2) improved water quality, 3) an improved aquatic community, and 4) restoration of anadromous fish passage (under former-crest pool). Reserve success criteria include 1) anadromous fish passage (above former-crest pool), 2) downstream benefits below the dam, and 3) human values (scientific value and human recreation).

In order to evaluate project success for the above criteria, a monitoring network was deployed throughout the former Site Impoundment and in reference areas both upstream and downstream of the former dam (Figure 3, Appendix A). Within the network, biological surveys were conducted to provide baseline (i.e., pre-dam removal) aquatic community data and to assess changes in community composition following dam removal. Monitoring cross-section stations were established to assess changes in bankfull channel geometry, channel substrate composition, and aquatic habitat. Fish, mussel, and snail surveys were conducted to record diversity and qualitative prevalence of taxa within these groups. Anadromous fish survey locations were also established to track the extent of anadromous fish passage within the upstream watershed (Figure 4A, Appendix A). Water quality data (i.e. dissolved oxygen concentrations) within the former Site Impoundment and at a downstream reference area were obtained from North Carolina Division of Water Quality (NCDWQ) Ambient Monitoring Stations (AMS).

Year-3 (2008) Monitoring Results

Re-colonization of rare and protected aquatic species

The two federally endangered species that occur within the Little River sub-basin are the dwarf wedgemussel (*Alasmidonta heterodon*) and Tar spinymussel (*Elliptio steinstansanna*). Although baseline mollusk community data were obtained during pre-removal (baseline) biological surveys in 2005, mollusks will not be sampled again until the fourth year of project monitoring (2009) due to the length of time predicted for this taxonomic group to respond to habitat restoration. Favorable habitat for these mollusk species has developed within much of the former Site Impoundment.

Water quality

AMS data indicate that dissolved oxygen concentrations within the former Site Impoundment generally continued to persist above the established success criteria threshold of 6.0 mg/L. The exceptions were four measurements sampled in July through September of 2007 when dissolved oxygen concentrations sampled at the reference station were below 6.0 mg/L, and one measurement taken in June of 2008, when the oxygen concentration sampled at the reference station was slightly above 6.0 mg/L. The improvement in dissolved oxygen levels is reflected in the removal of a 20 mile reach (stretching downstream from the confluence of the Little River and Little Buffalo Creek) in the most recent draft (2008) of the North Carolina Impaired Waters (303(d)) List. Benthic biotic indices (used as a proxy for water quality) were again lower (more indicative of better water quality) in samples within the former Site Impoundment relative to those from reference samples, indicating continued improvement in water quality. Benthic biotic indices within the former Site Impoundment were also lower during Year-3 monitoring than in the same locations during Baseline (2004) monitoring, further indicating a progressive improvement in water quality. **In summary, water quality monitoring data demonstrate the achievement of project success criteria.**

Improved aquatic community

Benthic data from stations within the former Site Impoundment indicate that the number of EPT (Ephemeroptera [mayflies], Plecoptera [stoneflies], and Trichoptera [caddisflies]) taxa has exceeded the number of EPT taxa from reference samples. The total number of benthic taxa from samples within the former Site Impoundment also exceeded the total number of taxa from reference samples. **In summary, benthic monitoring data has achieved success criteria**. Fish sampling data indicate that fish communities within the former Site Impoundment continue to transition from those associated with lentic conditions (pre-dam removal) to those characteristic of lotic, free-flowing conditions.

Anadromous fish passage

In 2006 (the first year of project monitoring), spawning adults of American shad (*Alosa sapidissima*) were captured in the Little River immediately below Atkinson Mill Dam (Figure 4B, Appendix A), indicating that anadromous fish passage under the crest pool has been achieved. American shad were also captured well above the limits of the former Site Impoundment within Buffalo Creek, indicating that the Lowell Mill Dam removal will likely generate additional SMUs (stream mitigation units) in the watershed pursuant to the reserve success criteria guidelines (see discussion below).

In addition to the above primary criteria, the project has also achieved success in fulfilling reserve success criteria. The Lowell Mill Dam removal project has provided funding to the University of North Carolina at Chapel Hill in support original research by Adam Riggsbee, Ph.D, and to Joshua K. Raabe and Joseph E. Hightower, Ph.D of North Carolina State University. Dr. Riggsbee's research investigates the effects of the dam's removal on nutrient and sediment dynamics as they are transported from the former Site Impoundment. In addition to his published dissertation, Dr. Riggsbee has published three papers (Riggsbee et al. 2007, 2008 and Doyle et al. 2008) and one in revision that detail his research. Mr. Raabe and Dr. Hightower's research involves the installation of a fish weir at the former dam location. The weir was used to observe fish movement patterns to better understand how anadromous fish use habitat in different parts of the Little River. The study results will enable scientists to better predict the potential benefits of fish passage devices (fish ladders) versus complete dam removal. Also, the Lowell Mill Dam project has funded the design and completion of a public park developed at the site of the former mill and dam. This new public facility has been donated to Johnston County for use as a family recreation park.

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1.0 PROJECT BACKGROUND

1.1 Location and Setting

The project location includes the site of the former Lowell Mill Dam and associated mill works at coordinates 35.56N, 78.15W situated within the Little River, approximately 0.3 mile south (downstream) of Interstate Highway 95 (I-95, Exit 105), between the towns of Micro and Kenly (Figure 1, Appendix A). For the purposes of this document, the former dam site and immediate adjacent areas will hereafter be referred to as the "Site."

Approximately 36,875 linear feet of the Little River, Little Buffalo Creek, and an unnamed tributary (Tributary 1) (Figure 2, Appendix A) were impounded by the Lowell Mill Dam. These stream reaches collectively comprise the "Site Impoundment."

The dam served to obstruct the movement of fish and other mobile aquatic organisms and further restricted the upstream dispersal of benthic organisms, which rely on mobile aquatic host species to complete life cycle events. The functional benefit area (FBA) for this restoration project is defined as the maximum extent of the watershed lying upstream of the dam which could serve as anadromous fish spawning habitat. This area includes approximately 204,920 linear feet (38.8 miles) of main stream channel along the Little River, Buffalo Creek, Little Buffalo Creek, and Long Branch in Johnston County (Figure 2, Appendix A). The FBA begins at the Site and extends upstream along these waterways to include relatively free-flowing (unimpeded) tributaries in the watershed. Its upper limit is defined by dams (Atkinson Mill, Lake Wendell) or stream headwaters.

1.2 Restoration Structure and Objectives

The Lowell Mill Dam removal is one of the first stream restoration projects of its kind in North Carolina. The project entailed stream restoration via the removal of Lowell Mill Dam, a run-of-river dam, in which the bankfull channel is impounded but the river valley is typically not flooded, as is often the case with larger storage dams.

Site restoration efforts consisted primarily of the physical removal of the Lowell Mill Dam and the adjacent mill works. Construction activities associated with the removal of the dam were phased in order to minimize impacts to aquatic resources upstream, downstream, and in the immediate vicinity of the Site (see Riggsbee et al. 2007a-d). Furthermore, throughout the dam removal process, numerous construction practices were undertaken to minimize potential impacts to aquatic resources.

The project is expected to generate at least 36,875 Stream Mitigation Units (SMUs) for use by the North Carolina Ecosystem Enhancement Program (EEP) (Table 1). Primary and reserve success criteria are being monitored in accordance with the DRTF guidance. The mitigation ratios have also been derived from the DRTF guidance. Depending on project monitoring results (predominately anadromous fish survey data), up to 48,859 additional SMUs may potentially be generated in accordance with the DRTF guidance (Table 1).

Table 2 displays project mitigation success criteria, the parameters used to evaluate success, and the anticipated results of project monitoring. Project monitoring results are presented in Section 2.0.

Table 1. Potential Stream Mitigation Units (SMUs)[1] Generated by Removal of Lowell Mill Dam

	Channel Restored (feet)	**Mitigation Ratio**	**SMUs**
Primary success criteria:			
1) Re-colonization of rare and endangered aquatic species 2) Improved water quality 3) Improved aquatic community 4) Anadromous fish passage (under crest pool)	36,875 feet of free-flowing river and tributaries **under the crest pool**	1:1	36,875
Reserve success criteria:			
Anadromous fish passage (**above crest pool**)	Up to 204,920 feet of second order or higher, free-flowing tributaries	5:1	40,984
Downstream benefits below the dam	500 feet below dam	1:1	500
Human values 1) Scientific value 2) Human recreation	36,875	Up to 20 percent bonus	7,375
Total potential additional SMUs			48,859
Committed SMUs			**36,875**

[1] Primary success criteria will be monitored to verify and confirm positive changes to each functional criterion as outlined in this report and in the Dam Removal Guidance. Reserve criteria will be monitored for possible augmentation of the primary SMUs.

Table 2. Mitigation Success Criteria Evaluation

	Criterion	Parameter	Anticipated Change/Result
Primary success criteria:	Re-colonization of rare and endangered aquatic species	Presence/absence of rare/endangered individuals	Unknown
		Rare/endangered species habitat	Improvement/expansion
	Improved water quality	Benthic biotic indices	Decrease (= improve)
		AMS dissolved oxygen data	Increase within former Site Impoundment (must be ≥ 6.0 mg/L or consistent with reference station data)
	Improved aquatic community	Ephemeroptera, Plecoptera, and Trichoptera taxa, total number of benthic taxa	Increase (converge with reference station data)
		Fish, Mussel, and Snail community data	Affirm shifts in communities from lentic to lotic character
	Anadromous fish passage (under crest pool)	Presence/absence of spawning adults within or above former Site Impoundment	Presence
Reserve success criteria:	Anadromous fish passage (above crest pool)	Presence/absence of spawning adults above former Site Impoundment within FBA	Presence
	Downstream benefits below dam	Little River bankfull channel within formerly eddied/scoured areas below dam	Narrowing/increased stabilization of channel
	Scientific value	Published research	Successful completion
	Public recreation	Construction of planned on-Site park	Successful completion

1.3 Project History and Background

Table 3. Project Activities and Reporting History: Lowell Mill Dam Restoration Site

Activity Report	**Scheduled Completion**	**Data Collection Complete**	**Actual Completion or Delivery**
Restoration Plan	July 1, 2004	N/A	August 1, 2005
Final Design	July 1, 2004	N/A	August 1, 2005
Construction	January 2006	N/A	January 2006
Temporary S&E mix applied to entire project area	Dec.-Jan. 2006	N/A	Dec.-Jan. 2006
Permanent seed mix applied to reach/segments	January 2006	N/A	January 2006
Installation of trees, shrubs	February 2006	N/A	February 2006
Mitigation Plan	January 15, 2005	N/A	June 30, 2006
Minor repairs made filling small washed out areas	N/A	N/A	N/A
Final Report	N/A	N/A	N/A
Year-1 Vegetation Monitoring	N/A	N/A	N/A
Year-1 Stream Monitoring	August 2006	July 2006	July 2006
Year-2 Vegetation Monitoring	N/A	N/A	N/A
Year-2 Stream Monitoring	August 2007	July 2007	November 2007
Year-3 Vegetation Monitoring	N/A	N/A	N/A
Year-3 Stream Monitoring	August 2008	August 2008	November 2007

1.4 Project Restoration Goals

The primary goal of the Lowell Mill Dam removal is the restoration of formerly impounded reaches of the Little River and affected tributaries to their pre-disturbance, lotic conditions. To demonstrate the achievement of this goal, the affected river and stream reaches have been and will continue to be monitored for successful reestablishment of several functional attributes, which include lotic flow and habitat improvements for aquatic communities that are characteristic of a coastal plain environment. Baseline data were collected in 2005 prior to the removal of the dam and mill works, Year-1 monitoring activities were accomplished in 2006, Year-2 monitoring activities were accomplished in 2007, and Year-3 monitoring activities were accomplished in 2008. Additionally, efforts will be made to confirm that anadromous fish species have been restored to their historical spawning grounds and that vertebrate and invertebrate species favoring lotic habitats, including rare or endangered species, are able to re-colonize these restored habitats. The specific goals of this project are to:

- **Restore approximately 36,875 linear feet of free-flowing river** and stream channels formerly inundated under the spillway crest pool elevation of Lowell Mill Dam.

- **Restore the natural flow** and corresponding sediment transport relationships through and well beyond the approximately 36,875 linear feet of former impoundment.

- **Improve water quality and aquatic communities within impaired (303[d]) rivers** and streams degraded by stagnated flow within the former Site Impoundment. A minimum of 36,875 feet of river and stream channel will be converted from impeded, lentic conditions into restored, lotic streams and rivers supporting a more diverse aquatic community characteristic of pre-impoundment conditions.

- **Restore rare and endangered species habitat** within rivers and streams formerly lost within the Site Impoundment. Twenty documented rare aquatic species will directly benefit from restoration of a continuous, free-flowing river, including dwarf wedgemussel and the only documented populations of Tar River spinymussel in the Neuse River Basin.

- **Restore anadromous fish passage**, foraging, and spawning opportunities within 36,875 linear feet within the former Site Impoundment, as well as an additional 204,920 linear feet of main stem stream and river channels within the FBA above the former Site Impoundment.

- **Provide new academic research and data** regarding the effects of dam removal on aquatic and terrestrial ecosystems.

- **Provide public recreation opportunities**, including the establishment of a park and canoe/kayak launch facilities at the Site.

- **Generate a minimum of 36,875 linear feet of Stream Mitigation Units (SMUs)** for use by the EEP to offset impacts to streams in the specific Neuse River hydrologic unit (see Table 1). Additional SMUs may also be generated for use by the EEP, dependent upon results of post-project monitoring programs.

Table 4. Project Contacts: Lowell Mill Dam Restoration Site

Designer Milone and MacBroom, Inc. (MMI)	307B Falls Street Greenville, SC 29601 (864) 271-9598
Construction Contractor Backwater Environmental, Inc.	P.O. Box 1654 Pittsboro, NC 27312 (919) 523-4375
Planting Contractor Carolina Silvics, Inc.	908 Indian Trail Road Edenton, NC 27932 (252) 482-8491
Seeding Contactor Backwater Environmental, Inc.	P.O. Box 1654 Pittsboro, NC 27312 (919) 523-4375
Seed Mix Sources Mellow Marsh Farm	1312 Woody Store Road Siler City, NC 27344 (919) 742-1200
Nursery Stock Suppliers Mellow Marsh Farm Taylor's Nursery Coastal Plain Conservation Nursery International Paper Supertree Nursery	 1312 Woody Store Road Siler City, NC 27344 (919) 742-1200 3705 New Bern Avenue Raleigh, NC 27610 (919) 231-6161 3067 Conners Drive Edenton, NC 27932 (252) 482-5707 5594 Highway 38 South Blenheim, SC 29516 (800) 222-1290
Ecological Monitors EcoScience: A Division of PBS&J The Catena Group	1101 Haynes Street Suite 101 Raleigh, NC 27604 (919) 828-3433 410-B Millstone Drive Hillsborough, NC 27278
Stream Monitoring POC	Jens Geratz
Vegetation Monitoring POC	N/A (project does not require vegetation monitoring)

Table 5. Project Background: Lowell Mill Dam Restoration Site

Project County	Johnston County, NC
Drainage Area	Approximately 215 square miles
Impervious cover estimate (%)	<10%
Stream Order	4th-order
Physiographic Region	Upper Coastal Plain
Ecoregion (Griffith and Omernik)	Rolling Coastal Plain/Northern Outer Piedmont
Rosgen Classification of As-built	N/A
Cowardin Classification	R2SB3/4
Dominant soil types	N/A (stream restoration project only)
Reference Site ID	N/A
USGS HUC for Project and Reference	03020201
NCDWQ Sub-basin for Project and Reference	03-04-06
NCDWQ classification for Project and Reference	WS-V NSW (Little River and Tributary 1), C NSW (Little Buffalo Creek, Buffalo Creek, and Long Branch)
Any portion of any project segment 303d listed [2004/2006 NC 303(d) List]?	Yes (Little River from confluence with Little Buffalo Creek to 4.2 miles upstream of NC 581)
Any portion of any project segment upstream of a 303d listed segment?	Yes (see above—reach extends downstream of project extents)
Reasons for 303d listing or stressor	Low dissolved oxygen
Percent of project easement fenced	N/A

2.0 PROJECT MONITORING RESULTS

Project monitoring results—discussed below—document Year-3 (2008) monitoring activities. Monitoring stations were established prior to dam removal to collect baseline (pre-dam removal) data (Figure 3, Appendix A). One additional station was added immediately downstream of the former dam in 2006 to evaluate the geomorphic restoration of the channel below the dam under the reserve success criteria (Table 1). Anadromous fish survey locations are displayed on Figure 4A (Appendix A). Pre-removal baseline data (2005), Year-1 monitoring data (2006), Year-2 monitoring data (2007), and Year-3 monitoring data (2008) will be referenced and compared to evaluate improvements in water quality, the aquatic community, re-colonization of rare and endangered species, and anadromous fish passage within the former Site Impoundment.

2.1 Water Quality

2.1.1 Biotic Indices

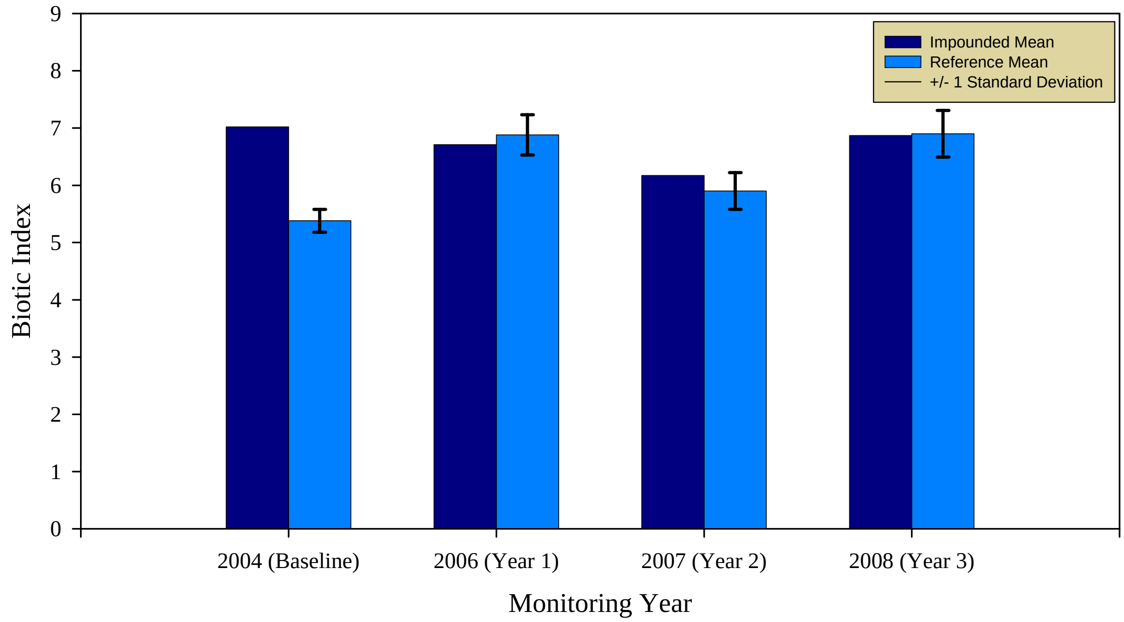
Table 6 displays the biotic index values for pre-removal (performed in 2004), Year-1, Year-2, and Year-3 monitoring. According to the project's Mitigation Plan (Restoration Systems 2006b), success criteria will be achieved when the mean value of the biotic index from benthic stations within the former Site Impoundment falls within one standard deviation of the mean of the same dataset collected at the reference stations by the end of the project monitoring period.

Table 6. Benthic Biotic Indices of Formerly Impounded and Reference Stations

	2004 (Baseline)		2006 (Year-1)		2007 (Year-2)		2008 (Year-3)	
	FORMERLY IMPOUNDED STATIONS	**REFERENCE STATIONS**	**FORMERLY IMPOUNDED STATIONS**	**REFERENCE STATIONS**	**FORMERLY IMPOUNDED STATIONS**	**REFERENCE STATIONS**	**FORMERLY IMPOUNDED STATIONS**	**REFERENCE STATIONS**
	Biotic Index	Biotic Index	Biotic Index	Biotic Index	Biotic Index	Biotic Index	Biotic Index	Biotic Index
High	7.36	5.52	7.71	7.31	7.00	6.47	8.04	7.16
Low	6.72	5.24	6.11	6.56	5.57	5.32	5.89	6.05
Mean	**7.02**	5.38	**6.71**	6.88	**6.17**	5.90	**6.87**	6.75
Median	6.98	5.38	6.57	6.83	6.20	5.91	6.96	6.90
Standard Deviation	0.32	0.20	0.58	0.35	0.43	0.32	0.76	0.41
Standard Deviation of Reference mean **(Success Criterion)**	**5.58**		**7.23**		**6.22**		**7.16**	

Since the mean of the biotic index from the formerly impounded stations (μ=6.87) is within one standard deviation of the reference station (μ=7.16), success in this category may be inferred. The mean of the biotic index from the formerly impounded stations has slightly risen from Year-2 lows (i.e., indicative of a benthic community more tolerant of poorer water quality). Severe drought conditions within Johnston County during benthic sampling contributed to low flow conditions and may have affected benthic macroinvertebrate populations. The North Carolina Drought Management Advisory Council reports that drought conditions of this degree have not been recorded in North Carolina in the 100 years of modern records. Figure 6 (Appendix A) displays drought conditions in Johnston County from fall 2007 to fall 2008. Continued sampling is recommended to ensure that data sets are more reflective of normal ambient conditions without the influence of extraordinary factors such as 100-year droughts. These trends are illustrated in Graph 1.

Graph 1. Mean Biotic Index of Formerly Impounded Stations vs. Mean Biotic Index of Reference Stations with Standard Deviation



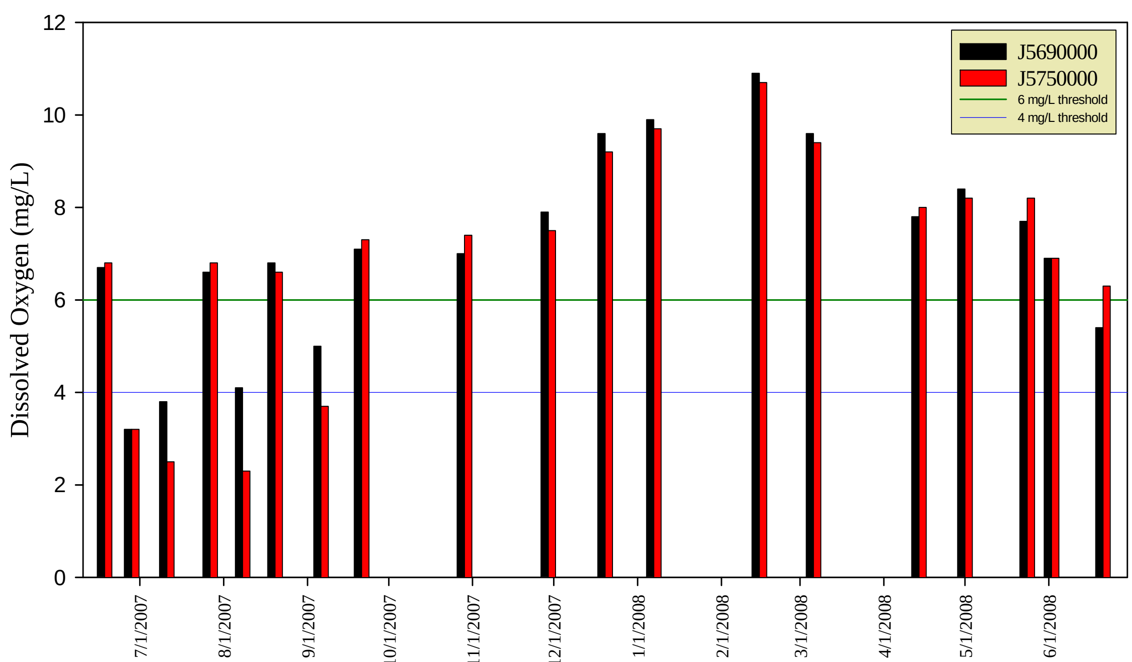
Ambient Monitoring Station Dissolved Oxygen Data

Dissolved oxygen concentrations at a 0.1-meter depth are measured at an Ambient Monitoring Station (AMS) within the former Site Impoundment on the Little River at US 301 (Station ID# J5690000), approximately 1.5 miles upstream of the Site. A reference AMS is located approximately 1.0 miles downstream of the Site on the Little River at State Road (SR) 2339 (Station ID# J5750000). Dissolved oxygen concentrations (mg/L) are measured at least once a month at both stations.

Graph 2 displays measured dissolved oxygen concentrations at both stations from June 18, 2007 to June 21, 2008. Data dating back to February 23, 2004 were included in the 2006 Annual Monitoring Report (AMR) (Restoration Systems 2006a) and data dating back to June 11, 2006 were included in the 2007 AMR (Restoration Systems 2007). As stated in the Mitigation Plan (Restoration Systems 2006b), in order to achieve success criteria, dissolved oxygen concentrations measured within the former Site Impoundment (AMS J5690000) must not dip below 6.0 mg/L unless concentrations are also less than 6.0 mg/L at the reference station (AMS J5750000) within the same sampling timeframe. A dissolved oxygen concentration of 6.0 mg/L is commonly accepted as the threshold below which aquatic organisms are stressed. According to standards outlined in the North Carolina Division of Water Quality (NCDWQ) “Redbook” (NCDWQ 2004), dissolved oxygen concentrations within the former Site Impoundment cannot fall below the minimum NCDWQ standard for Class WS-V waters. The NCDWQ standard is an instantaneous value of no less than 4.0 mg/L (daily average no less than 5.0 mg/L). The standard of 4.0 mg/L is used as a criterion for removal from the 303(d) list. Dissolved oxygen concentrations within the former Site Impoundment fell below 6.0 mg/L for five measurements of the available data. During July, August, and September of 2007, both stations measured concentrations below 6.0 mg/L four times (Graph 2). Success criteria were achieved at these measurements. One measurement in June of 2008 recorded station AMS J5690000 slightly under the 6.0 mg/L threshold while reference station AMS J5750000 was slightly over the threshold. This measurement fails to meet success criteria. Data will continue to be monitored to determine whether this measurement was an anomaly or a trend. The 4.0 mg/L success criteria was met as dissolved oxygen concentrations for both stations dipped below the 4.0 mg/L threshold twice in July 2007, but have since persisted above the threshold.

The 2006 North Carolina Impaired Waters (303(d)) List (NCDWQ 2006) featured a section of the Little River beginning at the confluence of Little Buffalo Creek and extending 20 miles downstream to 4.2 miles upstream of NC 581. The segment was listed as impaired due to failing to meet the 4.0 mg/L threshold consistently. However, the 2008 Draft 303(d) List does not include this segment. A conversation with Cam McNutt of **NCDWQ confirmed that measurements taken since the dam removal have exceeded the threshold for success, and this portion of the Little River has been delisted.**

Graph 2. AMS Dissolved Oxygen Concentrations*



* The green line highlights a dissolved oxygen concentration of 6.0 mg/L, which must be exceeded by AMS #J5690000 in order to achieve success criteria (unless dissolved oxygen concentrations at reference AMS #J5750000 are also below 6.0 mg/L within the same sampling timeframe). The blue line highlights a dissolved oxygen concentration of 4.0 mg/L, which must be exceeded by AMS #J5690000 in order to achieve success criteria according to NCDWQ for WS-V streams (unless dissolved oxygen concentrations at reference AMS #J5750000 are also below 4.0 mg/L within the same sampling timeframe).

2.2 Aquatic Communities

2.2.1 Benthic Macroinvertebrates

Tables 7 and 8 provide baseline (2004), Year-1, Year-2, and Year-3 benthic macroinvertebrate data for both formerly impounded and reference stations. Since the mean numbers of total taxa and EPT richness from the formerly impounded stations are within one standard deviation of the reference station means, success criteria is being achieved. Graph 3 displays the measurements of total taxa and Graph 4 displays EPT richness since 2004 baseline monitoring. Similar to the trends displayed by this year's biotic index data, Year-3 numbers for total taxa and EPT richness at formerly impounded and reference stations have decreased since their Year-2 highs. Benthic macronivertebrate data is provided in Appendix B. Data in Appendix B are based on laboratory identifications of benthic macroinvertebrate taxa by Pennington and Associates, Inc. (P&A) of Cookeville, Tennessee. P&A is a North Carolina Division of Water Quality (NCDWQ)-certified benthic identification laboratory.

Table 7. Total Number of Benthic MacroinvertebrateTaxa

	2004 (Baseline)		2006 (Year-1)		2007 (Year-2)		2008 (Year-3)	
	FORMERLY IMPOUNDED STATIONS	**REFERENCE STATIONS**	**FORMERLY IMPOUNDED STATIONS**	**REFERENCE STATIONS**	**FORMERLY IMPOUNDED STATIONS**	**REFERENCE STATIONS**	**FORMERLY IMPOUNDED STATIONS**	**REFERENCE STATIONS**
	Total Taxa	Total Taxa	Total Taxa	Total Taxa	Total Taxa	Total Taxa	Total Taxa	Total Taxa
High	45.00	57.00	90.00	43.00	77.00	74.00	65.00	53.00
Low	25.00	56.00	33.00	35.00	55.00	37.00	19.00	27.00
Mean	37.33	56.50	**41.86**	39.75	**62.14**	55.50	**45.57**	43.50
Median	42.00	56.50	37.00	40.50	59.00	55.50	47.00	47.00
Standard Deviation	10.79	0.71	10.33	3.40	7.61	15.16	14.65	11.82
Standard Deviation of Reference mean **(Success Criterion)**	**55.79**		**36.35**		**40.34**		**31.68**	

Graph 3. Mean Total Taxa of Formerly Impounded Stations vs. Mean Total Taxa of Reference Stations with Standard Deviation

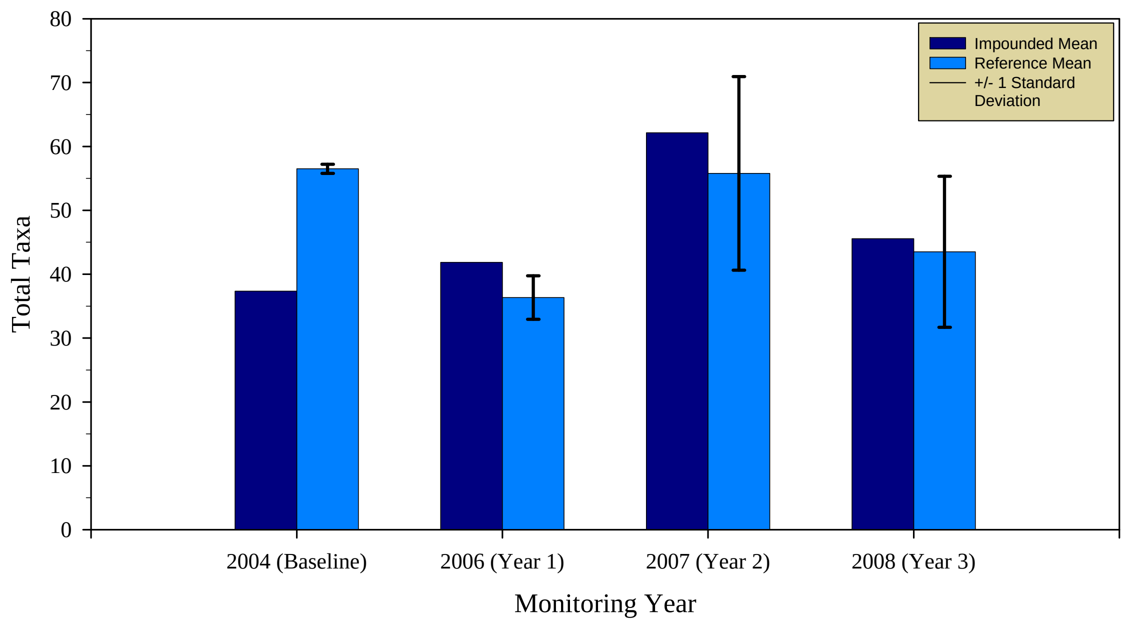
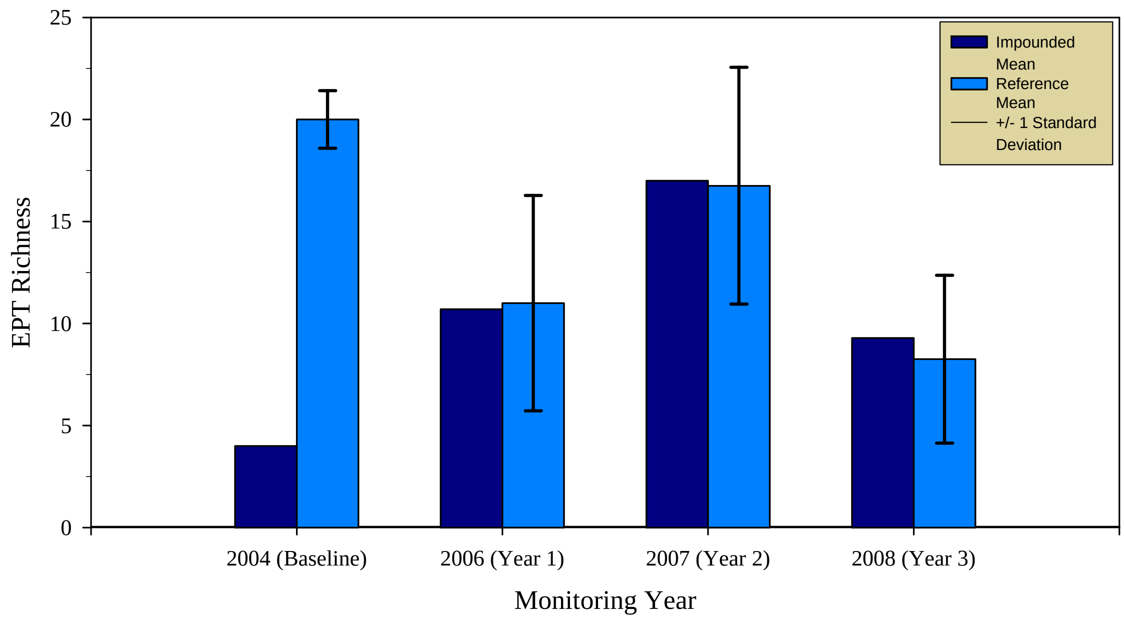


Table 8. EPT Richness

	2004 (Baseline)		2006 (Year-1)		2007 (Year-2)		2008 (Year-3)	
	FORMERLY IMPOUNDED STATIONS	**REFERENCE STATIONS**	**FORMERLY IMPOUNDED STATIONS**	**REFERENCE STATIONS**	**FORMERLY IMPOUNDED STATIONS**	**REFERENCE STATIONS**	**FORMERLY IMPOUNDED STATIONS**	**REFERENCE STATIONS**
	EPT Richness	EPT Richness	EPT Richness	EPT Richness	EPT Richness	EPT Richness	EPT Richness	EPT Richness
High	6.00	21.00	21.00	19.00	26.00	23.00	16.00	13.00
Low	0.00	19.00	0.00	6.00	5.00	9.00	1.00	3.00
Mean	4.00	20.00	**10.70**	11.00	**17.00**	16.75	**9.29**	8.25
Median	6.00	20.00	11.00	9.50	16.00	13.00	11.00	8.50
Standard Deviation	3.46	1.41	6.37	5.28	6.88	5.80	4.64	4.11
Standard Deviation of Reference mean **(Success Criterion)**	**18.59**		**5.72**		**10.95**		**4.25**	

Graph 4. Mean EPT Richness of Formerly Impounded Stations vs. Mean EPT Richness of Reference Stations with Standard Deviation



2.2.2 Fish

Year-3 fish sampling was performed by The Catena Group (TCG). Sampling was performed at stations displayed on Figure 3 (Appendix A). TCG's report summarizing fish sampling is located in Appendix C.

Data indicate that the former Site Impoundment fish communities are continuing to transition from those characteristic of impounded, lentic conditions to lotic, free-flowing conditions.

Qualitative observations during aquatic surveys by TCG revealed that habitat for fish is continuing to transition from lentic to lotic conditions in direct response to dam removal. As a result of this improvement, sampling found an increase in the average North Carolina Index of Biotic Integrity score from 46 in Year-1 to 48.7 in Year-3. This year's sampling also found an overall increase in species richness. For additional information, please consult TCG's report (Appendix C).

2.2.3 Anadromous Fish

Year-2 sampling focused on anadromous fish surveys, and was performed in the spring of 2007 by TCG. Figure 4A (Appendix A) provides anadromous fish survey locations for Year-2 monitoring. The confirmed presence of American shad (*Alosa sapidissima*) was documented in the Year-2 Annual Monitoring Report. Figure 4B (Appendix A) displays the confirmed presence of American shad within the FBA.

2.2.4 Mollusks

Mussel, snail, and clam sampling data will be used to evaluate success for the aquatic community and threatened and endangered aquatic species criteria. Mollusks were sampled at the fish, mussel, and snail survey locations depicted on Figure 3 (Appendix A) by TCG preceding dam removal to obtain baseline community data in 2005. Year-3 mussel sampling showed declines in recovery rates of mussels downstream of the dam removal. TCG attributes much of the declines to an influx of sediment caused by the dam removal and low river flows caused by extreme drought conditions in 2007 and early 2008 (Figure 6). The losses measured by Year-3 sampling are not expected to have long-term adverse effects on the Little River's overall mussel population because of an improvement in lotic conditions and healthy mussel populations elsewhere in the river. For additional information, please consult TCG's report (Appendix C).

2.2.5 Habitat Assessment

2.2.5.1 Channel Cross-Sections

Twenty-four (24) cross-section stations have been established within the former Site Impoundment and at four reference locations to assess bankfull channel stability following dam removal. Cross-section locations are displayed on Figure 3 (Appendix A). Baseline (2005), Year-1, Year-2, and Year-3 cross-sectional surveys are displayed on Figures 5A-5C (Appendix A). Table 9 displays baseline, Year-1, Year-2, and Year-3 bankfull channel geometry, including bankfull cross-sectional area (Abkf), bankfull width (Wbkf), maximum bankfull depth (Dmax), mean bankfull depth (dbkf), and width-to-depth ratio (width:depth).

Since the submittal of last year's AMR, one high-flow event occurred on April 6th and 7th , 2008, with a discharge of 1430 cubic feet per second (cfs), as recorded at the United States Geologic Survey (USGS) Princeton gage (02088500). According to recurrence interval analysis conducted by EcoScience (using the annual maximum series taken from gage 02088500), a discharge of the magnitude of this event occurs within the restoration reach approximately every 1.2 years. A return interval between 1.2 and 1.4 years is assumed to represent bankfull discharge and thus is responsible for the shape and size of channels (Wolman and Miller 1960, Rosgen 1994).

Therefore, the aforementioned events with the approximate 1.2-year return interval represent channel forming flows.

In general, bankfull channel parameters were largely unchanged from Year-2 conditions in the second monitoring year. Based on this observation and the previously described recurrence interval analysis, channel geometry within the former site impoundment is likely stable. The following should be noted: 1) cross-section 20, which was installed approximately 200 feet downstream of the former Lowell Mill dam on the Little River, was established following dam removal. Thus, there is no baseline bankfull channel geometry data for this station; and 2) cross-section 16, located just upstream of the former dam site, was impacted during dam removal activities. Hence the discrepancies in cross-sectional dimensions and bankfull channel geometry between baseline and Year-1 monitoring data. The bankfull channel parameters for cross-section 16 appear to have stabilized in subsequent monitoring years.

2.2.5.2 Sediment Class Size Distribution

Sediment grain size distributions were assessed at each channel cross-section location (Figure 3, Appendix A). Table 10 displays baseline, Year-1, Year-2, and Year-3 sediment grain size distributions for each cross-section.

