Dwarf Wedgemussel Viability Study: Phase 1

Complete 540 - Triangle Expressway Southeast Extension

Swift Creek Watershed

Wake and Johnston Counties, North Carolina

Photo 1. Swift Creek at Little Creek Confluence. Dwarf Wedgemussel (inset).

Prepared for:

North Carolina Department of Transportation
1 South Wilmington Street
Raleigh, NC 27601
Tel: (919) 707-2700   Fax: (919) 715-5511

March 21, 2014

Executive Summary

Swift Creek, a major tributary of the Neuse River Basin located in Wake and Johnston Counties, North Carolina, is known to support the federally Endangered Dwarf Wedgemussel (DWM), and several other rare aquatic species. The Swift Creek DWM population has been identified as essential for the recovery of the species by the US Fish & Wildlife Service (USFWS).

The NC Department of Transportation (NCDOT) proposes transportation improvements from the NC 55 Bypass in Apex to the US 64/US 264 Bypass in Knightdale. These improvements, known as the Complete 540 - Triangle Expressway Southeast Extension project, would extend the existing Triangle Expressway (NC 540), effectively completing the 540 Outer Loop around Raleigh. Inevitably, this proposed project would require at least one crossing of Swift Creek.

Before assessing potential project related impacts to the Swift Creek DWM population, a comprehensive update to the environmental baseline of the Swift Creek population is needed with regards to projected long term population and habitat viability. The purpose of the Phase 1 component of the updated baseline study is threefold: characterize existing conditions of the Swift Creek Watershed (SCW), provide a summary of conservation measures that have been implemented to protect DWM in the SCW, and assess historic trends and future viability of the DWM population and habitat conditions. Population viability attributes that were considered include range of occupied habitat, relative abundance, and evidence of reproduction and recruitment. Habitat viability attributes include general channel stability and micro-habitat characteristics like stream bank conditions and substrate composition.

A number of studies have been conducted in the past assessing various aspects of the Swift Creek Watershed. This report draws from these studies in order to begin to develop a clearer and more concise picture of the current and projected future conditions of the watershed, with regard to land use and water quality. Data gaps in the watershed baseline information are also identified.

The second part of this study provides an accounting of various conservation measures that have been implemented in the SCW to protect the stream, and more specifically the DWM. A Local Watershed Management Plan was developed for the upper part of the SCW, and various recommendations from that plan have been adopted by various municipalities. Additionally, highway and water treatment projects have taken place in the watershed in the recent past, which incorporated various conservation measures to offset identified impacts to the species and the watershed. Conservation measures that have been adopted range from development restrictions, and Best Management Practices (BMPs) that avoid/minimize future impacts, to various measures such as guaranteed low flow releases that were developed to offset impacts from particular projects.

Population trends of the DWM and other freshwater mussel species occurring in Swift Creek were examined to determine current population conditions compared to the past. The trend analysis measures include relative abundance, age class distribution and detection probability. Trends of in-stream habitat conditions, flow, channel stability, and substrate composition were also analyzed. Historic hydrograph data was analyzed to assess how often aquatic life is exposed to extreme low flows. Aerial photography was used to illustrate the condition of the stream channel and its movement, or lack of movement, across the landscape, and geomorphology attributes were measured and compared between sites that currently support the DWM and sites that do not.

The preliminary results of this Phase 1 study demonstrate that there are numerous stressors to aquatic communities, particularly the DWM population, in the SCW. Many of these stressors are directly and indirectly related to the urbanization of the watershed in recent years. It appears that mussel populations have declined in conjunction with these recent changes in the watershed. The declines appear to have leveled off, and there is some indication that mussel recruitment has increased within the last few years. The geomorphology component of the study identified that the heterogeneous distribution of substrate size within a site may be important for the DWM.

Based on this analysis, it is apparent that the long term viability of the DWM population in Swift Creek is threatened; however there is not sufficient information at this time to conclude whether the species will continue to persist in the SCW in the future. Numerous recommendations of analyses to consider in Phase 2 of this study are included in the report that will help better understand future DWM viability.

Table of Contents

1.0 INTRODUCTION 1
1.1. Study Area 3
2.0 SPECIES DESCRIPTION 5
2.1. Characteristics 5
2.2. Distribution and Habitat Requirements 6
2.3. Threats, Particularly the Swift Creek Population 7
2.3.1. Sedimentation 7
2.3.2. Habitat Alteration 7
2.3.3. Toxic Contaminants 8
2.3.4. Urbanization/Impervious Surface 10
2.3.4.1. Peak Discharge 11
2.3.4.2. Runoff Volume 11
2.3.4.3. Decreased Base Flow 12
2.3.4.4. Thermal Pollution 13
2.3.5. Invasive Species 14
2.3.6. Loss of Riparian Buffers 14
2.3.7. Degradation Caused by All-terrain Vehicle Use 14
3.0 WATERSHED CONDITIONS 15
3.1. Land Use and Population Growth 15
3.1.1. Natural Heritage Areas, Parks and Green Space 18
3.2. Surface Water Classification and Use Support Ratings in SCW 20
3.3. Water Quality Conditions in SCW 21
3.3.1. Water Quality Monitoring 21
3.3.1.1. Upper SCW 24
3.3.1.2. Lower SCW 25
3.3.2. 303(d) Impaired Streams 26
3.3.2.1. Upper SCW 27
3.3.2.2. Lower SCW 29
3.3.3. Point Source Pollution 30
3.3.4. Non-point Source Pollution 32
3.4. NCDWQ 2003 Assessment Report on the Upper SCW 32
3.4.1. Toxicity 32
3.4.2. Stormflow Scour 33
3.4.3. Hydromodification 33
3.4.4. Recommendations for Improvement 33
3.5. Watershed Conditions: Summary 35
3.6. Watershed Conditions: Phase 2 Considerations 35
4.0 ACCOUNTING OF CONSERVATION MEASURES IN SCW 36
4.1. General Conservation Measures 36

4.1.1. Neuse River Riparian Buffer Rules 36
4.1.2. Neuse River Basin Stormwater Rules 36
4.1.3. Phase II stormwater (NPDES Permits) 37
4.2. Specific Conservation Measures for the SCW 37
4.2.1. Swift Creek Land Management Plan 37
4.2.2. Apex 37
4.2.3. Cary 39
4.2.4. Garner 39
4.2.5. Raleigh 40
4.2.6. Wake County 40
4.2.7. Johnston County 41
4.2.8. NCDOT Measures 45
4.2.9. Stormwater Basin Evaluation 46
4.3. Accounting of Conservation Measures: Summary 46
4.4. Accounting of Conservation Measures: Phase 2 Considerations 46
5.0 DWM POPULATION TRENDS IN SWIFT CREEK 47
5.1. NC Scientific Council Recommendation on Viability Measures 47
5.2. Study Approach 48
5.3. History of Mussel Surveys and Mussel Fauna in Swift Creek 48
5.4. DWM Occurrences and Distribution in Swift Creek 50
5.5. Mussel Population Trends in Swift Creek 50
5.5.1. Relative Abundance Trends 50
5.5.1.1. DWM 52
5.5.1.2. Atlantic Pigtoe 53
5.5.1.3. Elliptio Species 53
5.5.1.4. Notched Rainbow 54
5.5.1.5. Triangle Floater 55
5.5.1.6. Yellow Lance 55
5.5.1.7. Eastern Lampmussel 56
5.5.1.8. Creeper 56
5.5.1.9. Roanoke Slabshell 57
5.5.1.10. Eastern Floater 58
5.5.1.11. Paper Pondshell 58
5.6. Age Class Distribution Analysis 59
5.6.1. DWM 60
5.6.2. Atlantic Pigtoe 61
5.6.3. Triangle Floater 61
5.6.4. Yellow Lance 62
5.6.5. Eastern Lampmussel 62
5.6.6. Creeper 63

5.6.7. Notched Rainbow ... 63
5.7. Mussel Detection Probability Analysis ... 64
5.8. Population Trends Summary ... 65
5.9. Population Trends Phase 2 Considerations ... 66
6.0 IN-STREAM HABITAT VIABILITY IN SWIFT CREEK ... 67
6.1. Stream Flow (Hydrograph Analysis) ... 67
6.1.1. Stream Flow Summary ... 68
6.1.2. Phase 2 Considerations ... 68
6.2. Current and Historic Channel Stability ... 69
6.2.1. Channel Stability Summary ... 70
6.2.2. Channel Stability Phase 2 Considerations ... 71
6.3. In-stream DWM Habitat Assessment Analysis ... 71
6.3.1. Geomorphology Summary ... 71
6.3.2. Phase 2 Considerations ... 71
7.0 DWM POPULATION VIABILITY IN SWIFT CREEK ... 72
7.1. Length of Occupied Habitat Criterion ... 72
7.2. Occur at 75% of Sites within Occupied Habitat Criterion ... 73
7.3. CPUE > 5 Individuals per hour at 50% of Occupied Sites Criterion ... 73
7.4. Evidence of Recent Reproduction Criterion ... 74
7.5. Overall Mussel Population Trends ... 74
7.6. Viability Conclusions ... 75
7.7. Recommendations ... 75
8.0 RESOURCES ... 76

Table of Tables

Table 1. Rare Aquatic Species in Swift Creek ... 1
Table 2. Land Cover in the Neuse River Basin: 1982 vs. 1997 (NCDWQ, 2009) ... 16
Table 3. Land Use cover in Swift Creek Watershed, NLCD 2006 ... 18
Table 4. Upper SCW and Study Area Total Acreage of Open Space (compared to total area). . 20
Table 5. Water Quality Monitoring Sites in Swift Creek Watershed ... 24
Table 6. Upper SCW Impaired (Category 5) Streams 2012. Use of streams for "Aquatic Life". 27
Table 7. Study Area Impaired (Category 5) Streams 2012. Use of streams for "Aquatic Life". 30
Table 8. NPDES permitted dischargers in Swift Creek Watershed ... 32
Table 9. Number of mussel survey hours by sections ... 52
Table 10. Percent Composition in Age Groups (yr) adapted from Michaelson (1995) ... 60
Table 11. Detection Probabilities by Species ... 65
Table 12. Periods of Extreme Low Flows: Swift Creek and Middle Creek ... 68

Table of Figures

Figure 1 2
Figure 2 4
Figure 3 17
Figure 4 19
Figure 5 23
Figure 6 28
Figure 7 31
Figure 8 34
Figure 9 38
Figure 10 43
Figure 11 44
Figure 12 49
Figure 13 51

Appendices

Appendix A – Lower Neuse River Basin Monitoring Results
Appendix B – Stormwater Basin Evaluation Sheet
Appendix C – 2010, 2011, & 2012 Freshwater Mussel Surveys
Appendix D – Catch Per Unit Effort Data
Appendix E – Detection Probability Data
Appendix F – Hydrograph Tables
Appendix G – Dwarf Wedgemussel Habitat Assessment Survey Report

1.0 INTRODUCTION

The North Carolina Department of Transportation (NCDOT) proposes transportation improvements from the NC 55 Bypass in Apex to the US 64/US 264 Bypass in Knightdale within Wake and Johnston Counties, referred to as the Complete 540 - Triangle Expressway Southeast Extension project (Figure 1). The project may impact streams within the Neuse River Basin, including Swift Creek, a major tributary to the Neuse River.

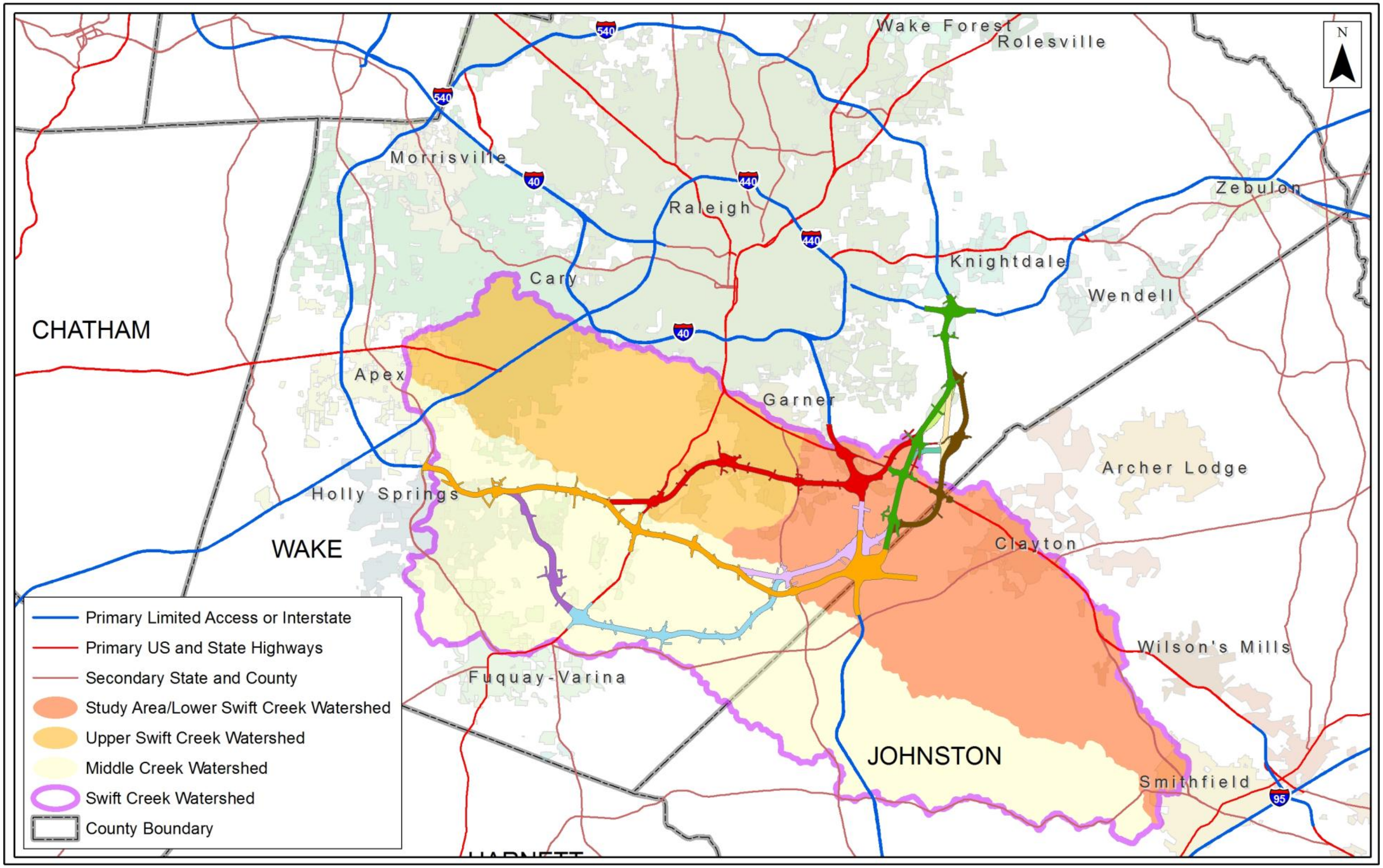
The North Carolina Wildlife Resources Commission (NCWRC) identified the Swift Creek Watershed (SCW) as one of 25 areas in North Carolina considered essential for the continued survival of endangered or threatened aquatic wildlife species (Alderman et al. 1993), as it supports several rare aquatic species (Table 1), including the federally endangered Dwarf Wedgemussel (*Alasmidonta heterodon*) (DWM). Additionally, the Swift Creek population of the DWM has been identified as essential for the recovery of the species (USFWS 1993).

Table 1. Rare Aquatic Species in Swift Creek

Scientific Name	Common Name	NCWRC Status*	Nature Serve Status**	Federal Status
Alasmidonta heterodon	Dwarf Wedgemussel	E	S1	E
Alasmidonta undulata	Triangle Floater	T	S2	~
Anguilla rostrata	American Eel	~	S4	~
Elliptio lanceolata	Yellow Lance	E	S1	~
Elliptio roanokensis	Roanoke Slabshell	T	S1	~
Fusconia masoni	Atlantic Pigtoe	E	S1	~
Lampsilis radiata	Eastern Lampmussel	T	S1S2	~
Lasmigona subviridis	Green Floater	E	S1	~
Lythrurus matutinus	Pinewoods Shiner	~	S3	~
Necturs lewisi	Neuse River Waterdog	SC	S2	~
Noturus furiosus	Carolina Madtom	T	S2	~
Strophitus undulatus	Creeper	T	S2	~
Villosa constricta	Notched Rainbow	SC	S3	~

*E, T, and SC denote Endangered, Threatened, and Special Concern respectively.
**S-ranks, referring to NC State ranks, range from S1 (imperiled) to S5 (secure), with S1S2 indicating some uncertainty in the appropriate rank.

As required by the Nature Preserves Act (NCGS 113A-164 of Article 9), the North Carolina Natural Heritage Program (NCNHP) compiles the North Carolina Department of Environment and Natural Resources (NCDENR) priority list of "Significant Natural Heritage Areas" (SNHAs). These sites are inventoried and evaluated on the basis of rare plant and animal species, rare or high quality natural communities, and special animal habitats, collectively termed the "Elements" of natural diversity. The sites are rated with regard to national and state significance, and nearly 250 acres of lower Swift Creek are rated as "Exceptional", which is the highest rating, followed by "Very High", "High", "Moderate", and "General". It is noted that sites on the list should be given priority for protection; however, it does not imply that all of the areas currently receive protection (NCNHP 2013).



The Catena Group

Client:

Dwarf Wedgemussel Viability Study: Phase 1

Complete 540 Triangle Expressway Southeast Extension: Detailed Study Alternatives

Wake & Johnston Counties, North Carolina

Date: February 2014

Scale: 0 1 2 Miles

Job No.: 1154

Figure 1

Since the DWM is present within the proposed Study Area (Defined in Section 1.1), potential direct, indirect, and cumulative impacts to this species will need to be fully assessed and disclosed as required by Section 7 of the Endangered Species Act of 1973, as amended. This will be accomplished during the planning and environmental studies for the Complete 540 project.

In a letter to NCDOT dated February 17, 2011, the US Fish and Wildlife Service (USFWS) indicated that an updated Environmental Baseline of the DWM population in Swift Creek will be needed to determine if the proposed action has the potential to jeopardize the continued existence of this species. The USFWS proposed a three-tiered study to be implemented by NCDOT to develop this updated Environmental Baseline:

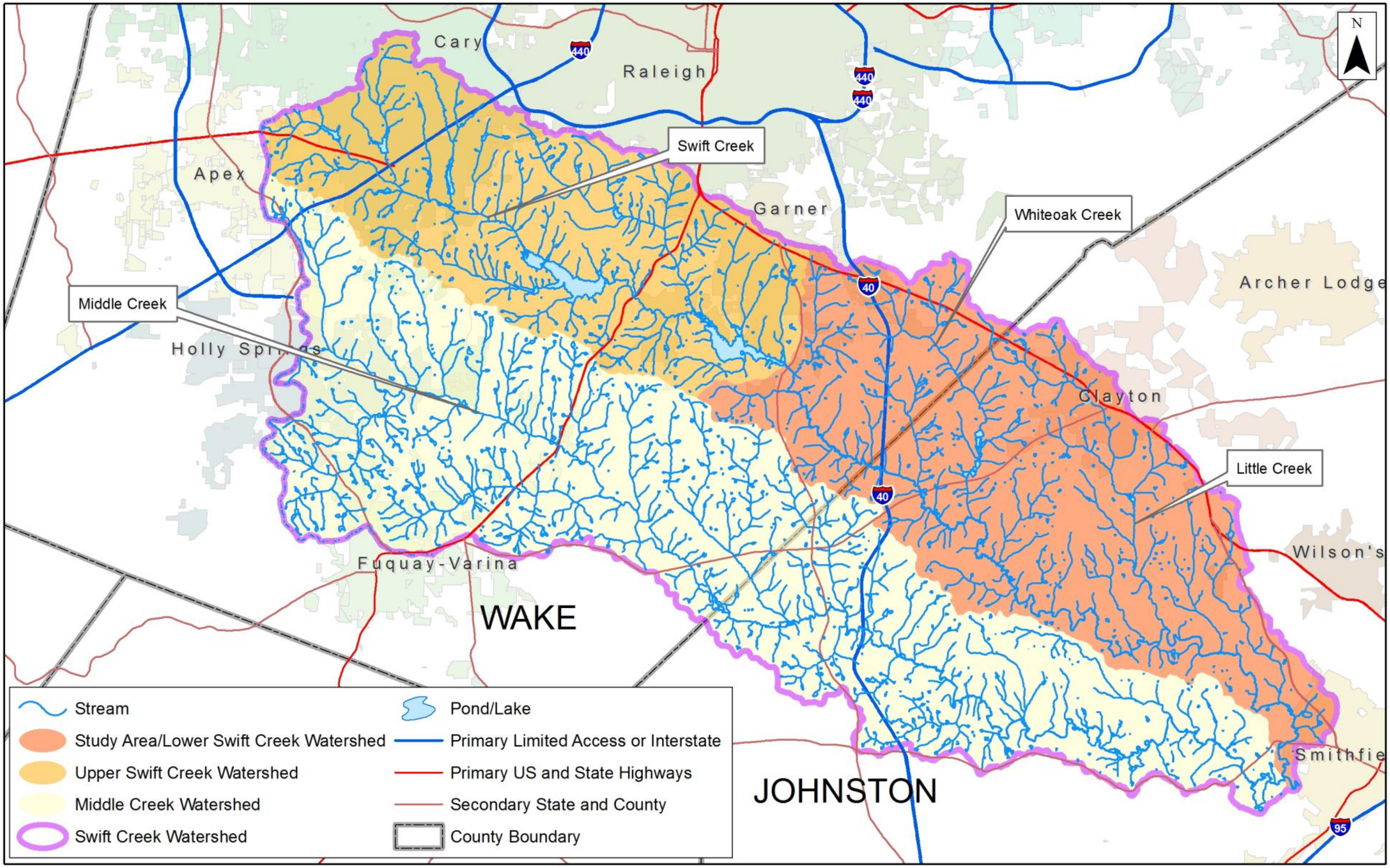
1. Provide an accounting (compliance/ implementation) of conservation measures that have been implemented in Swift Creek to protect DWM
2. Assess the effectiveness of existing conservation measures and environmental protections in Swift Creek with regard to habitat and population stability
3. Assess historic trends, and current viability of DWM population and habitat conditions in Swift Creek

The Catena Group, Inc. (Catena) was retained by H.W. Lochner, Inc. (Lochner), to develop and implement this study. This report summarizes the initial phase of this study which:

1. Identifies conservation measures that have been implemented in SCW
2. Assesses conditions of SCW
3. Assesses historic trends and current viability of the DWM population, and its habitat, in Swift Creek

1.1. Study Area

SCW is located in Wake and Johnston Counties in Central North Carolina and is part of the Neuse River Basin (Figure 2). The watershed is contained entirely within the Piedmont Physiographic Province. The headwaters of Swift Creek are in the towns of Apex and Cary, Wake County, NC; from there, the stream flows southeast until joining the Neuse River near Smithfield in Johnston County, NC. The system includes two major reservoirs, Lake Wheeler and Lake Benson, which serve as water sources for the Triangle Area. The drainage area of SCW is approximately 289 square miles, with a major tributary, Middle Creek accounting for 45% of the drainage area. SCW encompasses several municipalities, including portions of Raleigh, residential areas, forested areas, and agricultural fields. From the headwaters to and including Lake Benson is considered the Upper SCW; below the Lake Benson dam down to the convergence with the Neuse River is considered the Lower SCW (Figure 2). The DWM population occurs within the Lower SCW, thus it is where the majority of this study is focused,



The Catena Group

Client:

Dwarf Wedgemussel Viability Study: Phase 1

Swift Creek Watershed with Study Area

Wake & Johnston Counties, North Carolina

Date: February 2014

Scale: 0 1 2 Miles

Job No.: 1154

Figure 2

and is referred to as the Study Area. However, conditions in the Upper SCW have some influence on the Lower SCW therefore relevant data from the upper part of the watershed is provided and discussed in this report.

2.0 SPECIES DESCRIPTION

Alasmidonta heterodon (Dwarf Wedgemussel)

Federal Status: Endangered
Family: Unionidae
Listed: March 14, 1990

2.1.Characteristics

DWM was originally described as *Unio heterodon* (Lea 1829). Simpson (1914) subsequently placed it in the genus *Alasmidonta*. Ortman (1919) placed it in a monotypic subgenus *Prolasmidonta*, based on the unique soft-tissue anatomy and conchology. Fuller (1977) believed the characteristics of *Prolasmidonta* warranted elevation to full generic rank and renamed the species *Prolasmidonta heterodon*. Clarke (1981) retained the genus name *Alasmidonta* and considered *Prolasmidonta* to be a subjective synonym of the subgenus *Pressodonta* (Simpson 1900).

The specific epithet *heterodon* refers to the chief distinguishing characteristic of this species, which is the only North American freshwater mussel that consistently has two lateral teeth on the right valve and only one on the left (Fuller 1977). All other laterally dentate freshwater mussels in North America normally have two lateral teeth on the left valve and one on the right. DWM is generally small, with a shell length ranging between 25 mm and 38 mm. The largest specimen reported by Clarke (1981) was 56.5 mm long, taken from the Ashuelot River in New Hampshire. The periostracum is generally olive green to dark and nacre bluish to silvery white, turning to cream or salmon colored towards the umbonal cavities. Sexual dimorphism occurs in DWM, with the females having a swollen region on the posterior slope, and the males are generally flattened. Clarke (1981) provides a detailed description of the species.

Nearly all freshwater mussel species have similar reproductive strategies; a larval stage (glochidium) becomes a temporary obligatory parasite on a fish. This species is considered to be a long-term brooder, with gravid females reportedly observed in the fall months. Like other freshwater mussels, this species' eggs fertilized in the female as sperm are taken in through their siphons as they respire. The eggs develop within the female's gills into larvae (glochidia). The females later release the glochidia, which then attaches to the gills or fins of a specific host fish species. Based on anecdotal evidence, such as dates when gravid females are present or absent, it appears that release of glochidia occurs primarily in April in North Carolina (Michaelson and Neves 1995). Recent research has confirmed at least three potential fish host species for DWM to be the tessellated darter (*Etheostoma olmstedi*), Johnny darter (*E. nigrum*), and mottled sculpin (*Cottus bairdii*) (Michaelson 1993). McMahon and Bogan (2001) and Pennak (1989) should be consulted for a general overview of freshwater mussel reproductive biology.

2.2.Distribution and Habitat Requirements

The historic range of DWM was confined to Atlantic slope drainages from the Peticodiac River in New Brunswick, Canada, south to the Neuse River, North Carolina. Occurrence records exist from at least 70 locations, encompassing 15 major drainages, in 11 states, and 1 Canadian Province (USFWS 1993). When the recovery plan for this species was written, DWM was believed to have been extirpated from all but 36 localities, 14 of them in North Carolina (USFWS 1993). The most recent assessment (2007 5-Year Review) indicates that DWM is currently found in 15 major drainages, comprising approximately 70 “sites” (one site may have multiple occurrences) (USFWS 2007). At least 45 of these sites are based on less than five individuals or solely on relict shells. It appears that the populations in North Carolina, Virginia, and Maryland are declining as evidenced by low densities, lack of reproduction, or inability to relocate any individuals in follow-up surveys. Populations in New Hampshire, Massachusetts, and Connecticut appear to be stable, while the status of populations in the Delaware River watershed affected by the recent floods of 2005 is uncertain.

Strayer et al. (1996) conducted range-wide assessments of remaining DWM populations and assigned a population status to each of the populations. The status rating is based on range size, number of individuals, and evidence of reproduction. Seven of the 20 populations assessed were considered “poor”, and two others were considered “poor to fair” and “fair to poor” respectively. In North Carolina, populations are found in portions of the Neuse and Tar River basins; however it is believed to have been extirpated from the main-stem of the Neuse River.

DWM inhabits creeks and rivers of varying sizes (down to approximately two meters [6 ft] wide), with slow to moderate flow. A variety of preferred substrates have been described that range from coarse sand, to firm muddy sand to gravel (USFWS 1993). In North Carolina, DWM often occurs within submerged root mats along stable streambanks (USFWS 2007). Two general in-stream habitat types, Shallow Fast Coarse (SFC) or Deep Stream Margin Roots (DSMR) habitats were identified as primarily supporting this species in Swift Creek (Entrix 2005). The wide range of substrate types used by this species suggests that the stability of the substrate is likely as important as the composition.

2.3. Threats, Particularly the Swift Creek Population

The cumulative effects of several factors, including sedimentation, point and non-point discharge, and stream modifications (impoundments, channelization, etc.) have contributed to the decline of this species throughout its range. With the exception of the Neversink population in New York, which has an estimated population of over 80,000 DWM individuals, all of the other populations are generally small in numbers and restricted to short reaches of isolated streams. The low numbers of individuals and the restricted range of most of the surviving populations make them extremely vulnerable to extirpations from a single catastrophic event or activity (Strayer et al. 1996). Catastrophic events may consist of natural events such as flooding or drought, as well as human influenced events such as toxic spills associated with highways, railroads, or industrial-municipal complexes. Based on expert opinion of a North Carolina DWM (NC DWM) Work Group assembled by the USFWS Raleigh field office in 2012, the "Allee effect", defined as a high risk of demographic extirpation due to low population abundance and lack of dispersal, was identified as the second highest threat behind "unsuitable physical habitat" to the Swift Creek population (Smith et al. 2014).

2.3.1. Sedimentation

Siltation resulting from substandard land-use practices associated with activities such as agriculture, forestry, and land development has been recognized as a major contributing factor to degradation of mussel populations (USFWS 1996). Siltation has been documented to be extremely detrimental to mussel populations by degrading substrate and water quality, increasing potential exposure to other pollutants, and by direct smothering of mussels (Ellis 1936; Markings and Bills 1979). Sediment accumulations of less than 25 mm (one inch) have been shown to cause high mortality in most mussel species (Ellis 1936). In Massachusetts, a bridge construction project decimated a population of the DWM because of accelerated sedimentation and erosion (Smith 1981).

2.3.2. Habitat Alteration

The impact of impoundments on freshwater mussels has been well documented (USFWS 1992a; Neves 1993). Construction of dams transforms lotic habitats into lentic habitats, which results in changes in aquatic community composition. The changes associated with inundation adversely affect both adult and juvenile mussels as well as fish community structure, which could eliminate possible fish hosts for upstream transport of glochidia. Muscle Shoals on the Tennessee River in northern Alabama, once the richest site for naiads (mussels) in the world, is now at the bottom of Wilson Reservoir and covered with 5.79 meters (19 feet) of muck (USFWS 1992b). Large portions of all of the river basins within the DWM range have been impounded and this is believed to be a major factor contributing to the decline of the species (Master 1986; USFWS 1993).

2.3.3. Toxic Contaminants

The presence of toxic contaminants has been shown to contribute to widespread declines of freshwater mussel populations (Havlik and Marking 1987; Bogan 1993; Neves et al. 1997; Richter et al. 1997; Strayer et al. 2004). Toxic contaminants can produce lethal or sub-lethal responses to freshwater mussels. The NC DWM Work Group identified “low water quality due to contaminants” as the third most important threat to the Swift Creek population (Smith et al. 2014). The sensitivities of freshwater mussels to toxic contaminants is variable based on species, life stage (glochidium, juvenile, or adult), and environmental conditions, as well as concentration and exposure route (water column, sediments, etc.), frequency, and duration. Several studies have indicated that early life stages of freshwater mussels are among the most sensitive aquatic organisms to various inorganic toxicants such as copper (Jacobson et al. 1993; Jacobson et al. 1997; Milan et al. 2005; Wang et al. 2007a; Wang et al. 2007b) and ammonia (Wade 1992; Augsperger et al. 2003; Bartsch et al. 2003; Newton et al. 2003; Wang et al. 2007a; Wang et al. 2007b; Grabarkiewicz and Davis 2008).

