CARBONTON DAM – DEEP RIVER WATERSHED
RESTORATION SITE
2008 Annual Monitoring Report (Year-3)

Ecosystem Enhancement PROGRAM

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2008 Annual Monitoring Report (Year-3)

Chatham, Lee and Moore Counties, NC
NCEEP Project No. D-04012A
Design Firm: Milone and MacBroom, Inc.

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EXECUTIVE SUMMARY

Introduction

Dam removal projects performed pursuant to the guidance released by the North Carolina Dam Removal Task Force (DRTF) are required to quantitatively demonstrate chemical and biological improvements to restored in-channel ecosystems in order to achieve compensatory mitigation credit (DRTF 2001). The following monitoring report documents the latest efforts of Restoration Systems, LLC, on behalf of the N.C. Ecosystem Enhancement Program (NCEEP), to document changes in the study area of the Carbonton Dam removal project (Cape Fear Hydrologic Unit 03030003). 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 Carbonton Dam is approximately 9 miles west of Sanford, North Carolina at the juncture of Chatham, Lee, and Moore Counties, North Carolina (Figure 1, Appendix A). The on-site dam removal activities restored unhindered flow to approximately 126,673 linear feet of the Deep River and associated tributaries from the impounding impact of the dam. The limits of the former Site Impoundment have been identified as any stream reach of the Deep River or associated tributaries located above the former Carbonton Dam with a thalweg elevation less than 227.6 feet above mean sea level (MSL), prior to dam removal. 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 within the former Site Impoundment shifted from a free-flowing (lotic) river system towards an impounded (lentic) condition following construction of a dam at the site. Rare and endangered mussel and fish habitat, which depended on free-flowing lotic conditions, was absent or greatly diminished within areas of the Deep River impounded by the former dam. These affected stream reaches will be hereafter referred to as the former "Site Impoundment."

The dam was removed in a manner that minimized impacts to water resources both upstream and downstream of the dam site. Dam removal began with dewatering (lowering) of the Site Impoundment on October 15, 2005, followed by breaching on November 11, 2005. Demolition activities continued in stages until dam removal was completed on February 3, 2006.

Third year monitoring activities began in March 2008. Monitoring is being performed for a minimum of five years, post dam removal--or until success criteria are achieved. Post removal monitoring data will be compared to baseline values collected in April-June 2005, Year-1 monitoring values collected in April-June 2006, and Year-2 monitoring values collected in March-July 2007.

Monitoring Plan

A monitoring plan was developed in accordance with the DRTF guidelines to evaluate the fulfillment of the project's primary success criteria, which include:

1) Re-colonization of rare and protected aquatic species, 2) improved water quality, and 3) an improved aquatic community. Reserve success criteria include: 1) downstream benefits below the dam, and 2) human values (scientific contributions and human recreation).

In order to evaluate project success for the above criteria, a monitoring network was deployed in 2005 throughout the former Site Impoundment, contributing waters, and reference areas both upstream and downstream of the former dam site (Figure 3, Appendix A). Within the established network, biological surveys were conducted to provide baseline (i.e., pre-dam removal) aquatic community data within the Site Impoundment, and will be monitored until 2010 to assess community changes following dam removal. Monitoring cross-section stations were also established to assess changes in bankfull channel geometry, channel substrate composition, and aquatic habitat. Water quality data 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).

Third Year Monitoring Results

Water Quality

Ambient Monitoring Station (AMS) data indicate that dissolved oxygen concentrations within the former Site Impoundment continue to persist above the established threshold required to meet the success criteria (mean value is 4.62 mg/L higher). Additionally, water temperature has remained below the state standard during Year-3 monitoring. Fecal coliform within the former Site Impoundment exceeded the state standard of 200 colonies/100 ml twice during Year-3 monitoring. It should be noted that for both events that resulted in high fecal coliform measurements, reference data from the Ramseur station were not sampled on the same day. Additionally, greater than 1-inch rain events occurred the day before the date of sampling for the Site Impoundment for both outlying data measurements. Therefore, it is expected that the reference station would have also shown similar spikes in fecal coliform data if they were available.

The Year-3 mean biotic index (used as a proxy for water quality) for formerly impounded stations is slightly more than (0.46) one standard deviation of the reference mean. Year-1 data show that following dam removal, the success criterion was met by 0.21, suggesting that some variability may be present between years.

Aquatic Community

Based on habitat reconnaissance performed prior to mollusk sampling throughout the restored reach of the Deep River, it appears that much of the former reservoir pool has reverted to lotic conditions. Riffle/run/pool habitats have formed at varying intervals throughout the restored reaches, promoting aquatic species recolonization. Morphological features at many of these sites have created various hydraulic conditions and, in turn, multiple microhabitats which correspond to potentially high quality habitat for aquatic species. A total of eleven freshwater mussel species, three aquatic snail species and one freshwater clam species were found within newly formed riffle habitats in the former impounded reach.

Recruitment of freshwater mussels was evident in the newly established riffle habitats in the upper (upstream) sections of the former reservoir pool, while lotic-adapted aquatic snails were found to have colonized riffle habitats throughout. Benthic data from stations within the former Site Impoundment

indicate that the number of EPT (Ephemeroptera [mayflies], Plecoptera [stoneflies], and Trichoptera [caddisflies]) taxa and the number of total taxa has decreased in Year-3 Monitoring. This negative shift also occurred for the same metrics among reference stations, suggesting an altered benthic community composition and abundance throughout the Deep River watershed, likely due to persistent drought conditions.

The NCDWQ Habitat Assessment Field Data Sheet was completed at each station in order to evaluate the quality of in-stream habitat and to provide a comparable score that describes the available habitat. Compared to baseline conditions, the mean total score of the formerly impounded stations quantitatively increased in Year-3 monitoring from 42.39 to 59.56, indicating improved aquatic habitat.

Rare and Protected Aquatic Species

Rare and Protected Aquatic Species success criteria within the former Site Impoundment is based on the documented presence of any rare species throughout the monitoring period. Success criteria were met last year when a total of 41 specimens of the endangered Cape Fear shiner (*Notropsis mekistocholas*) were collected. These individuals were identified throughout the former Site Impoundment at eight of the sampling sites, while an additional six sites continue to develop favorable habitat for future colonization.

Year-3 monitoring indicates that freshwater mussels are also re-colonizing habitats previously impounded by Carbonton Dam. A total of eleven freshwater mussel species, three aquatic snail species and one freshwater clam species were found within newly formed riffle habitats in the former impounded reach. The surveys documented several mussel species of conservation interest associated with lotic condition, including five state listed species: yellow lampmussel (*Lampsilis cariosa*), creeper (*Strophitus undulatus*), triangle floater (*Alasmidonta undulata*), eastern creekshell (*Villosa delumbis*), and the notched rainbow (*Villosa constricta*). The presence of notched rainbow is especially significant because this species is extremely rare and has only been collected once in the Deep River in the past 100 years.

Reserve Success Criteria

Reserve Success Criteria have been achieved based on the implementation/refereed publication of scientific research related to the removal of Carbonton Dam, and the establishment of a public park at the location of the former dam. The Carbonton Dam removal project provided funding to the University of North Carolina at Chapel Hill to support original research by Adam Riggsbee, PhD, and Jason Julian, PhD. Dr. Riggsbee has published three papers with one in revision from his dam removal research while Dr. Julian has published one paper pertaining to the restored reach of the Deep River.

Furthermore, a new public park has been established at the site of the former dam that consists of vehicle parking, picnicking sites, bank fishing, and improved access to the river for kayakers and canoeists. RS formally transferred the new park to the Deep River Park Association during a ceremony held on the grounds on November 22, 2008.

Summary

After the third year of monitoring, the removal of Carbonton Dam has resulted in the continued restoration of lotic conditions with functional improvements recorded in water quality, fish and mollusk abundance, and sediment transport. Mitigation success has been demonstrated for the following criteria: Re-introduction of rare and endangered aquatic species, water quality improvement with respect to

dissolved oxygen concentrations and benthic biotic indices, scientific research, and public recreation. Continued monitoring is necessary to confirm success for the convergence of benthic EPT taxa to reference data. See table below.

	Criterion	Parameter	Anticipated Change/Result	2008 Success
Primary success criteria:	Re-colonization of rare and protected aquatic species	Presence/absence of rare/protected individuals	Unknown	Yes
		Rare/protected species habitat	Improvement/expansion	Yes
	Improved water quality	Benthic biotic indices	Decrease (= improve)	Yes
		AMS dissolved oxygen data	Increase within former Site Impoundment (must be ≥ 4.0 mg/L or consistent with reference station data)	Yes
	Improved aquatic community	Ephemeroptera, Plecoptera, and Trichoptera taxa, total number of benthic taxa	Increase (i.e., converge with reference station data)	Ongoing, Improving
		Fish, Mussel, and Snail community data	Demonstrated shifts in communities from lentic to lotic character	Yes
Reserve success criteria:	Downstream benefits below dam	Deep River bankfull channel within formerly eddie/scour pool areas below dam	Narrowing/increased stabilization of channel	Ongoing
	Scientific value	Published research	Successful completion	Yes
	Public recreation	Construction of planned on-Site park	Successful completion	Yes

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1.0 PROJECT BACKGROUND

1.1 Location and Setting

In order to provide stream restoration in the Cape Fear River Basin (Hydrologic Unit 03030003), Restoration Systems, LLC (RS) has removed the Carbonton Dam formerly located at the juncture of Chatham, Lee, and Moore Counties, North Carolina (Figures 1 and 2, Appendix A). The former Carbonton Dam was located on the Deep River approximately 9 miles west of Sanford, North Carolina, immediately downstream of the bridge crossing of NC 42 (35.5200N, -79.3485W). The Deep River is a 4th-order river with a watershed upstream of the former dam location of approximately 1,000 square miles. For the purposes of this document, the 5.5-acre land parcel that supported the dam will be hereafter referred to as the "Site." All construction activities mentioned in this report occurred on-Site, unless specifically mentioned otherwise.

The on-Site construction activities freed approximately 126,673 linear feet of the Deep River and associated tributaries from the impounding impact of the dam. These benefited stream reaches will be hereafter referred to as the "Site Impoundment." The limits of the Site Impoundment have been identified as any stream reach of the Deep River or associated tributaries located above the former Carbonton Dam with a thalweg elevation less than 227.6 feet above mean sea level (MSL), prior to dam removal.

1.2 Restoration Structure and Objectives

The Site Impoundment formerly covered approximately 116 acres with water depths up to 25 feet and bank-to-bank impoundment widths from 150 to 260 feet. The former Site Impoundment occurred within the channel of the Deep River, which is characterized by steep banks with occasional areas of bank failure in locations where mature trees have been toppled by storms or flood flows. The lentic flow that characterized the Site Impoundment resulted in a stratified water column, where velocities were low near the surface, and stagnant at depths below the crest pool elevation.

Site restoration efforts consisted primarily of the physical removal of the Carbonton Dam. Construction activities associated with the removal of the dam were phased in order to minimize disturbance to aquatic resources upstream, downstream, and in the immediate vicinity of the Site. Furthermore, throughout the dam removal process, construction best management practices were utilized to prevent/minimize potential impacts to aquatic resources.

The demolition and removal of the Carbonton Dam is expected to generate at least 90,494 Stream Mitigation Units (SMUs) for use by the NCEEP. The majority of the credits generated by this project will be validated by evaluating the ecological benefits that occur in the Deep River over the five-year, post-removal monitoring period. Bonus factors (reserve success criteria) include downstream benefits and human values such as recreation and scientific research. Table 1 displays the amount of SMU credits that are proposed for this project. The primary success criteria are being monitored in accordance with the Dam Removal Task Force (DRTF) guidance. The mitigation ratios have also been derived from the DRTF guidance (DRTF 2004). The amount of restored channel was determined through methods described in Section 1.1.2 of the Restoration Plan (Restoration Systems 2005). The number of SMUs were determined by multiplying the amount of channel returned to lotic condition (linear feet) by the

mitigation ratios. While up to 114,356 SMUs may be potentially created in accordance with the DRTF guidance, the project will only be evaluated for the amount of credit that is committed to NCEEP.

Table 1. Stream Mitigation Units (SMUs)[1] Generated by Removal of the Carbonton Dam

Primary Success Criteria	Channel Restored (feet)	Mitigation Ratio	SMU
1) Water Quality 2) Improved Aquatic Community 3) Rare and Protected Aquatic Species	126,673 feet of free-flowing river and tributaries **under the crest pool**	0.7:1	88,671
Reserve Success Criteria	**Channel Restored (feet)**	**Mitigation Ratio**	**SMU**
Downstream Benefits Below the Dam	~ 500 feet below dam	0.7:1	350
Human Values 1) Human recreation 2) Scientific value	-----	Up to 20 percent bonus	Up to 25,335
Total Potential SMUs			114,356
Total Committed SMUs			**90,494**

[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. If all primary criteria are successfully met, these reserve criteria should result in excess, unsold credits becoming available at the end of the monitoring period

1.3 Project History and Background

Table 2. Project Activities and Reporting History: Carbonton Dam Restoration Site

Activity Report	Scheduled Completion	Data Collection Complete	Actual Completion or Delivery
Restoration Plan	July 2004	N/A	August 2005
Final Design	July 2004	N/A	August 2005
Construction	February 2006	N/A	February 2006
Temporary S&E mix applied to entire project area	February 2006	N/A	February 2006
Permanent seed mix applied to reach/segments	February 2006	N/A	February 2006
Installation of Trees and Shrubs	March 2006	N/A	March 2006
Mitigation Plan	January 2005	N/A	June 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	September 2006	July 2006	September 2006
Year-2 Stream Monitoring	September 2007	July 2007	November 2007
Year-3 Stream Monitoring	September 2008	October 2008	November 2008

1.4 Project Mitigation Goals

The desired result of this project is ecological improvement within the former Site Impoundment through restoration of natural, lotic flow conditions.

The specific goals of this project include:

- Restoration of approximately 126,673 linear feet of impounded river and stream channels to natural free-flowing riverine conditions.
- Restoration of previously inundated shallow water habitat for the Cape Fear shiner (*Notropis mekistocholas*), a federally endangered freshwater fish.
- Reduction or elimination of thermal stratification, which results in seasonal declines in dissolved oxygen concentrations below levels measured in reference reaches.
- Restoration of appropriate in-stream substrate.
- Restoration of upstream and downstream fish passage, and reconnection of currently disjunct populations of rare aquatic species of concern.
- Restoration of lotic mussel habitat.
- Improvement in the diversity and water quality tolerance metrics for benthic macroinvertebrate communities.
- Provide public recreational opportunities at the site of the former dam.
- Support independent academic research, resulting in peer-reviewed publications regarding the ecological consequences of large dam removal.

Table 3. Project Contacts: Carbonton 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 Coastal Plain Conservation Nursery Taylor's Nursery International Paper Nursery	1312 Woody Store Road Siler City, NC 27344 (919) 742-1200 3067 Conners Drive Edenton, NC 27932 (252) 482-5707 3705 New Bern Avenue Raleigh, NC 27610 (919) 231-6161 5594 Highway 38 South Blenheim, SC 29516 (800) 222-1290
Ecological Monitors EcoScience: A Division of PBS&J The Catena Group (TCG)	 1101 Haynes Street Suite 101 Raleigh, NC 27604 (919) 828-3433 410-B Millstone Drive Hillsborough, NC 27278 (919) 732-1300
Stream Monitoring POC	Matt Cusack
Vegetation Monitoring POC	N/A (project does not require vegetation monitoring)

Table 4. Project Background: Carbonton Dam Restoration Site

Project County	Chatham, Lee, and Moore Counties NC
Drainage Area	Approximately 1000 square miles
Impervious cover estimate (%)	<10%
Stream Order	4th-order
Physiographic Region	Piedmont
Ecoregion (Griffith and Omernik)	Triassic Basin
Rosgen Classification of As-built	N/A
Cowardin Classification	R2SB3/4
Reference Site ID	Deep River
Dominant Soil Types	N/A (stream restoration project only)
USGS HUC for Project and Reference	03030003
NCDWQ Sub-basin for Project and Reference	03-06-10
NCDWQ classification for Project and Reference	WS-IV HQW, WS-V HQW
Any portion of any project segment 303d listed?	No (NCDWQ 2006)
Reasons for 303d listing or stressor	
Any portion of any project segment upstream of a 303d listed segment?	Yes, Deep River, Sub-basin 03-06-11 (NCDWQ 2006)
Reasons for 303d listing or stressor	MS4 NPDES
Percent of project easement fenced	N/A

2.0 PROJECT MONITORING AND RESULTS

The monitoring results described herein document the Year-3 (2008) monitoring activities performed to determine the project's success in meeting the stated mitigation goals. Monitoring activities occurred at fifty-one (51) stations established prior to dam removal in 2005, as part of the monitoring deployment network (Figure 3, Appendix A). One (1) additional station was added in Year-1 (2006) monitoring for a total of fifty-two (52). Pre-removal baseline data (2005), Year-1, Year-2 and Year-3 monitoring data are compared to evaluate improvements in water quality, the aquatic community, rare and protected species, and human values within the former Site Impoundment.

2.1 WATER QUALITY

2.1.1 Biotic Indices

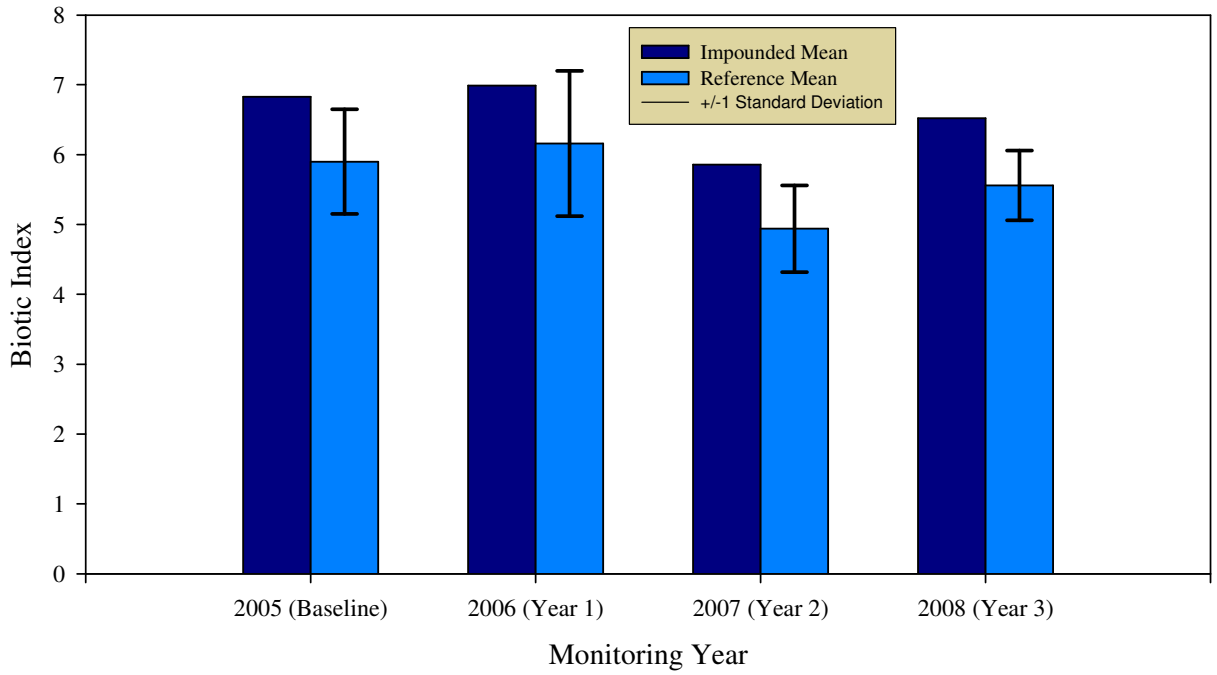
After identification of collected macroinvertebrates, the North Carolina Tolerance Values or Hilsenhoff Tolerance Values were assigned to each of the collected species. These Tolerance Values range from 0 for organisms intolerant of organic wastes to 10 for organisms very tolerant of organic wastes. The biotic indices of each station sampled for benthic macroinvertebrates were tallied, and then summary data were generated for comparison between formerly impounded and reference stations. Success for this particular mitigation goal is defined as follows: the mean biotic index of the impounded stations must be within one standard deviation of the mean biotic index of the reference stations. Table 5 presents the summary data for benthic biotic indices of both formerly impounded and reference stations.

Table 5. Benthic Biotic Indices of Formerly Impounded and Reference Stations

	2005 (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	7.97	6.91	8.58	7.62	8.52	5.71	8.19	6.36
Low	5.67	4.78	5.76	4.29	4.28	3.92	5.13	4.66
Mean	**6.83**	5.9	**6.99**	6.16	**5.86**	4.94	**6.52**	5.56
Median	6.79	5.99	6.72	6.02	5.3	5.02	6.40	5.60
Standard Deviation	0.83	0.75	0.95	1.04	1.52	0.62	1.05	0.50
Standard Deviation of Reference mean **(Success Criterion)**	**6.65**		**7.20**		**5.56**		**6.06**	

The mean biotic index from Year-3 monitoring in the formerly impounded stations (μ=6.52) is more than one standard deviation of the reference station (μ=6.06). Although the formerly impounded dataset was 0.46 above the reference station's standard deviation, the Year-3 reported value is within one standard deviation of the reference station's baseline value. Moreover, the Year-1 data show that the success criterion was met by 0.21. Therefore, some variability between years may be present. The following Graph 1 depicts the change in biotic indices from 2005 to present from both the formerly impounded and reference stations.

Graph 1. Mean Biotic Index of Formerly Impounded Stations vs. Reference Stations with Standard Deviation
Note: A lower index value is indicative of less tolerant species (= higher water quality)



2.1.2 Ambient Monitoring Station Network

Aside from the *in situ* sampling occurring at each monitoring cross-section, physical water quality parameters are currently collected at an Ambient Monitoring Station (AMS) located within the former Site Impoundment at NC 42 (B5575000), immediately upstream of the former Carbonton Dam. A reference AMS is located on the Deep River at Ramseur, NC (B5070000). These data have been obtained from the North Carolina Division of Water Quality (NCDWQ), and data coverage exists on a monthly basis for at least the last 10 years. AMS data dating back five years prior to dam removal are used to provide a historical record of water quality and compared to post-removal sampling. Due to time delay between collection date and public availability, the most recent AMS data available from NCDWQ is through December 5, 2007 at NC42, and through June 30, 2008 at Ramseur. Data collected by the AMS are not standard for all samples, but are always sampled at 0.1 meter depth and can include: water temperature (ºC), dissolved oxygen (mg/L), pH (field measured), conductance at 25ºC (µmhos/cm), turbidity (NTU), fecal coliform bacteria (number of colonies/100 milliliters), suspended residue (total suspended solids) (milligrams/Liter), ammonia as nitrogen (milligrams/Liter), total Kjeldahl nitrogen (milligrams/Liter), nitrite and nitrate as nitrogen (milligrams/Liter), total phosphorus (milligrams/Liter), and assorted metals. AMS data are used to evaluate physical water chemistry and associated parameters throughout the project's monitoring period. Water quality trends from AMS data are utilized in determining the project's overall success, using state standards established by NCDWQ's "Redbook".

2.1.2.1 Dissolved Oxygen

In order to achieve success, dissolved oxygen concentrations within the former Site Impoundment should not fall below the minimum NCDWQ standard for Class WS-IV waters (unless a similar failure is recorded at the reference station). The NCDWQ standard is an instantaneous value of no less than 4.0mg/L (daily average no less than 5.0 mg/L)**.** Table 6 provides the minimum, maximum, and mean instantaneous values for dissolved oxygen recorded within the former Site Impoundment, as well as the number of samples that fell below the state standard for all monitoring years.

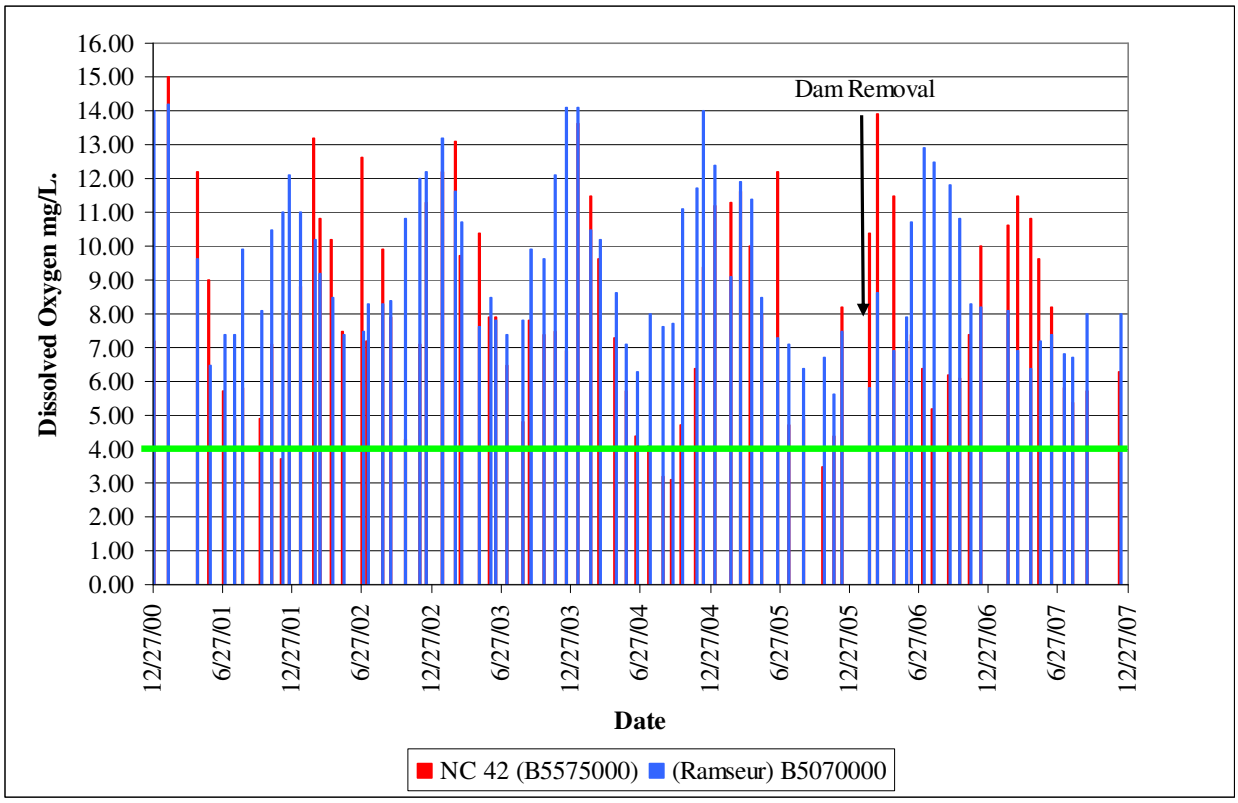
Table 6. Dissolved Oxygen Summary Data

	Baseline	Year-1	Year-2	Year-3
Minimum Value (mg/L)	1.10	7.20	5.20	5.40
Maximum Value (mg/L)	15.00	13.90	10.60	14.30
Mean Value (mg/L)	8.07	10.87	7.41	8.62
Number of Samples Below State Standard	6	0	0	0

Graph 2 depicts the AMS dissolved oxygen concentrations measured at a 0.1 meter depth within the Site Impoundment (B5575000), and at the reference location (B5070000), from December 2000 through December 2007. Since the removal of Carbonton Dam, instantaneous dissolved oxygen concentrations within the former Site Impoundment have remained at or above 4.0 mg/L.