Sediment grain size classes are defined as follows (per Wolman 1954):

Particle Size	Size Class
<2 mm	Sand/silt
2-8 mm	Fine gravel
8-16 mm	Medium gravel
16-32 mm	Coarse gravel
32-64 mm	Very coarse gravel
64-128 mm	Small cobble
128-256 mm	Large cobble

Table 9. Cross-section bankfull channel geometry

Station	2005 (Baseline)					2006 (Year 1)					2007 (Year 2)					2008 (Year 3)				
	Abkf (ft.)	Wbkf (ft.)	Dmax (ft.)	dbkf (ft.)	width: depth	Abkf (ft.)	Wbkf (ft.)	Dmax (ft.)	dbkf (ft.)	width: depth	Abkf (ft.)	Wbkf (ft.)	Dmax (ft.)	dbkf (ft.)	width: depth	Abkf (ft.)	Wbkf (ft.)	Dmax (ft.)	dbkf (ft.)	width: depth
1	547.3	84.5	9.1	6.5	13	583.1	84	9.5	6.9	12.2	594.5	83.8	9.8	7.1	11.8	604.09	84.46	9.84	7.152	11.809
2	614.3	88.2	9.4	7	12.6	579.3	85.5	8.6	6.8	12.6	599.4	87.9	8.8	6.8	12.9	606.92	86.21	8.75	7.04	12.246
3	304.6	52.3	6.8	5.8	9	308.6	52.3	6.7	5.9	8.9	311	52.1	6.8	6	8.7	314.94	54.34	6.74	5.796	9.3759
4	420.1	72.2	9	5.8	12.4	432.8	63.7	9.5	6.8	9.4	437.8	73.7	9	5.9	12.4	424.05	63.55	8.94	6.673	9.5239
5	344.2	62.9	6.5	5.5	11.4	326.7	62.8	6.5	5.2	12.1	326.5	63	6.3	5.2	12.1	334.39	62.96	6.46	5.311	11.854
6	425.8	71.6	8.5	5.9	12.1	403.4	71.3	8.1	5.7	12.5	405.4	71.7	8.2	5.7	12.7	413.03	71.14	8.04	5.806	12.253
7	618	91	9.4	6.8	13.4	607.5	89.1	9.1	6.8	13.1	627.5	92.2	9.6	6.8	13.6	622.58	90.4	9.01	6.887	13.126
8	514	78.6	10.5	6.5	12.1	506.2	77	10.2	6.6	11.7	497.8	81.6	10.1	6.1	13.4	509.07	82.34	10.24	6.183	13.318
9	615.2	72.1	11.4	8.5	8.5	517	67.7	10	7.6	8.9	591.7	72.8	11	8.1	8.9	600.74	74.79	11.02	8.032	9.3111
10	467.5	67.4	10.1	6.9	9.8	459.9	67.4	10.1	6.8	9.9	457	67.7	10	6.7	10	487.55	69.81	10.05	6.984	9.9958
11	612.5	121.8	9.2	5	24.4	605.5	122.8	9.3	4.9	25.1	560	127.7	8.2	4.4	29.1	593.6	132.79	8.25	4.47	29.705
12	848.2	111.5	9.9	7.6	14.7	781	111.6	9.4	7	15.9	719.4	111.1	8.9	6.5	17.2	710.53	110.81	8.77	6.412	17.281
13	666.7	89.7	11.1	7.4	12.1	645.8	88.6	10.2	7.3	12.1	676.4	87.9	11	7.7	11.4	679.78	86.25	10.87	7.882	10.943
14	786.9	105.6	10.6	7.4	14.3	780.3	104.9	10.4	7.4	14.2	780.4	105	10	7.4	14.1	775.53	107.53	9.92	7.212	14.909
15	940.5	114.8	12.3	8.2	14	915.5	113.9	12	8	14.2	940.1	121.4	12.4	7.7	15.7	930.25	115.19	12.14	8.076	14.264
16*	517.7	81.2	11	6.4	12.7	691.2	105.2	9.9	6.6	15.9	711.4	109.5	10.3	6.5	16.8	712.92	109.01	9.83	6.54	16.668
17	82.6	28.8	3.9	2.9	9.9	83.7	29.4	3.8	2.8	10.5	82.9	32	3.8	2.6	12.3	84.31	31.7	3.68	2.66	11.919
18	36.2	27.8	3.3	1.3	21.4	33.9	24.3	3	1.4	17.4	40.5	32.6	3.2	1.2	26.2	73.3	31.44	3.38	2.331	13.485
19	5.6	10.7	1	0.5	21.4	4.5	11.7	0.5	0.4	29.3	4	11	1.2	0.4	30.7	4.67	8.66	1.23	0.539	16.059
20	Cross-section not established in 2005					809.5	119.7	9.1	6.8	17.6	883.9	122.1	9.2	7.2	16.9	885.83	123.86	9.13	7.152	17.319
Reference 1	261.8	48.9	6.1	5.4	9.1	255.2	48.9	5.8	5.2	9.4	259.7	49.1	5.9	5.3	9.3	255.04	49.87	5.79	5.114	9.7515
Reference 2	368.5	67.5	6.8	5.5	12.3	364.8	66.3	7.5	5.5	12.1	347.9	66.3	6.9	5.2	12.6	352.72	67.51	6.91	5.225	12.921
Reference 3	419	66	8.6	6.4	10.3	403.3	62.4	8.6	6.5	9.6	400.9	65.8	8.4	6.1	10.8	405.6	66.46	8.33	6.103	10.89
Reference 4	582.1	80.2	8.6	7.7	10.4	580.3	80.3	9.3	7.2	11.2	570.4	80	8.5	7.1	11.2	571.66	80.68	8.31	7.086	11.387

**Cross-section 16 was disturbed during dam removal activities; hence, the large discrepancies between baseline and Year-1 data.*

Table 10: Sediment class size distribution

Station	Baseline (2005)				Year 1 (2006)				Year 2 (2007)				Year 3 (2008)			
	d16	d50	d84	d100	d16	d50	d84	d100	d16	d50	d84	d100	d16	d50	d84	d100
1	<2 mm	<2 mm	<2 mm	22-32 mm	<2 mm	<2 mm	<2 mm	16-22 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	Bedrock
2	<2 mm	<2 mm	<2 mm	11-16 mm	<2 mm	<2 mm	<2 mm	4-8 mm	<2 mm	<2 mm	<2 mm	16-22 mm	<2 mm	<2 mm	11-16 mm	22-32 mm
3*	<2 mm	<2 mm	<2 mm	22-32 mm	<2 mm	8-11 mm	22-32 mm	22-32 mm	<2 mm	<2 mm	11-16 mm	Bedrock	<2 mm	4-8 mm	53-64 mm	Bedrock
4*	<2 mm	<2 mm	11-16 mm	22-32 mm	<2 mm	<2 mm	<2 mm	2-4 mm	<2 mm	<2 mm	32-53 mm	Bedrock	<2 mm	4-8 mm	53-64 mm	Bedrock
5	<2 mm	<2 mm	<2 mm	4-8 mm	<2 mm	4-8 mm	22-32 mm	32-53 mm	11-16 mm	16-22 mm	32-53 mm	64-90 mm	<2 mm	11-16 mm	22-32 mm	180-256 mm
6	<2 mm	<2 mm	<2 mm	4-8 mm	<2 mm	<2 mm	<2 mm	4-8 mm	<2 mm	<2 mm	<2 mm	22-32 mm	<2 mm	<2 mm	<2 mm	<2 mm
7	<2 mm	<2 mm	2-4 mm	22-32 mm	<2 mm	<2 mm	4-8 mm	22-32 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	4-8 mm	11-16 mm
8	<2 mm	<2 mm	32-53 mm	32-53 mm	<2 mm	<2 mm	<2 mm	22-32 mm	<2 mm	<2 mm	16-22 mm	64-90 mm	<2 mm	<2 mm	22-32 mm	Bedrock
9	<2 mm	<2 mm	<2 mm	32-53 mm	<2 mm	2-4 mm	22-32 mm	22-32 mm	<2 mm	<2 mm	53-64 mm	Bedrock	<2 mm	11-16 mm	22-32 mm	Bedrock
10*	<2 mm	<2 mm	22-32 mm	32-53 mm	2-4 mm	2-4 mm	22-32 mm	32-53 mm	<2 mm	<2 mm	<2 mm	Bedrock	<2 mm	<2 mm	53-64 mm	Bedrock
11	<2 mm	<2 mm	<2 mm	2-4 mm	<2 mm	<2 mm	<2 mm	4-8 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	2-4 mm	11-16 mm
12	<2 mm	<2 mm	4-8 mm	22-32 mm	<2 mm	<2 mm	4-8 mm	22-32 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	4-8 mm	Bedrock
13	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	4-8 mm	4-8 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	53-64 mm
14	<2 mm	<2 mm	<2 mm	4-8 mm	<2 mm	<2 mm	4-8 mm	8-11 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
15	<2 mm	<2 mm	<2 mm	11-16 mm	<2 mm	<2 mm	8-11 mm	64-90 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
16	<2 mm	22-32 mm	32-53 mm	32-53 mm	<2 mm	8-11 mm	16-22 mm	64-90 mm	<2 mm	8-11 mm	53-64 mm	90-128 mm	<2 mm	<2 mm	22-32 mm	180-256 mm
17	<2 mm	<2 mm	<2 mm	<2 mm	4-8 mm	11-16 mm	16-22 mm	32-53 mm	8-11 mm	16-22 mm	32-53 mm	53-64 mm	8-11 mm	11-16 mm	22-32 mm	53-64 mm
18	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	8-11 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
19	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
20	Cross-section not established in 2005				<2 mm	<2 mm	4-8 mm	16-22 mm	<2 mm	<2 mm	4-8 mm	22-32 mm	<2 mm	<2 mm	4-8 mm	90-128 mm
Reference 1	<2 mm	11-16 mm	22-32 mm	32-53 mm	4-8 mm	16-22 mm	32-53 mm	128-180 mm	<2 mm	<2 mm	22-32 mm	64-90 mm	<2 mm	<2 mm	22-32 mm	90-128 mm
Reference 2	<2 mm	<2 mm	<2 mm	4-8 mm	<2 mm	<2 mm	<2 mm	8-11 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
Reference 3*	32-53 mm	53-64 mm	53-64 mm	53-64 mm	53-64 mm	53-64 mm	53-64 mm	53-64 mm	<2 mm	4-8 mm	22-32 mm	90-128 mm	<2 mm	32-53 mm	180-256 mm	Bedrock
Reference 4*	<2 mm	32-53 mm	32-53 mm	32-53 mm	4-8 mm	32-53 mm	53-64 mm	53-64 mm	<2 mm	11-16 mm	90-128 mm	Bedrock	<2 mm	<2 mm	22-32 mm	90-128 mm

**Station underlain by bedrock—sediment analysis reflects the distribution of the sediment veneer overlaying the channel bed.*

During baseline and Year-1 monitoring, weighted sieve analyses (using Rosgen [1994] methodology for performing bar samples) were performed to assess sediment grain size distributions of monitoring stations with water depths exceeding 3 feet, where a ponar dredge was used to collect sediment samples (see Mitigation Plan [Restoration Systems 2006b] for sampling methodology details). For water depths less than 3 feet (wadeable areas), 100-count pebble counts were performed consistent with the Wolman method (Wolman 1954). Since the sieve analyses provided substrate composition data based on sieve size, the sediment class sizes displayed on Table 10 reflect the sieve sizes that the particular grain size falls within (e.g., at Station 5 in 2006, the d50 occurred between the 4 mm and 8mm sieve sizes). In Year-2 and Year-3, drought conditions eliminated the need for ponar dredge sampling, and thus only 100-count pebble counts were performed at each monitoring section.

The d50 (median particle size) increased during the third year of project monitoring from the first year conditions at Stations 3, 4, 9, and Reference 3. The d50 decreased during the second year of monitoring from the first year conditions at Stations 5, 16, 17, and Reference 4. Stations 3, 4, Reference 3, and Reference 4 are underlain by bedrock. At these stations, sediment size class distributions reflect the grain size classes of the sediment veneer overlaying the channel bed. As stated in the project's Mitigation Plan (Restoration Systems 2006b), substrate within the former Site Impoundment is expected to coarsen over time. However, the duration of time required for this change to occur may eclipse the five-year project monitoring period, and some stations may remain in a state of flux for the length of the monitoring period while sediment from the former Site Impoundment is being flushed out. Thus, project success evaluation is not contingent upon changes in channel substrate size class.

2.2.5.3 Habitat Assessment Form Scores

NCDWQ Habitat Assessment Forms were completed at each cross-section station to evaluate the quality and extent of aquatic habitat. Table 11 displays the NCDWQ Habitat Assessment Form scores for each cross-section station. A blank NCDWQ Habitat Assessment Form has been included in Appendix D for reference. The mean scores of formerly impounded stations have increased for the third year following dam removal and the subsequent establishment of lotic flow conditions. The mean score for formerly impounded stations increased from 48.3 in 2005, to 56.2 in 2006, to 57.1 in 2007, and to 60.8 in 2008. The mean score for reference stations increased slightly to 74.5 in 2008 from a score of 72.8 in 2007, 77.5 in 2006, and 74.8 in 2005. The decrease in score in 2007 could mainly be attributed to the loss of instream habitat at Reference 1 as a result of heavy flow events transporting logs, sticks, and leafpacks downstream of the station's vicinity, and to an increase of sediment in the substrate as illustrated by a decreased d50 (as shown in Table 10).

Table 11: NCDWQ Habitat Assessment Form Scores

Baseline (2005)

Station	Channel Modification	Instream Habitat	Bottom Substrate	Pools	Riffles	Bank Stability	Light Penetration	Riparian Zone	TOTAL SCORE
XS-1	4	12	3	4	10	12	7	8	**60**
XS-2	4	10	3	8	0	12	2	10	**49**
XS-3	5	11	3	8	3	12	7	8	**57**
XS-4	5	11	3	8	3	12	7	8	**57**
XS-5	5	12	2	8	10	12	7	9	**65**
XS-6	4	11	3	8	0	12	7	10	**55**
XS-7	4	11	3	8	7	12	2	9	**56**
XS-8	5	11	2	8	0	12	7	9	**54**
XS-9	4	11	2	4	3	12	7	10	**53**
XS-10	4	11	2	0	0	12	7	10	**46**
XS-11	4	11	1	0	0	12	7	10	**45**
XS-12	4	11	1	0	0	12	2	10	**40**
XS-13	4	11	1	0	0	10	2	9	**37**
XS-14	4	11	3	0	0	11	2	8	**39**
XS-15	4	10	3	0	0	10	2	7	**36**
XS-16	5	10	3	0	0	11	7	6	**42**
XS-17	5	11	2	0	0	14	7	10	**49**
XS-18	5	10	1	0	0	14	7	10	**47**
XS-19	5	10	1	0	0	4	0	10	**30**
MEAN	**4.4**	**10.8**	**2.2**	**3.4**	**1.9**	**11.5**	**5.1**	**9.0**	**48.3**
REF-1	4	11	8	10	14	12	7	9	**75**
REF-2	4	11	3	8	10	12	7	9	**64**
REF-3	5	11	14	10	14	11	7	8	**80**
REF-4	4	11	14	8	14	12	7	10	**80**
MEAN	**4.3**	**11.0**	**9.8**	**9.0**	**13.0**	**11.8**	**7.0**	**9.0**	**74.8**

Year 1 (2006)

Station	Channel Modification	Instream Habitat	Bottom Substrate	Pools	Riffles	Bank Stability	Light Penetration	Riparian Zone	TOTAL SCORE
XS-1	4	7	3	10	3	12	7	8	**54**
XS-2	4	11	3	6	3	12	2	10	**51**
XS-3	5	11	8	8	3	14	7	8	**64**
XS-4	5	12	3	8	0	13	7	8	**56**
XS-5	5	14	8	8	3	12	7	9	**66**
XS-6	4	5	3	6	7	14	7	10	**56**
XS-7	4	10	3	6	7	12	2	9	**53**
XS-8	5	15	3	6	7	12	7	9	**64**
XS-9	4	15	1	6	0	12	7	10	**55**
XS-10	4	12	1	8	0	10	7	10	**52**
XS-11	4	9	3	4	7	12	7	10	**56**
XS-12	4	14	3	6	7	12	2	10	**58**
XS-13	4	10	3	6	10	12	2	9	**56**
XS-14	4	14	3	6	3	12	2	8	**52**
XS-15	4	11	8	8	7	14	2	7	**61**
XS-16	5	15	4	4	7	11	7	6	**59**
XS-17	5	11	8	6	3	13	7	10	**63**
XS-18	5	15	1	4	3	14	7	10	**59**
XS-19	5	5	1	6	7	4	0	10	**38**
XS-20*	4	11	3	4	7	12	2	8	**51**
MEAN	**4.4**	**11.4**	**3.7**	**6.3**	**4.7**	**12.0**	**4.9**	**9.0**	**56.2**
REF-1	4	12	12	8	14	12	7	9	**78**
REF-2	4	11	3	8	10	12	7	9	**64**
REF-3	5	15	11	8	14	14	7	8	**82**
REF-4	4	15	14	8	14	14	7	10	**86**
MEAN	**4.3**	**13.3**	**10**	**8**	**13**	**13**	**7**	**9**	**77.5**

Year 2 (2007)

Station	Channel Modification	Instream Habitat	Bottom Substrate	Pools	Riffles	Bank Stability	Light Penetration	Riparian Zone	TOTAL SCORE
XS-1	5	6	3	10	3	12	7	6	**52**
XS-2	5	6	3	6	3	14	7	10	**54**
XS-3	5	6	3	8	3	12	7	10	**54**
XS-4	5	7	3	8	0	12	7	9	**51**
XS-5	5	8	8	8	3	12	10	10	**64**
XS-6	4	6	3	6	7	14	2	10	**52**
XS-7	5	6	3	6	7	12	7	9	**55**
XS-8	5	10	3	6	7	14	7	10	**62**
XS-9	5	11	3	6	0	12	7	10	**54**
XS-10	4	5	3	8	0	12	7	9	**48**
XS-11	5	6	1	4	7	14	2	10	**49**
XS-12	5	6	1	6	7	14	7	10	**56**
XS-13	5	14	3	6	10	13	7	8	**66**
XS-14	5	18	3	6	3	14	7	9	**65**
XS-15	5	16	3	8	7	14	7	10	**70**
XS-16	4	16	6	4	7	14	2	4	**57**
XS-17	5	19	8	6	3	12	10	10	**73**
XS-18	5	6	1	4	3	14	10	10	**53**
XS-19	5	17	1	6	7	14	0	10	**60**
XS-20*	5	7	3	4	7	14	2	4	**46**
MEAN	**4.9**	**9.8**	**3.3**	**6.3**	**4.7**	**13.2**	**6.1**	**8.9**	**57.1**
REF-1	5	6	3	8	14	12	7	8	**63**
REF-2	5	11	3	8	10	12	7	8	**64**
REF-3	5	16	11	8	14	11	10	7	**82**
REF-4	5	15	11	8	14	12	7	10	**82**
MEAN	**4.3**	**13.3**	**10**	**8**	**13**	**13**	**7**	**9**	**72.8**

Year 3 (2008)

Station	Channel Modification	Instream Habitat	Bottom Substrate	Pools	Riffles	Bank Stability	Light Penetration	Riparian Zone	TOTAL SCORE
XS-1	5	12	3	10	10	13	7	7	**67**
XS-2	5	7	3	6	3	13	7	10	**54**
XS-3	5	16	4	8	3	12	7	10	**65**
XS-4	5	11	4	8	3	12	7	9	**59**
XS-5	5	20	8	8	12	12	10	10	**85**
XS-6	5	11	1	6	3	14	2	10	**52**
XS-7	4	11	3	8	7	12	2	10	**57**
XS-8	5	10	3	8	0	12	7	10	**55**
XS-9	4	15	4	6	0	12	7	10	**58**
XS-10	4	10	4	8	0	12	7	9	**54**
XS-11	5	6	3	4	7	14	2	10	**51**
XS-12	5	15	1	6	7	13	7	10	**64**
XS-13	5	14	3	6	10	14	7	8	**67**
XS-14	5	14	3	6	10	14	7	8	**67**
XS-15	5	15	3	4	10	14	7	10	**68**
XS-16	5	16	3	4	7	14	2	6	**57**
XS-17	5	19	8	6	3	12	10	10	**73**
XS-18	5	10	1	4	3	14	10	10	**57**
XS-19	5	14	1	6	0	14	0	10	**50**
XS-20*	5	15	3	4	7	12	2	8	**56**
MEAN	**4.9**	**13.1**	**3.3**	**6.3**	**5.3**	**13.0**	**5.9**	**9.3**	**60.8**
REF-1	5	11	4	10	14	12	10	9	**75**
REF-2	5	12	3	8	10	7	10	9	**64**
REF-3	5	16	12	10	14	12	7	8	**84**
REF-4	5	11	8	8	14	12	7	10	**75**
MEAN	**5.0**	**12.5**	**6.8**	**9.0**	**13.0**	**10.8**	**8.5**	**9.0**	**74.5**

*Cross-section 20 was not established until 2006

2.2.5.4 Photography and Videography

As discussed in the project's Mitigation Plan (Restoration Systems 2006b), photography and videography were conducted during baseline, Year-1, and Year-2 monitoring data collection to assess qualitative changes in channel cross-sections and in-stream habitat. Monitoring photographs and videos have been included on a data compact disc in Appendix E.

Cross-Section 15 on the Little River. Note the establishing vegetation on the far bank.

Cross-Section 19 on an unnamed tributary to Little River. This reach was formerly inundated, but now supports emergent vegetation.

Fish weir for scientific research at the former dam location

2.3 Rare and Protected Species

Two federally endangered species have been documented in the Little River sub-basin: the dwarf wedgemussel (*Alasmidonta heterodon*) and Tar spinymussel (*Elliptio steinstansanna*). Both of these species are mollusks. As discussed in Section 2.2.4 ("Mollusks"), mollusks will be sampled during the fourth year of project monitoring. Favorable habitat (lotic flow conditions with gradually coarsening substrate) for these mollusk species has developed within much of the former Site Impoundment (see Appendix C). The bull chub (*Nocomis raneyi*), listed on the state watch list, was found during fish sampling (see Appendix C).

2.4 Bonus Criteria

2.4.1 Scientific Research

The former Site Impoundment was subjected to a study by University of North Carolina at Chapel Hill scientist Adam Riggsbee, Ph.D. (Riggsbee 2006, 2007a-d). Sediment accumulated for many decades within the former Site Impoundment before the dam's removal. Dr. Riggsbee's study investigated the flushing of these sediments and associated nutrients and organic materials as they were routed through the downstream channel. Additionally, the study assessesed physical and biological controls on nitrogen and phosphorous leaching from wetland sediments exposed by dam removal. Dr. Riggsbee has also given numerous oral presentations at professional conferences regarding his research.

From March to May of 2007, a study investigating fish passage within and upstream of the former Site Impoundment was conducted at the former dam location. During these months, Joshua K. Raabe and Dr. Joseph E. Hightower of North Carolina State University installed a fish weir in the former dam location to capture, quantify, and observe the movement of fish in order to better understand how anadromous fish use habitat in different parts of the Little River. The study results will enable scientists to better predict the potential benefits of fish passage (fish ladders) versus complete dam removal. A report of the study's findings (Raabe 2008) is included in Appendix F.

3.0 REFERENCES

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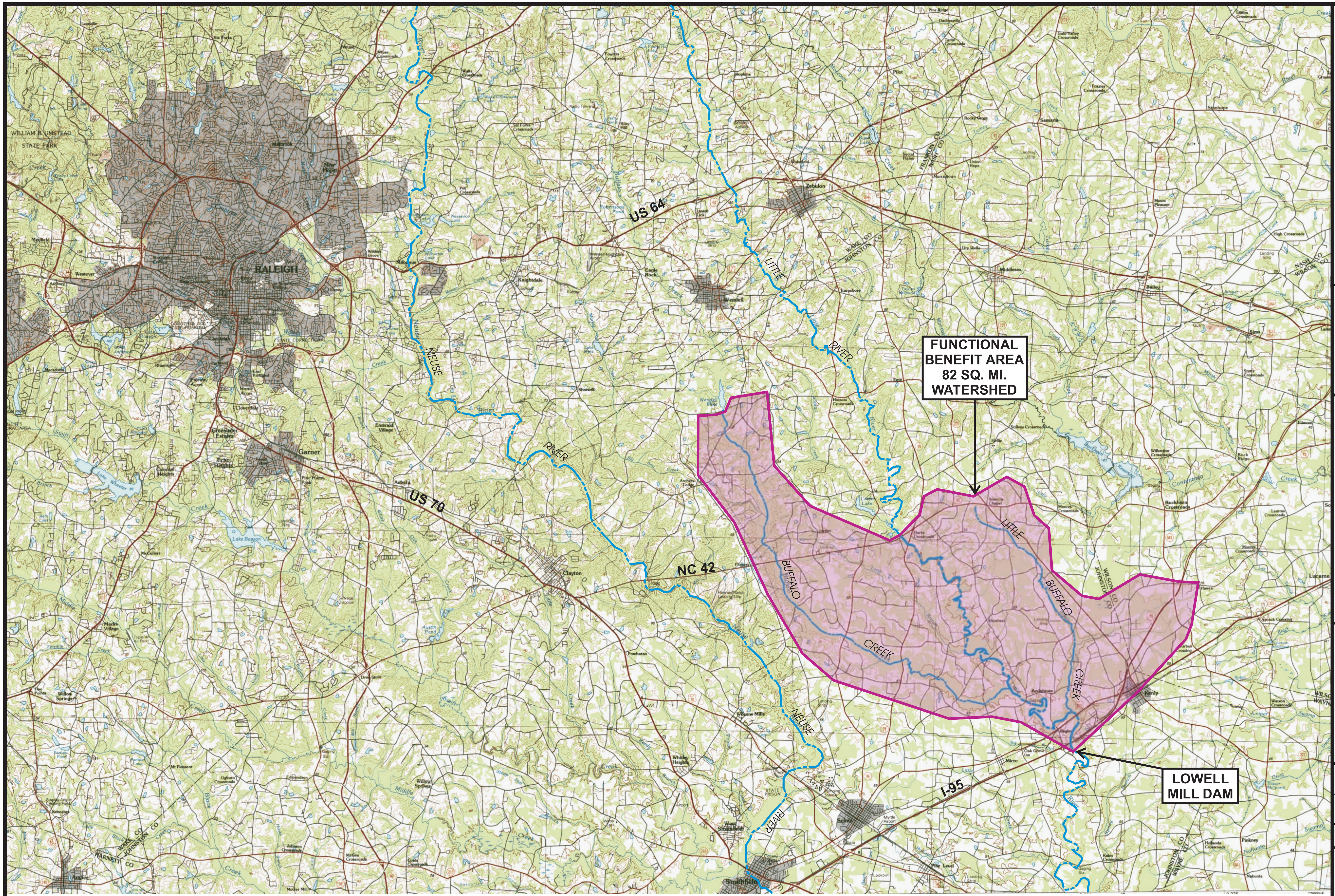
APPENDIX A: Figures



2 mi. 0 2 mi. 4 mi.

1:200000

Source: 2004 Terrain Navigator Pro (Raleigh, NC)

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LOWELL MILL DAM- LITTLE RIVER WATERSHED RESTORATION SITE

Johnston County
North Carolina

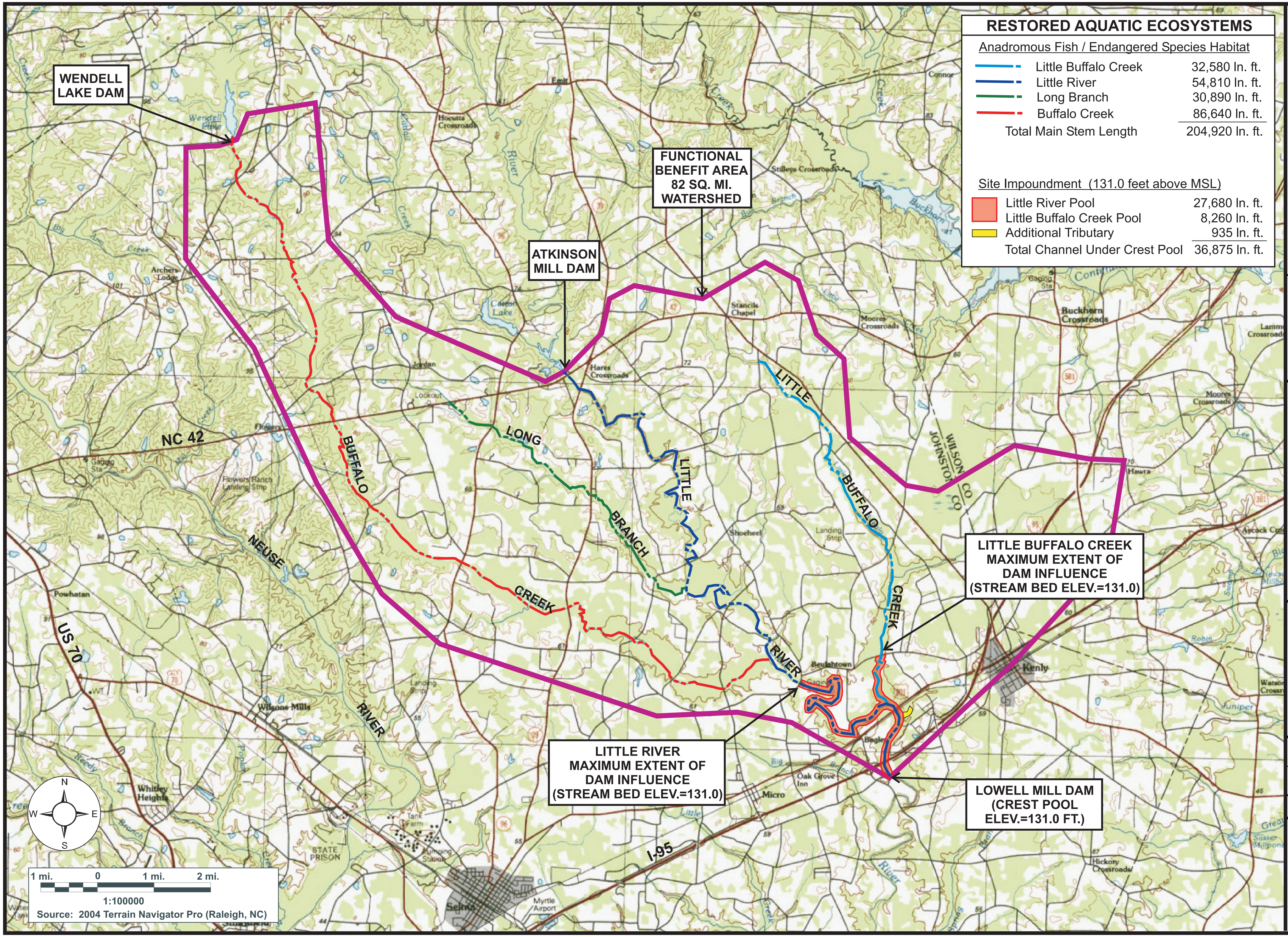
Title:

SITE LOCATION

Dwn By: MAF	Date: NOV 2008
Ckd By: JWG	Scale: As Shown
ESC Project No.:	08-405

FIGURE

1



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North Carolina

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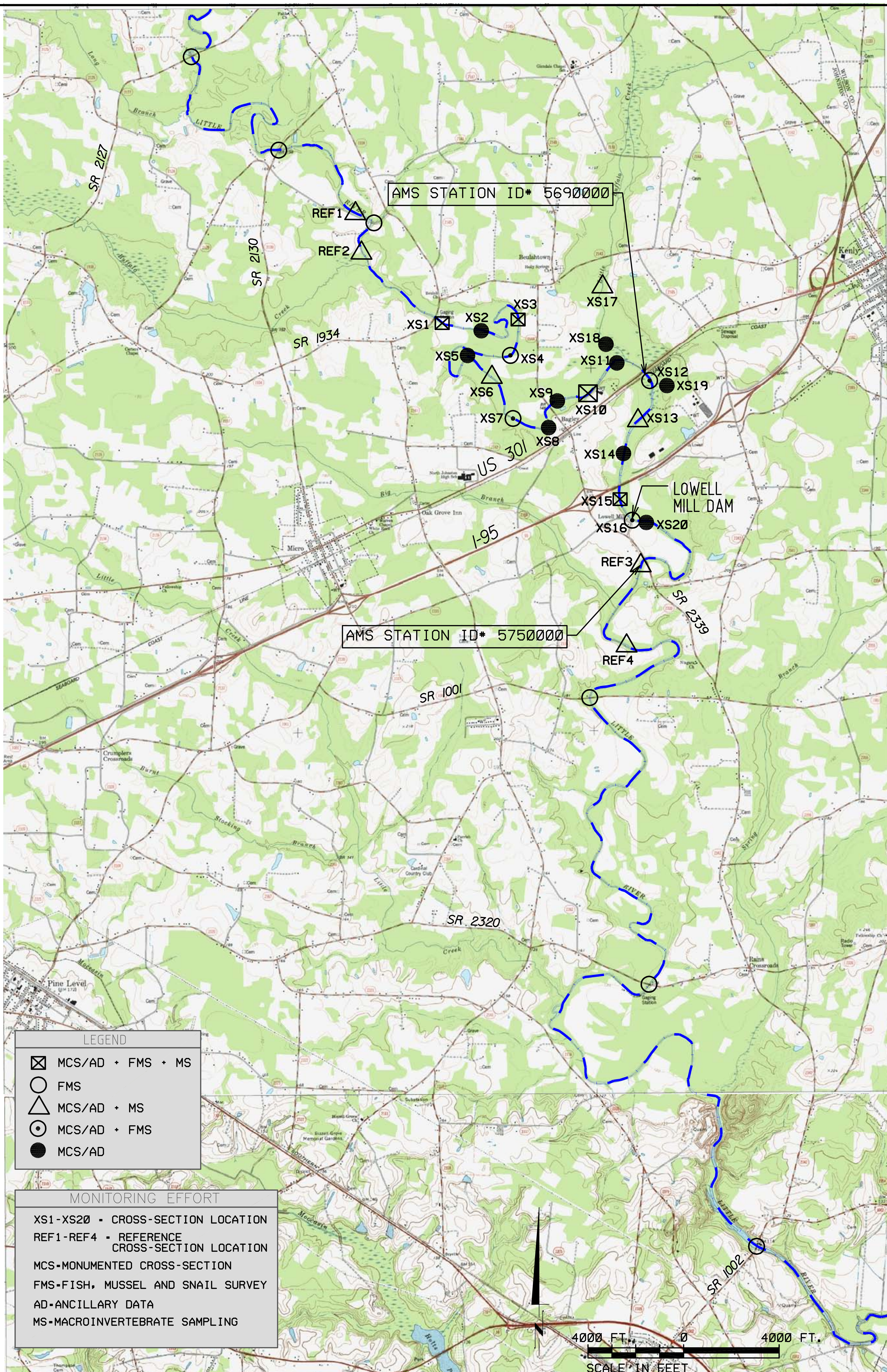
FUNCTIONAL BENEFIT AREA

Dwn By: MAF	Date: NOV 2008
Ckd By: JWG	Scale: As Shown
ESC Project No.:	08-405

FIGURE

2



CLIENT:

Ecosystem Enhancement PROGRAM

PROJECT:

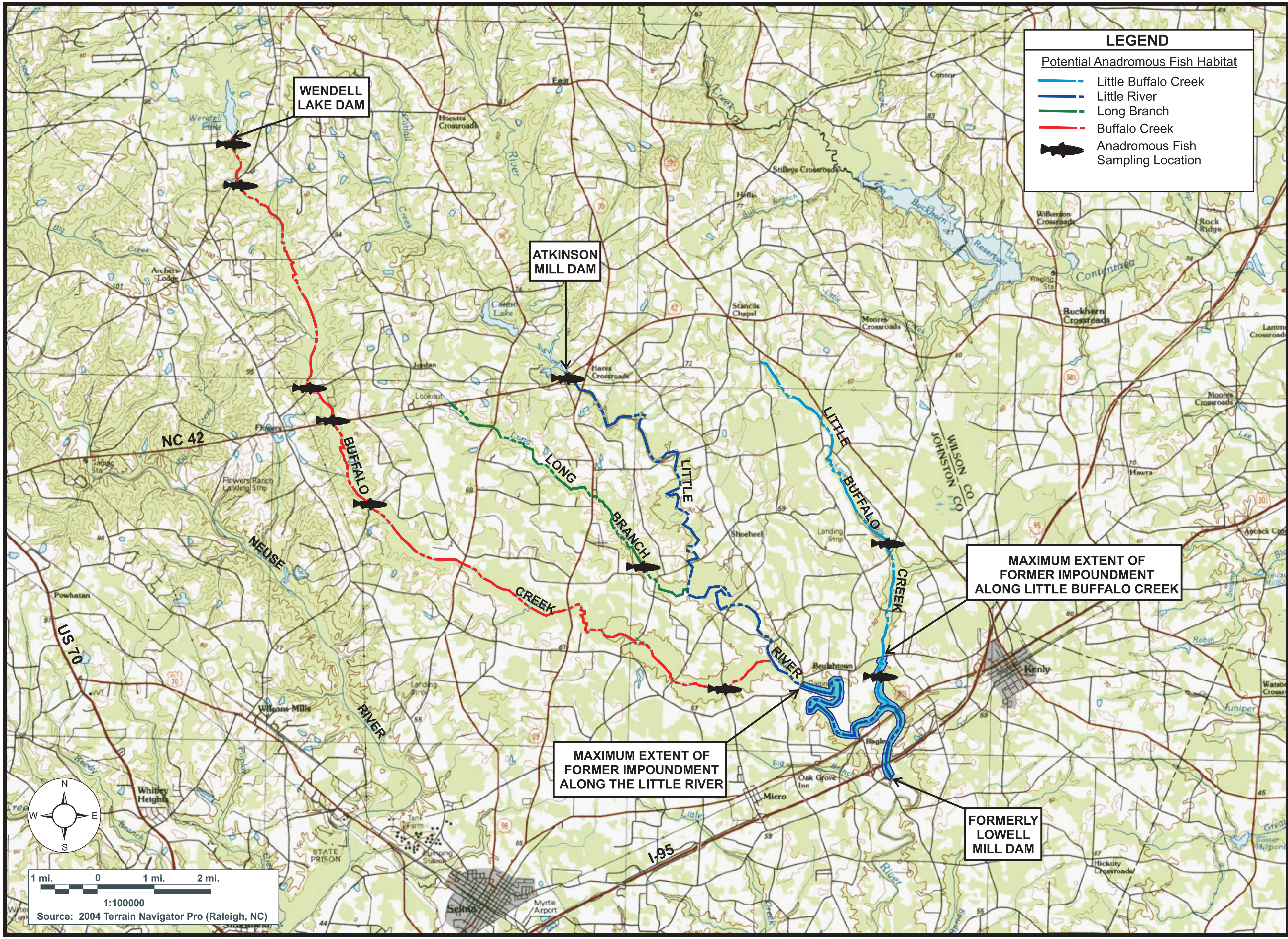
MONITORING NETWORK DEPLOYMENT

LOWELL MILL DAM – LITTLE RIVER WATERSHED RESTORATION SITE

Johnston County, North Carolina

Dwn By:	Ckd By:
MAF	JWG
Date: NOV 2008	
Scale: 1"=4000'	
ESC Project No.: 08-405	

FIGURE 3



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North Carolina

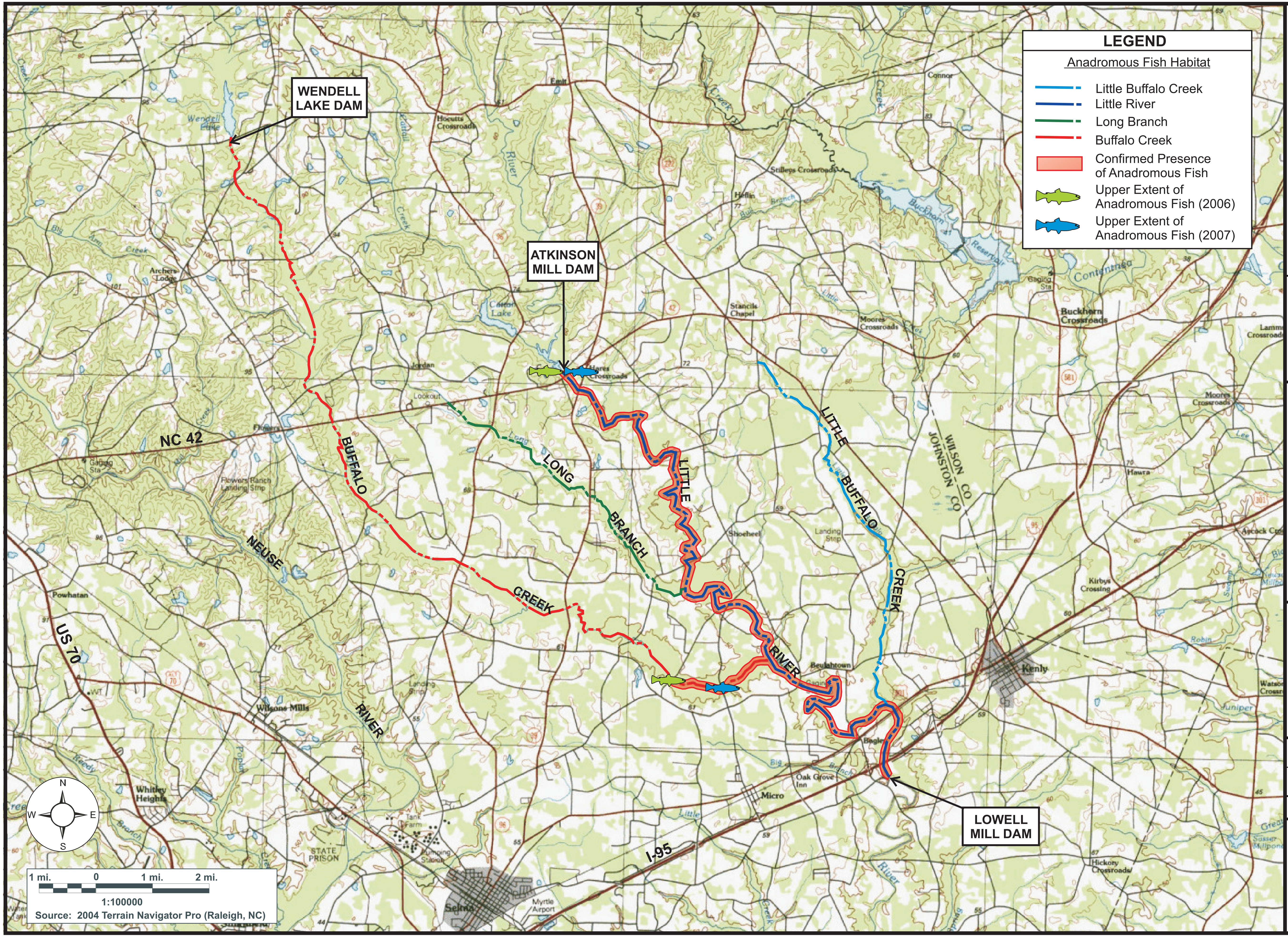
Title:

ANADROMOUS FISH SURVEY STATION LOCATIONS

Dwn By: MAF	Date: NOV 2008
Ckd By: JWG	Scale: As Shown
ESC Project No.:	08-405

FIGURE

4A



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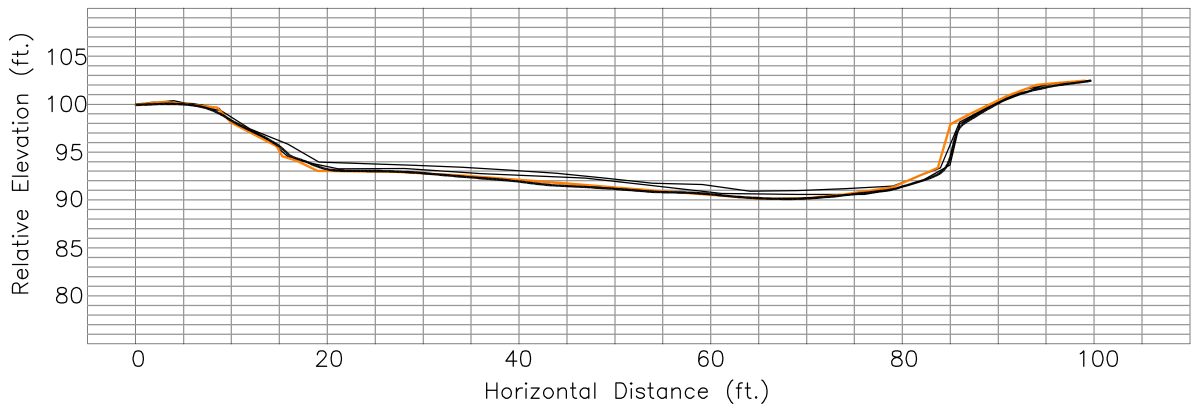
REPORTED PRESENCE OF ANADROMOUS FISH

Dwn By:	Date:
JRW	NOV 2008
Ckd By: JWG	Scale: As Shown
ESC Project No.:	08-405

FIGURE

4B

CROSS–SECTION 1



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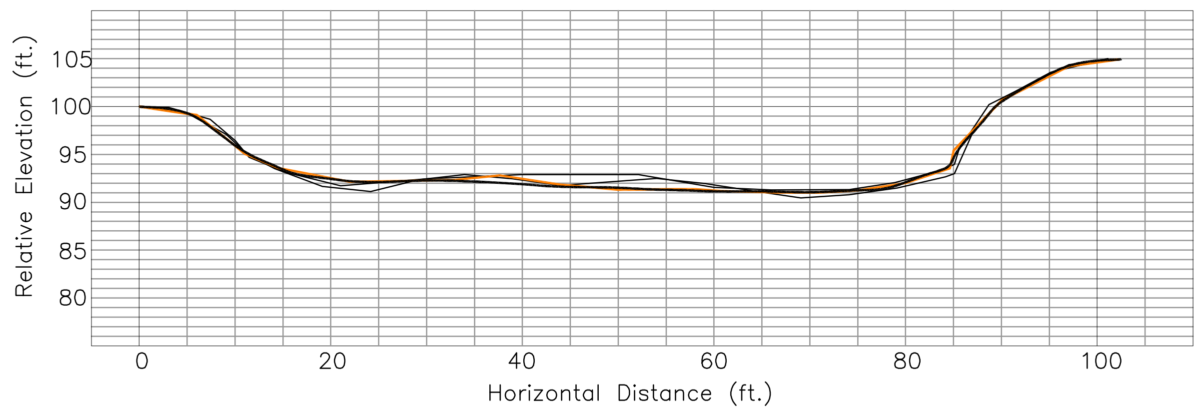