Anthropogenic sources of ammonia and copper in surface waters include sewage treatment effluent, industrial wastewater effluent, and runoff and ground water contamination from agriculture, lawn/turf management, livestock operations, and faulty septic systems. Sewage treatment effluent has been documented to significantly affect the diversity and abundance of mussel fauna (Goudreau et al. 1988). Goudreau et al. (1988) found that recovery of mussel populations might not occur for up to two miles below discharges of chlorinated sewage effluent.

Recent studies indicated that previous federal water quality criteria for many pollutants commonly found in wastewater discharges and stormwater runoff were likely not protective of freshwater mussels; nationwide regulations controlling the discharge or runoff of these pollutants are also not protective (Augspurger et al. 2003). The previous (1999) U.S. Environmental Protection Agency (EPA) recommended ‘freshwater ammonia aquatic life ambient water quality’ criteria were based on the most sensitive endpoints known at the time: the acute criterion was based primarily on effects on salmonids (where present) or other fish, and the chronic criterion was based primarily on reproductive effects on the benthic invertebrate *Hyalella* or on survival and growth of fish early life stages (when present) (USEPA 2009). Research demonstrated that these standards were not protective of freshwater mussel species, which are some of the most sensitive aquatic organisms to ammonia. As a result, the EPA recently revised the freshwater ammonia aquatic life ambient water quality criteria (acute and chronic standards) to reflect freshwater mussel species sensitivity thresholds (USEPA 2013).

Ward et al. (2007) sampled for ammonia, copper and chlorine at five locations within, or draining to, the portion of Swift Creek occupied by DWM, and found that ammonia and chlorine levels rarely exceeded ecological screening values; however, copper levels exceeded ecological screening values for both acute and chronic exposure at all sites.

Currently there are no water quality standards, or monitoring requirements for ammonia, copper and phosphorus in North Carolina (USFWS 2007). However, the Goose Creek Site Specific Management Plan (NCDENR 2009), which was developed to provide protection for another federally protected freshwater mussel species in North Carolina, requires that any direct or indirect discharge that may cause ammonia toxicity to the Carolina Heelsplitter implement measures to reduce ammonia (NH3-N) inputs to achieve 0.5 milligrams per liter or less of total ammonia based on chronic toxicity defined in 15A NCAC 02B .0202. This level of total ammonia is based on ambient water temperature equal to or greater than 25 degrees Celsius (NCDENR 2009). EPA water quality criteria, and North Carolina water quality standards are discussed further in Section 3.3.

In addition, recent studies indicate other toxicants present in wastewater effluent such as pharmaceuticals and personal care products (fluoxitine, estrogenic compounds, opiate derivatives etc.) cause a wide array of neurotoxicological (Gagné et al 2007a), reproductive (Bringolf et al. 2007; Gagné et al 2007b) and behavioral (Heltsley et al. 2006) impacts to freshwater mussels.

Other sources of toxic contaminants in surface waters arise from highway and urban runoff. Numerous pollutants have been identified in highway runoff, including various metals (lead, zinc, iron, copper, etc.), sediment, pesticides, deicing salts, nutrients (nitrogen, phosphorus), and petroleum hydrocarbons (Gupta et al. 1981; Yousef et al. 1985). The sources of these runoff constituents range from construction and maintenance activities to daily vehicular use. Hoffman et al. (1984) concluded that highway runoff can contribute up to 80 percent of the total pollutant loadings to receiving water bodies. Petroleum hydrocarbons, polycyclic aromatic hydrocarbons, lead, and zinc were some of the pollutants identified in this study.

The toxicity of highway runoff to aquatic ecosystems is poorly understood. A major reason for this poor understanding is a lack of studies focusing solely on highway runoff. Potential impacts of highway runoff have often been inferred from studies conducted on urban runoff; however, the relative loadings of pollutants are often much greater in urban runoff, because of a larger drainage area and lower receiving water dilution ratios (Dupuis et al. 1985). The negative effects of urban runoff inputs on benthic macroinvertebrate communities have been well documented (Garie and McIntosh 1986; Jones and Clark 1987; Field and Pitt 1990). Lieb (1998) found the macroinvertebrate community of a headwater stream in Pennsylvania to be highly degraded by urban runoff via a detention pond. Improvements were observed at continual distances downstream from the discharge point; however, all sites examined were still impaired compared to a reference community.

The few studies that examined actual highway runoff show that some species demonstrate little sensitivity to highway runoff exposure, while others are much more sensitive (Dupuis et al. 1985). Maltby et al. (1995) found elevated levels of hydrocarbons and metals in both stream sediments and the water column below a heavily traveled British motorway. They demonstrated that the benthic amphipod (*Gammarus pulex*) experienced a decrease in survival when exposed to sediments contaminated with roadway runoff. However, this species showed no increase in mortality when exposed to water contaminated with roadway runoff. Unfortunately, most of these studies only measured acute toxicity to runoff and did not examine long-term effects.

The effects of highway runoff on freshwater bivalves have not been studied extensively. Augspurger (1992) compared sediment samples and soft tissues of three Eastern Elliptio (*Elliptio complanata*), a relatively common species upstream and downstream of the I-95 crossing of Swift Creek of the Tar River Basin in Nash County, North Carolina. The sediment samples as well as the mussels exhibited higher levels of aliphatic hydrocarbons, arsenic, lead, zinc, and other heavy metal contaminants in the downstream samples. Because of the small sample size, the effect on the health of these mussels was not studied. In another study, contaminant analysis of stream sediments showed an increase of polycyclic aromatic hydrocarbons and some metals downstream of road crossings, although there was no direct correlation found between increasing contaminant levels and decreasing mussel abundance at these crossings (Levine et al. 2005). The Eastern Elliptio was the only mussel species that was found in large enough numbers for statistically valid comparisons. The Eastern Elliptio is generally considered more tolerant of water quality degradation than many other mussel species. Further research is needed before the effects of highway runoff on sensitive mussel species such as the DWM can be determined.

In addition, contamination of surface water from toxic spills along roadways is known to have significant impacts to aquatic communities. A toxic spill resulting from a tanker truck accident that was carrying Octocure 554 (a chemical liquid used in the rubber making process) killed several miles of mussel populations in the Clinch River near Cedar Bluff, Virginia (Richmond Times Dispatch 1998). The spill killed thousands of fish and mussels, including three federally protected species. The Clinch River contains one of the most diverse mussel faunas in the United States. The stretch of the river affected by the spill was one of the few remaining areas that contained a reproducing population of the endangered Tan Riffleshell (*Epioblasma florentina walkeri*). The toxic spill is believed to have eliminated this population.

2.3.4. Urbanization/Impervious Surface

The Swift Creek watershed has experienced urbanization in recent years, which is discussed in detail in Section 3.0. The correlation of increasing development within a watershed and decreasing water quality is well documented (Lenat et al. 1979; Garie and McIntosh 1986; Crawford and Lenat 1989; Lieb 1998), and is largely associated with increases in impervious surface area. These increases in impervious surface area can affect water quality in a variety of ways, particularly with regard to changes to stream flow, water temperature, total suspended sediment, and pollutant loadings.

Multiple studies have demonstrated that water quality and stream ecosystem degradation begins to occur in watersheds that have approximately ten percent coverage by impervious surfaces (Schueler 1994; Arnold and Gibbons 1996; Stewart et al. 2000). NCWRC recommendations for management of protected aquatic species watersheds are to limit imperviousness to six percent of the watershed (NCWRC 2002). The amount of impervious surface has increased in the SCW, constituting about eleven percent of the land area within Wake County (the more developed of the two counties). As a result, Wake County contributes about 4.29 inches/year of runoff (CDM 2003, Table 3-5). Of all the rainfall that falls onto these impervious surfaces, an estimated 95 percent becomes runoff. Johnston County is less developed than Wake County. As of 2006, the county was approximately nine percent urban. The portion of Johnston County that is in the SCW was approximately seven percent developed as of 2006. This is based on the National Land Cover Dataset (NCLD), and assuming all development is captured in the Low, Medium, and High Intensity Developed categories. The 2009 NCDWQ report indicates the entire SCW is 29.5 percent urbanized, with much of the growth occurring in the last 20 years. Increases in impervious surface area within a watershed can result in extremes in peak discharge, runoff volume, and base flow conditions.

2.3.4.1. Peak Discharge

Peak discharge is the maximum rate of stormwater flow expected from a storm event, measured in cubic feet per second (cfs). Peak discharge is often one metric used in analyzing impacts from development. Peak discharge affects channel stability (or instability), which is one of the identified constituent elements. Increases in peak discharge equates to higher velocity, which in turn increases the scouring effect (surface erodibility) of the runoff. Accordingly, sedimentation will increase as erosion rates increase. Increases of peak discharge rates, coupled with deforestation, have been shown to result in stream narrowing and incision and subsequent loss of ecosystem function (Sweeney et al. 2004). Increased runoff volume and peak discharge (from typical and atypical storm events) destabilize the stream channel.

2.3.4.2. Runoff Volume

Runoff volume is the amount of stormwater expected from a storm event, measured in acre-feet. Like peak discharge, runoff volume is another metric often used in determining impacts of development, especially on the aquatic environment. For example, increases in the amount of runoff normally equates to increased sediment. While the two indicators are related, when analyzed separately, both are useful in assessing impacts to aquatic systems.

In a stable system, an increase in the velocity may have little impact if volume does not change, provided that measures to slow the increased velocity have been implemented. However, the increased runoff volume may have enough sediment to cause detrimental impacts. Regardless, it is important to consider both the rate (peak discharge) and the amount (runoff volume) when assessing impacts to aquatic systems. Again, sufficient stormwater controls accompanying future development activities in any given watershed are essential for conservation of sensitive aquatic species such as DWM.

2.3.4.3. Decreased Base Flow

Increases of impervious surface lead to decreases in infiltration and base flow (groundwater flow) within adjacent streams. This can result in the following:

- Less water to cover the stream bottom during periods of reduced base flow.
- Increases in water evaporation and temperature in widened streams as a result of reduced overhanging tree cover and increased exposure to sunlight, especially in areas with shallower water.
- Extension of the waste water treatment plant (WWTP) effluent "plume" further downstream, if base flow is reduced and WWTP discharge remains constant or increases, as it takes longer for the stream to dilute the nutrients and other toxins in the effluent.

Permitted and un-permitted water withdrawals for crop and turf/lawn irrigation further exacerbate this effect. In North Carolina, permits are required for water withdrawals of one million gallons or greater. Withdrawals less than this are not regulated, and are often unknown. Numerous small withdrawal operations have been observed in the Lower SCW (Catena personal observations). During summer months withdrawals of up to 188 gallons per minute (gpm), or 0.42 cfs can significantly affect the available dilution for downstream dischargers (Belnick 2001).

In general, soils in the Piedmont portion of the Neuse River Basin are highly erodible and are underlain by fractured rock formations that have limited water storage capacity resulting in the streams that flow through them being naturally susceptible to periods of very low or even interrupted flow. Streams in this area tend to have low summer flows and limited ability to assimilate oxygen-consuming wastes (NCWRC 2005). In addition, the Upper SCW is close to the transitional area between the poorly drained soils of the Triassic basin and the moderately drained soils weathered from granitic rocks underlying the Lower SCW. As such, Swift Creek is even more susceptible to periods of interrupted flow, particularly in the upper reaches, which have almost no potential for sustained 7Q10 low flow discharge; 7Q10 is defined as the minimum average discharge for a consecutive seven day period occurring, on average, once in ten years (Weaver 1998). The natural susceptibility of these watersheds to periods of very low to interrupted flow is further compounded by anthropogenic factors such as water withdrawals and urbanization.

Prolonged periods of drought have been shown to adversely impact mussel species (Johnson et al. 2001; Golladay et al. 2005; USFWS 2012), as mussels may face increased water temperatures and reduced dissolved oxygen (DO) concentrations (hypoxia, or eventually anoxia), increased predation, and emersion or stranding (Johnson et al. 2001). Thin-shelled species like DWM may be inherently more prone to the consequences of drought than thicker shelled species like Elliptio mussels. Prolonged drought has been identified as major threat to the endangered Carolina Heelsplitter (USFWS 2012). Similarly, based on expert opinion of a NC DWM Work Group assembled by the USFWS Raleigh field office, drought ("unsuitable flow") was identified as one of the top three threats in all of the populations in the Tar River Basin (Smith et al. 2014).

While drought is recognized as a major threat for many mussel species, the actual low flow requirements of mussels is poorly understood. Johnson et al. (2001) and Golladay et al. (2005) assessed drought impacts on mussel assemblages in a number of streams in the Flint River Basin of southwestern Georgia. Flow rate, water temperature, water depth, and DO were monitored throughout the study and study sites were classified as flowing or non-flowing during the drought period. Sites that ceased flowing during the drought had significant declines in the abundance of all mussel species, some of which are endangered, as well as declines in species richness. However, sites that maintained some flow during the drought had increases in stable species of mussels and no change in special concern or endangered species through the drought. Mortality of mussels at sites that ceased flowing was attributed to reductions in DO concentration, which was highly correlated with water velocity.

As part of the Section 7 Consultation process for the Dempsey E. Benton Water Treatment Plant, a 60-year synthesized hydrologic time series was developed for Swift Creek using a ratio of the drainage area from the nearby, unregulated Middle Creek. The results of this analysis concluded that Swift Creek historically experienced near zero and zero flow conditions (Entrix 2005). Minimum flow releases are now guaranteed as a result of conservation measures developed for the project (see Section 4.2.5).

2.3.4.4. Thermal Pollution

Concerns over effects of thermal pollution from urban runoff on aquatic systems have increased in recent years. Elevation of stream temperature can raise Biochemical Oxygen Demand (BOD), lower DO, and alter faunal composition (Poole et al. 2001, Roa-Espinosa et al. 2003). Typically, runoff from a developed impervious area will have a temperature similar to the temperature of the impervious area. During the hot summer months, this could potentially make the stormwater runoff reach temperatures up to and above 90°F, which could be detrimental to the aquatic life. Traditional structural stormwater controls, such as open storm-water detention ponds/basins that do not allow for infiltration, do not protect receiving water bodies against adverse temperature effects. Various stormwater Best Management Practices (BMPs) have been shown to be effective in ameliorating temperature effects (NC State Cooperative Extension 2006a). For example, bioretention devices were shown to reduce runoff temperature by 5-10°F in Greensboro, NC (NC State Cooperative Extension 2006b). The loss of riparian buffers as well as peak discharge related channel widening can also contribute to stream temperature increases, by increasing sunlight exposure and decreasing water depth.

2.3.5. *Invasive Species*

The introduction of exotic species such as the Asian Clam (*Corbicula fluminea*) and Zebra Mussel (*Dreissena polymorpha*) has also been shown to pose significant threats to native freshwater mussels. The Asian Clam is now established in most of the major river systems in the United States (Fuller and Powell 1973), including those streams still supporting surviving populations of the DWM. Concern has been raised over competitive interactions for space, food, and oxygen with this species and native mussels, possibly at the juvenile stages (Neves and Widlak 1987; Alderman 1995). The zebra mussel, native to the drainage basins of the Black, Caspian, and Aral Seas, is an exotic freshwater mussel that was introduced into the Great Lakes in the 1980s and has rapidly expanded its range into the surrounding river basins, including those of the South Atlantic slope (O'Neill and MacNeill 1991). This species competes for food resources and space with native mussels and is expected to contribute to the extinction of at least 20 freshwater mussel species if it becomes established throughout most of the eastern United States (USFWS 1992b). The zebra mussel is not currently known from any river supporting DWM populations.

2.3.6. *Loss of Riparian Buffers*

Loss of riparian buffers can lead to degradation of adjacent aquatic habitats. The role of forested riparian buffers in protecting aquatic habitats is well documented (NCWRC 2002). Riparian buffers provide many functions including pollutant reduction and filtration, a primary source of carbon for aquatic food webs, stream channel stability, and maintenance of water and air temperatures. Numerous studies have recommended a range of buffer widths needed to maintain these functions. Recommended widths vary greatly depending on the parameter or function evaluated. Wide contiguous buffers of 100-300 feet are recommended to adequately perform all functions (NCWRC 2002). The NCWRC recommends a minimum 200-foot native, forested buffer on perennial streams and a 100-foot forested buffer on intermittent streams in watersheds that support federally endangered and threatened aquatic species (NCWRC 2002). Although not officially adopted, the USFWS uses the NCWRC recommendations as guidance when addressing federally protected aquatic species in North Carolina.

2.3.7. *Degradation Caused by All-terrain Vehicle Use*

Another human-related factor adversely impacting habitat of the DWM is recreational all-terrain vehicle (ATV) use. ATV tracks have been noted crossing streams as well as traveling stream channels throughout the Swift Creek watershed. In addition to directly running over mussels, ATVs destabilize stream banks and floodplains, causing sedimentation and buffer degradation.

While there is no quantitative data available on ATV use, locally, this can have significant impacts.

Photo 2. ATV Trails in Swift Creek Channel

3.0 WATERSHED CONDITIONS

An overall assessment of current and past conditions of the watershed is crucial to understanding mussel population viability. Various GIS layers, aerial photography, and publications were consulted to characterize the past and current conditions within the SCW.

GIS data layers utilized include the National Land Cover Database (NLCD) and the National Pollution Discharge Elimination System (NPDES) database. The land cover shapefile is available from the United States Department of Agriculture/Natural Resources Conservation Service GeoSpatial Data Gateway (USDA 2013). The nationwide comprehensive land cover data layer was created through a cooperative project conducted by the Multi-Resolution Land Characteristics (MRLC) Consortium using data through 2006. The NPDES shapefile is available online from NC OneMap as updated by the NCDWQ in 2006. The file identifies outfall locations and type of individual NPDES permitted wastewater discharges. The NC Division of Water Resources (NCDWR, formerly the NC Division of Water Quality (NCDWQ)) also keeps a more updated list of active NPDES permits. The list, updated September 6, 2013, was used along with the shapefile to locate active permitted dischargers (NCDWR 2013a). **Please note: References to NCDWQ indicate information that was published prior to the agency name change.**

3.1. Land Use and Population Growth

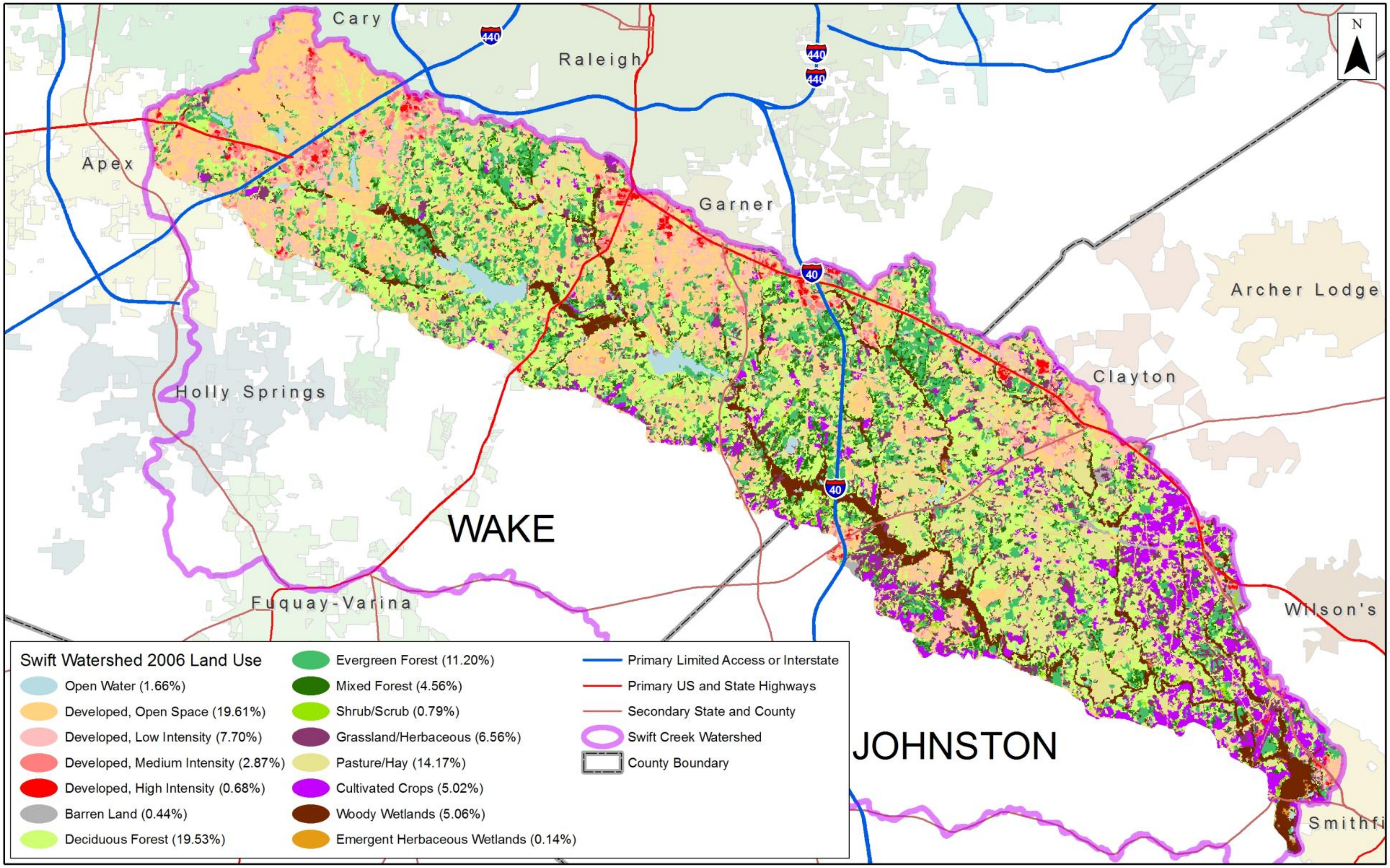
There has been development in SCW in the last half a century, particularly in the towns of Cary and Apex, and along highway corridors (AMEC 2004). Cary's population grew from 7,640 to over 135,000 between 1970 and 2010 (NCDWQ 2003a; US Census 2014). As of 2012, according to the latest US Census Bureau estimates, Cary's population is estimated to be over 145,000 (US Census 2014). Apex's population grew from 2,192 to over 37,000 between 1970 and 2010 (NCDWQ 2003a; US Census 2014). Apex's population is estimated to be over 40,000 as of 2012 (US Census 2014). The upper portion of SCW has mostly been built out over the last 20 years, with the remaining forested areas lying almost completely in nature preserves or floodplains (see Section 3.1.1 below). Further development will likely not affect the water quality within the Upper SCW, given the large majority of development has already taken place (NCDWQ 2003a). However, development is likely to happen in the Lower SCW where more undeveloped parcels remain.

The trend of development in recent years has occurred throughout much of the Neuse River Basin. Land cover information from the National Resources Inventory (NRI), which is published by the Natural Resource Conservation Service (NRCS), was collected several times between 1982 and 1997 and was presented in the 2009 Neuse River Basinwide Water Quality Plan, Chapter 16 – Community Changes and Challenges (NCDWQ 2009). While the data is outdated and presented at a larger scale than the project study area (the entire Neuse River Basin versus SCW), it demonstrates the development of the Neuse River Basin during the 15-year period for which data is available (Table 2). The most important change with regard to aquatic species is the conversion of agricultural land cover (-17%) and forest cover (-7.2%) to urban and developed land (+89.8%).

Table 2. Land Cover in the Neuse River Basin: 1982 vs. 1997 (NCDWQ, 2009)

Land Cover	1982 % of Total	1997 % of Total	% Change since 1982
Cultivated crop	28.8	23.9	-17.0
Uncultivated crop	0.4	1.5	275
Pasture	3.2	3.7	16.7
Forest	48.4	44.9	-7.2
Urban & built-up	6.9	13.1	89.9
Federal	2.1	2.3	9.5
Other	10.4	10.6	1.9

A more recent land cover dataset is available from the NLCD (Figure 3). The 2006 dataset is satellite data with a spatial resolution of 30 meters. The 2006 land use dataset is in a more manageable format, and thus SCW could be examined exclusively. Taken in coordination with the other land use dataset, it is a clearer picture of the amount of developed lands, compared to the amount of agriculture and forestry cover for SCW. The 2006 dataset also divides land use into more categories, such as varying degrees of development and types of forest (Table 3).



The Catena Group

Client:

Dwarf Wedgemussel Viability Study: Phase 1

Swift Creek Watershed Land Use - 2006

Wake & Johnston Counties, North Carolina

Date: February 2014

Scale: 0 1 2 Miles

Job No.: 1154

Figure 3

Table 3. Land Use cover in Swift Creek Watershed, NLCD 2006

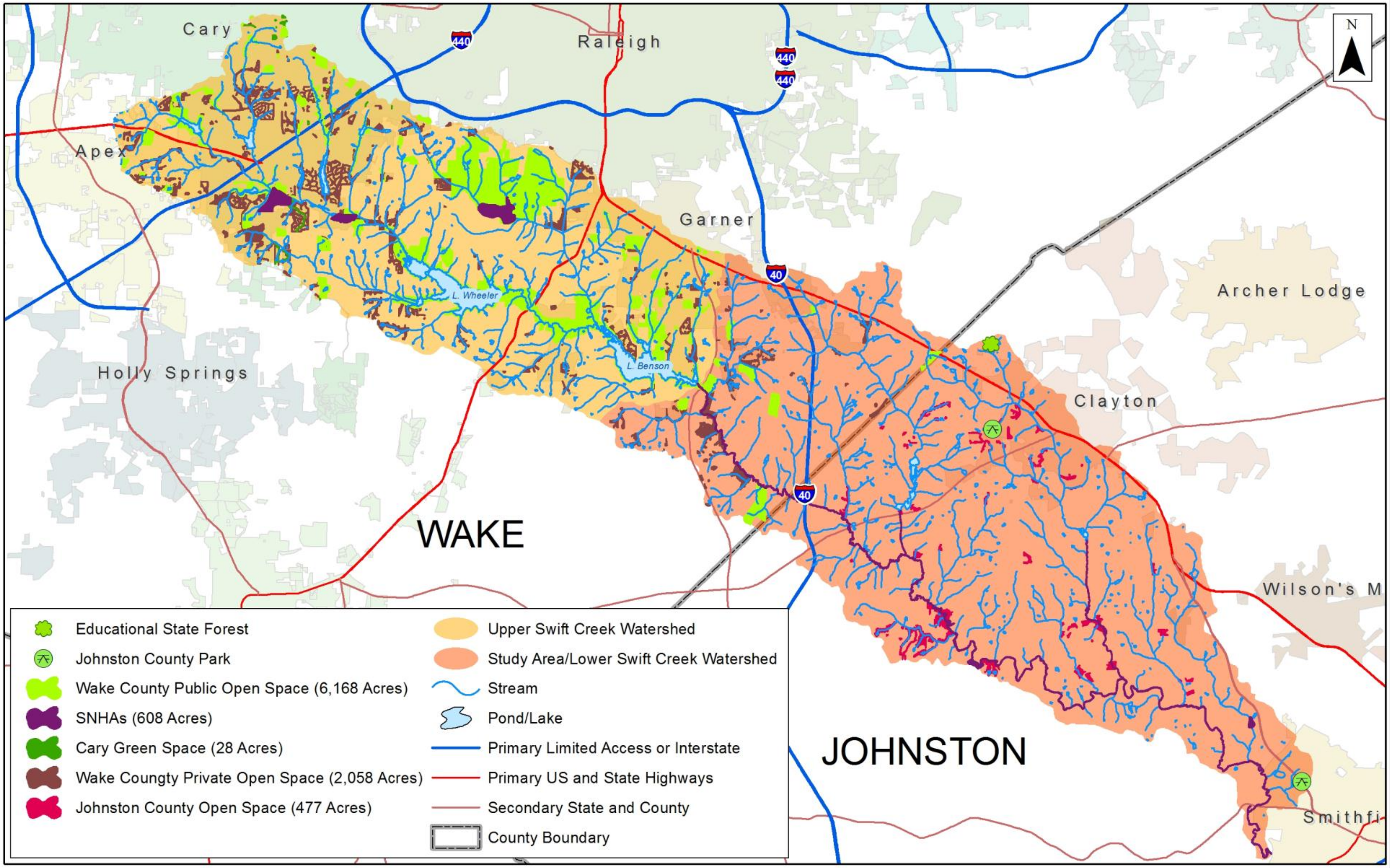
Land Use	Sum of Area (Square Miles)	Percent
Open water	2.57	1.66
Developed, open space	30.33	19.61
Developed, low intensity	11.92	7.70
Developed, medium intensity	4.45	2.87
Developed, high intensity	1.05	0.68
Barren land	0.69	0.44
Deciduous forest	30.21	19.53
Evergreen forest	17.33	11.20
Mixed forest	7.05	4.56
Shrub/scrub	1.22	0.79
Grassland/herbaceous	10.14	6.56
Pasture/hay	21.93	14.17
Cultivated crops	7.77	5.02
Woody wetlands	7.83	5.06
Emergent herbaceous wetlands	0.21	0.14
Total	154.70	100

Of the various water bodies within the watershed, Lake Wheeler makes up about 0.875 square mile, and Lake Benson about 0.521 square mile. Other ponded areas constitute the other 1.173 square miles of open water in the watershed.

3.1.1. Natural Heritage Areas, Parks and Green Space

There are several natural heritage areas, parks, and green spaces within the Upper SCW (Table 4; Figure 4). The Hemlock Bluffs Nature Preserve near Cary, upstream of Kildaire Farm Road, is approximately 122 acres in size and has a rating of Moderate (See Section 1.0). The Triangle Land Conservancy (TLC) maintains the Swift Creek Bluffs Nature Preserve, which is upstream of Holly Springs Road; it has a rating of Moderate, and is nearly 50 acres in size. TLC also maintains conservation easements on two farms, Theys and MacNair Farms (also referred to as Steep Hill Creek Bottomlands), totaling 130 acres. An area of approximately 160 acres around and including Yates Mill Pond has been rated as Exceptional.

In the Lower SCW (Figure 4), there is a 240-acre SNHA (Swift Creek (Wake/Johnston) Aquatic Habitat) along the main stem of Swift Creek from Lake Benson to Smithfield, as well as lower portions of White Oak and Little Creeks, which is rated as “High” (NCNHP 2013). A major portion of this SNHA is subject to protective measures that go above and beyond measures that apply to the entire Neuse River (see section 3.2.6). The NCNHP recommends a High Quality Water designation for this stretch of Swift Creek, which would not allow any additional discharges into the stream (NCNHP 2003). Adjacent to a portion of the Swift Creek Aquatic Habitat SNHA is the Swift Creek Magnolia Slopes, which has a rating of General and is almost 20 acres.



The Catena Group

Client:

Dwarf Wedgemussel Viability Study: Phase 1

SNHAs, Parks, & Green Space
Upper & Lower Swift Creek Watershed

Wake & Johnston Counties, North Carolina

Date: February 2014

Scale: 0 1 2 Miles

Job No.: 1154

Figure 4

Table 4. Upper SCW and Study Area Total Acreage of Open Space (compared to total area).