Throughout the five-year monitoring period, it is expected that mean dissolved oxygen values recorded at NC 42 will continue to demonstrate success as the river has returned to its natural lotic condition. It is also expected that dissolved oxygen levels within the former impoundment will stay above the state standard as free-flowing conditions persist.

Graph 2. Recorded Dissolved Oxygen Concentrations in the Deep River (Green line indicates state standard of 4.0mg/L)



2.1.2.2 Temperature

In order to achieve success, the water temperature within the former Site Impoundment should not exceed the NCDWQ standard of 90 degrees Fahrenheit during the monitoring period. Table 7 provides the minimum, maximum, and mean values for water temperature recorded within the former Site Impoundment during all monitoring years, as well as the number of samples the recorded value exceeded the state standard.

Table 7. Water Temperature Summary Data

	Baseline	Year-1	Year-2	Year-3
Minimum Value (deg F)	65.48	41.18	45.32	41.36
Maximum Value (deg F)	87.62	64.58	85.82	84.02
Mean Value (deg F)	63.26	52.76	67.57	63.99
Number of Samples Exceeding State Standard	0	0	0	0

Water temperature within the former Site Impoundment has remained below the state standard of 90 degrees Fahrenheit since dam removal on February 3, 2006.

2.1.2.3 Fecal Coliform

In order to achieve success, fecal coliform concentrations within the former Site Impoundment should not exceed an average daily count of 200/100 ml in any 30-day period. Table 8 shows the minimum,

maximum, and mean values for fecal coliform recorded within the former Site Impoundment during all monitoring years, as well as the number of samples the recorded value exceeded the state standard.

Table 8. Fecal Coliform Summary Data

	Baseline	Year-1	Year-2	Year-3
Minimum Value (count/100 ml)	3	22	26.0	14
Maximum Value (count/100ml	6300	47	160.0	5800.0
Mean Value (count/100ml)	369.7	35.7	62.6	782.3
Number of Samples Exceeding State Standard	31	0	0	2

Fecal coliform within the former Site Impoundment exceeded the state standard of 200/100 ml twice during Year-3 monitoring. The two events that exceeded the state standard both achieved significantly elevated levels (1700/100 ml and 5800/100 ml) and consequently raised the mean value to more than ten times the previous year's value. With the exception of these two events, all other daily fecal coliform values recorded during Year-3 monitoring were significantly lower than the state standard (≤100/100 ml). It should be noted that for both events that resulted in high fecal coliform measurements, reference data from the Ramseur station were not sampled on the same day. Additionally, greater than 1-inch rain events occurred the day before the date of sampling for the Site Impoundment for both outlying data measurements. Therefore, it is expected that the reference station would have also shown similar spikes in fecal coliform data had been collected on the same day (Ward 1990).

2.2 AQUATIC COMMUNITIES

To determine success for the aquatic community's habitat criterion, the former Site Impoundment was monitored for baseline data and included benthic macroinvertebrates, fishes, mussels, and snails, as well as the quality of available microhabitats that developed. Benthos, fishes and mussel and snail sampling following dam removal will be used to demonstrate an increased abundance and quality of aquatic habitat within restored reaches of the Deep River.

2.2.1 Benthic Macroinvertebrates

Benthic macroinvertebrates were sampled within the former Site Impoundment, as well as in the reference reaches both within the Deep River and its major tributaries. Stations were visited prior to dam removal (2005) and subsequently sampled in 2006, 2007, and 2008 at the same locations. The comparative metrics utilized for the success evaluation include the total number of organisms collected, the total taxa represented in the samples, the richness (diversity) of taxa from the Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) Orders (hereafter referred to as EPT taxa), and the biotic index of organic waste tolerance. Benthic macroinvertebrate data, located 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 NCDWQ-certified benthic identification laboratory.

Table 9 provides the baseline and Year-1 through Year-3 summary data for the benthic macroinvertebrate collections. The summary data shows that the mean value for the biotic index was the only metric that improved at impounded stations in Year-3 monitoring. Mean total organisms, total taxa, and EPT

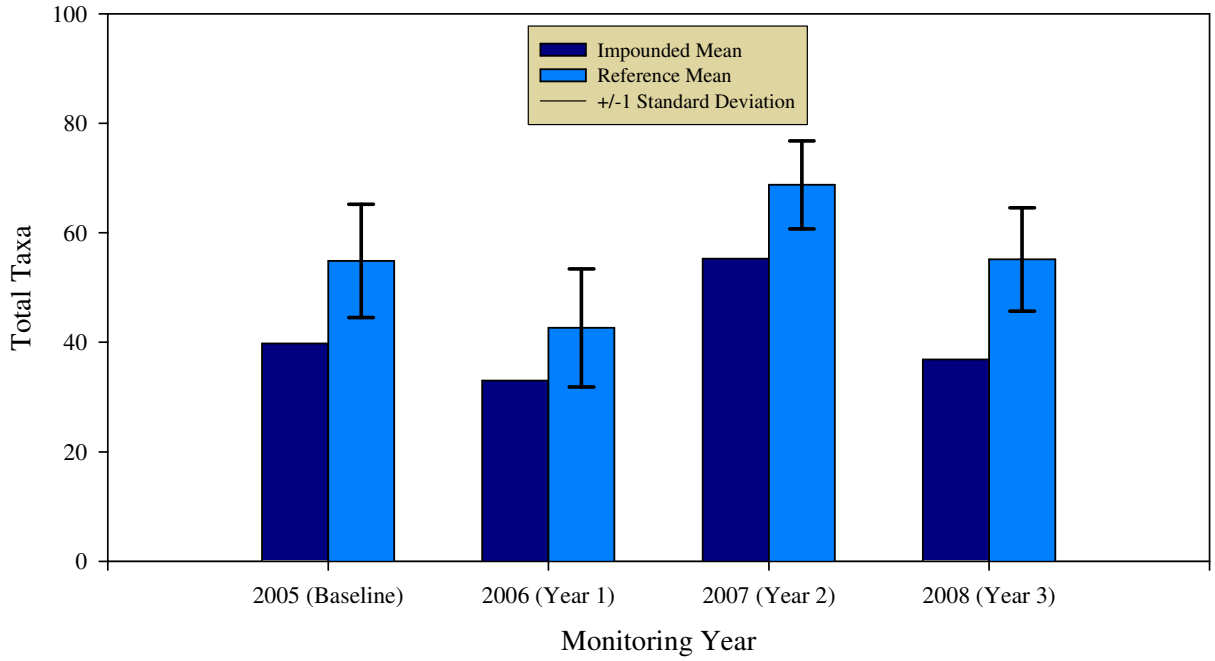
richness within formerly impounded stations worsened during Year-3 monitoring. This negative shift also occurred for the same metrics among reference stations, suggesting an altered benthic community composition and abundance throughout the Deep River watershed. Extreme and severe drought conditions within the Deep River watershed during benthic sampling (April 3-23) contributed to low flow conditions and may have contributed to degraded benthic macroinvertebrate collections. 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. Drought conditions in the Deep River watershed during Year-3 monitoring represent a progression of rainfall deficits experienced almost continually since dam removal. Figure 5 (Appendix A) displays drought conditions in North Carolina during Year-3 monitoring and shows the progression of drought intensity in the Deep River watershed, with the longest persistence of Exceptional Drought (Level D4) occurring in November through March 2008, just prior to Year-3 benthic sampling. 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.

Table 9. Benthic macroinvertebrate summary data

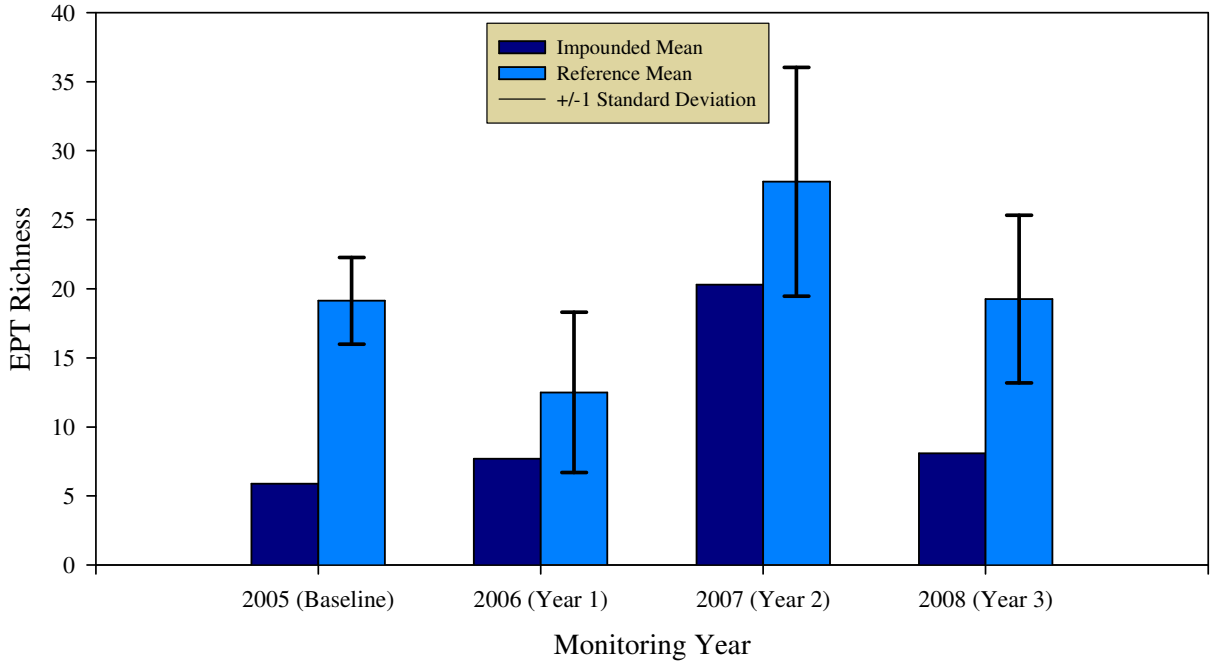
2005	Impounded Stations				Reference Stations			
	Total Organisms	Total Taxa	EPT Richness	Biotic Index	Total Organisms	Total Taxa	EPT Richness	Biotic Index
High	403.00	62.00	10.00	7.97	1168.00	70.00	24.00	6.91
Low	97.00	18.00	1.00	5.67	237.00	41.00	14.00	4.78
Mean	223.33	39.78	5.89	6.83	549.75	54.88	19.13	5.90
Median	207.00	43.00	6.00	6.79	404.00	56.00	19.00	5.99
Standard Deviation	96.69	12.02	2.76	0.83	340.66	10.33	3.14	0.75
2006	Impounded Stations				Reference Stations			
	Total Organisms	Total Taxa	EPT Richness	Biotic Index	Total Organisms	Total Taxa	EPT Richness	Biotic Index
High	360.00	49.00	15.00	8.58	546.00	61.00	21.00	7.62
Low	55.00	17.00		5.76	89.00	33.00	5.00	4.29
Mean	177.50	33.00	7.70	6.99	220.63	42.63	12.50	6.16
Median	160.00	33.50	6.50	6.72	155.00	37.00	12.50	6.02
Standard Deviation	87.71	11.65	5.85	0.95	158.86	10.76	5.81	1.04
2007	Impounded Stations				Reference Stations			
	Total Organisms	Total Taxa	EPT Richness	Biotic Index	Total Organisms	Total Taxa	EPT Richness	Biotic Index
High	1168.00	83.00	36.00	8.52	1242.00	83.00	38.00	5.71
Low	117.00	31.00	1.00	4.28	506.00	59.00	14.00	3.92
Mean	466.40	55.30	20.30	5.86	849.63	68.75	27.75	4.94
Median	475.00	60.00	24.50	5.30	861.50	66.50	31.00	5.02
Standard Deviation	318.14	18.76	13.00	1.52	250.69	8.01	8.28	0.62
2008	Impounded Stations				Reference Stations			
	Total Organisms	Total Taxa	EPT Richness	Biotic Index	Total Organisms	Total Taxa	EPT Richness	Biotic Index
High	342.00	73.00	20.00	8.19	687	66.00	27	6.36
Low	21.00	16.00	1.00	5.13	246.00	41.00	10.00	4.66
Mean	160.80	36.90	8.10	6.52	384.25	55.13	19.25	5.56
Median	145.00	34.00	6.00	6.40	339.50	58.50	20.50	5.60
Standard Deviation	106.57	17.21	6.30	1.05	157.35	9.45	6.07	0.50

Graph 3 and Graph 4 depict the change in mean total taxa and mean EPT richness from 2005 to present from both the formerly impounded and reference stations. The graphs show that mean total taxa and mean EPT richness decreased across all stations in the current monitoring year.

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



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



2.2.2 Fishes

Fish surveys were not conducted during Year-3 monitoring due to the overwhelming success of sampling efforts during Year-2 monitoring. A total of 34 fish species were collected at the fifteen fish monitoring sites. Survey collections demonstrate that riffle adapted species continue to colonize in newly restored habitats that were previously impounded. Additionally, at least ten of the sampling sites contain emerging fish communities that emulate reference conditions found beyond the former impoundment. Overall, a greater number of fish species were documented throughout the former impoundment during Year-2 monitoring relative to baseline and Year-1 surveys.

2.2.3 Mollusks

Year-3 monitoring emphasized mussel, snail, and clam sampling to support success evaluation for the aquatic community and threatened and endangered aquatic species criteria. Mollusks were last sampled by The Catena Group (TCG) preceding dam removal to obtain baseline data. Since these fauna are slow colonizers due to their dependence on host fish species, 2008 represents the first year for mollusk sampling since dam removal. Freshwater mollusks were conducted at 14 monitoring locations throughout the restored reach of the Deep River (Figure 1, TCG Report, Appendix C). Habitat reconnaissance was conducted in the entire restored reach, and observations of in-stream habitat conditions and bank stability were recorded. At least 12 substantial riffle habitats have developed in the Deep River and a general progression towards a lotic community continues throughout the restored reach. Mollusk collections indicate a recruitment of freshwater mussel species in riffle-adapted habitats (primarily in the upper reach or the former reservoir pool), while lotic-adapted aquatic snails have colonized throughout. When comparing the mussel fauna observed during the pre-removal surveys with the 3-Year surveys, it is evident that the fauna has transitioned from one comprised of habitat generalists and lentic-adapted species, to one comprised of habitat generalists and lotic-adapted species. A total of eleven freshwater mussel species, three aquatic snail species and 1 freshwater clam species were found within newly formed riffle habitats in the former impounded reach (Table 10).

Table 10. Mollusk Sampling Results

Scientific Name	Common Name	TCG Sites
Freshwater Mussels		
*Alasmidonta undulate***	triangle floater	1,1a, 7, 8,9
Elliptio angustata	Carolina lance	1,1a,3,8
Elliptio complanata	Eastern elliptio	All except 12 and 13
Elliptio icterina	variable spike	1,1a,3,4,57,,8,9
Elliptio lazarus	Atlantic delicate spike	1,3,5,8
Elliptio producta	Atlantic spike	2,3
*Lampsilis cariosa***	yellow lampmussel	1,1a,2,3,4,5,8,9*,10*
Pyganodon cataracta	Eastern floater	10*
*Strophitus undulatus***	creeper	4,7,8,9
*Villosa constricta***	notched rainbow	2
*Villosa delumbis***	Eastern creekshell	1a,4,8,9
Uniomerus carolinianus	Florida pondhorn	8*, 10
Freshwater Snails and Clams	~	~
Campeloma decisum	pointed campeloma	2,5,8,10
Elimia catenaria	gravel elimia	All
Helisoma anceps	two-ridge rams-horn	2,5
Corbicula fluminea	Asian clam	All

** State-listed species

* Relict shell only

2.2.4 Habitat Assessment

Habitat assessment data were collected at all 52 monitoring stations to evaluate the potential for changing aquatic habitats to support changes in community populations. The NCDWQ Habitat Assessment Field Data Sheet was completed at each station in order to evaluate the quality and character of the sampled habitat niches and to provide a comparable score that describes the available habitat. Table 10 displays the NCDWQ Habitat Assessment Field Data Sheet scores from baseline and Year-3 monitoring. The categories channel modification, light penetration, and riparian vegetative zone width typically did not change in the span of a single monitoring year. Other categories including in-stream habitat, bottom substrate, and bank stability showed improvement within formerly impounded stations. Compared to baseline data, the mean total score of the formerly impounded stations quantitatively increased in Year-3 monitoring from 42.39 to 59.56. The mean total score for reference stations remained relatively unchanged with an increase of only 1.55. Success evaluation is defined as a perceived progression of the former Site Impoundment habitat values toward those of the lotic reference stations. During Year-3 monitoring, the mean total score for stations in the former Site Impoundment increased 1.65 percent compared to last year, and shifted to within only 1.55 points of matching Year-3's mean total score of the reference stations. Thus Year-3 scores of stations with the former Site Impoundment are equal to the reference station's total score during baseline monitoring.

Table 11. Comparison of Habitat Assessment Data from Baseline and Year 3 for Impounded and Reference Stations

	BASELINE (2005)									YEAR-3 MONITORING (2008)								
		Metric Subtotals									Metric Subtotals							
	Station	Channel Modification	Instream Habitat	Bottom Substrate	Pools	Riffles	Bank Stability	Light Penetration	Riparian Zone	TOTAL SCORE	Station	Channel Modification	Instream Habitat	Bottom Substrate	Pools	Riffles	Bank Stability	Light Penetration	Riparian Zone	TOTAL SCORE
FORMERLY IMPOUNDED STATIONS	1	4	7	1	0	0	9	0	7	**28**	1	4	12	8	8	14	12	0	7	**65**
	2	4	11	1	0	0	12	0	10	**38**	2	4	14	1	10	0	14	0	10	**53**
	3	5	12	3	0	0	14	2	9	**45**	3	5	15	8	0	0	9	2	9	**48**
	4	4	14	1	0	0	14	2	10	**45**	4	4	15	12	10	0	14	2	10	**67**
	5	4	12	1	0	0	14	2	10	**43**	5	4	19	15	10	14	13	2	10	**87**
	6	4	10	1	0	0	12	0	10	**37**	6	4	15	12	0	0	12	0	10	**53**
	7	4	10	1	0	0	12	0	9	**36**	7	4	15	11	8	0	14	0	9	**61**
	8	4	12	8	0	0	14	2	7	**47**	8	4	20	15	10	14	13	2	7	**85**
	9	4	10	1	0	0	14	2	8	**39**	9	4	15	8	10	0	14	2	8	**61**
	10	5	16	12	0	0	14	2	10	**59**	10	5	19	15	10	14	14	2	10	**89**
	11	4	14	12	0	0	11	2	10	**53**	11	4	10	1	8	7	14	2	10	**56**
	20	4	7	1	0	0	6	0	10	**28**	20	4	10	3	10	0	14	10	10	**61**
	21	5	6	1	0	0	4	0	2	**18**	21	5	10	1	10	0	14	7	6	**53**
	22	5	5	1	0	0	4	0	8	**23**	22	5	13	3	10	0	14	0	8	**53**
	23	5	9	1	0	0	5	2	8	**30**	23	5	17	1	4	0	14	2	8	**51**
	24	4	11	1	0	0	10	7	4	**37**	24	4	9	1	0	0	12	7	4	**37**
	27	5	9	1	0	0	12	10	10	**47**	27	5	16	3	6	3	12	10	10	**65**
	29	5	5	1	0	0	12	10	10	**43**	29	5	9	1	0	0	12	10	10	**47**
	30	5	13	1	0	0	14	10	10	**53**	30	5	16	3	0	0	10	10	10	**54**
	31	5	10	1	0	0	12	10	10	**48**	31	5	14	3	0	0	12	10	10	**54**
	32	4	5	1	0	0	10	8	10	**38**	32	4	5	1	0	0	10	8	10	**38**
	34	4	11	1	0	0	14	10	10	**50**	34	4	1	0	0	10	10	10	10	**45**
	36	4	6	1	0	0	4	8	8	**31**	36	4	5	1	0	0	6	8	8	**32**
	38	5	19	1	0	0	5	10	10	**50**	38	5	14	1	0	0	13	10	10	**53**
	40	2	16	1	0	0	14	8	10	**51**	40	2	15	1	0	0	14	8	10	**50**
	41	5	6	1	0	0	12	8	10	**42**	41	5	10	1	10	10	13	8	10	**67**
	42	5	11	1	0	0	12	10	10	**49**	42	5	10	1	4	14	14	10	10	**68**
	43	5	6	1	0	0	10	10	10	**42**	43	5	9	1	10	3	12	10	10	**60**
	47	5	11	6	0	0	14	10	10	**56**	47	5	15	3	6	14	12	10	10	**75**
	48	5	11	1	0	0	12	7	10	**46**	48	5	14	1	10	10	13	7	10	**70**
	49	5	11	1	0	0	12	7	10	**46**	49	5	15	4	8	0	11	7	10	**60**
	50	4	15	3	0	0	12	7	10	**51**	50	4	14	3	0	12	12	10	10	**65**
	51	5	12	1	0	0	12	10	10	**50**	51	5	10	1	8	0	12	10	10	**56**
	55	Station not established in 2005								**N/A**	55	5	20	8	10	14	14	7	8	**86**
	MEAN	**4.45**	**10.39**	**2.15**	**0.00**	**0.00**	**10.97**	**5.33**	**9.09**	**42.39**	**MEAN**	**4.47**	**12.94**	**4.47**	**5.59**	**4.50**	**12.44**	**5.97**	**9.18**	**59.56**
REFERENCE STATIONS	12	4	20	12	6	7	14	2	10	**75**	12	4	20	15	6	7	14	2	10	**78**
	14	2	14	3	4	10	4	2	0	**39**	14	4	16	15	6	16	11	2	0	**70**
	15	4	11	8	8	0	10	7	10	**58**	15	4	11	8	8	0	10	7	10	**58**
	16	4	11	12	8	0	12	2	10	**59**	16	4	11	11	10	0	14	2	10	**62**
	17	4	11	2	4	3	12	2	10	**48**	17	4	11	8	4	0	12	2	10	**51**
	18	4	11	8	6	3	10	7	6	**55**	18	4	11	14	8	10	5	7	6	**65**
	19	4	16	11	6	0	12	2	10	**61**	19	4	16	11	10	0	14	2	10	**67**
	25	5	8	1	8	0	12	10	10	**54**	25	5	5	1	8	0	14	10	10	**53**
	26	5	10	1	8	0	14	10	10	**58**	26	5	0	1	0	0	6	10	10	**32**
	33	5	6	8	8	16	13	10	10	**76**	33	5	5	4	0	0	14	10	10	**48**
	35	4	5	1	4	0	10	8	10	**42**	35	4	5	1	8	0	14	8	10	**50**
	37	5	16	1	3	7	14	10	9	**65**	37	5	10	1	0	7	14	10	9	**56**
	39	5	11	3	6	0	12	7	9	**53**	39	5	15	1	0	10	12	7	9	**59**
	44	4	16	2	8	3	13	7	10	**63**	44	4	14	4	10	10	12	7	10	**71**
	45	4	15	6	6	0	12	8	10	**61**	45	4	16	6	10	12	12	8	10	**78**
	52	4	20	15	6	7	14	0	10	**76**	52	4	16	12	10	16	16	0	10	**84**
	53	4	20	11	4	14	12	2	9	**76**	53	4	20	15	10	7	10	2	10	**78**
	54	5	6	1	8	0	13	10	10	**53**	54	5	0	1	0	0	14	10	10	**40**
	MEAN	**4.22**	**12.61**	**5.89**	**6.17**	**3.89**	**11.83**	**5.89**	**9.06**	**59.56**	**MEAN**	**4.33**	**11.22**	**7.17**	**6.00**	**5.28**	**12.11**	**5.89**	**9.11**	**61.11**

2.2.4.1 Sediment Class Size Distribution

Sediment grain size distribution was analyzed at 38 monitoring stations in 2008 (24 formerly impounded, 14 reference). At each of the 38 stations, 100-count pebble counts were performed consistent with the Wolman method (Wolman 1954). As expected D16, D50, and D84 values from stations within the former Site Impoundment continued coarsening during Year-3 monitoring. Values for D16, D50, and D84 have increased in each of the three monitoring years following dam removal. The medium grain size (D50) for impounded stations sampled in 2008 is 9.30 mm coarser than dam pre-removal substrate (2005). The D16 and D84 size class indices also coarsened within impounded stations. Reference stations showed only minor changes in sediment size class following dam removal. Table 12 provides baseline, Year-1, Year-2, and Year-3 sediment grain size distributions attained by pebble count method for both reference and impounded stations.

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
>256 mm	Boulder

EcoScience staff performs a pebble count in a restored riffle at Station 12.