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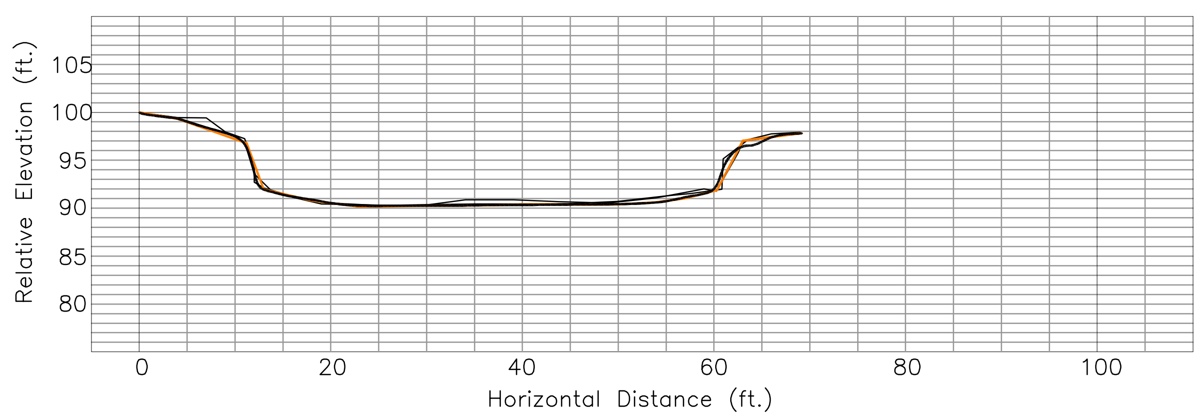

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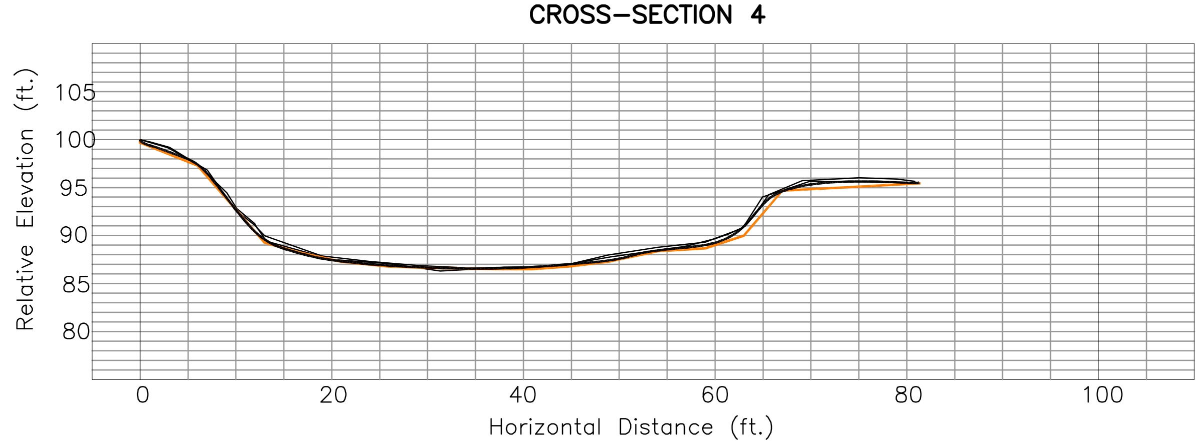

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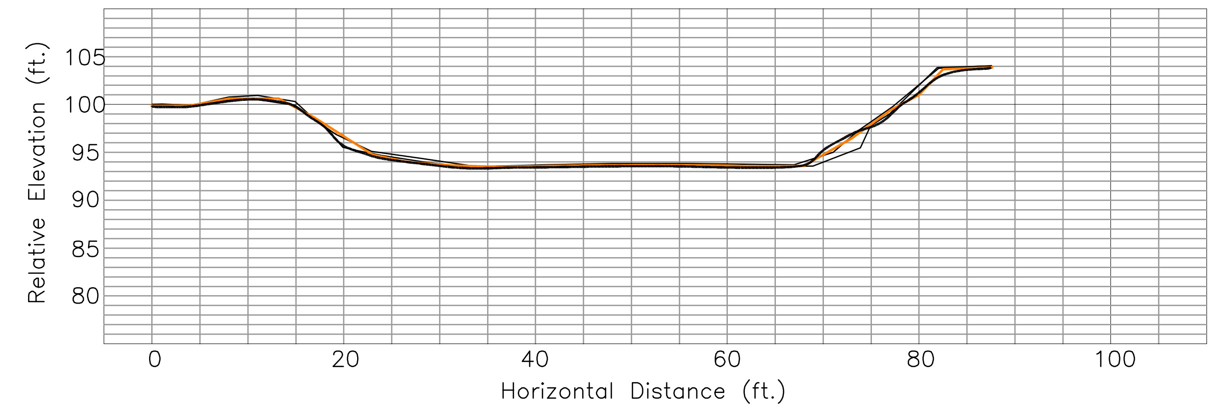

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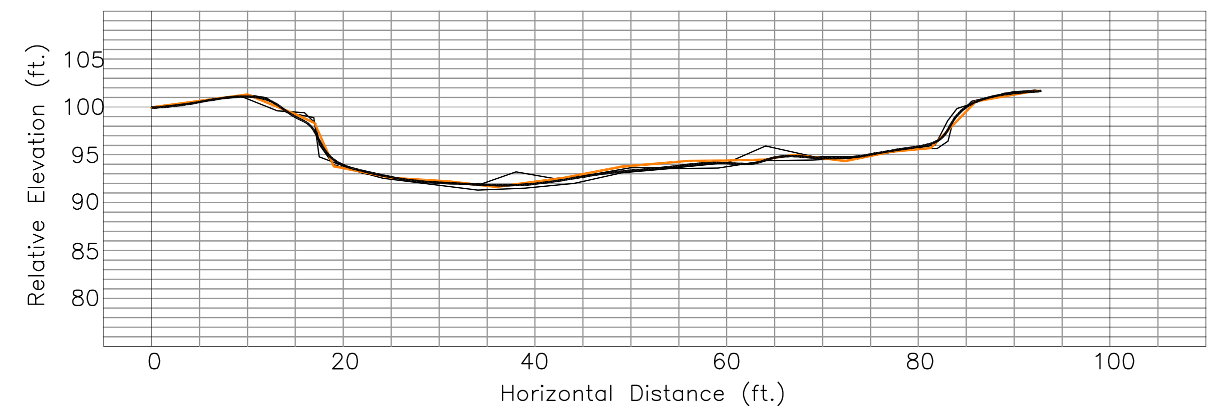

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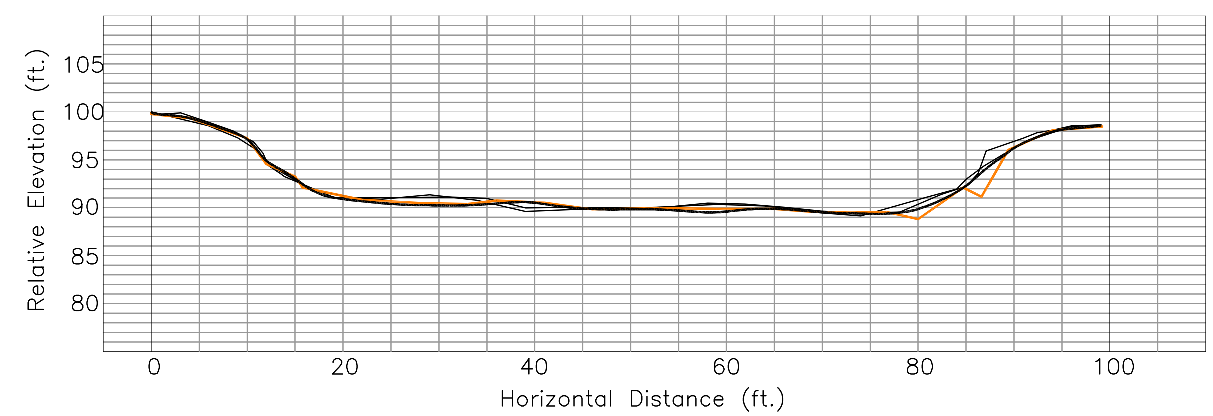

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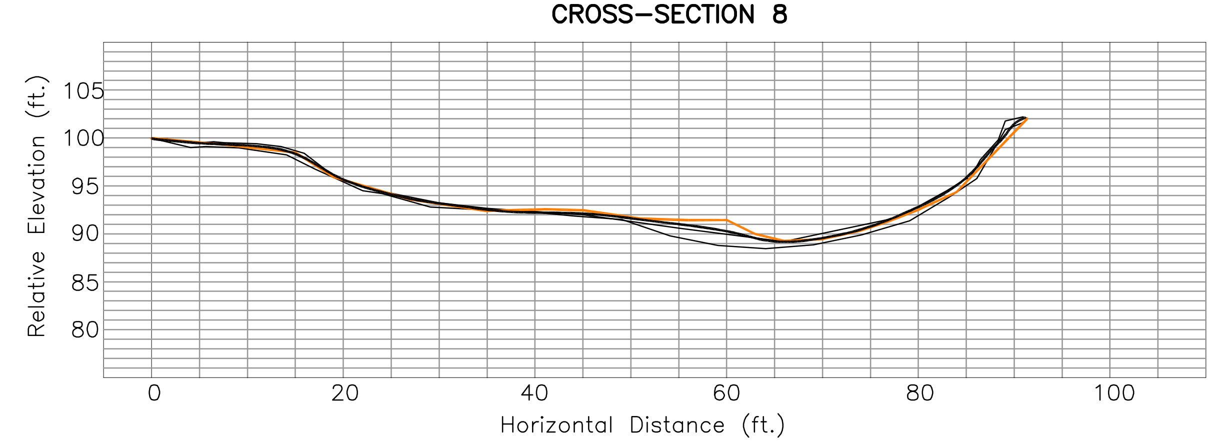

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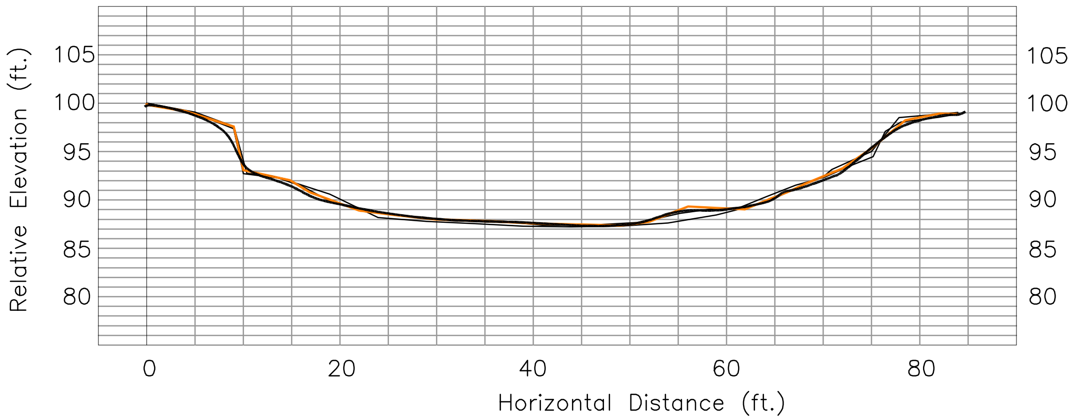
JOHNSTON COUNTY, NORTH CAROLINA

Title:
MONITORING CROSS–SECTIONS

Dsn. By:	Dwn. By: TAL
Ckd. By: JWG	Date: NOV 2008
Scale: AS SHOWN	
ESC Project No.: 08–405	

SHEET
5A

CROSS-SECTION 9



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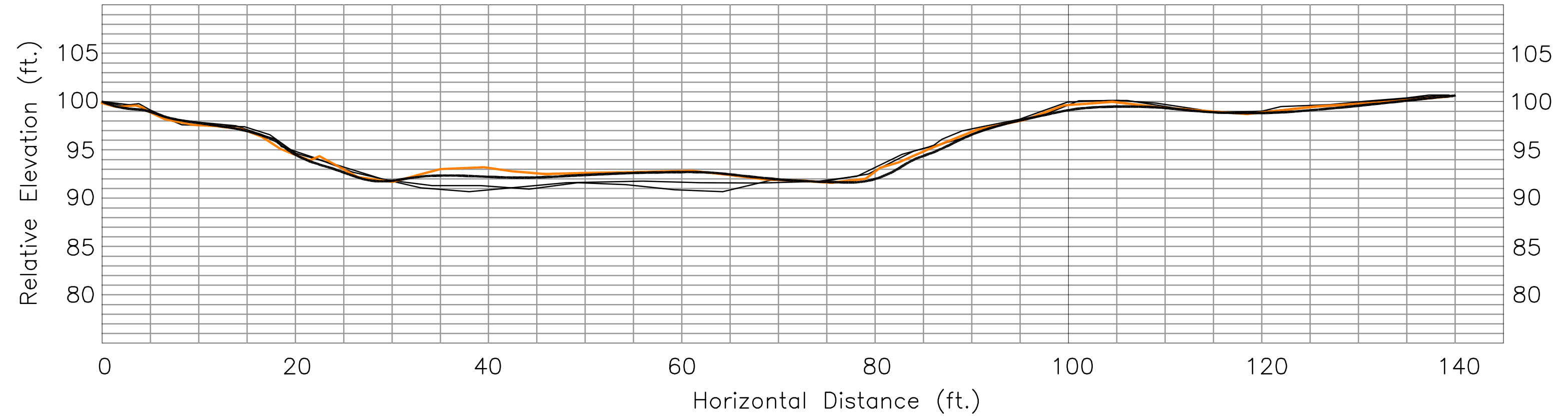

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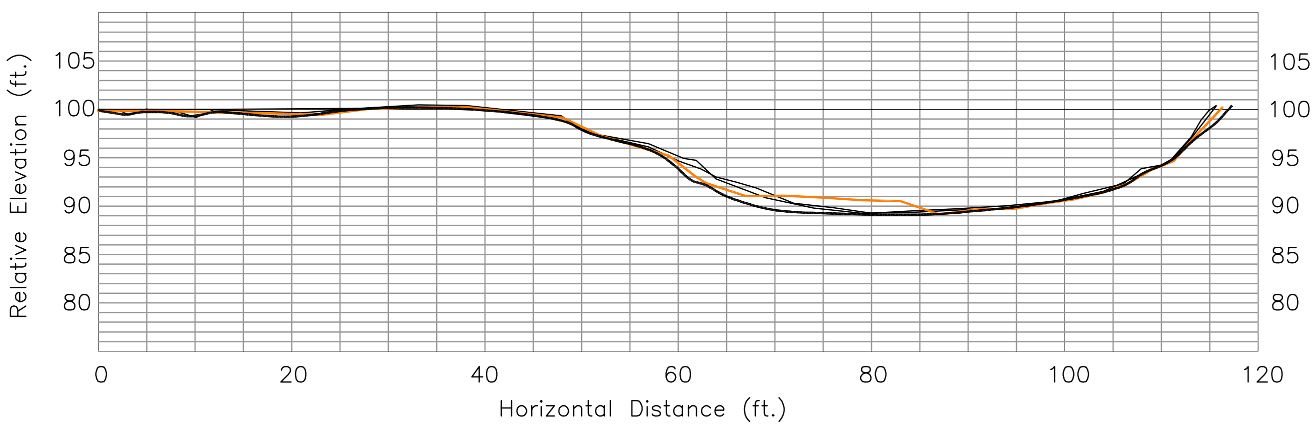

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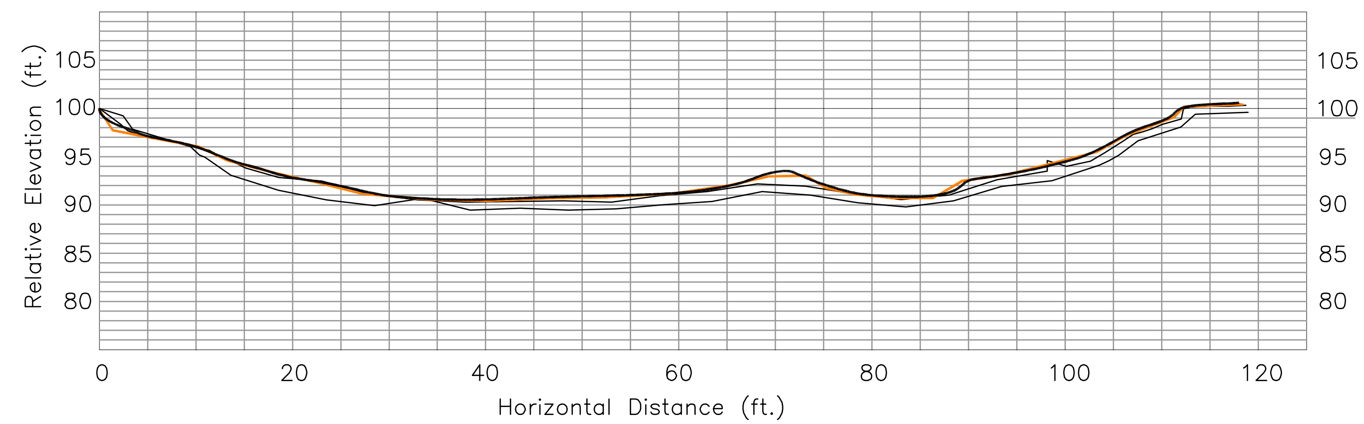

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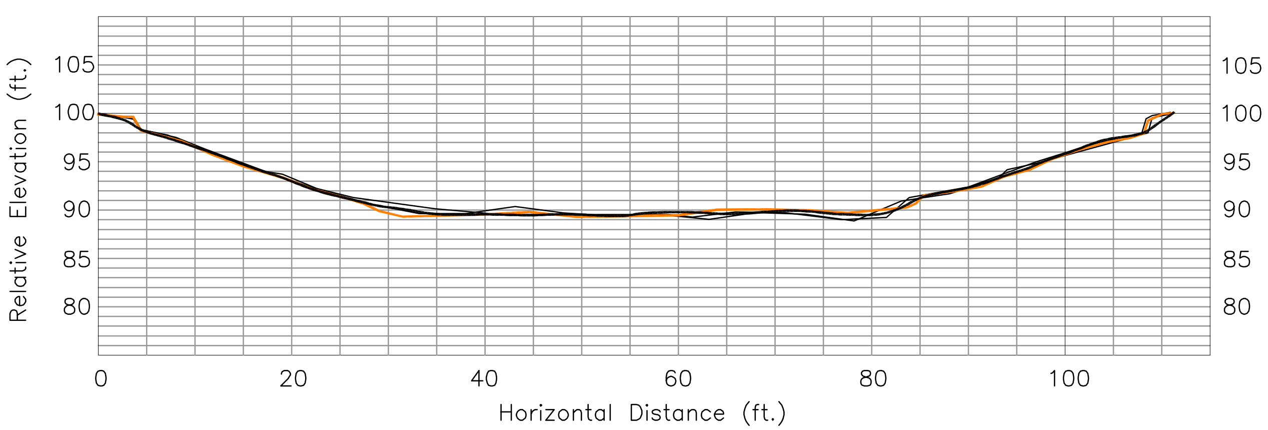

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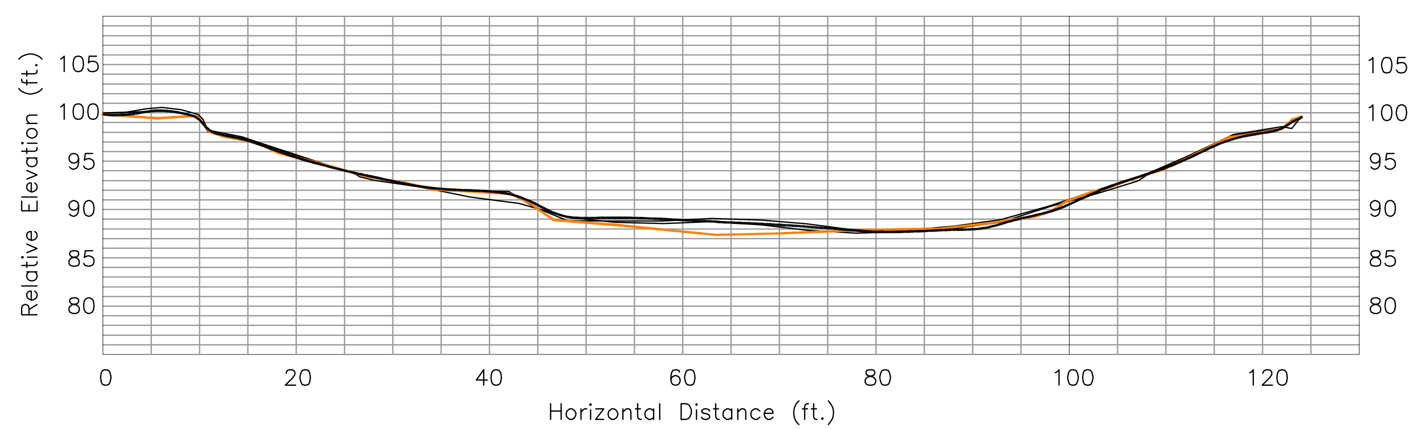

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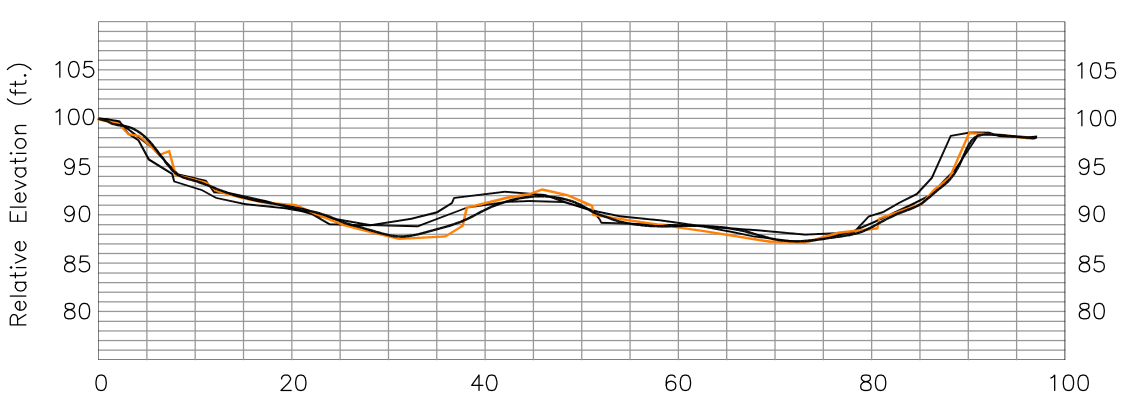

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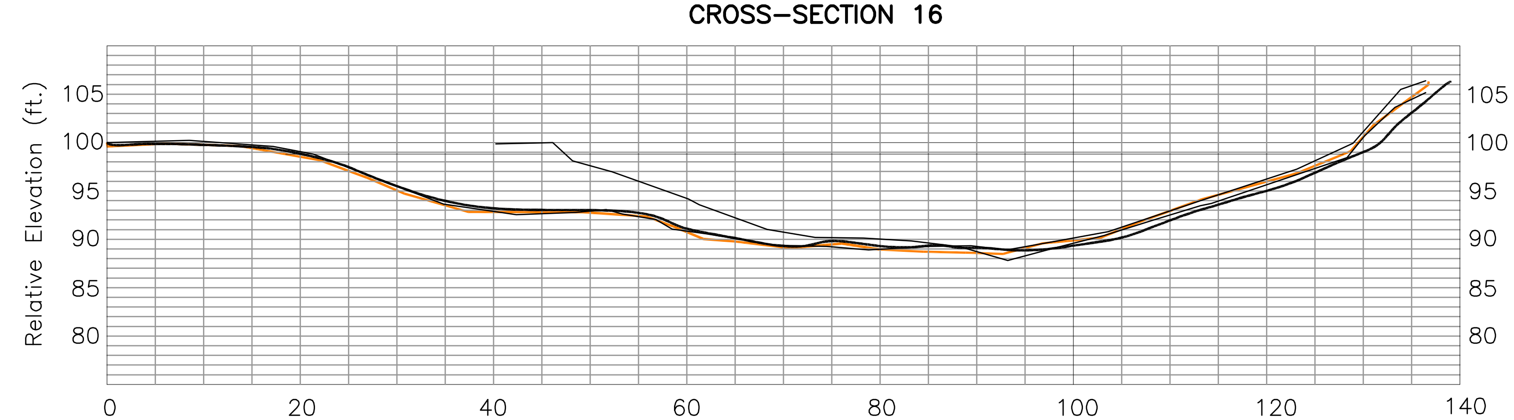

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5B

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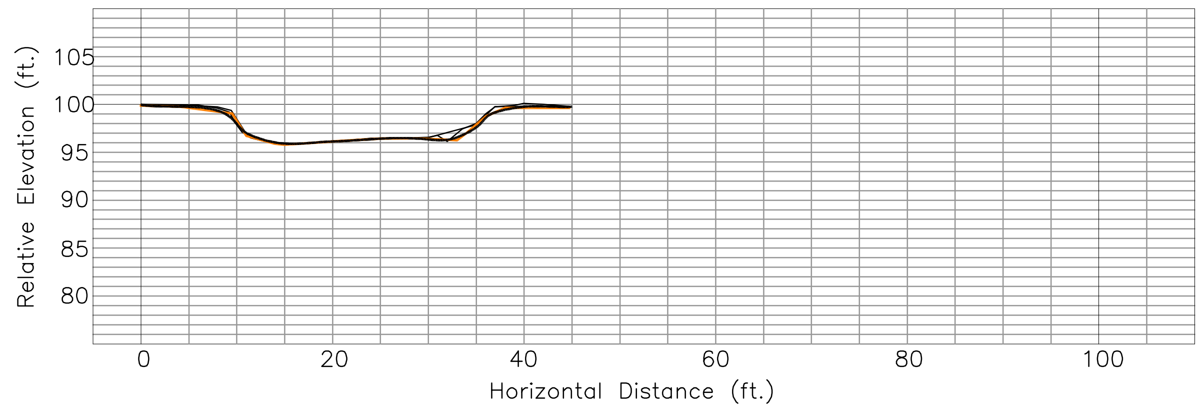

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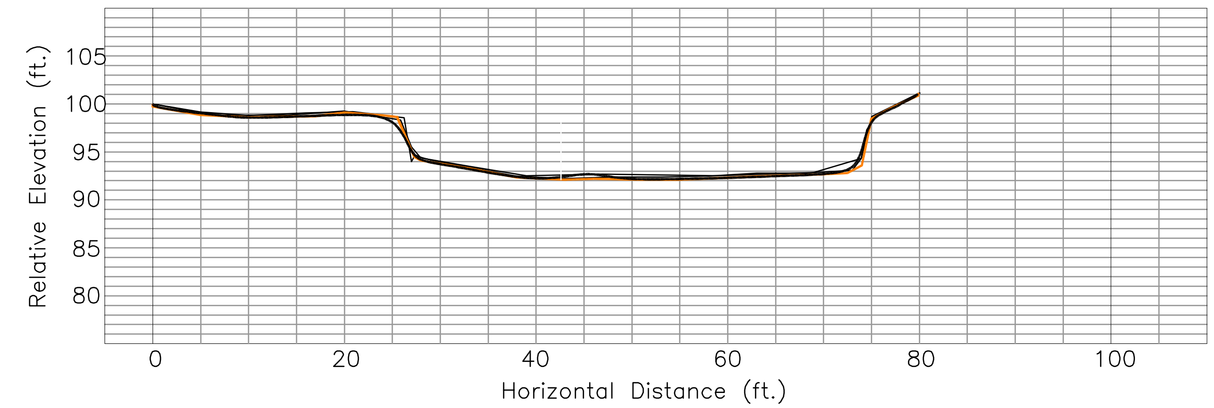

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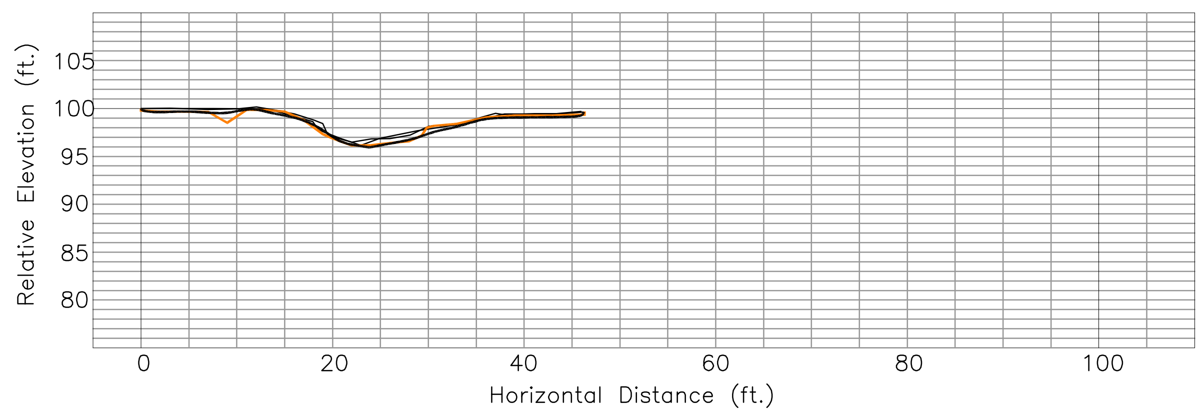

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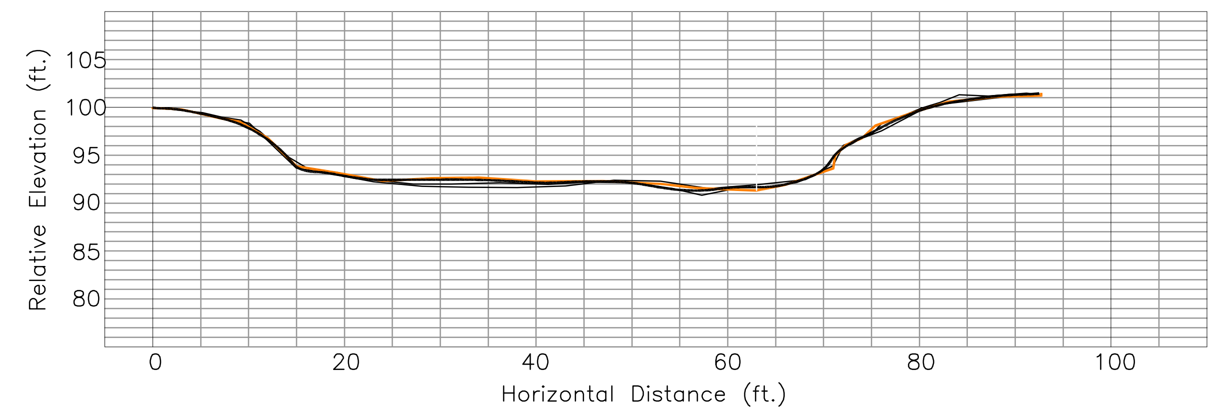

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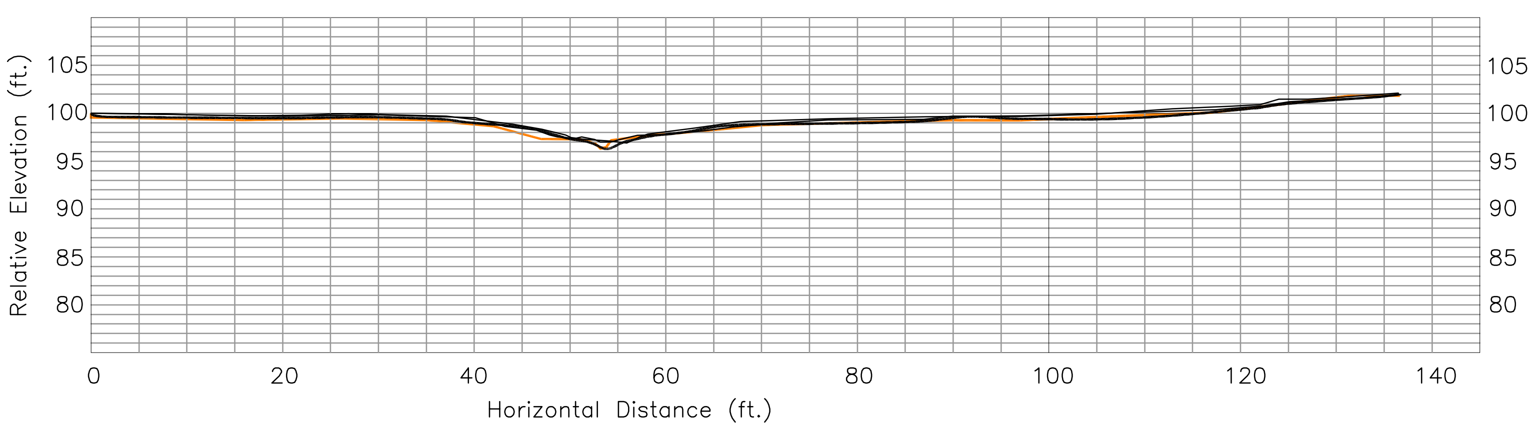

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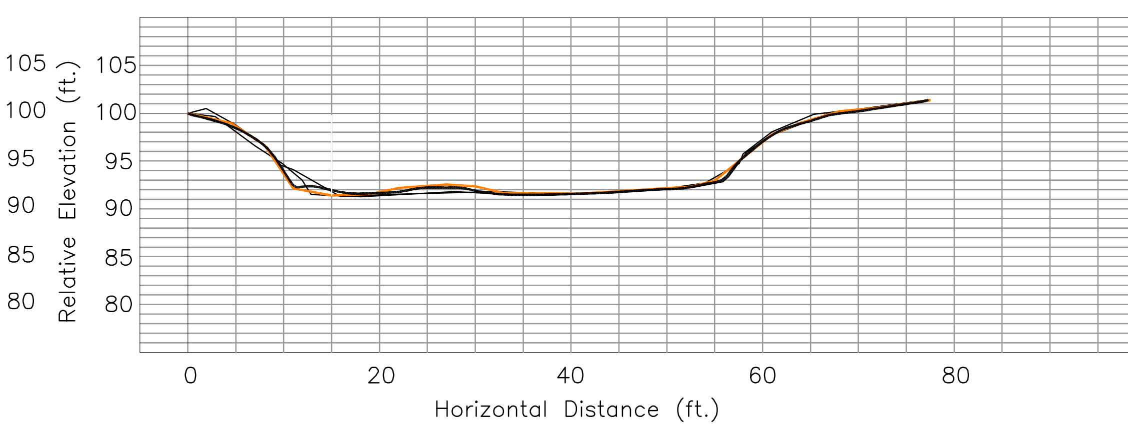

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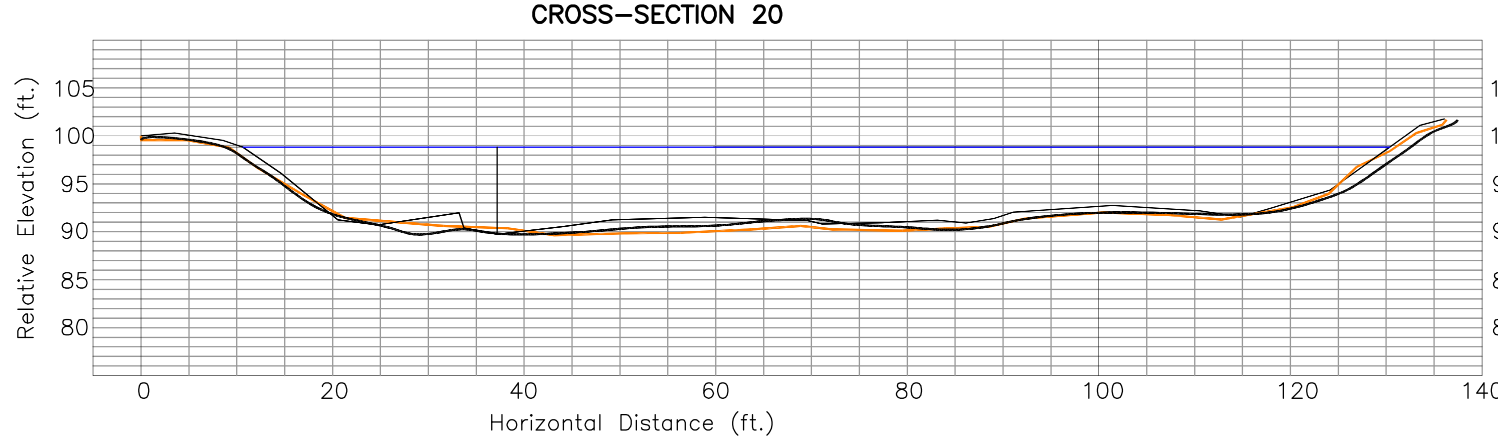

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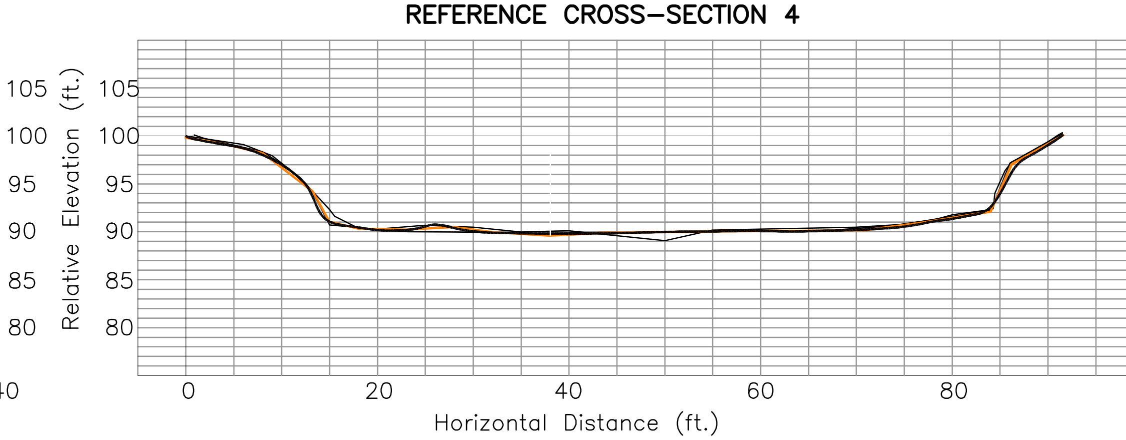

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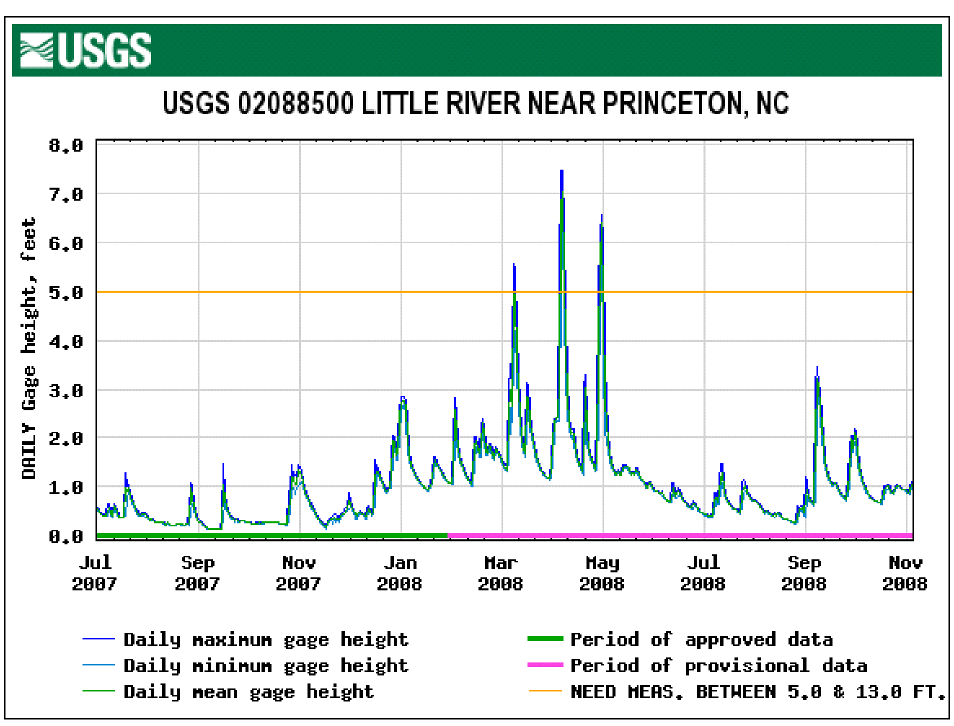
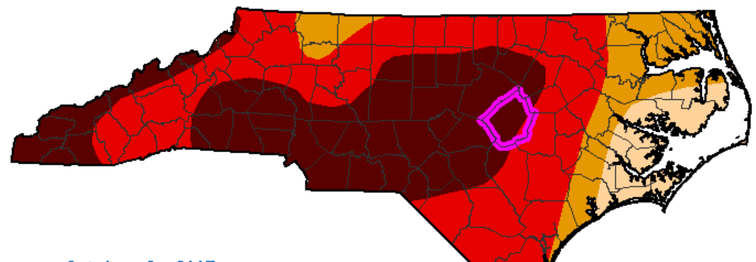
ESC Project No.: 08-405	