Upper SCW	Acres
SNHAs	332
Wake County Public	5741
Wake County Private	1610
Cary Green Space	28
TLC	130
Total Open Space	*7841*
Total Area	*42279*

Study Area (Lower SCW)	Acres
SNHAs	276
Wake County Public	427
Wake County Private	448
Johnston County Open Space	477
Parks	84
Total Open Space	*1712*
Total Area	*56673*

Also of significance are public parks and open or green spaces designated by municipalities. There are a number of such areas in both the Upper and Lower SCW (Table 4).

3.2. Surface Water Classification and Use Support Ratings in SCW

The State of North Carolina assigns a best usage classification to all waters of North Carolina. These classifications provide a level of water quality protection to ensure that the designated usage of that water body is maintained. The minimum designation of Class C waters are defined as waters that are suitable for aquatic life propagation and survival, fishing, wildlife, secondary recreation and agriculture. Class C imposes a minimum standard of protection for all waters of North Carolina. Swift Creek is classified as a Water Supply-III (WS-III), Nutrient Sensitive Waters (NSW) from the headwaters to the dam at Lake Benson. WS-III classification indicates a water body used as a source for drinking water where a more strict classification is not feasible, and also protected for Class C uses. WS-III waters are generally in low to moderately developed watersheds. NSW is a supplemental classification intended for waters needing additional nutrient management due to being subject to excessive growth of microscopic or macroscopic vegetation. Swift Creek from the dam at Lake Benson to the Neuse River is a Class C, NSW stream, including Mahler's Creek, White Oak Creek, Little Creek and Reedy Branch.

There is also a Critical Area (CA) classification on the waters of Swift Creek from about one mile above Lake Benson to the dam at Lake Benson. A CA classification is defined as land within a half-mile upstream and draining to an intake area or draining to the water supply reservoir (NCDWR 2014). These are areas where the risks associated with pollution to drinking water supplies are greater than in other areas in the watershed.

The entire Neuse River Basin is classified as NSW. Based on the use of surface water within the watershed as a drinking water source, in addition to the desire to protect the many natural resources present, the entire SCW is identified as a high priority for protection in Wake County (CH2M Hill 2003). From Lake Benson to its confluence with the Neuse River, Swift Creek is classified as C NSW.

Both point source and non-point source discharges contribute to water quality degradation by introducing various pollutants into the water body. Federal and state legislation exists that is intended to help maintain or restore the environmental quality of North Carolina waters.

3.3. Water Quality Conditions in SCW

As discussed in Section 2.3, degradation of water quality is a major threat to aquatic species including DWM. Section 304(a)(1) of the Clean Water Act (CWA) requires the EPA to develop criteria for water quality that accurately reflects the latest scientific knowledge. These criteria are used as guidance to States and authorized Tribes, which under Section 303(c)(2)(B) of the CWA are required to adopt numeric criteria for §307(a) priority toxic pollutants for which the EPA has published §304(a) criteria, if the discharge or presence of the pollutant can reasonably be expected to interfere with designated uses, such as aquatic life. The §307(a) list contains 65 compounds and families of compounds, which the Agency has interpreted to include 126 priority toxic pollutants. In addition to narrative and numeric (chemical-specific) criteria, other types of water quality criteria include:

- Biological Criteria (description of the desired aquatic community)
- Nutrient Criteria (protection against nutrient over-enrichment and eutrophication)
- Sediment Criteria (protection from adverse effects of contaminated and uncontaminated sediments)

The CWA also requires states to "hold public hearings for the purpose of reviewing applicable water quality standards and, as appropriate, modifying and adopting standards" at least once every three years, referred to as Triennial Reviews-33 U.S.C. § 1313(c)(1). The most recent Triennial Review hearing was held on November 19, 2013, with a comment period that ended on January 03, 2014. The NC Conservation Network (NCCN) provided numerous comments, pointing out that the Triennial Review hearing was "four years overdue" as the last public hearing was held in 2006 (NCCN 2014). NCCN also stated that North Carolina "lags behind neighboring states in adopting standards" that meet EPA water quality criteria recommendations. They cite that NC currently does not have water quality standards for ammonia and various heavy metals including Copper, and recommend the EPA criteria be used to develop these standards (NCCN 2014). Numerous other recommendations are also made with regard to establishing standards, and revising existing standards of various other toxicants.

3.3.1. Water Quality Monitoring

Physical, chemical, and biological parameters are routinely monitored to assess water quality of a particular water body to determine if the established uses of the water body are being maintained. Water quality monitoring programs have been implemented by the NCDWR to assess water quality trends throughout the State. As discussed in Section 3.3, numeric standards of chemical and physical parameters have been established to determine if designated uses are met.

Biological criteria can be monitored in a variety of ways, including benthic macroinvertebrates and fish community composition. Benthic macroinvertebrates, or benthos, are monitored to assess water quality by sampling for selected organisms. The species richness and overall biomass, as well as the presence of various groups intolerant of water quality degradation, are reflections of water quality. A biodiversity rating is given to a sampled water body based on the taxa richness of the stream and a qualitative sampling for intolerant forms such as mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera), collectively referred to as EPT. Stream biodiversity can be rated as Excellent, Good, Good-Fair, Fair and Poor. Excellent and Good ratings indicate that the best usage classification for that stream is being Supported (S); Good-Fair rating indicates that the usage is Supported, but is also Threatened (ST); Fair rating indicates Partial Support (PS) of the best usage; and a Poor rating indicates that the best usage classification is Not Supported (NS).

There are 11 monitoring sites at which water quality and/or discharge rates are measured within SCW, operated by the US Geologic Survey (USGS), the City of Raleigh, or the Lower Neuse Basin Association (LNBA) (Table 5; Figure 5). For stations that monitor discharge, there are maximum, minimum, and mean of daily discharge values calculated in cfs for each day of the recording period. Discharge data is analyzed in Section 6.0. USGS monitoring stations were found using the USGS National Water Information System mapper (USGS 2013).

Water quality is determined based on a set of parameters that indicate the health and function of a water body. The NCDWQ's "Redbook" of Surface Waters and Wetlands Standards (NCDWQ 2003b) provides standard levels at which parameters should be measured to indicate good water quality. Additionally, USEPA has published guidelines on specific parameters, ammonia and copper in particular, that provide more detailed information for aquatic species sensitivity to these parameters (USEPA 2007 and 2013). In this analysis, the EPA's 2013 criteria for ammonia are used, which are dependent on pH and temperature to determine appropriate ammonia ecological thresholds. The EPA's criteria for copper, however, are not used, as this determination requires the measurement of an additional eight parameters, which were not always available. For simplicity, the NCDWQ copper standard (7 ug/L) is used instead. Other parameters of importance to aquatic life, particularly freshwater mussels, examined here are (with respective standard levels): DO (>5.0 mg/L), pH (6.0-9.0), turbidity (<50 Nephelometric Turbidity Units (NTU)), and temperature.

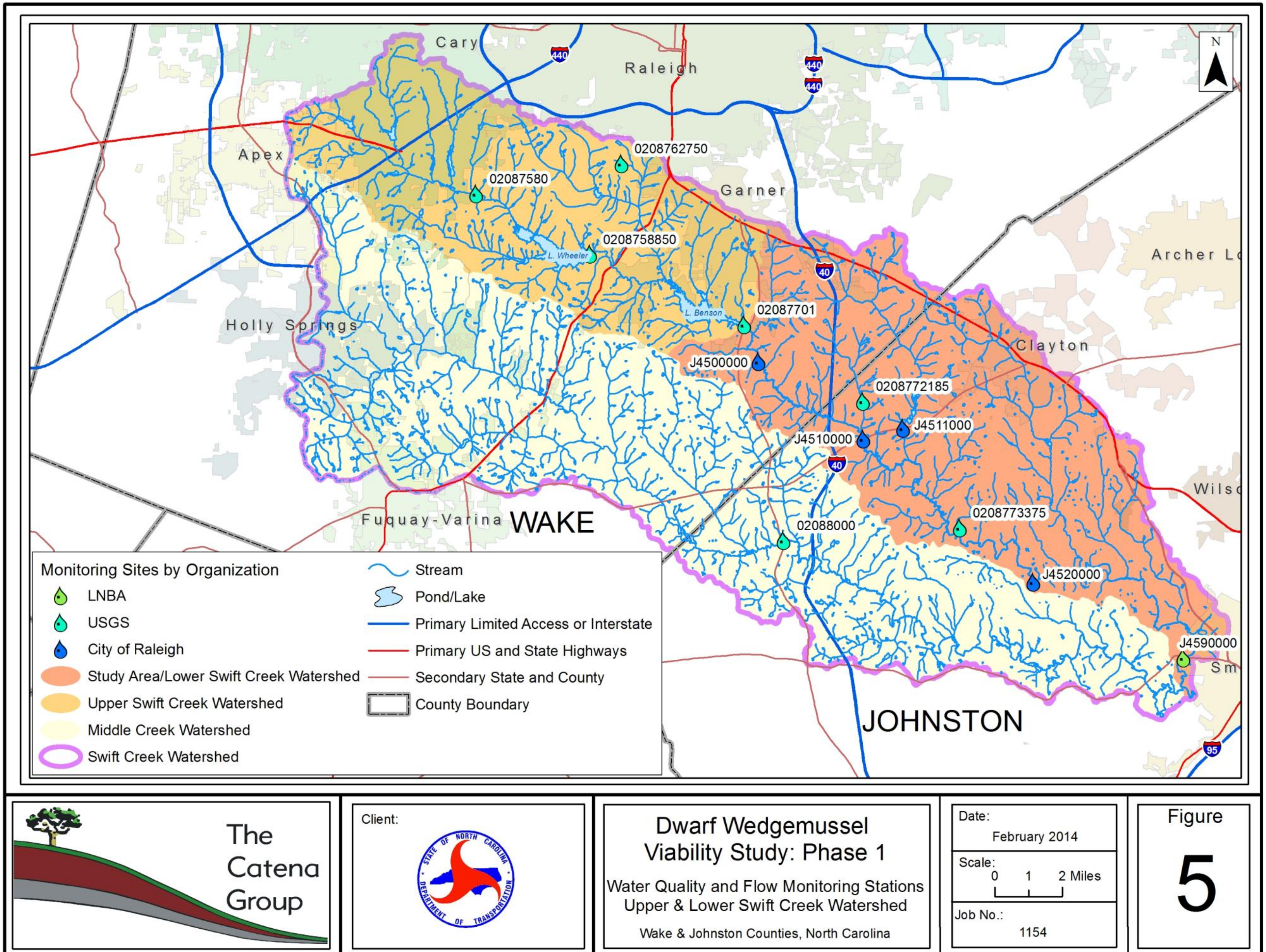

Cary
Raleigh
Apex
Garner
Holly Springs
Archer Lo
Clayton
Wilso
Fuquay-Varina
WAKE
JOHNSTON
Sm
L. Wheeler
L. Benson
0208762750
02087580
0208758850
02087701
J4500000
0208772185
J4511000
J4510000
0208773375
02088000
J4520000
J4590000
Monitoring Sites by Organization
LNBA
USGS
City of Raleigh
Study Area/Lower Swift Creek Watershed
Upper Swift Creek Watershed
Middle Creek Watershed
Swift Creek Watershed
Stream
Pond/Lake
Primary Limited Access or Interstate
Primary US and State Highways
Secondary State and County
County Boundary
N
The Catena Group
Client:
Dwarf Wedgemussel Viability Study: Phase 1
Water Quality and Flow Monitoring Stations
Upper & Lower Swift Creek Watershed
Wake & Johnston Counties, North Carolina
Date:
February 2014
Scale:
0 1 2 Miles
Job No.:
1154
Figure
5

Table 5. Water Quality Monitoring Sites in Swift Creek Watershed

Upper/ Lower	Site No.	Location	Operator	Parameters measured
Upper	02087580	Swift Crk near Apex	USGS	WQ, discharge
Upper	0208762750	UT to Swift Crk near Yates Mill Pond	USGS	WQ, discharge
Upper	0208758850	Swift Crk at McCullars Crossroads	USGS	Discharge
Upper	02087701	Lake Benson at Dam near Garner, NC	USGS	WQ
Lower	J4500000 (52)	Swift Crk near Garner (Indian Creek)	City of Raleigh	WQ
Lower	J4510000 (54)	Swift Crk at NC 42 near Clayton	City of Raleigh	WQ
Lower	J4520000 (56)	Swift Crk at SR 1562 near Smithfield	City of Raleigh	WQ
Lower	J4511000 (55)	White Oak Crk at NC 42 near Clayton	City of Raleigh	WQ
Lower	0208772185	Swift Crk at NC 42 near Clayton, NC	USGS	Discharge
Lower	0208773375	Swift Crk at SR1555 near Clayton	USGS	Discharge
Lower	J4590000	Swift Crk at NC 210 near Smithfield	LNBA	WQ

3.3.1.1. Upper SCW

The USGS station near Apex (Site No. 02087580) collected water quality data from 1989 to 1995 and then again from 2000 to 2011. Monthly temperature measurements were taken, with temperatures ranging between 1°C and 28.2°C. Ammonia was measured on a monthly basis. Ammonia levels did not exceed either the acute or chronic levels (USEPA 2013). Of the more than 200 DO measurements, approximately 20 samples dipped below the 5.0 mg/L standard, the lowest reading being 1.7 mg/L of DO. Monthly pH measurements indicated the pH levels fell outside the NCDWR recommended range (6.0 to 9.0, NCDWQ 2003b) only three times. Copper measurements were taken 25 times between 1989 and 1995. These 25 measurements did not exceed the NCDWR water quality standard.

The LNBA also took water quality measurements at this station between 2006 and 2010, referring to it as the station at SR 1152 Holly Springs Road near Macedonia. Water quality measurements taken included DO, pH, temperature, turbidity, and ammonia, among others. The results presented by the NCDWRs Basinwide Assessment of Ambient Monitoring (2013). Temperature measurements range between 4.3°C and 29.4°C in 85 samples. Ammonia measurements were taken a total of 60 times during sampling, and ranged between 0.01 mg/L and 0.33 mg/L. DO was described by LNBA as below 5.0 mg/L on 11 samples out of 84. Additionally, DO levels were below 4.0 mg/L in one sample. The pH levels were not recorded outside of the 6.0 and 9.0 range during sampling. The results do not have an elevated level for ammonia. Three samples out of 60 exceeded the elevated level of turbidity (50 NTU). For the result statistics done by LNBA, see Appendix A.

The USGS station near Yates Mill Pond (0208762750) collected data from 2002 to 2011. Water quality measurements at this station were less frequent than at other stations. Water temperature measurements were taken 19 times and ranged between 6.6°C and 21.2°C. Ammonia levels never exceeded acute or chronic levels, though some measurements did not have corresponding pH and temperature measurements. Ammonia chronic and acute standards are dependent on pH and temperature, but because the pH measurements were generally low (6.0 or below), and ammonia becomes less of an issue with lower pH levels, there is less of a chance these ammonia levels posed a risk to aquatic life. Measurements of 19 samples for DO levels indicated just one sample below the standard level of 5.0 mg/L. Twelve of the 22 samples measuring pH were below 6.0, the level the NCDWR recommends for healthy water bodies. Two copper measurements were below the standard for that parameter (USGS, 2013). The Yates Mill Pond station also has daily flow rate statistics for 2003 to 2004.

The USGS station in Lake Benson (02087701) collected data from 1970 to 2011, although only one sample was taken in 1970 and then none were taken again until 1989. Samples were taken from April to November. Approximately 100 temperature readings were taken ranging from 10°C to 33°C. Ammonia measurements exceeded the chronic levels in two out of 101 samples (taken August 30, 2006 and August 8, 2009), but did not exceed acute levels. DO readings were taken on 100 samples, 38 of which were below 5 mg/L. pH measurements were taken in some cases in both the field and in the lab. Lab measurements, however, were not taken after 1995. The pH level at this station dropped below 6.0 on three occasions (July 5, 2006 and twice on April 26, 2007). Copper measurements were taken fairly regularly, and exceeded 7 ug/L on one occasion (April 15, 2010). The USGS station at McCullars Crossroads collected discharge data starting in 1988 (USGS 2013).

3.3.1.2. Lower SCW

Water quality data collected by the City of Raleigh from 2009 to 2012 includes collection of samples on 42 dates. These were obtained from Edward Buchan, Environmental Coordinator with the City of Raleigh on July 17, 2012. For Phase 2, an updated accounting of this dataset is recommended.

Temperatures at Indian Creek discharge (station number J4500000) near Garner ranged between 4.3°C and 29.4°C. Ammonia levels did not exceed the chronic or acute levels. DO fell below 5.0 mg/L on 10 different occasions. The pH levels remained between 6.0 and 9.0 on days when samples were collected. Turbidity levels did not exceed 50 nephelometric turbidity units (NTU) on days when samples were collected (Buchan 2012).

Temperatures at NC 42 (station number J4510000) near Clayton ranged between 4.4 and 28.8°C. Ammonia levels did not exceed the chronic or acute levels. DO did not dip below 5.0 mg/L. The pH levels remained between 6.0 and 9.0 on days when sampling was conducted. Turbidity was measured at 90 NTU on January 22, 2010, exceeding the 50 NTU level (Buchan 2012).

Temperatures at SR 1562 (station number JJ4520000) near Smithfield ranged between 4.9°C and 27.4°C. Ammonia levels did not exceed the chronic or acute levels. DO and pH levels remained within the appropriate range on days when sampling at this station was conducted. Turbidity was measured at 55 NTU on January 22, 2010, exceeding the 50 NTU level (Buchan 2012).

Temperatures at White Oak Creek at NC 42 near Clayton ranged from 4.6°C to 28.7°C. Ammonia levels did not exceed the chronic or acute standard level. DO measurements were below 5.0 mg/L on 12 days when samples were taken; pH levels remained between 6.0 and 9.0 on days when samples were taken during the sampling period. Turbidity was measured at 60 NTU on March 31, 2010, exceeding the 50 NTU level (Buchan, 2012).

The USGS station on Swift Creek at NC 42 near Clayton (0208772185) measured flow rates from 1988 to 1997 on 28 occasions, with an average flow of 73 cfs. The greatest flow occurred on May 1, 1996 (796 cfs) and the lowest flow occurred on August 8, 1990 (5.9 cfs). The USGS station on Swift Creek at SR 1555 near Clayton (0208773375) has been taking measurements of flow rates since 2008. For a more detailed discussion of this monitoring station, see Section 6.0.

The LNBA station at NC 210 near Smithfield had temperatures range between 3.9°C and 29.9°C in 85 samples. Ammonia measurements were taken a total of 60 times during sampling, with values ranging between 0.01 and 0.44 mg/L. Sample levels of DO were never below 4.0 mg/L from a total of 85 samples, and below 5.0 mg/L in one sample. The pH levels were not recorded outside of the 6.0 and 9.0 range during sampling. Turbidity measurements exceeded 50 NTU in four out of 60 samples. Detailed statistics for data recorded at this station are in Appendix A (NCDWQ 2013).

In addition to water quality data collected from USGS, the City of Raleigh, and LNBA, a study was done by the USFWS from June 2003 to July 2004 (Ward et al. 2007). Water quality samples were taken from three streams within North Carolina in which federally endangered freshwater mussel populations are known to exist. One of the watersheds studied was Swift Creek, including two monitoring locations on White Oak Creek, and the use of station J4510000 near Clayton was colocated with a sampling point in the study area. Ammonia, copper, and chlorine levels were analyzed. As discussed in Section 2.3.3, the study concluded that copper levels were elevated in Swift Creek. A more thorough assessment of this study and the raw data associated with it are recommended for Phase 2.

3.3.2. 303(d) Impaired Streams

As mandated in Section 303(d) of the CWA, states, territories, and authorized tribes are required to develop lists of impaired waters, which are defined as water bodies that do not meet water quality standards that states, territories, and authorized tribes have set for them, even after point sources of pollution have installed the minimum required levels of pollution control technology. These water quality standards include designated uses, numeric and narrative criteria, and anti-degradation requirements as defined in 40 CFR 131. Failures to meet standards may be due to an individual pollutant, multiple pollutants, or unknown causes of impairment, originating from point and non-point sources and/or atmospheric deposition. The law requires that these jurisdictions establish priority rankings for waters on the lists and develop Total Maximum Daily Load limits (TMDLs) of identified pollutants for these waters. All waters in NC are rated Category 5 on the 2012 303(d) list for Mercury; Category 5 impaired waters require development of a TMDL for the parameter of concern (NCDWQ 2012). Once a TMDL is established for a stream segment, the segment is removed from the 303(d) list.

There are a number of streams that are impaired in the SCW (NCDWQ 2012, Figure 6). Based on the most recent report by the NCDWR (NCDWQ 2012), much of the Upper SCW is impaired, or has only recently been removed from the 303(d) list upon adoption of a TMDL. A large portion of the Lower SCW is also impaired, from Lake Benson to the confluence with Little Creek north east of Smithfield. All of the streams rated as impaired were due to NS ratings. The NS ratings were attributed to habitat degradation from impoundments, Municipal Storm Sewer Systems, WWTP NPDES sources, and stormwater runoff (NCDWQ 2012).

3.3.2.1. Upper SCW

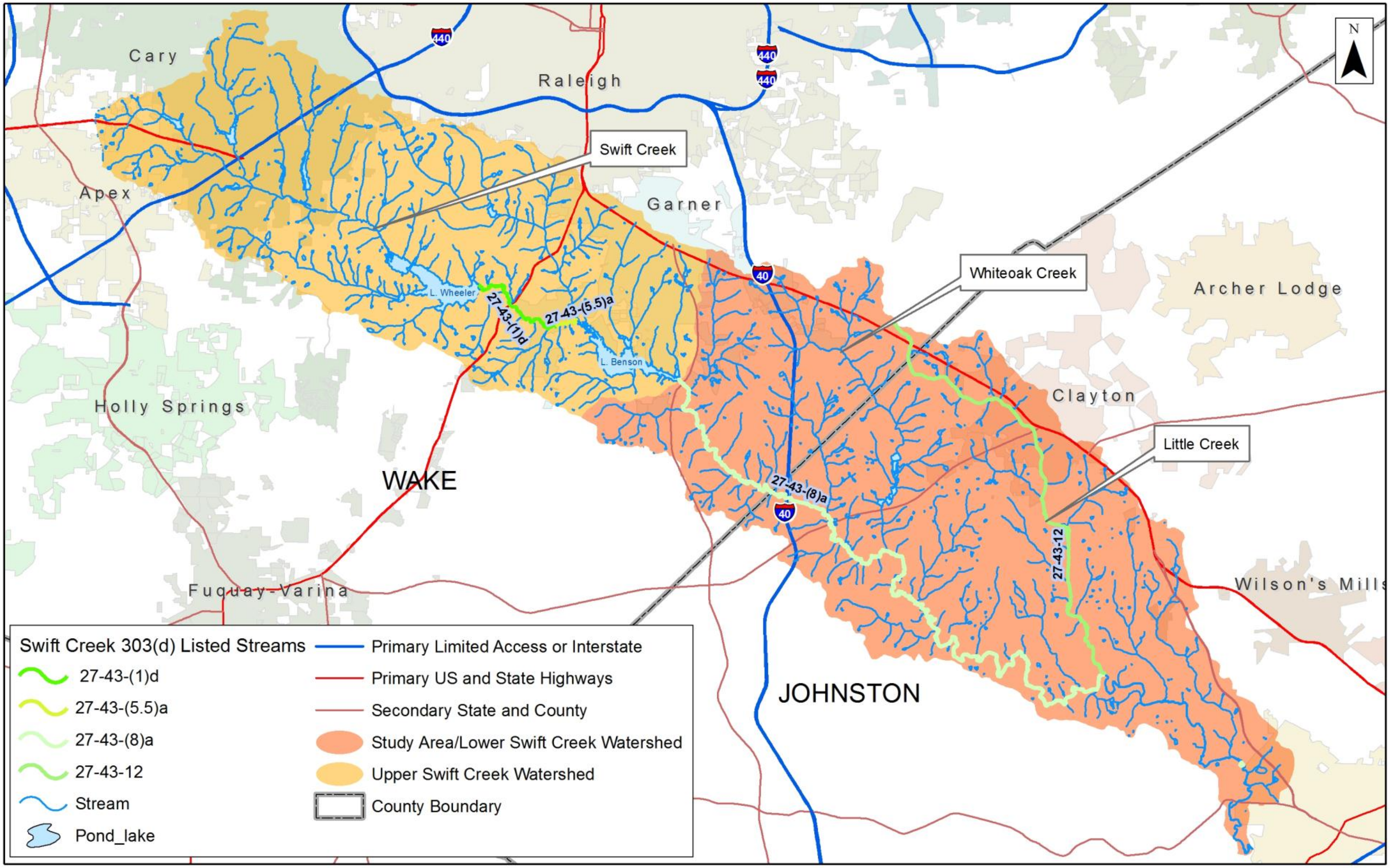
There are two stream segments in the Upper SCW listed as impaired (NCDWQ 2012, Table 6). The headwaters of Swift Creek to the confluence with Williams Creek (Assessment Unit # 27-43-(1)a), a distance of 2.6 miles, was added to the 303(d) list in 1998 for Fair Bioclassification. This segment of Swift Creek now has an approved TMDL for ecological/biological integrity.

Table 6. Upper SCW Impaired (Category 5) Streams 2012. Use of streams for "Aquatic Life".

Stream	AU Number	Length/Area	Reason for Rating	Parameter (Year)
Swift Creek	27-43-(1)d	2.4 FW Miles	Poor Bioclassification	Ecological/Bio Int, Benthos (2008)
Swift Creek (Lake Benson)	27-43-(5.5)a	0.87 FW Miles	Poor Bioclassification	Ecological/Bio Int. Benthos (2008)

FW: Freshwater

From the confluence with Williams Creek to the backwaters of Lake Wheeler (AU# 27-43-(1)b), a distance of 5.5 miles, Swift Creek was listed as impaired in 1998 for Poor Bioclassification. This segment of Swift Creek also has an approved TMDL for this parameter (NCDWQ 2012). As determined in the 2009 Basinwide Water Quality Plan, this stretch of stream had Fair benthic ratings at two monitoring sites (JB52 – Holly Springs Road and JB53 – Hemlock Bluffs). The land cover along this stretch is predominantly residential, with severely eroding stream banks and little vegetation. Ambient water monitoring data within this stretch (JA24) has shown low DO levels, elevated fecal coliform levels, elevated turbidity levels and elevated conductivity levels, which are indicative of nonpoint source pollution. The Town of Cary had a wastewater spill in this stretch of the stream in June 2006 totaling 7.9 million gallons. This is, therefore, a stressed segment of Swift Creek and has been highly impacted by growth and an accidental



The Catena Group

Client

Dwarf Wedgemussel Viability Study: Phase 1

2012 303(d) Impaired Streams of Swift Creek Watershed

Wake & Johnston Counties, North Carolina

Date: February 2014

Scale: 0 1 2 Miles

Job No.: 1154

Figure 6

sewage spill (NCDWQ 2009), though it now has a TMDL and has been removed from the 303(d) list (NCDWQ 2012).

Williams Creek (AU# 27-43-2) was also listed as impaired in 1998 for Poor Bioclassification. This segment is 2.6 miles and has an approved TMDL for Ecological/biological Integrity Benthos (NCDWQ 2012). Lake Wheeler (AU# 27-43-(1)c) was not rated on the 2012 303(d) list of impaired streams (NCDWQ 2012), though Chloraphyll a and pH were assessed and determined to have insufficient or inconclusive data. Primary recreational activities in the lake, including swimming and water skiing, were suspended in the summer of 2006 due to elevated bacteria levels which may partially be attributed to the wastewater spill mentioned above. This suspension remains in effect. The lake remains open for boating and fishing (NCDWQ 2009).

Swift Creek from Lake Wheeler Dam to the backwaters of Lake Benson (AU# 27-43-(1)d) and AU# 27-43-(5.5)a), a total of 3.3 miles, is impaired due to Poor Bioclassification at sampling site JB56 (NCDWQ 2012, Table 6). Erosion, habitat degradation and urban influences are all problems associated with this stretch of stream (NCDWQ, 2009).

Lake Benson (AU# 27-43-(5.5)b) was not rated on the 2012 303(d) list (NCDWQ 2012), though Chlorophyll a and high temperature were assessed and determined to have insufficient or inconclusive data. The City of Raleigh, as a condition of building the Dempsey E. Benton Water Treatment Plant in May 2010, has worked to ensure DO levels remain at optimum levels in the lake. An aeration system has been installed, and several surveys of DO levels have been conducted, the most recent (July 2012) of which indicates that waters below the aeration system have remained lower than the 5 mg/L critical level recommended by the NCDWR, but that these levels were an improvement over those observed for the same time period in 2011. In general, surface waters had higher DO levels than bottom water (email communication, City of Raleigh, July 2012).

3.3.2.2. Lower SCW

Two stream segments are currently considered impaired in the Lower SCW (Table 7). In 2009, Swift Creek (AU# 27-43-(8), 32.7 miles) below Lake Benson was considered to have good water quality and stream conditions and was rated as Supporting for aquatic life and recreational uses based on Good and Good-Fair benthic ratings at JB54 and JB55 (NCDWQ 2009). Additionally, there were no exceedances at ambient monitoring sites JA25 and JA26. However, sedimentation and erosion were identified as moderately impacting parts of this segment of the stream. In 2012, the upper portion of this stretch of Swift Creek (AU# 27-43-(8)a, 20.6 miles from dam at Lake Benson to Little Creek) was placed on 303(d) list for aquatic life because of a Fair Bioclassification rating. Little Creek (AU# 27-43-12) has been listed as impaired for ecological/biological integrity since 1998 (NCDWQ 2012). The length of this segment, from the headwaters of Little Creek to the confluence with Swift Creek, is 11.4 miles.

Table 7. Study Area Impaired (Category 5) Streams 2012. Use of streams for "Aquatic Life".