Table 12. Sediment Class Size Distribution

	Station	Baseline (2005)			Year-1 (2006)			Year-2 (2007)			Year-3 (2008)		
		d16	d50	d84	d16	d50	d84	d16	d50	d84	d16	d50	d84
FORMERLY IMPOUNDED	3	<2 mm	<2 mm	<2 mm	<2 mm	2-8 mm	>256 mm	<2 mm	64-128 mm	>256 mm	<2 mm	128-256 mm	>256 mm
	4	<2 mm	<2 mm	<2 mm	2-8 mm	8-16 mm	16-32 mm	<2 mm	2-8 mm	16-32 mm	<2 mm	2-8 mm	16-32 mm
	6	16-32 mm	16-32 mm	16-32 mm	2-8 mm	2-8 mm	2-8 mm	<2 mm	8-16 mm	>256 mm	2-8 mm	16-32 mm	16-32 mm
	8	<2 mm	<2 mm	<2 mm	<2 mm	8-16 mm	16-32 mm	<2 mm	32-64 mm	16-32 mm	<2 mm	16-32 mm	>256 mm
	10	2-8 mm	8-16 mm	16-32 mm	<2 mm	2-8 mm	32-64 mm	16-32 mm	32-64 mm	>256 mm	16-32 mm	32-64 mm	>256 mm
	22	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	23	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	24	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	27	<2 mm	<2 mm	<2 mm	<2 mm	2-8 mm	8-16 mm	<2 mm	2-8 mm	8-16 mm	<2 mm	<2 mm	<2 mm
	29	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	30	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	2-8 mm
	31	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	32	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	34	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	36	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	38	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	41	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	42	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	2-8 mm	<2 mm	<2 mm	2-8 mm	<2 mm	<2 mm	<2 mm
	43	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	47	<2 mm	<2 mm	16-32 mm	<2 mm	8-16 mm	16-32 mm	<2 mm	2-8 mm	16-32 mm	<2 mm	2-8 mm	16-32 mm
	49	<2 mm	<2 mm	<2 mm	2-8 mm	2-8 mm	2-8 mm	<2 mm	8-16 mm	16-32 mm	<2 mm	8-16 mm	16-32 mm
	50	<2 mm	<2 mm	16-32 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	8-16 mm	<2 mm	8-16 mm	8-16 mm
	51	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	2-8 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	55	Cross-section not established in 2005			2-8 mm	8-16 mm	16-32 mm	2-8 mm	16-32 mm	32-64 mm	<2 mm	16-32 mm	32-64 mm
REFERENCE	12	8-16 mm	16-32 mm	>256 mm	2-8 mm	8-16 mm	64-128 mm	2-8 mm	16-32 mm	128-256 mm	2-8 mm	16-32 mm	128-256 mm
	14	<2 mm	64-128 mm	>256 mm	<2 mm	2-8 mm	128-256 mm	<2 mm	8-16 mm	32-64 mm	<2 mm	8-16 mm	128-256 mm
	16	<2 mm	2-8 mm	32-64 mm	2-8 mm	16-32 mm	32-64 mm	<2 mm	16-32 mm	64-128 mm	2-8 mm	32-64 mm	64-128 mm
	18	<2 mm	32-64 mm	32-64 mm	8-16 mm	32-64 mm	64-128 mm	8-16 mm	32-64 mm	64-128 mm	8-16 mm	32-64 mm	64-128 mm
	19	2-8 mm	32-64 mm	32-64 mm	<2 mm	<2 mm	32-64 mm	<2 mm	16-32 mm	64-128 mm	<2 mm	2-8 mm	32-64 mm
	25	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	26	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	33	<2 mm	2-8 mm	16-32 mm	<2 mm	2-8 mm	8-16 mm	<2 mm	2-8 mm	8-16 mm	<2 mm	2-8 mm	8-16 mm
	35	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	39	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	44	<2 mm	8-16 mm	16-32 mm	<2 mm	<2 mm	8-16 mm	<2 mm	2-8 mm	16-32 mm	<2 mm	<2 mm	16-32 mm
	45	<2 mm	8-16 mm	64-128 mm	<2 mm	<2 mm	16-32 mm	<2 mm	2-8 mm	32-64 mm	<2 mm	2-8 mm	16-32 mm
	52	8-16 mm	32-64 mm	64-128 mm	2-8 mm	8-16 mm	128-256 mm	2-8 mm	16-32 mm	64-128 mm	<2 mm	32-64 mm	64-128 mm
	54	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm

2.2.4.2 Channel Cross-sections

Cross-sectional surveys of channel geometry were performed at all 52 monitoring stations during 2008. Thirty-four (34) permanent cross-sections were revisited throughout the former Site Impoundment and on tributaries where functional restoration is expected to occur. Eighteen (18) permanent cross-sections were revisited on reference reaches above and below the former Site Impoundment. Cross-section locations are displayed on Figure 3 (Appendix A). All monitoring years' cross-sectional surveys are displayed on Figures 4A-4D (Appendix A). Table 13 provides 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).

In general, bankfull channel parameters were largely unchanged compared to conditions assessed during Year-1 monitoring. Only minor scouring and erosion of bank material was detected at formerly impounded stations, with an associated, minor increase in bankfull areas. High flow, bankfull events that occurred during Year-3 monitoring (April 28, 2008 [2,220 cfs] and August 27, 2008 [8,470 cfs]) have further demonstrated that the Deep River channel is geomorphically stable, and that erosion is episodic and localized. Station 55 was established following dam removal and therefore no baseline (2005) bankfull channel geometry data are available for this station. At Stations 7, 15, and 17, only one of the original benchmark pins was recovered and a new pin was established in 2006. Hence, the discrepancies in cross-sectional dimensions and bankfull channel geometry between the baseline and Year-1 monitoring data at these locations.

EcoScience staff prepare to perform a Total Station cross-sectional survey of the Deep River at Station 8.

Table 13. 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
Formerly Impounded Stations	**1**	4707.0	235.2	27.2	20.0	11.8	4702.7	235.0	27.7	20.0	11.8	4884.9	235.2	28.5	20.8	11.3	5094.7	239.1	27.5	21.3	11.2
	2	3837.0	196.3	28.0	19.6	10.0	3771.9	196.0	27.0	19.2	10.2	3883.0	201.7	27.1	19.3	10.5	3800.6	201.8	26.8	18.8	10.7
	3	2849.0	166.2	23.9	17.1	9.7	2897.2	158.8	24.3	18.2	8.7	2964.5	159.2	24.7	18.6	8.6	2947.3	160.4	24.7	18.4	8.7
	4	4229.1	185.2	29.9	22.8	8.1	3632.1	193.7	24.4	18.8	10.3	3457.1	191.9	23.4	18.0	10.6	3608.8	193.1	24.3	18.7	10.3
	5	2783.1	174.6	23.7	15.9	11.0	2792.5	165.8	23.2	16.8	9.9	2860.5	169.0	23.7	16.9	10.0	2932.8	169.8	23.8	17.3	9.8
	6	3362.5	188.2	22.8	17.9	10.5	3450.9	187.7	22.8	18.4	10.2	3487.0	189.2	23.4	18.4	10.3	3435.9	192.7	23.1	17.8	10.8
	7	2443.2	149.8	19.0	16.3	9.2	2869.7	173.8	20.4	16.5	10.5	2897.3	193.8	20.4	15.0	13.0	2947.8	193.0	20.6	15.3	12.6
	8	3098.8	181.6	24.1	17.1	10.6	3341.5	185.2	28.6	18.0	10.3	3434.9	184.9	25.4	18.6	10.0	3506.3	190.3	26.2	18.4	10.3
	9	2064.0	172.5	15.0	12.0	14.4	2108.0	173.5	15.0	12.2	14.2	2094.4	176.6	14.9	11.9	14.9	2076.5	176.5	14.8	11.8	15.0
	10	2221.5	199.0	18.0	11.2	17.8	2423.6	195.9	18.6	12.4	15.8	2353.2	199.9	18.9	11.8	17.0	2414.3	198.7	18.9	12.1	16.4
	11	3591.3	199.5	24.3	18.0	11.1	3720.9	199.3	24.6	18.7	10.7	3706.3	198.9	24.8	18.6	10.7	3714.1	199.3	25.0	18.6	10.7
	20	72.2	42.9	3.6	1.7	25.2	86.2	44.1	4.4	2.0	22.1	108.9	45.5	4.2	2.4	19.0	105.0	44.7	5.3	2.4	19.0
	21	149.6	57.9	3.6	2.6	22.3	187.8	77.9	4.4	2.4	32.5	199.1	64.8	4.8	3.1	21.1	161.7	63.2	5.0	2.6	24.7
	22	148.9	49.1	4.8	3.0	16.4	184.1	56.8	5.8	3.2	17.8	195.5	52.1	5.9	3.8	13.9	159.6	50.2	5.9	3.2	15.8
	23	76.6	30.2	4.7	2.5	12.1	104.8	34.5	5.7	3.0	11.5	116.7	38.8	6.7	3.0	12.9	141.7	40.2	8.0	3.5	11.4
	24	65.6	39.6	2.9	1.7	23.3	54.4	37.1	2.4	1.5	24.7	41.4	31.2	2.1	1.3	23.5	54.9	32.3	3.3	1.7	19.0
	27	62.3	24.9	3.9	2.5	10.0	73.4	28.6	4.5	2.6	11.0	81.8	28.78	5.7	2.8	10.1	78.4	28.34	6.4	2.8	10.2
	29	43.2	13.5	4.8	2.5	5.4	64.2	16.6	6.2	10.4	1.6	66.3	16.46	6.4	4.0	4.1	53.7	14.69	6.5	3.7	4.0
	30	153.2	22.1	8.8	6.9	3.2	115.5	29.5	6.5	3.9	7.6	113.5	30.68	6.5	3.7	8.3	85.6	28.38	5.6	3.0	9.4
	31	141.2	29.3	6.5	4.8	6.1	147.3	28.9	6.9	5.1	5.7	160.6	29.75	7.9	5.4	5.5	167.8	28.9	8.9	5.8	5.0
	32	72.1	15.5	7.5	4.6	3.4	75.7	15.9	8.0	4.8	3.3	78.5	15.87	8.6	4.9	3.2	84.3	16.97	9.2	5.0	3.4
	34	37.1	18.7	4.1	2.0	9.4	39.8	18.7	4.2	2.1	8.9	35.0	18.14	3.8	1.9	9.4	46.9	20.34	4.9	2.3	8.8
	36	111.3	21.5	9.2	5.2	4.1	111.6	21.1	9.3	5.3	4.0	110.6	21.56	9.7	5.1	4.2	113.1	21.45	9.8	5.3	4.1
	38	269.7	43.2	8.6	6.2	7.0	256.3	40.7	8.0	32.0	1.3	254.1	40.91	7.9	6.2	6.6	282.7	41.25	8.5	6.9	6.0
	40	329.2	53.3	8.2	6.2	8.6	431.2	53.3	10.6	8.1	6.6	461.1	54.78	11.4	8.4	6.5	445.9	54.01	11.4	8.3	6.5
	41	429.9	50.3	11.4	8.6	5.9	521.8	48.2	13.4	10.8	4.5	419.4	51.4	10.9	8.2	6.3	411.1	50.16	10.7	8.2	6.1
	42	139.4	30.9	6.0	4.5	6.9	156.9	32.1	7.0	4.9	6.6	167.7	30.2	7.4	5.6	5.4	143.5	30.22	7.2	4.7	6.4
	43	155.9	29.4	6.7	5.3	5.6	176.8	31.1	7.4	5.7	5.5	187.0	32.67	8.0	5.7	5.7	180.2	31.48	7.8	5.7	5.5
	47	318.5	60.5	7.8	5.3	11.4	312.7	56.3	8.0	5.6	10.1	320.7	60.6	8.1	5.3	11.4	315.7	60.1	8.1	5.3	11.4
	48	695.0	72.9	13.8	9.5	7.7	630.8	69.5	13.4	9.1	7.6	674.5	70.4	12.8	9.6	7.3	680.1	72.2	13.5	9.4	7.7
	49	550.4	59.7	13.7	9.2	6.5	380.5	59.1	10.1	6.5	9.1	406.8	54.5	12.0	7.5	7.3	398.7	59.5	10.4	6.7	8.9
	50	378.9	59.8	7.7	6.3	9.5	388.6	59.2	8.7	6.6	9.0	381.5	58.1	8.1	6.6	8.9	380.0	58.1	8.2	6.5	8.9
	51	209.5	39.9	10.8	5.3	7.5	203.9	35.6	10.7	5.7	6.2	211.2	38.0	10.8	5.6	6.8	226.1	38.4	11.2	5.9	6.5
	55	N/A	N/A	N/A	N/A	N/A	3357.6	228.4	18.0	14.7	15.5	3428.4	236.0	18.7	14.5	16.3	3425.4	235.4	18.6	14.5	16.2
Reference Stations	**12**	3054.7	212.8	17.4	14.4	14.8	3029.3	213.0	17.5	14.2	15.0	3065.6	213.3	17.6	14.4	14.8	2925.4	212.03	17.5	13.8	15.4
	14	6111.5	393.8	22.6	15.5	25.4	5924.9	402.6	21.6	14.7	27.4	6458.5	454.5	21.2	14.2	32.0	5948.3	452.6	21.5	13.1	34.4
	15	3241.5	187.2	23.7	17.3	10.8	3583.2	200.0	24.9	17.9	11.2	3668.1	202.6	25.7	18.1	11.2	3655.7	207.2	25.4	17.6	11.7
	16	2370.1	176.7	16.3	13.4	13.2	2382.1	173.3	16.6	13.7	12.7	2526.5	187.2	17.3	13.5	13.9	2506.1	185.9	17.4	13.5	13.8
	17	2864.3	193.5	24.7	20.0	9.7	3466.6	201.9	22.7	17.2	11.7	3561.8	202.4	24.0	17.6	11.5	3530.3	202.3	23.3	17.5	11.6
	18	1722.0	181.5	12.3	9.5	19.1	1697.3	174.5	12.2	9.7	18.0	1756.4	174.6	12.7	10.1	17.4	1795.2	174.8	12.8	10.3	17.0
	19	2647.0	167.9	21.1	15.8	10.6	2581.6	167.6	20.6	15.4	10.9	2662.1	166.9	21.1	15.9	10.5	2677.0	166.6	21.1	16.1	10.4
	25	22.7	19.9	2.3	1.1	18.1	24.4	20.7	2.3	10.6	2.0	24.6	20.7	2.3	1.2	17.4	28.3	22	2.4	1.3	17.1
	26	5.9	13.1	0.9	0.5	26.2	5.9	12.7	0.8	0.5	25.4	11.1	17.59	1.9	0.6	27.8	7.8	15.72	1.0	0.5	31.7
	33	9.6	7.0	2.2	1.4	5.0	15.4	9.8	3.0	1.6	6.1	25.9	20.13	3.7	1.3	15.6	25.4	20.03	3.8	1.3	15.8
	35	93.2	28.1	6.3	3.3	8.5	102.8	26.9	6.3	3.8	7.1	101.3	28.99	7.8	3.5	8.3	105.0	30.52	7.6	3.4	8.9
	37	6.2	11.3	1.0	0.6	18.8	6.0	9.5	1.1	0.6	15.8	7.3	11.04	1.4	0.7	16.7	8.5	10.97	1.4	0.8	14.2
	39	287.6	42.0	9.3	6.9	6.1	272.5	40.4	8.7	6.8	5.9	283.7	41.23	9.1	6.9	6.0	287.7	40.92	9.2	7.0	5.8
	44	310.3	49.7	8.1	6.2	8.0	332.3	51.9	8.4	6.4	8.1	360.5	52.3	8.7	6.9	7.6	359.6	52.9	8.6	6.8	7.8
	45	289.3	59.8	8.9	4.8	12.5	293.7	56.0	9.0	5.2	10.8	306.9	57.4	8.7	5.3	10.7	315.5	57.5	9.1	5.5	10.5
	52	2909.8	228.1	16.0	12.8	17.8	2798.1	220.9	15.6	12.7	17.4	2825.7	220.9	15.6	12.8	17.3	2910.9	220.9	15.1	13.2	16.8
	53	2146.7	165.6	20.4	13.0	12.7	1882.9	160.7	19.3	11.7	13.7	2134.4	165.0	19.8	12.9	12.8	2142.2	164.5	23.5	13.0	12.6
	54	17.7	10.7	2.7	1.7	6.3	14.6	9.4	2.4	1.6	5.9	17.4	10.9	2.7	1.6	6.8	19.7	12.1	3.1	1.6	7.4

*New cross-section pins established in 2006.

2.2.4.3 Flow Velocity

Flow velocity was not measured during Year-3 (2008) monitoring because a substantial increase in river flow was demonstrated in Year-1 (2006) monitoring. Surface and stream bottom flow velocities in the former Impoundment exhibited an increase greater than one order of magnitude in Year-1 monitoring; thus the success criterion was met. Following the initial increase in velocity from the removal of Carbonton Dam, stream flow will now fluctuate greatly as determined by drought and precipitation events, and can no longer be attributed to restoration efforts.

2.2.4.4 Photography and Videography

Photography and videography were conducted during Year-3 monitoring data collection to assess qualitative changes in channel cross-sections and in-stream habitat. Monitoring pictures and videos for all stations have been included on a digital video disc (DVD) in Appendix E.

2.3 RARE AND PROTECTED SPECIES

The documented presence of any rare species within the former Site Impoundment throughout the five-year monitoring period will constitute success in fulfilling the rare and protected aquatic species criterion. The federally endangered Cape Fear shiner was found during Year-2 fish surveys by TCG at eight sampling sites throughout the Deep River. A total of 41 individuals of the endangered Cape Fear shiner were collected during the Year-2 surveys. Furthermore, favorable habitat areas for the Cape Fear shiner have developed at many other locations, and the recruitment of new populations is expected to continue over time.

The emphasis of the Year-3 monitoring effort is to document whether freshwater mussels are also re-colonizing habitats previously impounded by Carbonton Dam. A total of eleven freshwater mussel species, three aquatic snail species and 1 freshwater clam species were found within newly formed riffle habitats in the former impounded reach. The surveys documented several mussel species of conservation interest associated with lotic condition, including five state listed species: yellow lampmussel (*Lampsilis cariosa*), creeper (*Strophitus undulatus*), triangle floater (*Alasmidonta undulata*), eastern creekshell (*Villosa delumbis*), and the notched rainbow (*Villosa constricta*). The presence of notched rainbow is especially significant because this species is extremely throughout the Deep River. Four collected mussel species (triangle floater, yellow lampmussel, creeper and eastern creekshell) were targeted rare species identified in the pre-removal report.

2.4 RESERVE CRITERIA

2.4.1 Public Recreation

In 2007 RS completed the establishment of Carbonton Park as a recreational area in the vicinity of the former Carbonton Dam. The newly completed park consists of vehicle parking, picnicking sites, bank fishing, and improved access to the river for kayakers and canoeists. RS formally transferred the new park with an endowment to the Deep River Park Association during a ceremony on November 22, 2008.

The amount of credit to be derived from the successful implementation of the park has not yet been determined. Under exceptional circumstances, if all primary criteria are successfully met, these reserve criteria should result in excess, unsold credits becoming available at the end of the monitoring period.

2.4.2 Scientific Research

The former Site Impoundment was subject to original research by Adam Riggsbee, PhD and Jason Julian, PhD—recent graduates of the University of North Carolina at Chapel Hill (UNC). RS provided UNC with unrestricted funding to support basic research efforts. To date, Julian has published two papers related to his dissertation, which investigated the environmental processes controlling benthic light availability and the resulting controls on primary and secondary productivity (Julian et al 2008a and 2008b). The research may be beneficial in measuring the positive impacts to biological productivity that occurs from lowering the water levels after dam removal to facilitate light penetration to the riverbed. Additional research by Riggsbee investigated the role of sediment suspensions (resulting from dam removal and bankfull discharges) on nutrient and organic matter availability within the water column (Riggsbee et al. 2007 and Riggsbee et al., 2008). Dr. Riggsbee has published three papers with an additional manuscript in revision that originated during his dissertation research (Riggsbee et.al. 2007, Riggsbee et al., 2008 and Doyle et al. 2008), while Dr. Julian has published two papers (Julian et.al. 2008a and Julian et al., 2008b) pertaining to the restored reach of the Deep River. Drs. Riggsbee and Julian have also given numerous oral presentations at professional conferences regarding their research.

The amount of credit to be derived from the support of this research by RS has not yet been determined. Under exceptional circumstances, if all primary criteria are successfully met, these reserve criteria should result in excess, unsold credits becoming available at the end of the monitoring period.

2.5 SUMMARY

After the third year of monitoring, the removal of Carbonton Dam has resulted in the continued restoration of lotic conditions with functional improvements recorded in water quality, fish and mollusk abundance, and sediment transport. Mitigation success has been demonstrated for the following criteria: Re-introduction of rare and endangered aquatic species, water quality improvement with respect to dissolved oxygen concentrations and benthic biotic indices, scientific research, and public recreation. Continued monitoring is necessary to confirm success for the convergence of benthic EPT taxa to reference data, and the recolonization of mollusks in the newly restored lotic community. See Table 14 below.

Table 14 shows the primary and reserve mitigation success criteria and parameters for this project. The final column evaluates the success in fulfilling project criteria.

Table 14. Mitigation Success Criteria Summary

	Criterion	Parameter	Anticipated Change/Result	2008 Success
Primary success criteria:	Re-colonization of rare and protected aquatic species	Presence/absence of rare/protected individuals	Unknown	Yes
		Rare/protected species habitat	Improvement/expansion	Yes
	Improved water quality	Benthic biotic indices	Decrease (= improve)	Yes
		AMS dissolved oxygen data	Increase within former Site Impoundment (must be ≥ 4.0 mg/L or consistent with reference station data)	Yes
	Improved aquatic community	Ephemeroptera, Plecoptera, and Trichoptera taxa, total number of benthic taxa	Increase (i.e., converge with reference station data)	Ongoing, Improving
		Fish, Mussel, and Snail community data	Demonstrated shifts in communities from lentic to lotic character	Yes
Reserve success criteria:	Downstream benefits below dam	Deep River bankfull channel within formerly eddie/scour pool areas below dam	Narrowing/increased stabilization of channel	Ongoing
	Scientific value	Published research	Successful completion	Yes
	Public recreation	Construction of planned on-Site park	Successful completion	Yes

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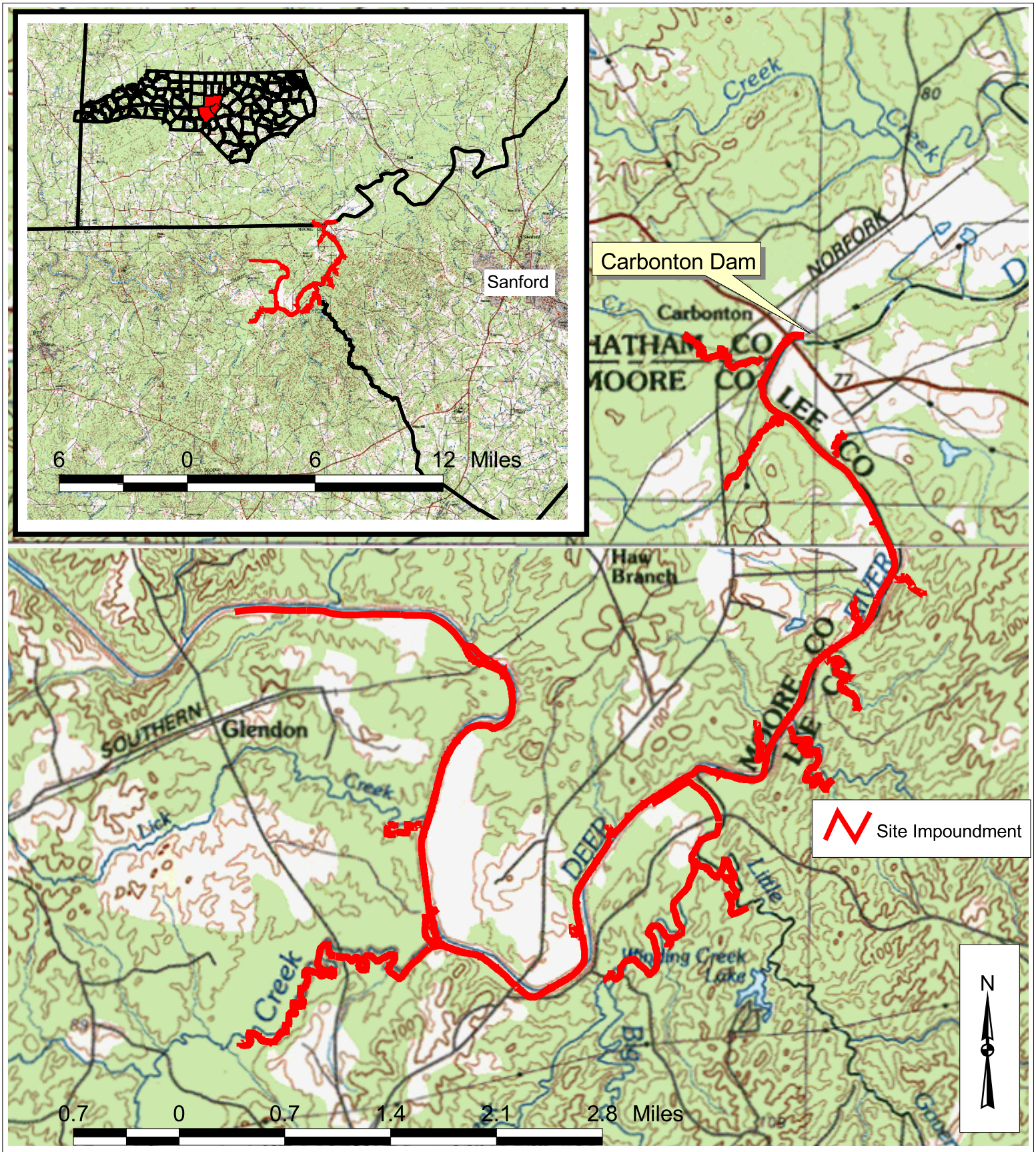
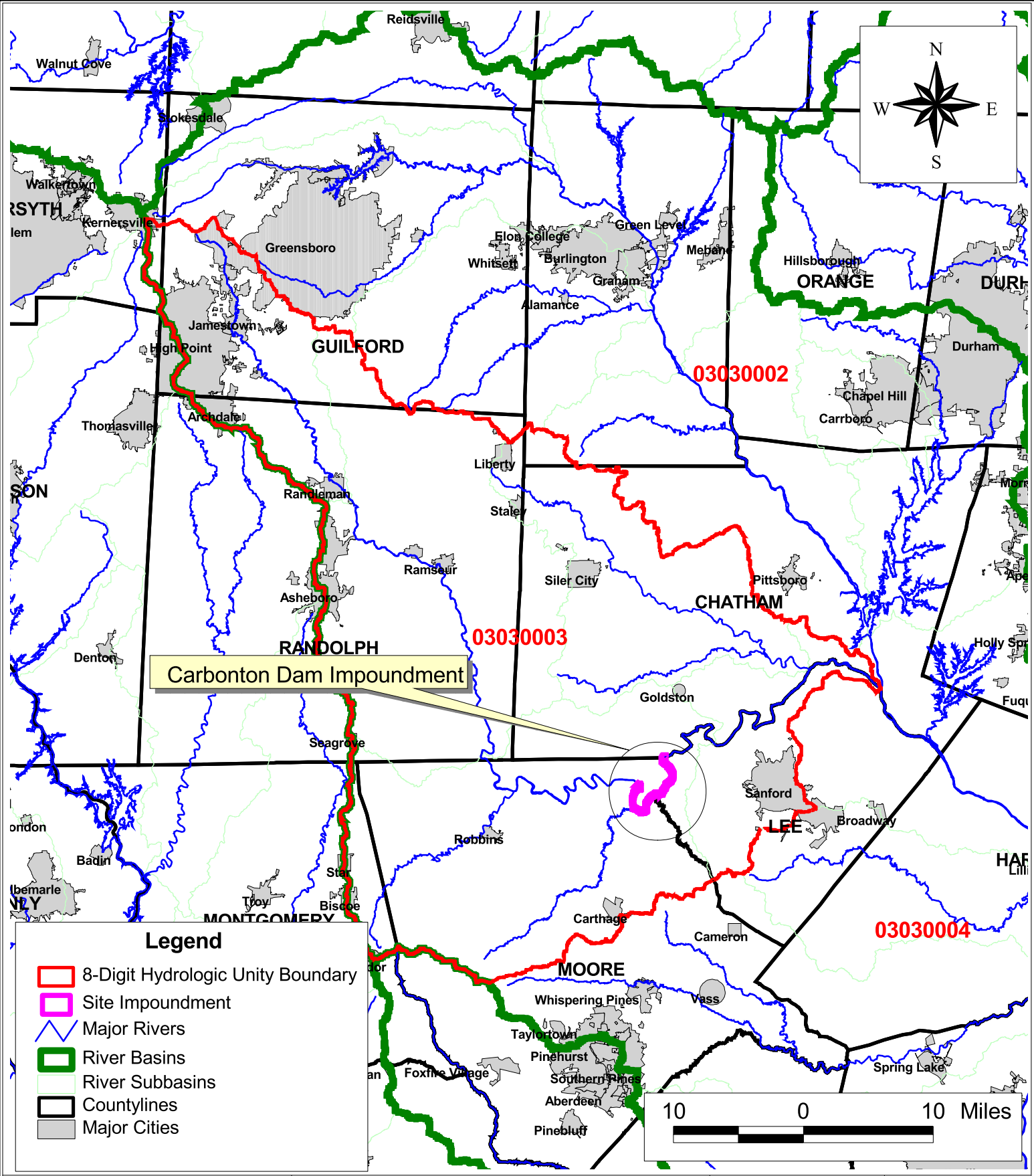
APPENDIX A: FIGURES