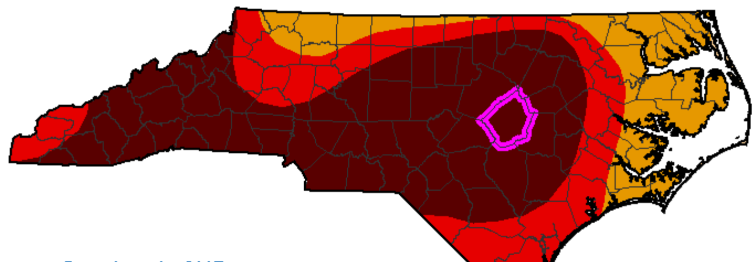
SHEET
5C

Johnston County Drought Data

Date	DM Level	Drought Level Description	Drought Conditions by Percent Area					
			None	D0	D1	D2	D3	D4
10/28/2008		Normal	99.25	0.75	0	0	0	0
10/21/2008		Normal	98.88	1.12	0	0	0	0
10/14/2008		Normal	98.88	1.12	0	0	0	0
10/7/2008		Normal	98.99	1.01	0	0	0	0
9/30/2008		Normal	98.99	1.01	0	0	0	0
9/23/2008	D0	Abnormally Dry	69.94	29.26	0.81	0	0	0
9/16/2008	D0	Abnormally Dry	22.88	76.31	0.81	0	0	0
9/9/2008	D0	Abnormally Dry	22.88	76.31	0.81	0	0	0
9/2/2008	D1	Moderate Drought	0	8.25	91.75	0	0	0
8/26/2008	D1	Moderate Drought	0	8.25	91.75	0	0	0
8/19/2008	D1	Moderate Drought	0	1.68	98.32	0	0	0
8/12/2008	D1	Moderate Drought	0	1.68	98.32	0	0	0
8/5/2008	D1	Moderate Drought	0	0.27	99.73	0	0	0
7/29/2008	D1	Moderate Drought	0	0	100	0	0	0
7/22/2008	D1	Moderate Drought	0	0	100	0	0	0
7/15/2008	D1	Moderate Drought	0	0.01	99.99	0	0	0
7/8/2008	D1	Moderate Drought	0	0	100	0	0	0
7/1/2008	D2	Severe Drought	0	0	8.2	91.8	0	0
6/24/2008	D1	Moderate Drought	0	0	100	0	0	0
6/17/2008	D1	Moderate Drought	0	0	100	0	0	0
6/10/2008	D1	Moderate Drought	0	0.76	99.24	0	0	0
6/3/2008	D0	Abnormally Dry	18.48	81.52	0	0	0	0
5/27/2008	D0	Abnormally Dry	18.48	81.52	0	0	0	0
5/20/2008	D0	Abnormally Dry	18.48	81.52	0	0	0	0
5/13/2008	D0	Abnormally Dry	0	100	0	0	0	0
5/6/2008	D0	Abnormally Dry	0	100	0	0	0	0
4/29/2008	D0	Abnormally Dry	0	100	0	0	0	0
4/22/2008	D1	Moderate Drought	0	0	92.25	7.75	0	0
4/15/2008	D2	Severe Drought	0	0	73.49	26.51	0	0
4/8/2008	D2	Severe Drought	0	0	73.49	26.51	0	0
4/1/2008	D3	Extreme Drought	0	0	0	74.89	25.11	0
3/25/2008	D3	Extreme Drought	0	0	0	74.89	25.11	0
3/18/2008	D3	Extreme Drought	0	0	0	74.89	25.11	0
3/11/2008	D3	Extreme Drought	0	0	0	74.89	25.11	0
3/4/2008	D4	Exceptional Drought	0	0	0	1.61	70.95	27.44
2/26/2008	D4	Exceptional Drought	0	0	0	1.61	70.95	27.44
2/19/2008	D4	Exceptional Drought	0	0	0	0	0	100
2/12/2008	D4	Exceptional Drought	0	0	0	0	0	100
2/5/2008	D4	Exceptional Drought	0	0	0	0	0	100
1/29/2008	D4	Exceptional Drought	0	0	0	0	0	100
1/22/2008	D4	Exceptional Drought	0	0	0	0	0	100
1/15/2008	D4	Exceptional Drought	0	0	0	0	0	100
1/8/2008	D4	Exceptional Drought	0	0	0	0	0	100
1/1/2008	D4	Exceptional Drought	0	0	0	0	0	100
12/25/2007	D4	Exceptional Drought	0	0	0	0	0	100
12/18/2007	D4	Exceptional Drought	0	0	0	0	0	100
12/11/2007	D4	Exceptional Drought	0	0	0	0	0	100
12/4/2007	D4	Exceptional Drought	0	0	0	0	0	100
11/27/2007	D4	Exceptional Drought	0	0	0	0	0.47	99.53
11/20/2007	D4	Exceptional Drought	0	0	0	0	31.48	68.52
11/13/2007	D3	Extreme Drought	0	0	0	32.32	67.68	0
11/6/2007	D3	Extreme Drought	0	0	0	55.56	44.44	0
10/30/2007	D3	Extreme Drought	0	0	0	57.58	42.42	0
10/23/2007	D4	Exceptional Drought	0	0	0	0	0	100
10/16/2007	D4	Exceptional Drought	0	0	0	0	0	100
10/9/2007	D4	Exceptional Drought	0	0	0	0	14.15	85.85
10/2/2007	D4	Exceptional Drought	0	0	0	0	14.15	85.85
9/25/2007	D3	Extreme Drought	0	0	0	0	100	0
9/18/2007	D3	Extreme Drought	0	0	0	0	100	0
9/11/2007	D3	Extreme Drought	0	0	0	0	100	0
9/4/2007	D3	Extreme Drought	0	0	0	0	100	0
8/28/2007	D2	Severe Drought	0	0	0	100	0	0
8/21/2007	D2	Severe Drought	0	0	0	100	0	0
8/14/2007	D2	Severe Drought	0	0	0	100	0	0
8/7/2007	D1	Moderate Drought	0	0	100	0	0	0
7/31/2007	D1	Moderate Drought	0	0	100	0	0	0
7/24/2007	D1	Moderate Drought	0	0	100	0	0	0
7/17/2007	D1	Moderate Drought	0	0	100	0	0	0
7/10/2007	D1	Moderate Drought	0	0	100	0	0	0
7/3/2007	D1	Moderate Drought	0	0.34	99.66	0	0	0




October 2, 2007
NCDWR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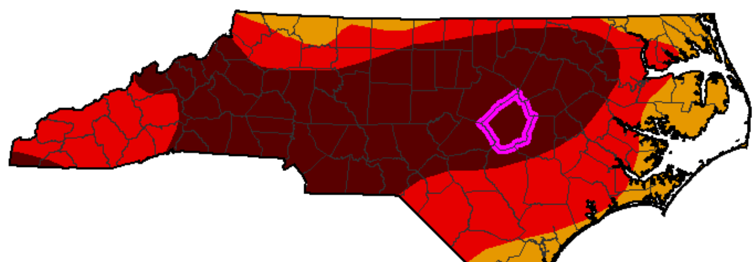
NCDWR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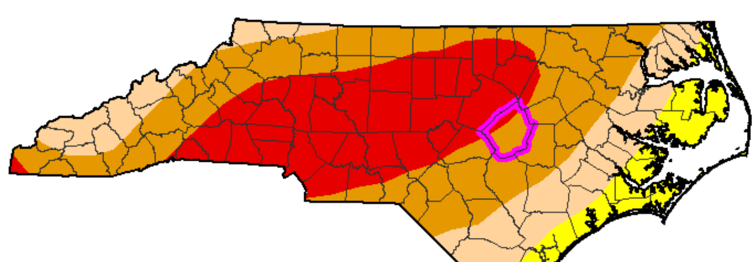
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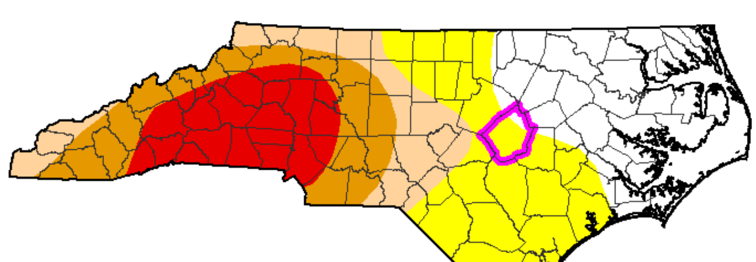
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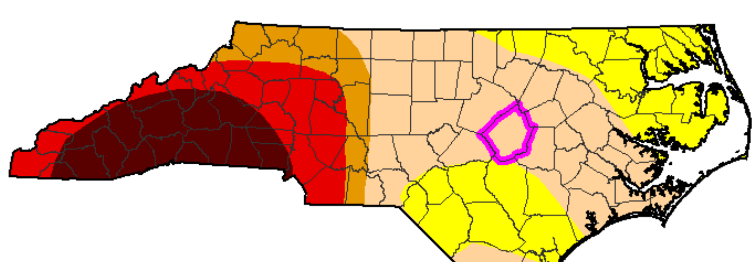
NCDWR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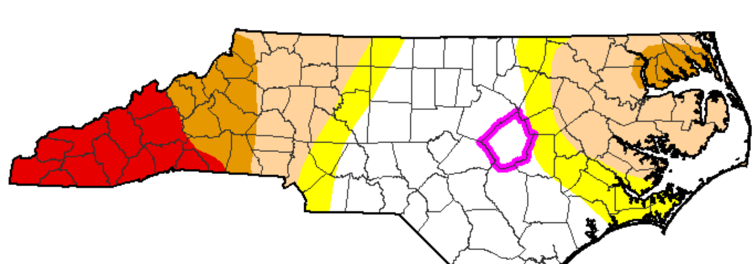
October 7, 2008
NCDWR

Drought Classifications
- D0 - Abnormally Dry
- D1 - Moderate Drought
- D2 - Severe Drought
- D3 - Extreme Drought
- D4 - Exceptional Drought

EcoScience A division of PBS&J	Client:	Project: **Lowell Mill Dam Monitoring Year 3** Johnston County, North Carolina	Title: **North Carolina Drought Monitor Data**	Dwn By: JRW	Ckd By: JWG	FIGURE 6
				Date: Nov 08	Scale: N/A	
				ESC Project No.: 08-405.00		

APPENDIX B: Benthic Macroinvertebrate Data

BENTHIC MACROINVERTEBRATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

			Stations										
SPECIES	**T.V.**	**F.F.G.**	**1**	**3**	**6**	**10**	**13**	**15**	**17**	**R1**	**R2**	**R3**	**R4**
PLATYHELMINTHES													
Turbellaria													
Tricladida													
Dugesiidae													
Girardia (Dugesia) tigrina	**7.2**		4	1	2	2		2				2	1
MOLLUSCA													
Gastropoda													
Basommatophora													
Physidae													
Physella sp.	**8.8**	**CG**				1		1					
ANNELIDA													
Oligochaeta	***10**	**CG**											
Tubificida													
Enchytraeidae	**9.8**	**CG**	1										
Lumbricidae		**SC**		1	1		3		1				
Tubificidae w.h.c.	**7.1**	**CG**		1		1							
Branchiura sowerbyi	**8.3**	**CG**			2								
Tubificidae w.o.h.c.	**7.1**	**CG**		1			2	4		1			
Lumbriculida													
Lumbriculidae	**7**	**CG**	5	5	6	5	10	2	8	5	1	2	
Branchiobdellida				1					1				
Hirudinea		**P**				1							32
Rhynchobdellida													
Glossiphoniidae		**P**						1				1	
Batrachobdella phalera	**7.6**	**P**				1							
Helobdella triserialis	**9.2**	**P**						1					1
Placobdella papillifera	**9**	**P**			1								
Placobdella parasitica	**8.7**				1	1		2		2			
ARTHROPODA													
Arachnoidea													
Acariformes	**5.5**			1									
Lebertiidae	**5.5**												
Lebertia sp.	**5.5**												4
Crustacea													
Ostracoda				1	1								
Copepoda													
Cyclopoida			1										
Isopoda													
Asellidae		**SH**											
Caecidotea sp.	**9.1**	**CG**	1					1	4			1	
Lirceus sp.	**7.9**	**CG**						1	3				
Amphipoda		**CG**											
Crangonyctidae													
Crangonyx sp.	**7.9**	**CG**	3		1				13	1			1
Hyalellidae													
Hyalella azteca	**7.8**	**CG**	1			7	8	13				1	19
Decapoda													
Cambaridae	**7.5**			1		1		2	1	1			1

BENTHIC MACROINVERTEBRATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	T.V.	F.F.G.	1	3	6	10	13	15	17	R1	R2	R3	R4
Palaemonidae													
Palaemonetes sp.	7.1	CG		3		3	4	3		6	1		1
Collembola						1		2				1	
Insecta													
Ephemeroptera													
Baetidae		CG					1						
Baetis intercalaris	7	CG	2	7	4		19	8				16	2
Baetis sp.		CG			1								
Centroptilum sp.	6.6	CG						1					1
Plauditus sp.		CG		1			5	2		1		6	
Pseudocloeon sp.	4	CG	2	6	2		8	1					1
Caenidae		CG											
Caenis sp.	7.4	CG	12	47	18	75	115	87		8		71	84
Ephemeridae		CG											
Hexagenia sp.	4.9	CG				3		1		2			
Ephemerellidae		SC						1					
Attenella sp.				6	1		2	1				2	
Ephemerella needhami	0	CG		1									
Ephemerella sp.	2	SC										2	
Timpanoga sp.		CG											1
Heptageniidae		SC											
Maccaffertium (Stenonema) sp.		SC	5	26	28	15	41	7		2		25	13
Stenacron interpunctatum	6.9	SC		1		1				2			
Isonychiidae		FC											
Isonychia sp.	3.5	FC	15	21	8	2	7	25		1		2	
Odonata													
Aeshnidae		P		2		1	2					2	
Boyeria vinosa	5.9	P	1		2		2	1			1	1	
Nasiaeschna pentacantha	8.1		1					1					
Calopterygidae		P											
Calopteryx sp.	7.8	P										1	
Coenagrionidae		P						10				1	
Argia sp.	8.2	P	1	5	2	12	7	8		2	4	16	22
Enallagma sp.	8.9	P	1				6		1	3		4	7
Gomphidae		P	1	2				2					4
Dromogomphus sp.	5.9	P								1			
Dromogomphus spinosus	5.1	P				1					1		
Gomphus sp.	5.8	P			1					1		3	2
Progomphus obscurus	8.2	P			2		4	1				3	
Libellulidae		P							4				1
Epicordulia princeps	5.6	P		1									
Erythemis sp.						1		2				4	4
Libellula sp.	9.6	P				3		5					
Macromia sp.	6.2	P			2	1	1	1				2	1
Neurocordulia alabemensis										1			
Neurocordulia obsoleta	5.2			1	2	4	1				2	3	1
Pachydiplax longipennis	9.9							2			1		1
Perithemis tenera	9.9	P						2		1			
Plathemis lydia	10							2					

BENTHIC MACROINVERTEBRATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	T.V.	F.F.G.	1	3	6	10	13	15	17	R1	R2	R3	R4
Plecoptera													
Perlidae		**P**											
Perlesta placida sp. gp.	**4.7**	**P**	29	46	35	8	19	12	9	2	13	12	8
Perlodidae		**P**											
Isoperla sp.		**P**			1	5	5	1				1	
Hemiptera													
Corixidae	**9**	**PI**						1					
Belostomatidae													
Belostoma sp.	**9.8**	**P**				2		1					
Gerridae		**P**											
Gerris sp.						1		1					
Trepobates sp.		**P**				1							
Naucoridae													
Pelocoris sp.	**7**							1					
Nepidae		**-**											
Ranatra sp.	**7.8**	**P**				1				1			
Pleidae							1	1					
Megaloptera													
Corydalidae		**P**											
Chauliodes pectinicornis	**9.6**						1						
Corydalus cornutus	**5.2**	**P**	1										
Sialidae		**P**											
Sialis sp.	**7.2**	**P**						1					
Trichoptera													
Hydropsychidae		**FC**						1					
Cheumatopsyche sp.	**6.2**	**FC**	2	2	3		12	6			2	8	6
Hydropsyche sp.		**FC**			1								
Leptoceridae		**CG**											
Nectopsyche sp.	**2.9**	**SH**						1					
Nectopsyche exquisita	**4.1**	**SH**											1
Nectopsyche pavida	**4.1**											1	
Oecetis avara	**4.7**	**P**										1	
Polycentropodidae		**FC**											
Phylocentropus sp.						1		1		1	2	1	
Coleoptera													
Carabidae					2								
Curculionidae							1						
Dytiscidae		**P**								1			
Coptotomus sp.	**9.3**							1	1				
Neoporus sp.	**8.6**		4	3	4	14	12	11	15	1		2	5
Elmidae		**CG**											
Ancyronyx variegata	**6.5**	**SC**		3			2			2	2	6	5
Dubiraphia sp.	**5.9**	**SC**									1		6
Dubiraphia vittata	**4.1**	**SC**		3		2		2				2	
Macronychus glabratus	**4.6**	**SH**	9	49	13	3	21	2		10	6	30	17
Stenelmis sp.	**5.1**	**SC**			1							1	
Gyrinidae		**P**											
Dineutus sp.	**5.5**	**P**	3	5	10		12	3					
Haliplidae													

BENTHIC MACROINVERTEBRATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	**T.V.**	**F.F.G.**	**1**	**3**	**6**	**10**	**13**	**15**	**17**	**R1**	**R2**	**R3**	**R4**
Peltodytes sp.	**8.7**	**SH**	2			11	17	22		3	1	3	4
Peltodytes duodecimpunctatus			1	1						1			4
Hydrophilidae		**P**											
Berosus sp.	**8.4**	**CG**					2						1
Helochares sp.		**P**					1						
Sperchopsis tesselatus	**6.1**	**CG**				4	4				1	1	1
Sperchopsis sp.													
Noteridae													
Suphisellus sp.								1					1
Ptilodactylidae		**SH**				1							
Scirtidae		**SC**											
Cyphon sp.			1										
Staphylinidae		**P**									1		
Diptera													
Ceratopogonidae		**P**			1	2	1						1
Atrichopogon sp.	**6.5**	**P**										1	
Bezzia/Palpomyia gp.	**6.9**	**P**				1				1			
Chironomidae													
Ablabesmyia mallochi	**7.2**	**P**	1	2	4	13	19	11		3	1	8	4
Chironomus sp.	**9.6**	**CG**		2		1	1	1	3	8	2		1
Cladopelma sp.	**3.5**	**CG**									1		
Cladotanytarsus sp.	**4.1**	**FC**					1						
Clinotanypus sp.		**P**				1							7
Conchapelopia sp.	**8.4**	**P**				2							
Corynoneura sp.	**6**	**CG**	5	6	3					4	1	1	1
Cricotopus bicinctus	**8.5**	**CG**	6	2	17	3	90	4		6		2	
Cricotopus sp.		**CG**			7					3		4	
Cryptochironomus sp.	**6.4**	**P**	1										1
Dicrotendipes sp.	**8.1**	**CG**		2	1	1	1	1				3	1
Dicrotendipes simpsoni	**10**				3	3				4		5	1
Einfeldia natchitocheae										1			
Labrundinia sp.	**5.9**	**P**	1					1		1		2	
Nanocladius alternantherae				9			1				2		
Nanocladius sp.	**7.1**	**CG**								1			
Orthocladius sp.		**CG**					1						
Orthocladius lignicola	**5.4**	**CG**		1									
Parametriocnemus sp.	**3.7**	**CG**	1		18		1						
Phaenopsectra obediens	**6.5**	**SC**				2				1		1	
Polypedilum fallax	**6.4**	**SH**	2	13	1	15	1			3		32	1
Polypedilum illinoense	**9**	**SH**			1	12	19	1	1		1		1
Potthastia sp.	**6.4**	**CG**		6									
Potthastia longimana	**6.5**	**CG**						1					
Procladius bellus											1		
Procladius sp.	**9.1**	**P**				4		5	2	2		2	5
Procladius (Holotanypus) sp.											3		
Pseudochironomus sp.	**5.4**	**CG**		2									4
Rheocricotopus robacki	**7.3**	**CG**			2		1	1					
Rheotanytarsus sp.	**5.9**	**FC**		1									1
Stenochironomus sp.	**6.5**	**SH**			1								

BENTHIC MACROINVERTEBRATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	**T.V.**	**F.F.G.**	**1**	**3**	**6**	**10**	**13**	**15**	**17**	**R1**	**R2**	**R3**	**R4**
Tanytarsus sp.	**6.8**	**FC**	7	1	13	11	7		2	1	2		6
Thienemanniella xena	**5.9**	**CG**	1	4	21	3	1					1	2
Tribelos fuscicorne						5		2	1				
Tribelos jucundum	**6.3**			8					1	14	3	2	2
Tribelos sp.	**6.3**	**CG**											4
Xenochironomus xenolabis	**7.1**	**P**		2						2		2	
Xylotopus par	**6**	**SH**	2										
Zavrelimyia sp.	**9.1**	**P**			4				1				
Culicidae		**FC**											
Anopheles sp.	**8.6**	**FC**					1						
Psychodidae		**CG**											1
Sciaridae					3								
Simuliidae		**FC**											
Simulium sp.	**6**	**FC**					2	1			1		
Tabanidae		**PI**											
Chrysops sp.	**6.7**	**PI**					1						
Tipulidae		**SH**					1						
Tipula sp.	**7.3**	**SH**				1	2						
TOTAL NO. OF ORGANISMS			**136**	**316**	**258**	**277**	**510**	**305**	**72**	**118**	**58**	**307**	**308**
TOTAL NO. OF TAXA			**36**	**47**	**46**	**53**	**53**	**65**	**19**	**43**	**27**	**51**	**53**
EPT TAXA			**7**	**11**	**11**	**8**	**11**	**16**	**1**	**8**	**3**	**13**	**9**
NCBI			**5.94**	**5.73**	**6.10**	**7.38**	**7.28**	**7.14**	**7.70**	**###**	**6.05**	**6.70**	**7.10**
NCBI ASSIGNED VALUES			**6.22**	**5.89**	**6.33**	**7.48**	**6.96**	**7.15**	**8.04**	**###**	**6.11**	**6.65**	**6.97**
										4.1			

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	T.V.	Sta. 1		Sta. 3		Sta. 6	
Girardia (Dugesia) tigrina	**7.2**	4	28.8	1	7.2	2	14.4
Physella sp.	**8.8**		0		0		0
Enchytraeidae	**9.8**	1	9.8		0		0
Tubificidae w.h.c.	**7.1**		0	1	7.1		0
Branchiura sowerbyi	**8.3**		0		0	2	16.6
Tubificidae w.o.h.c.	**7.1**		0	1	7.1		0
Lumbriculidae	**7**	5	35	5	35	6	42
Batrachobdella phalera	**7.6**		0		0		0
Helobdella triserialis	**9.2**		0		0		0
Placobdella papillifera	**9**		0		0	1	9
Placobdella parasitica	**8.7**		0		0	1	8.7
Acariformes	**5.5**		0	1	5.5		0
Lebertiidae	**5.5**		0		0		0
Lebertia sp.	**5.5**		0		0		0
Caecidotea sp.	**9.1**	1	9.1		0		0
Lirceus sp.	**7.9**		0		0		0
Crangonyx sp.	**7.9**	3	23.7		0	1	7.9
Hyalella azteca	**7.8**	1	7.8		0		0
Cambaridae	**7.5**		0	1	7.5		0
Palaemonetes sp.	**7.1**		0	3	21.3		0
Baetis intercalaris	**7**	2	14	7	49	4	28
Centroptilum sp.	**6.6**		0		0		0
Pseudocloeon sp.	**4**	2	8	6	24	2	8
Caenis sp.	**7.4**	12	88.8	47	347.8	18	133.2
Hexagenia sp.	**4.9**		0		0		0
Ephemerella needhami	**0**		0	1	0		0
Ephemerella sp.	**2**		0		0		0
Stenacron interpunctatum	**6.9**		0	1	6.9		0
Isonychia sp.	**3.5**	15	52.5	21	73.5	8	28
Boyeria vinosa	**5.9**	1	5.9		0	2	11.8
Nasiaeschna pentacantha	**8.1**	1	8.1		0		0
Calopteryx sp.	**7.8**		0		0		0
Argia sp.	**8.2**	1	8.2	5	41	2	16.4
Enallagma sp.	**8.9**	1	8.9		0		0
Dromogomphus sp.	**5.9**		0		0		0
Dromogomphus spinosus	**5.1**		0		0		0
Gomphus sp.	**5.8**		0		0	1	5.8
Progomphus obscurus	**8.2**		0		0	2	16.4
Epicordulia princeps	**5.6**		0	1	5.6		0
Libellula sp.	**9.6**		0		0		0
Macromia sp.	**6.2**		0		0	2	12.4
Neurocordulia obsoleta	**5.2**		0	1	5.2	2	10.4
Pachydiplax longipennis	**9.9**		0		0		0
Perithemis tenera	**9.9**		0		0		0
Plathemis lydia	**10**		0		0		0
Perlesta placida sp. gp.	**4.7**	29	136.3	46	216.2	35	164.5
Corixidae	**9**		0		0		0
Belostoma sp.	**9.8**		0		0		0
Pelocoris sp.	**7**		0		0		0

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	**T.V.**	**Sta. 1**		**Sta. 3**		**Sta. 6**	
Ranatra sp.	**7.8**		0		0		0
Chauliodes pectinicornis	**9.6**		0		0		0
Corydalus cornutus	**5.2**	1	5.2		0		0
Sialis sp.	**7.2**		0		0		0
Cheumatopsyche sp.	**6.2**	2	12.4	2	12.4	3	18.6
Nectopsyche sp.	**2.9**		0		0		0
Nectopsyche exquisita	**4.1**		0		0		0
Nectopsyche pavida	**4.1**		0		0		0
Oecetis avara	**4.7**		0		0		0
Coptotomus sp.	**9.3**		0		0		0
Neoporus sp.	**8.6**	4	34.4	3	25.8	4	34.4
Ancyronyx variegata	**6.5**		0	3	19.5		0
Dubiraphia sp.	**5.9**		0		0		0
Dubiraphia vittata	**4.1**		0	3	12.3		0
Macronychus glabratus	**4.6**	9	41.4	49	225.4	13	59.8
Stenelmis sp.	**5.1**		0		0	1	5.1
Dineutus sp.	**5.5**	3	16.5	5	27.5	10	55
Peltodytes sp.	**8.7**	2	17.4		0		0
Berosus sp.	**8.4**		0		0		0
Sperchopsis tesselatus	**6.1**		0		0		0
Atrichopogon sp.	**6.5**		0		0		0
Bezzia/Palpomyia gp.	**6.9**		0		0		0
Ablabesmyia mallochi	**7.2**	1	7.2	2	14.4	4	28.8
Chironomus sp.	**9.6**		0	2	19.2		0
Cladopelma sp.	**3.5**		0		0		0
Cladotanytarsus sp.	**4.1**		0		0		0
Conchapelopia sp.	**8.4**		0		0		0
Corynoneura sp.	**6**	5	30	6	36	3	18
Cricotopus bicinctus	**8.5**	6	51	2	17	17	144.5
Cryptochironomus sp.	**6.4**	1	6.4		0		0
Dicrotendipes sp.	**8.1**		0	2	16.2	1	8.1
Dicrotendipes simpsoni	**10**		0		0	3	30
Labrundinia sp.	**5.9**	1	5.9		0		0
Nanocladius sp.	**7.1**		0		0		0
Orthocladius lignicola	**5.4**		0	1	5.4		0
Parametriocnemus sp.	**3.7**	1	3.7		0	18	66.6
Phaenopsectra obediens	**6.5**		0		0		0
Polypedilum fallax	**6.4**	2	12.8	13	83.2	1	6.4
Polypedilum illinoense	**9**		0		0	1	9
Potthastia sp.	**6.4**		0	6	38.4		0
Potthastia longimana	**6.5**		0		0		0
Procladius sp.	**9.1**		0		0		0
Pseudochironomus sp.	**5.4**		0	2	10.8		0
Rheocricotopus robacki	**7.3**		0		0	2	14.6
Rheotanytarsus sp.	**5.9**		0	1	5.9		0
Stenochironomus sp.	**6.5**		0		0	1	6.5
Tanytarsus sp.	**6.8**	7	47.6	1	6.8	13	88.4
Thienemanniella xena	**5.9**	1	5.9	4	23.6	21	123.9
Tribelos jucundum	**6.3**		0	8	50.4		0

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	**T.V.**	**Sta. 1**		**Sta. 3**		**Sta. 6**	
Tribelos sp.	**6.3**		0		0		0
Xenochironomus xenolabis	**7.1**		0	2	14.2		0
Xylotopus par	**6**	2	12		0		0
Zavrelimyia sp.	**9.1**		0		0	4	36.4
Anopheles sp.	**8.6**		0		0		0
Simulium sp.	**6**		0		0		0
Chrysops sp.	**6.7**		0		0		0
Tipula sp.	**7.3**		0		0		0
TOTAL NO. OF ORGANISMS		**127**	**754.7**	**266**	**1524**	**211**	**1288**
			5.943		5.73		6.102

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	**T.V.**	**Sta. 10**		**Sta. 13**	
Girardia (Dugesia) tigrina	**7.2**	2	14.4		0
Physella sp.	**8.8**	1	8.8		0
Enchytraeidae	**9.8**		0		0
Tubificidae w.h.c.	**7.1**	1	7.1		0
Branchiura sowerbyi	**8.3**		0		0
Tubificidae w.o.h.c.	**7.1**		0	2	14.2
Lumbriculidae	**7**	5	35	10	70
Batrachobdella phalera	**7.6**	1	7.6		0
Helobdella triserialis	**9.2**		0		0
Placobdella papillifera	**9**		0		0
Placobdella parasitica	**8.7**	1	8.7		0
Acariformes	**5.5**		0		0
Lebertiidae	**5.5**		0		0
Lebertia sp.	**5.5**		0		0
Caecidotea sp.	**9.1**		0		0
Lirceus sp.	**7.9**		0		0
Crangonyx sp.	**7.9**		0		0
Hyalella azteca	**7.8**	7	54.6	8	62.4
Cambaridae	**7.5**	1	7.5		0
Palaemonetes sp.	**7.1**	3	21.3	4	28.4
Baetis intercalaris	**7**		0	19	133
Centroptilum sp.	**6.6**		0		0
Pseudocloeon sp.	**4**		0	8	32
Caenis sp.	**7.4**	75	555	115	851
Hexagenia sp.	**4.9**	3	14.7		0
Ephemerella needhami	**0**		0		0
Ephemerella sp.	**2**		0		0
Stenacron interpunctatum	**6.9**	1	6.9		0
Isonychia sp.	**3.5**	2	7	7	24.5
Boyeria vinosa	**5.9**		0	2	11.8
Nasiaeschna pentacantha	**8.1**		0		0
Calopteryx sp.	**7.8**		0		0
Argia sp.	**8.2**	12	98.4	7	57.4
Enallagma sp.	**8.9**		0	6	53.4
Dromogomphus sp.	**5.9**		0		0
Dromogomphus spinosus	**5.1**	1	5.1		0
Gomphus sp.	**5.8**		0		0
Progomphus obscurus	**8.2**		0	4	32.8
Epicordulia princeps	**5.6**		0		0
Libellula sp.	**9.6**	3	28.8		0
Macromia sp.	**6.2**	1	6.2	1	6.2
Neurocordulia obsoleta	**5.2**	4	20.8	1	5.2
Pachydiplax longipennis	**9.9**		0		0
Perithemis tenera	**9.9**		0		0
Plathemis lydia	**10**		0		0
Perlesta placida sp. gp.	**4.7**	8	37.6	19	89.3
Corixidae	**9**		0		0
Belostoma sp.	**9.8**	2	19.6		0
Pelocoris sp.	**7**		0		0

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	T.V.	Sta. 10		Sta. 13	
Ranatra sp.	**7.8**	1	7.8		0
Chauliodes pectinicornis	**9.6**		0	1	9.6
Corydalus cornutus	**5.2**		0		0
Sialis sp.	**7.2**		0		0
Cheumatopsyche sp.	**6.2**		0	12	74.4
Nectopsyche sp.	**2.9**		0		0
Nectopsyche exquisita	**4.1**		0		0
Nectopsyche pavida	**4.1**		0		0
Oecetis avara	**4.7**		0		0
Coptotomus sp.	**9.3**		0		0
Neoporus sp.	**8.6**	14	120.4	12	103.2
Ancyronyx variegata	**6.5**		0	2	13
Dubiraphia sp.	**5.9**		0		0
Dubiraphia vittata	**4.1**	2	8.2		0
Macronychus glabratus	**4.6**	3	13.8	21	96.6
Stenelmis sp.	**5.1**		0		0
Dineutus sp.	**5.5**		0	12	66
Peltodytes sp.	**8.7**	11	95.7	17	147.9
Berosus sp.	**8.4**		0	2	16.8
Sperchopsis tesselatus	**6.1**	4	24.4	4	24.4
Atrichopogon sp.	**6.5**		0		0
Bezzia/Palpomyia gp.	**6.9**	1	6.9		0
Ablabesmyia mallochi	**7.2**	13	93.6	19	136.8
Chironomus sp.	**9.6**	1	9.6	1	9.6
Cladopelma sp.	**3.5**		0		0
Cladotanytarsus sp.	**4.1**		0	1	4.1
Conchapelopia sp.	**8.4**	2	16.8		0
Corynoneura sp.	**6**		0		0
Cricotopus bicinctus	**8.5**	3	25.5	90	765
Cryptochironomus sp.	**6.4**		0		0
Dicrotendipes sp.	**8.1**	1	8.1	1	8.1
Dicrotendipes simpsoni	**10**	3	30		0
Labrundinia sp.	**5.9**		0		0
Nanocladius sp.	**7.1**		0		0
Orthocladius lignicola	**5.4**		0		0
Parametriocnemus sp.	**3.7**		0	1	3.7
Phaenopsectra obediens	**6.5**	2	13		0
Polypedilum fallax	**6.4**	15	96	1	6.4
Polypedilum illinoense	**9**	12	108	19	171
Potthastia sp.	**6.4**		0		0
Potthastia longimana	**6.5**		0		0
Procladius sp.	**9.1**	4	36.4		0
Pseudochironomus sp.	**5.4**		0		0
Rheocricotopus robacki	**7.3**		0	1	7.3
Rheotanytarsus sp.	**5.9**		0		0
Stenochironomus sp.	**6.5**		0		0
Tanytarsus sp.	**6.8**	11	74.8	7	47.6
Thienemanniella xena	**5.9**	3	17.7	1	5.9
Tribelos jucundum	**6.3**		0		0

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	**T.V.**	**Sta. 10**		**Sta. 13**	
Tribelos sp.	**6.3**		0		0
Xenochironomus xenolabis	**7.1**		0		0
Xylotopus par	**6**		0		0
Zavrelimyia sp.	**9.1**		0		0
Anopheles sp.	**8.6**		0	1	8.6
Simulium sp.	**6**		0	2	12
Chrysops sp.	**6.7**		0	1	6.7
Tipula sp.	**7.3**	1	7.3	2	14.6
TOTAL NO. OF ORGANISMS		**241**	**1779.1**	**444**	**3230.9**
			7.3822		7.2768

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	T.V.	Sta. 15		Sta. 17		Sta. R1
Girardia (Dugesia) tigrina	**7.2**	2	14.4		0	
Physella sp.	**8.8**	1	8.8		0	
Enchytraeidae	**9.8**		0		0	
Tubificidae w.h.c.	**7.1**		0		0	
Branchiura sowerbyi	**8.3**		0		0	
Tubificidae w.o.h.c.	**7.1**	4	28.4		0	1
Lumbriculidae	**7**	2	14	8	56	5
Batrachobdella phalera	**7.6**		0		0	
Helobdella triserialis	**9.2**	1	9.2		0	
Placobdella papillifera	**9**		0		0	
Placobdella parasitica	**8.7**	2	17.4		0	2
Acariformes	**5.5**		0		0	
Lebertiidae	**5.5**		0		0	
Lebertia sp.	**5.5**		0		0	
Caecidotea sp.	**9.1**	1	9.1	4	36.4	
Lirceus sp.	**7.9**	1	7.9	3	23.7	
Crangonyx sp.	**7.9**		0	13	102.7	1
Hyalella azteca	**7.8**	13	101.4		0	
Cambaridae	**7.5**	2	15	1	7.5	1
Palaemonetes sp.	**7.1**	3	21.3		0	6
Baetis intercalaris	**7**	8	56		0	
Centroptilum sp.	**6.6**	1	6.6		0	
Pseudocloeon sp.	**4**	1	4		0	
Caenis sp.	**7.4**	87	643.8		0	8
Hexagenia sp.	**4.9**	1	4.9		0	2
Ephemerella needhami	**0**		0		0	
Ephemerella sp.	**2**		0		0	
Stenacron interpunctatum	**6.9**		0		0	2
Isonychia sp.	**3.5**	25	87.5		0	1
Boyeria vinosa	**5.9**	1	5.9		0	
Nasiaeschna pentacantha	**8.1**	1	8.1		0	
Calopteryx sp.	**7.8**		0		0	
Argia sp.	**8.2**	8	65.6		0	2
Enallagma sp.	**8.9**		0	1	8.9	3
Dromogomphus sp.	**5.9**		0		0	1
Dromogomphus spinosus	**5.1**		0		0	
Gomphus sp.	**5.8**		0		0	1
Progomphus obscurus	**8.2**	1	8.2		0	
Epicordulia princeps	**5.6**		0		0	
Libellula sp.	**9.6**	5	48		0	
Macromia sp.	**6.2**	1	6.2		0	
Neurocordulia obsoleta	**5.2**		0		0	
Pachydiplax longipennis	**9.9**	2	19.8		0	
Perithemis tenera	**9.9**	2	19.8		0	1
Plathemis lydia	**10**	2	20		0	
Perlesta placida sp. gp.	**4.7**	12	56.4	9	42.3	2
Corixidae	**9**	1	9		0	
Belostoma sp.	**9.8**	1	9.8		0	
Pelocoris sp.	**7**	1	7		0	

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	**T.V.**	**Sta. 15**		**Sta. 17**		**Sta. R1**
Ranatra sp.	**7.8**		0		0	1
Chauliodes pectinicornis	**9.6**		0		0	
Corydalus cornutus	**5.2**		0		0	
Sialis sp.	**7.2**	1	7.2		0	
Cheumatopsyche sp.	**6.2**	6	37.2		0	
Nectopsyche sp.	**2.9**	1	2.9		0	
Nectopsyche exquisita	**4.1**		0		0	
Nectopsyche pavida	**4.1**		0		0	
Oecetis avara	**4.7**		0		0	
Coptotomus sp.	**9.3**	1	9.3	1	9.3	
Neoporus sp.	**8.6**	11	94.6	15	129	1
Ancyronyx variegata	**6.5**		0		0	2
Dubiraphia sp.	**5.9**		0		0	
Dubiraphia vittata	**4.1**	2	8.2		0	
Macronychus glabratus	**4.6**	2	9.2		0	10
Stenelmis sp.	**5.1**		0		0	
Dineutus sp.	**5.5**	3	16.5		0	
Peltodytes sp.	**8.7**	22	191.4		0	3
Berosus sp.	**8.4**		0		0	
Sperchopsis tesselatus	**6.1**		0		0	
Atrichopogon sp.	**6.5**		0		0	
Bezzia/Palpomyia gp.	**6.9**		0		0	1
Ablabesmyia mallochi	**7.2**	11	79.2		0	3
Chironomus sp.	**9.6**	1	9.6	3	28.8	8
Cladopelma sp.	**3.5**		0		0	
Cladotanytarsus sp.	**4.1**		0		0	
Conchapelopia sp.	**8.4**		0		0	
Corynoneura sp.	**6**		0		0	4
Cricotopus bicinctus	**8.5**	4	34		0	6
Cryptochironomus sp.	**6.4**		0		0	
Dicrotendipes sp.	**8.1**	1	8.1		0	
Dicrotendipes simpsoni	**10**		0		0	4
Labrundinia sp.	**5.9**	1	5.9		0	1
Nanocladius sp.	**7.1**		0		0	1
Orthocladius lignicola	**5.4**		0		0	
Parametriocnemus sp.	**3.7**		0		0	
Phaenopsectra obediens	**6.5**		0		0	1
Polypedilum fallax	**6.4**		0		0	3
Polypedilum illinoense	**9**	1	9	1	9	
Potthastia sp.	**6.4**		0		0	
Potthastia longimana	**6.5**	1	6.5		0	
Procladius sp.	**9.1**	5	45.5	2	18.2	2
Pseudochironomus sp.	**5.4**		0		0	
Rheocricotopus robacki	**7.3**	1	7.3		0	
Rheotanytarsus sp.	**5.9**		0		0	
Stenochironomus sp.	**6.5**		0		0	
Tanytarsus sp.	**6.8**		0	2	13.6	1
Thienemanniella xena	**5.9**		0		0	
Tribelos jucundum	**6.3**		0	1	6.3	14

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	T.V.	Sta. 15		Sta. 17		Sta. R1
Tribelos sp.	**6.3**		0		0	
Xenochironomus xenolabis	**7.1**		0		0	2
Xylotopus par	**6**		0		0	
Zavrelimyia sp.	**9.1**		0	1	9.1	
Anopheles sp.	**8.6**		0		0	
Simulium sp.	**6**	1	6		0	
Chrysops sp.	**6.7**		0		0	
Tipula sp.	**7.3**		0		0	
TOTAL NO. OF ORGANISMS		**269**	**1921.1**	**65**	**500.8**	**107**
			7.1416		7.7046	

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	T.V.		Sta. R2		Sta. R3	
Girardia (Dugesia) tigrina	**7.2**	0		0	2	14.4
Physella sp.	**8.8**	0		0		0
Enchytraeidae	**9.8**	0		0		0
Tubificidae w.h.c.	**7.1**	0		0		0
Branchiura sowerbyi	**8.3**	0		0		0
Tubificidae w.o.h.c.	**7.1**	7.1		0		0
Lumbriculidae	**7**	35	1	7	2	14
Batrachobdella phalera	**7.6**	0		0		0
Helobdella triserialis	**9.2**	0		0		0
Placobdella papillifera	**9**	0		0		0
Placobdella parasitica	**8.7**	17.4		0		0
Acariformes	**5.5**	0		0		0
Lebertiidae	**5.5**	0		0		0
Lebertia sp.	**5.5**	0		0		0
Caecidotea sp.	**9.1**	0		0	1	9.1
Lirceus sp.	**7.9**	0		0		0
Crangonyx sp.	**7.9**	7.9		0		0
Hyalella azteca	**7.8**	0		0	1	7.8
Cambaridae	**7.5**	7.5		0		0
Palaemonetes sp.	**7.1**	42.6	1	7.1		0
Baetis intercalaris	**7**	0		0	16	112
Centroptilum sp.	**6.6**	0		0		0
Pseudocloeon sp.	**4**	0		0		0
Caenis sp.	**7.4**	59.2		0	71	525.4
Hexagenia sp.	**4.9**	9.8		0		0
Ephemerella needhami	**0**	0		0		0
Ephemerella sp.	**2**	0		0	2	4
Stenacron interpunctatum	**6.9**	13.8		0		0
Isonychia sp.	**3.5**	3.5		0	2	7
Boyeria vinosa	**5.9**	0	1	5.9	1	5.9
Nasiaeschna pentacantha	**8.1**	0		0		0
Calopteryx sp.	**7.8**	0		0	1	7.8
Argia sp.	**8.2**	16.4	4	32.8	16	131.2
Enallagma sp.	**8.9**	26.7		0	4	35.6
Dromogomphus sp.	**5.9**	5.9		0		0
Dromogomphus spinosus	**5.1**	0	1	5.1		0
Gomphus sp.	**5.8**	5.8		0	3	17.4
Progomphus obscurus	**8.2**	0		0	3	24.6
Epicordulia princeps	**5.6**	0		0		0
Libellula sp.	**9.6**	0		0		0
Macromia sp.	**6.2**	0		0	2	12.4
Neurocordulia obsoleta	**5.2**	0	2	10.4	3	15.6
Pachydiplax longipennis	**9.9**	0	1	9.9		0
Perithemis tenera	**9.9**	9.9		0		0
Plathemis lydia	**10**	0		0		0
Perlesta placida sp. gp.	**4.7**	9.4	13	61.1	12	56.4
Corixidae	**9**	0		0		0
Belostoma sp.	**9.8**	0		0		0
Pelocoris sp.	**7**	0		0		0