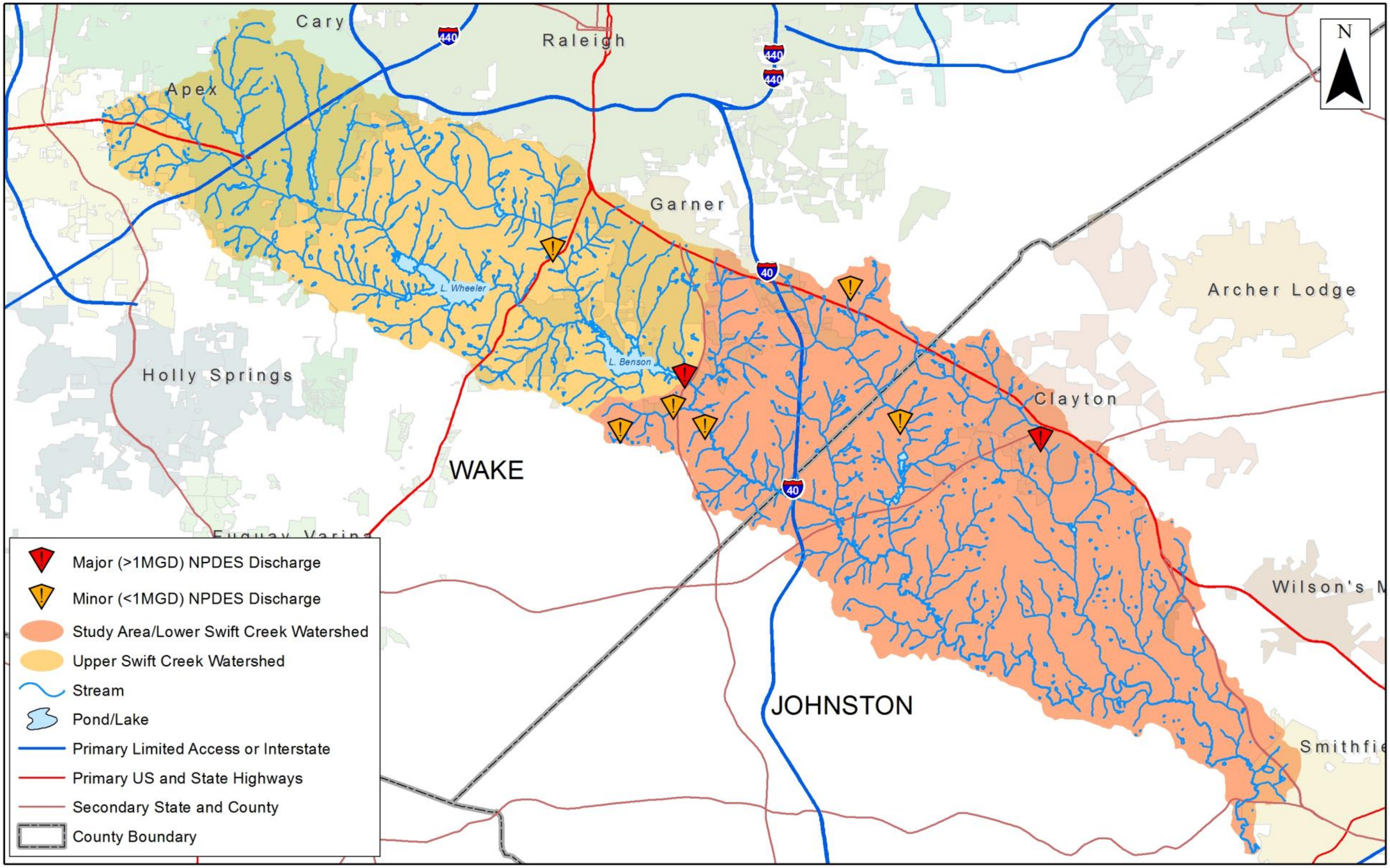
Stream	AU Number	Length/Area	Reason for Rating	Parameter (Year)
Swift Creek	27-43-(8)a	20.6 FW Miles	Fair Bioclassification	Ecological/Bio Int, Benthos (2012)
Little Creek	27-43-12	11.4 FW Miles	Fair Bioclassification	Ecological/Bio Int. Benthos (1998)

3.3.3. Point Source Pollution

Point source discharge is defined as discharges that enter surface waters through a pipe, ditch, or other well-defined point of discharge. These include municipal (city and county) and industrial wastewater treatment facilities, small domestic discharging treatment systems (schools, commercial offices, subdivisions and individual residents), and stormwater systems from large urban areas and industrial sites. The primary substances and compounds associated with point source discharge include nutrients, oxygen demanding wastes, and toxic substances such as chlorine, ammonia, and metals.

Under Section 301 of the CWA, discharge of pollutants into surface waters is prohibited without a permit by the Environmental Protection Agency (EPA). Section 402 of the CWA establishes the National Pollutant Discharge Elimination System (NPDES) permitting program, which delegates permitting authority to qualifying states. In North Carolina, NCDWR is responsible for permitting and enforcement of the NPDES program. Point source dischargers located throughout North Carolina are permitted through the NPDES program. All dischargers are required to register for a permit. NPDES dischargers are divided into two classes: major and minor. Major discharges are permitted to discharge one million gallons per day (MGD) or greater. Minor discharges are permitted to discharge less than 1 MGD. In the SCW, there are two major discharges (Dempsey E. Benton WTP and Little Creek WWTP) and five minor discharges (Figure 7; Table 8).

In SCW there are several types of permitted discharges (Figure 7, Table 8). The Dempsey E. Benton Water Treatment Plant (WTP), a municipal discharger, was opened May 12, 2010, and discharges into Lake Benson. The Indian Creek Overlook WWTP, a domestic source, was taken off line as part of the Dempsey E. Benton project in order to reduce the amount of pollutants being discharged into SCW (City of Raleigh, personal communication, July 2012).



The Catena Group

Client:

Dwarf Wedgemussel Viability Study: Phase 1

NPDES Permitted Dischargers

Wake & Johnston Counties, North Carolina

Date: February 2014

Scale: 0 1 2 Miles

Job No.: 1154

Figure 7

Table 8. NPDES permitted dischargers in Swift Creek Watershed

Permit	Facility	Type	Flow (Gal/day)	Operating
NC0088285	Dempsey E. Benton WTP	Water Treatment Plant	4,000,000	Yes
NC0060771	Indian Creek Overlook WWTP	100% Domestic < 1MGD	~	No
NC0060526	Pope Industrial Park WWTP	100% Domestic < 1MGD	8,000	Yes
NC0055701	Nottingham WTP	Water Treatment Plant	1,100	Yes
NC0025453	Little Creek WWTP	Municipal, Large	2,500,000	Yes
NC0049034	Mount Auburn Training Ctr WWTP	100% Domestic < 1MGD	2,400	Yes
NC0056499	Mill Run Mobile Home Prk WWTP	100% Domestic < 1MGD	~	No
NC0060330	White Oak Plant. WWTP	Municipal, <1MGD	~	No

3.3.4. Non-point Source Pollution

Non-point source (NPS) pollution refers to runoff that enters surface waters through stormwater or snowmelt. There are many types of land use activities that contribute to non-point source pollution, including land development, construction activity, animal waste disposal, mining, agriculture, and forestry operations, as well as impervious surfaces such as roadways and parking lots. Various NPS management programs have been developed by a number of agencies to control specific types of NPS pollution (e.g. pesticide, urban, and construction related pollution, etc.). Each of these management plans develops BMPs to control for a specific type of NPS pollution. For example, financial incentives to reduce agricultural NPS pollution are provided through North Carolina’s Agriculture Cost Share Program, administered by NCDENR’s Division of Soil and Water Conservation to protect water quality by installing BMPs on agricultural lands. The effects of non-point pollution on aquatic species associated with impervious surface area are discussed in section 2.3.4.

3.4. NCDWQ 2003 Assessment Report on the Upper SCW

An assessment of the biological impairment in the Upper SCW above Holly Springs Road was conducted by the NCDWR (NCDWQ 2003a). The goal of the report was to identify the sources and activities leading to impairments in the stream. Additionally, the report recommends a watershed plan for improving biological conditions in the stream. According to the report, the main sources of impairment appear to be toxicity from stormwater runoff, removal of organisms during storm events (stormwater scour), and hydromodificiation from impoundments along the stream (NCDWQ 2003a).

3.4.1. Toxicity

Toxicity levels in stormwater samples indicate it as a major contributor to biological impairment. Analysis of water collected after a storm event resulted in mortality of 50 percent of test organisms when a sample was diluted to approximately 60 percent of the ambient concentration.

Tolerant species were the dominant organisms found at most of the benthos sampling stations in the Upper SCW (NCDWQ 2009). A further discussion and assessment of this study as it relates to the Study Area is recommended for Phase 2.

3.4.2. Stormflow Scour

Scour as a result of high stormflow, and the resulting loss of organisms and microhabitat, is a likely cause of impairment in the stream. Though difficult to distinguish from other stressors, data suggest there is frequent loss of substrate due to storm events (NCDWQ 2009). Additional assessments of stormflow scour as it relates to the Study Area are recommended for Phase 2.

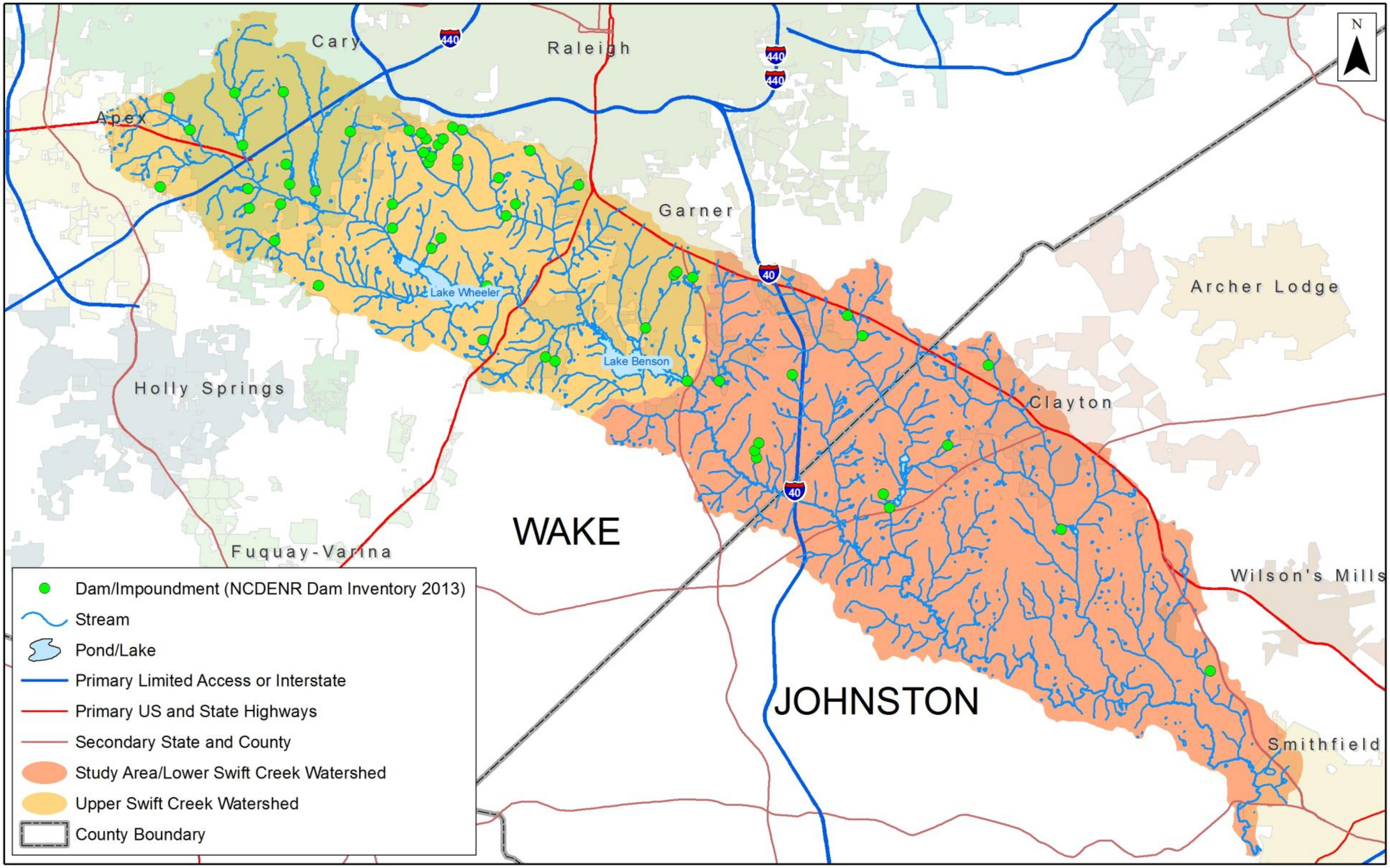
3.4.3. Hydromodification

Hydromodification is the alteration of a stream by the construction of an impoundment or dam. There are 58 identified impoundments in the Upper SCW and the Study Area (Figure 8, NCDENR 2013), which obstruct movement of aquatic organisms such as fish. NCDENR regulates a structure that is 25 feet high or more and impounds 50 acre-feet or more. Of the 58 impoundments illustrated in Figure 8, 31 do not meet either of the two requirements, so are not regulated by the state. Most of these impoundments are not required to have a minimum release volume, meaning there could be zero flow downstream of the impoundment during drought conditions. This reduction in flow negatively impacts water quality in the stream by altering temperature, reducing DO, and reducing habitat (NCDWQ 2009). There are numerous other small impoundments in the SCW that have not been identified, that cumulatively also effect conditions in the watershed.

3.4.4. Recommendations for Improvement

The 2003 Assessment Report (NCDWQ 2003a) provides the following actions in order to curb impairment in the Upper SCW:

1. Implement cost effective stormwater retrofit projects
2. Identify and address toxic inputs
3. Minimum releases from impoundments should be investigated
4. Targeted stream channel restoration in conjunction with stormwater retrofits
5. Reduce nutrient and organic loading (through implementation of the above four)
6. Require effective post-construction stormwater management for any new development
7. Enforcement of sediment and erosion control (particularly Apex, Cary & Wake County)
8. Enhanced watershed education programs



The Catena Group

Client:

STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

Dwarf Wedgemussel Viability Study: Phase 1

Locations of Dams/Impoundments
Upper & Lower Swift Creek Watershed

Wake & Johnston Counties, North Carolina

Date: February 2014

Scale: 0 1 2 Miles

Job No.: 1154

Figure 8

3.5. Watershed Conditions: Summary

In the later part of the 20th century, much of the land use in the SCW transformed from being relatively rural to largely urban, with the expansion of the greater Raleigh metropolitan area. This is particularly true in the Upper SCW. While the Lower SCW is less developed, it is trending towards urbanization as well.

There is a fairly comprehensive amount of water quality data in the Upper SCW, and periodic exceedences of various water quality parameters have occurred throughout. Comparatively, less data are available for the Lower SCW, and what is available rarely extends beyond the past ten years. While there is a paucity of data, recent trends indicate water quality concerns in the Lower SCW, as well as the section of Swift Creek from Lake Benson to the Little Creek confluence, as it went from a FS status in 2009 to NS status in 2012 (NCDWQ 2009 and 2012).

3.6. Watershed Conditions: Phase 2 Considerations

Further analysis, acquiring updates of the City of Raleigh water quality data set, and analyzing the raw data from the Ward et al. (2007) study, will enhance the understanding of water quality conditions in the study area.

Additionally, as mentioned above, more water quality monitoring is needed to evaluate current trends and future conditions, particularly as they relate to DWM population viability. Efforts should be made to identify particular parameters to be monitored, as well as locations. This should be done in coordination with various stakeholders in the Lower SCW. A Regional Watershed Plan (RWP) is being developed by the NC Ecosystem Enhancement Program (EEP) for the Neuse 01 watershed, which includes all of SCW. As part of the development of a watershed plan, existing water quality data is often supplemented with data collected specifically for the watershed plan. Coordination with the parties involved in the development of the Neuse 01 RWP should take place in the second phase of this study.

Another component of watershed management plans is the formation of a stakeholder group. Stakeholder groups typically consist of local municipalities, various regulatory and conservation groups, and local citizens, who collectively provide input in the data collection and analysis as well as decision making process. Several local government entities were interviewed for this study, including Johnston County, City of Raleigh and Town of Cary. Representatives from USFWS, EEP and NCNHP were also interviewed. A subset of the stakeholder group for the Neuse 01 should be involved in the Swift Creek DWM population study.

Other potential stakeholders include:

- Wake/Johnston Soil and Water Conservation Districts
- Neuse Riverkeeper Foundation
- Triangle Land Conservancy
- Triangle J Council of Governments (TJCOG)
- Public and Private Schools (particularly science clubs) in the SCW

4.0 ACCOUNTING OF CONSERVATION MEASURES IN SCW

There have been several conservation measures put in place that help protect water quality and habitat within the SCW. Some of these measures also apply to areas outside of the SCW, while others were developed and implemented specifically to protect SCW. The information discussed below was gathered by reviewing applicable rules and regulations that apply to water quality protection, as well as gathering information from various entities that have a specific stake in protection of SCW.

4.1. General Conservation Measures

There are a number of protective measures that have been adopted that apply to the entire Neuse River Basin, which go beyond what is required in many other river basins in North Carolina.

4.1.1. Neuse River Riparian Buffer Rules

The State of North Carolina requires 30-foot vegetated riparian buffers in its water supply watershed protection rules, while requirements for Neuse River basin are set at a 50-foot minimum buffer on each side of perennial and intermittent water bodies. New buffers are not required on existing land uses, unless that land use changes (NCDWQ 2003a). These buffers are not required on ephemeral channels.

4.1.2. Neuse River Basin Stormwater Rules

As of 1998, all waters of the Neuse River Basin have been under the Neuse Nutrient Sensitive Waters rules, a result of the NSW classification. In addition to the 50-foot minimum riparian buffer rule, new development within the Neuse River Basin cannot exceed nitrogen loads of 3.6 lbs/acre/yr. Only Jordan Lake and Falls Lake have more restrictive nitrogen loading rates (NCDWR 2013b). Also, post-development peak flow rates cannot be any greater than flows from pre-development sites for the 1-year 24-hour storm. The stormwater rules also required government entities to implement a public education program, remove illicit discharges, and install stormwater retrofits where feasible. The Town of Apex is not subject to these rules; development existing before 1998 is also not subject to these rules (NCDWQ 2003a).

4.1.3. Phase II stormwater (NPDES Permits)

Developed by the EPA, Phase II stormwater rules require small communities not previously under federal stormwater requirements to obtain permits for discharging stormwater. These rules apply to Cary and Apex. The rules include six minimum requirements: public education and outreach, public participation, illicit discharge detection and elimination, construction runoff control, post-construction management to new and redevelopment, and pollution prevention (NCDWQ 2003a).

4.2. Specific Conservation Measures for the SCW

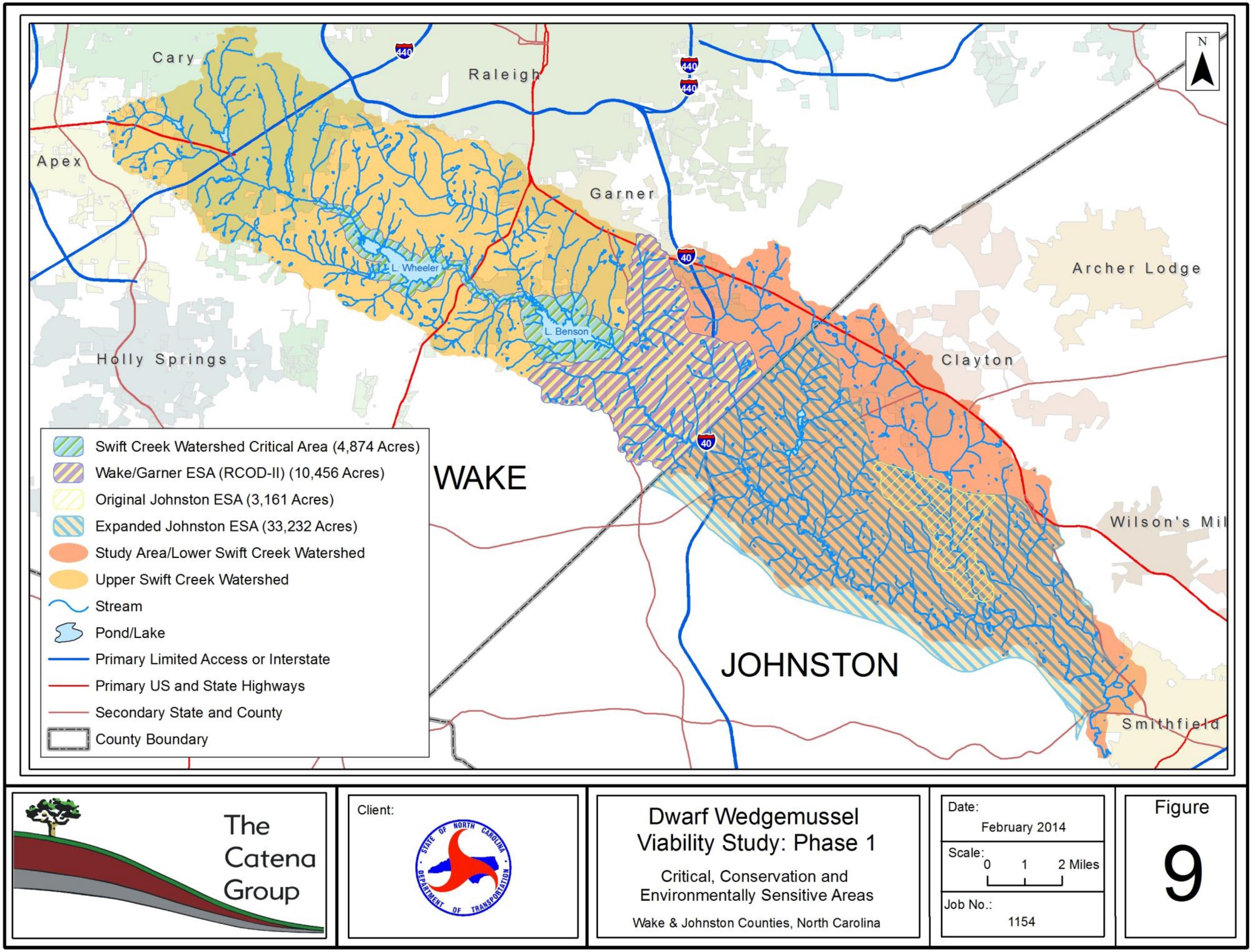
A number of entities have developed various conservation measures specifically to conserve and protect SCW.

4.2.1. Swift Creek Land Management Plan

Wake County and local governments (Apex, Cary, Raleigh, and Garner) adopted the Swift Creek Land Management Plan (SCLMP) on April 19, 1990, to allow for further development of SCW without jeopardizing the health of the stream as a water supply source for Lakes Benson and Wheeler (Wake County 2013). The plan requires vegetative buffers and places limits on impervious surfaces (Memorandum 1988, NCDWQ 2003a). The plan also calls for the control of point source discharges. Areas of critical importance for protection (called critical areas) were identified as: Lake Benson, Swift Creek between Lake Benson and Lake Wheeler, Lake Wheeler and Swift Creek above Lake Wheeler, Little Swift Creek, and Yates Mill Creek (Figure 9). The plan establishes imperviousness limitations for areas without stormwater control measures; 6% in critical areas and 12% in non-critical areas (Figure 9) (AMEC, 2004). Critical areas are those of the watershed closest to the water supply source where it is most important to minimize the discharge and maximize the filtration of potential pollutants (Wake County 2013).

4.2.2. Apex

The Town of Apex adopted a Land Use Plan in 2010 that requires 40% of new developments in the resource conservation area be set aside for open space, a 100 foot riparian buffer on perennial streams, a 50 foot buffer on intermittent streams, and no residential development in the 100-yr floodplain. Additionally, the town must capture runoff from 1-inch of rainfall on areas in excess of 12% impervious cover while also removing 85% of TSS. A joint study with the Towns of Cary and Holly Springs of Secondary Cumulative Impact Mitigation Program (SCIMP) was also a requirement of the Plan (AMEC 2004).


Cary
Raleigh
Apex
Garner
Archer Lodge
Holly Springs
Clayton
Wilson's Mil
Smithfield
WAKE
JOHNSTON
L. Wheeler
L. Benson
440
40
N
Swift Creek Watershed Critical Area (4,874 Acres)
Wake/Garner ESA (RCOD-II) (10,456 Acres)
Original Johnston ESA (3,161 Acres)
Expanded Johnston ESA (33,232 Acres)
Study Area/Lower Swift Creek Watershed
Upper Swift Creek Watershed
Stream
Pond/Lake
Primary Limited Access or Interstate
Primary US and State Highways
Secondary State and County
County Boundary
The Catena Group
Client:
STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
Dwarf Wedgemussel Viability Study: Phase 1
Critical, Conservation and Environmentally Sensitive Areas
Wake & Johnston Counties, North Carolina
Date: February 2014
Scale: 0 1 2 Miles
Job No.: 1154
Figure 9

4.2.3. Cary

The Town of Cary has an estimated 950 acres of land under strict impervious surface limitations. Cary joined Apex and Holly Springs in signing the SCIMP, as described in Section 3.2.1. Cary has a Growth Management Plan (Town of Cary 2000), in which riparian buffer rules are more restrictive than state requirements and 50 foot Neuse River Riparian Buffer requirements. These rules require a 100 foot buffer on perennial and intermittent streams, and a 50 foot buffer on all other streams that appear on the latest soil survey maps. Cary refers to these as Urban Transition Buffers. The Town has also investigated ways to implement a mitigation banking program (AMEC 2004), or a mitigation credit union, but as of the Draft Stormwater Master Plan (Town of Cary 2013), there is not a specific mitigation mechanism in place. Any developments involving mitigation options will be monitored in Phase 2.

4.2.4. Garner

Wake County implements the Town of Garner's Sediment and Erosion Control program. Garner maintains a Swift Creek Overlay District (or Resource Conservation Area), an area in which development is restricted in order to protect Swift Creek. Garner was a signatory of the SCLMP, and therefore has committed to protecting that resource. Garner also developed a Regional Retention Pond BMP Retrofit Plan to install BMPs in the SCW (Garner 2001; AMEC 2004), the effectiveness of which will be further investigated in Phase 2 of the study.

As a conservation measure associated with the Clayton Bypass project, a 10.7-mile highway connecting I-40 in Wake County and US-70 in Johnston County that opened in 2008, Garner also entered into a Memorandum of Understanding (MOU) with NCDOT and USFWS (2006). Garner continues the use of its current buffer standards, defining an undisturbed buffer to include the 100 year floodplain plus 50 feet on streams (listed in Section 7.2.D of Garner's Unified Development Ordinance). The MOU also affirms Garner's Development Standards for Stormwater Management, which limits nitrogen export load to 3.6 lbs/acre/yr; otherwise, developers can make a one-time payment to the EEP. Residential development exceeding 6 lbs/acre/yr and other development that exceeds 10 lbs/acre/yr must implement stormwater control measures to achieve loads below those thresholds to be eligible for mitigation payments. Garner adheres to the rules set out in the SCLMP, with limits set at 6% and 12% for critical and non-critical areas, respectively. Garner has considered adopting stormwater controls equivalent to Wake County's Stormwater Control, Management, and Watercourse Buffer Regulations (Section 2-10-40). These controls will be amended to treat impervious surfaces on a project basis, rather than on an individual lot basis. This action will be taken when Garner expands into Wake County's Resource Conservation Overlay District-II (RCOD-II) area, or in the Swift Creek watershed below Lake Benson.

4.2.5. Raleigh

The City of Raleigh implements its own Sediment and Erosion Control (S&EC) program and requires standards that are more stringent than the state minimum (AMEC 2004). In particular, a S&EC plan must be submitted prior to any land-disturbing activity greater than 12,000 square feet. Land-disturbing activities resulting in uncovered areas are limited at any time to a maximum total area of 20 acres within High Quality Water Zones. Raleigh operates the Dempsey E. Benton WTP, which opened May 12, 2010. Raleigh coordinated with the USFWS on terms and conditions for mitigation of impacts from the WTP to the DWM. These measures are:

- Tiered minimum flow release schedule from the WTP, which would decrease the amount of water from Lake Benson/Swift Creek when outflows are reduced. Raleigh is required to notify the USFWS when Tier 3 flows (0.8 cubic feet per second) last for more than seven consecutive days
- Limit the maximum base withdrawal rate and the frequency of the maximum withdrawal rate
- Manage Lake Benson Dam to prevent rapid reductions in downstream flows
- Suitable intake-outlet structure designs
- Water quality and quantity monitoring programs
- Decommissioning two small wastewater treatment facilities on Swift Creek (Indian Creek Overlook and Mill Run Mobile Home Park WWTPs)
- Purchase of two greenway corridors in the SCW: Steep Hill Creek Corridor and Lake Wheeler/Lake Benson Corridor (Arcadis 2005; USFWS 2006)

City of Raleigh Public Utilities representatives have confirmed that these measures had been implemented. Water quality monitoring has been conducted (see Section 3.3.1), with temperature, DO, pH, conductivity, fecal coliform, suspended solids, turbidity, and ammonia being measured approximately twice a month. Mussel surveys, which the city of Raleigh is funding, will be conducted once every five years following construction for 20 years. The two WWTPs have been decommissioned. Steep Hill Creek Corridor has been purchased, and portions of the Lake Wheeler/Lake Benson Corridor are in preservation, with money being pursued to purchase the remaining areas (Buchan 2012). This information will be updated as part of Phase 2.

4.2.6. Wake County

Wake County implements the S&EC Program for all unincorporated county lands and the following municipalities: Town of Garner, Fuquay Varina, Holly Springs, Morrisville, Knightdale, Wendell, and Zebulon. Buffer rules for Wake County exceed the Neuse River Riparian Buffer Rules and NSW nitrogen regulations, with buffer standards of 100 feet, instead of the 50 foot Neuse riparian buffer. Wake County also has a current land use plan, a Growth Management Plan, and a Consolidated Open Space Plan. Minimum lot sizes are required to be 40,000 sq ft in non-critical areas, and 80,000 sq ft in critical areas (AMEC 2004). In 2000, the Wake County Board of Commissioners established the Watershed Management Task Force, which was made up of officials from local governments. The Task Force was in charge of overseeing the development of the County Watershed Plan. As a result, CH2M Hill completed a Comprehensive Watershed Management Plan, a report in which recommendations were made to the commissioners and local governments in order to protect and enhance water quality (NCDWQ 2003a).

As part of the Section 7 Consultation process of the Endangered Species Act of 1972 for the Clayton Bypass project, Wake County signed a MOU with USFWS and NCDOT (MOU 2005). In this document, Wake County agreed to prohibit fill and new development in floodways or floodway fringes on lots created after May19, 2003. The MOU also limits nitrogen export load to 3.6 lbs/acre/yr. Developers can otherwise make a one-time payment to EEP; residential development exceeding 6 lbs/acre/yr and other development that exceeds 10 lbs/acre/yr must implement stormwater control measures to achieve loads below those thresholds to be eligible for mitigation payments. Peak stormwater runoff from new development can be no greater for post development for the one year, 24-hour storm event, except for the following: when increase in runoff is 10% or less; maximum impervious surface of a lot is 15% or less (30% or less for residential development); and pervious surfaces are used to control runoff to the maximum extent. An RCOD-II (Figure 9) was created in which perennial streams have a 100 foot buffer. The ordinance amendment will list the impervious surface limits that apply in the County's underlying zoning districts and that are required by its Storwmater Control, Management and Water Course Buffer Regulations (MOU 2005).

Wake County, in coordination with the USFWS, also agreed to several measures in preparation for the Dempsey E. Benton WTP. The USFWS issued a Biological Opinion (BO), requiring Wake County to implement the following measures: put further restrictions on the RCOD-II; restrict the allowed activities within stream buffers in the RCOD-II; recodify existing county stormwater regulations in the RCOD-II Ordinance; limit impervious surfaces to no more than 15% in residential areas and no more than 30% in residential areas with stormwater controls in place (USFWS 2006).