RESTORATION SYSTEMS, LLC Natural Resources Restoration & Conservation	Site Location Deep River- Carbonton Dam Restoration Site Lee, Chatham, and Moore Counties, North Carolina	**FIGURE** **1**	Drawn By: MTC Date: SEP 2006 Chkd By: APS Project No: 06-288.03 **SCALE: AS SHOWN**



EcoScience Corporation
Raleigh, North Carolina

Hydrologic Units

Deep River-Carbonton Dam Restoration Site

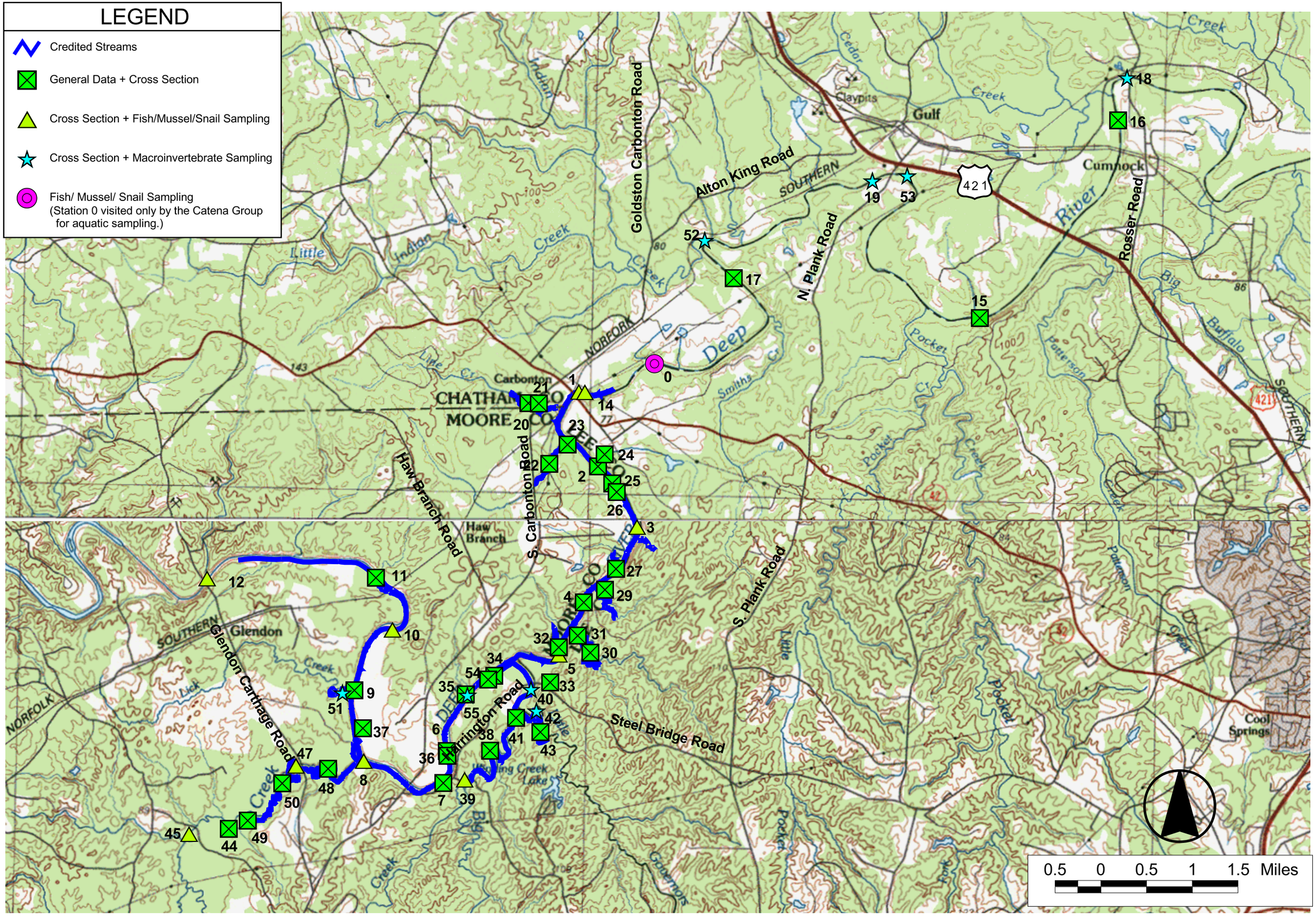
Chatham, Lee, and Moore Counties, North Carolina

Drawn By: MTC
Chkd By: GRM
Date: SEP 2006
Project: 06-288

FIGURE 2

LEGEND

- Credited Streams
- General Data + Cross Section
- Cross Section + Fish/Mussel/Snail Sampling
- Cross Section + Macroinvertebrate Sampling
- Fish/ Mussel/ Snail Sampling
  (Station 0 visited only by the Catena Group for aquatic sampling.)



EcoScience Corporation
Raleigh, North Carolina

RESTORATION SYSTEMS, LLC
Natural Resources Restoration & Conservation

CLIENT:
Ecosystem Enhancement Program

PROJECT:

CARBONTON DAM-DEEP RIVER WATERSHED RESTORATION SITE

CHATHAM, LEE, AND MOORE COUNTIES, NORTH CAROLINA

TITLE:

MONITORING STATION LOCATIONS

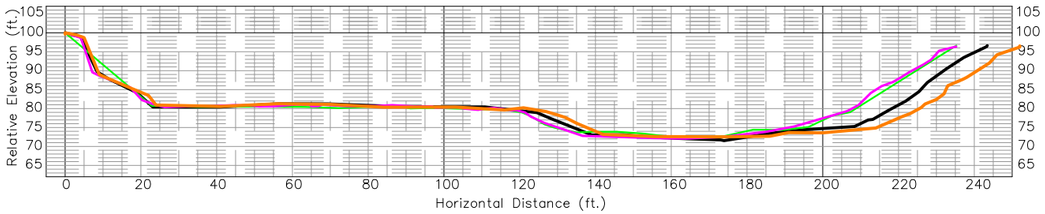
Dwn By:	Date:
MCG	SEPT 2006
Ckd By:	Scale:
MTC	AS SHOWN

ESC Project No.: 06-288

FIGURE

3

STATION 1



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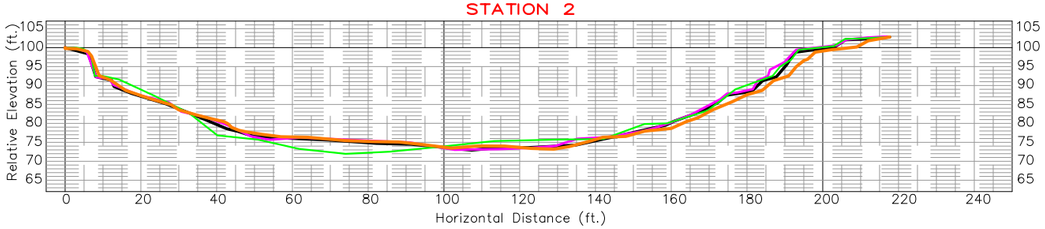

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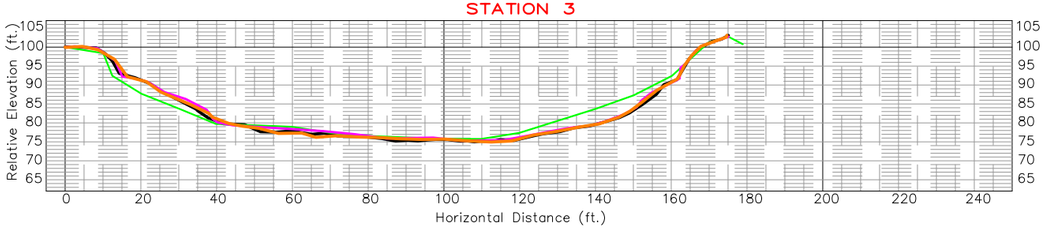

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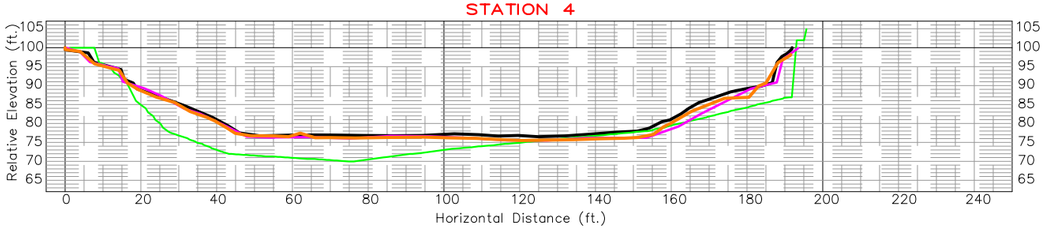

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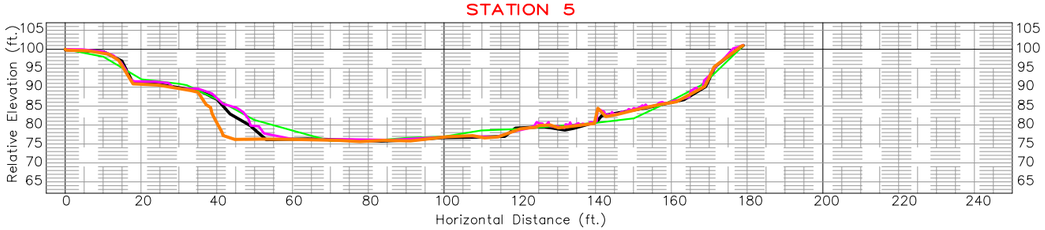

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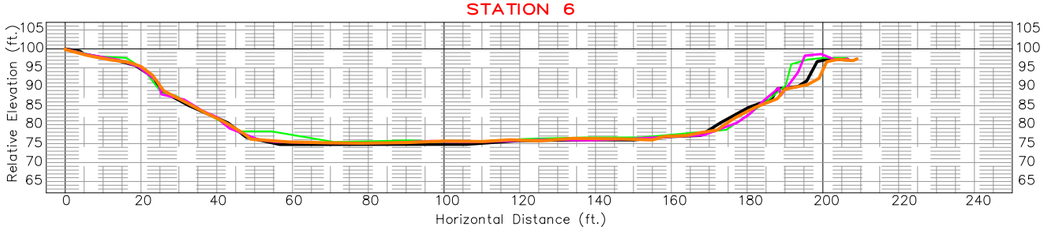

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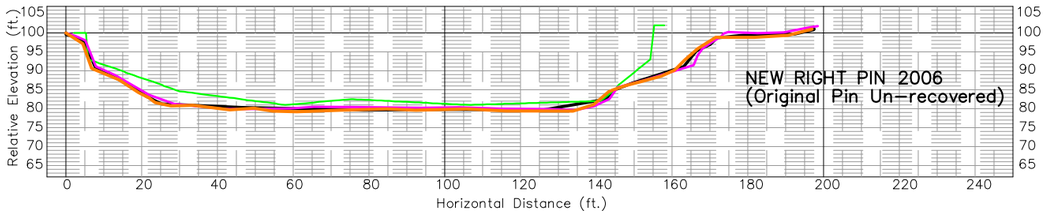

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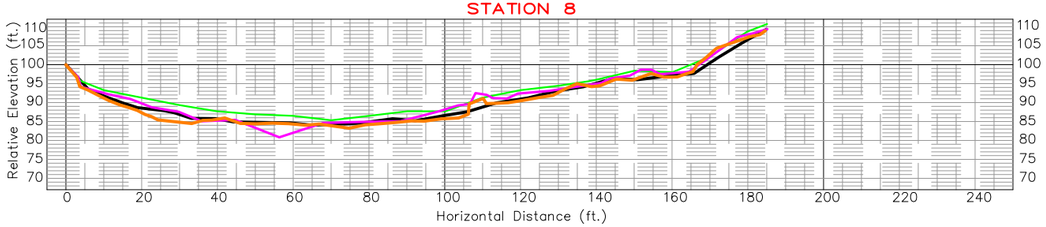

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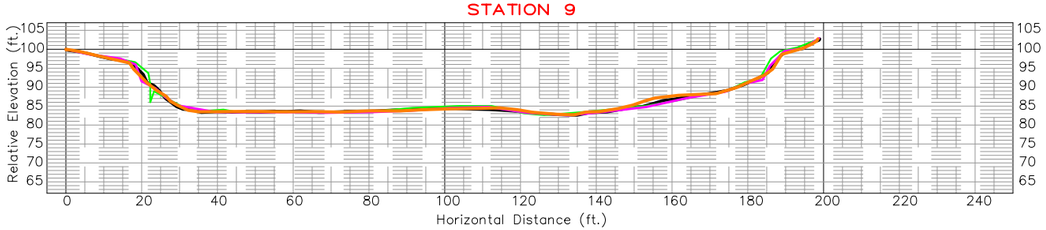

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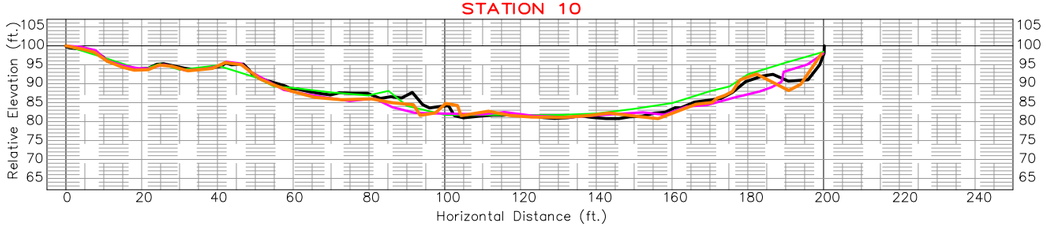

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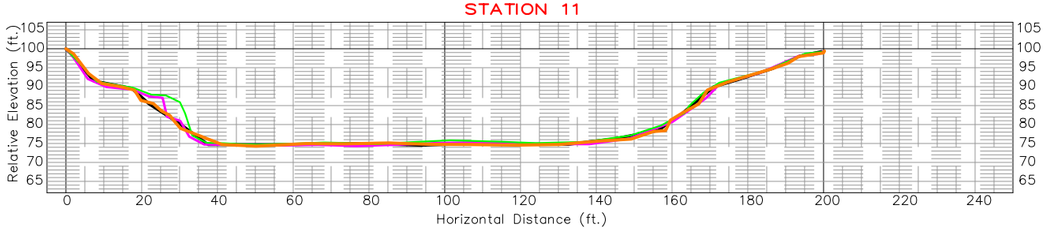

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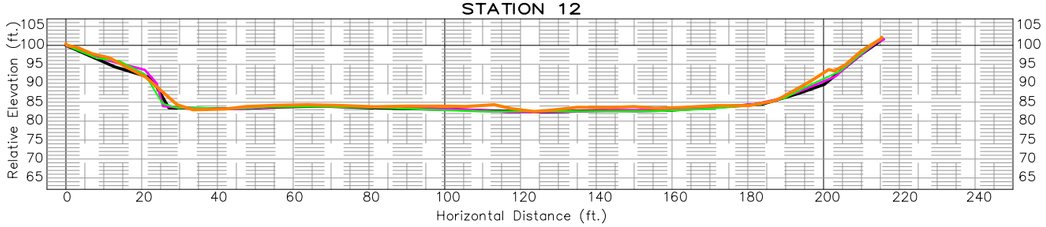

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CARBONTON DAM
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WATERSHED
RESTORATION
SITE

CHATHAM, LEE, AND MOORE COUNTIES, NORTH CAROLINA

Title:

MONITORING
CROSS-SECTIONS

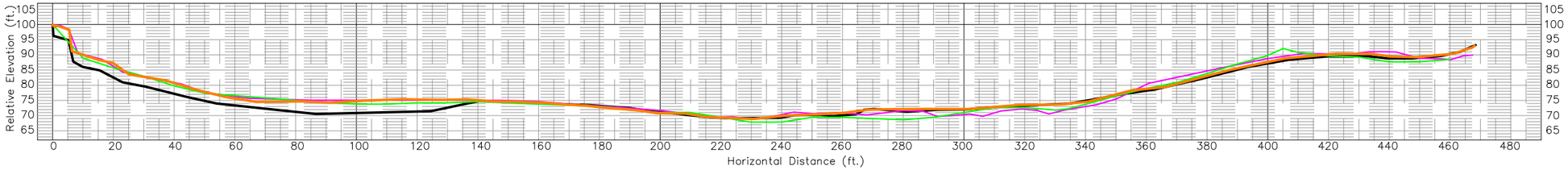
Dwn. By:	Ckd. By:
MTD/TAL	MCG
Date:	Scale:
OCT 2008	AS SHOWN

ESC Project No.: 08-404

SHEET

4A

STATION 14



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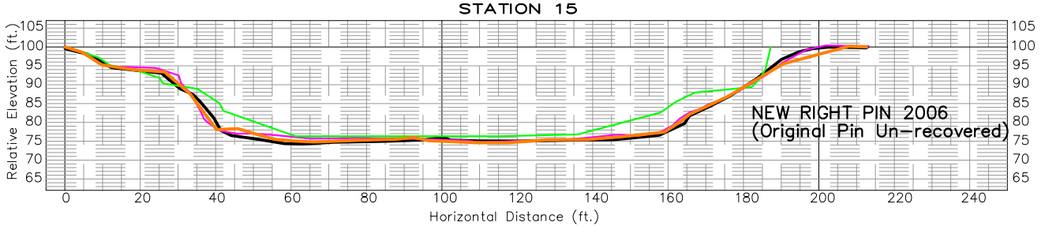

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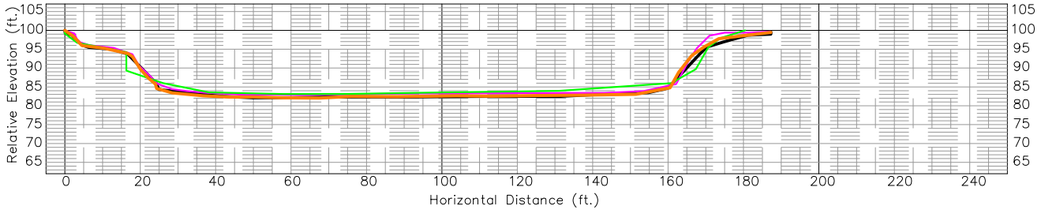

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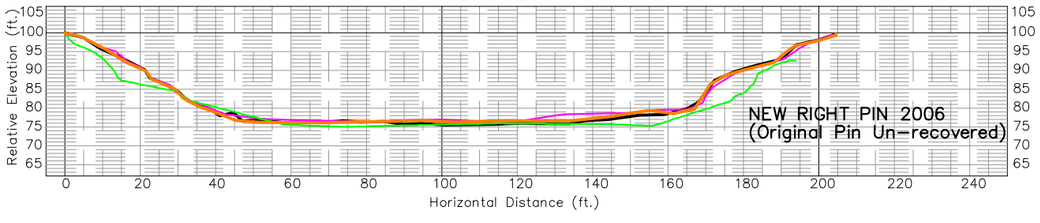

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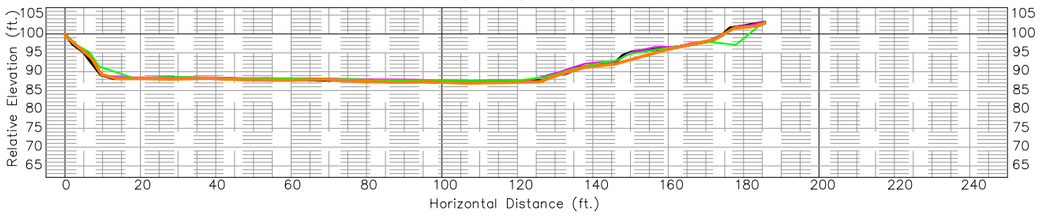

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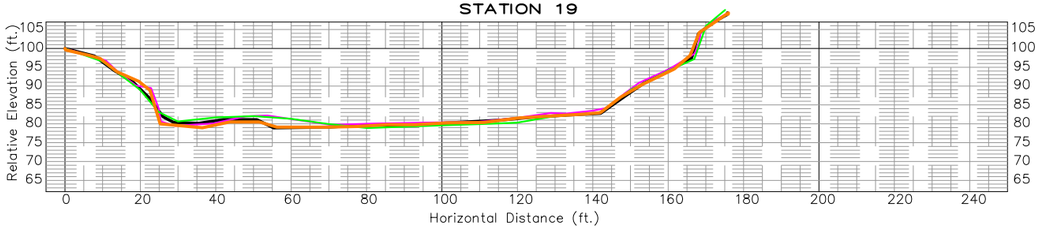

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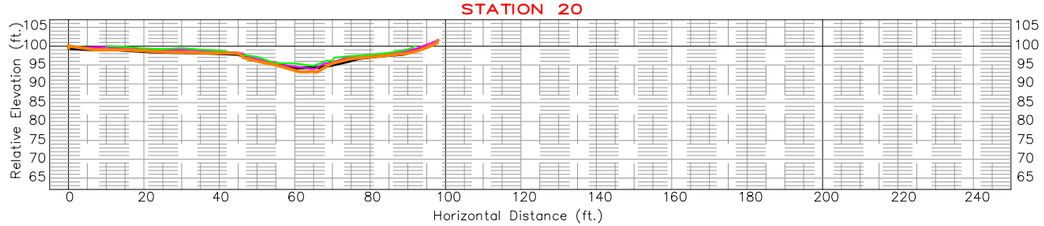

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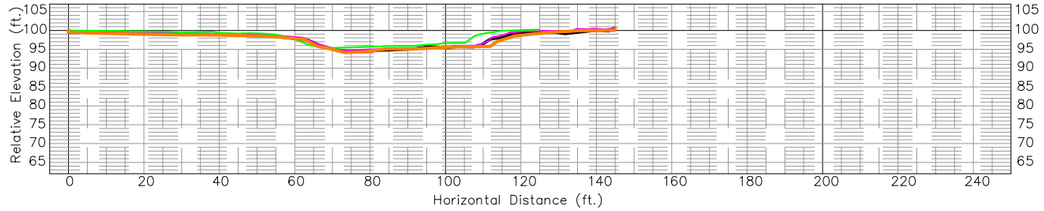

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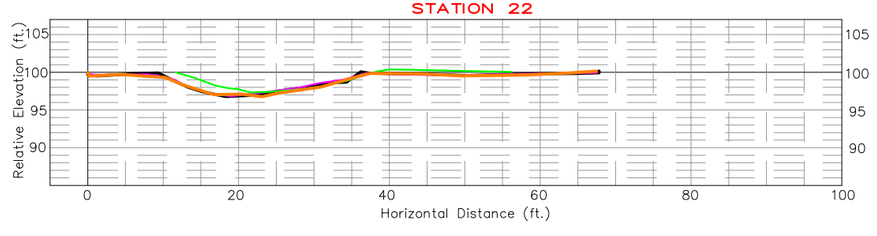

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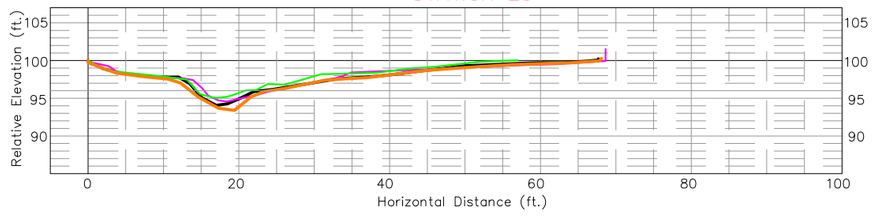

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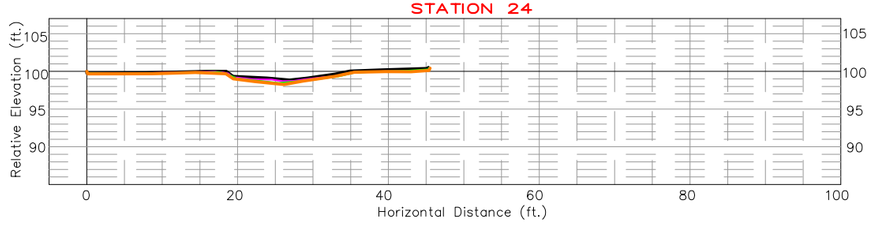

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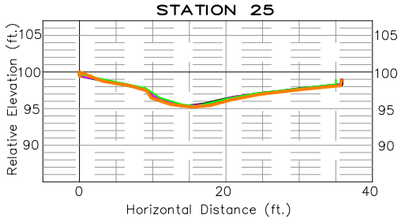
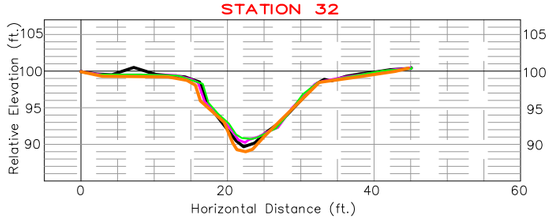
Date:	Scale:
07/26/08	AS SHOWN