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	T.V.		Sta. R2		Sta. R3	
Ranatra sp.	**7.8**	7.8		0		0
Chauliodes pectinicornis	**9.6**	0		0		0
Corydalus cornutus	**5.2**	0		0		0
Sialis sp.	**7.2**	0		0		0
Cheumatopsyche sp.	**6.2**	0	2	12.4	8	49.6
Nectopsyche sp.	**2.9**	0		0		0
Nectopsyche exquisita	**4.1**	0		0		0
Nectopsyche pavida	**4.1**	0		0	1	4.1
Oecetis avara	**4.7**	0		0	1	4.7
Coptotomus sp.	**9.3**	0		0		0
Neoporus sp.	**8.6**	8.6		0	2	17.2
Ancyronyx variegata	**6.5**	13	2	13	6	39
Dubiraphia sp.	**5.9**	0	1	5.9		0
Dubiraphia vittata	**4.1**	0		0	2	8.2
Macronychus glabratus	**4.6**	46	6	27.6	30	138
Stenelmis sp.	**5.1**	0		0	1	5.1
Dineutus sp.	**5.5**	0		0		0
Peltodytes sp.	**8.7**	26.1	1	8.7	3	26.1
Berosus sp.	**8.4**	0		0		0
Sperchopsis tesselatus	**6.1**	0	1	6.1	1	6.1
Atrichopogon sp.	**6.5**	0		0	1	6.5
Bezzia/Palpomyia gp.	**6.9**	6.9		0		0
Ablabesmyia mallochi	**7.2**	21.6	1	7.2	8	57.6
Chironomus sp.	**9.6**	76.8	2	19.2		0
Cladopelma sp.	**3.5**	0	1	3.5		0
Cladotanytarsus sp.	**4.1**	0		0		0
Conchapelopia sp.	**8.4**	0		0		0
Corynoneura sp.	**6**	24	1	6	1	6
Cricotopus bicinctus	**8.5**	51		0	2	17
Cryptochironomus sp.	**6.4**	0		0		0
Dicrotendipes sp.	**8.1**	0		0	3	24.3
Dicrotendipes simpsoni	**10**	40		0	5	50
Labrundinia sp.	**5.9**	5.9		0	2	11.8
Nanocladius sp.	**7.1**	7.1		0		0
Orthocladius lignicola	**5.4**	0		0		0
Parametriocnemus sp.	**3.7**	0		0		0
Phaenopsectra obediens	**6.5**	6.5		0	1	6.5
Polypedilum fallax	**6.4**	19.2		0	32	204.8
Polypedilum illinoense	**9**	0	1	9		0
Potthastia sp.	**6.4**	0		0		0
Potthastia longimana	**6.5**	0		0		0
Procladius sp.	**9.1**	18.2		0	2	18.2
Pseudochironomus sp.	**5.4**	0		0		0
Rheocricotopus robacki	**7.3**	0		0		0
Rheotanytarsus sp.	**5.9**	0		0		0
Stenochironomus sp.	**6.5**	0		0		0
Tanytarsus sp.	**6.8**	6.8	2	13.6		0
Thienemanniella xena	**5.9**	0		0	1	5.9
Tribelos jucundum	**6.3**	88.2	3	18.9	2	12.6

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	**T.V.**		**Sta. R2**		**Sta. R3**	
Tribelos sp.	**6.3**	0		0		0
Xenochironomus xenolabis	**7.1**	14.2		0	2	14.2
Xylotopus par	**6**	0		0		0
Zavrelimyia sp.	**9.1**	0		0		0
Anopheles sp.	**8.6**	0		0		0
Simulium sp.	**6**	0	1	6		0
Chrysops sp.	**6.7**	0		0		0
Tipula sp.	**7.3**	0		0		0
TOTAL NO. OF ORGANISMS		**765.8**	**49**	**296.4**	**259**	**1734.1**
		7.157		6.049		6.6954

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	T.V.	Sta. R4	
Girardia (Dugesia) tigrina	**7.2**	1	7.2
Physella sp.	**8.8**		0
Enchytraeidae	**9.8**		0
Tubificidae w.h.c.	**7.1**		0
Branchiura sowerbyi	**8.3**		0
Tubificidae w.o.h.c.	**7.1**		0
Lumbriculidae	**7**		0
Batrachobdella phalera	**7.6**		0
Helobdella triserialis	**9.2**	1	9.2
Placobdella papillifera	**9**		0
Placobdella parasitica	**8.7**		0
Acariformes	**5.5**		0
Lebertiidae	**5.5**		0
Lebertia sp.	**5.5**	4	22
Caecidotea sp.	**9.1**		0
Lirceus sp.	**7.9**		0
Crangonyx sp.	**7.9**	1	7.9
Hyalella azteca	**7.8**	19	148.2
Cambaridae	**7.5**	1	7.5
Palaemonetes sp.	**7.1**	1	7.1
Baetis intercalaris	**7**	2	14
Centroptilum sp.	**6.6**	1	6.6
Pseudocloeon sp.	**4**	1	4
Caenis sp.	**7.4**	84	621.6
Hexagenia sp.	**4.9**		0
Ephemerella needhami	**0**		0
Ephemerella sp.	**2**		0
Stenacron interpunctatum	**6.9**		0
Isonychia sp.	**3.5**		0
Boyeria vinosa	**5.9**		0
Nasiaeschna pentacantha	**8.1**		0
Calopteryx sp.	**7.8**		0
Argia sp.	**8.2**	22	180.4
Enallagma sp.	**8.9**	7	62.3
Dromogomphus sp.	**5.9**		0
Dromogomphus spinosus	**5.1**		0
Gomphus sp.	**5.8**	2	11.6
Progomphus obscurus	**8.2**		0
Epicordulia princeps	**5.6**		0
Libellula sp.	**9.6**		0
Macromia sp.	**6.2**	1	6.2
Neurocordulia obsoleta	**5.2**	1	5.2
Pachydiplax longipennis	**9.9**	1	9.9
Perithemis tenera	**9.9**		0
Plathemis lydia	**10**		0
Perlesta placida sp. gp.	**4.7**	8	37.6
Corixidae	**9**		0
Belostoma sp.	**9.8**		0
Pelocoris sp.	**7**		0

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	T.V.	Sta. R4	
Ranatra sp.	**7.8**		0
Chauliodes pectinicornis	**9.6**		0
Corydalus cornutus	**5.2**		0
Sialis sp.	**7.2**		0
Cheumatopsyche sp.	**6.2**	6	37.2
Nectopsyche sp.	**2.9**		0
Nectopsyche exquisita	**4.1**	1	4.1
Nectopsyche pavida	**4.1**		0
Oecetis avara	**4.7**		0
Coptotomus sp.	**9.3**		0
Neoporus sp.	**8.6**	5	43
Ancyronyx variegata	**6.5**	5	32.5
Dubiraphia sp.	**5.9**	6	35.4
Dubiraphia vittata	**4.1**		0
Macronychus glabratus	**4.6**	17	78.2
Stenelmis sp.	**5.1**		0
Dineutus sp.	**5.5**		0
Peltodytes sp.	**8.7**	4	34.8
Berosus sp.	**8.4**	1	8.4
Sperchopsis tesselatus	**6.1**	1	6.1
Atrichopogon sp.	**6.5**		0
Bezzia/Palpomyia gp.	**6.9**		0
Ablabesmyia mallochi	**7.2**	4	28.8
Chironomus sp.	**9.6**	1	9.6
Cladopelma sp.	**3.5**		0
Cladotanytarsus sp.	**4.1**		0
Conchapelopia sp.	**8.4**		0
Corynoneura sp.	**6**	1	6
Cricotopus bicinctus	**8.5**		0
Cryptochironomus sp.	**6.4**	1	6.4
Dicrotendipes sp.	**8.1**	1	8.1
Dicrotendipes simpsoni	**10**	1	10
Labrundinia sp.	**5.9**		0
Nanocladius sp.	**7.1**		0
Orthocladius lignicola	**5.4**		0
Parametriocnemus sp.	**3.7**		0
Phaenopsectra obediens	**6.5**		0
Polypedilum fallax	**6.4**	1	6.4
Polypedilum illinoense	**9**	1	9
Potthastia sp.	**6.4**		0
Potthastia longimana	**6.5**		0
Procladius sp.	**9.1**	5	45.5
Pseudochironomus sp.	**5.4**	4	21.6
Rheocricotopus robacki	**7.3**		0
Rheotanytarsus sp.	**5.9**	1	5.9
Stenochironomus sp.	**6.5**		0
Tanytarsus sp.	**6.8**	6	40.8
Thienemanniella xena	**5.9**	2	11.8
Tribelos jucundum	**6.3**	2	12.6

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	**T.V.**	**Sta. R4**	
Tribelos sp.	**6.3**	4	25.2
Xenochironomus xenolabis	**7.1**		0
Xylotopus par	**6**		0
Zavrelimyia sp.	**9.1**		0
Anopheles sp.	**8.6**		0
Simulium sp.	**6**		0
Chrysops sp.	**6.7**		0
Tipula sp.	**7.3**		0
TOTAL NO. OF ORGANISMS		**239**	**1695.9**
			7.095816

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	T.V.	Sta. 1			Sta. 3			Sta. 6	
Girardia (Dugesia) tigrina	**7.2**	4	3	21.6	1	1	7.2	2	1
Physella sp.	**8.8**		0	0		0	0		0
Enchytraeidae	**9.8**	1	1	9.8		0	0		0
Tubificidae w.h.c.	**7.1**		0	0	1	1	7.1		0
Branchiura sowerbyi	**8.3**		0	0		0	0	2	1
Tubificidae w.o.h.c.	**7.1**		0	0	1	1	7.1		0
Lumbriculidae	**7**	5	3	21	5	3	21	6	3
Batrachobdella phalera	**7.6**		0	0		0	0		0
Helobdella triserialis	**9.2**		0	0		0	0		0
Placobdella papillifera	**9**		0	0		0	0	1	1
Placobdella parasitica	**8.7**		0	0		0	0	1	1
Acariformes	**5.5**		0	0	1	1	5.5		0
Lebertiidae	**5.5**		0	0		0	0		0
Lebertia sp.	**5.5**		0	0		0	0		0
Caecidotea sp.	**9.1**	1	1	9.1		0	0		0
Lirceus sp.	**7.9**		0	0		0	0		0
Crangonyx sp.	**7.9**	3	3	23.7		0	0	1	1
Hyalella azteca	**7.8**	1	1	7.8		0	0		0
Cambaridae	**7.5**		0	0	1	1	7.5		0
Palaemonetes sp.	**7.1**		0	0	3	3	21.3		0
Baetis intercalaris	**7**	2	1	7	7	3	21	4	3
Centroptilum sp.	**6.6**		0	0		0	0		0
Pseudocloeon sp.	**4**	2	1	4	6	3	12	2	1
Caenis sp.	**7.4**	12	10	74	47	10	74	18	10
Hexagenia sp.	**4.9**		0	0		0	0		0
Ephemerella needhami	**0**		0	0	1	1	0		0
Ephemerella sp.	**2**		0	0		0	0		0
Stenacron interpunctatum	**6.9**		0	0	1	1	6.9		0
Isonychia sp.	**3.5**	15	10	35	21	10	35	8	3
Boyeria vinosa	**5.9**	1	1	5.9		0	0	2	1
Nasiaeschna pentacantha	**8.1**	1	1	8.1		0	0		0
Calopteryx sp.	**7.8**		0	0		0	0		0
Argia sp.	**8.2**	1	1	8.2	5	3	24.6	2	1
Enallagma sp.	**8.9**	1	1	8.9		0	0		0
Dromogomphus sp.	**5.9**		0	0		0	0		0
Dromogomphus spinosus	**5.1**		0	0		0	0		0
Gomphus sp.	**5.8**		0	0		0	0	1	1
Progomphus obscurus	**8.2**		0	0		0	0	2	1
Epicordulia princeps	**5.6**		0	0	1	1	5.6		0
Libellula sp.	**9.6**		0	0		0	0		0
Macromia sp.	**6.2**		0	0		0	0	2	1
Neurocordulia obsoleta	**5.2**		0	0	1	1	5.2	2	1
Pachydiplax longipennis	**9.9**		0	0		0	0		0
Perithemis tenera	**9.9**		0	0		0	0		0
Plathemis lydia	**10**		0	0		0	0		0
Perlesta placida sp. gp.	**4.7**	29	10	47	46	10	47	35	10
Corixidae	**9**		0	0		0	0		0
Belostoma sp.	**9.8**		0	0		0	0		0
Pelocoris sp.	**7**		0	0		0	0		0

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	T.V.	Sta. 1			Sta. 3			Sta. 6	
Ranatra sp.	**7.8**		0	0		0	0		0
Chauliodes pectinicornis	**9.6**		0	0		0	0		0
Corydalus cornutus	**5.2**	1	1	5.2		0	0		0
Sialis sp.	**7.2**		0	0		0	0		0
Cheumatopsyche sp.	**6.2**	2	1	6.2	2	1	6.2	3	3
Nectopsyche sp.	**2.9**		0	0		0	0		0
Nectopsyche exquisita	**4.1**		0	0		0	0		0
Nectopsyche pavida	**4.1**		0	0		0	0		0
Oecetis avara	**4.7**		0	0		0	0		0
Coptotomus sp.	**9.3**		0	0		0	0		0
Neoporus sp.	**8.6**	4	3	25.8	3	3	25.8	4	3
Ancyronyx variegata	**6.5**		0	0	3	3	19.5		0
Dubiraphia sp.	**5.9**		0	0		0	0		0
Dubiraphia vittata	**4.1**		0	0	3	3	12.3		0
Macronychus glabratus	**4.6**	9	3	13.8	49	10	46	13	10
Stenelmis sp.	**5.1**		0	0		0	0	1	1
Dineutus sp.	**5.5**	3	3	16.5	5	3	16.5	10	10
Peltodytes sp.	**8.7**	2	1	8.7		0	0		0
Berosus sp.	**8.4**		0	0		0	0		0
Sperchopsis tesselatus	**6.1**		0	0		0	0		0
Atrichopogon sp.	**6.5**		0	0		0	0		0
Bezzia/Palpomyia gp.	**6.9**		0	0		0	0		0
Ablabesmyia mallochi	**7.2**	1	1	7.2	2	1	7.2	4	3
Chironomus sp.	**9.6**		0	0	2	1	9.6		0
Cladopelma sp.	**3.5**		0	0		0	0		0
Cladotanytarsus sp.	**4.1**		0	0		0	0		0
Conchapelopia sp.	**8.4**		0	0		0	0		0
Corynoneura sp.	**6**	5	3	18	6	3	18	3	3
Cricotopus bicinctus	**8.5**	6	3	25.5	2	1	8.5	17	10
Cryptochironomus sp.	**6.4**	1	1	6.4		0	0		0
Dicrotendipes sp.	**8.1**		0	0	2	1	8.1	1	1
Dicrotendipes simpsoni	**10**		0	0		0	0	3	3
Labrundinia sp.	**5.9**	1	1	5.9		0	0		0
Nanocladius sp.	**7.1**		0	0		0	0		0
Orthocladius lignicola	**5.4**		0	0	1	1	5.4		0
Parametriocnemus sp.	**3.7**	1	1	3.7		0	0	18	10
Phaenopsectra obediens	**6.5**		0	0		0	0		0
Polypedilum fallax	**6.4**	2	1	6.4	13	10	64	1	1
Polypedilum illinoense	**9**		0	0		0	0	1	1
Potthastia sp.	**6.4**		0	0	6	3	19.2		0
Potthastia longimana	**6.5**		0	0		0	0		0
Procladius sp.	**9.1**		0	0		0	0		0
Pseudochironomus sp.	**5.4**		0	0	2	1	5.4		0
Rheocricotopus robacki	**7.3**		0	0		0	0	2	1
Rheotanytarsus sp.	**5.9**		0	0	1	1	5.9		0
Stenochironomus sp.	**6.5**		0	0		0	0	1	1
Tanytarsus sp.	**6.8**	7	3	20.4	1	1	6.8	13	10
Thienemanniella xena	**5.9**	1	1	5.9	4	3	17.7	21	10
Tribelos jucundum	**6.3**		0	0	8	3	18.9		0

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	**T.V.**	**Sta. 1**			**Sta. 3**			**Sta. 6**	
Tribelos sp.	**6.3**		0	0		0	0		0
Xenochironomus xenolabis	**7.1**		0	0	2	1	7.1		0
Xylotopus par	**6**	2	1	6		0	0		0
Zavrelimyia sp.	**9.1**		0	0		0	0	4	3
Anopheles sp.	**8.6**		0	0		0	0		0
Simulium sp.	**6**		0	0		0	0		0
Chrysops sp.	**6.7**		0	0		0	0		0
Tipula sp.	**7.3**		0	0		0	0		0
TOTAL NO. OF ORGANISMS		**127**	**76**	**472.7**	**266**	**108**	**636.1**	**211**	**125**
				6.22			5.89		

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	**T.V.**		**Sta. 10**			**Sta. 13**		
Girardia (Dugesia) tigrina	**7.2**	7.2	2	1	7.2		0	0
Physella sp.	**8.8**	0	1	1	8.8		0	0
Enchytraeidae	**9.8**	0		0	0		0	0
Tubificidae w.h.c.	**7.1**	0	1	1	7.1		0	0
Branchiura sowerbyi	**8.3**	8.3		0	0		0	0
Tubificidae w.o.h.c.	**7.1**	0		0	0	2	1	7.1
Lumbriculidae	**7**	21	5	3	21	10	10	70
Batrachobdella phalera	**7.6**	0	1	1	7.6		0	0
Helobdella triserialis	**9.2**	0		0	0		0	0
Placobdella papillifera	**9**	9		0	0		0	0
Placobdella parasitica	**8.7**	8.7	1	1	8.7		0	0
Acariformes	**5.5**	0		0	0		0	0
Lebertiidae	**5.5**	0		0	0		0	0
Lebertia sp.	**5.5**	0		0	0		0	0
Caecidotea sp.	**9.1**	0		0	0		0	0
Lirceus sp.	**7.9**	0		0	0		0	0
Crangonyx sp.	**7.9**	7.9		0	0		0	0
Hyalella azteca	**7.8**	0	7	3	23.4	8	3	23.4
Cambaridae	**7.5**	0	1	1	7.5		0	0
Palaemonetes sp.	**7.1**	0	3	3	21.3	4	3	21.3
Baetis intercalaris	**7**	21		0	0	19	10	70
Centroptilum sp.	**6.6**	0		0	0		0	0
Pseudocloeon sp.	**4**	4		0	0	8	3	12
Caenis sp.	**7.4**	74	75	10	74	115	10	74
Hexagenia sp.	**4.9**	0	3	3	14.7		0	0
Ephemerella needhami	**0**	0		0	0		0	0
Ephemerella sp.	**2**	0		0	0		0	0
Stenacron interpunctatum	**6.9**	0	1	1	6.9		0	0
Isonychia sp.	**3.5**	10.5	2	1	3.5	7	3	10.5
Boyeria vinosa	**5.9**	5.9		0	0	2	1	5.9
Nasiaeschna pentacantha	**8.1**	0		0	0		0	0
Calopteryx sp.	**7.8**	0		0	0		0	0
Argia sp.	**8.2**	8.2	12	10	82	7	3	24.6
Enallagma sp.	**8.9**	0		0	0	6	3	26.7
Dromogomphus sp.	**5.9**	0		0	0		0	0
Dromogomphus spinosus	**5.1**	0	1	1	5.1		0	0
Gomphus sp.	**5.8**	5.8		0	0		0	0
Progomphus obscurus	**8.2**	8.2		0	0	4	3	24.6
Epicordulia princeps	**5.6**	0		0	0		0	0
Libellula sp.	**9.6**	0	3	3	28.8		0	0
Macromia sp.	**6.2**	6.2	1	1	6.2	1	1	6.2
Neurocordulia obsoleta	**5.2**	5.2	4	3	15.6	1	1	5.2
Pachydiplax longipennis	**9.9**	0		0	0		0	0
Perithemis tenera	**9.9**	0		0	0		0	0
Plathemis lydia	**10**	0		0	0		0	0
Perlesta placida sp. gp.	**4.7**	47	8	3	14.1	19	10	47
Corixidae	**9**	0		0	0		0	0
Belostoma sp.	**9.8**	0	2	1	9.8		0	0
Pelocoris sp.	**7**	0		0	0		0	0

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	T.V.		Sta. 10			Sta. 13		
Ranatra sp.	**7.8**	0	1	1	7.8		0	0
Chauliodes pectinicornis	**9.6**	0		0	0	1	1	9.6
Corydalus cornutus	**5.2**	0		0	0		0	0
Sialis sp.	**7.2**	0		0	0		0	0
Cheumatopsyche sp.	**6.2**	18.6		0	0	12	10	62
Nectopsyche sp.	**2.9**	0		0	0		0	0
Nectopsyche exquisita	**4.1**	0		0	0		0	0
Nectopsyche pavida	**4.1**	0		0	0		0	0
Oecetis avara	**4.7**	0		0	0		0	0
Coptotomus sp.	**9.3**	0		0	0		0	0
Neoporus sp.	**8.6**	25.8	14	10	86	12	10	86
Ancyronyx variegata	**6.5**	0		0	0	2	1	6.5
Dubiraphia sp.	**5.9**	0		0	0		0	0
Dubiraphia vittata	**4.1**	0	2	1	4.1		0	0
Macronychus glabratus	**4.6**	46	3	3	13.8	21	10	46
Stenelmis sp.	**5.1**	5.1		0	0		0	0
Dineutus sp.	**5.5**	55		0	0	12	10	55
Peltodytes sp.	**8.7**	0	11	10	87	17	10	87
Berosus sp.	**8.4**	0		0	0	2	1	8.4
Sperchopsis tesselatus	**6.1**	0	4	3	18.3	4	3	18.3
Atrichopogon sp.	**6.5**	0		0	0		0	0
Bezzia/Palpomyia gp.	**6.9**	0	1	1	6.9		0	0
Ablabesmyia mallochi	**7.2**	21.6	13	10	72	19	10	72
Chironomus sp.	**9.6**	0	1	1	9.6	1	1	9.6
Cladopelma sp.	**3.5**	0		0	0		0	0
Cladotanytarsus sp.	**4.1**	0		0	0	1	1	4.1
Conchapelopia sp.	**8.4**	0	2	1	8.4		0	0
Corynoneura sp.	**6**	18		0	0		0	0
Cricotopus bicinctus	**8.5**	85	3	3	25.5	90	10	85
Cryptochironomus sp.	**6.4**	0		0	0		0	0
Dicrotendipes sp.	**8.1**	8.1	1	1	8.1	1	1	8.1
Dicrotendipes simpsoni	**10**	30	3	3	30		0	0
Labrundinia sp.	**5.9**	0		0	0		0	0
Nanocladius sp.	**7.1**	0		0	0		0	0
Orthocladius lignicola	**5.4**	0		0	0		0	0
Parametriocnemus sp.	**3.7**	37		0	0	1	1	3.7
Phaenopsectra obediens	**6.5**	0	2	1	6.5		0	0
Polypedilum fallax	**6.4**	6.4	15	10	64	1	1	6.4
Polypedilum illinoense	**9**	9	12	10	90	19	10	90
Potthastia sp.	**6.4**	0		0	0		0	0
Potthastia longimana	**6.5**	0		0	0		0	0
Procladius sp.	**9.1**	0	4	3	27.3		0	0
Pseudochironomus sp.	**5.4**	0		0	0		0	0
Rheocricotopus robacki	**7.3**	7.3		0	0	1	1	7.3
Rheotanytarsus sp.	**5.9**	0		0	0		0	0
Stenochironomus sp.	**6.5**	6.5		0	0		0	0
Tanytarsus sp.	**6.8**	68	11	10	68	7	3	20.4
Thienemanniella xena	**5.9**	59	3	3	17.7	1	1	5.9
Tribelos jucundum	**6.3**	0		0	0		0	0

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	**T.V.**		**Sta. 10**			**Sta. 13**		
Tribelos sp.	**6.3**	0		0	0		0	0
Xenochironomus xenolabis	**7.1**	0		0	0		0	0
Xylotopus par	**6**	0		0	0		0	0
Zavrelimyia sp.	**9.1**	27.3		0	0		0	0
Anopheles sp.	**8.6**	0		0	0	1	1	8.6
Simulium sp.	**6**	0		0	0	2	1	6
Chrysops sp.	**6.7**	0		0	0	1	1	6.7
Tipula sp.	**7.3**	0	1	1	7.3	2	1	7.3
TOTAL NO. OF ORGANISMS		**791.8**	**241**	**138**	**1031.6**	**444**	**165**	**1148.4**
		6.334			7.4754			6.96

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	**T.V.**	**Sta. 15**			**Sta. 17**			**Sta. R1**
Girardia (Dugesia) tigrina	**7.2**	2	1	7.2		0	0	
Physella sp.	**8.8**	1	1	8.8		0	0	
Enchytraeidae	**9.8**		0	0		0	0	
Tubificidae w.h.c.	**7.1**		0	0		0	0	
Branchiura sowerbyi	**8.3**		0	0		0	0	
Tubificidae w.o.h.c.	**7.1**	4	3	21.3		0	0	1
Lumbriculidae	**7**	2	1	7	8	3	21	5
Batrachobdella phalera	**7.6**		0	0		0	0	
Helobdella triserialis	**9.2**	1	1	9.2		0	0	
Placobdella papillifera	**9**		0	0		0	0	
Placobdella parasitica	**8.7**	2	1	8.7		0	0	2
Acariformes	**5.5**		0	0		0	0	
Lebertiidae	**5.5**		0	0		0	0	
Lebertia sp.	**5.5**		0	0		0	0	
Caecidotea sp.	**9.1**	1	1	9.1	4	3	27.3	
Lirceus sp.	**7.9**	1	1	7.9	3	3	23.7	
Crangonyx sp.	**7.9**		0	0	13	10	79	1
Hyalella azteca	**7.8**	13	10	78		0	0	
Cambaridae	**7.5**	2	1	7.5	1	1	7.5	1
Palaemonetes sp.	**7.1**	3	3	21.3		0	0	6
Baetis intercalaris	**7**	8	3	21		0	0	
Centroptilum sp.	**6.6**	1	1	6.6		0	0	
Pseudocloeon sp.	**4**	1	1	4		0	0	
Caenis sp.	**7.4**	87	10	74		0	0	8
Hexagenia sp.	**4.9**	1	1	4.9		0	0	2
Ephemerella needhami	**0**		0	0		0	0	
Ephemerella sp.	**2**		0	0		0	0	
Stenacron interpunctatum	**6.9**		0	0		0	0	2
Isonychia sp.	**3.5**	25	10	35		0	0	1
Boyeria vinosa	**5.9**	1	1	5.9		0	0	
Nasiaeschna pentacantha	**8.1**	1	1	8.1		0	0	
Calopteryx sp.	**7.8**		0	0		0	0	
Argia sp.	**8.2**	8	3	24.6		0	0	2
Enallagma sp.	**8.9**		0	0	1	1	8.9	3
Dromogomphus sp.	**5.9**		0	0		0	0	1
Dromogomphus spinosus	**5.1**		0	0		0	0	
Gomphus sp.	**5.8**		0	0		0	0	1
Progomphus obscurus	**8.2**	1	1	8.2		0	0	
Epicordulia princeps	**5.6**		0	0		0	0	
Libellula sp.	**9.6**	5	3	28.8		0	0	
Macromia sp.	**6.2**	1	1	6.2		0	0	
Neurocordulia obsoleta	**5.2**		0	0		0	0	
Pachydiplax longipennis	**9.9**	2	1	9.9		0	0	
Perithemis tenera	**9.9**	2	1	9.9		0	0	1
Plathemis lydia	**10**	2	1	10		0	0	
Perlesta placida sp. gp.	**4.7**	12	10	47	9	3	14.1	2
Corixidae	**9**	1	1	9		0	0	
Belostoma sp.	**9.8**	1	1	9.8		0	0	
Pelocoris sp.	**7**	1	1	7		0	0	

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	**T.V.**	**Sta. 15**			**Sta. 17**			**Sta. R1**
Ranatra sp.	**7.8**		0	0		0	0	1
Chauliodes pectinicornis	**9.6**		0	0		0	0	
Corydalus cornutus	**5.2**		0	0		0	0	
Sialis sp.	**7.2**	1	1	7.2		0	0	
Cheumatopsyche sp.	**6.2**	6	3	18.6		0	0	
Nectopsyche sp.	**2.9**	1	1	2.9		0	0	
Nectopsyche exquisita	**4.1**		0	0		0	0	
Nectopsyche pavida	**4.1**		0	0		0	0	
Oecetis avara	**4.7**		0	0		0	0	
Coptotomus sp.	**9.3**	1	1	9.3	1	1	9.3	
Neoporus sp.	**8.6**	11	10	86	15	10	86	1
Ancyronyx variegata	**6.5**		0	0		0	0	2
Dubiraphia sp.	**5.9**		0	0		0	0	
Dubiraphia vittata	**4.1**	2	1	4.1		0	0	
Macronychus glabratus	**4.6**	2	1	4.6		0	0	10
Stenelmis sp.	**5.1**		0	0		0	0	
Dineutus sp.	**5.5**	3	3	16.5		0	0	
Peltodytes sp.	**8.7**	22	10	87		0	0	3
Berosus sp.	**8.4**		0	0		0	0	
Sperchopsis tesselatus	**6.1**		0	0		0	0	
Atrichopogon sp.	**6.5**		0	0		0	0	
Bezzia/Palpomyia gp.	**6.9**		0	0		0	0	1
Ablabesmyia mallochi	**7.2**	11	10	72		0	0	3
Chironomus sp.	**9.6**	1	1	9.6	3	3	28.8	8
Cladopelma sp.	**3.5**		0	0		0	0	
Cladotanytarsus sp.	**4.1**		0	0		0	0	
Conchapelopia sp.	**8.4**		0	0		0	0	
Corynoneura sp.	**6**		0	0		0	0	4
Cricotopus bicinctus	**8.5**	4	3	25.5		0	0	6
Cryptochironomus sp.	**6.4**		0	0		0	0	
Dicrotendipes sp.	**8.1**	1	1	8.1		0	0	
Dicrotendipes simpsoni	**10**		0	0		0	0	4
Labrundinia sp.	**5.9**	1	1	5.9		0	0	1
Nanocladius sp.	**7.1**		0	0		0	0	1
Orthocladius lignicola	**5.4**		0	0		0	0	
Parametriocnemus sp.	**3.7**		0	0		0	0	
Phaenopsectra obediens	**6.5**		0	0		0	0	1
Polypedilum fallax	**6.4**		0	0		0	0	3
Polypedilum illinoense	**9**	1	1	9	1	1	9	
Potthastia sp.	**6.4**		0	0		0	0	
Potthastia longimana	**6.5**	1	1	6.5		0	0	
Procladius sp.	**9.1**	5	3	27.3	2	1	9.1	2
Pseudochironomus sp.	**5.4**		0	0		0	0	
Rheocricotopus robacki	**7.3**	1	1	7.3		0	0	
Rheotanytarsus sp.	**5.9**		0	0		0	0	
Stenochironomus sp.	**6.5**		0	0		0	0	
Tanytarsus sp.	**6.8**		0	0	2	1	6.8	1
Thienemanniella xena	**5.9**		0	0		0	0	
Tribelos jucundum	**6.3**		0	0	1	1	6.3	14

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	T.V.	Sta. 15			Sta. 17			Sta. R1
Tribelos sp.	**6.3**		0	0		0	0	
Xenochironomus xenolabis	**7.1**		0	0		0	0	2
Xylotopus par	**6**		0	0		0	0	
Zavrelimyia sp.	**9.1**		0	0	1	1	9.1	
Anopheles sp.	**8.6**		0	0		0	0	
Simulium sp.	**6**	1	1	6		0	0	
Chrysops sp.	**6.7**		0	0		0	0	
Tipula sp.	**7.3**		0	0		0	0	
TOTAL NO. OF ORGANISMS		**269**	**130**	**929.3**	**65**	**43**	**345.9**	**107**
				7.1485			8.0442	

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	T.V.			Sta. R2			Sta. R3	
Girardia (Dugesia) tigrina	**7.2**	0	0		0	0	2	1
Physella sp.	**8.8**	0	0		0	0		0
Enchytraeidae	**9.8**	0	0		0	0		0
Tubificidae w.h.c.	**7.1**	0	0		0	0		0
Branchiura sowerbyi	**8.3**	0	0		0	0		0
Tubificidae w.o.h.c.	**7.1**	1	7.1		0	0		0
Lumbriculidae	**7**	3	21	1	1	7	2	1
Batrachobdella phalera	**7.6**	0	0		0	0		0
Helobdella triserialis	**9.2**	0	0		0	0		0
Placobdella papillifera	**9**	0	0		0	0		0
Placobdella parasitica	**8.7**	1	8.7		0	0		0
Acariformes	**5.5**	0	0		0	0		0
Lebertiidae	**5.5**	0	0		0	0		0
Lebertia sp.	**5.5**	0	0		0	0		0
Caecidotea sp.	**9.1**	0	0		0	0	1	1
Lirceus sp.	**7.9**	0	0		0	0		0
Crangonyx sp.	**7.9**	1	7.9		0	0		0
Hyalella azteca	**7.8**	0	0		0	0	1	1
Cambaridae	**7.5**	1	7.5		0	0		0
Palaemonetes sp.	**7.1**	3	21.3	1	1	7.1		0
Baetis intercalaris	**7**	0	0		0	0	16	10
Centroptilum sp.	**6.6**	0	0		0	0		0
Pseudocloeon sp.	**4**	0	0		0	0		0
Caenis sp.	**7.4**	3	22.2		0	0	71	10
Hexagenia sp.	**4.9**	1	4.9		0	0		0
Ephemerella needhami	**0**	0	0		0	0		0
Ephemerella sp.	**2**	0	0		0	0	2	1
Stenacron interpunctatum	**6.9**	1	6.9		0	0		0
Isonychia sp.	**3.5**	1	3.5		0	0	2	1
Boyeria vinosa	**5.9**	0	0	1	1	5.9	1	1
Nasiaeschna pentacantha	**8.1**	0	0		0	0		0
Calopteryx sp.	**7.8**	0	0		0	0	1	1
Argia sp.	**8.2**	1	8.2	4	3	24.6	16	10
Enallagma sp.	**8.9**	3	26.7		0	0	4	3
Dromogomphus sp.	**5.9**	1	5.9		0	0		0
Dromogomphus spinosus	**5.1**	0	0	1	1	5.1		0
Gomphus sp.	**5.8**	1	5.8		0	0	3	3
Progomphus obscurus	**8.2**	0	0		0	0	3	3
Epicordulia princeps	**5.6**	0	0		0	0		0
Libellula sp.	**9.6**	0	0		0	0		0
Macromia sp.	**6.2**	0	0		0	0	2	1
Neurocordulia obsoleta	**5.2**	0	0	2	1	5.2	3	3
Pachydiplax longipennis	**9.9**	0	0	1	1	9.9		0
Perithemis tenera	**9.9**	1	9.9		0	0		0
Plathemis lydia	**10**	0	0		0	0		0
Perlesta placida sp. gp.	**4.7**	1	4.7	13	10	47	12	10
Corixidae	**9**	0	0		0	0		0
Belostoma sp.	**9.8**	0	0		0	0		0
Pelocoris sp.	**7**	0	0		0	0		0

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	T.V.			Sta. R2			Sta. R3	
Ranatra sp.	**7.8**	1	7.8		0	0		0
Chauliodes pectinicornis	**9.6**	0	0		0	0		0
Corydalus cornutus	**5.2**	0	0		0	0		0
Sialis sp.	**7.2**	0	0		0	0		0
Cheumatopsyche sp.	**6.2**	0	0	2	1	6.2	8	3
Nectopsyche sp.	**2.9**	0	0		0	0		0
Nectopsyche exquisita	**4.1**	0	0		0	0		0
Nectopsyche pavida	**4.1**	0	0		0	0	1	1
Oecetis avara	**4.7**	0	0		0	0	1	1
Coptotomus sp.	**9.3**	0	0		0	0		0
Neoporus sp.	**8.6**	1	8.6		0	0	2	1
Ancyronyx variegata	**6.5**	1	6.5	2	1	6.5	6	3
Dubiraphia sp.	**5.9**	0	0	1	1	5.9		0
Dubiraphia vittata	**4.1**	0	0		0	0	2	1
Macronychus glabratus	**4.6**	10	46	6	3	13.8	30	10
Stenelmis sp.	**5.1**	0	0		0	0	1	1
Dineutus sp.	**5.5**	0	0		0	0		0
Peltodytes sp.	**8.7**	3	26.1	1	1	8.7	3	3
Berosus sp.	**8.4**	0	0		0	0		0
Sperchopsis tesselatus	**6.1**	0	0	1	1	6.1	1	1
Atrichopogon sp.	**6.5**	0	0		0	0	1	1
Bezzia/Palpomyia gp.	**6.9**	1	6.9		0	0		0
Ablabesmyia mallochi	**7.2**	3	21.6	1	1	7.2	8	3
Chironomus sp.	**9.6**	3	28.8	2	1	9.6		0
Cladopelma sp.	**3.5**	0	0	1	1	3.5		0
Cladotanytarsus sp.	**4.1**	0	0		0	0		0
Conchapelopia sp.	**8.4**	0	0		0	0		0
Corynoneura sp.	**6**	3	18	1	1	6	1	1
Cricotopus bicinctus	**8.5**	3	25.5		0	0	2	1
Cryptochironomus sp.	**6.4**	0	0		0	0		0
Dicrotendipes sp.	**8.1**	0	0		0	0	3	3
Dicrotendipes simpsoni	**10**	3	30		0	0	5	3
Labrundinia sp.	**5.9**	1	5.9		0	0	2	1
Nanocladius sp.	**7.1**	1	7.1		0	0		0
Orthocladius lignicola	**5.4**	0	0		0	0		0
Parametriocnemus sp.	**3.7**	0	0		0	0		0
Phaenopsectra obediens	**6.5**	1	6.5		0	0	1	1
Polypedilum fallax	**6.4**	3	19.2		0	0	32	10
Polypedilum illinoense	**9**	0	0	1	1	9		0
Potthastia sp.	**6.4**	0	0		0	0		0
Potthastia longimana	**6.5**	0	0		0	0		0
Procladius sp.	**9.1**	1	9.1		0	0	2	1
Pseudochironomus sp.	**5.4**	0	0		0	0		0
Rheocricotopus robacki	**7.3**	0	0		0	0		0
Rheotanytarsus sp.	**5.9**	0	0		0	0		0
Stenochironomus sp.	**6.5**	0	0		0	0		0
Tanytarsus sp.	**6.8**	1	6.8	2	1	6.8		0
Thienemanniella xena	**5.9**	0	0		0	0	1	1
Tribelos jucundum	**6.3**	10	63	3	3	18.9	2	1

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	T.V.			Sta. R2			Sta. R3	
Tribelos sp.	**6.3**	0	0		0	0		0
Xenochironomus xenolabis	**7.1**	1	7.1		0	0	2	1
Xylotopus par	**6**	0	0		0	0		0
Zavrelimyia sp.	**9.1**	0	0		0	0		0
Anopheles sp.	**8.6**	0	0		0	0		0
Simulium sp.	**6**	0	0	1	1	6		0
Chrysops sp.	**6.7**	0	0		0	0		0
Tipula sp.	**7.3**	0	0		0	0		0
TOTAL NO. OF ORGANISMS		**75**	**522.7**	**49**	**37**	**226**	**259**	**114**
			6.9693			6.1081		

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	T.V.		Sta. R4		
Girardia (Dugesia) tigrina	**7.2**	7.2	1	1	7.2
Physella sp.	**8.8**	0		0	0
Enchytraeidae	**9.8**	0		0	0
Tubificidae w.h.c.	**7.1**	0		0	0
Branchiura sowerbyi	**8.3**	0		0	0
Tubificidae w.o.h.c.	**7.1**	0		0	0
Lumbriculidae	**7**	7		0	0
Batrachobdella phalera	**7.6**	0		0	0
Helobdella triserialis	**9.2**	0	1	1	9.2
Placobdella papillifera	**9**	0		0	0
Placobdella parasitica	**8.7**	0		0	0
Acariformes	**5.5**	0		0	0
Lebertiidae	**5.5**	0		0	0
Lebertia sp.	**5.5**	0	4	3	16.5
Caecidotea sp.	**9.1**	9.1		0	0
Lirceus sp.	**7.9**	0		0	0
Crangonyx sp.	**7.9**	0	1	1	7.9
Hyalella azteca	**7.8**	7.8	19	10	78
Cambaridae	**7.5**	0	1	1	7.5
Palaemonetes sp.	**7.1**	0	1	1	7.1
Baetis intercalaris	**7**	70	2	1	7
Centroptilum sp.	**6.6**	0	1	1	6.6
Pseudocloeon sp.	**4**	0	1	1	4
Caenis sp.	**7.4**	74	84	10	74
Hexagenia sp.	**4.9**	0		0	0
Ephemerella needhami	**0**	0		0	0
Ephemerella sp.	**2**	2		0	0
Stenacron interpunctatum	**6.9**	0		0	0
Isonychia sp.	**3.5**	3.5		0	0
Boyeria vinosa	**5.9**	5.9		0	0
Nasiaeschna pentacantha	**8.1**	0		0	0
Calopteryx sp.	**7.8**	7.8		0	0
Argia sp.	**8.2**	82	22	10	82
Enallagma sp.	**8.9**	26.7	7	3	26.7
Dromogomphus sp.	**5.9**	0		0	0
Dromogomphus spinosus	**5.1**	0		0	0
Gomphus sp.	**5.8**	17.4	2	1	5.8
Progomphus obscurus	**8.2**	24.6		0	0
Epicordulia princeps	**5.6**	0		0	0
Libellula sp.	**9.6**	0		0	0
Macromia sp.	**6.2**	6.2	1	1	6.2
Neurocordulia obsoleta	**5.2**	15.6	1	1	5.2
Pachydiplax longipennis	**9.9**	0	1	1	9.9
Perithemis tenera	**9.9**	0		0	0
Plathemis lydia	**10**	0		0	0
Perlesta placida sp. gp.	**4.7**	47	8	3	14.1
Corixidae	**9**	0		0	0
Belostoma sp.	**9.8**	0		0	0
Pelocoris sp.	**7**	0		0	0

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	T.V.		Sta. R4		
Ranatra sp.	**7.8**	0		0	0
Chauliodes pectinicornis	**9.6**	0		0	0
Corydalus cornutus	**5.2**	0		0	0
Sialis sp.	**7.2**	0		0	0
Cheumatopsyche sp.	**6.2**	18.6	6	3	18.6
Nectopsyche sp.	**2.9**	0		0	0
Nectopsyche exquisita	**4.1**	0	1	1	4.1
Nectopsyche pavida	**4.1**	4.1		0	0
Oecetis avara	**4.7**	4.7		0	0
Coptotomus sp.	**9.3**	0		0	0
Neoporus sp.	**8.6**	8.6	5	3	25.8
Ancyronyx variegata	**6.5**	19.5	5	3	19.5
Dubiraphia sp.	**5.9**	0	6	3	17.7
Dubiraphia vittata	**4.1**	4.1		0	0
Macronychus glabratus	**4.6**	46	17	10	46
Stenelmis sp.	**5.1**	5.1		0	0
Dineutus sp.	**5.5**	0		0	0
Peltodytes sp.	**8.7**	26.1	4	3	26.1
Berosus sp.	**8.4**	0	1	1	8.4
Sperchopsis tesselatus	**6.1**	6.1	1	1	6.1
Atrichopogon sp.	**6.5**	6.5		0	0
Bezzia/Palpomyia gp.	**6.9**	0		0	0
Ablabesmyia mallochi	**7.2**	21.6	4	3	21.6
Chironomus sp.	**9.6**	0	1	1	9.6
Cladopelma sp.	**3.5**	0		0	0
Cladotanytarsus sp.	**4.1**	0		0	0
Conchapelopia sp.	**8.4**	0		0	0
Corynoneura sp.	**6**	6	1	1	6
Cricotopus bicinctus	**8.5**	8.5		0	0
Cryptochironomus sp.	**6.4**	0	1	1	6.4
Dicrotendipes sp.	**8.1**	24.3	1	1	8.1
Dicrotendipes simpsoni	**10**	30	1	1	10
Labrundinia sp.	**5.9**	5.9		0	0
Nanocladius sp.	**7.1**	0		0	0
Orthocladius lignicola	**5.4**	0		0	0
Parametriocnemus sp.	**3.7**	0		0	0
Phaenopsectra obediens	**6.5**	6.5		0	0
Polypedilum fallax	**6.4**	64	1	1	6.4
Polypedilum illinoense	**9**	0	1	1	9
Potthastia sp.	**6.4**	0		0	0
Potthastia longimana	**6.5**	0		0	0
Procladius sp.	**9.1**	9.1	5	3	27.3
Pseudochironomus sp.	**5.4**	0	4	3	16.2
Rheocricotopus robacki	**7.3**	0		0	0
Rheotanytarsus sp.	**5.9**	0	1	1	5.9
Stenochironomus sp.	**6.5**	0		0	0
Tanytarsus sp.	**6.8**	0	6	3	20.4
Thienemanniella xena	**5.9**	5.9	2	1	5.9
Tribelos jucundum	**6.3**	6.3	2	1	6.3

BENTHIC MACROINVERTEB RATES COLLECTED FROM LOWELL MILL DAM, JOHNSTON CO., NC, 5/7/08.