4.2.7. Johnston County

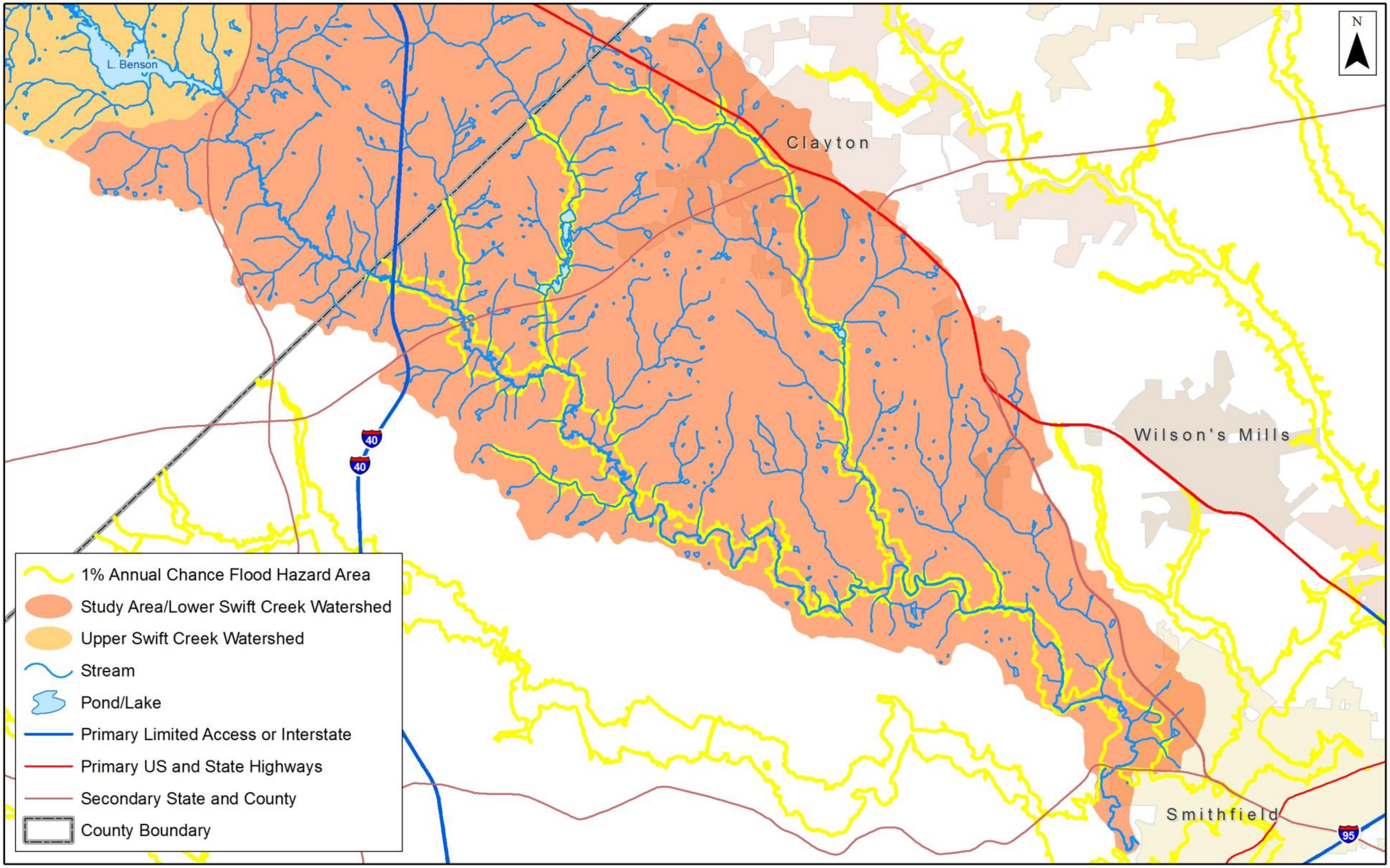
NCDOT provided funding to Johnston County for a Watershed Administrator position to implement watershed ordinances as part of development of the Clayton Bypass. The funds were initially received in 1999 and NCDOT supplied funding for five years ($25,000 per year, for a total of $125,000). At that time, the County's stormwater department had just been formed, and a stormwater administrator position was created for the entire county (not just SCW). The passing of the Neuse River Buffer Rules in 1998 was also a driver for creating both the department and the position. When the administrator position was created, Johnston County also developed an Environmentally Sensitive Area (ESA) designation that set limits on impervious surfaces and nitrogen loading rates within the ESA. The ESA was first established around Little Creek from US 70 Bypass to Swift Creek (Figure 9).

Johnston County also entered into an MOU with USFWS and NCDOT to protect SCW for the Clayton Bypass project. In this MOU, the county agreed to expand the boundaries of its ESA (Figure 9). There are stormwater restrictions within the ESA that limit impervious surfaces to 12% in residential areas and 50% in non-residential (versus 15% and 60%, respectively, outside of an ESA). The percent of impervious cover can be increased if BMPs are utilized, payments are made to Land Dedication Fund, or there is a direct dedication of land to preservation. No development is allowed within flood hazard areas (Figure 10), including residential and non-residential structures and improvements to existing structures (MOU 2005). Johnston County implemented modification to the Stormwater Management Ordinance limiting total nitrogen from new development to 3.6 lbs/acre/year. Commercial development may make an offset payment to EEP, but shall not exceed nitrogen loads of 8 lb/acre/yr. Residential development does not have the EEP offset payment option (MOU 2005). A 100-foot undisturbed riparian buffer is required along perennial streams in the ESA, which Johnston County has defined as the main stem channels of Swift Creek, White Oak Creek, Little Creek (from US 70 to Swift Creek) and Little River (from county line to NC 39). All other streams in the ESA do not require the increased 100-foot buffer, but do fall under Neuse River buffer requirements.

There are several areas that are exempt from the current ESA, such as some properties in the I-40/NC-42 interchange area. For example, the Golden Corral property was exempt as it was approved prior to the adoption of the ESA regulations. However, the Wal-Mart property was not exempt, and various stormwater BMPs were incorporated into site development.

Under the BMP management program, developers must submit a stormwater management plan, get certification from an engineer in the final stages, and follow-up with an annual inspection approved by the county through a private company. If the inspections indicate non-compliance, they are then required to bring the project into compliance within a year or receive a Notice of Violation.

Johnston County teamed with the Triangle Land Conservancy (TLC) to develop criteria to consider which lands warrant being purchased through the Land Dedication Fund. However, finding conservation areas within SCW has been very challenging (Guerrero, personal communication). While there is still a fair amount of land that has not been developed, many of the landowners in the watershed believe their land is highly sought after for developers and the County alike. So far, no lands have been dedicated within the Swift Creek watershed. Since the



The Catena Group

Client:

Dwarf Wedgemussel Viability Study: Phase 1

Johnston County Flood Hazard Areas

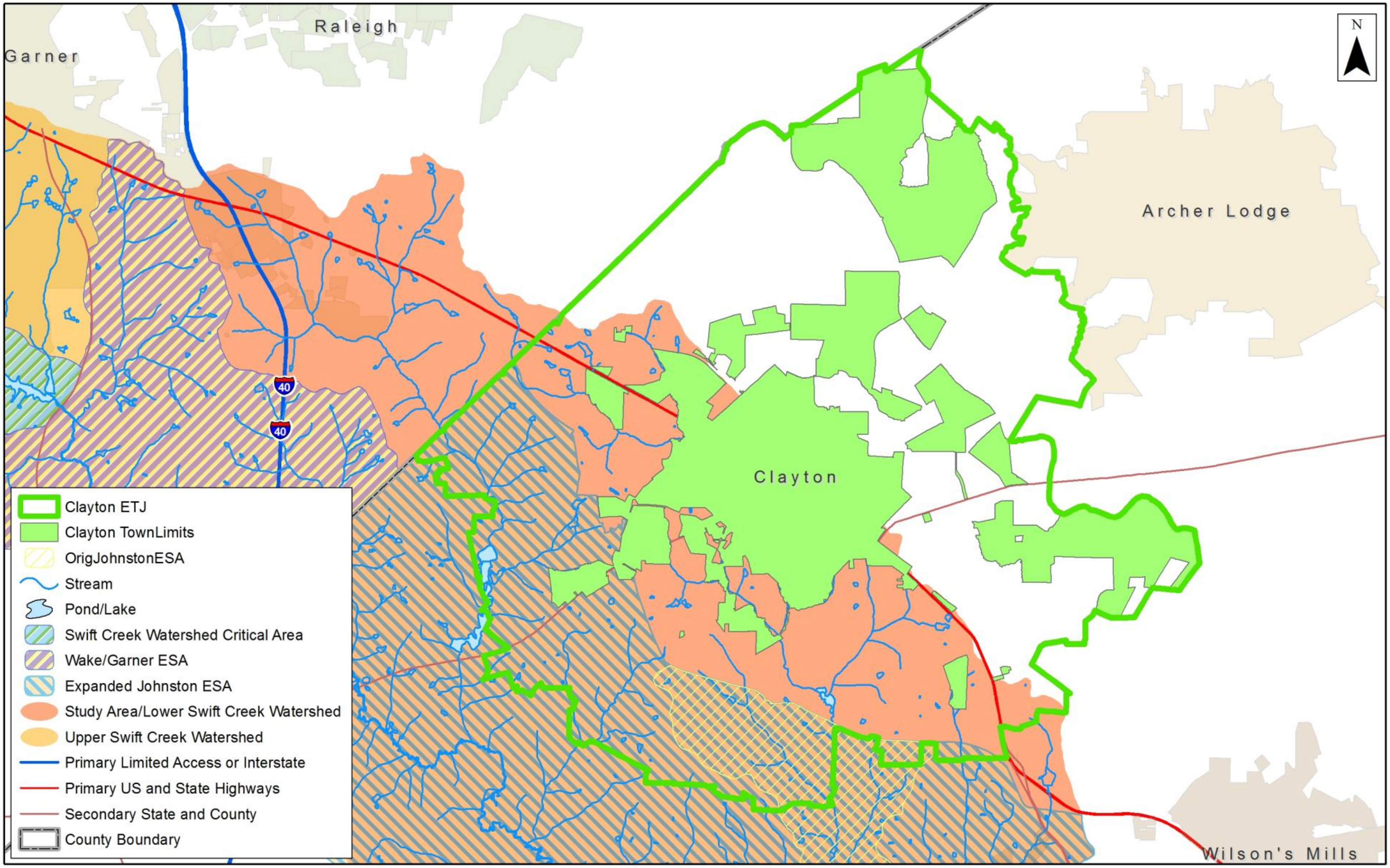
Johnston County, North Carolina

Date: February 2014

Scale: 0 0.5 1 Miles

Job No.: 1154

Figure 10



The Catena Group

Client:

Dwarf Wedgemussel Viability Study: Phase 1

Town of Clayton
Extended 2008 ETJ

Wake & Johnston Counties, North Carolina

Date: February 2014

Scale: 0 0.5 1 Miles

Job No.: 1154

Figure 11

signing of the MOU in 2005 for the Clayton Bypass, which expanded the ESA to include Swift, White Oak, and Little Creeks, the Town of Clayton has expanded the Extraterritorial Jurisdiction (ETJ) from one mile to two miles around its boundary (Figure 11). This effectively made the ESA regulations no longer applicable within the ETJ. Therefore, Johnston County and Clayton signed another MOU to ensure that areas previously designated as ESA remained subject to the ESA regulations. Clayton is now part of the NPDES Phase II Stormwater Rule, indicating they must adopt a stormwater management plan, among other requirements. Johnston County noted that there are several other areas in SCW that may be in need of stormwater improvements or retrofits in order to improve water quality in the watershed:

- Summerwind (northwest of I-40/NC-42 interchange): A residential and multi-use development. As the site was in the early stages of development, off-site erosion was an issue. NCDWR took the developer to court for sediment loss into the stream and exceeding permitted limits. However, the original developer has since gone bankrupt, but the property is now under new ownership and development has reinitiated.
- Tetra (northwest of I-40/NC-42 interchange): A commercial and multi-use area.
- Pump Station (east of I-40/NC-42 interchange on Swift Creek): A sewer lift station located near Lowe's at I-40/NC-42, next to Swift Creek, which has been degraded.

Johnston County is planning to pass a buffer ordinance and a S&EC ordinance, which the Public Utilities Department would be responsible for overseeing. Clayton's buffer and S&EC would also fall under Johnston County. Further communication with Johnston County should occur in Phase II of this study to learn the particulars of this ordinance, as well as other issues.

4.2.8. NCDOT Measures

As part of the roadway design of the Clayton Bypass, and in coordination with USFWS, NCWRC, and other environmental agencies, NCDOT implemented as the following measures:

- Added hazardous spill catch basins, extended controlled access to project sites
- Removed curbs and gutters, installed basin designed to meet runoff for 25-year storms
- Utilized faircloth skimmer with jute baffles and polyacrylamide
- Installed erosion control matting in exposed areas near critical habitat and in ditch lines.

Additionally, NCDOT implemented a water quality monitoring program, seeding and mulching, and erosion and sedimentation control measures. DWM propagation efforts by Dr. Richard Neves at Virginia Tech were funded by NCDOT in which 500 juveniles were propagated for release (Beck and Neves 2001); however, the juveniles were not released over concern of contaminating current populations. Additionally, the design of the Clayton Bypass shifted the alignment of the I-40 interchange away from Swift Creek and included four bridges and drainage design features, thus reducing the impact on the stream (MOU 2005). NCDOT also provided funding to Johnston County for the creation of the aforementioned Watershed Administrator position.

4.2.9. Stormwater Basin Evaluation

A Stormwater Basin Evaluation Sheet (SBES) was developed as part of Phase 1 of this study, with the intent to create a methodology to identify locations of faulty or malfunctioning stormwater facilities (Appendix B). Many states, counties, and municipalities, such as Minnesota, Iowa, and North Carolina, have created manuals and forms to provide guidance for stormwater facility evaluation with almost all focusing on maintenance and inspections (Minnesota Pollution Control Agency 2008; Cedar Rapids 2008; NCDOT 2010). This SBES was created specifically to evaluate facilities and provide an overall rating (Good, Fair, or Poor) based on site specific characteristics. Stormwater facilities evaluations and rating are based on specific design standards set forth in the NCDENR Stormwater BMP Manual. The SBES further considers the feasibility in rehabilitating or retrofitting outdated, malfunctioning, or faulty stormwater basins.

Evaluations are conducted through thorough inspections of the three basin components that generally comprise all basins: inlet, basin, and outlet. The inlet includes the area immediately affected by stormwater inflow from which water is conveyed into the stormwater basin. The basin includes the treatment area or basin bottom along with any stormwater dissipating component, such as a forebay. The outlet is the area immediately affected by stormwater outflow from which all water is conveyed out of the stormwater basin.

4.3. Accounting of Conservation Measures: Summary

As described in Section 4.2, there are multiple conservation measures that have been developed and implemented within the SCW. These measures consist largely of establishing minimum buffer requirements, limiting the amount of imperviousness and nutrient inputs, and providing stormwater and erosion control measures. Additionally, measures associated with the Dempsey Benton WTP provide for maintenance of minimum flows in the Lower SCW. Many of these measures establish minimum buffer requirements. Other measures, such as establishing the USGS gauging station in the Lower SCW and developing artificial propagation techniques for the DWM, will aid in management decisions for this species in Swift Creek.

4.4. Accounting of Conservation Measures: Phase 2 Considerations

The objectives of this component of the study have largely been completed in Phase 1. However, further communication with Johnston County is needed to better understand the specifics of the protective measures in place, including allowable exemptions. Further refinement and field testing of the SBES should also be done in Phase 2 of this project.

5.0 DWM POPULATION TRENDS IN SWIFT CREEK

The overall goal of this study is to determine the long term viability of the Swift Creek DWM population. The recovery goal for the DWM (USFWS 1993) is "to restore and maintain viable populations …to a significant portion of its historical range in order to remove the species from the Federal list of endangered and threatened species". As mentioned earlier, the maintenance of a viable population in Swift Creek is listed as a recovery objective (USFWS 1993). The recovery plan defines a viable population as "a population containing a sufficient number of reproducing adults to maintain genetic variability and in which annual recruitment is adequate to maintain a stable population." While the definition of what constitutes a viable population is clear, a quantifiable measure of population viability has been difficult to determine.

5.1. NC Scientific Council Recommendation on Viability Measures

The NC Scientific Council on Freshwater and Terrestrial Mollusks (The Council), which currently consists of 17 scientists recognized for their respective knowledge on the status of mollusk species in North Carolina, was assembled by the North Carolina Nongame Wildlife Advisory Committee, an advisory committee that reports to the NCWRC, to evaluate status listings of the rare, threatened, and endangered mollusks of North Carolina. The Council recognized a need to develop a quantitative ranking system to use as a tool for determining imperiled status of species, to lessen the subjective biases of existing ranking systems. One component of developing such a ranking system is determining population viability. As such, the Council's quantifiable criteria to measure population viability of freshwater mussels suggested the species should:

- Occupy between 10-20 miles of continuous habitat if dendritic (occurring in main stem and tributaries), or greater than 20 miles if linear, with no gaps greater than 2 miles of unoccupied habitat.
- Occur at 75% of sites within occupied habitat.
- Have a relative abundance as measured by CPUE of $\geq$ 5 individuals per hour at 50% of sites within occupied habitat.
- Exhibit evidence of reproduction; contain gravid individuals, and/or multiple size classes, including younger individuals.

These criteria have not been tested on mussel populations in the state, but were based in the collective opinions of the Council, and will likely need to be adjusted as these methods are applied and more information becomes available. While these measures of viability have not been officially adopted, this study evaluated these parameters in the analysis.

5.2. Study Approach

The study consists of two components; a desktop evaluation of previous survey data to determine species abundances over time, and in-stream studies to evaluate particular indicators of population viability. The DWM has consistently been rare in Swift Creek since its discovery in 1991. Because of this rarity, the DWM cannot be analyzed singularly in this study. As with many rare species, it is often necessary to evaluate more common associate species to serve as surrogates in the analyses. Therefore, this analysis focuses on trend data specific to the DWM, while also considering the entire mussel fauna in Swift Creek.

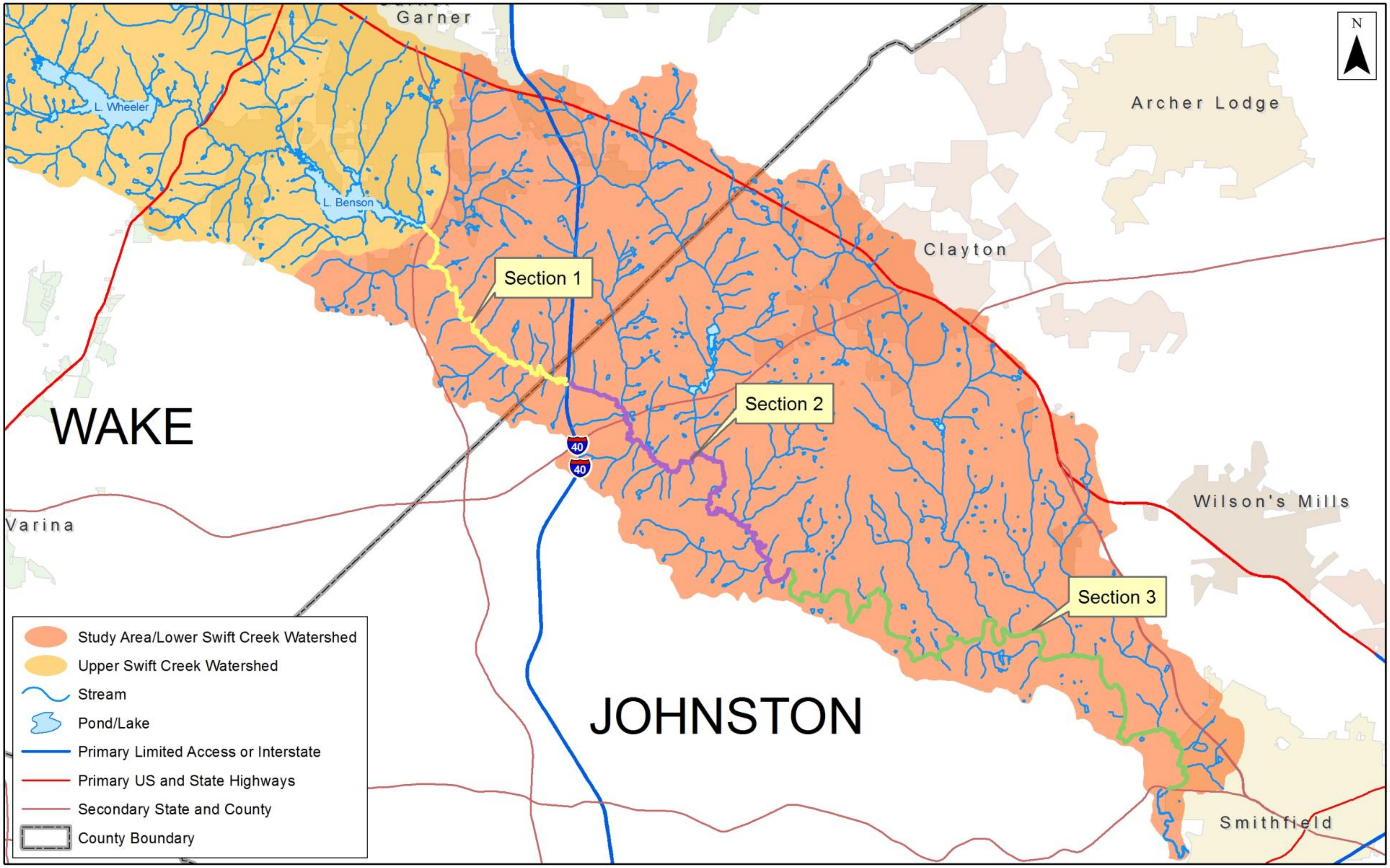
For purposes of data reporting, analysis, and discussion, the general study area of Swift Creek is divided into three sections of unequal length to account for general habitat conditions as follows (Figure 12):

1. Section 1 (Lake Benson to I-40),
2. Section 2 (I-40 to Barber Mill Road)
3. Section 3 (Barber Mill Road to NC 210)

With regards to the freshwater mussel fauna, Swift Creek is one of the most species rich and extensively surveyed water-bodies in North Carolina. However, nearly all of the surveys employed an "informal" sampling design using timed qualitative searches for mussels at various locations. The primary objective of this type of sampling is to determine presence/absence of a particular species, and is not recommended for population density studies, or long term monitoring (Strayer and Smith 2003). Thus, conclusions on population trends derived by simply analyzing the existing dataset without accounting for sampling variance would have inherent flaws as the dataset does not account for the level of uncertainty inherent with variables, such as survey effort, seasonality, surveyor experience, and survey conditions (water depth, visibility, flow etc.). To account for this, a probability-based design that involved a number of repeat surveys at selected sites was incorporated into the field component of this study to develop detection probabilities for the mussel species occurring in Swift Creek. These detection probabilities will assist in making inferences of trends from previous survey data. While this will not totally eliminate the unknown biases of the informally sampled dataset, it will strengthen assumptions made with regard to previous survey data being representative of the overall population.

5.3. History of Mussel Surveys and Mussel Fauna in Swift Creek

Until the 1990s, documented collections of freshwater mussels in the Swift Creek subbasin were very limited. Walter (1956) sampled mollusks at five stations and reported only five mussel species. Alderman (1991) reported 11 species, including the DWM at four stations. Since the discovery of DWM in Swift Creek in 1991, numerous mussel surveys have been conducted throughout the subbasin, including a relict shell survey at 118 stations in 1992 (Flowers and



The Catena Group

Client:

Dwarf Wedgemussel Viability Study: Phase 1

Study Area Section 1-3

Wake & Johnston Counties, North Carolina

Date: February 2014

Scale: 0 0.5 1 Miles

Job No.: 1154

Figure 12

Miller 1993), various status/monitoring surveys by the NCWRC from 1992-2006, comprehensive efforts in 1996 and 2003 undertaken by the NCDOT for the Clayton Bypass roadway project (NCDOT 2005a), and baseline and six-month post construction surveys for the Dempsey E. Benton WTP in 2007 and 2010 respectively. Additionally, surveys were conducted for the Complete 540 - Triangle Expressway Southeast Extension in 2010, 2011 and 2012. The results of these surveys were provided to Lochner and NCDOT in three separate reports, which are included in Appendix C.

Historically, at least 18 species of freshwater mussels have been reported to occur in the Swift Creek subbasin. The Green Floater reported as occurring in Swift Creek by Walter (1956) is the only species known from the creek that has not been found in recent years, as it was last collected (one specimen) in 1991 (Alderman 1991). Brief descriptions of each of the mussel species known from Swift Creek are provided in Appendix C.

5.4. DWM Occurrences and Distribution in Swift Creek

In Swift Creek a total of 44 live and 12 relict shells have been found at 34 distinct sites through 21 stream miles (Figure 13). The lower 10 miles, however, are represented by only one individual, and the species has not been found in this 10 mile section since 1991.

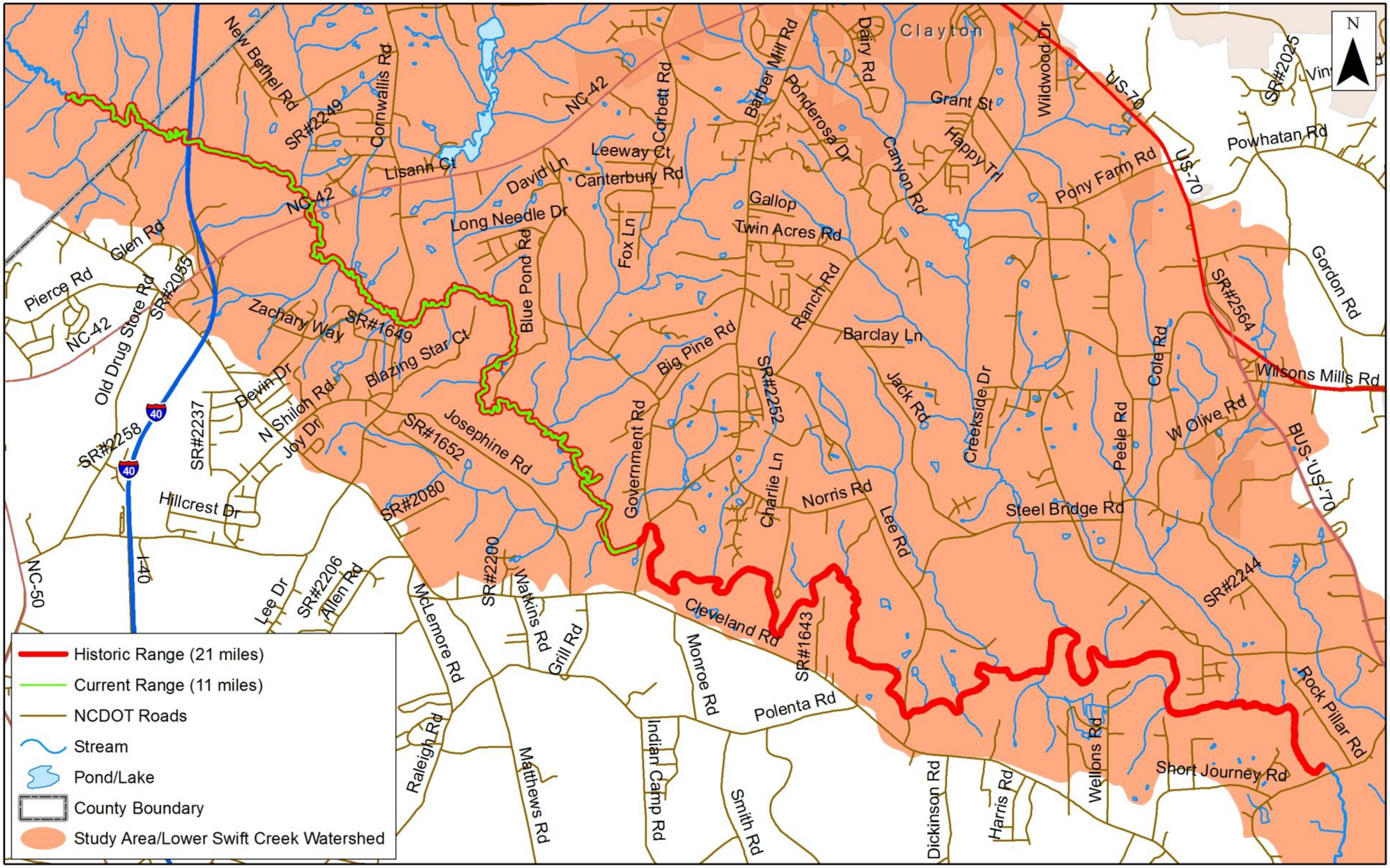
5.5. Mussel Population Trends in Swift Creek

The objective of this component of the study was to analyze population trends of the mussel species in Swift Creek. This analysis focuses on relative abundances, as measured by catch per unit effort (CPUE) of each species over time, and age class distribution (as inferred from size class data) over time for particular species which size class data is available.

5.5.1. Relative Abundance Trends

The CPUE, which indicates the number of individuals found in one hour of survey time, for each species occurring in Swift Creek was evaluated over time in the three sections of the study area. Two different measures of CPUE were considered:

1. CPUE for each species only at sites where it was detected within each section
2. CPUE for each species at all survey sites combined within each section, whether the species was detected or not



The Catena Group

Client:

Dwarf Wedgemussel Viability Study: Phase 1

Dwarf Wedgemussel Historic and Current Occupied Range

Wake & Johnston Counties, North Carolina

Date:	February 2014
Scale:	0 0.5 1 Miles
Job No.:	1154

Figure 13

These data were divided into the following five time periods:

1. ≤1991
2. 1992-1996
3. 1997-2001
4. 2002-2006
5. 2007-2012

It is important to note that each of these periods contains variability in data collection as to methods, level of effort, survey site location, etc. Many of the survey sites, particularly in the first three time periods, focused on the best habitat for rare species, such as the DWM, Atlantic Pigtoe and Yellow Lance, while later surveys were more comprehensive of a variety of habitat conditions with the stream. As such, conclusions based on apparent trends, particularly for habitat specialists like the Atlantic Pigtoe, need to account for variability in survey methodologies. Variability in survey methodologies is less likely to be a factor when evaluating trends with habitat generalists such as the *Elliptio* species. The number of survey hours per section for each time period is shown in Table 9.

Table 9. Number of mussel survey hours by sections

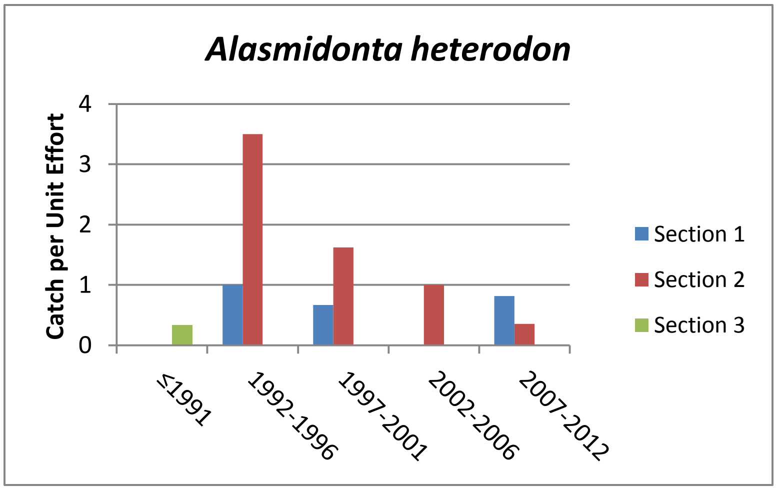
	Study Area Section		
Time Period	**1**	**2**	**3**
≤1991	0	10	17
1992-1996	29	25	25
1997-2001	105	96	21
2002-2006	254	287	238
2007-2012	1,660	5,065	1,437

The CPUE results for each species only at sites where it was detected within each section evaluated are provided below. The CPUE for each species at all survey sites within each section combined showed similar trends, and these results are included in Appendix D.

5.5.1.1. DWM

As mentioned in section 5.4, a total of 44 live DWM have been found in Swift Creek since 1991, with the majority (37) found in Section 2, and only one individual found in Section 3. Since the 1992-1996 period, it has declined steadily from a high of 3.5/hr in Section 2 during the 1992-1996 period to <0.5/hr in both Section 1 and Section 2 in the 2007-2012 period (Chart 1).