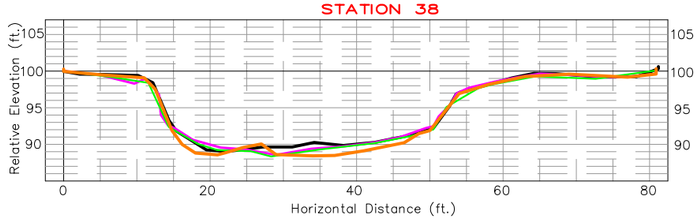
ESC Project No.: 08-404

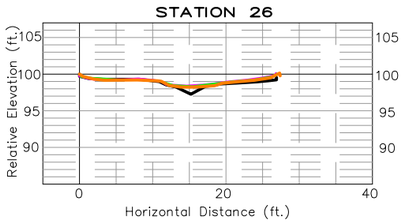
SHEET

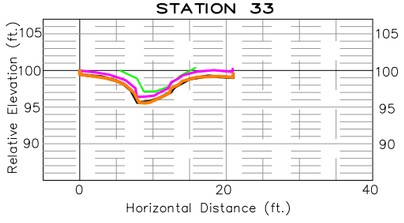
4B

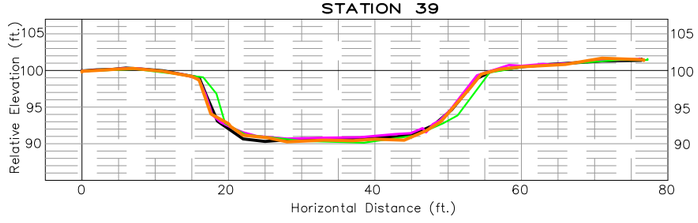


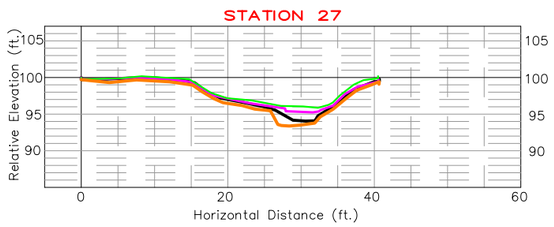


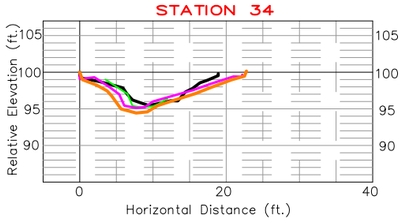


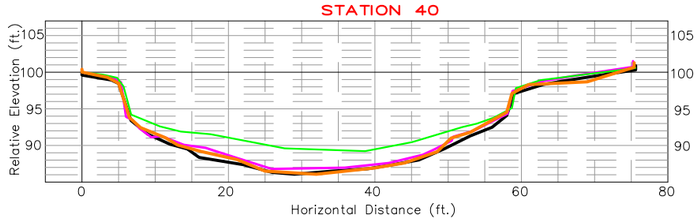


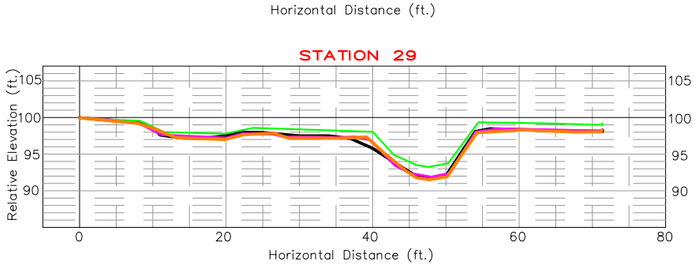


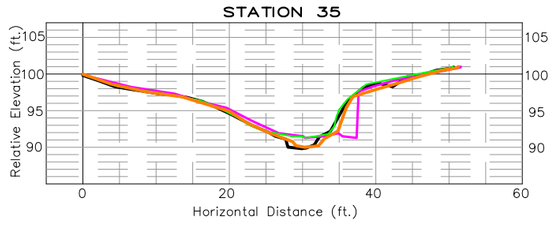


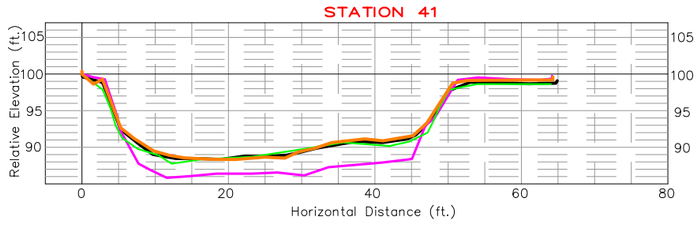


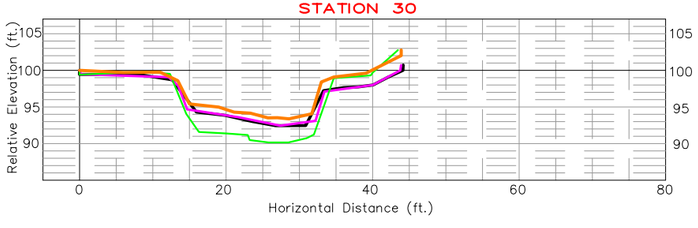


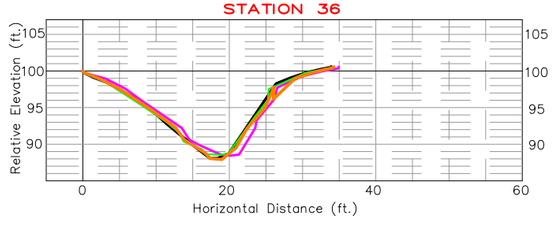


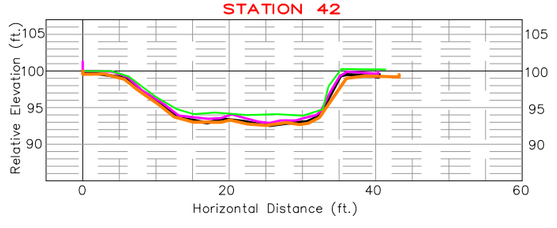


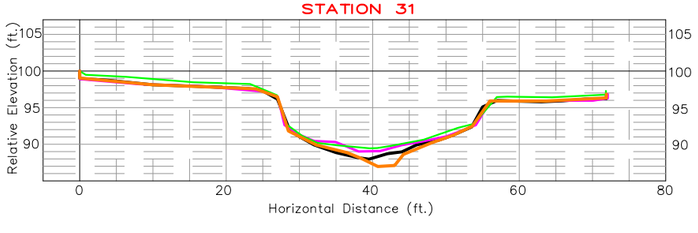


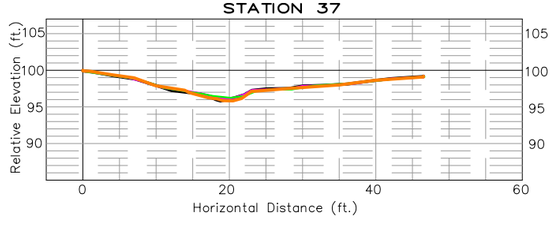


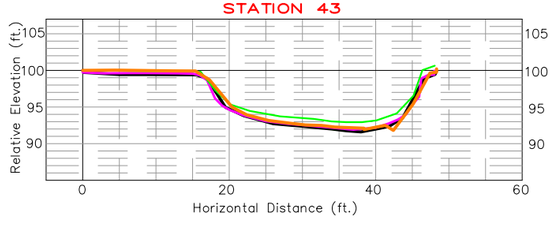












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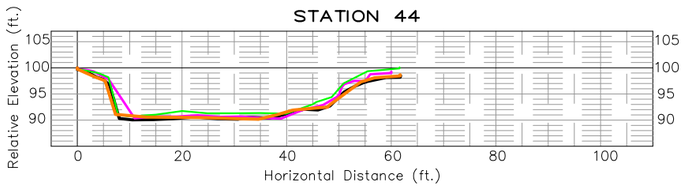
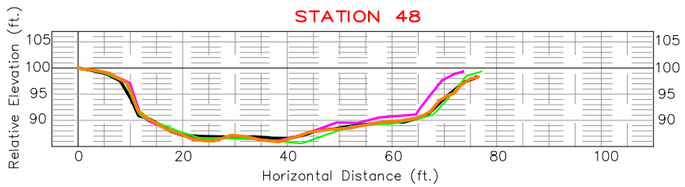
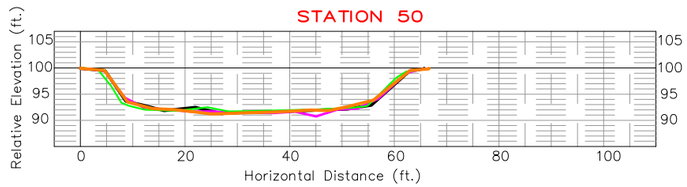
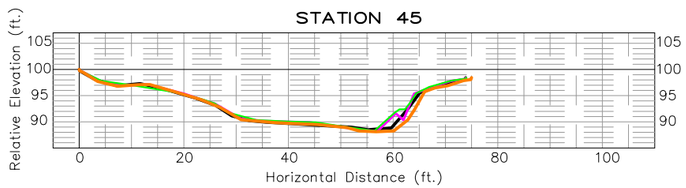
SHEET

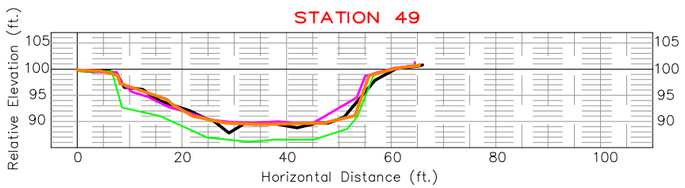
4C

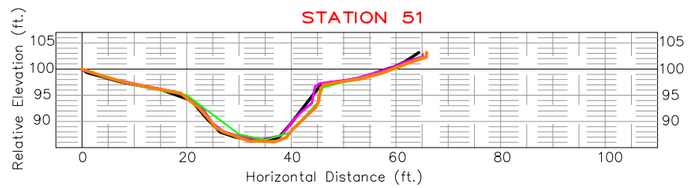


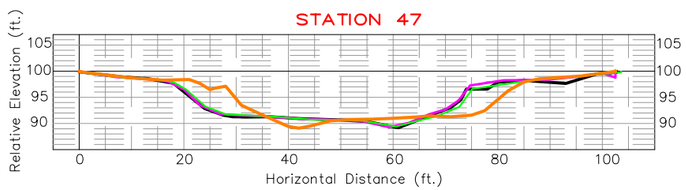


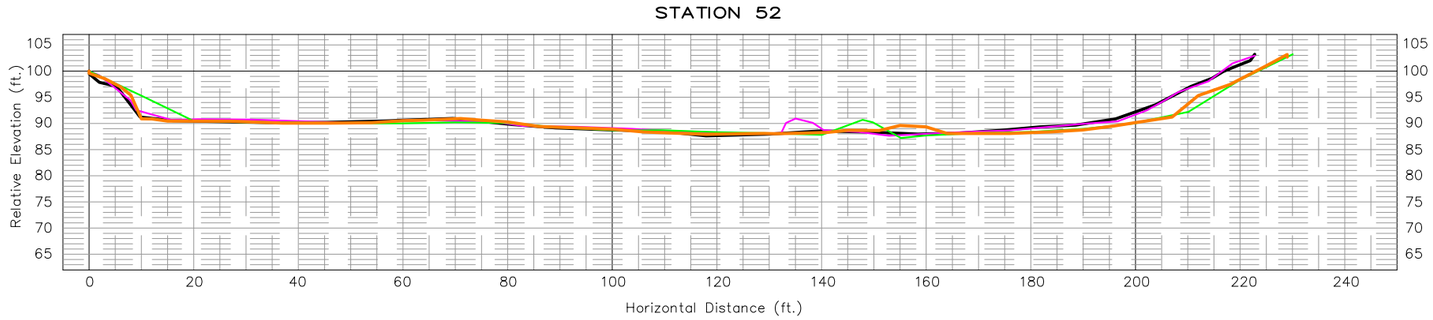


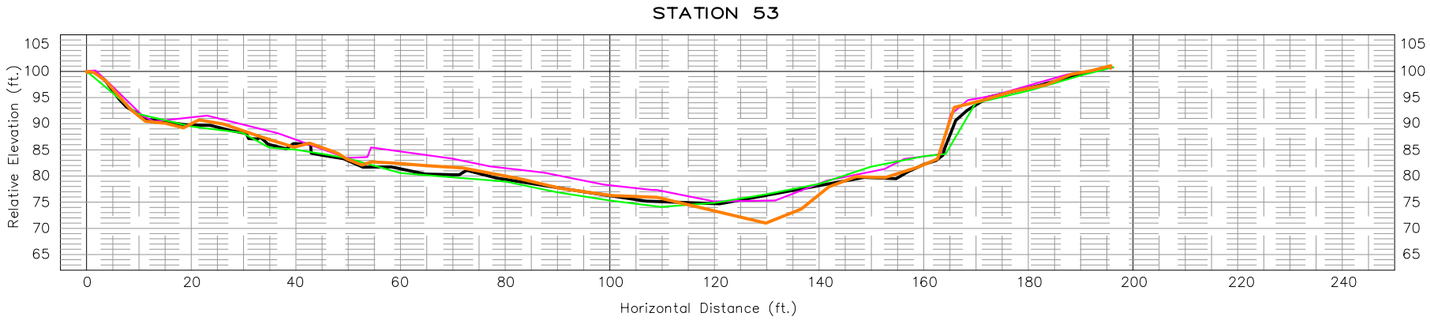


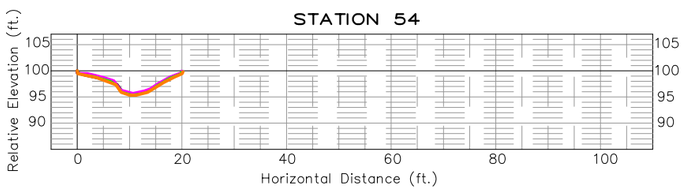


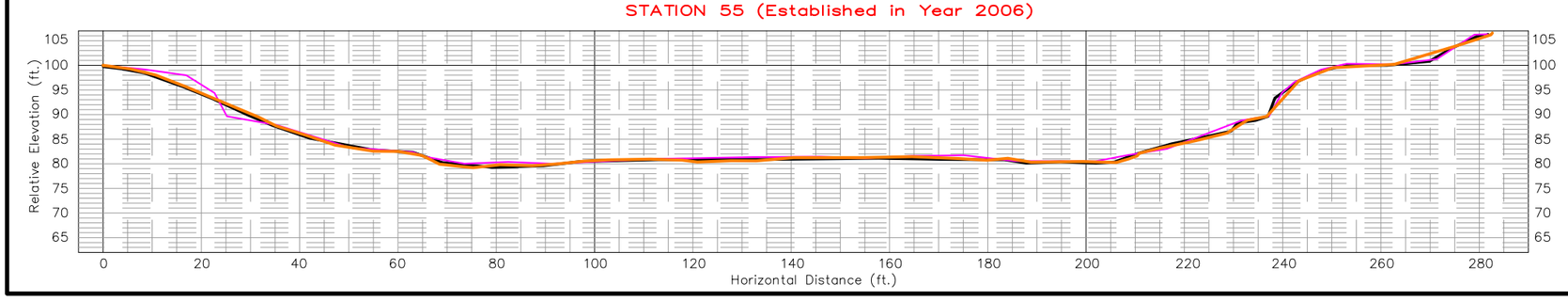












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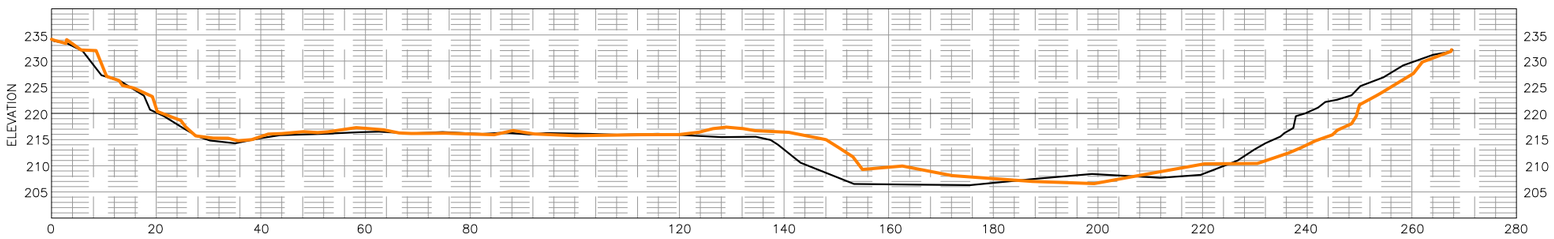
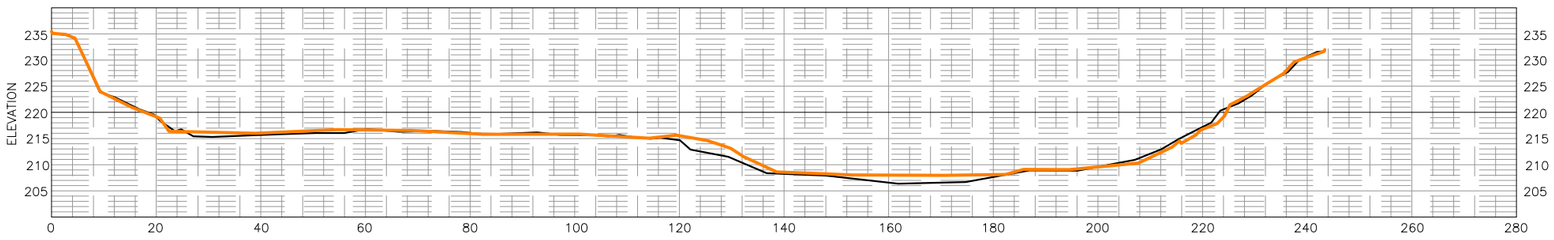
SHEET
4D

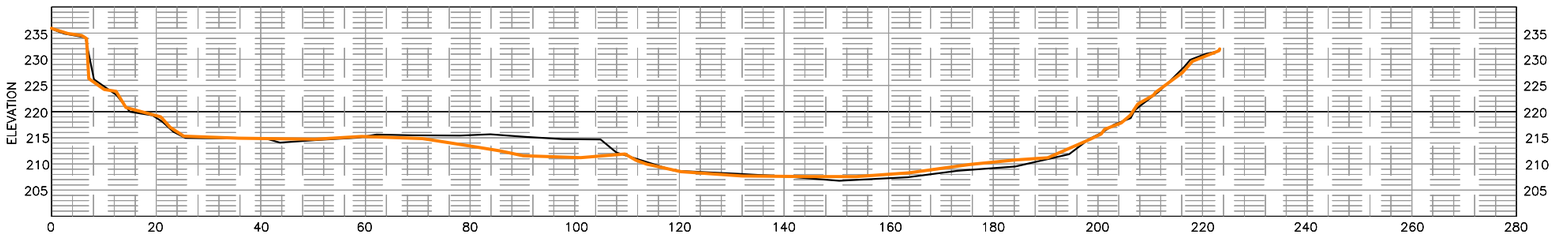
GRAVEL BAR STATION 1



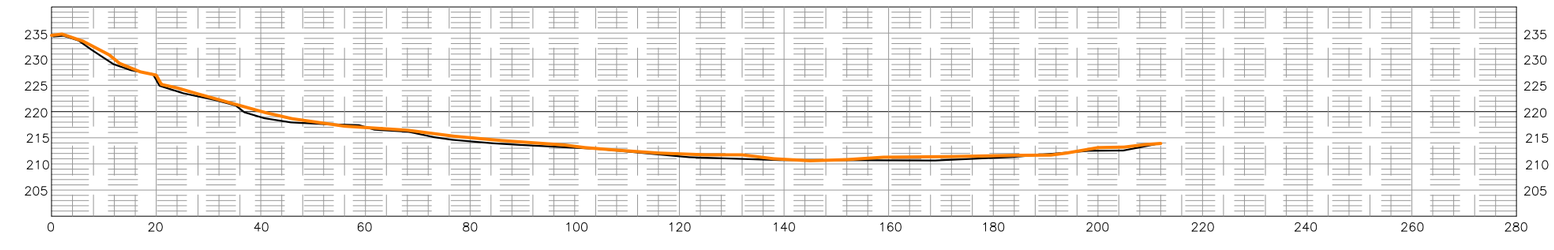
GRAVEL BAR STATION 2



GRAVEL BAR STATION 3



GRAVEL BAR STATION 4



EcoScience
A division of PBS&J

LEGEND:

YEAR 2007 MONITORING

YEAR 2008 MONITORING

Client:

Ecosystem Enhancement

Project:

CARBONTON DAM
DEEP RIVER
WATERSHED
RESTORATION
SITE

CHATHAM, LEE, AND MOORE COUNTIES, NORTH CAROLINA

Title:

GRAVEL BAR MONITORING CROSS-SECTIONS

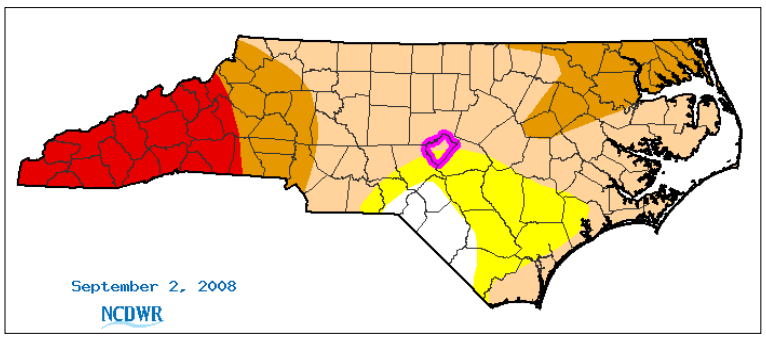
Dwn. By:	Ckd. By:
MTD/TAL	MCG
Date:	Scale:
OCT 2008	AS SHOWN
ESC Project No.:	
08-404	

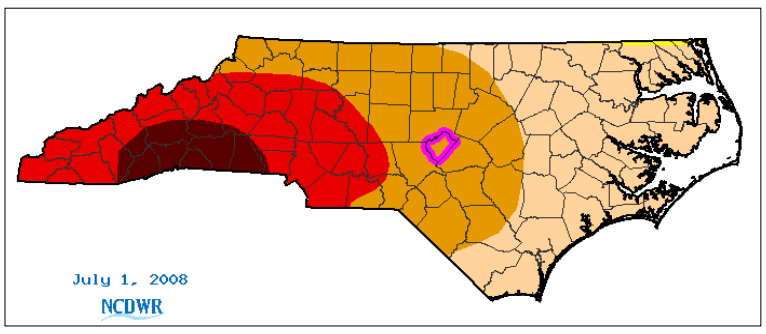
SHEET

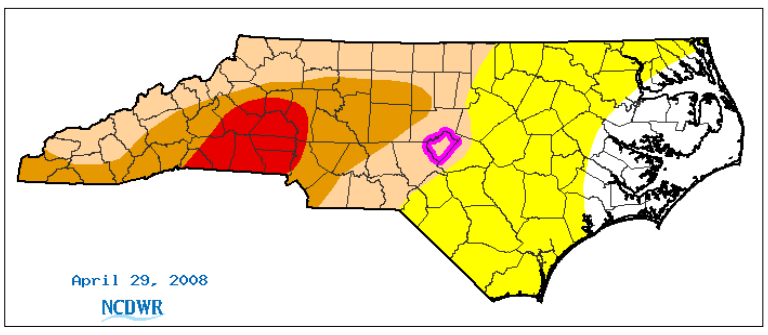
4E

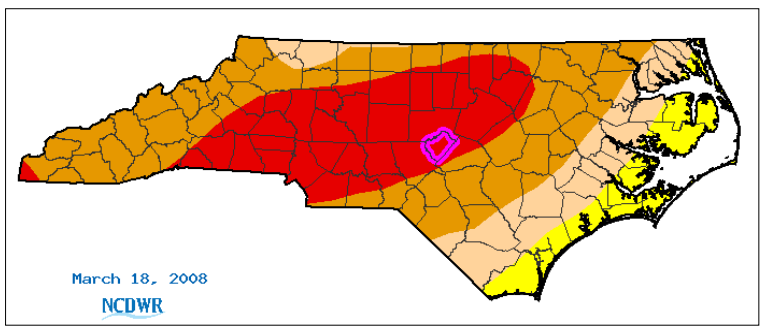
Lee County Drought Data

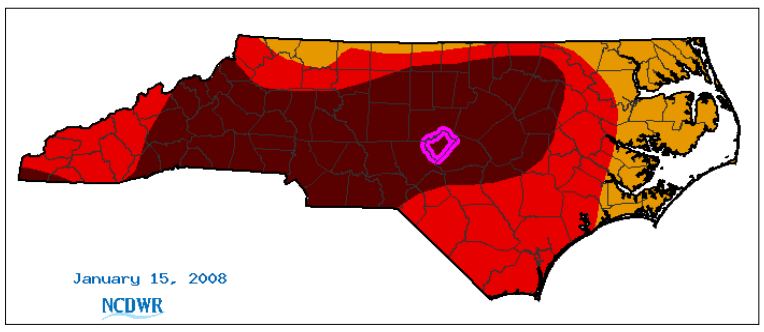
Date	DM Level	Drought Level Description	Drought Conditions by Percent Area None	D0	D1	D2	D3	D4
9/2/2008	D1	Moderate Drought	0.00	38.11	61.89	0.00	0.00	0.00
8/26/2008	D1	Moderate Drought	0.00	38.11	61.89	0.00	0	0
8/19/2008	D1	Moderate Drought	0.00	0.00	100.00	0.00	0	0
8/12/2008	D1	Moderate Drought	0.00	0.00	100.00	0.00	0	0
8/5/2008	D1	Moderate Drought	0.00	0.00	100.00	0.00	0	0
7/29/2008	D1	Moderate Drought	0.00	0.00	100.00	0.00	0	0
7/22/2008	D1	Moderate Drought	0.00	0.00	100.00	0.00	0	0
7/15/2008	D1	Moderate Drought	0.00	0.00	100.00	0.00	0	0
7/8/2008	D1	Moderate Drought	0.00	0.00	90.63	9.38	0	0
7/1/2008	D2	Severe Drought	0.00	0.00	0.00	100.00	0	0
6/24/2008	D1	Moderate Drought	0.00	0.00	82.68	17.32	0	0
6/17/2008	D1	Moderate Drought	0.00	0.00	82.68	17.32	0	0
6/10/2008	D1	Moderate Drought	0.00	0.00	100.00	0.00	0	0
6/3/2008	D1	Moderate Drought	0.00	0.00	100.00	0.00	0	0
5/27/2008	D1	Moderate Drought	0.00	0.00	100.00	0.00	0	0
5/20/2008	D1	Moderate Drought	0.00	0.00	100.00	0.00	0	0
5/13/2008	D1	Moderate Drought	0.00	0.00	100.00	0.00	0	0
5/6/2008	D1	Moderate Drought	0.00	0.00	100.00	0.00	0	0
4/29/2008	D1	Moderate Drought	0.00	0.00	100.00	0.00	0	0
4/22/2008	D2	Severe Drought	0.00	0.00	0.00	100.00	0	0
4/15/2008	D2	Severe Drought	0.00	0.00	0.00	100.00	0	0
4/8/2008	D2	Severe Drought	0.00	0.00	0.00	100.00	0	0
4/1/2008	D3	Extreme Drought	0.00	0.00	0.00	0.00	100	0
3/25/2008	D3	Extreme Drought	0.00	0.00	0.00	0.00	100	0
3/18/2008	D3	Extreme Drought	0.00	0.00	0.00	0.00	100	0
3/11/2008	D3	Extreme Drought	0.00	0.00	0.00	0.00	100	0
3/4/2008	D4	Exceptional Drought	0.00	0.00	0.00	0.00	1.86	98.14
2/26/2008	D4	Exceptional Drought	0.00	0.00	0.00	0.00	1.86	98.14
2/19/2008	D4	Exceptional Drought	0.00	0.00	0.00	0.00	0	100
2/12/2008	D4	Exceptional Drought	0.00	0.00	0.00	0.00	0	100
2/5/2008	D4	Exceptional Drought	0.00	0.00	0.00	0.00	0	100
1/29/2008	D4	Exceptional Drought	0.00	0.00	0.00	0.00	0	100
1/22/2008	D4	Exceptional Drought	0.00	0.00	0.00	0.00	0	100
1/15/2008	D4	Exceptional Drought	0.00	0.00	0.00	0.00	0	100
1/8/2008	D4	Exceptional Drought	0.00	0.00	0.00	0.00	0	100
1/1/2008	D4	Exceptional Drought	0.00	0.00	0.00	0.00	0	100
12/25/2007	D4	Exceptional Drought	0.00	0.00	0.00	0.00	0	100
12/18/2007	D4	Exceptional Drought	0.00	0.00	0.00	0.00	0	100
12/11/2007	D4	Exceptional Drought	0.00	0.00	0.00	0.00	0	100
12/4/2007	D4	Exceptional Drought	0.00	0.00	0.00	0.00	0	100
11/27/2007	D4	Exceptional Drought	0.00	0.00	0.00	0.00	0	100
11/20/2007	D4	Exceptional Drought	0.00	0.00	0.00	0.00	0	100
11/13/2007	D3	Extreme Drought	0.00	0.00	0.00	0.00	100	0
11/6/2007	D3	Extreme Drought	0.00	0.00	0.00	0.00	100	0
10/30/2007	D3	Extreme Drought	0.00	0.00	0.00	0.00	100	0
10/23/2007	D4	Exceptional Drought	0.00	0.00	0.00	0.00	0	100
10/16/2007	D4	Exceptional Drought	0.00	0.00	0.00	0.00	0	100
10/9/2007	D4	Exceptional Drought	0.00	0.00	0.00	0.00	0	100
10/2/2007	D4	Exceptional Drought	0.00	0.00	0.00	0.00	0	100
9/25/2007	D3	Extreme Drought	0.00	0.00	0.00	0.00	100	0
9/18/2007	D3	Extreme Drought	0.00	0.00	0.00	0.00	100	0
9/11/2007	D3	Extreme Drought	0.00	0.00	0.00	0.00	100	0
9/4/2007	D3	Extreme Drought	0.00	0.00	0.00	0.00	100	0
8/28/2007	D2	Severe Drought	0.00	0.00	0.00	81.17	18.82	0
8/21/2007	D2	Severe Drought	0.00	0.00	0.00	86.12	13.88	0
8/14/2007	D2	Severe Drought	0.00	0.00	0.00	100.00	0	0
8/7/2007	D1	Moderate Drought	0.00	0.00	100.00	0.00	0	0
7/31/2007	D1	Moderate Drought	0.00	0.00	100.00	0.00	0	0
7/24/2007	D1	Moderate Drought	0.00	3.32	96.68	0.00	0	0
7/17/2007	D1	Moderate Drought	0.00	3.32	96.68	0.00	0	0
7/10/2007	D1	Moderate Drought	0.00	3.32	96.68	0.00	0	0
7/3/2007	D1	Moderate Drought	0.00	3.32	96.68	0.00	0	0