SPECIES	**T.V.**		**Sta. R4**		
Tribelos sp.	**6.3**	0	4	3	18.9
Xenochironomus xenolabis	**7.1**	7.1		0	0
Xylotopus par	**6**	0		0	0
Zavrelimyia sp.	**9.1**	0		0	0
Anopheles sp.	**8.6**	0		0	0
Simulium sp.	**6**	0		0	0
Chrysops sp.	**6.7**	0		0	0
Tipula sp.	**7.3**	0		0	0
TOTAL NO. OF ORGANISMS		**758.4**	**239**	**104**	**725.2**
		6.6526			6.973077

APPENDIX C: Lowell Dam Removal Year-3 Monitoring Report (The Catena Group)

LOWELL DAM REMOVAL YEAR-3
AQUATIC SPECIES MONITORING REPORT

Little River Watershed Restoration Site Neuse River Basin Cataloging Unit 03020201

Prepared for:

Restoration Systems LLC
1101 Haynes Street, Suite 107
Raleigh, NC 27604

Prepared by:

The Catena Group, Inc.
410-B Millstone Drive
Hillsborough, NC 27278

November 19, 2008

Thomas E. Dickinson

Thomas E. Dickinson

EXECUTIVE SUMMARY

The removal of Lowell Dam on the Little River by Restoration Systems, LLC (RS) is projected to result in the restoration of approximately 37,000 linear feet of river and tributaries within the Neuse River Basin. This effort is expected to restore habitat for mussels, fish (including anadromous species), and other lotic adapted aquatic species. Lowell Mill Dam was recognized as an impediment to anadromous species spawning runs and its removal was designated by the North Carolina Dam Removal Task Force (DRTF) as the highest priority for dam removal in North Carolina (DRTF 2001).

The restoration success criteria established by the DRTF and the goals of RS required documenting the diversity of aquatic fauna and characterizing habitat within the reservoir pool created by the dam, and the subsequent monitoring of changes in faunal composition and habitat following dam removal. The Catena Group Inc. (TCG) was retained by RS in 2005, to conduct the pre-dam removal aquatic species surveys for freshwater mussels and clams, aquatic snails, aquatic salamanders, and freshwater fish, the results of which are provided in the Lowell Pre-Removal Survey Report (April 04, 2006). The river's transition from lentic to lotic conditions is expected to result in broad shifts in the distribution of aquatic species, including mussels, clams and snails; however, life cycles and other natural history characteristics predict some lag in the time between actual habitat conversion to large-scale dispersal and recruitment to these restored habitats.

Following the dam removal in January 2006, a five-year monitoring plan of aquatic communities (freshwater mussels, aquatic snails, aquatic salamanders and freshwater fish communities) and anadromous species was developed.

The monitoring plan for 2006 (Year-1 Monitoring) focused on anadromous species surveys and fish community surveys patterned after the North Carolina Division of Water Quality (NCDWQ) Standard Operating Procedure Biological Monitoring Stream Fish Community Assessment (NCDENR 2001) and implemented to document changes in fish communities in the Little River over time following dam removal. This evaluation results in a numerical score called the North Carolina Index of Biotic Integrity (NCIBI) being assigned to the water body. As part of the 5-Year Monitoring Plan, the scores at each site can be compared over time following dam removal to assess changes in fish species composition, which is reflective of water quality changes. Additionally, for freshwater mussels, a specific quantitative study was designed to monitor potential adverse sedimentation effects resulting from the dam's removal.

The results of the 2006 Year-1 monitoring studies, which are provided in the Lowell Dam Removal Year- 1 Monitoring Report (September 11, 2006), demonstrated that migration runs of the anadromous American shad (*Alosa sapidissima*) had been restored throughout the Little River main stem, upstream to the existing Atkinson's Mill Dam, as well as within the lower portion of Buffalo Creek. Further, the fish community surveys indicated lotic adapted aquatic communities are developing in the former reservoir pool following dam removal. The quantitative freshwater mussel study suggested that release of sediment from the dam had some adverse effect on the mussel beds below the former dam; however, further monitoring was needed to determine the extent of the impacts.

The monitoring plan for 2007 (Year-2 Monitoring) focused on anadromous species surveys in Buffalo Creek, Little Buffalo Creek and Long Branch, as well as continued quantitative mussel community monitoring. This effort again confirmed migrating American shad upstream of the former Lowell Dam in the Little River and the lower portion of Buffalo Creek, however, shad were not found in either the middle, or upper sections of Buffalo Creek, Long Branch, or Little Buffalo Creek (Year-2 Monitoring Report October 15, 2007). The quantitative mussel study indicated that while little mortality could be associated with the dam removal, mark/recapture (recovery) rates of the tagged mussels decreased dramatically with increased proximity to the former dam site. The lower recovery rate was believed to be primarily caused by a wedge of sediment that was released when the dam was removed and gradually migrated downstream.

For the 2008 monitoring (Year-3 Monitoring), efforts focused on repeating the fish community surveys conducted during Year-1 Monitoring as well as continued quantitative mussel community monitoring. The results of which follow:

<u>Fish Community Monitoring:</u>
Fish surveys were conducted on August 19 and 21, 2008, at all of the Year-1 monitoring sampling sites, using the same methodologies as in 2006. Again, TCG Site 9 (Impoundment 6) was omitted due to the water level being too deep to follow the sampling protocol The NCIBI scores of the Year-3 monitoring surveys indicate a general trend of improvement from Year-1, with an average score increase of 2.7 points. However, three of the six sites showed increases in score, while three showed decreases. The most significant example of a decrease was at site 2, where the score declined six points, although it still maintained a “good” score of 48. The most significant increase observed was at site 3, where an eight point increase pushed the rating from a “fair” score of 38 to an “excellent” score of 54. At site 3, an increase in species richness was the biggest driver for the higher Year-3 score (eight species), although corresponding increases in numbers and trophic guild were also factors. The decrease at site 2 was mostly related to a slight decrease in species richness (down by two species) that lowered the score of some metrics and changes in trophic guild. Theses differences are likely only reflective of seasonal and sampling variation and should be considered minor as the score still remains in the “good” range.

<u>Quantitative Mussel Community Monitoring:</u>
Freshwater mussels were quantitatively sampled in the Little River at varying intervals (approximately 30, 200 and 400 meters) below the Lowell dam, as well as at an upstream control site (Micro Road/SR 2130) prior to dam removal.

Transects were resurveyed approximately three months and fifteen months after dam removal, which assessed initial mortality resulting from dam removal and detected movement of mussels within and outside the transects. Untagged (immigrated) mussels which were captured during the 3-month and 15-month monitoring were measured, assigned a tag ("newly tagged"), and returned to their respective quadrates as before. Mortality was assessed by the number of recovered dead, tagged shells. Recapture of individual mussels two meters (e.g. two quadrates) or greater in any direction from their original quadrate was considered movement. Mussels recovered in quadrates adjacent to their original ones were not considered to have moved, since exact location of replacement within a respective quadrate was not recorded during the initial sampling.

A total of 605 freshwater mussels were tagged in the four study transects prior to dam removal. The eastern elliptio (*Elliptio complanata*) accounted for 98% (591) and six other species comprised the remaining 2% (14). Significant freshwater mussel mortality attributable to the dam removal was not evident during the 3-month, or the 15-month quantitative mussel survey monitoring. However; mark/recapture (recovery) rates of the tagged mussels decreased dramatically with increased proximity to the former dam site; 45.2% at 30 meters, 59.4% at 200 meters, and 80.4% at 400 meters. The lower recovery rates are believed to be primarily caused by a wedge of sediment that was released when the dam was removed and gradually migrated downstream, as the recovery rate at the upstream control remained high. In addition, a large number of fresh-dead untagged mussels were found at the three transects below the former dam (65, 137 and 97 respectively) compared to only 5 at the upstream control transect.

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1.0 INTRODUCTION

The removal of Lowell Dam on the Little River within the Neuse River Basin by Restoration Systems LLC (RS) is projected to result in the restoration of more than 34,990 linear feet of river and tributaries under the former reservoir pool. The project is expected to restore significant riverine habitat for mussels, fish (including anadromous fish), and other lotic aquatic species documented within the Little River, as well as providing a mitigation bank for future activities within the Neuse River Basin.

Based on the restoration success criteria established by U.S. Fish and Wildlife Service (USFWS) and the goals of RS, documenting the effectiveness of the restoration initiative requires that the aquatic fauna that occurred within the reservoir pool be identified and then monitored for changes in composition after the dam is removed. The Catena Group Inc. (TCG) was retained by RS in 2005 to conduct pre-removal aquatic species surveys at selected locations within the former reservoir pool, as well as at a number of upstream and downstream locations. The aquatic fauna sampled include freshwater mussels and clams, aquatic snails, aquatic salamanders, and freshwater fish. The results of the pre-removal surveys were presented in a report submitted to RS on April 04, 2006 (Lowell Pre-removal Survey Report).

A five-year monitoring plan of aquatic species communities (freshwater mussels, aquatic snails, aquatic salamanders and freshwater fish) and anadromous fish has been initiated to evaluate the success of the dam removal.

The monitoring plan for 2006 (Year-1 Monitoring) focused on anadromous species surveys and fish community surveys patterned after the North Carolina Division of Water Quality (NCDWQ) Standard Operating Procedure Biological Monitoring Stream Fish Community Assessment (NCDENR 2001) and implemented to document changes in fish communities in the Little River over time following dam removal. This evaluation results in a numerical score called the North Carolina Index of Biotic Integrity (NCIBI) being assigned to the water body. The NCIBI evaluates 12 metrics (parameters) pertaining to species richness and composition, trophic composition, and fish abundance and condition. As part of the 5-Year Monitoring Plan, the scores at each site can be compared over time following dam removal to assess changes in fish species composition, which is reflective of water quality changes. Additionally, for freshwater mussels, a specific quantitative study was designed to monitor potential adverse sedimentation effects resulting from the dam's removal.

The results of the 2006 Year-1 monitoring studies, which are provided in the Lowell Dam Removal Year- 1 Monitoring Report (September 11, 2006), demonstrated that migration runs of the anadromous American shad (*Alosa sapidissima*) had been restored throughout the Little River main stem, upstream to the existing Atkinson's Mill Dam, as well as within the lower portion of Buffalo Creek. Further, the fish community surveys indicated lotic adapted aquatic communities were developing in the former reservoir pool following dam removal. The quantitative freshwater mussel study suggested that release of sediment from the dam had some adverse effect on the mussel beds below the former dam; however, further monitoring was needed to determine the extent of the impacts.

The monitoring plan for 2007 (Year-2 Monitoring) focused on anadromous species surveys in Buffalo Creek, Little Buffalo Creek and Long Branch, as well as continued quantitative mussel community monitoring. This effort again confirmed migrating American shad upstream of the former Lowell Dam in the Little River and the lower portion of Buffalo Creek, however, shad were not found in either the middle, or upper sections of Buffalo Creek, Long Branch, or Little Buffalo Creek (Year-2 Monitoring Report October 15, 2007). The quantitative mussel study indicated that while little mortality could be associated with the dam removal, mark/recapture (recovery) rates of the tagged mussels decreased dramatically with increased proximity to the former dam site. The lower recovery rate was believed to be primarily caused by a wedge of sediment that was released when the dam was removed and gradually migrated downstream.

For the 2008 monitoring (Year-3 Monitoring), efforts focused on repeating the fish community surveys conducted during Year-1 Monitoring as well as continued quantitative mussel community monitoring. The results of which follow:

The fish community survey plan involves conducting aquatic species surveys at the same six stations within the former reservoir pool that were sampled during the pre-removal and Year-1 fish surveys (Table 1 & Figure 1). Fish surveys were not conducted at sites 6 (CX-12) and 7 (CX 16) during the pre-removal surveys due to water depth.

Table 1. Post Dam Removal Permanent Monitoring Survey Locations

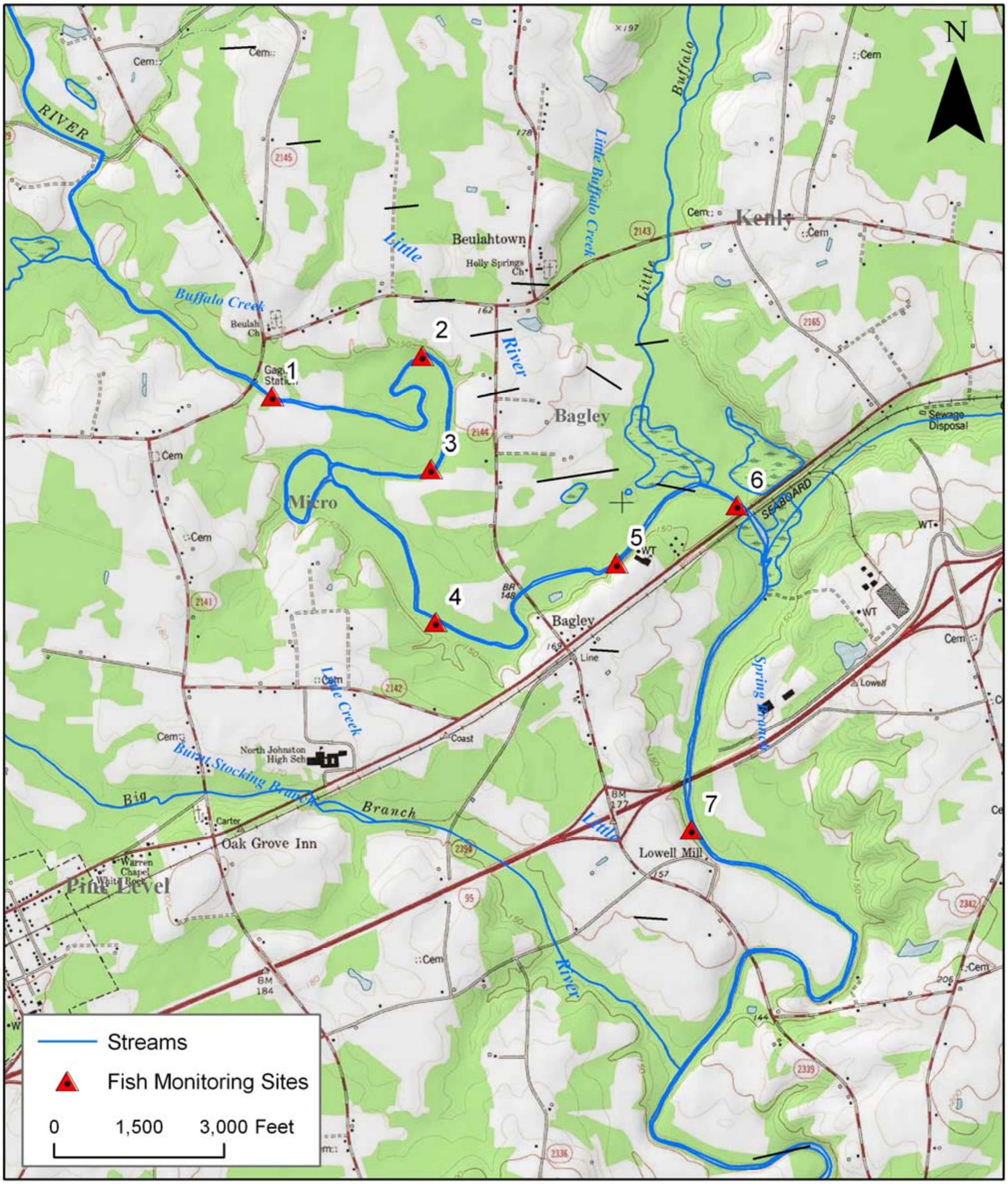
Site #	Corresponding TCG Pre-removal Site #	GPS Location
1	4- Impoundment 1 (CX-1)	35.58878ºN, -78.18713ºW
2	5-Impoundment 2 (CX-3)	35.59071ºN, -78.17819ºW
3	6-Impoundment 3 (CX-4)	35.58519ºN, -78.17772ºW
4	7-Impoundment 4 (CX-7)	35.57771ºN, -78.17752ºW
5	8-Impoundment 5 (CX-10)	35.58051ºN, -78.16672ºW
6	9-Impoundment 6 (CX-12)	35.58329ºN, -78.15951ºW
7	10-Impoundment 7 (CX-16)	35.56751ºN, -78.16239ºW

CX denotes corresponding Cross Sections being evaluated by RS

The quantitative mussel sampling involved repeating monitoring surveys at three transects (30-meter, 200-meter and 400-meter below the former dam) and one upstream control site. The results of the Year-3 fish community monitoring are presented in this report. The results of these studies will factor into the decision for future monitoring.

2.0 FISH COMMUNITY SURVEY EFFORTS

Year-3 freshwater fish surveys were conducted on August 19 and 21, 2008, at all of the sites listed in Table 1 and depicted in Figure 1, with the exception of TCG Site 9 (Impoundment 6), which was omitted due to the water level being too deep to follow the



The Catena Group	**Site Map** Lowell Dam Removal Third-Year Fish Monitoring Johnston County, North Carolina	Date: October 2008 Scale: As Shown Job No.: 3235	Figure 1

sampling protocol. These Year-3 efforts were carried out by TCG personnel Tom Dickinson, Shay Garriock, Kate Montieth, and Chris Sheats.

2.1 Fish Community Survey Methodology

A fish sampling protocol patterned after the North Carolina Division of Water Quality (NCDWQ) Standard Operating Procedure Biological Monitoring Stream Fish Community Assessment (NCDENR 2001) was developed specifically for this project, to document changes in fish communities in the Little River following dam removal. The NCDWQ Assessment assesses water quality based on an evaluation of the fish community. This evaluation results in a numerical score called the North Carolina Index of Biotic Integrity (NCIBI) being assigned to the water body. The NCIBI evaluates 12 metrics (parameters) pertaining to species richness and composition, trophic composition, and fish abundance and condition. Each metric value is converted into a score of 1, 3 or 5, with 5 representing conditions expected for a relatively undisturbed reference stream in the specific river basin, or ecoregion (NCDENR 2001). NCIBI reference indices for the Outer Piedmont of the Neuse River Basin have been developed. The sampling protocol states that the NCIBI is applicable only in streams within ecoregions that have established reference indices, and only if collection methodology and data analysis is strictly followed.

The purpose of applying the NCIBI methodology to the post-removal monitoring is not necessarily to compare scores generated at each of the monitoring sites with other streams in the reference ecoregion, but rather to compare scores generated at the monitoring sites overtime to monitor changes at each site in response to the dam removal. Specifically, the scores generated during the Year-1 monitoring surveys are compared to scores generated using the same methodologies under similar conditions (time of year, water levels, etc) in future years.

A standard 600 linear feet of stream at each of the survey sites listed in Table 1 (except Site 6:CX 12) and depicted in Figure 1 was sampled for fish community parameters using a 4-person survey team, with two backpack electroshocker units, and dipnets. Survey methodology, data analysis, and interpretation (scoring) essentially follow procedures outlined in Standard Operating Procedures Biological Monitoring Stream Fish Community Assessment (NCDENR 2001).

3.0 FISH COMMUNITY SURVEY RESULTS

It was apparent from field observations and fish surveys that the habitats within the former reservoir pool created by the Lowell Dam are continuing the process of reverting to lotic conditions, as a total of 34 fish species were captured within the former reservoir pool (Tables 2-7).

3.1 Species Composition and Site Descriptions

Brief descriptions of current habitat conditions and the results of the fish surveys for each site are provided below.

3.2 Site 1 (CX-1)

The habitat is characterized by shallow runs and pools with a dominantly sand substrate. Gravel is present in the runs and rocky cobble is occasionally present along clay banks. Large vegetated sand bars and woody debris remain common throughout. Accumulations of silt and detritus occur in the pools and slack-water areas downstream of bars and along the river banks. In addition to the fish species located, one two-toed amphiuma (*Amphiuma means*), and two Neuse River waterdog (*Necturus lewisii*) were captured during the surveys.

Table 2. Site 1 (CX-1): Fish Species Found Yr-3

Scientific Name	Common Name	#	# of Size Classes
Anguilla rostrata	American eel	10	4
Aphredoderus sayanus	pirate perch	13	3
Cyprinella analostanus	satinfin shiner	24	6
Esox americanus	redfin pickerel	3	2
Etheostoma nigrum	johnny darter	6	2
Etheostoma olmstedi	tessellated darter	74	4
Etheostoma vitreum	glassy darter	1	1
Gambusia holbrookii	eastern mosquitofish	29	3
Lepisosteus osseus	longnose gar	3	2
Lepomis auritus	redbreast sunfish	58	6
Lepomis macrochirus	bluegill	40	5
Lepomis microlophus	redear sunfish	4	3
Luxilus albeolus	white shiner	1	1
Micropterus salmoides	largemouth bass	2	1
Moxostoma colapsum	notchlip redhorse	2	1
Nocomis raneyi	bull chub	1	1
Notropis amoenus	comely shiner	4	2
Notropis cummingsae	dusky shiner	2	1
Notropis hudsonius	spottail shiner	20	3
Notropis procne	swallowtail shiner	67	4
Noturus gyrinus	margined madtom	1	1
Percina nevisense	chainback darter	17	3
Percina roanoka	Roanoke darter	15	4
Pomoxis nigromaculatus	black crappie	1	1
Scartomyzon cervinus	black jumprock	1	1

3.3 Site 2 (CX-3)

This site occurs in a fairly sharp bend in the river. Habitat consists of a long shallow riffle run area with a consolidated sand and gravel substrate with scattered cobble. Prior to dam removal, this site was considered to provide the "best" aquatic species habitat within the reservoir pool. High quality habitat conditions remains at this site.

Table 3. Site 2 (CX-3): Fish Species Found Yr-3

Scientific Name	Common Name	#	# of Size Classes
Anguilla rostrata	American eel	12	4
Aphredoderus sayanus	pirate perch	15	2
Cyprinella analostanus	satinfin shiner	26	5
Enneacanthus gloriosus	bluespotted sunfish	2	2
Esox americanus	redfin pickerel	2	2
Etheostoma nigrum	johnny darter	4	2
Etheostoma olmstedi	tessellated darter	47	4
Etheostoma vitreum	glassy darter	1	1
Gambusia holbrookii	eastern mosquitofish	28	3
Hypentellium nigricans	northern hogsucker	5	2
Ictalurus punctatus	channel catfish	1	1
Lepisosteus osseus	longnose gar	2	2
Lepomis auritus	redbreast sunfish	61	6
Lepomis gulosus	warmouth	1	1
Lepomis macrochirus	bluegill	25	5
Lepomis microlophus	redear sunfish	3	2
Luxilus albeolus	white shiner	2	2
Micropterus salmoides	largemouth bass	7	3
Nocomis leptocephalus	bluehead chub	3	2
Nocomis raneyi	bull chub	1	1
Notropis amoenus	comely shiner	12	2
Notropis procne	swallowtail shiner	36	4
Noturus gyrinus	margined madtom	12	4
Percina nevisense	chainback darter	14	3
Percina roanoka	Roanoke darter	20	3

3.4 Site 3 (CX-4)

Site 3 is located below a wide bend of the river with clay banks and bedrock outcrops. The habitat is characterized as a series of riffles and runs separated by shallow pools. The substrate is dominated by rocky cobble and sand, with large accumulations of woody debris and a fair amount of fine sediments (silt and mud) in the pools. Stream banks are actively eroding, although some re-vegetation of this area was observed this year.

Table 4. Site 3 (CX-4): Fish Species Found Yr-3

Scientific Name	Common Name	#	# of Size Classes
Anguilla rostrata	American eel	9	3
Aphredoderus sayanus	pirate perch	5	2
Enneacanthus gloriosus	bluespotted sunfish	1	1
Etheostoma nigrum	johnny darter	2	2
Etheostoma olmstedi	tessellated darter	24	3
Gambusia holbrookii	eastern mosquitofish	43	3
Ictalurus punctatus	channel catfish	2	1
Lepisosteus osseus	longnose gar	2	2
Lepomis auritus	redbreast sunfish	50	6
Lepomis gulosus	warmouth	1	1
Lepomis macrochirus	Bluegill	24	4
Lepomis microlophus	redear sunfish	2	2
Micropterus salmoides	largemouth bass	2	2
Moxostoma macrolepidotum	shorthead redhorse	1	1
Notropis amoenus	comely shiner	1	1
Notropis cummingsae	dusky shiner	2	1
Notropis hudsonius	spottail shiner	25	3
Notropis procne	swallowtail shiner	32	4
Noturus gyrinus	margined madtom	3	2
Percina nevisense	chainback darter	11	2
Percina roanoka	Roanoke darter	27	3

3.5 Site 4 (CX-7)

This site occurs in a long straight run of the river. Multiple small riffles formed by woody debris occur throughout, separating pool habitats. The substrate is sand and mud in slack-water areas below bars and along the river banks. Vegetated shallow sand bars and woody debris are common. Approximately 0.5 miles upstream of this site, a larger beaver dam and associated impoundment has become well established.

Table 5. Site 4 (CX-7): Fish Species Found Yr-3

Scientific Name	Common Name	#	# of Size Classes
Ameiurus platycephalus	flat bullhead	4	3
Anguilla rostrata	American eel	3	3
Aphredoderus sayanus	pirate perch	1	1
Cyprinella analostanus	satinfin shiner	53	5
Etheostoma nigrum	johnny darter	1	1
Etheostoma olmstedi	tessellated darter	15	2
Etheostoma vitreum	glassy darter	2	1
Gambusia holbrookii	eastern mosquitofish	20	3
Lepomis auritus	redbreast sunfish	43	6
Lepomis macrochirus	bluegill	8	3

Scientific Name	Common Name	#	# of Size Classes
Lepomis microlophus	redear sunfish	5	2
Luxilus albeolus	white shiner	4	3
Micropterus salmoides	largemouth bass	7	3
Nocomis leptocephalus	bluehead chub	2	2
Nocomis raneyi	bull chub	2	2
Notropis amoenus	comely shiner	1	1
Notropis hudsonius	spottail shiner	1	1
Notropis procne	swallowtail shiner	98	4
Noturus gyrinus	margined madtom	2	1
Percina nevisense	chainback darter	10	2
Percina roanoka	Roanoke darter	8	3
Pomoxis nigromaculatus	black crappie	1	1
Scartomyzon cervinus	black jumprock	2	1

3.6 Site 5 (CX-10)

This site, just downstream of the WRC boat landing located off of SR 2144 (Weaver Road), has a short run and small riffles formed by woody debris. Deep pools occur up and downstream of the site. The substrate is sand with silt deposits in slack-water areas below bars and along the river banks. A steep rocky slope occurs along the right descending side. Vegetated sand bars and accumulations of woody debris are common.

Table 6. Site 5 (CX-10): Fish Species Found Yr-3

Scientific Name	Common Name	#	# of Size Classes
Anguilla rostrata	American eel	6	3
Aphredoderus sayanus	pirate perch	7	2
Cyprinella analostanus	satinfin shiner	40	5
Enneacanthus gloriosus	bluespotted sunfish	1	1
Esox americanus	redfin pickerel	2	2
Etheostoma nigrum	johnny darter	2	1
Etheostoma olmstedi	tessellated darter	21	3
Etheostoma vitreum	glassy darter	6	2
Gambusia holbrookii	eastern mosquitofish	35	3
Ictalurus punctatus	channel catfish	2	1
Lepomis auritus	redbreast sunfish	103	6
Lepomis macrochirus	bluegill	34	4
Lepomis microlophus	redear sunfish	16	3
Micropterus salmoides	largemouth bass	15	3
Moxostoma colapsum	notchlip redhorse	4	1
Notropis amoenus	comely shiner	17	4
Notropis hudsonius	spottail shiner	30	3
Notropis petersoni	coastal shiner	1	1
Notropis procne	swallowtail shiner	64	4

Scientific Name	Common Name	#	# of Size Classes
Noturus gyrinus	margined madtom	3	2
Percina nevisense	chainback darter	6	2
Percina roanoka	Roanoke darter	23	3
Scartomyzon cervinus	black jumprock	1	1

3.7 Site 6 (CX-12)

Site 6 is in the vicinity of the US 301 crossing of the river. During the pre-removal survey, the habitat was characterized as a deep (max. depth 10 feet) slack-water run of the river, with substrate composed of sand and occasional rock. Large amounts of woody debris and fallen trees were evident. Habitat conditions have changed little following dam removal, which continues into Year-3. Although it is now shallower, the site remains a 2 to 5 foot deep slack-water pool/run, with large amounts of woody debris. This site was not sampled in Year-3 because there was not a 600 foot wadeable stretch that could be sampled using the NCIBI methodology.

3.8 Site 7 (CX-16)

This site is the location of the former Lowell Dam, extending upstream 600 feet through a fairly long, straight, and narrow section of the river. Well vegetated sand bars occur throughout that confined the channel to mostly run and riffle habitat. A few shallow pools occur below bars and woody debris piles. Substrate consisted of coarse sand, gravel, and silt accumulations behind bars and in pools. Moderate accumulations of woody debris were scattered throughout.

Table 7. Site 7 (CX- 16): Fish Species Found Yr-3

Scientific Name	Common Name	#	# of Size Classes
Anguilla rostrata	American eel	4	2
Aphredoderus sayanus	pirate perch	1	1
Cyprinella analostanus	satinfin shiner	111	5
Etheostoma olmstedi	tessellated darter	10	2
Etheostoma vitreum	glassy darter	7	2
Gambusia holbrookii	eastern mosquitofish	30	3
Lepomis auritus	redbreast sunfish	174	5
Lepomis macrochirus	bluegill	8	4
Lepomis microlophus	redear sunfish	6	3
Luxilus albeolus	white shiner	9	3
Micropterus salmoides	largemouth bass	24	3
Nocomis leptocephalus	bluehead chub	4	2
Nocomis raneyi	bull chub	2	1
Notropis amoenus	comely shiner	60	4
Notropis hudsonius	spottail shiner	30	3
Notropis petersoni	coastal shiner	3	1
Notropis procne	swallowtail shiner	132	5
Noturus gyrinus	margined madtom	4	2

Scientific Name	Common Name	#	# of Size Classes
Percina nevisense	chainback darter	20	2
Percina roanoka	Roanoke darter	8	2
Pylodictis olivaris	flathead catish	1	1

3.9 NCIBI Scores

The NCIBI scores of the Year-3 monitoring surveys range from 42 (Good-Fair) at Site 4 to 56 (Excellent) at Site 3 (Table 8). Compared to Year-1 scores, a general trend of improvement is evident in Year -3 with an average score increase of 2.7 points. Score sheets for each site are included in Appendix A.

Table 8. Comparison of Year-1 and Year-3 NCIBI Scores Permanent Monitoring Locations

Site #	Year -1 NCIBI Score	Year -3 NCIBI Score
1 (CX-1)	46 (Good)	50 (Good)
2 (CX-3)	54 (Excellent)	48 (Good)
3 (CX-4)	38 (Fair)	56(Excellent)
4 (CX-7)	46 (Good)	42 (Good-Fair)
5 (CX-10)	44 (Good-Fair)	50 (Good)
6 (CX-12)	Not Sampled	Not Sampled
7 (CX-16)	48 (Good)	46 (Good)
Average	46	48.7

CX denotes corresponding Cross Sections being evaluated by RS

4.0 FISH COMMUNITY SURVEY DISCUSSION/CONCLUSIONS

The results of the Year-3 fish community monitoring continue to indicate that the Little River is transitioning towards lotic conditions within the former reservoir pool as a result of dam removal. Some areas within the former impoundment appear to still retain some of the pre-removal lentic habitat characteristics such as slack flow, large deposits of fine sediments and accumulations of woody debris. The lack of normal major flow events in the Little River watershed since the removal of the dam in late 2005 extending through the exceptional drought of 2007 have likely contributed to the slow pace of habitat change. Despite these abnormal rainfall years, the fish surveys employing NCIBI methodologies conducted at the defined monitoring locations during Year-3 further documented establishment of lotic habitats and improving habitat conditions in this reach overtime following dam removal.

4.1 Fish Surveys

Lotic fish communities are developing within the former reservoir pool in response to dam removal. As with Year-1, the most upstream sites, Sites 1 and 2, contained the highest species diversity, both with 25 species. Based on habitat observations and aquatic species survey results during the 2005 pre-removal surveys, it was concluded that these upstream sites may have already been reverting to lotic conditions as a result of the water level lowering efforts that began in November of 2004 (Lowell Pre-removal Survey

Report). During Year-3, sites 3-6 showed the most significant increase in diversity with increases of as many as 8 species compared to the Year-1 monitoring (Site 3).

While the average IBI score increased from Year-1 to Year-3, three of the six sites showed increases in score, while three showed decreases. The most significant example of a decrease was at site 2, where the score declined six points, although still maintained a “good” score of 48. The most significant increase observed was at site 3, where an eight point increase pushed the rating from a “fair” score of 38 to an “excellent” score of 54. At site 3, an increase in species richness was the biggest driver for the higher Year-3 score (eight species), although corresponding increases in numbers and trophic guild were important. The decrease at site 2 was mostly related to a slight decrease in species richness (down by two species) that lowered the score of some metrics and changes in trophic guild. Theses differences are likely only reflective of seasonal and sampling variation and should be considered minor as the score still remains in the “good” range.

Although different fish survey methodologies were used during the pre-removal surveys in 2005 (Lowell Pre-removal Survey Report) and the Year-1 and Year-3 monitoring surveys, general comparisons between these results can be made. As shown below (Table 9), the trend from pre-removal and continuing through the two monitoring efforts is toward greater species richness at most sites.

Table 9. Comparison of Pre-removal, Year-1, and Year-3 Monitoring Surveys

Site #	# Species Pre-removal	# Species Year-1 Monitoring	# Species Year-3 Monitoring
1 (CX-1)	21	23	25
2 (CX-3)	26	27	25
3 (CX-4)	16	13	21
4 (CX-7)	15	18	23
5 (CX-10)	11	19	23
6 (CX-12)	5*	Not Sampled	Not Sampled
7 (CX-16)	3*	21	21

*visual observations only

Although differences in sampling methodologies may account for some of the differences in species richness, it can be concluded that habitat restoration in response to dam removal is a major reason for these changes. Because the combined methodologies used during the pre-removal surveys were likely to detect more species than the NCIBI survey methodology, which only utilizes back-pack electro-fishing, the increases in species richness are more likely attributable to other factors, such as improved habitat conditions.

From Year-1 to Year-3, a general increase in species diversity and population vitality has been shown using the NCIBI methodology.

4.2 Future Fish Survey Monitoring

Habitat within the former impoundment is expected to continue to transition from lentic to lotic conditions in response to dam removal. As discussed earlier, this further transition pertains primarily to the middle and lower portions of the former reservoir pool, as the upper segments appear to be more advanced in this habitat transition. This transition is expected to continue to be reflected in changes of the aquatic communities.

It is recommended that fish survey monitoring take place in Year-5 of the monitoring plan. However, each site, particularly the upper sites, does not necessarily have to be sampled every year. Additionally, reference sites in the Little River outside of the former dam effects should be sampled in a similar manner near the end (Year- 5) of the monitoring program for comparison.

5.0 QUANTITATIVE MUSSEL SURVEY EFFORTS

The four monitoring transects that were established and permanently marked prior to dam removal were visited on October 02, and 13, 2008 by TCG personnel Tim Savidge, Tom Dickinson and Chris Sheats. Each cross-river transect is divided into 16, 18, 20 and 10 (depending on the exact width of each transect) 1-m^2 quadrates respectively. Mussel surveys were conducted across each transect, and all mussels collected in each quadrate were collected. Live and dead tagged mussels were measured and recorded, with the live ones being returned to the substrate, and the dead ones kept as voucher specimens. Any live untagged mussels were identified to species level, measured, assigned a tag and returned to the quadrate where it was found. All dead untagged mussel shells were removed from the river and deposited in the adjacent woodland.

6.0 QUANTITATIVE MUSSEL SURVEY RESULTS

A total of 605 freshwater mussels were tagged in the four study transects prior to dam removal. The eastern elliptio (*Elliptio complanata*) accounted for 98% (591) and six other species comprised the remaining 2% (14). Significant freshwater mussel mortality attributable to the dam removal was not evident during the 3-month quantitative mussel survey monitoring. However, mark/recapture (recovery) rates of the tagged mussels decreased dramatically with increased proximity to the former dam site; 45.2% at 30 meters, 59.4% at 200 meters (Table 10). The lower recovery rate was believed to be primarily caused by a wedge of sediment that was released when the dam was removed and gradually migrated downstream. At the 3-month monitoring, the wedge had reached the 30 meter and 200 meter transects, covering the substrate with anywhere from 1-5 centimeters of sediment. The wedge had not progressed to the 400 meter transect, and recovery rates (80.4 %) were similar to those at the upstream control site (84.2%). However; the sediment wedge did move past the 400 meter transect shortly after the 3-month monitoring (personal observations), and a sharp decline in recovery rate from 80.4 % (3-months) to 25.6% was recorded during the 15-months monitoring (Table 10), while the rate at the control site remained relatively high (76.3%). The Recovery rate of original tagged mussels at the 30 meter Transect, continued to drop during the 15-month monitoring (45.2% to 3.2%); however, there was little change in recovery rate of original tagged mussels (59.4% to 52.6%) at the 200 meter transect.

With the exception of the 30 Meter Transect, which had already experienced a sharp decline in recovery rate during the 15-month monitoring, a significant drop in recovery rate was observed at all of the Transects, including the control during the 32-month monitoring (Table 10). However; the recovery at the control site was still significantly higher than at the Transects below the former dam. In addition, no mortality of original tagged mussels was observed at the Control Site, while 6.5%, 16.7% and 12.8% mortality was observed at the 30-Meter, 200-Meter and 400-Meter Transects respectively. The number of dead Untagged mussels also continued to rise at the three sites below the former dam, while remaining relatively the same at the control site (Table 10).

Table 10. Quantitative Mussel Study: Group 1 – Mussels tagged at study inception (0-months): 3-month, 15-month, and 32-month Monitoring Results.

	30 Meter Transect			200 Meter Transect			400 Meter Transect			Upstream Control		
Tagged Mussels	**31**			**96**			**439**			**38**		
	3 Months	*15 Months*	*32 Months*	*3 Months*	*15 Months*	*32 Months*	*3 Months*	*15 Months*	*32 Months*	*3 Months*	*15 Months*	*32 Months*
% Recovered - Tagged (% Moved*)	45.2 (71.4)	3.2 (100)	3.2 (0%)	59.4 (42.1)	52.6 (18)	2.1 (0)	80.4 (17)	25.6 (6.25)	3.6 (20)	84.2 (6.2)	76.3 (0)	28.9 (0)
% Dead – Tagged	0	0	6.5	1	2.1	16.7	0.2	0.5	12.8	0	0	0
# Dead - Untagged	4	65	75	37	137	163	25	97	136	0	5	6

*Moved = any tagged mussel found greater that 2 meters (e.g. two quadrates) in any direction from its original quadrate

Recovery rates of the "newly tagged" (tagged during the 3-month and 15-month monitoring) mussels was again lower at all three transects (20 m, 200 m, 400 m) below the former dam (4.2%, 11.7% and 7.7% respectively) than at the upstream control transect (26.5%). Additionally, no mortality of "newly tagged" mussels was observed at the control site, while rates of 4.2%, 10% and 9.6% were observed respectively at the 30-meter, 200-meter and 400-meter transects (Table 11). While there were a large number of dead mussels at all three transects below the former dam site, a number of live untagged mussels were also observed. These individuals were tagged and returned to the location they were found.

Table 11. Quantitative Mussel Study: Group 2 – Mussels Tagged at 3-months and 15-months ("Newly Tagged"), 32-month Monitoring Results.

	30 Meter Transect	200 Meter Transect	400 Meter Transect	Upstream Control
#Tagged Mussels	28	269	710	80
% Recovered (% Moved*)	4.2 (0)	11.2 (0)	7.7 (43)	26.5 (0)
% Dead	4.2	10	9.6	0

	30 Meter Transect	200 Meter Transect	400 Meter Transect	Upstream Control
# Live - Untagged	15	73	113	35

*Moved = any tagged mussel found greater that 2 meters (e.g. two quadrates) in any direction from its original quadrate

7.0 QUANTITATIVE MUSSEL SURVEY DISCUSSION/CONCLUSIONS

As mentioned in Section 5.0, a wedge of sediment that was released when the dam was removed and gradually migrated downstream was believed to attribute to low recovery rates of mussels at the transects below the former dam. Much of this migrating sediment has accumulated along the right descending side of the river creating sand bars that have been colonized by various species of herbaceous and woody vegetation (Photo 1). The extreme drought conditions that persisted in the Little River in 2007 and early 2008, and subsequent low flows, likely attributed to the creation of the sand bars and subsequent plant colonization.

Photo 1. Upstream view of sediment deposits covering mussels at the 200 meter transect.

As a result, this area of the river appears to be wetted only during high flow events; thus, mussels occurring on this side of the river were either buried by sediment, or cut off from flow (Photo 2). Subsequently, a large number of dead mussels were observed in these areas. The percentages of dead tagged mussels is likely higher as it is possible that many dead mussels in the three transects below the dam

Photo 2. Downstream view of sediment deposits diverting flow away from the right descending bank.

were washed out of the10-meter upstream/downstream survey limits for each transect. This is supported by 2 dead shells originating at the 30 meter transect being recovered at the 200-meter transect. Additional surveys, which are beyond the scope of this project, would be needed to investigate this hypothesis.

While recovery rates of “original tagged” and “newly tagged” mussels at the control site dropped significantly from the 15-month monitoring to the 32-month monitoring, little mortality was observed. The lower recovery rate is likely due in part to poor survey conditions, as ambient light levels were comparatively lower at this site than any of the 3 transects below the former dam (surveyed late in the day). While this part of the river undoubtedly experienced extreme low flow as did the rest of the river, drought-related mortality is likely lower than the three transects below the former dam, as there was no sediment wedge to compound the drought effects.

In addition to having the lowest recapture (recovery) rates, the three transects below the former dam had higher percentages of recaptured mussels exhibiting movement than the upstream control transect, which had relatively little signs of movement during any of the monitoring periods.

While much of this mortality and evidence of stress (movement) observed in the three transects below the former dam are likely attributable to bedload sediment transport associated with dam removal, these losses are not expected to have significant long-term adverse effects on the overall mussel populations in the river, which should experience an overall improvement as lotic conditions have been restored to approximately six river miles of habitat with dam removal. The pre-removal surveys demonstrated that “good” mussel beds occur throughout the Little River both upstream and downstream of the former impoundment site that will serve as a source for recruitment into the impacted reach below the dam, as well as the newly restored reach in the former impoundment. Additionally, a thalweg habitat has formed on the left descending side of the river as a result of the deposited sediment wedge, creating “high quality” mussel habitat. Most of the untagged (“newly immigrated”) mussels were found in these areas. Recruitment and additional immigration of mussels into this area is expected to occur in the future.