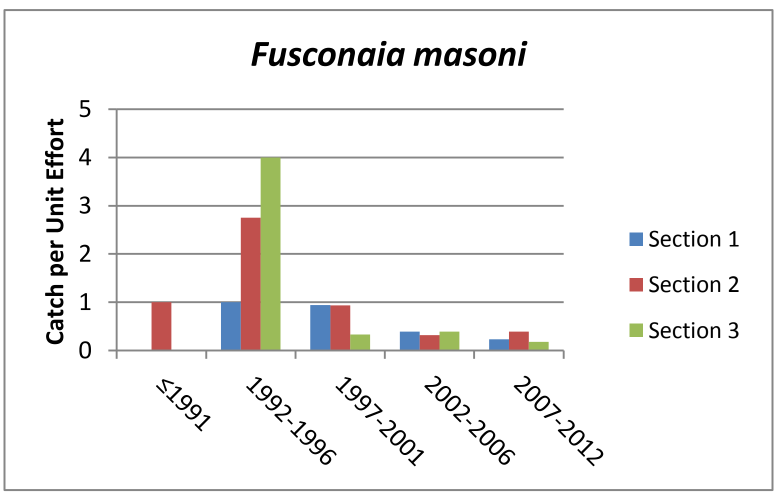
Chart 1. CPUE of Dwarf Wedgemussel



5.5.1.2. Atlantic Pigtoe

The Atlantic Pigtoe has been found in all three sections of Swift Creek in every sampling period, with the exception of <1991, when it was reported only in Section 2. This is likely due to a limited amount of survey effort during this sampling period. Chart 2 indicates a declining trend of Atlantic Pigtoe CPUE since the 1992-1996 period.

Chart 2. CPUE of Atlantic Pigtoe

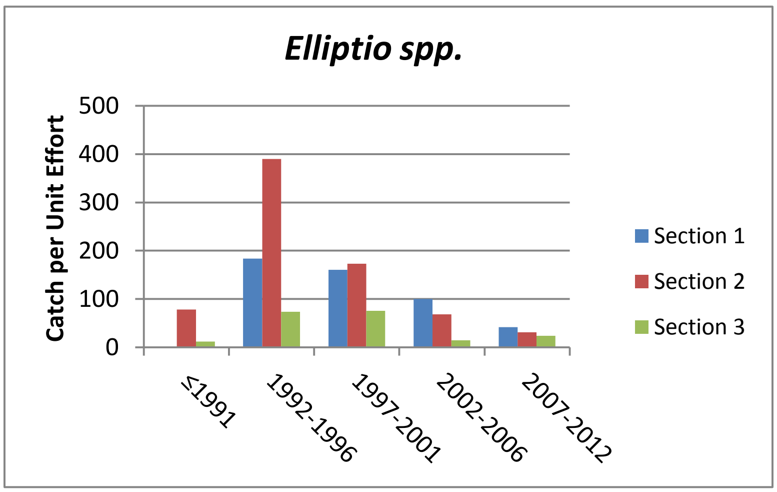


5.5.1.3. Elliptio Species

This composite of *Elliptio* species represents at least three species (*E. complanata* complex, *E. icterina* complex and *E. congerea*). Due to plasticity of shell morphologies and taxonomic uncertainties within the genus, discrepancies regarding species identification exist within the dataset. For example, the Box Spike (*E. cistelliformis*) is reported from Swift Creek. This species, which was described from the Neuse River Basin was synomonized with *E. complanata* (Johnson 1970). Thus, some surveyors in Swift Creek may have recognized the *E. cistelliformis* form as separate from *E. complanata*, while others may have grouped them together. To account for this, all *Elliptio* species excluding *E. lanceolata*, *E. roanokensis* and various lanceolate *Elliptio* forms (*E. fisheriana*, *E. producta*, *E.* spp. c.f. lance and *E. viridula*), were grouped together for this analysis. *Elliptio* species generally account for the highest percentage of the freshwater mussel fauna in most Southern Atlantic Slope streams (Johnson 1970), which is the case within Swift Creek.

As with the DWM and Atlantic Pigtoe, a declining trend in relative abundance of the *Elliptio* species is evident since the 1992-1996 period in all three sections of Swift Creek (Chart 3). This decline is even more dramatic.

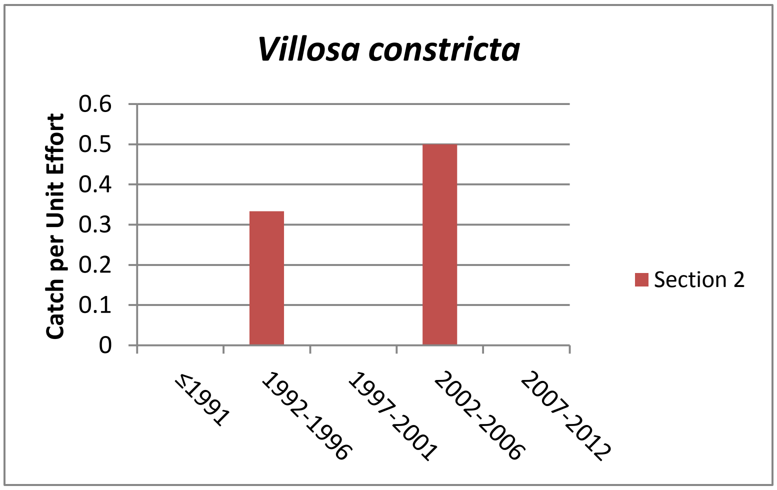
Chart 3. CPUE of Elliptio Species



5.5.1.4. Notched Rainbow

The notched Rainbow is extremely uncommon in the study area, being found only in Section 2 in very low numbers ≤ 0.5/hr (Chart 4). Live individuals have not been found since 2006; however, two fresh dead shells were found in 2012 as part of this study. Given its rarity, population trends are not able to be determined within the time period of the data set.

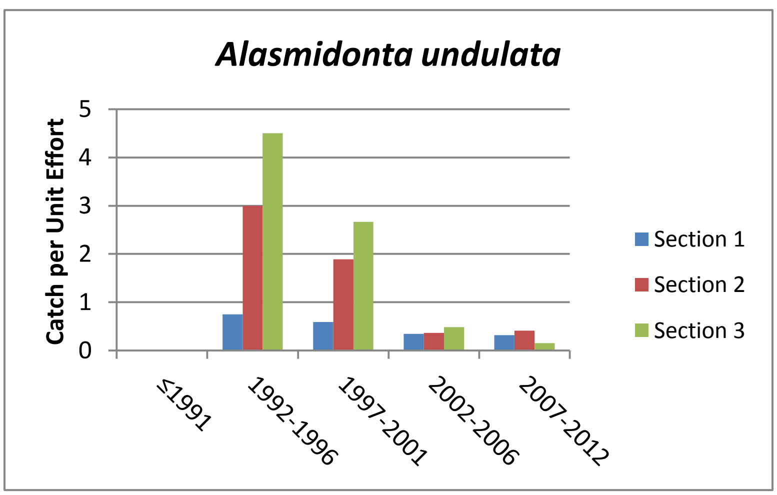
Chart 4. CPUE of Notched Rainbow



5.5.1.5. Triangle Floater

The Triangle Floater has been found in all three sections, being found most often in Section 2 and Section 3. The CPUE declined slightly between the 1992-1996 and the 1997-2001 periods, and then declined significantly in the following periods being consistently < 0.5/hr in all three sections.

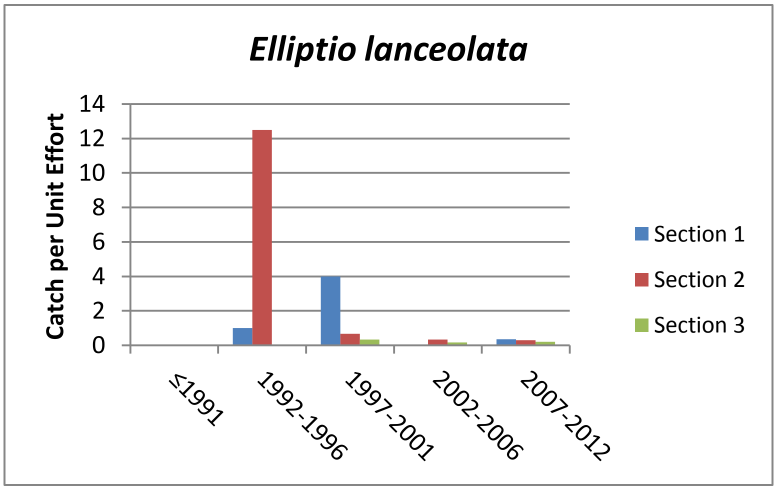
Chart 5. CPUE of Triangle Floater



5.5.1.6. Yellow Lance

The Yellow Lance has been found in all three sections, and has become increasingly rare since the 1992-1996 period (Chart 6).

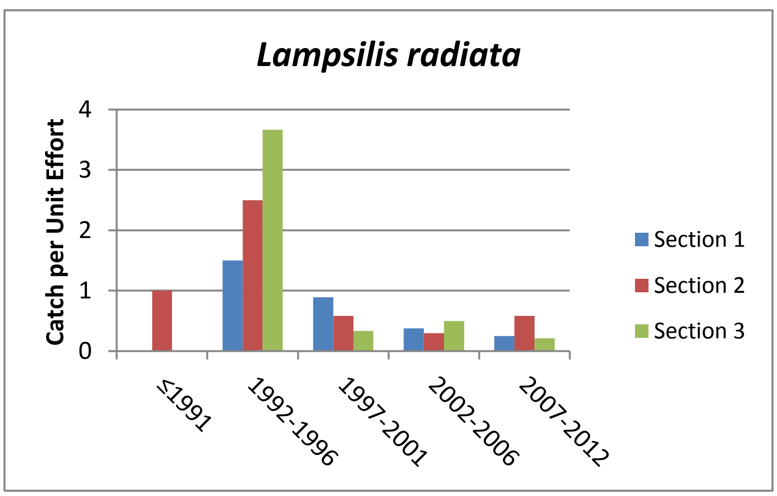
Chart 6. CPUE of Yellow Lance



5.5.1.7. Eastern Lampmussel

The Eastern Lampmussel occurs in all three sections, and the CPUE declined between the 1992-1996 and the 1997-2001 periods; however, it has remained fairly consistent since that time (Chart 7).

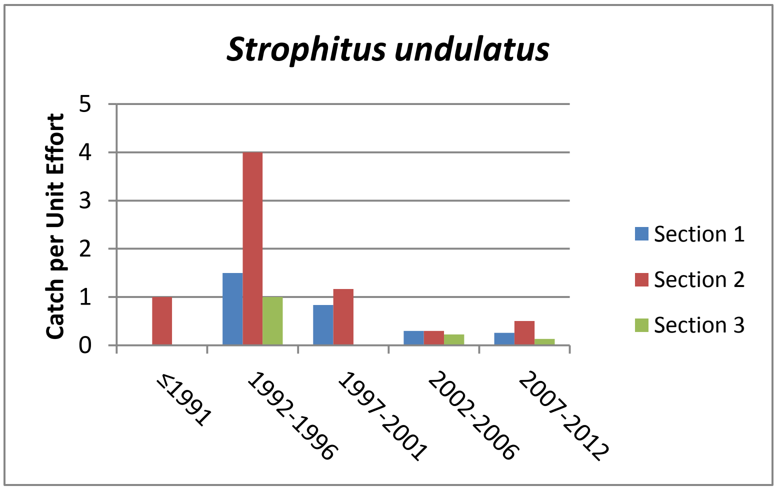
Chart 7. CPUE of Eastern Lampmussel



5.5.1.8. Creeper

The CPUE declined after the 1992-1996 period, and has been consistently ≤ 0.5/hr in all three sections in the last two sampling periods (Chart 8).

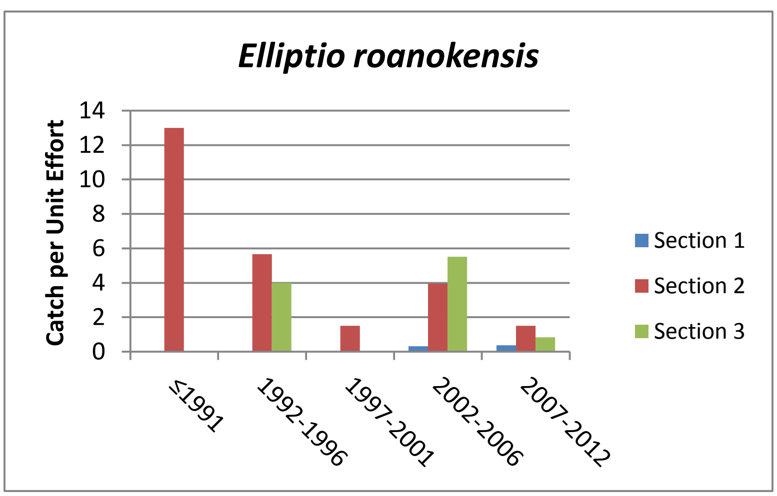
Chart 8. CPUE of Creeper



5.5.1.9. Roanoke Slabshell

The Roanoke Slabshell has been found in all three sections, but most often in Section 2. The highest CPUE occurred in the <1991 sampling period. Since that time, there are not any clear trends, as the 1992-1996 and 2002-2006 periods are very similar with CPUE between four and six individuals per hour, whereas the CPUE for the 1997-2001 and 2007-2012 periods is less than two individuals per hour (Chart 9). These differences in CPUE may be a reflection of sampling effort, as this species typically occurs within the deeper habitats, which are not as easily sampled and are often not targeted.

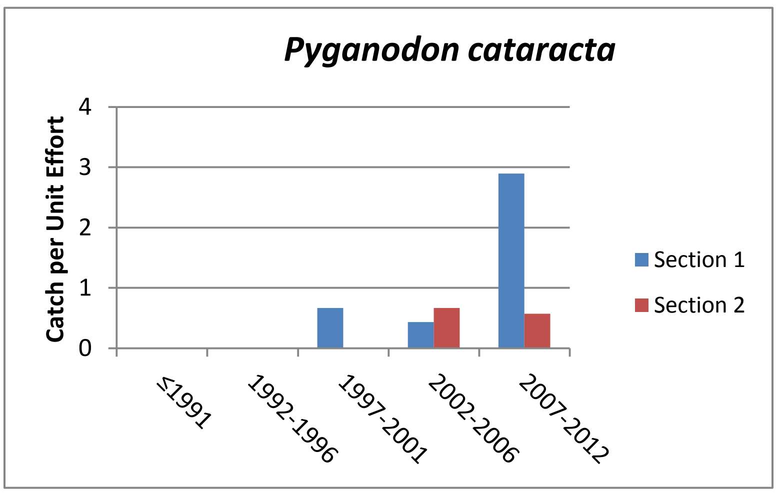
Chart 9. CPUE of Roanoke Slabshell



5.5.1.10. Eastern Floater

The Eastern Floater is a wide-ranging, common species throughout the Southern Atlantic Slope and is considered more tolerant than most mussel species of habitat modification and many forms of pollution (Connecticut Dept. Environmental Protection 2011). This species was not detected in Swift Creek in surveys prior to the third sampling period (1997-2001), where it was found in low numbers in Section 1 (Chart 10). Since this time it appears that this species is expanding its range in Swift Creek, as it was found in Section 1 and 2 during the fourth (2002-2006) and fifth sampling periods (2007-2012), with an apparent increase in relative abundance in Section 1 in the fifth sampling period. This increase in range and relative abundance may be indicative of continuing habitat modification in the stream.

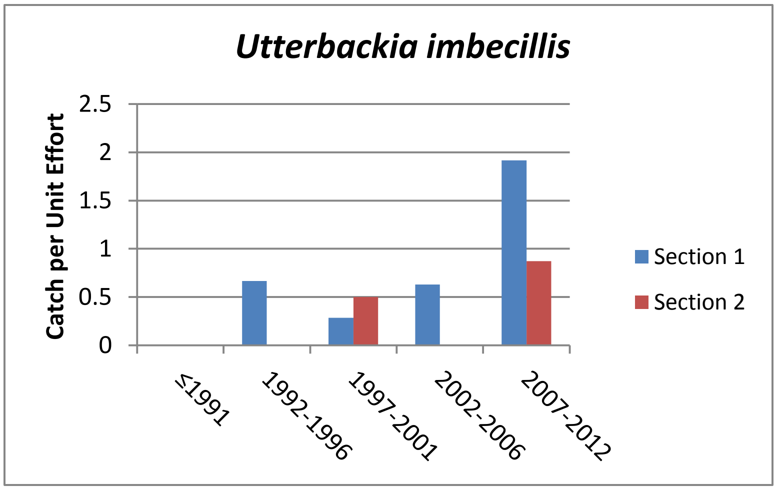
Chart 10. CPUE of Eastern Floater



5.5.1.11. Paper Pondshell

Similar to the Eastern Floater, the Paper Pondshell is a wide-ranging, common species throughout the Southern Atlantic Slope and is considered more tolerant than most mussel species of habitat modification (Williams *et. al* 2008). As with the Eastern Floater, this species has only been found in Section 1 and 2 of Swift Creek (Chart 11). There appears to be a slight increase in relative abundance in Section 1 during the fifth sampling period.

Chart 11. CPUE of Paper Pondshell



5.6. Age Class Distribution Analysis

Healthy mussel populations are usually represented by multiple age classes. Although not a perfect correlation, shell length is often used to estimates age of mussels. Size class data is readily available for sampling periods four and five for the following species:

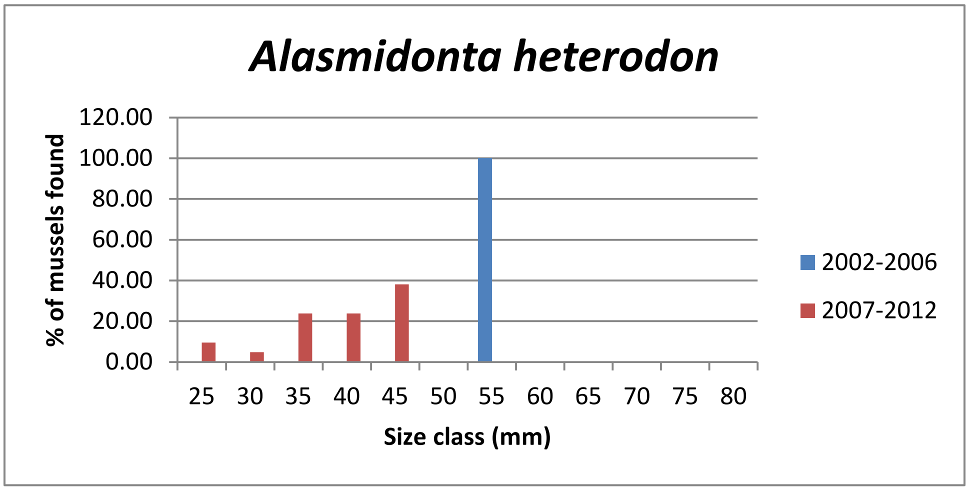
- Dwarf Wedgemussel
- Triangle Floater
- Yellow Lance
- Atlantic Pigtoe
- Eastern Lampmussel
- Creeper
- Notched Rainbow

This data was compiled and sorted into various size cohorts for each species. Size cohorts for each species were divided by five millimeter increments, with the exception of the Eastern Lampmussel, which was divided into 10 mm increment, as this species attains a large size and grows relatively quickly. While the size cohorts cannot be used to determine exact age of the populations, a population with multiple size cohorts is reflective of a population with multiple age classes. Some size class data also exists for these species for earlier sampling periods, but was not gathered consistently to be used in this analysis. In addition, the DWM, Yellow Lance, and Notched Rainbow were found too infrequently to make any conclusions on age class distribution over time. For example, in the 2002-2006 time period only one individual DWM and one Yellow Lance were found, and thus the population for that time period is represented by only one age class.

5.6.1. DWM

While size class distribution trends overtime cannot be determined given the fact that only one individual was found during the 2002-2006 survey period, data from the 2007-2012 period indicate that while represented by very few individuals, the DWM population consists of multiple size classes (Chart 12).

Chart 12. Size Class Distribution of Dwarf Wedgemussel



While determining the exact age of an individual mussel in the field is difficult, age can be estimated by size (total length) and growth rests. Michaelson (1995) determined the age of 43 DWM from the upper Tar River in North Carolina, and then evaluated the range in shell size for each age group (Table 10). For example, 75 % of the individuals in the 13.0-16.9 mm size class were one year old, and 25% were two years old. Aging individuals greater than 37 mm and 6 years old is difficult, as growth rates decline as individuals age (Michaelson 1995).

Table 10. Percent Composition in Age Groups (yr) adapted from Michaelson (1995)

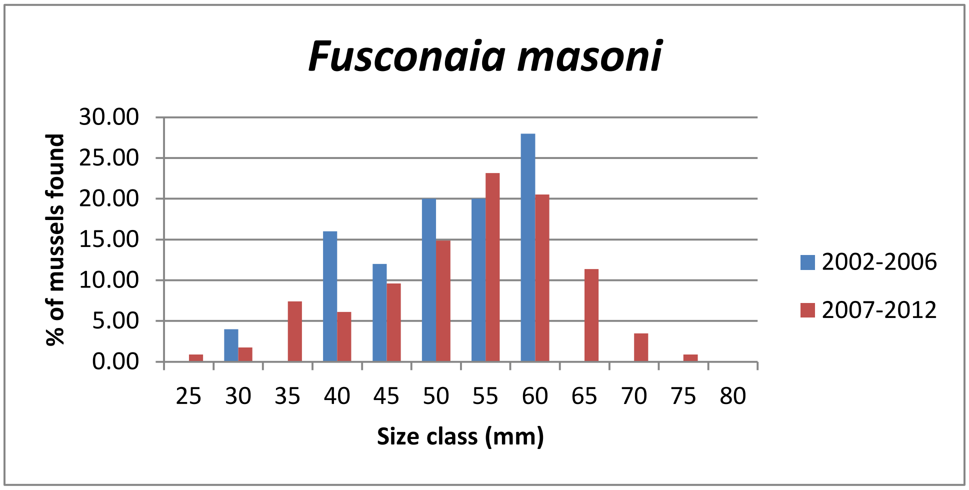
Length (mm)	1 yr	2 yr	3 yr	4 yr	5 yr	6 yr	> 6 yr
9.0-12.9	80	20	~	~	~	~	~
13-.0-16.9	75	25	~	~	~	~	~
17.0-20.9	~	100	~	~	~	~	~
21.0-24.9	~	22	78	~	~	~	~
25.0-28.9	~	~	27	64	9	~	~
29.0-32.9	~	~	~	20	60	20	~
33.0-36.9	~	~	~	~	~	100	~
N =	7	12	10	8	4	2	0

Using these age percentages for size classes the DWM found in Swift Creek during the 2007-2012 period likely represent at least three age classes, including relatively young (3-4 year old) individuals (Table 10).

5.6.2. Atlantic Pigtoe

Comparison of size class distribution for Atlantic Pigtoe for the two time periods indicate that the 2007-2012 period indicates more of a “normal distribution (bell shaped curve) than the 2002-2006 period, suggesting multiple age classes with recent recruitment.

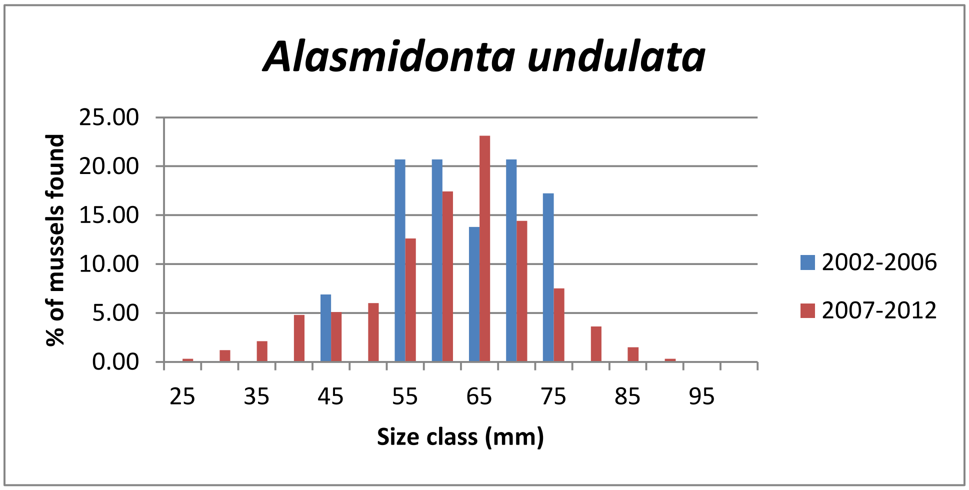
Chart 13. Size Class Distribution of Atlantic Pigtoe



5.6.3. Triangle Floater

Like with the Atlantic Pigtoe, the size class distribution of the 2007-2012 exhibits a more bell shape curve than the 2002-2006 period (Chart 14), also suggesting multiple age classes with recent recruitment.

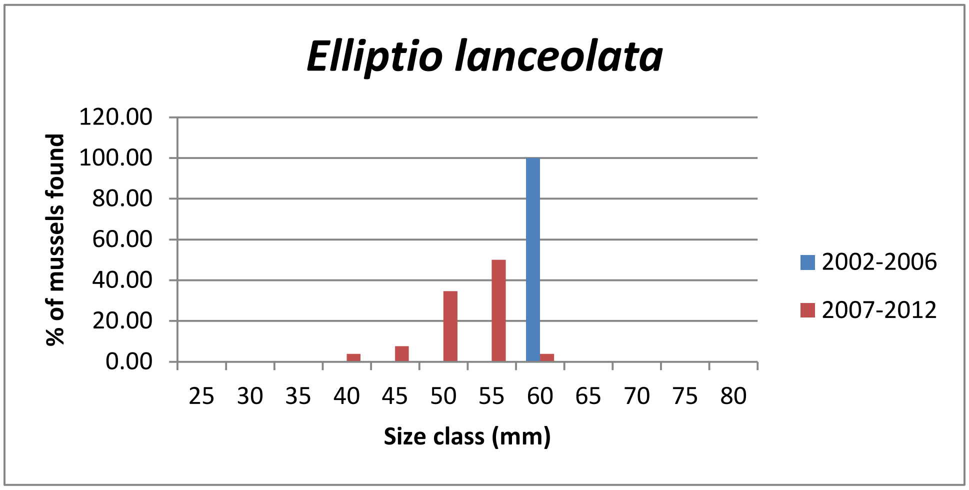
Chart 14. Size Class Distribution of Triangle Floater



5.6.4. *Yellow Lance*

While there are a number of size classes present, the Yellow Lance population is represented by very few individuals (one in the 2002-2006 period), thus it is difficult to make any conclusions regarding age class distribution (Chart 15).

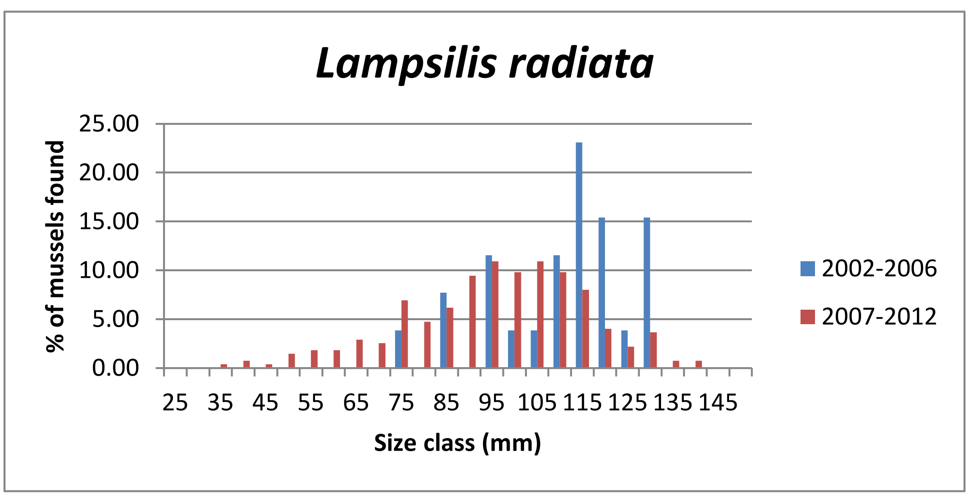
Chart 15. Size Class Distribution of Yellow Lance



5.6.5. *Eastern Lampmussel*

The Eastern Lampmussel population appeared to be dominated by mostly large (older) individuals in the 2002-2006 period compared with the 2007-2012 period (Chart 16), where it there is a bell shape distribution, suggesting recent recruitment.

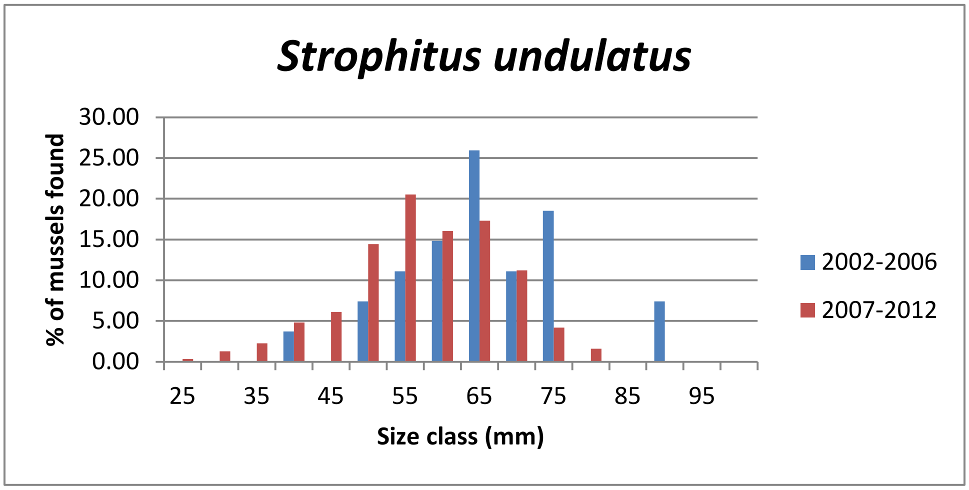
Chart 16. Size Class Distribution of Eastern Lampmussel



5.6.6. *Creeper*

The size class distribution for the Creeper exhibits a bell shape curve for both time periods; however, smaller (younger) size classes are more represented in the 2007-2012 period (Chart 17), suggesting recent recruitment.

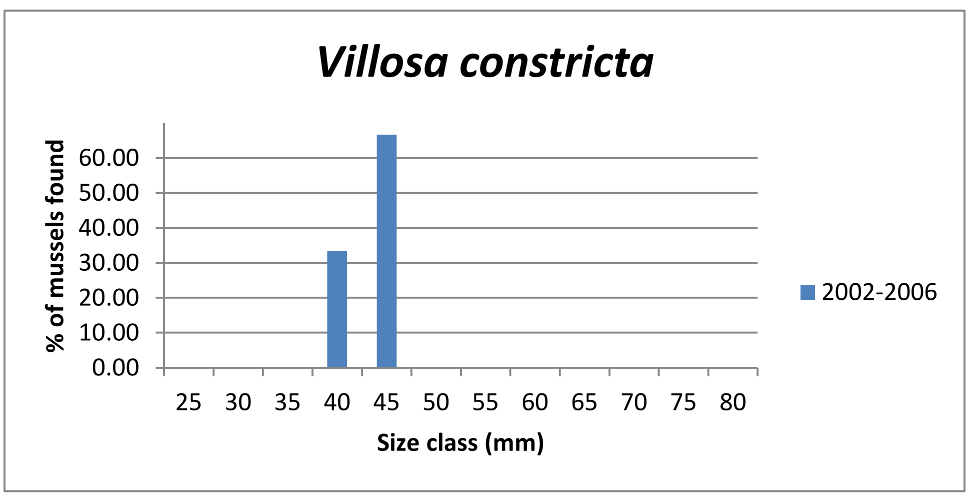
Chart 17. Size Class Distribution of Creeper



5.6.7. *Notched Rainbow*

The Notched Rainbow population is represented by only three individuals, and only within one time period (Chart 18), thus it is difficult to make any conclusions regarding age class distribution.