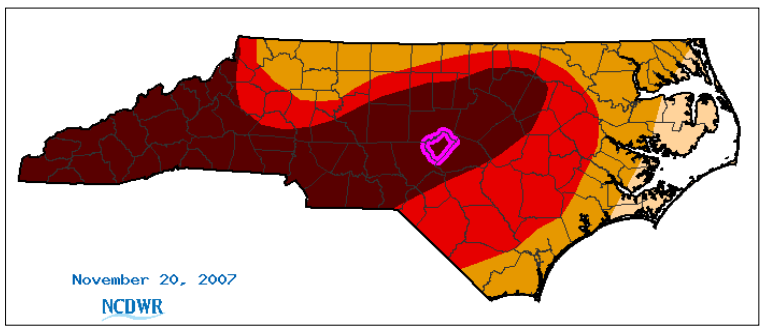


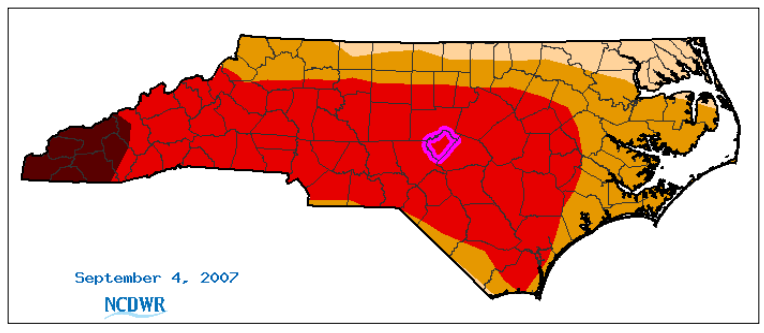


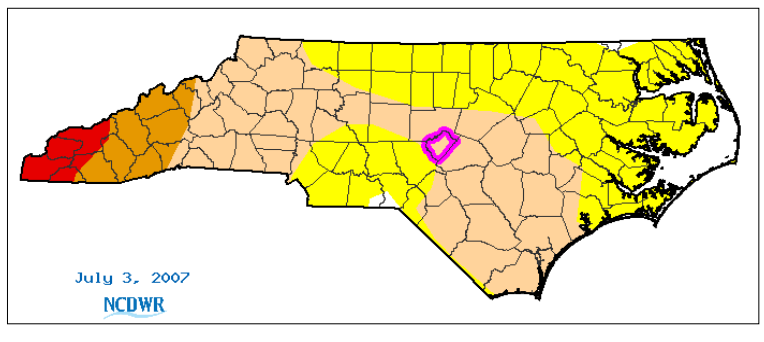


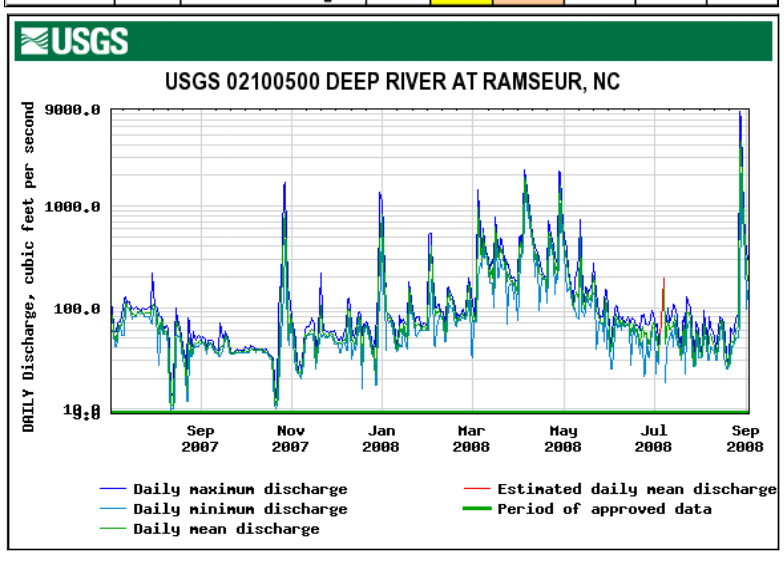












EcoScience, A division of PBS&J	Client: Ecosystem Enhancement Program	Project: **Carbonton Dam Monitoring Year 3** Chatham, Lee, and Moore Counties, North Carolina	Title: **North Carolina Drought Monitor Data**	Dwn By: MCG; Ckd By: MTC; Date: Nov 08; Scale: N/A; ESC Project No.: 08-404.00	FIGURE 5

APPENDIX B: BENTHIC MACROINVERTEBRATE DATA

SPECIES	T.V.	F.F.G.	IMPOUNDED									
			Sta. 1	Sta. 3	Sta. 5	Sta. 8	Sta. 10	Sta. 40	Sta. 42	Sta. 47	Sta. 51	Sta. 55
PLATYHELMINTHES												
Turbellaria												
Tricladida												
Planariidae												
Girardia (Dugesia) tigrina	**7.2**		1					1				
NEMATODA	**6**											
MOLLUSCA												
Bivalvia												
Veneroida												
Corbiculidae												
Corbicula fluminea	**6.12**	**FC**	1									
Sphaeriidae	**6.6**	**FC**										
Musculium transversum	***8**	**FC**							1			
Gastropoda												
Pleuroceridae	**3.4**											
Elimia sp.	**2.46**	**SC**	1									
Basommatophora												
Ancylidae		**SC**										
Ferrissia rivularis	***6**	**SC**								1		
ANNELIDA												
Oligochaeta		**CG**										
Tubificida												
Enchytraeidae	**9.8**	**CG**				1						3
Lumbricidae		**CG**	6		2	1		2				
Naididae	***8**	**CG**	2	1					1	1	5	
Dero sp.	**10**	**CG**						3		1	2	
Nais communis	**8.8**	**CG**	2									
Pristina sp.	**9.6**	**CG**										
Tubificidae w.h.c.	**7.1**	**CG**										
Tubificidae w.o.h.c.	**7.1**	**CG**	13			1		1				
Branchiura sowerbyi	**8.28**	**CG**	3	1								
Limnodrilus hoffmeisteri	**9.5**	**CG**										
Spirosperma sp.	**10**	**CG**										
Lumbriculida												
Lumbriculidae	**7.03**	**CG**			4	2		3	21	6	2	
Branchiobdellida										1		
Hirudinea		**P**										
Arhynchobdellida												
Erpobdellidae		**P**										
Erpobdella sp.	**8.3**	**P**								1		
Rhynchobdellida												
Glossiphoniidae		**P**										
Helobdella elongata	**9.5**	**P**	1									
ARTHROPODA												
Arachnoidea												
Acariformes												
Arrenuridae	**5.5**											
Arrenurus sp.	**5.5**		7									
Lebertiidae	**5.5**											

Lebertia sp.	**5.5**											
Torrenticolidae	**5.5**											
Torrenticola sp.	**5.5**											
Crustacea												
Ostracoda			6									
Copepoda												
Cyclopoida			2									
Cladocera												
Chydoridae			2	1								
Isopoda												
Asellidae		**SH**										
Caecidotea sp.	**9.1**	**CG**	7			1		27	2	3	48	
Amphipoda												
Crangonyctidae												
Crangonyx sp.	**7.9**	**CG**	1	1				2	36	8	16	
Hyalellidae												
Hyalella azteca	**7.75**	**CG**	2					29				
Decapoda												
Cambaridae	**7.5**											
Cambarus sp.	**7.62**	**CG**								3	2	
Palaemonidae												
Palaemonetes kadiakensis	**7.1**	**CG**	1	2	1	5				7		
Insecta												
Collembola					1			2	1			
Ephemeroptera												
Baetidae		**CG**										
Acerpenna pygmaea	**3.9**											
Baetis intercalaris	**7**	**CG**										1
Plauditus sp.	***4**	**CG**				1	1		1	22		1
Pseudocloeon sp.	**4**	**CG**		1						2		1
Caenidae		**CG**										
Caenis sp.	**7.4**	**CG**	9	3		2	5			1		1
Ephemerellidae		**SC**										
Attenella sp.												
Ephemerella sp.	**2.04**	**SC**										
Ephemerella needhami	**0**	**CG**										
Eurylophella sp.	**4.34**	**SC**	1				1			1		1
Serratella sp.		**SC**										
Timpanoga sp.		**CG**	8	1			1			5		
Heptageniidae												
Leucrocuta sp.	**2.4**	**SC**	1									
Maccaffertium (Stenonema) s	***4**	**SC**										
Maccaffertium (Stenonema) e	**3.8**	**SC**	2				1					1
Maccaffertium (Stenonema) r	**5.5**	**SC**	48	2	1		21					7
Maccaffertium (Stenonema) p	**2**	**SC**										
Stenacron interpunctatum	**3.58**	**SC**	1				1					
Isonychiidae		**FC**										
Isonychia sp.	**3.5**	**FC**	3				1					
Leptophlebiidae	***2**	**CG**		1								
Leptophlebia sp.	**6.2**	**CG**	3							1		
Paraleptophlebia sp.	**0.94**	**CG**	3				2				15	
Potamanthidae		**CG**										

Anthopotamus (Potamanthus	**1.5**	**CG**	27				1	1	1				
Siphlonuridae													
Siphlonurus sp.	**5.8**	**CG**	2					6					
Odonata													
Aeshnidae	**5.6**	**P**											
Boyeria vinosa	**5.97**	**P**											2
Boyeria grafiana	**6.1**	**P**											
Nasiaeschna pentacantha	**8.1**		1					1					
Coenagrionidae	***9**	**P**											
Argia sp.	**8.17**	**P**	4	3		1				1			1
Enallagma sp.	**8.9**	**P**				1				1			
Corduliidae	***5**	**P**											
Epicordulia princeps	**5.6**	**P**											
Macromia sp.	**6.16**	**P**	3	3		1	2			2			
Neurocordulia sp.	**5**												
Neurocordulia obsoleta	**5.2**		4				7						4
Gomphidae	***1**	**P**											
Arigomphus sp.													
Dromogomphus spinosus	**5.1**	**P**	1				1						
Erpetogomphus designatus			1										
Erpetogomphus sp.													
Gomphus sp.	**5.8**	**P**	2		1		1			2			
Hagenius brevistylus	**4**	**P**		1									
Perithemis tenera	**9.9**	**P**						4					
Libellulidae	**6.7**	**P**								1			
Erythemis simplicicollis	**9.7**						1						
Libellula cyanea													
Libellula semifasciata													
Libellula sp.	**9.6**	**P**						1					
Pachydiplax longipennis	**9.9**		1					5	1		1		
Somatochlora sp.	**9.2**	**P**											
Plecoptera							2						
Nemouridae		**SH**											
Amphinemura sp.	**3.3**	**SH**					1		1	12			
Perlidae	***1**	**P**											
Acroneuria cf. filicis													
Acroneuria mela	**0.9**		2				5						
Acroneuria sp.		**P**											
Neoperla sp.	**1.5**	**P**											
Perlesta placida sp. gp.	**4.7**	**P**				1			6	27			
Perlesta sp.	**4.7**	**P**	9				1						
Perlodidae	***2**	**P**											
Cultis decisus	**1.6**	**P**											
Isoperla sp.	***2**	**P**	8	1	2	1		9		61			1
Taeniopterygidae		**SH**											
Taeniopteryx sp.	**5.4**	**SH**						1		1			
Hemiptera													
Belostomatidae													
Belostoma sp.	**9.8**	**P**						2					
Corixidae	**9**	**PI**	1	1				6	1	1			
Hydrometridae													
Hydrometra sp.													

Pleidae				1									
Paraplea sp.							2						
Nepidae		-											
Ranatra sp.	**7.8**	**P**						2					
Veliidae		**P**											
Microvelia sp.		**P**								1			
Stenovelia stagalis								1					
Megaloptera													
Corydalidae		**P**											
Chauliodes pectinicornis	**9.6**							1					
Corydalus cornutus	**5.2**	**P**	2		1		1						
Nigronia serricornis	**5**	**P**					1	1					
Sialidae		**P**											
Sialis sp.	**7.17**	**P**						6					
Trichoptera													
Hydropsychidae	***4**	**FC**											
Ceratopsyche sp.		**FC**											
Cheumatopsyche sp.	**6.2**	**FC**	1										
Hydropsyche sp.	**5**	**FC**											
Hydropsyche simulians													
Macrostemum carolina			1										
Hydroptilidae	***4**	**PI**											
Hydroptila sp.	**6.2**	**PI**											
Leptoceridae	***4**	**CG**											
Ceraclea sp.	**2**	**CG**											
Nectopsyche sp.	**2.9**	**SH**		1									
Nectopsyche exquisita	**4.1**	**SH**											
Triaenodes sp.	**4.46**	**SH**								2			
Triaenodes injustus	**2.5**	**SH**	6	4	1		3						2
Lepidostomatidae		**SH**											
Lepidostoma sp.	**0.9**	**FC**	2				1						
Limnephilidae													
Ironoquia sp.		-											
Philopotamidae		**FC**											
Chimarra cf. obscura	**2.76**	**FC**	8										
Polycentropodidae		**FC**											
Polycentropus sp.	**3.5**	**FC**					1						
Coleoptera													
Carabidae					1								6
Chrysomelidae													
Dryopidae						3							
Helichus fastigiatus							1						
Dytiscidae		**P**							1				
Hydroporus sp.	**8.6**	**PI**		1									
Neoporus sp. (Hydroporus)	**8.62**	**PI**	3			2		19	13	2	12		
Elmidae		**CG**											
Ancyronyx variegata	**6.49**	**SC**											
Dubiraphia vittata	**4.1**	**SC**											
Macronychus glabratus	**4.58**	**SH**	2				8			2			12
Microcylloepus pusillus	**2.1**	**SC**											
Stenelmis sp.	**5.1**	**SC**	12				2						
Gyrinidae		**P**											

Dineutus sp.	**5.54**	**P**			1					3		1
Gyrinus sp.	**6.17**	**P**								2		
Haliplidae												
Peltodytes sp.	**8.73**	**SH**		3		2		3			1	1
Peltodytes duodecimpunctatus				2				1		1		
Peltodytes sexmaculatus												
Heteroceridae										1		
Hydrophilidae											1	
Berosus sp.	**8.43**	**CG**										
Enochrus sp.	**8.8**	**CG**									1	2
Helochares sp.		**P**						1				
Hydrochus sp.	**6.55**	**SH**									1	
Sperchopsis tessellatus	**6.13**	**CG**		1				1				
Tropisternus sp.	**9.7**	**P**						2				
Psephenidae		**SC**										
Psephenus herricki	**2.35**	**SC**		1			2					
Scirtidae		**SC**					5	4				
Scirtes sp.				2						1	2	1
Staphylinidae		**P**		1	1		1	1		2	1	1
Diptera												
Ceratopogonidae	***5**	**P**			1			2		1	1	
Bezzia/Palpomyia gp.	**6.9**	**P**	2	1						1		1
Chironomidae												
Ablabesmyia mallochi	**7.2**	**P**	28	2			10					1
Ablabesmyia rhamphe gp.	**7.2**	**P**										
Cardiocladius obscurus	**5.9**	**P**										
Chironomus sp.	**9.63**	**CG**		1		3		2		1	50	
Cladotanytarsus sp.	**4.09**	**FC**	5				1					
Clinotanypus sp.	***6**	**P**						3				
Conchapelopia sp.	**8.4**	**P**				2	1					
Corynoneura sp.	**6.01**	**CG**	1	2		13	10	3	1			1
Cricotopus sp.	***7**	**CG**	3				1	3	16	1		
Cricotopus bicinctus	**8.5**	**CG**	11	22		9	29	1	3	38		9
Cricotopus trifascia	**2.8**	**CG**	1	2			1					
Dicrotendipes neomodestus	**8.1**	**CG**	1									
Dicrotendipes simpsoni	**10**									1		
Diplocladius cultriger	**7.4**	**CG**										
Eukiefferiella claripennis gp.	**5.6**	**CG**	9				4	1				3
Glyptotendipes sp.	**9.5**	**FC**										
Hydrobaenus pilipes	**9.5**	**SC**	1									
Nanocladius distinctus	**7.07**	**CG**		2			3					
Nilotanypus sp.	**3.9**	**P**										
Orthocladius sp.		**CG**	1				4	5	1	5		
Paracladopelma sp.	**5.51**	**CG**	1									
Parakiefferiella sp.	**5.4**	**CG**	1	3	1							
Paralauterborniella nigrohalte	**4.8**	**CG**										
Parametriocnemus sp.	**3.65**	**CG**										
Pentaneura inconspicia									1		2	
Polypedilum flavum (convictu	**4.9**	**SH**	7	2		6	1					3
Polypedilum halterale gp.	**9**	**SH**										
Polypedilum illinoense	**7.3**	**SH**		6	1	4	3					1
Potthastia longimana	**9**	**CG**										

Procladius sp.	**9.1**	**P**	15					5	2			
Psectrocladius sp.	**3.6**	**SH**										
Pseudochironomus sp.	**5.4**	**CG**	2									
Rheotanytartsus exiguus gp.	**5.9**		3									1
Tanytarsus sp.	**6.76**	**FC**	2			1	1	1				
Thienemanniella xena	**5.86**	**CG**	2			2	131	5		7		1
Tribelos jucundum	**6.3**											
Tvetenia paucunca	**3.7**	**CG**								4		
Tvetenia vitracies	**3.6**	**CG**	2									
Unniella multivirga	**0**	**CG**								1		
Zavrelimyia sp.	**9.11**	**P**										
Culicidae		**FC**									9	
Anopheles sp.	**8.6**	**FC**									2	
Dixidae		**CG**							1			
Dolichopodidae		**P**								1		
Sarcophagidae												
Sciaridae							1					
Simuliidae	***6**	**FC**										
Prosimulium sp.	**6**	**FC**										
Simulium sp.	**6**	**FC**	2	3	1					4		1
Stratiomyidae		**CG**										
Odontomyia sp.							1					
Tabanidae		**PI**						3			1	
Chrysops sp.	**6.73**	**PI**	1									
Tabanus sp.	**9.2**	**PI**					1					
Tipulidae	***3**	**SH**		1								
Antocha sp.	**4.3**	**CG**										
Hexatoma sp.	**4.3**	**P**										
Limnophila sp.	***4**	**P**						1			1	
Pseudolimnophila sp.	**7.22**	**P**							1	1		
Ormosia sp.	**6.3**	**CG**	1			2					1	
Tipula sp.	**7.33**	**SH**										1

TOTAL NO. OF ORGANIMS	**342**	**87**	**21**	**68**	**287**	**184**	**113**	**256**	**177**	**73**
TOTAL NO. OF TAXA	**73**	**37**	**16**	**25**	**48**	**45**	**22**	**49**	**23**	**31**
EPT INDEX	**20**	**8**	**3**	**4**	**17**	**4**	**4**	**11**	**1**	**9**
BIOTIC INDEX	**5.60**	**6.74**	**5.47**	**7.02**	**5.89**	**7.72**	**7.44**	**5.13**	**8.19**	**6.06**
Assigned BIOTIC INDEX VALUE	**5.90**	**6.52**	**5.60**	**6.94**	**5.74**	**7.69**	**7.37**	**5.67**	**7.32**	**5.90**
EPT ABUNDANCE	**145**	**14**	**4**	**5**	**49**	**17**	**9**	**135**	**15**	**16**

SPECIES	T.V.	F.F.G.	REFERENCE							
			Sta. 12	Sta. 14	Sta. 18	Sta. 19	Sta. 39	Sta. 45	Sta. 52	Sta. 53
PLATYHELMINTHES										
Turbellaria										
Tricladida										
Planariidae										
Girardia (Dugesia) tigrina	**7.2**									1
NEMATODA	**6**					1				
MOLLUSCA										
Bivalvia										
Veneroida										
Corbiculidae										
Corbicula fluminea	**6.12**	**FC**								
Sphaeriidae	**6.6**	**FC**			1					
Musculium transversum	***8**	**FC**								
Gastropoda										
Pleuroceridae	**3.4**									
Elimia sp.	**2.46**	**SC**								
Basommatophora										
Ancylidae		**SC**								
Ferrissia rivularis	***6**	**SC**	1							
ANNELIDA										
Oligochaeta		**CG**								
Tubificida										
Enchytraeidae	**9.8**	**CG**			1	1			1	
Lumbricidae		**CG**	6	4			4	1		
Naididae	***8**	**CG**	13	6	6	18		1	17	4
Dero sp.	**10**	**CG**								
Nais communis	**8.8**	**CG**								
Pristina sp.	**9.6**	**CG**		1						
Tubificidae w.h.c.	**7.1**	**CG**	1				3			
Tubificidae w.o.h.c.	**7.1**	**CG**		1	1	1				
Branchiura sowerbyi	**8.28**	**CG**				1				
Limnodrilus hoffmeisteri	**9.5**	**CG**					3			
Spirosperma sp.	**10**	**CG**	5					1		
Lumbriculida										
Lumbriculidae	**7.03**	**CG**	6	6	2	3	16	12	6	8
Branchiobdellida										
Hirudinea		**P**							1	
Arhynchobdellida										
Erpobdellidae		**P**								
Erpobdella sp.	**8.3**	**P**	1	1				1		
Rhynchobdellida										
Glossiphoniidae		**P**								
Helobdella elongata	**9.5**	**P**					1	1		
ARTHROPODA										
Arachnoidea										
Acariformes										
Arrenuridae	**5.5**									
Arrenurus sp.	**5.5**				2				1	
Lebertiidae	**5.5**									

Lebertia sp.	**5.5**		2							
Torrenticolidae	**5.5**									
Torrenticola sp.	**5.5**							1		
Crustacea										
Ostracoda				1				1		
Copepoda							1			
Cyclopoida				1						
Cladocera										
Chydoridae										
Isopoda										
Asellidae		**SH**								
Caecidotea sp.	**9.1**	**CG**				1	14	8		3
Amphipoda										
Crangonyctidae										
Crangonyx sp.	**7.9**	**CG**					24	14		2
Hyalellidae										
Hyalella azteca	**7.75**	**CG**	1						1	
Decapoda										
Cambaridae	**7.5**									
Cambarus sp.	**7.62**	**CG**					4	3		
Palaemonidae										
Palaemonetes kadiakensis	**7.1**	**CG**		1	1	1				
Insecta										
Collembola					1					
Ephemeroptera										
Baetidae		**CG**								1
Acerpenna pygmaea	**3.9**				3					5
Baetis intercalaris	**7**	**CG**								
Plauditus sp.	***4**	**CG**	2			1	6	69	4	
Pseudocloeon sp.	**4**	**CG**								
Caenidae		**CG**								
Caenis sp.	**7.4**	**CG**	2	3	11	7	1		8	18
Ephemerellidae		**SC**			1					
Attenella sp.							1	1		
Ephemerella sp.	**2.04**	**SC**	4	1	1				1	1
Ephemerella needhami	**0**	**CG**							8	2
Eurylophella sp.	**4.34**	**SC**	1	2					1	
Serratella sp.		**SC**	4		2					
Timpanoga sp.		**CG**			2	3	1	1	1	7
Heptageniidae										
Leucrocuta sp.	**2.4**	**SC**	3	2		2			4	
Maccaffertium (Stenonema) sp.	***4**	**SC**	21			20				
Maccaffertium (Stenonema) exiguun	**3.8**	**SC**			3				6	1
Maccaffertium (Stenonema) modestu	**5.5**	**SC**		27	105	56			121	61
Maccaffertium (Stenonema) pudicun	**2**	**SC**	4	9	14	20			6	11
Stenacron interpunctatum	**3.58**	**SC**	5	1	2	15				9
Isonychiidae		**FC**								
Isonychia sp.	**3.5**	**FC**	1	4	1	1		1	17	
Leptophlebiidae	***2**	**CG**					1		1	
Leptophlebia sp.	**6.2**	**CG**				1	1		1	
Paraleptophlebia sp.	**0.94**	**CG**								3
Potamanthidae		**CG**								