The below average rainfall/discharge levels that have persisted in the watershed for much of the period since dam removal have undoubtedly increased the severity and duration of the sediment effects on the mussel beds, by 1) resulting in higher amounts of deposition, and 2) cutting off flow from parts of the channel below the deposits. Average or above average rainfall incidence might have “flushed” the sand wedge well downstream and even dispersed the sediment more homogenously throughout the downstream reaches of the river. In other words, while post dam removal sediment effects are predictable following dam removal, their impacts on benthic communities might be lessened by more frequent storm events. Continued monitoring of these transects will document the population responses to the dam removal and associated sediment impacts.

8.0 LITERATURE CITED

NCDENR 2001. Standard Operating Procedures Biological Monitoring Stream Fish Community Assessment and Fish Tissue. Available online at http://www.esb.enr.state.nc.us/BAUwww/IBI%20Methods%202001.pdf

APPENDIX A. NCIBI SCORE SHEETS FOR EACH SITE SAMPLED YEAR-1 FISH COMMUNITY MONITORING

Table 1. NCIBI Score Site 1 (CX-1) Yr 3

Metric/score criteria	Site Metric #	Site Metric Score
No. of species ≥ 16 species = 5 10-15 species = 3 <10 species = 1	25	5
No. of fish ≥ 225 fish = 5 150-224 fish = 3 <150 fish = 1	399	5
No. of species of darters ≥ 3 species = 5 1-2 species = 3 0 species = 1	5	5
No. of species of sunfish ≥ 4 species = 5 3 species = 3 0-2 species = 1	3	3
No. of species of suckers ≥ 3 species = 5 1-2 species = 3 0 species = 1	2	3
No. of intolerant species ≥ 3 species = 5 1-2 species = 3 0 species = 1	2	3
% of tolerant individuals ≤ 35% = 5 36-50% = 3 >50% = 1	28%	5
% of omnivorous and herbivorous individuals 10-35% = 5 36-50% = 3 >50% or <10% = 1	5%	1
% of insectivorous individuals 65-90% = 5 45-64% = 3 <45% or >90% = 1	90%	5
% of piscivorous individuals 1.4-15% = 5 0.4-1.3% = 3 <0.4% or >15% = 1	4.8%	5
% of diseased fish ≤1.75% = 5 1.76-2.75% = 3 >2.75% = 1	<1%	5
% of species with multiple age groups ≥50% = 5 35-49% = 3 <35% = 1	64%	5
NCIBI Score		50 (Good)

Table 2. NCIBI Score Site 2 (CX-3) Yr 3

Metric/score criteria	Site Metric #	Site Metric Score
No. of species ≥ 16 species = 5 10-15 species = 3 <10 species = 1	25	5
No. of fish ≥ 225 fish = 5 150-224 fish = 3 <150 fish = 1	332	5
No. of species of darters ≥ 3 species = 5 1-2 species = 3 0 species = 1	5	5
No. of species of sunfish ≥ 4 species = 5 3 species = 3 0-2 species = 1	5	5
No. of species of suckers ≥ 3 species = 5 1-2 species = 3 0 species = 1	1	3
No. of intolerant species ≥ 3 species = 5 1-2 species = 3 0 species = 1	2	3
% of tolerant individuals ≤ 35% = 5 36-50% = 3 >50% = 1	35%	5
% of omnivorous and herbivorous individuals 10-35% = 5 36-50% = 3 >50% or <10% = 1	2.4%	1
% of insectivorous individuals 65-90% = 5 45-64% = 3 <45% or >90% = 1	91.5%	1
% of piscivorous individuals 1.4-15% = 5 0.4-1.3% = 3 <0.4% or >15% = 1	6.9%	5
% of diseased fish ≤1.75% = 5 1.76-2.75% = 3 >2.75% = 1	<1%	5
% of species with multiple age groups ≥50% = 5 35-49% = 3 <35% = 1	84%	5
NCIBI Score		48 (Good)

Table 3. NCIBI Score Site 3 (CX- 4)

Metric/score criteria	Site Metric #	Site Metric Score
No. of species ≥ 16 species = 5 10-15 species = 3 <10 species = 1	21	5
No. of fish ≥ 225 fish = 5 150-224 fish = 3 <150 fish = 1	268	5
No. of species of darters ≥ 3 species = 5 1-2 species = 3 0 species = 1	4	5
No. of species of sunfish ≥ 4 species = 5 3 species = 3 0-2 species = 1	5	5
No. of species of suckers ≥ 3 species = 5 1-2 species = 3 0 species = 1	1	3
No. of intolerant species ≥ 3 species = 5 1-2 species = 3 0 species = 1	2	2
% of tolerant individuals ≤ 35% = 5 36-50% = 3 >50% = 1	35%	5
% of omnivorous and herbivorous individuals 10-35% = 5 36-50% = 3 >50% or <10% = 1	10%	5
% of insectivorous individuals 65-90% = 5 45-64% = 3 <45% or >90% = 1	85%	5
% of piscivorous individuals 1.4-15% = 5 0.4-1.3% = 3 <0.4% or >15% = 1	4.8%	5
% of diseased fish ≤1.75% = 5 1.76-2.75% = 3 >2.75% = 1	<1%	5
% of species with multiple age groups ≥50% = 5 35-49% = 3 <35% = 1	71%	5
NCIBI Score		56 (Excellent)

Table 4. NCIBI Score Site 4 (CX- 7)

Metric/score criteria	Site Metric #	Site Metric Score
No. of species ≥ 16 species = 5 10-15 species = 3 <10 species = 1	23	5
No. of fish ≥ 225 fish = 5 150-224 fish = 3 <150 fish = 1	293	5
No. of species of darters ≥ 3 species = 5 1-2 species = 3 0 species = 1	5	5
No. of species of sunfish ≥ 4 species = 5 3 species = 3 0-2 species = 1	3	3
No. of species of suckers ≥ 3 species = 5 1-2 species = 3 0 species = 1	1	3
No. of intolerant species ≥ 3 species = 5 1-2 species = 3 0 species = 1	2	3
% of tolerant individuals ≤ 35% = 5 36-50% = 3 >50% = 1	41%	3
% of omnivorous and herbivorous individuals 10-35% = 5 36-50% = 3 >50% or <10% = 1	1.7%	1
% of insectivorous individuals 65-90% = 5 45-64% = 3 <45% or >90% = 1	94%	1
% of piscivorous individuals 1.4-15% = 5 0.4-1.3% = 3 <0.4% or >15% = 1	3.7%	5
% of diseased fish ≤1.75% = 5 1.76-2.75% = 3 >2.75% = 1	<1%	5
% of species with multiple age groups ≥50% = 5 35-49% = 3 <35% = 1	35%	3
NCIBI Score		42 (Good-Fair)

Table 5. NCIBI Score Site 5 (CX-10)

Metric/score criteria	Site Metric #	Site Metric Score
No. of species ≥ 16 species = 5 10-15 species = 3 <10 species = 1	23	5
No. of fish ≥ 225 fish = 5 150-224 fish = 3 <150 fish = 1	439	5
No. of species of darters ≥ 3 species = 5 1-2 species = 3 0 species = 1	5	5
No. of species of sunfish ≥ 4 species = 5 3 species = 3 0-2 species = 1	4	5
No. of species of suckers ≥ 3 species = 5 1-2 species = 3 0 species = 1	2	3
No. of intolerant species ≥ 3 species = 5 1-2 species = 3 0 species = 1	2	3
% of tolerant individuals ≤ 35% = 5 36-50% = 3 >50% = 1	40%	3
% of omnivorous and herbivorous individuals 10-35% = 5 36-50% = 3 >50% or <10% = 1	7.3%	1
% of insectivorous individuals 65-90% = 5 45-64% = 3 <45% or >90% = 1	87%	5
% of piscivorous individuals 1.4-15% = 5 0.4-1.3% = 3 <0.4% or >15% = 1	5.2%	5
% of diseased fish ≤1.75% = 5 1.76-2.75% = 3 >2.75% = 1	<1%	5
% of species with multiple age groups ≥50% = 5 35-49% = 3 <35% = 1	74%	5
NCIBI Score		50 (Good)

Table 6. NCIBI Score Site 7(CX-16)

Metric/score criteria	Site Metric #	Site Metric Score
No. of species ≥ 16 species = 5 10-15 species = 3 <10 species = 1	21	5
No. of fish ≥ 225 fish = 5 150-224 fish = 3 <150 fish = 1	548	5
No. of species of darters ≥ 3 species = 5 1-2 species = 3 0 species = 1	4	5
No. of species of sunfish ≥ 4 species = 5 3 species = 3 0-2 species = 1	3	3
No. of species of suckers ≥ 3 species = 5 1-2 species = 3 0 species = 1	0	1
No. of intolerant species ≥ 3 species = 5 1-2 species = 3 0 species = 1	2	3
% of tolerant individuals ≤ 35% = 5 36-50% = 3 >50% = 1	39%	3
% of omnivorous and herbivorous individuals 10-35% = 5 36-50% = 3 >50% or <10% = 1	6.6%	1
% of insectivorous individuals 65-90% = 5 45-64% = 3 <45% or >90% = 1	88%	5
% of piscivorous individuals 1.4-15% = 5 0.4-1.3% = 3 <0.4% or >15% = 1	5.3%	5
% of diseased fish ≤1.75% = 5 1.76-2.75% = 3 >2.75% = 1	<1%	5
% of species with multiple age groups ≥50% = 5 35-49% = 3 <35% = 1	81%	3
NCIBI Score		46 (Good)

APPENDIX D: NCDWQ Habitat Assessment Form

Habitat Assessment Field Data Sheet
Mountain/ Piedmont Streams

Biological Assessment Unit, DWQ **TOTAL SCORE________**

Directions for use: The observer is to survey a **minimum of 100 meters with 200 meters preferred** of stream, preferably in an **upstream** direction starting above the bridge pool and the road right-of-way. The segment which is assessed should represent average stream conditions. To perform a proper habitat evaluation the observer needs to get into the stream. To complete the form, select the description which best fits the observed habitats and then circle the score. If the observed habitat falls in between two descriptions, select an intermediate score. A final habitat score is determined by adding the results from the different metrics.

Stream______________________Location/road: ____________(Road Name___________)County_______________

Date__________________**CC#**______________Basin_____________________Subbasin______________________

Observer(s)_________ Type of Study: ☐ Fish ☐Benthos ☐ Basinwide ☐Special Study (Describe) _______________

Latitude ____________Longitude _____________Ecoregion: ☐ MT ☐ P ☐ Slate Belt ☐ Triassic Basin

Water Quality: Temperature_______ ^{0}C DO _______mg/l Conductivity (corr.) ______µS/cm pH _____

Physical Characterization: Visible land use refers to immediate area that you can see from sampling location - include what you estimate driving thru the watershed in watershed land use.

Visible Land Use: ______%Forest ______%Residential ______%Active Pasture _______% Active Crops
_____%Fallow Fields ______% Commercial ______%Industrial ______%Other - Describe:_____________

Watershed land use : ☐Forest ☐Agriculture ☐Urban ☐ Animal operations upstream

Width: (meters) Stream_________ Channel (at top of bank)_______ **Stream Depth**: (m) Avg______Max ____
☐ Width variable ☐ Large river >25m wide

Bank Height (from deepest part of riffle to top of bank-first flat surface you stand on): (m)________

Bank Angle: _________ º or ☐ NA (Vertical is 90º, horizontal is 0º. Angles > 90º indicate slope is towards mid-channel, < 90º indicate slope is away from channel. NA if bank is too low for bank angle to matter.)

☐ Channelized Ditch

☐Deeply incised-steep, straight banks ☐Both banks undercut at bend ☐Channel filled in with sediment

☐ Recent overbank deposits ☐Bar development ☐Buried structures ☐Exposed bedrock

☐ Excessive periphyton growth ☐ Heavy filamentous algae growth ☐Green tinge ☐ Sewage smell

Manmade Stabilization: ☐N ☐Y: ☐Rip-rap, cement, gabions ☐ Sediment/grade-control structure ☐Berm/levee

Flow conditions : ☐High ☐Normal ☐Low

Turbidity: ☐Clear ☐ Slightly Turbid ☐Turbid ☐Tannic ☐Milky ☐Colored (from dyes)

Good potential for Wetlands Restoration Project?? ☐ YES ☐NO Details____________________________

Channel Flow Status

Useful especially under abnormal or low flow conditions.

A. Water reaches base of both lower banks, minimal channel substrate exposed .... ☐
B. Water fills >75% of available channel, or <25% of channel substrate is exposed....................... ☐
C. Water fills 25-75% of available channel, many logs/snags exposed.. ☐
D. Root mats out of water.. ☐
E. Very little water in channel, mostly present as standing pools... ☐

Weather Conditions:________________________**Photos:** ☐N ☐Y ☐ Digital ☐35mm

Remarks:____
____

I. Channel Modification

	Score
A. channel natural, frequent bends	5
B. channel natural, infrequent bends (channelization could be old)	4
C. some channelization present	3
D. more extensive channelization, >40% of stream disrupted	2
E. no bends, completely channelized or rip rapped or gabioned, etc	0

☐ Evidence of dredging ☐Evidence of desnagging=no large woody debris in stream ☐Banks of uniform shape/height

Remarks____ Subtotal____

II. Instream Habitat: Consider the percentage of the reach that is favorable for benthos colonization or fish cover. If >70% of the reach is rocks, 1 type is present, circle the score of 17. Definition: leafpacks consist of older leaves that are packed together and have begun to decay (not piles of leaves in pool areas). Mark as **R**are, **C**ommon, or **A**bundant.

____Rocks ____Macrophytes ____Sticks and leafpacks ____Snags and logs ____Undercut banks or root mats

AMOUNT OF REACH FAVORABLE FOR COLONIZATION OR COVER

	>70% Score	40-70% Score	20-40% Score	<20% Score
4 or 5 types present	20	16	12	8
3 types present	19	15	11	7
2 types present	18	14	10	6
1 type present	17	13	9	5
No types present	0			

☐ No woody vegetation in riparian zone Remarks____ Subtotal_____

III. Bottom Substrate (silt, sand, detritus, gravel, cobble, boulder) Look at entire reach for substrate scoring, but only look at riffle for embeddedness, and use rocks from all parts of riffle-look for "mud line" or difficulty extracting rocks.

	Score
A. substrate with good mix of gravel, cobble and boulders	
1. embeddedness <20% (very little sand, usually only behind large boulders)	15
2. embeddedness 20-40%	12
3. embeddedness 40-80%	8
4. embeddedness >80%	3
B. substrate gravel and cobble	
1. embeddedness <20%	14
2. embeddedness 20-40%	11
3. embeddedness 40-80%	6
4. embeddedness >80%	2
C. substrate mostly gravel	
1. embeddedness <50%	8
2. embeddedness >50%	4
D. substrate homogeneous	
1. substrate nearly all bedrock	3
2. substrate nearly all sand	3
3. substrate nearly all detritus	2
4. substrate nearly all silt/ clay	1

Remarks____Subtotal_____

IV. Pool Variety Pools are areas of deeper than average maximum depths with little or no surface turbulence. Water velocities associated with pools are always slow. Pools may take the form of "pocket water", small pools behind boulders or obstructions, in large high gradient streams, or side eddies.

	Score
A. Pools present	
1. Pools Frequent (>30% of 200m area surveyed)	
a. variety of pool sizes	10
b. pools about the same size (indicates pools filling in)	8
2. Pools Infrequent (<30% of the 200m area surveyed)	
a. variety of pool sizes	6
b. pools about the same size	4
B. Pools absent	0

Subtotal_____

☐ Pool bottom boulder-cobble=hard ☐ Bottom sandy-sink as you walk ☐ Silt bottom ☐ Some pools over wader depth

Remarks____

Page Total_____

V. Riffle Habitats

Definition: Riffle is area of reaeration-can be debris dam, or narrow channel area.

	Riffles **Frequent** Score	Riffles **Infrequent** Score
A. well defined riffle and run, riffle as wide as stream and extends 2X width of stream....	16	12
B. riffle as wide as stream but riffle length is not 2X stream width	14	7
C. riffle not as wide as stream and riffle length is not 2X stream width	10	3
D. riffles absent..	0	

Channel Slope: ☐Typical for area ☐Steep=fast flow ☐Low=like a coastal stream Subtotal_____

VI. Bank Stability and Vegetation

FACE UPSTREAM

	Left Bank Score	Rt. Bank Score
A. Banks stable		
1. little evidence of erosion or bank failure(except outside of bends), little potential for erosion..	7	7
B. Erosion areas present		
1. diverse **trees**, shrubs, grass; plants healthy with good root systems..................................	6	6
2. few trees or small trees and **shrubs**; vegetation appears generally healthy..........................	5	5
3. sparse **mixed** vegetation; plant types and conditions suggest poorer soil binding................	3	3
4. mostly **grasses**, few if any trees and shrubs, high erosion and failure potential at high flow..	2	2
5. little or no bank vegetation, mass erosion and bank failure evident...	0	0

Total______

Remarks____

VII. Light Penetration Canopy is defined as tree or vegetative cover directly above the stream's surface. Canopy would block out sunlight when the sun is directly overhead. Note shading from mountains, but not use to score this metric.

	Score
A. Stream with **good** canopy with some breaks for light penetration	10
B. Stream with **full canopy** - breaks for light penetration absent..	8
C. Stream with **partial** canopy - sunlight and shading are essentially equal..................................	7
D. Stream with **minimal** canopy - full sun in all but a few areas...	2
E. **No canopy** and no shading...	0

Remarks____Subtotal____

VIII. Riparian Vegetative Zone Width

Definition: Riparian zone for this form is area of natural vegetation adjacent to stream (can go beyond floodplain). Definition: A break in the riparian zone is any place on the stream banks which allows sediment or pollutants to directly enter the stream, such as paths down to stream, storm drains, uprooted trees, otter slides, etc.

FACE UPSTREAM

Dominant vegetation: ☐ Trees ☐ Shrubs ☐ Grasses ☐ Weeds/old field ☐Exotics (kudzu, etc)

	Lft. Bank Score	Rt. Bank Score
A. Riparian zone **intact** (no breaks)		
1. width > 18 meters..	5	5
2. width 12-18 meters..	4	4
3. width 6-12 meters..	3	3
4. width < 6 meters..	2	2
B. Riparian zone **not intact** (breaks)		
1. breaks rare		
a. width > 18 meters..	4	4
b. width 12-18 meters..	3	3
c. width 6-12 meters..	2	2
d. width < 6 meters..	1	1
2. breaks common		
a. width > 18 meters..	3	3
b. width 12-18 meters..	2	2
c. width 6-12 meters..	1	1
d. width < 6 meters..	0	0

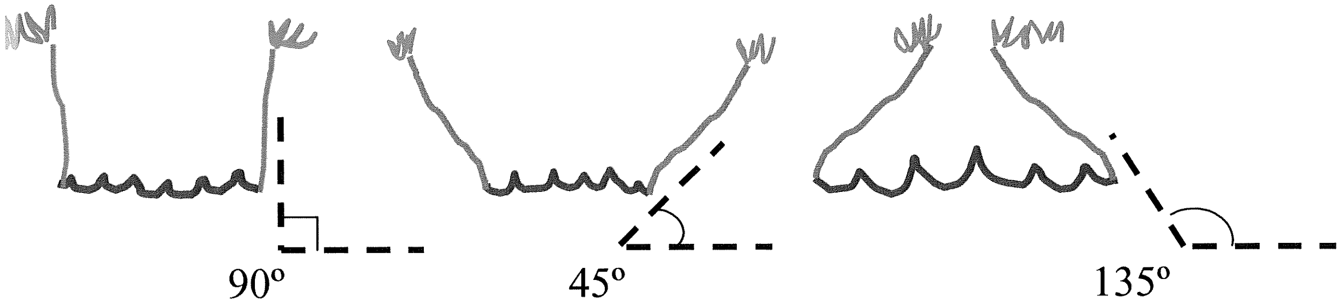
Remarks____ Total______

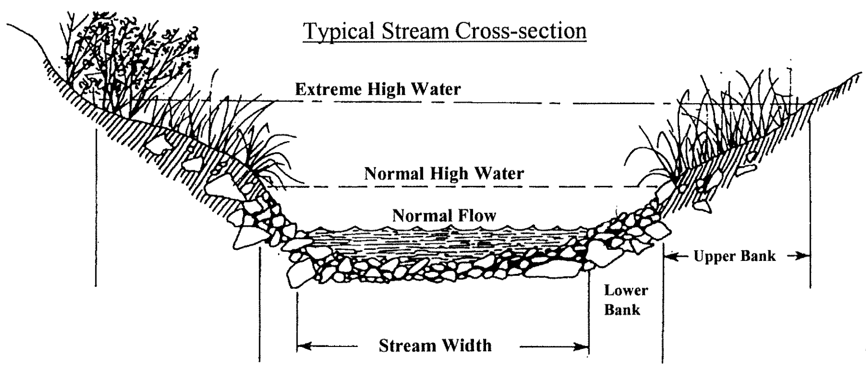
Page Total_______

☐ Disclaimer-form filled out, but score doesn't match subjective opinion-atypical stream. **TOTAL SCORE_______**

Supplement for Habitat Assessment Field Data Sheet

Diagram to determine bank angle:





This side is 45° bank angle.

Site Sketch:

Other comments:____

APPENDIX E: Monitoring Photographs

APPENDIX F: Fish Weir Study Report

Assessing benefits to migratory fishes of habitat restored by dam removal

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Joseph E. Hightower

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North Carolina State University, Department of Zoology
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Annual Report

February 20, 2008

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Acknowledgements

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Introduction

Degradation and loss of habitat has been considered a key component in the decline of native fish populations in many river systems (Nehlsen et al. 1991, Martinez et al. 1994, Rulifson 1994). Anthropogenic disturbances in watersheds and within rivers (e.g., dams) have altered water quality, temperature and flow regimes; erosion rates and sediment transport; food sources and cover, and access to spawning sites (Nehlsen et al. 1991, Kershner et al. 2004, Pringle et al. 2000). These changes can lead to increased competition with invasive species and reductions in reproduction, rearing of young, and overall recruitment to adults (Martinez et al. 1994, Rulifson 1994, Pringle et al. 2000). Due to these deleterious impacts on river ecosystems and fish populations, efforts have been made to restore riverine habitat. For instance, there has been an increased interest in removing dams, with a growing number of removals occurring in North Carolina (Burdick and Hightower 2006, Riggsbee et al. 2007) and throughout the United States (Stanley and Doyle 2003, Pejchar and Warner 2001, Catalano et al. 2007).

Past studies suggest that fish populations respond positively to dam removals. For example, dams were removed on two different inland Wisconsin rivers and within five years sportfish such as smallmouth bass (*Micropterus dolomieu*) and intolerant species thrived, tolerant species such as common carp (*Cyprinus carpio*) declined, measures of biotic integrity improved, and species recolonized upstream habitat (Kanehl et al. 1997, Catalano et al. 2007). On coastal rivers, dam removals can benefit resident fishes along with anadromous species that migrate from the ocean to utilize the rivers for spawning and rearing of young. One example is the Neuse River, North Carolina, where spawning migrations of American shad (*Alosa sapidissima*) and striped bass (*Morone* *saxatilis*) were impeded by a low-head dam (Beasley and Hightower 2000), but upon removal both species utilized upstream habitat for spawning (Burdick and Hightower 2006). Although these studies provide insights into the response of dam removals by fish populations, many projects go unstudied. Additional research is necessary to further understand the potential benefits of dam removals and river habitat restoration, including how specific fish species utilize restored habitat.

In the spring of 2007, a study was commenced on the Little River, North Carolina, with an overall goal of determining how fish are utilizing upstream habitat that has only recently become available due to three dam removals since 1998. American shad, having experienced dramatic and prolonged decreases in population size (Walburg and Nichols 1967, Rulifson 1994, Hightower et al. 1996), are of particular interest as they annually utilize the Little River as spawning habitat. The migration of American shad and other species is being monitored using a resistance board weir, a fish monitoring tool that is increasingly being utilized in Alaska and on the Pacific coast (Stewart 2002). Specific project objectives were to determine fish abundance, migratory patterns, and deposition of eggs and production of larvae relative to physical variables and habitat availability. This information can be used to refine and develop models that predict the impacts of dam removals on other river systems.

Methods

Study Site

The Little River originates in Franklin County, North Carolina, and flows through Wake, Johnston, and Wayne counties before entering the Neuse River near the city of Goldsboro. Buffalo Creek is the primary tributary to the Little River. Three low-head dams have been removed on the Little River (Figure 1). Cherry Hospital Dam, removed in 1998, was located less than three river kilometers (rkm) from the Neuse River confluence. Rains Mill Dam, located at rkm 37, was removed in 1999, while Lowell Mill Dam, located at 57 rkm, was removed in 2005. These dam removals started the restoration process, reconnecting 82 rkm of the Little River and up to 237 total rkm when considering tributary streams. A notched dam at the Goldsboro water treatment plant remains relatively close to the mouth of the river, and an impassable dam (Atkinson Mill Dam) located at rkm 82 is the furthest downstream dam (Figure 1).

The Little River's moderate size (average spring flows of 5.7-8.6 m^3/s) makes it feasible to conduct detailed studies of life histories and the impacts of dam removals on migratory fishes. Based on benthic macroinvertebrate monitoring, the water quality of the Little River has been classified as Good-Fair to Good (NCDENR 2006). The habitat in the river is particularly diverse, consisting of runs, riffles, and pools with substrates ranging from fine silt to bedrock. Fish species composition is typical of a coastal North Carolina stream, and includes an annual spawning migration of American shad. Additional species, such as resident, migratory suckers and gizzard shad (*Dorosoma cepedianum*), may also benefit from reconnection of the river reaches.

Adults

A combination of resistance board and metal picket weir was constructed and installed to monitor adult fish populations. Fish weirs are physical structures spanning the river channel that are pervious to water but prevent fish from migrating upstream or downstream. Ideally, fish are instead funneled into respective upstream or downstream live cages. Fish are removed from the live cages, counted for abundance, measured, often tagged, and then released in the direction they were migrating. Resistance board weirs are a relatively recent weir design that provide benefits over picket weirs as they are more durable in high flows, allow easier removal of debris and at times are self-cleaning, and also allow boats to navigate past them (Tobin 1994, Stewart 2002).

The weir was installed at the former Lowell Mill Dam site, the furthest upstream removed dam on the Little River (Figure 1). Installation of the fish weir began on March 13 and by March 16 the entire span of the river was blocked off by the weir. However, a large rain event caused substantial increases in flow and river height on March 17 that resulted in breaching and eventual wash-out of temporary fences on the periphery of the weir. As water levels receded, repairs were made and by March 21 the weir was fully functioning. On March 23, permanent metals pickets were installed at the entrances of each cage and by March 29 temporary fences were replaced by permanent metal picket weirs and improved bulkheads were installed. The weir was modified on April 3 to improve its effectiveness in capturing downstream migrating fish. Sandbags were used to partially sink a resistance board panel and create a flow of water into a net attached to the downstream end of the panel. No further modifications were made to the weir and it functioned properly for the remainder of the sampling season.

The resistance board weir was located in the area of highest flow, with live cages on each side, followed by picket weir and then plastic fencing for high water events (Figures 2-4). The resistance board weir was constructed according to Stewart (2002), with minor modifications. For instance, all portions of the weir and live cages were spaced a maximum of 2.5 cm apart to allow sufficient water but not American shad to pass through the weir. Additionally, an I-beam with aircraft cable held in place by eye bolts was installed along the river bottom to provide a level, sturdy connection for the resistance board weir panels. A total of 12 resistance board weir panels were connected to span 11.1 m of the river (Figures 2-3). The live cages had wooden frames of 1.7 m wide, 2.0 m long, and 1.8 m in height to retain fish. The downstream net attached to the sunken weir panel had an open diameter of 1.5 m and was 1.2 m deep (Figure 4). The picket weir sections (5.6 m on western side, 21.3 m on eastern side) were constructed of vertical, metal conduit pickets held in place by metal stringers that were supported by wooden anchor legs. In all, the weir fully spanned 41 m of river channel, with additional plastic mesh fencing on the river banks.

The weir live cages were checked each morning and often in the evening as well, with any captured fish being removed in a timely manner with a dipnet. All fish were identified to species, examined for gender, and measured for total length (mm). American shad and migratory suckers such as notchlip redhorse (*Moxostoma collapsum*) received an individually numbered Hallprint 12/13 mm fine T-bar anchor tag near the base of the dorsal fin. This is a rapid procedure and required no anesthetics. The permanent tags provided accurate identification of recaptured fish and will provide information on repeat spawners in subsequent years of the study. For all other fish species, the upper caudal fin was clipped with scissors for identification of recaptures. Fish were then released either upstream or downstream of the weir depending on the cage in which they were captured.

Electrofishing from a small jon boat supplemented the weir for capture of adult fishes. A Georator with a portable boom supplied 230V DC for electrofishing. All electrofishing occurred on reaches upstream of the weir site. Target species (American shad and suckers) were examined for gender, measured for total length (mm), and tagged as described above. During the first day of electrofishing, the physical river location was described for captured fish. On subsequent days locations were marked with a Garmin GPSmap 76Cx handheld unit.

The expected American shad run size within the Little River was based on the amount of available mainstem river habitat, using the rule-of-thumb of 124/ha (St. Pierre 1979). This rule-of-thumb is based on historical data for the Susquehanna and Connecticut rivers. St. Pierre (1979) felt that projections using that methodology would be conservative estimates of the potential size of a fully restored run. He also emphasized that the approaches used were based on numerous assumptions and should be viewed as only a first approximation (St. Pierre 1979). To determine the amount of available mainstem Little River habitat, river segments lengths were measured in ArcGIS and average width estimates were taken from Ferguson (2002).

Eggs and Larvae

To collect eggs and larvae, plankton tows were conducted twice a week during the field season. Fifteen minute oblique plankton tow samples were collected from bridge crossings at four sites on the Little River, two upstream and two downstream of the former Lowell Mill Dam site, and at one site on Buffalo Creek (Figure 5). Plankton tows were conducted using a bongo frame with two 0.3-m diameter plankton nets with 6:1 tail to mouth ratios and 500-µm mesh. At each sampling location and for each sample, water temperature (°C) was recorded approximately 0.2 m below the water surface with a handheld YSI 55 instrument. In addition, a standard General Oceanics Environmental flow meter was deployed adjacent to the net for estimates of the volume of water filtered.

Both nets were rinsed thoroughly and the samples were removed from the solid sampling cups at the cod end. All collected eggs and larvae were immediately fixed in 5-10% buffered formalin and stored in the sampling cups. The eggs were later counted, identified to species when possible, and staged for development in the laboratory. Larvae were measured (mm) and identified to species when possible.

Physical Variables

Water temperature (°C) was recorded continuously during the sampling period at 1.5-h intervals with Onset HOBO-TEMP loggers. One logger was installed at the weir site on March 21 and recorded data until the weir was removed on May 23. A second logger was installed at the furthest upstream Little River plankton sampling site and recorded data from March 26 to May 29. Water discharge (flow) and gage height data were recorded by the United States Geological Survey at a monitoring station (0208850) near Princeton, North Carolina.

Results

Adults

In the 2007 Little River spring sampling period, 901 fish were encountered at the weir with 876 unique individuals being captured in the live cages. American shad were the most common species with 502 captures, followed by 301 gizzard shad and 58 notchlip redhorse (Table 1). Other species were captured at the weir in lower abundances (Table 1). A decomposing bowfin (*Amia calva*) and longnose gar (*Lepisosteus osseus*) washed onto the weir panels, but although these species were common throughout the river during electrofishing runs, no live specimens were captured at the weir.

Water flow and depth were important migratory factors for resident gizzard shad. Three high periods (mean daily flow > 5.7 m^3/s) occurred during March-May; however, the first occurred before weir installation began and the second occurred before it was completed (Figure 6). The weir was fully functioning during the third high flow period, when the highest density of upstream migrating fish occurred. The highest catches were of gizzard shad, with 127 captured moving upstream on April 16 and 43 on both April 17 and 18 (Figure 7). In contrast, no gizzard shad migrated downstream on April 16, one on April 17, and three on April 18. Overall, the 213 gizzard shad migrating upstream during this three-day period accounted for 72.4% of the 294 unique gizzard shad collected at the weir (Figure 7). Eight total gizzard shad recaptures occurred at the weir, four in each direction. Of the 288 unique gizzard shad measured, 83 were female (mean=383.2 mm, SE=2.72), 122 were male (mean=361.0 mm, SE=2.46), and 82 were unknown (mean=379.0 mm, SE=4.28). During an electrofishing run on April 24, a fin-clipped gizzard shad was recaptured at the base of Atkinson Mill Dam. This fish had been fin-clipped at the weir, so it had migrated upstream to the furthest extent possible.

Water flow and depth also influenced movement of resident, non-migratory species. The high-flow period occurring in mid-April was the only time that largemouth bass were collected at the weir, with four moving upstream and one migrating downstream (Table 1). Additionally, one black crappie and two sunfish (*Lepomis* spp.) migrated upstream, while one sunfish (*Lepomis* spp.) and one brown bullhead moved downstream during four days of the increased flow.

American shad were most likely also influenced by water flow and depth, making upstream migrations before the weir was properly functioning. American shad were present in the Little River during the entire sampling period in 2007, including an observation of one individual during weir installation on March 14 and one collected on May 23, the date of the weir removal. In total, 45 American shad were sampled migrating upstream at the weir, 440 migrating downstream, and 17 cases where the migration direction was unclear, for a total of 502 American shad collected at the weir (Table 1). There is a clear disparity between upstream and downstream migrating fish, suggesting that American shad migrated upstream before the weir was installed or when the weir was not functioning correctly. Only nine American shad migrated upstream while eight migrated downstream during the late-April high flow period. Interestingly, five American shad migrated upstream between May 17 and 21, and one additional individual, for which the migration direction was unclear, was captured on May 23, the day the weir was removed (Figure 8).

Downstream migrations by American shad may have been more influenced by water temperatures than flow. From April 24 to May 3, 10 or more American shad migrated downstream each day with a peak of 67 individuals on May 1 (Figure 8). Mean daily water temperatures rose during this period, from 19.0 °C on April 24 to a high of 22.8 °C on May 2. Over the next four days, water temperatures receded slightly and 23 more American shad migrated downstream. Only three more individuals clearly migrated downstream after these dates (Figure 8). Visually, the health of downstream migrating American shad varied. Sex could not always be determined, but males appeared healthier than females, who at times were extremely gaunt and swam weakly once released. Gashes were observed on dorsal regions of live individuals, and a few dead individuals were found onshore with distinct puncture wounds (Figure 9). Little

River predators included snakes actively hunting at the weir site, turtles and mammals in live cages, and birds. Any untagged American shad were tagged as they migrated downstream, and 315 tagged individuals migrated downstream past the weir in 2007.

Electrofishing confirmed the presence of American shad utilizing habitat upstream of the former Lowell Mill Dam site. The first electrofishing run from Atkinson Mill Dam to SR 2123 occurred on April 4. During this run, 14 American shad were sampled, including individuals in a reach just downstream of Atkinson Mill Dam. A second run spanning the same river reach occurred on April 24 and eight American shad were sampled (Figure 10). Many of these fish were collected in similar locations in the river as the first run, but only the fish collected on the second run are depicted in Figure 10. Quantitative data collection was not completed on the habitat use of these fish, but most were captured in run or riffle areas dominated by rock substrates. A final electrofishing run occurred on May 2 in the river reach from SR 1934 to the weir site. During this run, which was primarily slow flowing pool habitat, only one American shad was collected just upstream of the weir site (Figure 10). Water levels were too low to adequately navigate the electrofishing boat after this date. In total, 23 American shad were sampled and tagged during electrofishing runs and no recaptures occurred, for a combined total of 525 captures between the weir and electrofishing sampling.

Useful information about the timing of migration and residence time on the spawning grounds was obtained from 10 of 18 recaptured American shad, from a total of 53 tagged or fin-clipped individuals released upstream of the weir. Twenty-nine were tagged and one was fin-clipped at the weir during their upstream migration. However, eight of these experienced a fallback response as they were recaptured at the weir on the same or following day. Of the remaining 22 weir-marked American shad, six were recaptured migrating downstream at the weir and provided useful data. The mean days upstream was 14.7, with the shortest duration upstream being 3 days and the longest 35 days. During electrofishing runs, 22 American shad were tagged and one was fin-clipped upstream of the weir. Only two electrofishing-tagged individuals were recaptured migrating downstream at the weir; one 24 days after the tagging date and the other 27 days later. One fin-clipped American shad was recaptured migrating downstream at the weir, but the origin of sampling (weir or electrofishing) was undetermined.

Overall, there were 508 unique American shad sampled in 2007 between the former Lowell Mill Dam site and Atkinson Mill Dam. Seventy-nine were female (489.1 mm, SE=2.96), 292 were male (424.0 mm, SE=1.40), 122 were unknown (479.9 mm, SE=2.88), and 15 did not have measurements associated with them. Using the rule-of-thumb of 124/ha, the expected size of a fully restored run would be approximately 6,100 American shad within this habitat reach and over 22,600 in accessible reaches of the Little River (Table 2).

Notchlip redhorse were relatively abundant, with a total of 100 sampled through the weir and electrofishing. Of 90 measurable fish, five were females (mean=480.8 mm, SE=24.12), 20 were males (mean=473.1 mm, SE=12.91), and 65 were unknown (453.7 mm, SE=9.27). An apparent spawning migration occurred between March 28 and April 1 as eight individuals were caught moving upstream at the weir (Figure 11). One redhorse was also collected in the upstream cage on April 28. An additional 42 notchlip redhorses were captured via electrofishing upstream of the weir between April 4 and May

2 (Figure 12). None of these 51 fish had been previously captured and all were either tagged or fin clipped.

Notchlip redhorses appeared to suffer a high rate of spawning mortality. A total of 49 redhorses were collected heading downstream at the weir from April 1 to May 1 (Figure 11). However, none of these fish were recaptures and 43 were mortalities. Dead notchlip redhorses were found on the panels of the resistance board weir, along the picket weir, in the downstream cage and net, and in slow pools just upstream of the weir. One dead individual was observed floating downstream and onto the resistance board weir panels. A fair number of the mortalities were already in later stages of decomposition. The remaining six downstream-migrating live notchlip redhorse were in fair to poor conditions. Open flesh wounds and a lack of scales on the ventral area of the caudal peduncle and fin were observed on some live and dead individuals (Figure 13).

Eggs and Larvae

Plankton sampling sites in the Little River and Buffalo Creek varied in terms of depth, substrate and temperature (Table 2). The uppermost Little River site (1) was located downstream of a rocky run habitat, but was quite shallow. Site 2 was the deepest site, with primarily pool habitat located above it. Site 3 was the first site downstream of the former Lowell Mill Dam, and had rock substrates with relatively high flow. The final site on the Little River, site 4, was fairly deep with very slow moving pool habitat. Mean water temperatures increased from upstream to downstream at the Little River sites. The Buffalo Creek site, which was sandy with some rock substrate, had a lower mean water temperature than any of the Little River sites. Despite being very shallow, especially at the end of the season, it had the highest mean volume sampled (Table 2).

Plankton sampling was relatively unsuccessful for collecting American shad eggs and larvae. A total of 14 eggs were collected and only 3 larvae, all in the month of April. The highest collection period was on April 20, which coincided with one of the high flow periods. The majority of the eggs were collected from sites 3 and 4, while no American shad eggs or larvae were collected from Buffalo Creek (Table 2). While plankton sampling did not collect many American shad larvae, high densities of other species were captured and are currently being identified.

Discussion

Prior to the removal of Lowell Mill Dam on the Little River, resident upstream fish could migrate downstream by spilling over the dam, but upstream migration, including that by anadromous fish, was precluded. Following dam removal, both resident and anadromous fish species were captured at the weir moving upstream and downstream. In total, 876 unique fish took advantage of the unobstructed migration and some migrated past the former dam site in both directions. American shad and gizzard shad utilized the entire extent of restored habitat as they migrated up to the impassable Atkinson Mill Dam. Increased spawning migrations by American shad following dam removals have been documented in previous studies (Walburg and Nichols 1967, Burdick and Hightower 2006). In addition to utilizing upstream habitat for spawning, the reconnected river allows fish to move freely for food, cover, and preferred water temperatures, flow, and depth in the Little River, but also in tributaries and the Neuse River.

River flow and water depth proved to be influential migration factors. Over 70% of gizzard shad that were collected migrated during a three-day high flow period in April.

The increased flow may have been a spawning migration cue as spawning events typically have large aggregates of adult gizzard shad (Etnier and Starnes 1993). Migration of other resident species (largemouth bass, black crappie, and channel catfish) was only detected during periods of high flow and water depth. North Carolina has experienced record drought conditions in 2007, and the Little River flows are well below normal base levels. Periods of high flow following rain events may have provided sufficient water depths for resident fish to move within the river. Increased flow and water depth may also ease navigation past instream obstructions such as beaver dams and boulder rock ledges that are present in the Little River. In addition, the notched dam at the Goldsboro water treatment plant may inhibit fish movement during low flow periods.

Similar to gizzard shad, American shad may utilize increased flow as a spawning migration cue and to ease migration past obstructions. There was an obvious disparity between sampled upstream- and downstream-migrating American shad at the weir. Therefore, American shad either migrated upstream prior to weir installation, possibly during a high flow period at the beginning of March, or during the high flow period in the middle of March when the weir was not functioning properly. The downstream migration of American shad did not appear to be influenced by flow as few individuals moved downstream during high flow periods. Instead, the majority migrated downstream during declining flow from April 24 to May 3.

Water temperature is another physical cue for spawning migrations and can influence survival during early life stages. American shad were present in the Little River during the entire sampling period, which had a mean daily water temperature range of 11.85 °C to 22.84 °C. This range falls within the 8 °C to 26 °C range reported by

Walburg and Nichols (1967) for American shad spawning activity. Although the number of collected eggs was low, the highest density of collected American shad eggs occurred on April 22 with a mean daily water temperature of 16.8 °C. This was shortly after a high flow period and when water temperatures began rising into the optimal range of 14 to 21 °C (Walburg and Nichols 1967). It is possible that American shad migrated upstream during the high flow period, completed spawning, and then began to emigrate downstream.

North Carolina is believed to be a transition zone between semelparous and iteroparous populations of American shad (Leggett and Carscadden 1978). The extent of spawning mortality could not be assessed in 2007, but at least 315 individuals successfully migrated downstream past the weir site. A few of the females were very gaunt, but other individuals appeared healthy. Energy depletion due to migration and lack of food consumption may result in direct spawning mortalities (Chittenden 1976, Leonard and McCormick 1999). It is possible that the observed dead American shad with puncture wounds were already dead and brought onto shore by scavenger animals. However, predators such as snakes, turtles, and mammals were seen actively hunting in the Little River and may cause notable mortalities during the spawning period. Recapture of tagged individuals in subsequent years will provide insight into iteroparity, whereas a properly functioning weir for the entire sampling period can provide insights into within-season spawning mortalities.