Chart 18. Size Class Distribution of Notched Rainbow



5.7. Mussel Detection Probability Analysis

One concern with making population trend conclusions for cryptic species like freshwater mussels is their inherent difficulty of being detected. The ability to detect a particular species during a mussel survey is dependent on a variety of factors including surveyor experience, survey conditions, and survey design, as well as particular biological traits of the particular species, including size, habitat preferences, and behavioral attributes such as vertical (burrowing up and down in the substrate), and horizontal (moving across the substrate) movement. Larger sized species such as the Elliptio mussels are typically easier to detect than very small species like the DWM. Detectability is further compounded for the DWM, as Deep Stream Margin Roots, one of the in-stream microhabitats identified as primarily supporting this species in Swift Creek (Entrix 2005), are very difficult to sample. As such, population size estimates for species that are difficult to detect may be underestimated because of this attribute.

Understanding the detection probability for a species is crucial in determining population size and viability. As discussed in Section 5.3, the DWM has consistently been detected in Swift Creek in low numbers since 1991. The fact that the species has persisted in the creek for well over 20 years, despite relatively few individuals ever being recorded, coupled with evidence of reproduction (presence of gravid individuals) and recruitment (small size classes present), there is a potential that the DWM has been under-detected in Swift Creek.

To account for the imperfect detection of the DWM and other mussel species, a sampling design was developed where mussel surveys were conducted at nine sites: three currently occupied sites, three formerly occupied sites and three randomly selected sites. Each site was then re-surveyed in the same season using similar methodologies and under similar conditions. The results of these surveys are provided in Appendix E.

Detection probabilities for each species occurring at the nine sites were then developed using the statistical program PRESENCE version 5.9 (Hines 2006). PRESENCE is software that has been developed primarily to fit occupancy models to detection/non-detection data. Two models were evaluated for 13 different mussel species:

- Group 1: constant P: species at all sites/samples are detected with a single probability, P
- Group 2: survey-specific P: survey-specific detection probability at all sites, P(1)=detection probability for 1st survey, P(2)=detection probability for 2nd survey, etc.

The results of this analysis demonstrate the varying levels of detection between species. For instance, with both models the probability that *Elliptio complanata* and *E. icterina* occur at a site is 100%, with 100% detection probability. The Yellow Lance (*E. lanceolata*) on the other hand has a high detection probability (100% with both models) as well; however, there is a low probability (11% both models) that it is present. Whereas with the DWM, the probability that it occurs at a site is 44% with a 50% detection probability with one model, and a 33% presence probability with a range of detection probability from 33% to 100% with the second model. The occupancy and detection probabilities for each species are shown in Table 11.

Table 11. Detection Probabilities by Species

	Group 1: Constant P			Group 2: Survey Specific P		
Species	**Psi ***	**P** site 1**	**P** site 2**	**Psi ***	**P** site 1**	**P** site 2**
A. heterodon	0.4444	0.5000	0.5000	0.3333	1.0000	0.3333
A. undulata	0.6944	0.8000	0.8000	0.6667	1.0000	0.6667
E. complanata	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
E. congarea	0.9389	0.7692	0.7692	0.8889	1.0000	0.6250
E. icterina	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
E. lanceolata	0.1111	1.0000	1.0000	0.1111	1.0000	1.0000
E. roanokensis	1.0000	0.5000	0.5000	1.0000	0.5556	0.4444
E. sp cf mediocris	0.9259	0.6000	0.6000	0.9259	0.6000	0.6000
E. sp cf producta	1.0000	0.1111	0.1111	1.0000	0.1111	0.1111
F. masoni	0.8000	0.8333	0.8333	0.8000	0.8333	0.8333
L. radiate	0.9074	0.8571	0.8571	0.9074	0.8571	0.8571
P. cataracta	0.4444	0.5000	0.5000	0.3333	1.0000	0.3333
S. undulatus	0.9074	0.8571	0.8571	0.8889	0.75000	1.0000

* Psi = probability that species is present, ** P = probability that species will be detected

5.8. Population Trends Summary

With the exception of the Eastern Floater and Paper Pondshell, which are considered tolerant of habitat degradation, the relative abundance (CPUE) of all other mussel species in Swift Creek has declined since the mid 1990's. As discussed in Section 5.1, there are imperfections with the Swift Creek mussel survey dataset in that it does not account for variables such as surveyor experience, survey design, survey effort, survey conditions and seasonal variations, all of which factor into the effectiveness of a survey. Additionally, as shown in Table 9 in Section 5.5.1, there has been a disproportionately greater amount of survey time spent in Swift Creek in the six year period between 2007 and 2012 than in the 16 years previously.

While these inherent flaws undoubtedly contribute to some of the differences in relative abundances over time, it is apparent that population levels have declined to some degree. Variability in survey methodologies may be more important in explaining CPUE differences of small sized species, which in Swift Creek tend to also be rare. The variability is less likely to be a factor when evaluating trends with larger sized species like the Elliptio mussels which, as shown in Table 11 have a high detection probability (100%), and also tend to also be habitat generalists. While still very common in Swift Creek, the relative abundance of Elliptio mussels has declined dramatically and appears to be continuing to decline.

Another species that is in obvious decline in Swift Creek is the Yellow Lance. While never being abundant in Swift Creek, a CPUE of greater than 12 individuals per hour was recorded in Section 2 in the 1992-1996 time period. The CPUE has been < 0.5/hr in the last three sampling periods. Given the fact that the species has a high (100%) detection probability (Table 11), the current low CPUE can be attributed to increasing rarity This is further supported by the low occupancy probability (11%) shown in Table 11.

The detection probability analysis suggests that DWM may be under detected in Swift Creek. While this may be true, it is still one of the rarest species occurring in the stream, which is reflected in the very low CPUE.

It is apparent that overall mussel populations have declined in Swift Creek over the 22 year period; however, there are some indications of positive trends in the most recent years, particularly with some of the "rare" species, including Atlantic Pigtoe, Triangle Floater, Eastern Lampmussel and Creeper. The CPUE for these species were very similar between the 2002-2006 and the 2007-2012 periods. However, based on size class analysis there seems to be a more "normal" distribution of age classes in the 2007-2012 period compared to the previous one. This suggests recent recruitment, which if it continues will likely correlate to increased CPUE, as individuals grow and become more easily detected. A longer dataset with regards to size class is needed to determine if this is an actual trend.

5.9. Population Trends Phase 2 Considerations

The dataset used for the population trend analysis does not include data collected in 2013. This data should be added to the existing dataset. In addition, more information should be analyzed within the existing dataset. The size class distribution component examined data from only two time periods (2002-2006, and 2007-2012), because those were the only two periods where that information was easily accessible. In many instances size information was recorded during earlier time periods; however, it is more difficult to access due to the way data was entered into the database during those time periods. Evaluating the size data from the earlier time periods may be useful in investigating whether the trend of increased recruitment observed in the 2007-2013 period is an indication population increase, or whether this is a cyclical phenomenon. Additionally, there may also be size class information available for the more common species such as the Elliptio mussels, as often a subset of individuals are measured. Declines in relative abundance were evident for the Elliptio mussels; understanding age distribution within the Elliptio population will be useful in evaluating population trends.

Further development of the detection probability component of this study is warranted. The analysis completed in Phase 1 included only a very small sample size (nine sites, or 18 surveys). The same sites should be re-surveyed multiple times, and additional sites should be added, to bolster the reliability of the results, as well as to account for variability between years. Incorporating other covariates such as seasonality and survey conditions should also be incorporated into the analysis.

6.0 IN-STREAM HABITAT VIABILITY IN SWIFT CREEK

The NC DWM Work Group identified "unsuitable physical habitat" as the most important threat to the Swift Creek population (Smith et al. 2014). Thus, the continued persistence of the DWM in Swift Creek will be largely dependent on the suitability of future habitat conditions. To evaluate this, various habitat parameters including water quantity, channel stability, and substrate composition were considered.

6.1. Stream Flow (Hydrograph Analysis)

The effects of extended drought on freshwater mussels were discussed in Section 2.3.4. As part of this component of the study, stream flow data from two USGS gauging stations were analyzed over the entire period of record to assess current and historic water quantity conditions (Figure 5). Only one gauging station currently exists on Swift Creek below Lake Benson that records discharge. It is at SR 1555 near Clayton (208773375) and has been in operation from 2008 to the present. There is a gauge on Middle Creek (2088000) at NC-50 near Clayton that has discharge records from 1939 to present. Though Middle Creek is not within the Lower SCW, the two watersheds are directly adjacent to one another and contribute to the larger Swift Creek watershed. Therefore, the gauge on Middle Creek is used here as a surrogate indicator for long term hydrograph data of the SCW.

Two drought indicator thresholds were evaluated;

1. Consecutive days at or below 1 cfs
2. Consecutive days at or below 5 cfs

For each gauge, the number of times (periods) either of the above two drought indicator thresholds was met, it was noted in Table 12 (see Appendix F for complete data table). For example in the 1980-1989 time period at the Middle Creek gauge, there were 20 different times (periods) when the flow was at or below 1 cfs for more than one consecutive day, with a total of 224 days below 1 cfs.

The data from the Swift Creek SR 1555 gauge demonstrates that the stream has experienced periodic episodes of low flow throughout the period of record. However, the relatively short period of record does not allow for extensive analysis of flow conditions in the lower portion of Swift Creek. The data from Middle Creek is much more extensive. The LSC and Middle Creek watersheds can be assumed to have similar precipitation levels and land use, as headwaters of both streams are within the jurisdictions of Raleigh suburban towns, such as Apex, Cary and Garner. Middle Creek has also experienced periodic episodes of low flow, and sometimes extremely low flows, the most notable occurring in the summers of 1954 and 1986, which lasted more than 35 days.

Table 12. Periods of Extreme Low Flows: Swift Creek and Middle Creek

	Swift Creek at SR 1555 near Clayton (208773375)		Middle Creek at NC-50 near Clayton (2088000)	
	Number of Periods of Threshold Events (Total Number of Days)		Number of Periods of Threshold Events (Total Number of Days)	
Year Range	**at or Below 1cfs**	**at or Below 5cfs**	**at or Below 1cfs**	**at or Below 5cfs**
1940-1949	~	~	0	16 (93)
1950-1959	~	~	4 (55)	22 (251)
1960-1969	~	~	2 (27)	3 (90)
1970-1979	~	~	2 (26)	28 (222)
1980-1989	~	~	20 (224)	54 (696)
1990-1999	~	~	1 (3)	6 (41)
2000-2009	0	1 (4)	0	1 (1)
2010-2013	0	5 (14)	0	0

~ - Gauge was installed in 2009 – no previous data available

While there was also a gauge in the Lower SCW at NC-42 that operated between 1988 and 1997; unlike the other gauges, which average the daily flow rates, the NC 42 gauge only collected a single flow measurement during 28 different days during the eight year period. As such, this dataset is too limited to be used in this analysis.

6.1.1. Stream Flow Summary

As discussed in Section 2.3.4.3, the geology of the SCW makes it inherently susceptible to extended low flow periods, particularly in the upper portions. The stream flow data confirms the propensity for extended periods of low flow. The fact that the Swift Creek gauge had 14 days of consistently low flows in just the last four years suggests that Swift Creek has not had as consistent flows as Middle Creek, as no drought indicator thresholds were reached at the Middle Creek gauge during the last four years..

The tiered minimum flow releases guaranteed from Lake Benson provide a level of protection against extreme low flows that did not exist previously. Further analysis is needed to understand if these minimum flow guarantees are sufficient to maintain the DWM population.

6.1.2. Phase 2 Considerations

The hydrograph analysis in Phase 1 focused only on low flow events. As discussed in Section 2.3.4, extreme peak discharge can also be detrimental to freshwater mussels. A similar analysis as was done with low flow should also be done in Phase 2 for peak discharge, with thresholds established based on geomorphology and mussel characteristics.

6.2.Current and Historic Channel Stability

Aerial photos of the Study Area were obtained from NCDOT's Photogrammetry Unit, and analyzed to determine general channel course stability and adjacent land use during the time period available (1969 to 2010). It is important to note that complete aerial coverage of the Study Area is not available for any given year. The same three sections used in the viability component of this study were used here (Figure 12):

- Section 1 – Lake Benson to I-40
- Section 2 – I-40 to Barber Mill
- Section 3 – Barber Mill to NC-210.

During the time period analyzed, there was no major channel migration observed. However, below the NC 42 crossing, the main channel is braided into two distinct smaller channels (east and west). According to the landowner, prior to the early 1990's the west channel carried the majority of flow, and the east channel had flow only during high flow periods (Henry Ford landowner, personal communication). Since that time, the majority of flow has been concentrated in the east channel, and the west channel consists of stagnant, deep scour pools, and very shallow sand bar dominated areas with very little flow. This is further supported by mussel survey data from that time period. In fact, the DWM was recorded at a site in the west channel in 1994; however, it was not located in 2011, and 2012 and based on current habitat conditions (stagnant pool) that site is no longer considered to be occupied. There is an embedded gas line ford crossing of the east channel that is significantly perched to a point that is likely a barrier to upstream migration of fish (Photo 3).

Photo 3. Perched Utility Crossing in East Braid of Swift Creek below NC 42

Examination of the aerial photography also provides a visual depiction of the conversion of land use that occurred within the Study Area in recent years. Some of the major land conversion events are noted for each of the sections.

Section 1: At some point between 1971 and 1986, sections of the I-40 corridor were cleared of vegetation. Between 1971 and 1991, square retention ponds off Wren Road were constructed as were the spray fields near New Bethel Church Road. Between 1986 and 1991 the Indian Creek Overlook neighborhood, which had a small domestic WWTP (recently decommissioned), was built. Between 1997 and 2010 the Southern Trace Neighborhood was built near the NC-50 and Benson Road intersection, southeast of the Ten-Ten Road intersection.

Section 2: In 1985, construction of the I-40/NC-42 intersection had begun and was completed by 1991. Between 1985 and 1997, an increase in development of the I-40/NC-42 interchange was evident (Photo 4). Between 1997 and 2010, a bigger pond was added at the end of Zachary Way (SR 2060), which is west of Cornwallis Road and south of Swift Creek. There was also a new area of houses on Cornwallis Road opposite of this pond site, and south of Swift Creek off Josephine Road (SR 1526).

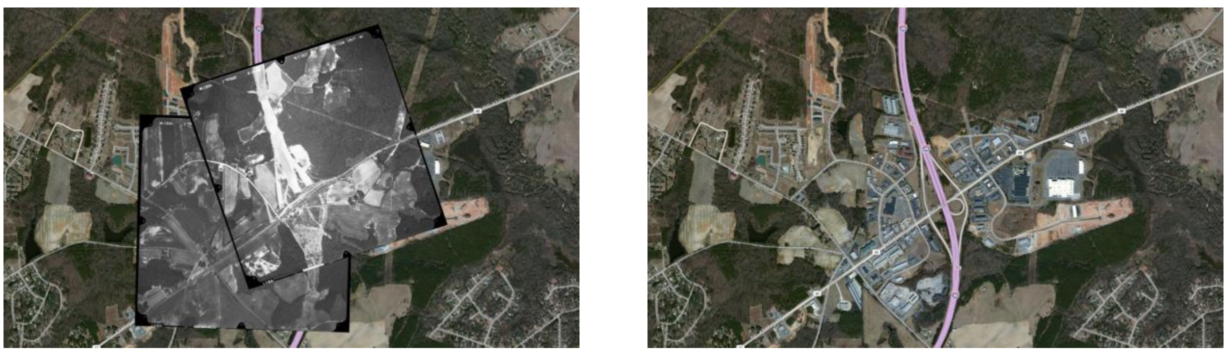


Photo 4. I-40/NC 42 interchange: 1985 on the left and 2012 on the right.

Section 3: Between 1969 and 1991 the Johnston County Airport was constructed. Also during that time, a new area of houses was constructed at Norris Road and Sterling Drive, which is north of Swift Creek. Between 1991 and 1994, the Johnston County Airport runway was expanded. Between 1994 and 2010, there were several developments in this section. A new area of houses was constructed south of Swift Creek at Cleveland Road (SR 1010) and Wood Creek Lane near Monroe Road (SR 1513). A new pond was constructed at the end of Casey Road northeast of Swift Creek near the intersection of Little Church Road (SR 1563). Lastly, a new area of houses was built at Clayton Pointe Drive (SR 3174) and Rock Pillar Road (SR 1572).

6.2.1. Channel Stability Summary

There is no evidence that large scale channel migration and instability has occurred in the Study Area. However, there is some indication that smaller scale channel migration may have occurred. These small scale changes would not be evident using aerial photography. However, the aerial photo analysis clearly demonstrates the urbanization of the Lower SCW. The effects of urbanization on in-stream channel stability are described in Section 2.3.4.

6.2.2. Channel Stability Phase 2 Considerations

The large scale channel stability component has been completed. An in-stream assessment of existing channel and riparian conditions would provide a better understanding of future channel stability, and should be considered in Phase 2.

6.3. In-stream DWM Habitat Assessment Analysis

Throughout its range, the DWM has been reported from a wide variety of habitats (from small streams to large rivers) and substrates (sand and gravel to muddy sand and clay (USFWS 1993). Two general in-stream habitat types, Shallow Fast Coarse (SFC) or Deep Stream Margin Roots (DSMR) habitats were identified as primarily supporting this species in Swift Creek (Entrix 2005). As part of the Phase I Study, a Habitat Assessment within Swift Creek was performed to further understand the habitat requirements of DWM in Swift Creek. The geomorphology analysis component addresses the current habitat conditions in Swift Creek and its ability to continue to support the DWM. Habitat assessment and characterization was conducted in Swift Creek in January and February, 2013 in nine locations that had previously been surveyed for freshwater mussels, with DWM as the target species. The assessment consisted of stream cross sectional profiles, longitudinal profiles, particle size distribution analyses, and qualitative analyses accompanied by photo documentation for each site. The report, Complete 540 – Triangle Expressway Dwarf Wedgemussel Habitat Assessment Survey Report (Catena 2013), is Appended (G).

6.3.1. Geomorphology Summary

The results revealed a correlation in DWM presence and substrate particle size. While the sites where the DWM occurs generally have gravel dominated substrate, the species is often found within small microhabitats of clay. These data could be further expanded with additional transects throughout each survey site to accurately depict habitat conditions in order to better understand habitat needs of the DWM. The three previously occupied sites occur within the upper portion of the DWM range in Swift Creek. A likely reason these areas are no longer occupied is due to a shifting sand substrate, which is generally indicative of unstable conditions. Further study of the relationship between substrate particle size and the presence of DWM is needed along with in-stream habitat monitoring (particularly in the upper sections) to fully understand the likelihood of persistence of DWM in Swift Creek.

6.3.2. Phase 2 Considerations

While it appears there is a general correlation between DWM and substrate particle size, the assessment could be expanded to include more sites as well as to re-survey some of the original sites to assess any changes that happened within the past year. It is recommended that the report be provided to the USFWS and NCWRC followed by a discussion as to the benefit of additional studies.

7.0 DWM POPULATION VIABILITY IN SWIFT CREEK

Continued analysis and studies are needed before making a definitive conclusion regarding the long term viability of the DWM within Swift Creek. The preliminary indicators of long term viability are mixed; however, the potential for this species to persist into the future in Swift Creek is highly dependent of habitat viability, which was discussed in Section 6.0. Each of the population viability criteria are discussed below, along with overall mussel population trends.

7.1. Length of Occupied Habitat Criterion

The historic range of the DWM population in the mainstem of Swift Creek has been reported to be approximately 21 miles (Figure 13). However, as mentioned in Section 6.4, the lower 10 miles of this range are represented by only one individual found in 1991. Considering the occurrences of DWM in the tributaries White Oak Creek, Little Creek, and Middle Creek, and the fact that there are no known physical barriers that would limit connectivity (thus creating > two miles of unoccupied habitat), the assumed historic occupied habitat would be approximately 53.7 miles. This 53.7 miles was derived by adding the historic 21 mile range in Swift Creek to the combined distances of the most upstream DWM records in the respective tributaries to the respective confluences with Swift Creek (0.2 mile in White Oak Creek, 2.0 miles in Little Creek and 25.0 miles in Middle Creek), plus an additional 5.5 miles of Swift Creek from the most downstream historic occurrence to the confluence of Middle Creek.

There is however, no survey data to support the 53.7 mile range, and using a two mile distance of un-occupied habitat as a distance to separate populations, it is possible that the 53.7 mile range represents a metapopulation, comprised of a number of smaller local populations. If this is the case, the Little Creek, Middle Creek and the lower 10 miles of Swift Creek are three local populations, of which the latter two appear to have been extirpated.

The survey efforts of 2007, 2010, 2011 and 2012 establish a current occupied range of at least 11 miles (Figure 13) in Swift Creek, with no gaps of unoccupied habitat greater than two miles. Whether this indicates a reduction in range of 10 miles of a population, or whether two distinct populations occurred in Swift Creek is unclear; however the 11 mile section has consistently been occupied since 1992. Eleven miles of occupied habitat are at the lower limits of the first population criterion. While the species was not found in Little Creek during the 2011 surveys, habitat conditions appear relatively stable and are similar to those observed when DWM was found in 2003, suggesting that the species may still persist in Little Creek. Based on this assumption, it is unclear if this would constitute a separate population since there are greater than two miles with no recent DWM records between the downstream limits of the current 11 mile occupied range in Swift Creek and the confluence of Little Creek, or if it would represent a dendriditic expansion of the 11 miles of occupied habitat (assuming DWM is present in the greater than 2-mile gaps). More intensive surveys at various time intervals are needed in Little Creek as well as within Swift Creek near the confluence with Little Creek to determine DWM occupancy.

7.2. Occur at 75% of Sites within Occupied Habitat Criterion

Since 2007, within the 11 miles of Swift Creek believed to be occupied, the DWM was found at 6 of 62 surveyed sites (9.67%) in 2007, 5 of 83 sites (6.02%) in 2010, 3 of 47 sites (6.38%) in 2011 and 8 of 44 (18.18%) in 2012. However, when considering the results of the occupancy and detection probability analysis, the predicted occupancy is much higher (44% in one model and 33% in the other model). This is still well below the 75% occupancy target.

7.3. CPUE > 5 Individuals per hour at 50% of Occupied Sites Criterion

The CPUE for DWM has consistently been very low since its discovery in Swift Creek, and has declined from a high of 3.5/hr in Section 2 during the 1992-1996 period to <0.5/hr in both Section 1 and Section 2 in the 2007-2012. One of the hypotheses for the low CPUE of DWM at occupied sites was attributed to non-specific survey methods to detect all mussel species rather than specifically targeted DWM. As such, habitat specific surveys targeting DWM were performed beginning in 2011 at all of the known DWM sites in the Swift Creek watershed. The theory was that the CPUE for DWM would be higher in occupied areas applying these targeted methodologies. However, these targeted surveys failed to detect the DWM at any of the previously known sites, although it was found at three previously unknown sites, further demonstrating its rarity in Swift Creek. The reasons for not detecting this species at any of the target sites are unclear, as many of these sites still contained the microhabitats associated with DWM. In addition, numerous mussels of other species that were tagged at some sites in 2007 were recovered in the same locations in 2011, which suggests a relatively stable habitat. In 2012 however, the DWM was detected at three of the previously known sites, as well as at four previously un-sampled sites.

As mentioned in Section 5.3, the viability criteria have not been tested on mussel populations in the state, but were based in the collective opinions of the Council, and applied across the board to all mussel species. As demonstrated in this study, different species have differing levels of detection, and a CPUE criterion for one species may not necessarily be applicable to another species. These criteria will likely need to be adjusted as these methods are applied and more information becomes available.

7.4. Evidence of Recent Reproduction Criterion

Evidence of recent reproduction within a population can be determined by either finding gravid (holding progeny) individuals, and/or finding multiple size classes, including younger individuals. In the southern portion of its range, the period of gravidity reported for DWM is from November through April. However, based on previous survey data in Swift Creek the majority (81%) of DWM were collected between mid-May and October, which may suggest that at least in Swift Creek, the DWM may be more easily detected during periods when it is not gravid. It is unclear if this is a reflection of seasonal variation in detection probability, or due to a smaller number of surveys conducted during periods of gravidity.

In order to evaluate this, the 2011 surveys were initially designed to be performed during the later portion of the gravidity period, more specifically late March to late April. While these months are only a portion of the period of gravidity, survey conditions (amount of daylight, water levels and temperatures etc.) would allow for maximum survey efficiency. However, due to weather patterns, all of the surveys could not be performed during this time frame, and no gravid individuals were observed. In 2012 however, two of six live individuals found were gravid. One of those individuals was observed to be gravid in early March, and then again in late November, which indicates two successful periods of reproduction, as the species releases glochidia in late spring (Michaelson 1993).

Evidence of reproduction can also be determined by the presence of young age classes. While overall numbers of DWM in Swift Creek were very low, the 2007, 2010, 2011 and 2012 surveys indicate continuing reproduction, as small (young) size-class individuals were found in each of those years. It is unclear whether this reproduction is sufficient to maintain population viability, particularly when considering the indication of declines in relative abundances of the mussel fauna over time.

7.5. Overall Mussel Population Trends

As stated throughout this report, the DWM is very rare within Swift Creek, but it has persisted in the stream for over 20 years. This rarity, whether inherent in southern populations, or a result of population declines, makes it difficult to project future viability when there is no information on population(s) numbers prior to 1991. As such, inferences on DWM must be made from also evaluating population trends of the other species occurring in the Study Area. As summarized in Section 5.8, the indicators of future viability developed from the population trends analyses are mixed. On one hand there is a declining trend in relative abundances of nearly all species, and on the other, there is some evidence that indicates these declines have leveled off, and there is increased recruitment of younger individuals.

7.6. Viability Conclusions

The results of the various components of this study indicate that the mussel fauna of Lower SCW is subject to multiple stressors which may threaten future viability. The Notched Rainbow, Yellow Lance and DWM appear to be the most vulnerable species. Further analysis of population and habitat trends is needed to clearly determine continued persistence of the DWM in Swift Creek. Changes in the watershed have happened in a relatively short period of time, and the mussel fauna appears to have declined in conjunction with these changes. The decline seems to have leveled off in recent years, which when coupled with evidence of recent reproduction and recruitment, may suggest a chance for the species to persist into the future.

This level of uncertainty is due to numerous factors, including a lack of historic population data, an insufficient amount of time to evaluate effectiveness of the various conservation measures that have been implemented, not knowing what additional protective measures may be implemented, and not knowing what population management resources will be available. For example, the NC DWM Work Group concluded that population augmentation through captive propagation is an essential component of management strategies to ensure DWM persistence in North Carolina (Smith et al. 2014). This is especially true with populations such as Swift Creek where the Allee effect (high risk of demographic extirpation due to low population abundance and lack of dispersal) is one of the major limiting factors of population viability. As mentioned in Section 4.2.8, the DWM has successfully been propagated (Beck and Neves 2001). Additionally, in North Carolina, a cooperative program between the NCWRC and the College of Veterinary Medicine at North Carolina State University is actively propagating imperiled mussel species. The feasibility of using this technology and available resources must be factored into management decisions regarding the Swift Creek DWM population.

7.7. Recommendations

A number of items to be considered in Phase 2 of this study have been identified throughout this report. These are briefly summarized below, along with general recommendations on how to address these items in the next phase of this study.

- Greater analysis of water quality monitoring data, including Ward et al. 2007 study (Section 2.3.3)
- Update to City of Raleigh water quality data set (Section 3.6)
- Expand water quality monitoring efforts, particularly of parameters that threaten the DWM and in the Lower SCW (Section 3.6)
- Further consider the management strategies identified by the NC DWM Work Group and gather information from the work group as recommendations of course of action(s) are made (Section 2.3)

- Explore the feasibility and likelihood of success of using population augmentation to achieve long term viability of the Swift Creek DWM population (Section 4.2.8)
- Assessment of EEP efforts within Study Area (Section 4.2.7)
- Continue coordination with Neuse 01 Regional Watershed Planning and appropriate stakeholders (Section 3.6)
- Identify and locate BMPs/retrofit sites using SBES (Section 4.2.9), refine and field test evaluation form
- Keep abreast of changes to local ordinances, regulations, policies that impact the Study Area and the DWM (Sections 4.2.3), particularly in Johnston County (Sections 4.2.7)
- Update population trend analysis with 2013 survey data (Section 5.0)
- Compile size class data from earlier time periods (Section 5.0)
- Expand detection probability study – increase number of visits per site per season and number of sites, use multiple season data (Section 5.7)
- Analyze peak discharge events (similar to low flow events analysis done here) (Section 6.1)
- In-stream assessment of existing channel and riparian conditions (Section 6.3)
- Expand geomorphology assessment to include more sites and re-survey of original sites to assess changes over the past year (Section 6.3)
- Research more thoroughly the Notices of Violations within Swift Creek (Section 3.3.3)
- Compare aerial photos to USGS topographic maps (Section 6.2)
- Incorporate information from the geomorphology assessment into description habitat requirement description of DWM habitats (Section 2,2) based on the expansion of geomorphology assessment (confer with USFWS and NCWRC) (Section 6.3)
- Purchase rain gage data for lower Swift Creek, compare to streamflow (Section 6.1)
- EDR First Search Report

8.0 RESOURCES

Alderman, J.M. (1995). Freshwater mussel inventory of the Stevens Creek Subbasin, Long Creek Ranger District, Sumter National Forest, South Carolina. Unpublished report tot he U.S. Forest Service. 38 pp.

AMEC Earth & Environmental, Inc (AMEC). (2004). Swift Creek Local Watershed Plan – Phase I.

Arcadis. (2005). Biological Assessment for DWM in Support of the Dempsey E. Benton Water Treatment Plan Project.

Arnold, C.L., and C.J. Gibbons (1996). Impervious surface coverage—the emergence of a key environmental indicator. Journal of the American Planning Association 62:243–258.

Augspurger, T. (1992). Environmental Contaminant Impacts of Highway Runoff on Freshwater Mussels, Swift Creek, Nash County, North Carolina, US Fish and Wildlife Service. Ecological Services, Raleigh Field Office, NC.

Augspurger, T., A.E. Keller, M.C. Black, W.G. Cope and F.J. Dwyer. (2003). Water quality guidance for protection of freshwater mussels (Unionidae) from ammonia exposure. *Environmental Toxicology and Chemistry* 22: 2569-2575.

Bartsch, M.R., T.J. Newton, J.W. Allran, J.A. O'Donnell, and W.B. Richardson. (2003). Environmental Toxicology and Chemistry 22(11):2561-2568.

Beck, K.M., and R.J. Neves. (2001). Propagation studies of the endangered dwarf wedgemussel. Final Report to the North Carolina Department of Transportation, Raleigh, NC. 63 pp.