Anthopotamus (Potamanthus) myop.	**1.5**	**CG**	4	12	3	20			29	8
Siphlonuridae										
Siphlonurus sp.	**5.8**	**CG**					8			
Odonata										
Aeshnidae	**5.6**	**P**								
Boyeria vinosa	**5.97**	**P**				1		3	1	1
Boyeria grafiana	**6.1**	**P**								1
Nasiaeschna pentacantha	**8.1**									14
Coenagrionidae	***9**	**P**			1					
Argia sp.	**8.17**	**P**	5	3	2	12			5	6
Enallagma sp.	**8.9**	**P**	3			1				1
Corduliidae	***5**	**P**								
Epicordulia princeps	**5.6**	**P**	1			2				
Macromia sp.	**6.16**	**P**	1	2	1	3			1	3
Neurocordulia sp.	**5**									
Neurocordulia obsoleta	**5.2**			2	13	1			2	
Gomphidae	***1**	**P**								
Arigomphus sp.						1				
Dromogomphus spinosus	**5.1**	**P**							1	
Erpetogomphus designatus					1				1	
Erpetogomphus sp.				2						1
Gomphus sp.	**5.8**	**P**	4						1	1
Hagenius brevistylus	**4**	**P**	1							
Perithemis tenera	**9.9**	**P**								
Libellulidae	**6.7**	**P**				1		1		1
Erythemis simplicicollis	**9.7**									
Libellula cyanea				1						
Libellula semifasciata				1						
Libellula sp.	**9.6**	**P**								1
Pachydiplax longipennis	**9.9**			2						
Somatochlora sp.	**9.2**	**P**					3			
Plecoptera			2		3					
Nemouridae		**SH**						1		
Amphinemura sp.	**3.3**	**SH**			2		13	13	2	1
Perlidae	***1**	**P**	1		1					
Acroneuria cf. filicis						3				
Acroneuria mela	**0.9**		3	3		4				1
Acroneuria sp.		**P**			1				3	
Neoperla sp.	**1.5**	**P**	26	1		1			7	2
Perlesta placida sp. gp.	**4.7**	**P**	3	10	32	7	6	36	95	23
Perlesta sp.	**4.7**	**P**								
Perlodidae	***2**	**P**					1			
Cultis decisus	**1.6**	**P**							1	
Isoperla sp.	***2**	**P**	1	3	1		29	76	11	3
Taeniopterygidae		**SH**								
Taeniopteryx sp.	**5.4**	**SH**					5	2		
Hemiptera										
Belostomatidae										
Belostoma sp.	**9.8**	**P**								
Corixidae	**9**	**PI**					4			
Hydrometridae										
Hydrometra sp.								1		

Pleidae										
Paraplea sp.										
Nepidae		**-**								
Ranatra sp.	**7.8**	**P**	1		1	3				
Veliidae		**P**								
Microvelia sp.		**P**						2		
Stenovelia stagalis										
Megaloptera										
Corydalidae		**P**								
Chauliodes pectinicornis	**9.6**									
Corydalus cornutus	**5.2**	**P**	1			1			1	
Nigronia serricornis	**5**	**P**								
Sialidae		**P**								
Sialis sp.	**7.17**	**P**								
Trichoptera										
Hydropsychidae	***4**	**FC**							2	
Ceratopsyche sp.		**FC**	2							
Cheumatopsyche sp.	**6.2**	**FC**		2	1	1			3	1
Hydropsyche sp.	**5**	**FC**	3		2				3	3
Hydropsyche simulians									1	
Macrostemum carolina										
Hydroptilidae	***4**	**PI**								
Hydroptila sp.	**6.2**	**PI**								1
Leptoceridae	***4**	**CG**								
Ceraclea sp.	**2**	**CG**	1							
Nectopsyche sp.	**2.9**	**SH**							2	2
Nectopsyche exquisita	**4.1**	**SH**				1				
Triaenodes sp.	**4.46**	**SH**						2		
Triaenodes injustus	**2.5**	**SH**			1	3			6	14
Lepidostomatidae		**SH**								1
Lepidostoma sp.	**0.9**	**FC**	2							
Limnephilidae										
Ironoquia sp.		**-**					2			1
Philopotamidae		**FC**								
Chimarra cf. obscura	**2.76**	**FC**	30	1	1	2			29	
Polycentropodidae		**FC**								
Polycentropus sp.	**3.5**	**FC**			1					2
Coleoptera										
Carabidae										
Chrysomelidae										1
Dryopidae										
Helichus fastigiatus										
Dytiscidae		**P**					1			
Hydroporus sp.	**8.6**	**PI**								
Neoporus sp. (Hydroporus)	**8.62**	**PI**					22	1		
Elmidae		**CG**								
Ancyronyx variegata	**6.49**	**SC**			1					
Dubiraphia vittata	**4.1**	**SC**	1	1		1				3
Macronychus glabratus	**4.58**	**SH**	3	2	4	3		2	2	6
Microcylloepus pusillus	**2.1**	**SC**							1	
Stenelmis sp.	**5.1**	**SC**	13	2	2	2		3	29	1
Gyrinidae		**P**								

Dineutus sp.	**5.54**	**P**							
Gyrinus sp.	**6.17**	**P**							
Haliplidae									
Peltodytes sp.	**8.73**	**SH**							
Peltodytes duodecimpunctatus			1						
Peltodytes sexmaculatus			3			1			
Heteroceridae									
Hydrophilidae									
Berosus sp.	**8.43**	**CG**							
Enochrus sp.	**8.8**	**CG**							
Helochares sp.		**P**							
Hydrochus sp.	**6.55**	**SH**						2	
Sperchopsis tessellatus	**6.13**	**CG**							
Tropisternus sp.	**9.7**	**P**							
Psephenidae		**SC**							
Psephenus herricki	**2.35**	**SC**	4		1				
Scirtidae		**SC**							
Scirtes sp.					1				2
Staphylinidae		**P**	1					2	
Diptera									
Ceratopogonidae	***5**	**P**			1				1
Bezzia/Palpomyia gp.	**6.9**	**P**				2		1	1
Chironomidae									
Ablabesmyia mallochi	**7.2**	**P**	2		4	4			2	8
Ablabesmyia rhamphe gp.	**7.2**	**P**		1	3					
Cardiocladius obscurus	**5.9**	**P**							2	
Chironomus sp.	**9.63**	**CG**				1				
Cladotanytarsus sp.	**4.09**	**FC**		1						3
Clinotanypus sp.	***6**	**P**								12
Conchapelopia sp.	**8.4**	**P**	4		8	13			3	2
Corynoneura sp.	**6.01**	**CG**	3	1	1	1		1	2	1
Cricotopus sp.	***7**	**CG**		10	7	5	16	90	11	5
Cricotopus bicinctus	**8.5**	**CG**	7	29	50	16	11	67	49	32
Cricotopus trifascia	**2.8**	**CG**			3				3	
Dicrotendipes neomodestus	**8.1**	**CG**		1	3	1				7
Dicrotendipes simpsoni	**10**								1	
Diplocladius cultriger	**7.4**	**CG**					2			
Eukiefferiella claripennis gp.	**5.6**	**CG**	9	8	8	1	9		64	4
Glyptotendipes sp.	**9.5**	**FC**					4			
Hydrobaenus pilipes	**9.5**	**SC**					5			
Nanocladius distinctus	**7.07**	**CG**				1				1
Nilotanypus sp.	**3.9**	**P**		1		1				
Orthocladius sp.		**CG**	1	7	1	11	22	61	19	1
Paracladopelma sp.	**5.51**	**CG**								
Parakiefferiella sp.	**5.4**	**CG**	1	1	5	1	1			3
Paralauterborniella nigrohalteralis	**4.8**	**CG**			1					
Parametriocnemus sp.	**3.65**	**CG**						2		
Pentaneura inconspicia					1				2	5
Polypedilum flavum (convictum)	**4.9**	**SH**	1	3	3	4			18	5
Polypedilum halterale gp.	**9**	**SH**	2							
Polypedilum illinoense	**7.3**	**SH**	1							
Potthastia longimana	**9**	**CG**			1				2	

Procladius sp.	**9.1**	**P**								
Psectrocladius sp.	**3.6**	**SH**					1			
Pseudochironomus sp.	**5.4**	**CG**		1	1					
Rheotanytartsus exiguus gp.	**5.9**			2	7				3	1
Tanytarsus sp.	**6.76**	**FC**	1	1						1
Thienemanniella xena	**5.86**	**CG**	12	56	52	4	1	31	46	39
Tribelos jucundum	**6.3**			1						
Tvetenia paucunca	**3.7**	**CG**					5	11		
Tvetenia vitracies	**3.6**	**CG**								
Unniella multivirga	**0**	**CG**								
Zavrelimyia sp.	**9.11**	**P**				5				
Culicidae		**FC**								
Anopheles sp.	**8.6**	**FC**								
Dixidae		**CG**								
Dolichopodidae		**P**								
Sarcophagidae							1			
Sciaridae										
Simuliidae	***6**	**FC**								
Prosimulium sp.	**6**	**FC**							1	
Simulium sp.	**6**	**FC**	1		6	1	15	10	13	3
Stratiomyidae		**CG**								
Odontomyia sp.										
Tabanidae		**PI**								
Chrysops sp.	**6.73**	**PI**						1		1
Tabanus sp.	**9.2**	**PI**								
Tipulidae	***3**	**SH**								
Antocha sp.	**4.3**	**CG**						1		
Hexatoma sp.	**4.3**	**P**					1			
Limnophila sp.	***4**	**P**								
Pseudolimnophila sp.	**7.22**	**P**								
Ormosia sp.	**6.3**	**CG**					1			
Tipula sp.	**7.33**	**SH**		1			1		1	
TOTAL NO. OF ORGANIMS			**249**	**246**	**403**	**300**	**271**	**539**	**687**	**379**
TOTAL NO. OF TAXA			**59**	**51**	**62**	**58**	**42**	**41**	**62**	**66**
EPT INDEX			**22**	**15**	**23**	**19**	**13**	**10**	**27**	**25**
BIOTIC INDEX			**4.66**	**5.68**	**5.87**	**5.44**	**6.36**	**5.51**	**5.21**	**5.72**
Assigned BIOTIC INDEX VALUE			**4.92**	**5.39**	**5.55**	**5.66**	**6.62**	**5.70**	**5.06**	**5.53**
EPT ABUNDANCE			**125**	**81**	**194**	**168**	**75**	**202**	**373**	**182**

APPENDIX C: CARBONTON DAM REMOVAL YEAR-3 FISH MONITORING REPORT
PROVIDED BY THE CATENA GROUP

The Catena Group

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CARBONTON DAM REMOVAL YEAR-3 MONITORING REPORT

Deep River Watershed Restoration Site Cape Fear River Basin Cataloging Unit 030300003

Prepared For:

Restoration Systems LLC

Prepared By:

The Catena Group, Inc.

November 12, 2008

Timothy W. Savidge

EXECUTIVE SUMMARY

The Carbonton dam removal project performed by Restoration Systems, LLC (RS) is projected to result in the restoration of ~10 river miles of the mainstem Deep River, as well as portions of three major tributaries (McLendons Creek, Big Governors Creek and Little Governors Creeks) and fifteen smaller tributaries. One of the goals of the restoration effort is to restore habitat for the federally Endangered Cape Fear shiner *(Notropis mekistocholas)*, several species of rare mussels, and other riverine aquatic species, including fish and mollusks. Restoring this stretch of river will also re-connect the upstream and downstream populations of the Cape Fear shiner, which have been essentially isolated[1] since the dam was constructed in the early 1900's.

The restoration success criteria established by the interagency Dam Removal Task Force (DRTF) and the goals of RS require documenting the diversity of aquatic fauna and characterizing habitat within the reservoir pool created by the dam, and then monitoring changes in faunal composition and habitat following the dam's removal. The Catena Group Inc. (TCG) was retained by RS in 2005 to conduct the pre-dam removal aquatic species surveys. Eighteen sites were surveyed for freshwater mussels and clams, aquatic snails, and freshwater fish, the results of which were provided in the August 07, 2006 Pre-removal Survey Report (TCG 2006). The success criteria for the Cape Fear Shiner were met during the 2-year post removal studies, and documented in the October 01, 2007 Carbonton Dam Removal Year-2 Monitoring Report (TCG 2007). The thrust of the Year 3 monitoring effort is to document whether freshwater mussels, in particular the targeted rare species identified in the pre-removal report (TCG 2006) are recolonizing habitats previously impoundment by the dam, and to document the evolving habitats at each of the monitoring stations.

Surveys targeting freshwater mussels were conducted at each of the 13 established Deep River impoundment monitoring stations. General observations of in-stream habitat conditions and bank stability were recorded throughout the former reservoir pool and at each of the monitoring stations. At least 12 substantial riffle habitats have developed. Morphological features at many of these sites have created various hydraulic conditions and in turn, multiple microhabitats which correspond to potentially high quality habitat for aquatic species, including the Cape Fear shiner and various rare mussel species.

Based on field observations and mussel surveys during the Year-3 monitoring studies, it appears that the habitats within the former reservoir pool are continuing to transition to habitats more typical of lotic conditions. The surveys documented several mussel species of conservation interest associated with lotic environments, including five state-listed species: yellow lampmussel (*Lampsilis cariosa*), creeper (*Strophitus undulatus*), triangle floater (*Alasmidonta undulata*), eastern creekshell (*Villosa delumbis*), and the notched rainbow (*Villosa constricta*). Survey results indicate that mussel recruitment has occurred in the riffle habitats in the upper limits of the former reservoir pool; however, recruitment is not evident in the lower sections.

[1] In the strictest sense, the isolation has been substantial, but not total, since fish from upstream groups can transit over the dam during full flows. This would theoretically enable some genetic exchange between upstream and downstream groups.

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1.0 INTRODUCTION

The removal of the Carbonton dam on the Deep River by Restoration Systems LLC (RS) is projected to result in the restoration of ~10 river miles (RM) of the mainstem Deep River, as well as portions of three major tributaries (McLendons Creek, Big Governors Creek and Little Governors Creeks), and fifteen smaller tributaries, all within the Cape Fear River Basin. Specific goals of the project are to restore habitat for the federally Endangered Cape Fear shiner *(Notropis mekistocholas)*, several species of rare mussels, and other riverine aquatic species. Restoring this stretch of river will also re-connect the upstream and downstream populations of Cape Fear shiner, which have been essentially isolated[1] since the dam was constructed in the early 1900's.

The restoration success criteria established by the interagency Dam Removal Task Force (DRTF) and the goals of RS require documenting the diversity of aquatic fauna and characterizing habitat within the reservoir pool created by the dam, and then monitoring changes in faunal composition and habitat following the dam's removal. The Catena Group Inc. (TCG) was retained by RS in 2005 to conduct the pre-dam removal aquatic species surveys. Eighteen sites were surveyed for freshwater mussels and clams, aquatic snails, and freshwater fish, the results of which were provided in the August 07, 2006 Pre-removal Survey Report (TCG 2006).

1.1 Monitoring Plan

A five-year monitoring plan has been initiated to evaluate the success of the dam removal. Success criteria identified include the documentation of Cape Fear shiner recruitment into the formerly impounded reach of the river and establishment of lotic fish, freshwater mussel and aquatic snail communities. This five-year monitoring plan involves conducting aquatic species (fish, freshwater mussels and aquatic snails) surveys at 16 permanent monitoring stations within the former reservoir pool, that were established in the pre-removal surveys. Fourteen stations are in the Deep River and one each in McClendons Creek and Big Governors Creek.

The success criteria (re-establishment within former reservoir pool) for the Cape Fear Shiner, and establishment of lotic fish communities were met during the 2-year post removal studies, and documented in the October 01, 2007 Carbonton Dam Removal Year-2 Monitoring Report (TCG 2007). The thrust of the Year 3 monitoring effort is to document whether freshwater mussels, in particular the targeted rare species identified in the pre-removal report (TCG 2006), are re-colonizing habitats previously impounded by the dam, and to document the evolving habitats at each of the monitoring stations. Based on field observations in the Year-1 and Year-2 studies, the decision was made not to sample McClendons Creek and Big Governors Creek, as these did not appear to be as far along in habitat transitioning as the sites on the Deep River.

[1] In the strictest sense, the isolation has been substantial, but not total, since fish from upstream groups can transit over the dam during full flows. This would theoretically enable some genetic exchange between upstream and downstream groups.

2.0 SURVEY EFFORTS

Freshwater mollusk surveys were conducted for the Year-3 monitoring effort at the fourteen Deep River monitoring locations (Table 1), by the following TCG personnel Tim Savidge, Tom Dickinson and Chris Sheats on August 07, and October 01, 2008. The locations of the sampled sites are depicted in Figure 1.

Table 1. Permanent Monitoring Survey Locations-Carbonton Dam Reservoir Pool

Site #	Site Location	GPS Location
1	Deep River (impoundment)	35.49298ºN, -79.41518ºW
1a	Deep River (impoundment)	35.49315 ºN, -79.40278ºW
2	Deep River (impoundment)	35.48996ºN, -79.38668ºW
3	Deep River (impoundment)	35.48269ºN, -79.38307ºW
4	Deep River (impoundment)	35.46404ºN, -79.39042ºW
5	Deep River (impoundment)	35.46126ºN, -79.38965ºW
6	Deep River (impoundment)	35.45722ºN, -79.38024ºW
7	Deep River (impoundment)	35.47221ºN, -79.36856ºW
8	Deep River (impoundment)	35.47767ºN, -79.36000ºW
9	Deep River (impoundment)	35.47855ºN, -79.35072ºW
10	Deep River (impoundment)	35.49891ºN, -79.33601ºW
11	Deep River (impoundment)	35.50792ºN, -79.34282ºW
12	Deep River (impoundment)	35.51258ºN, -79.34925ºW
13	Deep River (impoundment)	35.51962ºN, -79.34761ºW

2.1 Survey Methodology

The surveys had two components, habitat reconnaissance and fresh water mollusk sampling.

2.1.1 Habitat Reconnaissance

Habitat reconnaissance was conducted in the entire restored reach of the Deep River by canoeing from the upper limits of the former reservoir pool downstream to the former dam. Observations of in-stream habitat conditions and bank stability were recorded. Mollusk surveys were conducted at the monitoring stations, as navigated to with GPS.

2.1.2 Mollusk Sampling

Specific visual searches were conducted for freshwater bivalves and freshwater snails at each of the monitoring stations shown in Figure 1. The survey team spread out across the stream into survey lanes to provide total width coverage as they ascended the site. All appropriate habitat types within a given survey reach were searched for bivalves thoroughly via visual surveys using primarily mask/snorkel and/or bathyscopes (glass-bottom view buckets). Tactile methods were also employed when appropriate. All species of freshwater mussel were recorded and returned to the substrate. Searches were also conducted for relict shells. The presence of a shell was equated with presence of that species, but not factored into the Catch per Unit Effort (CPUE), which is defined as the number of individuals found per person hour of search time. All species that are

monitored by the NC Natural Heritage Program (NCNHP) were measured (total length). Snails were hand picked from rocks and woody debris. Dip nets were used, where appropriate, to sift through leaf packs. Collected snails were identified to the species level and each species was assigned a relative abundance rating to correspond to the survey site.

The CPUE (# per survey hour) was calculated for freshwater mussels, while relative abundance used for other mollusk species was estimated using the following criteria:

Freshwater Snails and Clams (per approximate square meter):

- Very abundant: > 50 estimated
- Abundant: 31-50 estimated
- Common: 11-30 estimated
- Uncommon: 3-10 estimated
- Rare: 1-2 estimated

The length of the survey reach, and amount of survey time varied between sites, and was dependent on amount of suitable habitat.

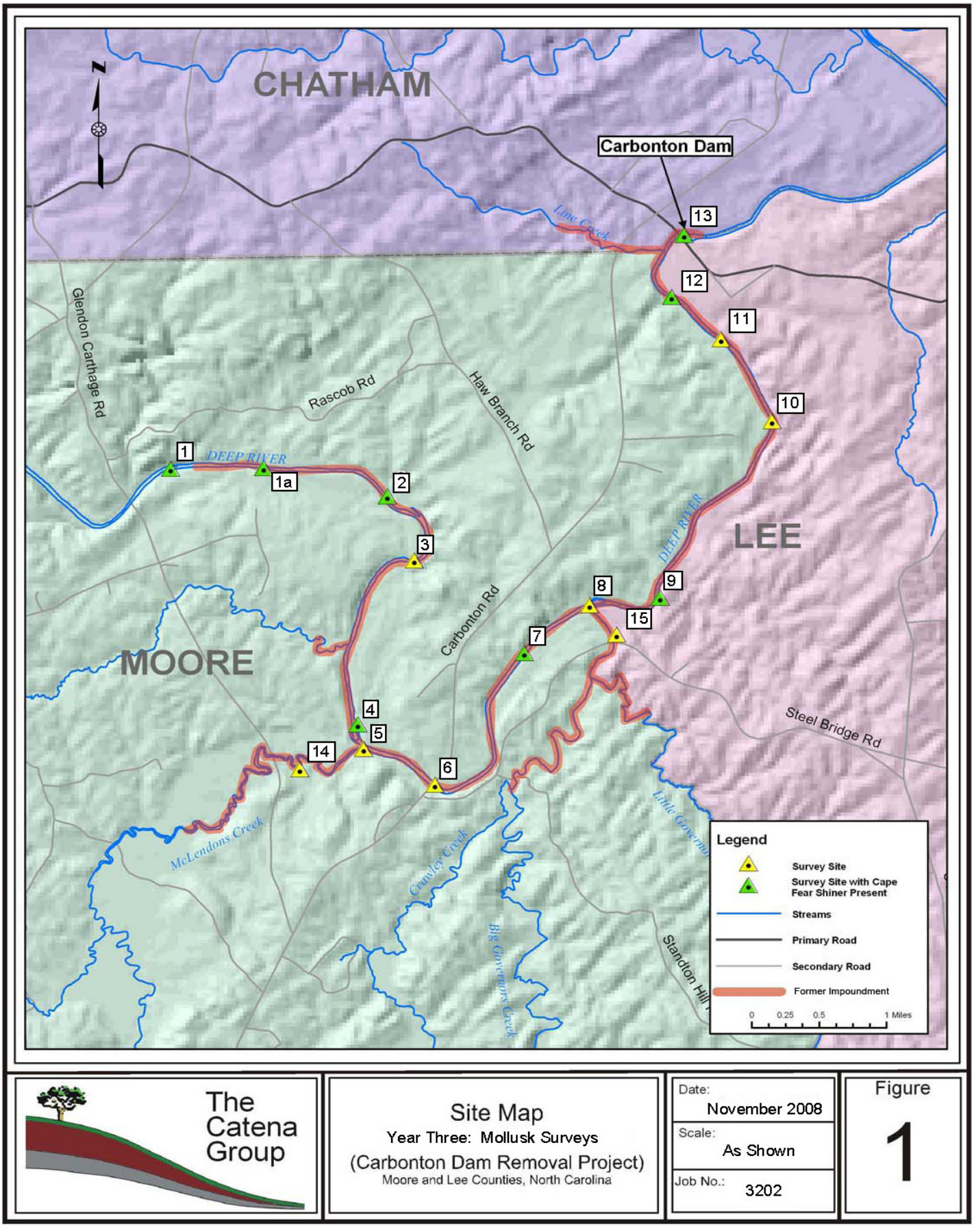
3.0 RESULTS

Based on field observations, it appears that much of the habitat within the former reservoir pool has reverted to lotic conditions. Riffle/run/pool habitats have formed at varying intervals throughout the restored reaches. Recruitment of freshwater mussels is evident in the newly established riffle habitats in the upper (upstream) sections of the former reservoir pool, while lotic-adapted aquatic snails have colonized riffle habitats throughout.

3.1 Habitat Reconnaissance

The Year-1 monitoring report questioned whether riffle habitat would form at Sites 9 and 10, as predicted during the pre-removal studies. In Year-1 these sites were characterized by moderate to deep rocky run/pool habitats; however, Year 2 sampling indicated that cobble/gravel bars were beginning to form near Site 9 (TCG 2007). As a result a small amount of riffle habitat has formed at this site. Little change has been noted at Site 10. Numerous other areas with similar characteristics (deep rocky runs) were also observed throughout the Deep River, but were not marked or recorded, as the intent of the habitat reconnaissance was to mark the riffle areas. All other riffle habitats that were noted as having formed in the Year-1 and Year-2 studies appear to be more developed and stable.

In general, vegetation has colonized the river banks throughout the former impounded, and the banks appear to be stable with very little scour and erosion noted. As was noted in the Year-2 studies (TCG 2007), there were a few areas where patches of moderate streambank erosion and scour was observed, most notably below site 10 and in the general vicinity of the WRC boat landing. While these areas still exist, although not



The Catena Group

Site Map
Year Three: Mollusk Surveys
(Carbonton Dam Removal Project)
Moore and Lee Counties, North Carolina

Date: November 2008
Scale: As Shown
Job No.: 3202

Figure 1

measured they appear to be smaller in size, with less severity of erosion. Also, as noted in the Year-2 studies (TCG 2007) the invasive Japanese hops (*Humulus japonica*) has become established along most of the river bank in the lower reaches of the former impoundment. The plant is considered to be an invasive species and can be spread by wind, water, and soil movement to an area where it quickly forms dense thickets that excludes native vegetation and greatly alters the natural ecosystem. The species has a shallow root system so, in the absence of other native vegetation, sites overgrown by Japanese hops could become susceptible to erosion following winter dieback of leaf material. Measures to control this species include manually pulling up the plants, or use of herbicides (http://www.na.fs.fed.us/fhp/invasive_plants/weeds/japanese-hop.pdf).