It is clear that American shad are utilizing restored habitat, but the impact on population levels cannot yet be determined as pre-dam removal population estimates were not conducted. Over 500 American shad migrated past the former Lowell Mill Dam site in 2007. The total number may be higher if American shad migrated past the weir site prior to its proper functioning and experienced spawning mortalities upstream of the weir. This number is drastically lower than the estimate of 6,100 adults for this reach based on the 124 adults/ha suggested by St. Pierre (1979). Savoy and Crecco (1994) argued that St. Pierre's rule-of-thumb estimator is too high, and using data from the Connecticut and Pawcatuck rivers they proposed a lower estimate of 7 adults/ha and an upper estimate of 64 adults/ha for the Thames River. Another potential explanation for the discrepancy is that American shad require a minimum of two years and more often three to six years to mature into spawning adults (Walburg and Nichols 1967). Therefore, any impacts of the Lowell Mill Dam removal in 2005 would not occur, at the earliest, until 2008 when individuals from the spring of 2006 year-class would recruit into the adult spawning population. Also, the distribution pattern and fraction of the Little River population that remained downstream of the weir site is unknown. Untagged individuals in reaches below the weir site were observed during general boating trips but were not included in the total number of American shad. Overall, dam removals on the Little River began in 1998, so only a few generations have had access to restored habitat and any population response may not yet be apparent.

The life history of notchlip redhorse has received little study in the past. Notchlip redhorse are believed to be potadromous, meaning they migrate within their native river for spawning purposes. A small migration was detected at the weir, with eight individuals migrating upstream over a three-day period. However, the overall timing and extent of these migrations was not determined. During electrofishing runs and observational boating trips, depressions of cleared rock substrate were found throughout the river. Open wounds on the ventral portion of caudal fins on collected notchlip redhorse may have been a result of vigorous movement of substrate that created depression areas during spawning events. Notchlip redhorse experienced high spawning mortality in the Little River in 2007. It is unclear if they annually experience high spawning mortality due to these activities or if this was a rare case brought on by other factors such as adverse water temperatures, dissolved oxygen, or disease.

The resistance board weir was an effective tool for monitoring fish migrations in the Little River. The weir consistently captured upstream moving fish that were healthy when removed from the cage for sampling. The downstream cage was not effective at capturing fish, as only one fish was captured in the cage during the entire sampling period. Also, some mortality occurred as fish washed onto the resistance board panels. However, the attached net improved catch rates of downstream-migrating fish and decreased mortalities. The net was installed in an area of higher flow that better funneled fish into the net compared to the cage that was located in minimal flow. In future years, the downstream cage could be installed in a similar fashion. This would provide more space for captured fish and limit escapes and invasion of predators as holes were routinely chewed into the net.

The resistance board weir was able to withstand periods of high flow. While the storm event in the beginning of the sampling season resulted in the weir not functioning properly, this was a result of the breaching of temporary fences and not the resistance board weir. The resistance board weir was easier to clean of debris than the picket weir, as walking on the panels allowed the river current to remove debris. However, small debris collected between the pickets of the resistance board weir and weighed the panels down. This debris had to be removed by hand or by jumping on the panels to dislodge the debris and allow it to move downstream. Replacing portions of the picket weir with resistance board panels could prove advantageous for future years of the study.

Future Study

In the second year of this study (2008), a few changes in the sampling protocol are planned. The first priority will be to install the weir at the beginning of the spring spawning season. Installation will begin prior to March 1 to ensure that the beginning of the American shad spawning migration is sampled. In addition, we propose to move the weir downstream, closer to mouth of the river and near the site where the Cherry Hospital Dam was removed (Figure 1). At this location, essentially all American shad entering the Little River will be sampled, thus providing a better idea of the total abundance of fish utilizing the river for spawning migrations.

The use of passive integrated transponder (PIT) tags instead of the T-bar anchor tags is also proposed for the 2008 season. These small microchips are inserted into the body of fish to allow for permanent identification of individual fish. Similar to the T-bar anchor tags, this will allow the duration of an individual’s stay in the river to be determined, to estimate spawning mortality, and to identify repeat spawners in subsequent years. An added benefit of the PIT tags is that migration can be monitored without the need to handle the fish, by installing antennas across the river channel (Castro-Santos et al. 1996, Zydlewski et al. 2001). As a fish passes through an antenna, the microchip is activated, resulting in a passive recording of the migration past this point and a better understanding of the extent of the overall migration by individual fish. Antennas are planned to be installed at a site downstream and directly across the notched dam at the Goldsboro water treatment plant (Figure 1). These two antennas will provide information on whether the notched dam is a migration impediment. In addition, fish passage will be evaluated relative to physical variables (e.g., water flow and depth) and structural characteristics of the passage way (e.g., slope, length). An additional antenna will be installed at the former Lowell Mill Dam site to compare data between 2007 and 2008 (Figure 1).

In 2008, quantification of American shad spawning and available habitat will allow for development of resource selection models. American shad clearly migrated upstream for spawning, and their locations during electrofishing suggested that they were selecting particular habitat. However, these were observations and quantitative data are necessary to avoid bias and to develop models. Therefore, the locations of American shad spawning habitat will be determined either with electrofishing or manual tracking of PIT tags. These spawning areas can then be quantified for substrate, flow, depth, and other physical variables. Similarly, random river locations will be chosen to quantify the same physical variables for habitat. The combination of these two data sets will allow for development of resource selection models that can predict the probability of an American shad utilizing different habitat types for spawning.

The apparent spawning mortality of notchlip redhorse was an unexpected event, but offers an opportunity for future study. If few notchlip redhorse are sampled at the weir, electrofishing in upstream reaches can be used to capture individuals for tagging. Efforts can be made to recapture these individuals, including information on mortalities. In addition, determining where notchlip redhorse are spawning would allow for quantification of their spawning habitat. These data can be compared to available habitat throughout the river to develop models of their spawning habitat use.

In addition to changes with the weir and tagging methods of adults, the sampling of eggs and larvae will also be improved upon. American shad spawning activity is more intense after sunset (Walburg and Nichols 1967), so sampling during this period may increase the density of eggs collected. Another option is to sample at different locations or to increase the number of sampling sites. Effectiveness of plankton sampling may be low in the Little River, compared to the Neuse River (Burdick and Hightower 2006), because of the relatively low flows. Lastly, test runs in 2007 showed that stationary drift nets were successful at sampling eggs and larvae and may be utilized at known spawning sites.

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Tables

Table 1. Fish species composition, migration direction, and total number of fish sampled at the Little River weir site in 2007. Direction of migration was unknown for a few fish swept onto the resistance-board weir panels during a period when the weir did not fully block the river channel.

Species	Upstream	Downstream	Unknown	Total
American eel	1	.	.	1
American shad	45	440	17	502
black crappie	1	1	.	2
black jumprock	.	1	.	1
bowfin	.	1	.	1
bull chub	1	7	.	7
channel catfish	.	2		2
gizzard shad	260	36	6	302
largemouth bass	5	1	.	6
longnose gar	.	1	.	1
notchlip redhorse	9	49	.	58
shorthead redhorse	.	1	.	1
sucker (decomposed)	.	1	.	1
Lepomis spp.	3	11	.	14
brown bullhead	.	1	.	1
redfin pickerel	.	1	.	1
Total	324	554	23	901

Table 2. Expected American shad population size based on available habitat for river reaches in the Little River. Reaches are established according to locations of removed and present dams, while population estimates are based on 124 adults/ha (St. Pierre 1979).

Dam	Removal / Status	Location (rkm)	Reach (rkm)	Width (m)	Area (ha)	American shad
Cherry Hospital	1998	2.12	2.12	26	5.50	682.20
Rains Mill	1999	36.80	34.69	24	83.25	10323.15
Lowell Mill	2005	57.07	20.26	22	44.58	5528.02
Atkinson Mill	Present	81.69	24.63	20	49.25	6107.25
Total	.	.	81.69	20-26	182.59	22640.61

Table 3. Total number of American shad eggs and larvae along with sampling season mean water temperature and sample volume, and water depth on May 21, 2007, for five plankton sampling sites. The Buffalo Creek site was 0.07 rkm above its confluence with the Little River, or 64.6 rkm above the mouth of the Little River.

Site	Location (rkm)	Temperature (°C)	Volume (m^3)	Depth (m)	Total Eggs	Total Larvae
Little River 1	72.8	18.16	31.18	0.59	1	1
Little River 2	59.5	18.59	39.76	1.14	1	0
Little River 3	52.5	18.84	41.95	0.68	6	0
Little River 4	17.0	19.32	27.46	1.07	6	2
Buffalo Creek	0.07, 64.6	17.92	49.34	0.18	0	0

Figures

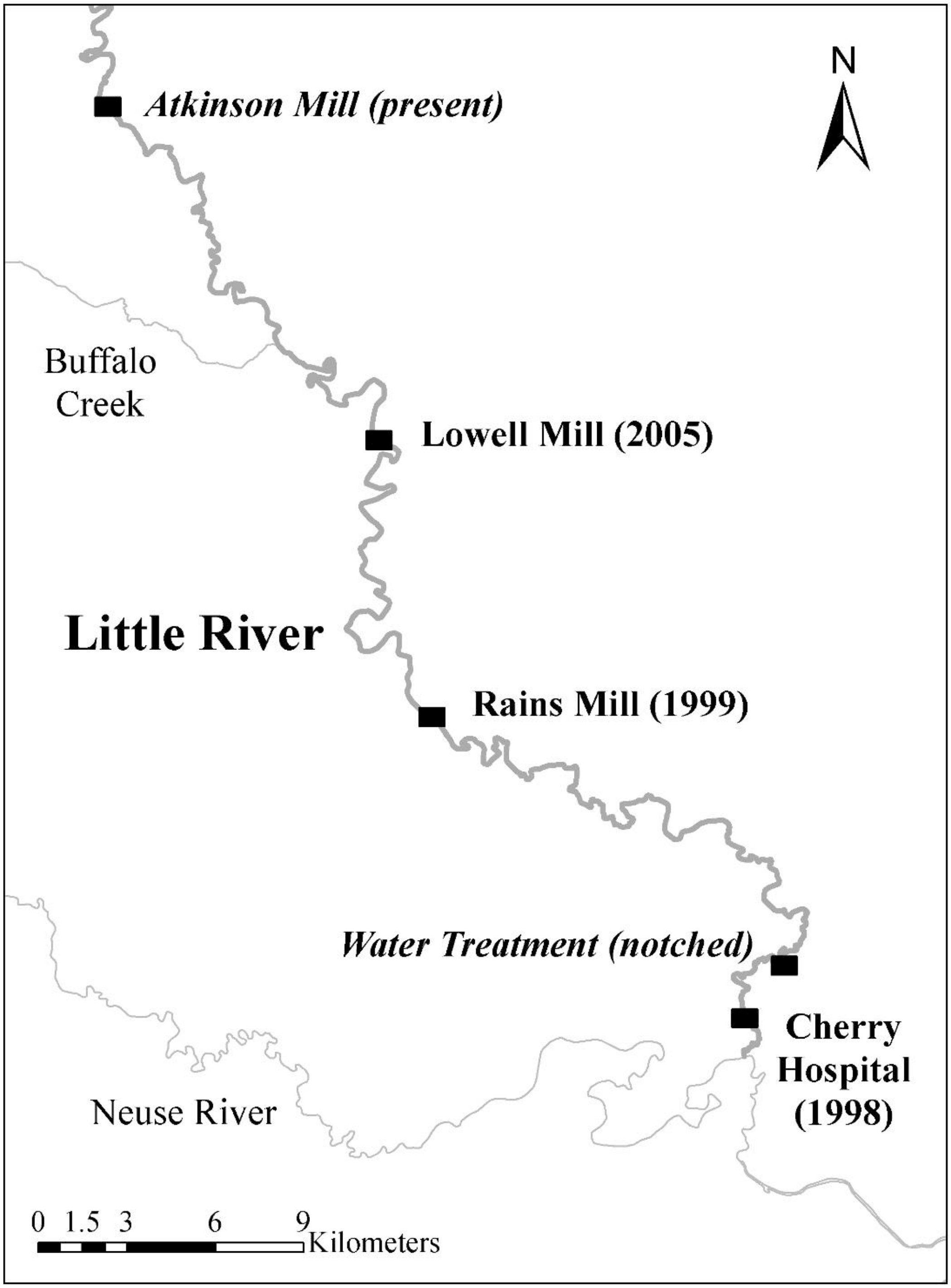

Figure 1. Locations of three dams removed since 1998, along with the location of a notched dam and the furthest downstream dam (Atkinson Mill) on the Little River.

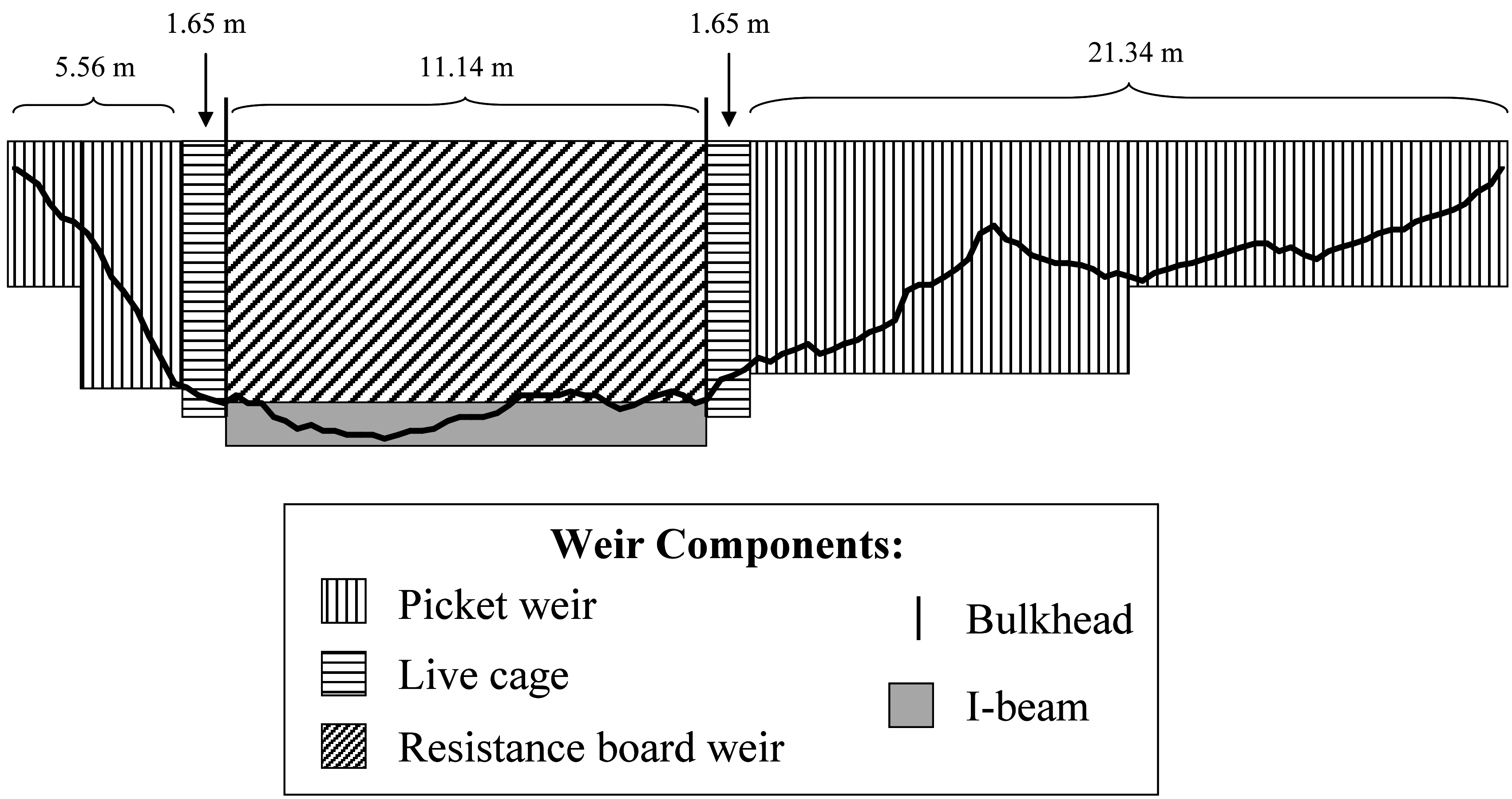

Figure 2. Cross-sectional view of weir components that spanned 41 meters of the Little River. View is looking upstream, with west on the left side of the diagram. Plastic fencing was installed on the banks for the river to contain fish during high flow periods.

Figure 3. Installed fish weir on the Little River, with resistance board weir in center and picket weir sections on both sides of live cages. Picture taken on March 30, 2007, view is looking downstream.

Figure 4. Modification of weir (April 3, 2007) to improve downstream capture of fish. Sandbags sunk portions of the resistance board panels, creating increased flow to the attached net.

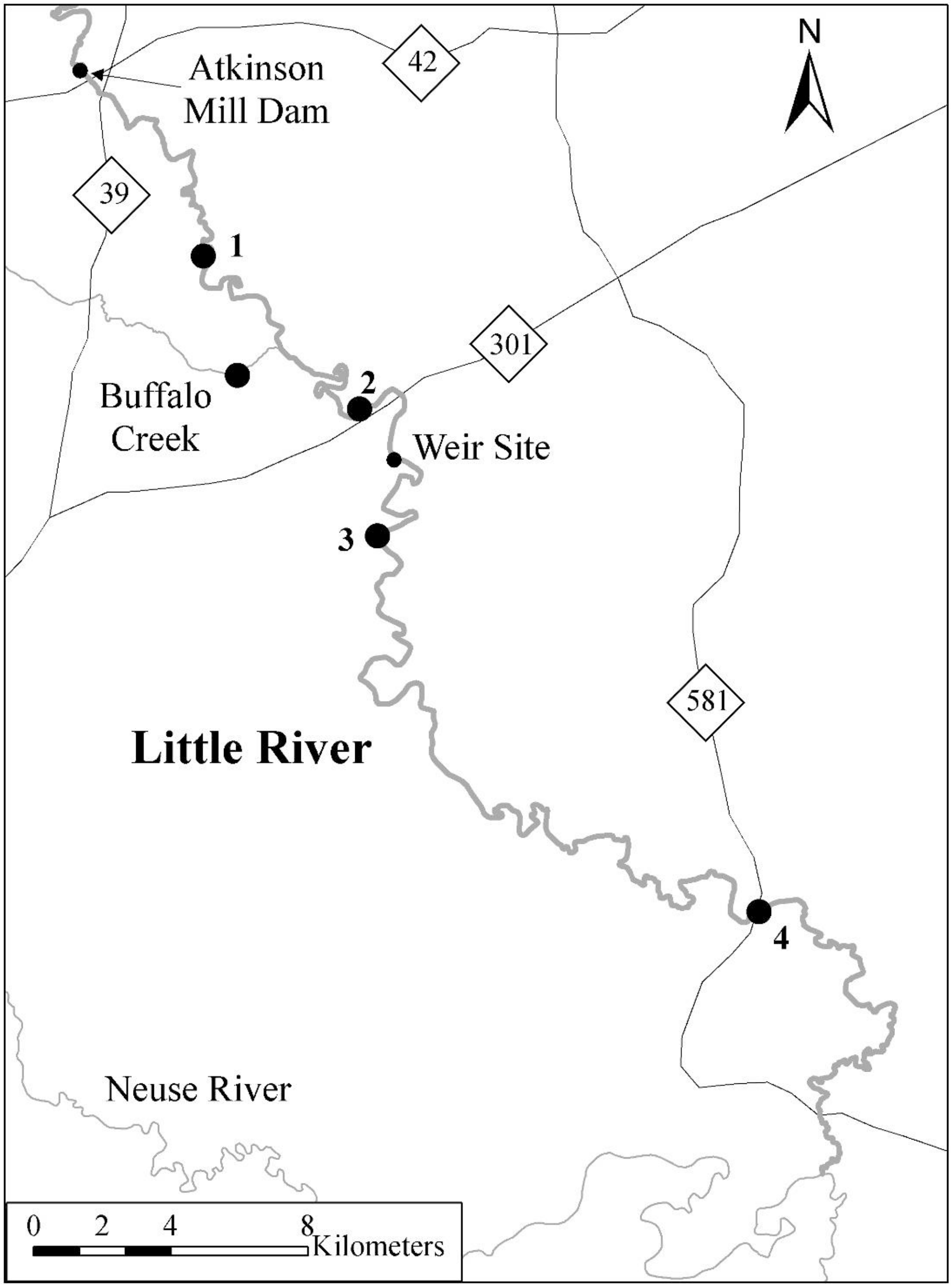

Figure 5. Four Little River and one Buffalo Creek plankton sampling sites. All sampling occurred from bridges, but only major roads are depicted for general reference.

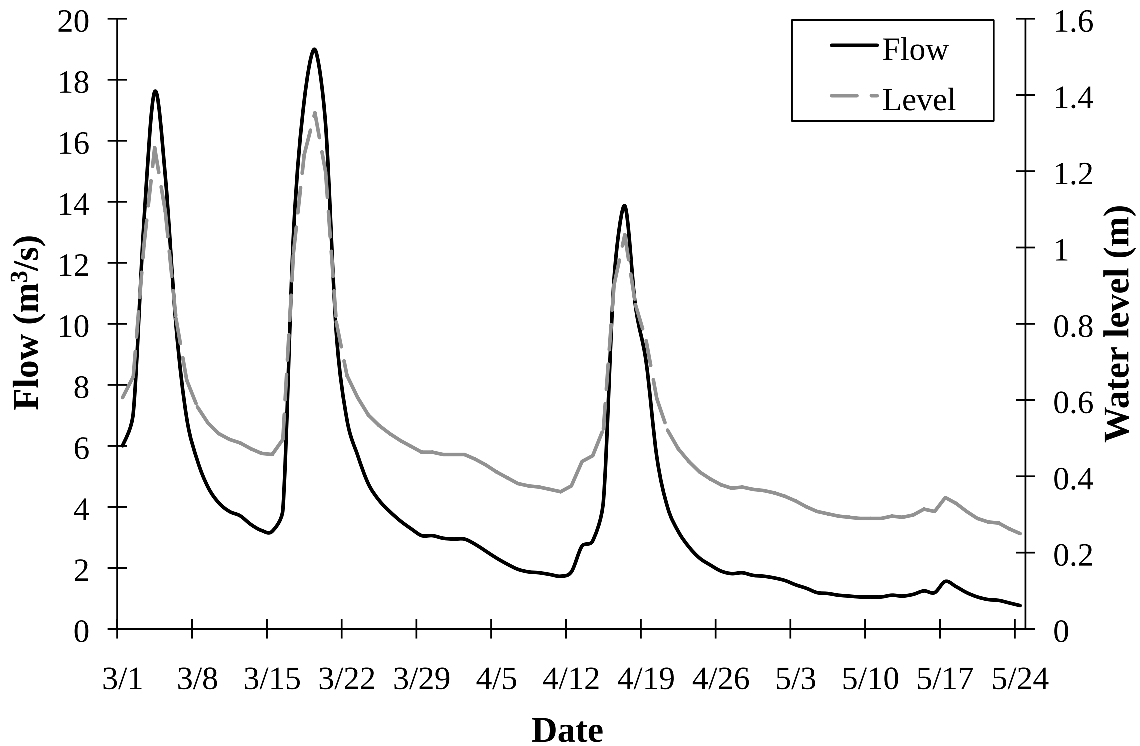

Figure 6. Flow and stage of the Little River during the 2007 sampling season, based on United States Geological Survey monitoring station 0208850 near Princeton, North Carolina.

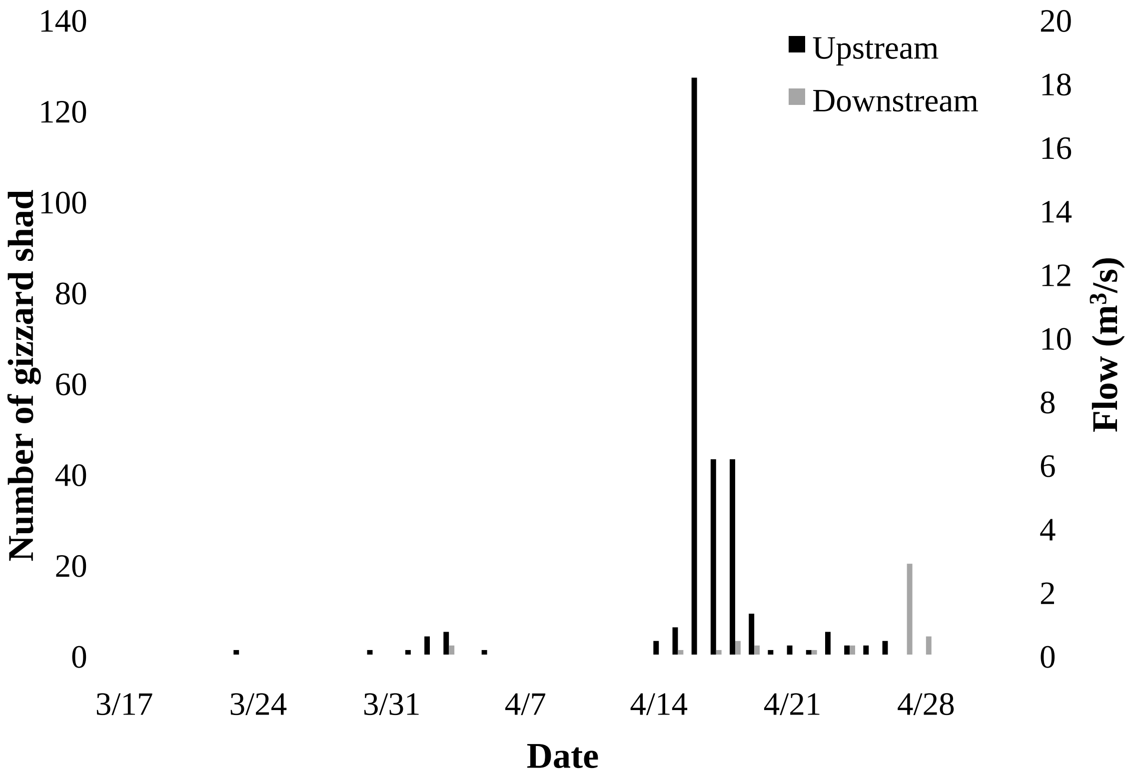

Figure 7. Upstream and downstream migrations of gizzard shad sampled at the Little River weir site relative to the flow regime in 2007.

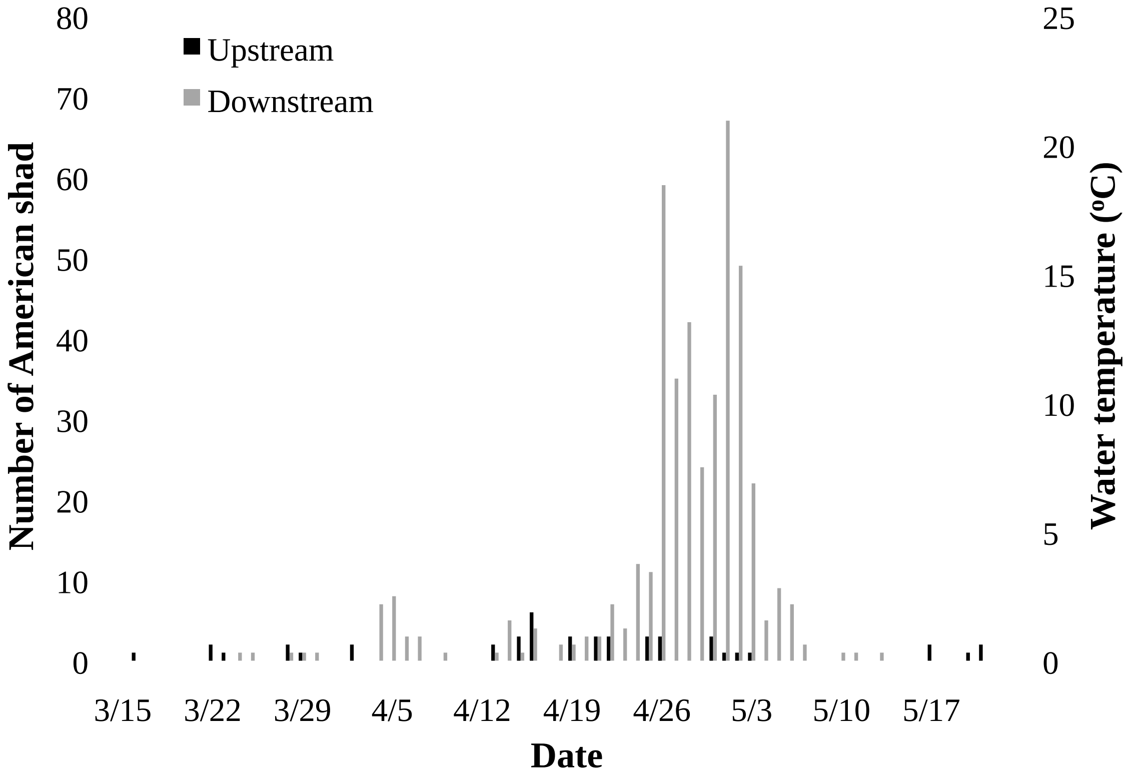

Figure 8. Upstream and downstream migrations of American shad sampled at the Little River weir site relative to the water temperature profile in 2007.

Figure 9. American shad found dead onshore on April 30, 2007, with distinct puncture wounds.

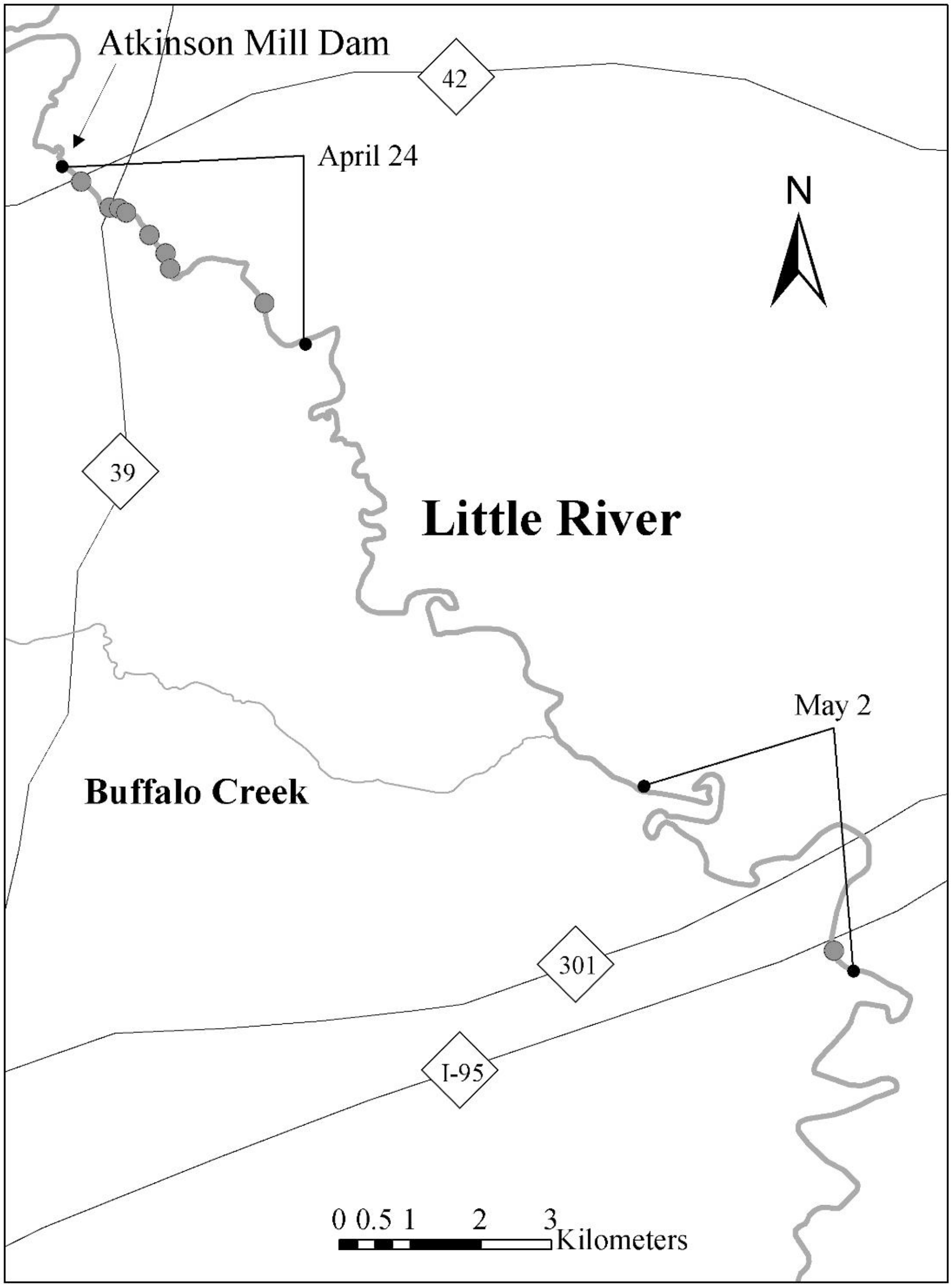

Figure 10. Locations of American shad sampled by electrofishing on April 24 and May 2, 2007.

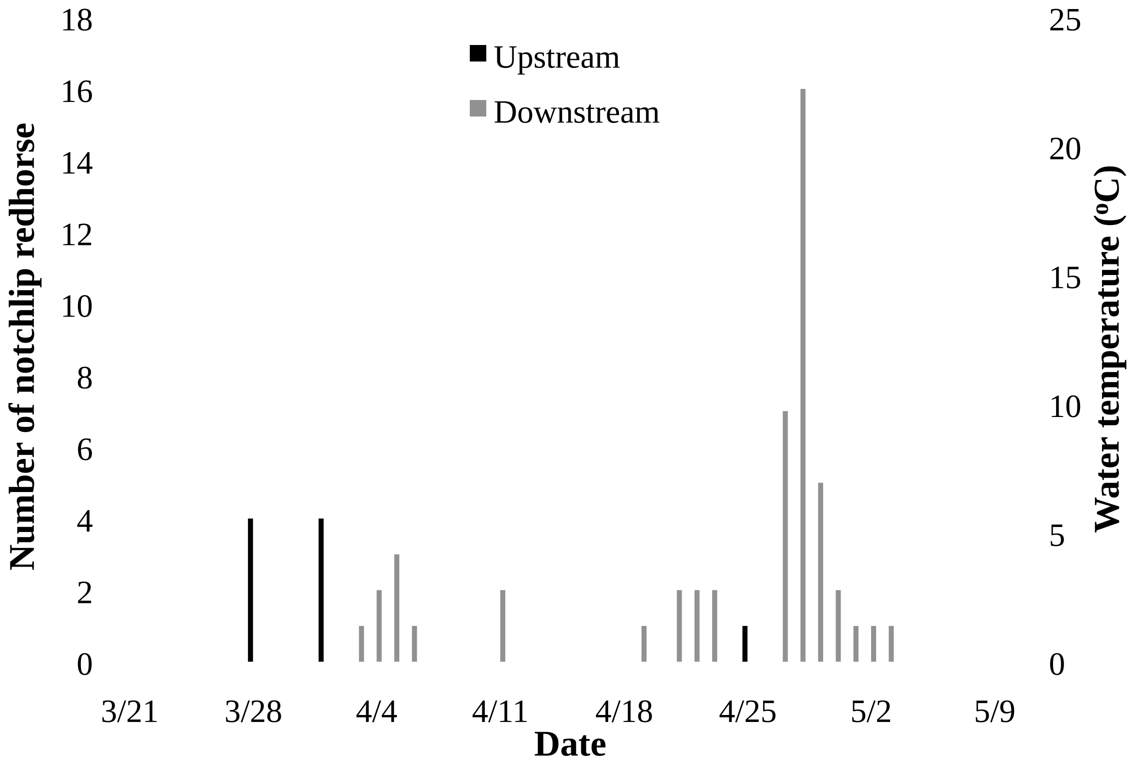

Figure 11. Upstream and downstream migrations of notchlip redhorse sampled at the Little River weir site relative to the water temperature profile in 2007. Downstream moving fish were either mortalities or in poor to fair condition.

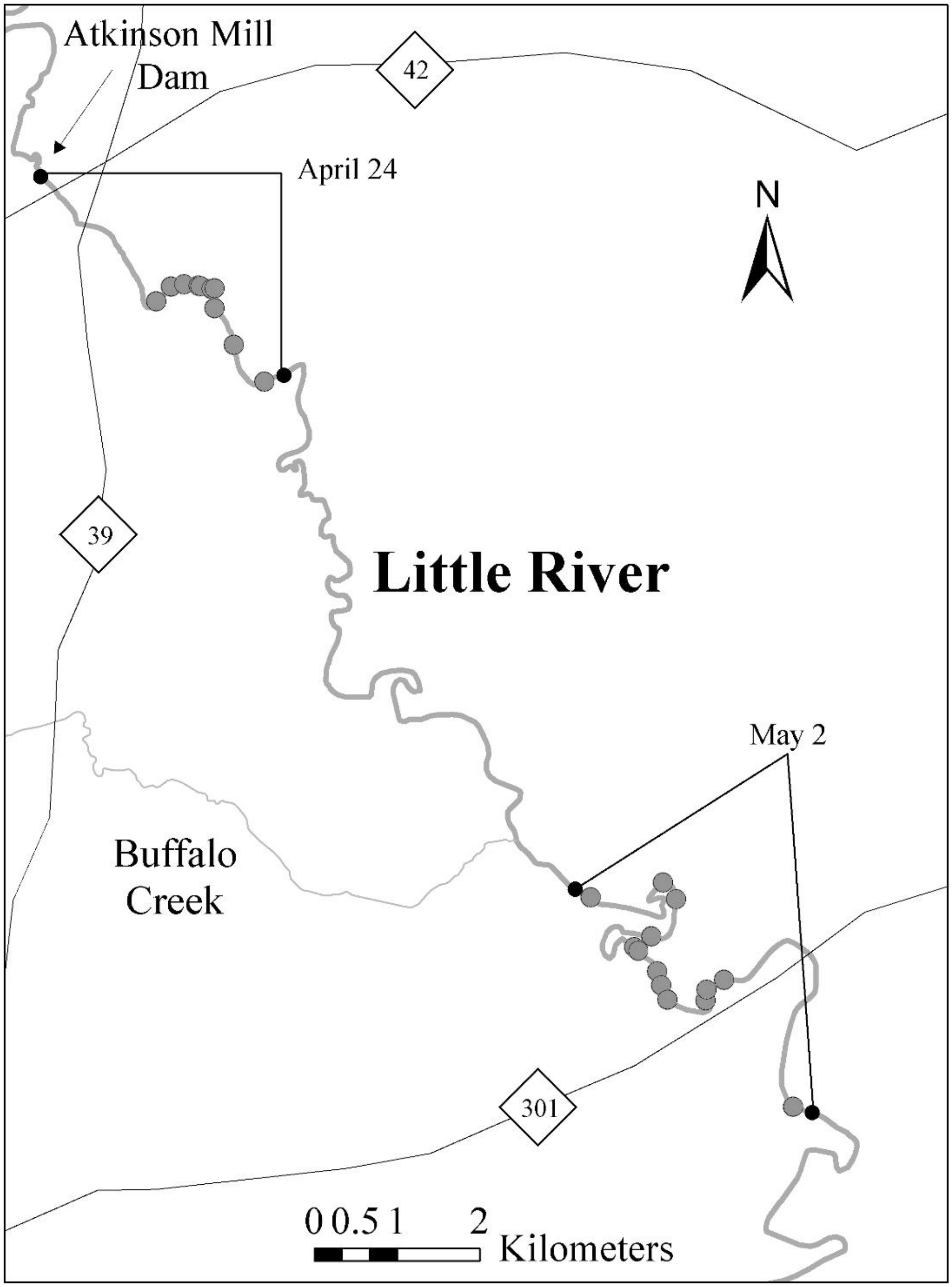

Figure 12. Locations of notchlip redhorse sampled by electrofishing on April 24 and May 2, 2007.

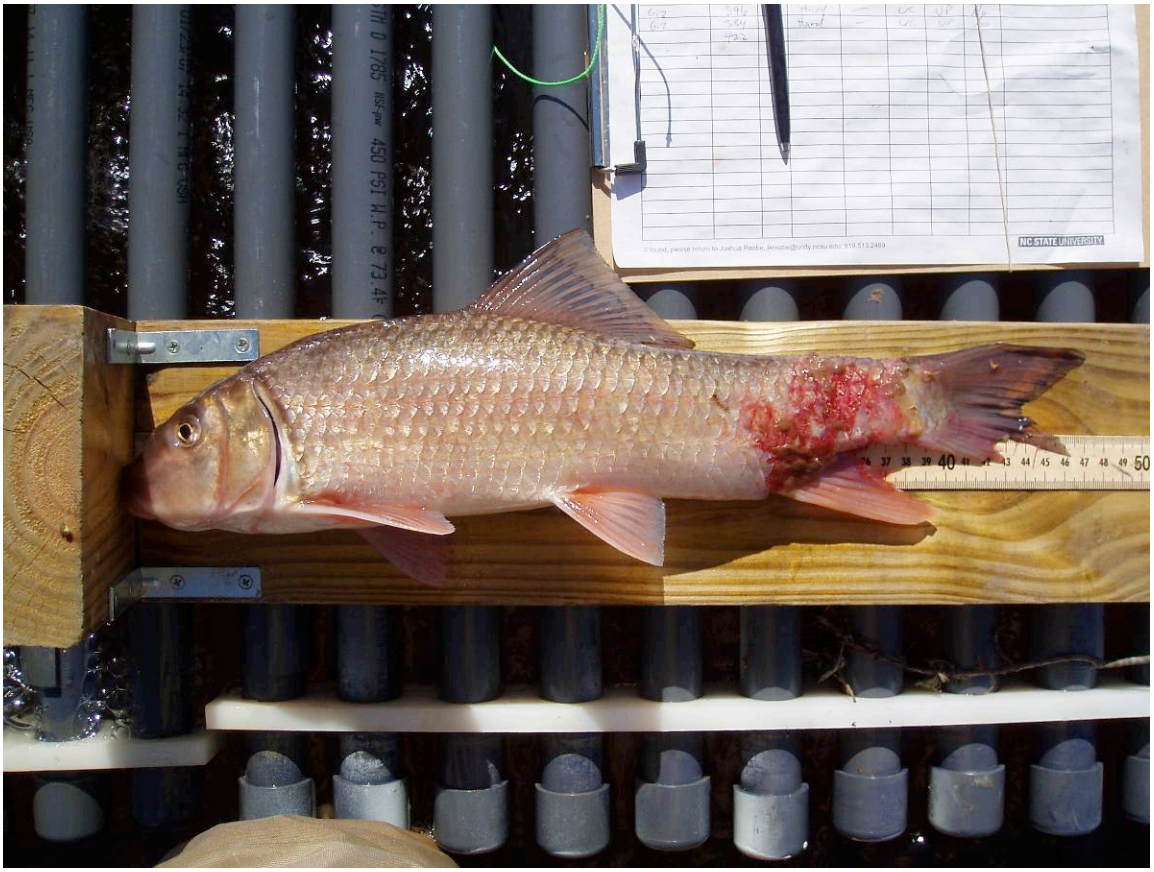

Figure 13. Notchlip redhorse collected at fish weir on April 23, 2007, with damage to tail and caudal peduncle.