3.2 Freshwater Mollusk Surveys

A total of eleven freshwater mussel species, two aquatic snail species and 1 freshwater clam species were found within newly formed riffle habitats in the former impounded reach (Table 2). Mussels were very rare to absent in the lower sites (Sites 11-13). The lentic-adapted gravel elimia (*Elimia catenaria*) was common to abundant throughout, while the pointed campeloma, a species more common in slow flowing habitats was rare to absent.

Table 2. Mollusk Species Collected

Scientific Name	Common Name	Sites
Freshwater Mussels		~
Alasmidonta undulata	triangle floater	1,1a, 7, 8,9
Elliptio angustata	Carolina lance	1,1a,3,8
Elliptio complanata	Eastern elliptio	All except 12 and 13
Elliptio icterina	variable spike	1,1a,3,4,57,,8,9
Elliptio lazarus	Atlantic delicate spike	1,3,5,8
Elliptio producta	Atlantic spike	2,3
Lampsilis cariosa	yellow lampmussel	1,1a,2,3,4,5,8,9*,10*
Pyganodon cataracta	Eastern floater	10*
Strophitus undulatus	creeper	4,7,8,9
Villosa constricta	notched rainbow	2
Villosa delumbis	Eastern creekshell	1a,4,8,9
Uniomerus carolinianus	Florida pondhorn	8*, 10
Freshwater Snails and Clams	~	~
Campeloma decisum	pointed campeloma	2,5,8,10
Elimia catenaria	gravel elimia	All
Helisoma anceps	two-ridge rams-horn	2,5
Corbicula fluminea	Asian clam	All

* relict shell only

3.2.1 Site 1 (Deep River-Impoundment):

This sampling station occurs near an old mill site. Some of the dam material (rock and timbers) remain in the river, and a riffle run sequence has continued to develop below the former mill site. The substrate is dominated by rock (from the old dam) and cobble. Coarse sand and gravel have accumulated in the shallow areas at the head and base of the

riffle. Cobble-gravel bars have formed below the old mill site and have been colonized by various species of herbaceous species and woody shrubs. Five freshwater mussel species, including the targeted yellow lampmussel were collected.

Table 3. Mollusk Species Collected Site 1

Scientific Name	Common Name	Abundance Indicator
Freshwater Mussels		**# (CPUE)**
Elliptio angustata	Carolina lance	1 (0.5/hr)
Elliptio complanata	Eastern elliptio	44 (22/hr)
Elliptio icterina	variable spike	1 (0.5/hr)
Elliptio lazarus	Atlantic delicate spike	1(0.5/hr)
Lampsilis cariosa	yellow lampmussel	1 (0.5/hr)
Freshwater Snails and Clams	**~**	**Relative Abundance**
Elimia catenaria	gravel elimia	Common
Corbicula fluminea	Asian clam	Abundant

3.2.2 Site 1a (Deep River-Impoundment):

A large gravel/cobble riffle has formed at this site, providing excellent habitat for target species and was thus sampled as an additional survey station in Year-2 (TCG 2007). The substrate is dominated by cobble/gravel and coarse sand, which extends across most of the river's width as a shallow riffle. Cobble-gravel bars have formed along each of the river banks. Six freshwater mussel species, including the targeted triangle floater, yellow lampmussel and eastern creekshell were collected. While conducting mussel surveys, several Cape Fear shiner were observed. One seine net haul was performed to confirm the underwater identifications, and 3 individual Cape Fear shiner were captured.

Table 4. Mollusk Species Collected Site 1a

Scientific Name	Common Name	Abundance Indicator
Freshwater Mussels		**# (CPUE)**
Alasmidonta undulata	triangle floater	2 (1.3/hr)
Elliptio angustata	Carolina lance	1 (0.7/hr)
Elliptio complanata	Eastern elliptio	160 (106.7/hr)
Elliptio icterina	variable spike	2 (1.3/hr)
Lampsilis cariosa	yellow lampmussel	1 (0.7/hr)
Villosa delumbis	Eastern creekshell	1 (0.7/hr)
Freshwater Snails and Clams	**~**	**Relative Abundance**
Elimia catenaria	gravel elimia	Abundant
Corbicula fluminea	Asian clam	Abundant

3.2.3 Site 2 (Deep River-Impoundment):

This site is situated within a long riffle/pool/riffle run sequence, with a rocky/cobble island bar that has formed from the center of the river to the left descending bank, creating a long run along the right descending bank. The substrate is dominated by cobble and gravel overlain with coarse sand. A variety of habitat conditions occur at this site providing habitats for lotic and lentic adapted species. Five mussel species were collected including the targeted yellow lampmussel and **the notched rainbow, which**

Notched rainbow individual found at Site 2.

had been collected only one other time in the Deep River within the last 100 years. The gravel elimia was very abundant in the riffle habitats, and the majority of individuals appeared to be newly recruited (small in size). Two seine net hauls were also performed and 5 individual Cape Fear shiner were captured.

Table 5. Mollusk Species Collected Site 2

Scientific Name	Common Name	Abundance Indicator
Freshwater Mussels		**# (CPUE)**
Elliptio complanata	Eastern elliptio	30 (30.0/hr)
Elliptio icterina	variable spike	2 (2.0/hr)
Elliptio producta	Atlantic spike	1 (1.0/hr)
Lampsilis cariosa	yellow lampmussel	1 (1.0/hr)
Villosa constricta	notched rainbow	1(1.0/hr)
Freshwater Snails and Clams	**~**	**Relative Abundance**
Campeloma decisum	pointed campeloma	Uncommon
Elimia catenaria	gravel elimia	Very Abundant
Helisoma anceps	Two-ridge rams-horn	Rare
Corbicula fluminea	Asian clam	Abundant

3.2.4 Site 3 (Deep River-Impoundment):

This site was selected prior to dam removal due to the presence of large rock outcroppings in an area of constricted channel. Since dam removal, much more of the rock outcropping is exposed and small (< 20 feet in length) riffles with accumulated gravel and cobble over bedrock have formed. A cobble/gravel bar has formed at the upstream extent of this site. Six freshwater mussel species were collected, including the targeted yellow lampmussel.

Table 6. Mollusk Species Collected Site 3

Scientific Name	Common Name	Abundance Indicator
Freshwater Mussels		**# (CPUE)**
Elliptio angustata	Carolina lance	1 (1.0/hr)
Elliptio complanata	Eastern elliptio	48 (48.0/hr)
Elliptio icterina	variable spike	3 (3.0/hr)
Elliptio lazarus	Atlantic delicate spike	1(1.0/hr)
Elliptio producta	Atlantic spike	1 (1.0/hr)
Lampsilis cariosa	yellow lampmussel	1 (1.0/hr)
Freshwater Snails and Clams	**~**	**Relative Abundance**

Elimia catenaria	gravel elimia	Common
Corbicula fluminea	Asian clam	Abundant

3.2.5 Site 4 (Deep River-Impoundment):

This site is situated within a long, riffle/run/pool sequence that is essentially contiguous with Site 5. The substrate is dominated by cobble and gravel overlain with coarse sand. A large bar of this material is present at the site with flow in a run along the left descending side of the river. Six freshwater mussel species were collected including the targeted yellow lampmussel, creeper and eastern creekshell.

Table 7. Mollusk Species Collected Site 4

Scientific Name	Common Name	Abundance Indicator
Freshwater Mussels		**# (CPUE)**
Elliptio complanata	Eastern elliptio	77 (77/hr)
Elliptio icterina	variable spike	51 (51/hr)
Lampsilis cariosa	yellow lampmussel	7 (7.0/hr)
Strophitus undulatus	creeper	3 (3.0/hr)
Villosa delumbis	Eastern creekshell	1 (1.0/hr)
Uniomerus carolinianus	Florida pondhorn	*
Freshwater Snails and Clams	**~**	**Relative Abundance**
Elimia catenaria	gravel elimia	
Corbicula fluminea	Asian clam	

* relict shell only

3.2.6 Site 5 (Deep River-Impoundment):

This site was selected prior to dam removal due to the presence of large boulder and bedrock rock outcroppings. Since dam removal, much more of the rock outcropping is exposed and the channel has braided flow around several of the large boulders creating hydraulic breaks where sediments have accumulated that have been colonized by herbaceous vegetation in some areas. This site is essentially contiguous with Site 4. This station is situated adjacent to a boulder/gravel/sand bar. Four mussel species including the targeted yellow lampmussel were collected.

Table 8. Mollusk Species Collected Site 5

Scientific Name	Common Name	Abundance Indicator
Freshwater Mussels		**# (CPUE)**
Elliptio complanata	Eastern elliptio	48 (48.0/hr)
Elliptio icterina	variable spike	1 (1.0/hr)
Elliptio lazarus	Atlantic delicate spike	2 (2.0/hr)
Lampsilis cariosa	yellow lampmussel	2 (2.0/hr)
Freshwater Snails and Clams	**~**	**Relative Abundance**
Campeloma decisum	pointed campeloma	Uncommon
Elimia catenaria	gravel elimia	Common
Helisoma anceps	Two-ridge rams-horn	Uncommon
Corbicula fluminea	Asian clam	Abundant

3.2.7 Site 6 (Deep River-Impoundment):

This sampling station occurs in a small riffle/run sequence on the left descending side of the river just below the SR 1621 (Carbonton Road) bridge. This habitat was created by large accumulations of woody debris trapped by the bridge. Only three individual eastern elliptio were found; however they were all young (newly recruited) individuals (21, 34 and 40 mm TL).

Table 9. Mollusk Species Collected Site 6

Scientific Name	Common Name	Abundance Indicator
Freshwater Mussels		**# (CPUE)**
Elliptio complanata	Eastern elliptio	3 (4.0/hr)
Freshwater Snails and Clams	**~**	**Relative Abundance**
Elimia catenaria	gravel elimia	Common
Corbicula fluminea	Asian clam	Abundant

3.2.8 Site 7 (Deep River-Impoundment):

This site is characterized by a large gravel/sand bar island in the center of the channel that has created a shallow riffle along the right descending bank and a riffle/run of moderate depth along the left descending bank. The island is colonized by herbaceous and woody vegetation and appears to flood on a fairly regular basis, as is evident by numerous pools within the island that retain water. This station exhibits some of the most complex habitat selected for monitoring, as a variety of substrate and hydraulic conditions are present. Four mussel species, including the targeted triangle floater and creeper were collected. The highest number of Cape Fear shiner found during the Year-2 studies were found at this site (TCG 2007). Numerous individuals were observed while conducting the mussel surveys, but no seine net hauls were performed.

Table 10. Mollusk Species Collected Site 7

Scientific Name	Common Name	Abundance Indicator
Freshwater Mussels		**# (CPUE)**
Alasmidonta undulata	triangle floater	1 (0.3/hr)
Elliptio complanata	Eastern elliptio	25 (8.3/hr)
Elliptio icterina	variable spike	3 (1.0/hr)
Strophitus undulatus	creeper	2 (0.7/hr)
Freshwater Snails and Clams	**~**	**Relative Abundance**
Elimia catenaria	gravel elimia	Abundant
Corbicula fluminea	Asian clam	Abundant

3.2.9 Site 8 (Deep River-Impoundment):

This site occurs at the mouth of Big Governors Creek and is dominated by a shallow sand/gravel riffle in a long riffle/run/pool sequence. A cobble/gravel point bar has formed at the confluence. Eight mussel species, including the targeted triangle floater, yellow lampmussel, creeper and eastern creekshell were collected.

Table 11. Mollusk Species Collected Site 8

Scientific Name	Common Name	Abundance Indicator
Freshwater Mussels		**CPUE**
Alasmidonta undulata	triangle floater	3 (1.0/hr)
Elliptio angustata	Carolina lance	1 (0.3/hr)
Elliptio complanata	Eastern elliptio	30 (10.0/hr)
Elliptio icterina	variable spike	2 (0.7/hr)
Elliptio lazarus	Atlantic delicate spike	1 (0.3/hr)
Lampsilis cariosa	yellow lampmussel	1 (0.3/hr)
Strophitus undulatus	creeper	1 (0.3/hr)
Villosa delumbis	Eastern creekshell	7 (2.3/hr)
Uniomerus carolinianus	Florida pondhorn	*
Freshwater Snails and Clams	**~**	**Relative Abundance**
Campeloma decisum	pointed campeloma	Uncommon
Elimia catenaria	gravel elimia	Common
Corbicula fluminea	Asian clam	Abundant

* relict shell only

3.2.10 Site 9 (Deep River-Impoundment):

This site was selected during the pre-removal surveys due to the presence of large boulder and bedrock rock outcroppings. Since dam removal much more of the rock outcropping is exposed, and during Year-2 gravel/sand bars that had begun to form adjacent to river banks were noted (TCG 2007). These bars have created small riffle areas. Six mussel species, including the targeted triangle floater, yellow lampmussel, creeper and eastern creekshell were collected.

Table 12. Mollusk Species Collected Site 9

Scientific Name	Common Name	Abundance Indicator
Freshwater Mussels		**CPUE**
Alasmidonta undulata	triangle floater	1 (1.0/hr)
Elliptio complanata	Eastern elliptio	11 (11.0/hr)
Elliptio icterina	Variable spike	2 (2.0/hr)
Lampsilis cariosa	yellow lampmussel	*
Strophitus undulatus	creeper	1 (1.0/hr)
Villosa delumbis	Eastern creekshell	2 (2.0/hr)
Freshwater Snails and Clams	**~**	**Relative Abundance**
Elimia catenaria	gravel elimia	Abundant
Corbicula fluminea	Asian clam	Abundant

* relict shell only

3.2.11 Site 10 (Deep River-Impoundment):

This site was selected during the pre-removal studies due to the presence of large boulder and bedrock rock outcroppings. Prior to dam removal, flow was virtually nonexistent and the rocky substrate was covered with large accumulations of fine sediments. Since dam removal, much more of the rock outcropping is exposed, however riffle habitat has not formed. It appears that most of the fine sediments have been flushed from this site, and

accumulations of gravel and sand are evident in some areas, but it is unclear whether riffle habitat will form. Three mussel species were found at this site, all of which were found along the right descending bank at the waters edge.

Table 13. Mollusk Species Collected Site 10

Scientific Name	Common Name	Abundance Indicator
Freshwater Mussels		**CPUE**
Elliptio complanata	Eastern elliptio	6 (4.6/hr)
Pyganodon cataracta	Eastern floater	*
Uniomerus carolinianus	Florida pondhorn	5 (3.8/hr)
Freshwater Snails and Clams	**~**	**Relative Abundance**
Campeloma decisum	pointed campeloma	Patchy Common
Elimia catenaria	gravel elimia	Patchy Uncommon
Corbicula fluminea	Asian clam	Common

* relict shell only

3.2.12 Site 11 (Deep River-Impoundment):

This site occurs in a long straight reach of the Deep River and is characterized by a gravel/cobble riffle/run area with a bar developing along the right descending side of the river. Only one eastern elliptio was found; however it was a young individual (29 mm TL). The gravel elimia was very abundant, primarily young individuals.

Table 14. Mollusk Species Collected Site 11

Scientific Name	Common Name	Abundance Indicator
Freshwater Mussels		**CPUE**
Elliptio complanata	Eastern elliptio	1 (1.0/hr)
Freshwater Snails and Clams	**~**	**Relative Abundance**
Elimia catenaria	gravel elimia	Very Abundant
Corbicula fluminea	Asian clam	Abundant

3.2.13 Site 12 (Deep River-Impoundment):

This site occurs in a long straight reach of the Deep River and is characterized by a gravel/cobble riffle/run transitioning into a boulder fall. No mussels were found. The gravel elimia was abundant.

Table 15. Mollusk Species Collected Site 12

Scientific Name	Common Name	Abundance Indicator
Freshwater Mussels		**CPUE**
None	~	~
Freshwater Snails and Clams	**~**	**Relative Abundance**
Elimia catenaria	gravel elimia	Abundant
Corbicula fluminea	Asian clam	Abundant

3.2.14 Site 13 (Deep River-Impoundment):

This site occurs in a shifting shallow riffle/run consisting of shifting sand and gravel beginning just below the location of the former Carbonton dam and extending upstream. No mussels were found. The gravel elimia was abundant.

Table 16. Mollusk Species Collected Site 13

Scientific Name	Common Name	Abundance Indicator
Freshwater Mussels		**CPUE**
None	~	~
Freshwater Snails and Clams	**~**	**Relative Abundance**
Elimia catenaria	gravel elimia	Patchy Common
Corbicula fluminea	Asian clam	Abundant

4.0 DISCUSSION

Semi-quantitative surveys for various freshwater fish were conducted at 15 specific locations in areas formerly impounded by Carbonton Dam to document establishment of lotic habitats and associated freshwater mollusk communities.

4.1 Habitat Reconnaissance

At least 12 substantial riffle habitats have developed within the Deep River. Morphological features at many of these sites have created various hydraulic conditions and, in turn, multiple microhabitats which correspond to potentially high quality habitat for aquatic species, including the targeted Cape Fear shiner and various rare mussel species. It is anticipated that mussel recruitment will continue in these areas as the substrates become more stable. Moderate to deep run habitats, as those observed at site 10, are also expected to provide quality habitats for various lotic-adapted fish and freshwater mussel species.

4.2 Freshwater Mollusk Surveys

While both freshwater mussels and aquatic snails were found within the former reservoir pool prior to dam removal, the Year-3 surveys demonstrate a transition from lentic to lotic adapted species as well as an increase in species diversity.

4.2.1 Freshwater mussel fauna

Prior to dam removal, the freshwater mussel fauna within the former reservoir pool was dominated by habitat generalist, or lentic-adapted species generally confined to bank habitats. Establishment of more lotic-adapted species was expected to occur in the newly formed riffle habitats following removal. This aspect of the monitoring plan was not implemented until Year-3, to allow for re-colonization of the newly restored habitats, and allow for the newly recruited individuals to attain a size that are easily detectable with the least habitat-invasive survey methodology.

4.2.1.1 Species Composition

When comparing the mussel fauna observed during the pre-removal surveys (TCG 2006) with the 3-Year surveys, it is evident that the fauna has transitioned from one comprised of habitat generalists and lentic-adapted species, to one comprised of habitat generalists and lotic-adapted species. For this analysis, each mussel species found was assigned a habitat guild based on habitat preferences reported in the literature as well as personal observations made by TCG staff with over 26 years collectively studying mussel distribution. It should be noted that these guilds represent habitats "typically" occupied by each species, and species can often be found "outside" of these habitats. The combined CPUE for each species (grouped by habitat guild) found in the former impounded reach are shown in Table 17.

Table 17. CPUE of Mussel Species Pre-Removal and Year-3

Mussel Species	CPUE Pre-removal	CPUE 3-Year
Lentic-adapted	**~**	**~**
Pyganodon cataracta	0.95/hr	0.0/hr*
Utterbackia imbecillis	0.23/hr	~
Habitat Generalists	**~**	**~**
Elliptio complanata	37.9/hr	25.0/hr
Elliptio producta	1.19/hr	0.1/hr
Uniomerus carolinianus	11.0/hr	0.3/hr
Lotic-adapted		
Alasmidonta undulata	0.23/hr	0.3/hr
Elliptio angustata	~	0.2/hr
Elliptio icterina	~	3.5/hr
Elliptio lazarus@	1.19/hr	0.3/hr
Elliptio roanokensis	0.23/hr	~
Lampsilis cariosa	0.0/hr*	0.7/hr
Strophitus undulates	~	0.3/hr
Villosa constricta	~	0.05/hr
Villosa delumbis	~	0.6/hr

@ identified as *Elliptio* sp. during the pre-removal surveys
* relict shell only

The freshwater mussel fauna prior to dam removal was represented by two lentic-adapted, three habitat generalist, and four lotic-adapted species. Of the four lotic-adapted species, the triangle floater and Roanoke slabshell were each represented by only one individual, and the yellow lampmussel was represented by only a relict shell (TCG 2006). Based on size and appearance, it was speculated that the Roanoke slabshell may have been alive prior to the dam being constructed (TCG 2006).

Sites 10 and 11 are the only sites that contained live mussels that did not exhibit a trend of increasing number of lotic-adapted species. Four additional lotic-adapted species were found during the Year-3 surveys, the variable spike, creeper, notched rainbow, and eastern creekshell.

The presence of the notched rainbow is especially significant, as this species is extremely rare in the entire length of the Deep River, with a single relict shell collected at the SR 14456 crossing in Moore County in 1997 (personal observation), being the only other recent collection.

While the overall CPUE appears to be lower during the Year-3 monitoring than pre-removal, this is more a reflection of habitat than relative abundance. As stated earlier, prior to dam removal, mussels were concentrated into small pockets of suitable habitat on the banks, thus the majority of search time was spent in these areas, and very little time was spent in other areas. The results of the Year-3 surveys indicate that mussels are more distributed across the river; thus sample time is not concentrated in small areas. In addition, no mussels were found at Sites 11, 12 and 13, lowering the overall CPUE.

Young creeper (top left), eastern creekshell (top right), eastern elliptio (bottom left) and triangle floater (bottom right) found in Deep River within formerly impounded reach during Year-3 monitoring.

4.2.1.2 Post-removal Mussel Recruitment

While field-determination of the exact age of an individual mussel can be difficult, size measurements, coupled with observations of growth rests and an understanding of typical growth rates by species and latitude allow for estimations to be made. With the exception of eastern elliptio, each individual mussel collected was measured. To save time and limit stress to individuals, a subset of the eastern elliptio were measured at sites where numbers were high. Based on size measurements, it appears that the majority of mussels found were individuals recruited into the former reservoir since dam removal (Table 18).

Young eastern creekshells and a triangle floater (bottom right) found in Deep River within the formerly impounded reach-3 year monitoring

Table 18. Estimated Age Groups of Live Mussels Collected Year-3

Scientific Name	(%) of post-removal age	(%) of pre-removal age
Alasmidonta undulata	100%	0%
Elliptio angustata	50%	50%
Elliptio complanata	79%	21%
Elliptio icterina	81%	19%
Elliptio lazarus	80%	20%
Elliptio producta	50%	50%
Lampsilis cariosa	64%	36%
Strophitus undulatus	100%	0%
Villosa constricta	100%	0%
Villosa delumbis	100%	0%
Uniomerus carolinianus	0%	100%

As discussed above (Sec. 4.2.1.1), Site 10 appears to retain many of the lentic characteristics that were present prior to dam removal. As a result, the species composition has changed little, and the live mussels that were found were dominated by older individuals (73%). This was the only site where older-aged individuals outnumbered younger ones.

4.3 Aquatic snail fauna

Prior to dam removal, one species, of aquatic snail, the pointed campeloma, was found in the former reservoir pool, being common at two of the four sites sampled. This species typically occurs in slow-flowing habitats. Three snail species, including the pointed campeloma, two-ridge Ram's horn and the gravel elimia were found during the Year-3 monitoring surveys. The riffle adapted gravel elimia was the most common species found, occurring at all of the sites, often in very high densities. The pointed campeloma and two-ridge Ram's horn were found in fairly low numbers at a few sites in pool habitats. Since most of the survey effort at each site was concentrated in riffle and run habitats, these two species are likely underrepresented; **however, the dominance and high abundance of the gravel elimia clearly demonstrates a post-removal transition from a lentic to lotic habitat, as this species was not encountered in the former reservoir pool during the pre-removal surveys.**

5.0 CONCLUSIONS

The results of the Year-3 Monitoring mollusk surveys demonstrate that the freshwater mussel and aquatic snail faunas have begun to transition from lentic-adapted to lotic-adapted species assemblages. This is most evident in the upper-most sites (Sites 1-9). Although this transition is not yet evident in the lower-most sites (Sites 10-13), as the substrate in these riffle habitats appear to be unstable. However, based on the establishment of the riffle adapted gravel elimia in these areas, mussel recruitment is expected to eventually occur once the habitat becomes stabilized. Additionally minimal fish sampling and observations further document the establishment of the Cape Fear shiner into the former reservoir pool, which was demonstrated in the Year-2 monitoring studies (TCG 2007).

6.0 WORKS CITED

2006, TCG. *Carbonton Dam Removal: Pre-Removal Survey Report*, August 07, 2006.

2007, TCG. *Carbonton Dam Removal: Year Two Monitoring Report,* October 01, 2007.

APPENDIX D: NCDWQ HABITAT ASSESSMENT FIELD DATA SHEET

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: _____° or ☐ NA (Vertical is 90°, horizontal is 0°. Angles > 90° indicate slope is towards mid-channel, < 90° 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.

A. Pools present	Score
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

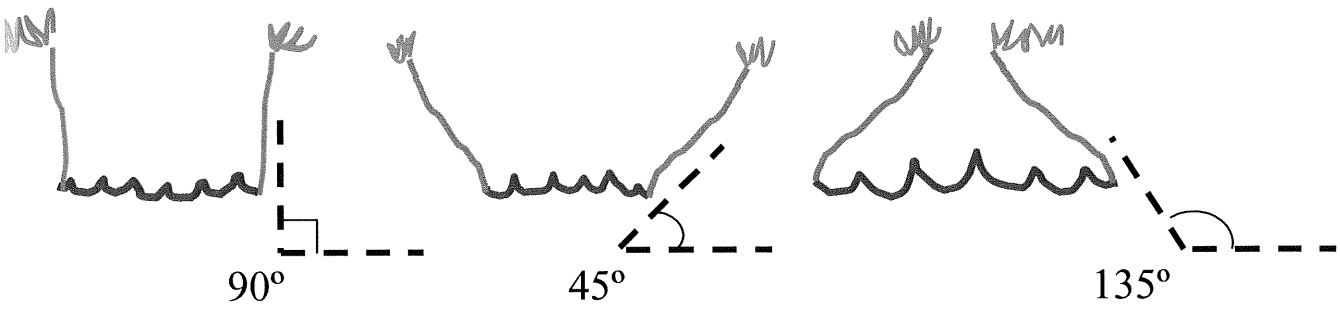
Remarks_____ Total_____

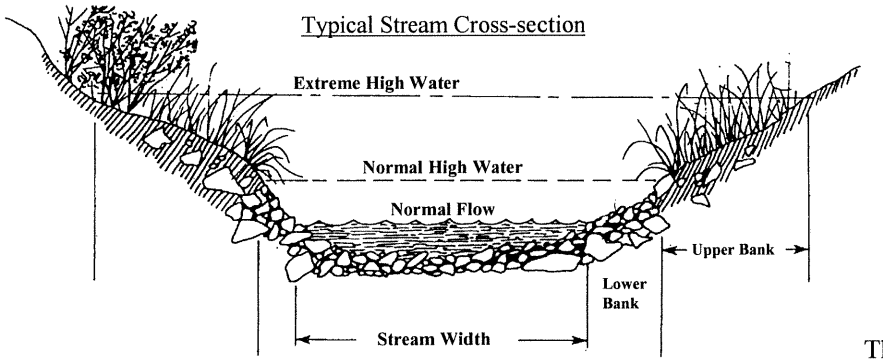
Page Total_____

☐ 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 PICTURES AND VIDEOS (DATA DVD)