Belnick, T. (2001). NCDWQ-NPDES. 2001. Letter to Tommy Stevens, *portal.ncdenr.org/c/document_library/get_file?uuid=935de4e9...*

Bogan, A.E. (1993). Freshwater bivalve extinctions (Mollusca: Unionoida): A search for causes. American Zoologist 33:599-609.

Bringolf, R. B., R. M. Heltsley, C. Eads, T. J. Newton, S. Fraley, D. Shea, and W. G. Cope. (2007). Environmental occurrence of fluoxetine and its effects on freshwater mussel reproduction. 5th Biennial Symposium of the Freshwater Mollusk Conservation Society, Little Rock, AR, March 12-15, 2007.

Buchan, Edward. (2012). Personal communication. City of Raleigh, Public Utilities Department. Environmental Coordinator. Water Quality Monitoring stations in Lower Swift Creek.

Cedar Rapids, Iowa. (2008). Best Management Practice for Maintenance of Private Storm Water Facilities. Public Works Department. March 2008. http://www.cedar-rapids.org/government/departments/public-works/engineering/stormwater/Documents/Best_Management_Practice_Maintenance_Private_Stormwater_Facilities.pdf

CDM. (2003). Wake County Comprehensive Groundwater Investigation.

CH2MHILL. (2003). Comprehensive Watershed Management Plan – Wake County.

Clarke, A.H. (1981). The tribe Alasmidontini (Unionidae: Anodontinae), Part I: Pegias, Alasmidonta, and Arcidens. Smithsonian Contributions to Zoology 326:1-101.

Crawford, J.K. and D.R. Lenat (1989). Effects Of Land Use On The Water Quality And Biota Of Three Streams In The Piedmont Province of North Carolina. Prepared for US Geological Survey. Water-Resources Investigations Report 89-4007.

Dupuis, T.V., N.P. Kobriger, W.K. Kreutzberger and V. Trippi (1985). Effects of Highway Runoff on Receiving Waters-Vol. III. Resource Document For Environmental Assessments. Report FHWA/RD-84/064. FHWA, U.S. Dept. of Transportation, 153 p.

Ellis, M.M. (1936). Erosion silt as a factor in aquatic environments. Ecology 17: 29-42.

Entrix. (2005). Biological Assessment for Dwarf Wedgemussel (*Alasmidonta heterodon*): Prepared in Support of the Dempsey E. Benton Water Treatment Plant Project. Prepared by ENTRIX, Inc., Atlanta, GA. June 2005.

Field, R. and R.E. Pitt (1990). Urban storm-induced discharge impacts: United States Environmental Protection Agency research program review. Water Science and Technology 22(10/11):1-7.

Fuller, S.L.H., and C.E. Powell. (1973). Range extensions of *Corbicula manilensis* (Philippi) in the Atlantic drainage of the United States. Nautilus. 87(2):59.

Fuller, S.L.H. (1977). Freshwater and terrestrial mollusks. In: John E. Cooper, Sarah S.Robinson, John B. Fundeburg (eds.) *Endangered and Threatened Plants and Animals of North Carolina.* North Carolina State Museum of Natural History, Raleigh.

Gagné, F., P. Cejka, C. André, R. Hausler, and C. Blaise (2007a). Neurotoxicological effects of a primary and ozonated treated wastewater on freshwater mussels exposed to an experimental flow-through system. Comp. Biochemistry and Physiology Part C: Toxicology & Pharmacology 146(4):460-470.

Gagné, F., C. Gagon, P. Turcotte, and C. Blaise. (2007b). Changes in Metallothionein Levels in Freshwater Mussels Exposed to Urban Wastewaters: Effects from Exposure to Heavy Metals? Biomark Insights 2:107-116.

Garie, H.L. and A. McIntosh. (1986). Distribution of benthic macroinvertebrates in a stream exposed to urban runoff. Water Resources Bulletin 22(3): 447-455.

Garner, Town of. (2001). Town of Garner Stormwater Program for Nitrogen Control. February 17, (2001). http://www.garnernc.gov/Publications/Engineering/stormwater.pdf

Golladay, S.W., P.L. Gagnon, M. Kearns, J.M. Battle, and D.W. Hicks. (2005). The effects of extended low-flows on freshwater mussels in the lower Flint River Basin, Georgia: a case study. U.S. Geological Survey Workshop, Linking Hydrological Change and Ecological Response in Streams and Rivers of the Easter United States. February 8-10, 2005.

Goudreau, S.E., R.J. Neves, et al. (1988). Effects of Sewage Treatment Effluents on Mollusks and Fish of the Clinch River in Tazewell County, Virginia. USFWS**:** 128.

Grabarkiewicz, J. and W. Davis (2008). An introduction to freshwater mussels as biological indicators. EPA-260-R-08-015. U.S. Environmental Protection Agency, Office of Environmental Information, Washington, DC.

Guerrero, Jamie. (2013). Johnston County Public Utilities Department, Development Engineering, Environmental, & Stormwater Manager. July 16, 2013.

Gupta, M.K., R.W. Agnew, and N.P Kobriger (1981). Constituents of highway runoff Volume I, State-of-the-art report: Federal Highway Administration Final Report FHWA/RD-81/042. 121 p.

Havlik, M.E. and L.L. Marking (1987). Effects of Contaminants on Naiad Mollusks (Unionidae): A Review. U.S. Department of the Interior, Fish and Wildlife Service, Resource Publication 164. Washington, D.C. 20 pp.

Heltsley, R.M., W.G. Cope, R.B. Bringolf, C.B. Eads, and D. Shea (2006). Prozacelicits spawning in native freshwater mussels. 232nd Annual Meeting of the American Chemical Society, San Francisco, CA. September 10-14, 2006.

Hines, J.E. (2006). PRESENCE – Software to estimate patch occupancy and related parameters. USGS-PWRC. http://www.mbr-pwrc.usgs.gov/software/presence.html

Hoffman, C.D., E.J. Mills, J.S. Latimer, and J.G. Quinn (1984). Urban runoff as a source of polycyclic aromatic hydrocarbons to coastal waters. Environ. Sci. Technol. 18(8): 580-587.

Jacobson PJ, Farris JL, Cherry DS, Neves RJ. (1993). Juvenile freshwater mussel (Bivalvia:Unionidae) responses to acute toxicity testing with copper. *Environ Toxicol Chem* 12:879–833.

Jacobson PJ, Neves RJ, Cherry DS, Farris JL. (1997). Sensitivity of glochidial stages of freshwater mussels (Bivalvia: Unionidae) to copper. *Environ Toxicol Chem* 16:2384–2392.

Johnson, P.M., A.E. Liner, S.W. Golladay, and W.K. Michener. (2001). Effects of drought on freshwater mussels and instream habitat in Coastal Plain tributaries of the Flint River, southwest Georgia (July-October 2000). Final Report presented to the Nature Conservancy. August 25, 2001.

Jones, R.C. and C. C. Clark (1987). Impact of watershed urbanization on stream insect communities. Water Resources Bulletin 23(6):1047-1055.

Lea, I. (1829). Description of a new genus of the family of naiades. *Unio heterodon (Alasmidonta heterodon).* Transactions of the American Philosophical Society: 428, pl. 8, fig. 11.

Lenat, D.R., D.L. Penrose, and K.W. Eagleson (1979). Biological evaluation of non-point source pollutants in North Carolina streams and rivers. Biological Series Number 102. Department of Natural Resources and Community Development, Raleigh, North Carolina.

Levine, J.F., W.G. Cope, A.E. Bogan, M. Stoskopf, L.L. Gustafson, B. Showers, D. Shea, C.B. Eads, P. Lazaro, W. Thorsen, D. Forestier, and E.F. Anderson (2005). Assessment of the Impact of Highway Runoff on Freshwater Mussels in North Carolina Streams: 109 p.

Lieb, D.A. (1998). The effects of urban runoff on the benthic macroinvertebrate community of Thompson Run, Centre County, Pennsylvania. Masters of Science Thesis Pennsylvania State University, 130pp.

Maltby, L., A.B.A. Boxall, D.M. Forrow, P. Calow and C.I. Betton (1995). The effects of motorway runoff on freshwater ecosystems: 2. Identifying major toxicants. Environmental Toxicology and Chemistry 14 (6):1093-1101.

Marking, L. L. and T. D. Bills (1979). Acute effects of silt and sand sedimentation on freshwater mussels. Proc. of the UMRCC symposium on the Upper Mississippi River bivalve mollusks. J. L. Rasmussen. Rock Island, Illinois, UMRCC: 204-211.

Master, L. (1986). *Alasmidonta heterodon*: results of a global status survey and proposal to list as an endangered species. A report submitted to Region 5 of the U.S. Fish and Wildlife Service. 10 pp. and appendices.

McMahon, R. F. and A. E. Bogan (2001). Mollusca: Bivalvia. Ecology and classification of North American freshwater invertebrates. J. H. Thorpe and A. P. Covich, Academic Press: 331-429.

Memorandum, September 8, (1988). Swift Creek Watershed Land Management Plan, Draft.

Michaelson, D.L. (1993). Life history of the endangered dwarf-wedgemussel, *Alasmidonta heterodon* (Lea 1830) (Pelecypoda: Unionidae), in the Tar River, North Carolina and Aquia Creek, Virginia. MS Thesis, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 122 pp.

Michaelson, D.L. and R.J. Neves. (1995). Life history and habitat of the endangered dwarf wedgemussel *Alasmidonta heterodon* (Bivalvia: Unionidae). *Journal of the North American Benthological Society* 14(2):324-340.

Milam, C.D., J.L. Farris , F.J. Dwyer, and D.K. Hardesty (2005). Acute toxicity of six freshwater mussel species (glochidia) to six chemicals:Implications for daphnids and *Utterbackia imbecillis* as surrogates for protection of freshwater mussels (Unionidae). Archives of Environmental Contamination and Toxicology 48:166–173.

Minnesota Pollution Control Agency. (2008). Stormwater Construction Inspection Guide. August 2008. http://www.pca.state.mn.us/index.php/view-document.html?gid=7416

MOU between NCDOT, USFWS and Town of Garner, Wake County and Johnston County (2005). MOU for the Construction of the Clayton Bypass. Signed March, 2005.

NCCN (2014) Triennial Review Talking Points for public meeting, available at http://www.ncconservationnetwork.org/NCWater

NCDOT. (2002). Lower Swift Creek Study Area.

NCDOT. (2010). Stormwater Control Inspection and Maintenance Manual. http://www.ncdot.gov/programs/environment/stormwater/download/swcontrolinspectionmaintjan2010.pdf

NCDENR. (2009). Site Specific Water Quality Management Plan for the Goose Creek Watershed. Administrative Code 15A NCAC 2B .0600-.0609

NCDENR (2013). Division of Energy, Mineral and Land Resources. September 23, 2013 Dam Inventory

NCDWQ. (2003a). Assessment Report: Biological Impairment in the Upper Swift Creek Watershed.

NCDWQ. (2003b). Surface Waters and Wetlands Standards. NC Administrative Code 15A NCAC 02B .0200.

NCDWQ. (2006). National Pollutant Discharge Elimination System shapefile. Accessed September 16, 2009. http://data.nconemap.com/geoportal/catalog/search/resource/details.page?uuid=%7B0F39E1E8-B44C-40C7-B0C1-EF330DC10D3A%7D

NCDWQ. (2009). Neuse River Basinwide Water Quality Plan.

NCDWQ. (2012) North Carolina 303(d) List of Impaired Streams

NCDWQ.(2013). Basinwide Assessment of Ambient Monitoring. http://portal.ncdenr.org/c/document_library/get_file?uuid=db2ac99b-3ac8-4042-a7cc-4108b7bce2b1&groupId=38364 Accessed January 2013.

NCDWR. (2014). Water Supply Watershed Protection Program – Frequently Asked Questions. Accessed January 2014. http://portal.ncdenr.org/web/lr/frequently-asked-questions

NCDWR. (2013a) List of Active NPDES permits. http://portal.ncdenr.org/web/wq/swp/ps/npdes. Accessed September 2013.

NCDWR. (2013b). Planning, Nutrient Strategies. http://www.ncdenr.gov/web/wq/ns. Accessed November 21, 2013

NC EEP. (2010). Wake-Johnston Collaborative Local Watershed Plan.

NCNHP. (2003). Swift Creek Aquatic Habitat – Wake County Natural Areas Inventory.

NCNHP Online Database Search. (2013). Department of Environment and Natural Resources, Office of Conservation, Planning, and Community Affairs, Raleigh, NC. September 19, 2013. Available at: www.ncnhp.org.

NC State Cooperative Extension. (2006a). Internet Site: http://www.bae.ncsu.edu/topic/bmp-temperature/

NC State Cooperative Extension. (2006b). Internet Site: http://www.bae.ncsu.edu/stormwater/PublicationFiles/Bioretention2006.pdf

NC State Historic Preservation Office (NC SHPO) Online Database Search.(2013). HPOWEB Services. November 30, 2013.Available at: http://gis.ncdcr.gov/hpoweb/

NCWRC (2002). Guidance memorandum to address and mitigate secondary and cumulative impacts to aquatic and terrestrial wildlife resources and water quality, NC Wildlife Resource Commission.

NCWRC. (2005). *North Carolina WildlifeAction Plan*. Raleigh, NC.

Neves, R.J. (1993). A state of the Unionids address. Pp. 1-10 in K.S. Cummings, A.C. Buchanan, and L.M. Kooch, eds. Proc. of the UMRCC Symposium on the Conservation and Management of Freshwater Mussels. UMRCC. Rock Island IL.189 pp.

Neves, R. J., A. E. Bogan, et al. (1997). Status of Mollusks in the Southeastern United States: A downard spiral of diversity. Aquatic Fauna in Peril: The Southeastern Perspective. G. W. Benz and D. E. Collins. Decatur, GA, Special Publication1, Aquatic Research Institute, Lenz Designs and Communications**:** 31-85.

Neves, R.J. and J.C. Widlak. (1987). Habitat ecology of juvenile freshwater mussels (Bivalvia: Unionidae) in a headwater stream in Virginia. American Malacological Bulletin 5: 1-7.

Newton, T.J., J.W., Allran, J.A., O'Donnell, M.R., Bartsch, and W.B. Richardson (2003). Effects of Ammonia on juvenile unionid mussels (*Lampsilis cardium*) in laboratory sediment toxicity tests. Environmental Toxicology and Chemistry 22(11):2554-2560.

O'Neill, C. R., Jr., and D. B. MacNeill. (1991). The zebra mussel (*Dreissena polymorpha*): an unwelcome North American invader. Sea Grant, Coastal Resources Fact Sheet. New York Sea Grant Extension. 12 pp.

Ortmann, A.E. (1919). A monograph of the naiades of Pennsylvania. Part III: Systematic account of the genera and species. Memoirs of the Carnegie Museum 8(1):xvi–384, 21 pls.

Pennak, R. W. (1989). Fresh-water Invertebrates of the United States, Protozoa to Mollusca. New York, John Wiley & Sons, Inc.

Poole, G., J. Risley and M. Hicks (2001). Spatial and temporal patterns of stream temperature (revised) Issue Paper 3, prepared as part of EPA Region 10 Temperature Water Quality Criteria Project.

Richmond Times Dispatch. (1998). Spill Poses a Danger to Mussel: Tan Riffleshell Eliminated from Clinch, Professor Says. Rex Bowman. September 2, 1998.

Richter BD, Braun DP, Mendelson MA, Master LL. (1997). Threat to imperiled freshwater fauna. *Conserv Biol* 11:1081–1093.

Roa-Espinosa, A., T.B. Wilson, J.M. Norman and K. Johnson (2003). Predicting the impact of urban development on stream temperature using a thermal urban runoff model (TURM). Pp 369-389 in Proceedings of National Conference Urban Stormwater: Enhancing programs at the local level, Chicago, Ill.,17-20-Feb. 2003. US EPA National Risk Management Laboratory, Cincinnati OH.

Schueler, T. (1994). The importance of imperviousness. Watershed Protection Techniques. 1(3):100–111.

Simpson, C.T. (1900). Synopsis of the naiades, or pearly fresh-water mussels. Proceedings of the United States National Museum 22(1205):501–1044.

Simpson, C.T. (1914). A descriptive catalogue of the naiades, or pearly fresh-water mussels. Parts I–III. Bryant Walker, Detroit, Michigan, xii + 1540 pp.

Smith, D. (1981). Selected freshwater invertebrates proposed for special concern status in Massachusetts (Mollusca, Annelida, Arthropoda). MA Dept. of Env. Qual. Engineering, Div. of Water Pollution Control. 26 pp.

Smith, D. R., S. E. McRae, T. Augsperger, J. A. Ratcliff, R. B. Nichols, C. B. Eads, T. Savidge, and A. E. Bogan (2014). Conservation Strategies For Dwarf Wedgemussel In North Carolina: Maximizing Persistence While Considering Management Cost And Effectivness. Unpublished Manuscript, 30 pp.

Stewart, J.S., D.M. Downes, L. Wang, J.A. Wierl, and R. Bannerman (2000). Influences of riparian corridors on aquatic biota in agricultural watersheds. Pages 209–214 *in* P.J. Wigington, Jr. and R.L. Beschta, eds. Proceedings of the American Water Resources Association International Conference on riparian ecology and management in multi-land use watersheds. Portland, Oregon.

Strayer, D. L., S. J. Sprague and S. Claypool, (1996). A range-wide assessment of populations of *Alasmidonta heterodon*, an endangered freshwater mussel (Bivalva:Unionidae). J.N. Am. Benthol. Soc., 15(3):308-317.

Strayer DL, Downing JA, Haag WR, King TL, Layzer JB, Newton, TJ, Nichols SJ. (2004). Changing perspectives on pearly mussels, North America’s most imperiled animals. *BioScience* 54:429–439.

Sweeny, B.W., T.L. Bott, J.K. Jackson, L.A. Kaplan, J.D. Newbold, L.J. Standley, W.C. Hession, and R.J. Horwitz (2004). Riparian deforestation, stream narrowing, and loss of stream ecosystem services. Proceedings of the National Academy of Sciences of the United States of America 101 (39) 14132-14137.

Tetra Tech, Inc. (2005). Swift Creek Detailed Assessment & Targeting of Management Report.

Town of Cary, (2000). Town of Cary Growth Management Plan. January 13, 2000. Town of Cary Planning Department. Available online: http://www.townofcary.org/Assets/Planning+Department/Planning+Department+PDFs/growthmanagement/Growth+Management+Plan.pdf.

Town of Cary. (2013). Draft Stormwater Master Plan. Prepared by Michael Baker Engineering and Kimley-Horn and Associates, Inc. http://budget.townofcary.org/engineering/stormwatermasterplan/draft-combined.pdf

US Census Bureau. (2014). US Department of Commerce. US Census Bureau. State and County QuickFacts. http://quickfacts.census.gov/qfd/index.html. Accessed January 2014.

US Department of Agriculture. Natural Resources Conservation Service GeoSpatial Data Gateway.(2013). http://datagateway.nrcs.usda.gov/GDGOrder.aspx. Accessed August 13, 2013.

USEPA. (2007). Aquatic Life Ambient Freshwater Quality Criteria – Copper. Accessed January 2014. http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/copper/upload/2009_04_27_criteria_copper_2007_criteria-full.pdf

USEPA (2013). Aquatic Life Ambient Water Quality Criteria For Ammonia– Freshwater 2013. EPA-822-R-13-001. Office of Water, Office of Science and Technology, Washington, DC.

USFWS (1992a). Special report on the status of freshwater mussels.

USFWS (1992b). Endangered and Threatened species of the southeast United States (The Red Book). FWS, Ecological Services, Div. of Endangered Species, Southeast Region. Govt Printing Office, Wash, DC: 1,070.

USFWS. (1993). Dwarf Wedge Mussel (*Alasmidonta heterodon*) Recover Plan. Hadley, MA: 43 pp.

USFWS (1996). Revised Technical/Agency Draft Carolina Heelsplitter Recovery Plan. DOI, Atlanta, GA: 47.

USFWS. (2006). Biological Opinion based on Review of Dempsey E. Benton Water Treatment Plant.

USFWS. (2007). Dwarf Wedgemussel (*Alasmidonta heterodon*) 5-Year Review: Summary and Evaluation. Concord, NH.

USFWS (2012). Carolina heelsplitter (*Lasmigona decorate*) 5-Year Review: Summary and Evaluation. Asheville, NC

USGS. (2013). National Water Information System: mapper. http://maps.waterdata.usgs.gov/mapper/. Accessed January 2013.

Wade, DC. (1992). Definitive evaluation of Wheeler Reservoir sediment toxicity using juvenile freshwater mussels (*Anodonta imbecillis* SAY). TVA/WR-92/25. Tennessee Valley Authority, Muscle Shoals, AL, USA.

Wake County Planning, Land Use & Zoning. (2013). Land Use Plan. Chapter V – Water Supply Watershed Protection Policies. http://www.wakegov.com/planning/growth/Documents/ChapterVWaterSupplyWatershed.pdf

Wang, N., Ingersoll, C.G., Greer, I.E., Hardesty, D.K., Ivey, C.D., Kunz, J.L., Brumbaugh, W.G.,Dwyer, F.J., Robers, A.D., Augspurger, T., Kane, C.M., Neves, R.J., and M.C. Barnhart (2007a) Assessing contaminant sensitivity of early life stages of freshwater mussels (Unionidae): Acute toxicity testing of copper, ammonia, and chlorine to glochidia and juvenile mussels. Environmental Toxicology and Chemistry. 38pp.

Wang, N., Ingersoll, C.G., Greer, I.E., Hardesty, D.K., Ivey, C.D., Kunz, J.L., Brumbaugh, W.G., Dwyer, F.J., Robers, A.D., Augspurger, T., Kane, C.M., Neves, R.J., and M.C. Barnhart (2007b). Assessing contaminant sensitivity of early life stages of freshwater mussels (Unionidae): Chronic toxicity testing of juvenile mussels with copper and ammonia. Environmental Toxicology and Chemistry. 35pp.

Ward, Sara; Augspurger, Tom; Dwyer, F. James; Kane, Cindy; Ingersoll, Christopher G. (2007). Risk Assessment of Water Quality in Three North Carolina, USA, Streams Supporting Federally Endangered Freshwater Mussels (Unionidae). Environmental Toxicoloty and Chemistry, Vol. 26, No 10, pp. 2075-2085.

Weaver, J. C. (1998). Low-flow Characteristics and Discharge Profiles for Selected Streams in the Neuse River Basin, North Carolina. U.S. Geological Survey, Water-Resources Investigations Report 98-4135.

Yousef, Y. A., H. H. Harper, L.P. Wiseman, J.M. Bateman (1985). Consequential species of heavy metals in highway runoff: Florida Department of Transportation Final Report FL-ER-29-85. 153 p.

Ambient Monitoring System Station
NCDENR, Division of Water Quality
Basinwide Assessment

Location: SWIFT CRK AT SR 1152 HOLLY SPRINGS RD NR MACEDONIA
Station #: J4414000 **Hydrologic Unit Code:** 03020201
Latitude: 35.71877 **Longitude:** -78.75270 **Stream class:** WS-III NSW
Agency: LNBA **NC stream index:** 27-43-(1)

Time period: 01/20/2006 to 12/20/2010

	# results	# ND	EL	Results not meeting EL #	%	%Conf	Percentiles Min	10th	25th	50th	75th	90th	Max
Field													
D.O. (mg/L)	84	0	<4	1	1.2		1.9	4.6	5.6	7	8.8	10.2	12.4
	84	0	<5	11	13.1	86.9	1.9	4.6	5.6	7	8.8	10.2	12.4
pH (SU)	85	0	<6	0	0		6.6	6.7	6.8	7	7.2	7.4	7.7
	85	0	>9	0	0		6.6	6.7	6.8	7	7.2	7.4	7.7
Spec. conductance (umhos/cm at 25°C)	85	0	N/A				57	85	110	161	208	236	321
Water Temperature (°C)	85	0	>32	0	0		4.3	7.5	12.7	21.9	25.2	26.9	29.4
Other													
TSS (mg/L)	60	3	N/A				1	2.9	4.8	8	12	30.3	193
Turbidity (NTU)	60	0	>50	3	5		3.7	5.1	7.5	10	17.2	33	160
Nutrients (mg/L)													
NH3 as N	60	8	N/A				0.01	0.01	0.02	0.06	0.11	0.18	0.33
NO2 + NO3 as N	60	2	>10	0	0		0.01	0.09	0.21	0.48	1.05	1.45	1.99
TKN as N	60	3	N/A				0.2	0.27	0.38	0.5	0.75	1.36	4.48
Total Phosphorus	60	2	N/A				0.02	0.04	0.06	0.08	0.13	0.24	2.84

Fecal Coliform Screening(#/100mL)

# results:	Geomean	# > 400:	% > 400:	%Conf:
60	112.1	8	13.3	

Key:
result: number of observations
ND: number of observations reported to be below detection level (non-detect)
EL: Evaluation Level; applicable numeric or narrative water quality standard or action level
Results not meeting EL: number and percentages of observations not meeting evaluation level
%Conf : States the percent statistical confidence that the actual percentage of exceedances is at least 10% (20% for Fecal Coliform)
Stations with less than 10 results for a given parameter were not evaluated for statistical confidence

Ambient Monitoring System Station
NCDENR, Division of Water Quality
Basinwide Assessment

Location: SWIFT CRK AT NC 210 NR SMITHFIELD
Station #: J4590000 **Hydrologic Unit Code:** 03020201
Latitude: 35.51860 **Longitude:** -78.38190 **Stream class:** C NSW
Agency: LNBA **NC stream index:** 27-43-(8)

Time period: 01/18/2006 to 12/10/2010

	# results	# ND	EL	Results not meeting EL #	%	%Conf	Percentiles Min	10th	25th	50th	75th	90th	Max
Field													
D.O. (mg/L)	85	0	<4	0	0		4.8	6.2	6.5	7.2	8.6	10.7	12.5
	85	0	<5	1	1.2		4.8	6.2	6.5	7.2	8.6	10.7	12.5
pH (SU)	85	0	<6	0	0		6.1	6.6	6.8	6.9	7	7.2	7.4
	85	0	>9	0	0		6.1	6.6	6.8	6.9	7	7.2	7.4
Spec. conductance (umhos/cm at 25°C)	85	1	N/A				50	74	89	121	161	177	218
Water Temperature (°C)	85	0	>32	0	0		3.9	7.6	12.9	22.3	25.6	27.4	29.9
Other													
TSS (mg/L)	60	3	N/A				1	2	3.4	6.2	10	28.4	2060
Turbidity (NTU)	60	0	>50	4	6.7		4.2	5.7	7	10.5	15.8	38.8	1500
Nutrients (mg/L)													
NH3 as N	60	13	N/A				0.01	0.01	0.02	0.04	0.09	0.21	0.44
NO2 + NO3 as N	60	2	N/A				0.01	0.05	0.13	0.18	0.24	0.35	0.52
TKN as N	60	1	N/A				0.2	0.37	0.42	0.56	0.87	1.21	8.09
Total Phosphorus	60	1	N/A				0.03	0.05	0.07	0.1	0.16	0.28	1.89

Fecal Coliform Screening(#/100mL)

# results:	Geomean	# > 400:	% > 400:	%Conf:
60	111.4	6	10	

Key:
result: number of observations
ND: number of observations reported to be below detection level (non-detect)
EL: Evaluation Level; applicable numeric or narrative water quality standard or action level
Results not meeting EL: number and percentages of observations not meeting evaluation level
%Conf : States the percent statistical confidence that the actual percentage of exceedances is at least 10% (20% for Fecal Coliform)
Stations with less than 10 results for a given parameter were not evaluated for statistical confidence

STORMWATER BASIN EVALUATION SHEET

Evaluator(s):	Subdivision/Project Site:
Company:	Lat. Long.:
Date:	River Basin:
County:	

Basin Type:	**Bioretention**	**Dry Detention**	
Stormwater Wetland	**Wet Detention**	**Other**	

Basin Ranking:	**GOOD**	**FAIR**	**POOR**
(Definitions for each ranking listed at bottom of sheet)			

General Observations Above Basin ***(Where stormwater is originating and how it is conveyed to basin, describe drainage area and its condition)***				
Inlet	N/A	**YES**	**NO**	**Notes/Comments**
Bare soil/poor vegatation coverage (< 50%) within stormwater conveyances?				
Erosion occuring within stormwater conveyances? *(Rills, gullies, scouring, undercutting, etc.)*				
Inlet structure clogged?				
Inlet structure cracked, damaged, or corroded?				
Erosion occuring at inlet structure? (Rills, gullies, scouring, undermining, *undercutting, etc.)*				
Basin				
Forebay (May not be applicable for All Basins)				
Sediment, trash, and/or debris accumulating in forebay?				
Excessive sediment, trash, and/or debris accumulated in forebay? *(Excessive is > 50% of forebay storage is occupied by foreign material)*				
Erosion within forebay? *(Rills, gullies, scouring, etc.)*				
Excessive algal growth present? *(> 50% coverage)*				
Treatment Area				
Planted woody vegatation dead, diseased, or dying?				
Does vegatation appear overgrown with little noticable pruning?				
Sediment, trash, and/or debris accumulating in basin?				
Excessive sediment, trash, and/ or debris accumulated in basin? *(Accumulated material is significantly decreasing the basin's storage and treatment functions)*				
Evidence of erosion within treatment area? *(drainage patterns, scouring, etc.)*				
Excessive algal growth present? *(> 50% coverage)*				
Evidence of stormwater short circuiting basin treatment area? *(A short circuit occurs when stormwater bypasses the designed treatment path flow)*				
Banks, Walls, and Embankments (May not be applicable for All Basins)				
Bare soil/poor vegatation coverage (< 50%) on banks, walls, and embankments?				
Shrubs or trees growing on the banks, walls, or embankments?				
Erosion of banks, walls, or embankments? *(Rills, gullies, slumping, caving, etc.)*				
Bypass Spillway (If applicable)				
Evidence bypass spill way is preferred path for stormwater outflow?				
Bypass spillway is hindered by debris or trash?				
Erosion occuring from spillway? *(Rills, gullies, scouring, undermining, undercutting, drainage patterns, missing vegatation)*				
Outlet				
Outlet structure clogged?				
Outlet structure cracked, damaged, or corroeded?				
Erosion occuring at outlet structure? *(Rills, gullies, missing vegatation, drainage patterns, undermining, undercutting, etc.)*				
Trash or debris noticably deposited from basin?				
Sediment from basin in receiving water, wetland, or outside of site boundary?				
Turbidity increase in receiving water below stormwater outfall from basin?				
General Observations Below Basin (What does stormwater discharge into? Are streams/wetlands present along stormwater path?)				
Stormwater Basin Rating				
Good: Minor structural and/or maintenance needs were present; device is functioning properly and is not likely affecting water quality.				
Fair: Moderate structural and/or maintenance needs are present; device is moderately functioning and is likely affecting water quality.				
Poor: Serious structural and/or maintenance needs are present; device not functioning properly and is significantly affecting water quality.				

Recommendations:

Site Sketch:

Freshwater Mussel Survey Report

Triangle Expressway Southeast Extension
(TIP No R-2721/R-2828/R-2829)

Wake and Johnston Counties, North Carolina

Prepared for:

H.W. Lochner, Inc.
2840 Plaza Place, Suite 202
Raleigh, NC 27612

Prepared by:

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

March 2011

EXECUTIVE SUMMARY

The freshwater mussel fauna within the project study corridor for the proposed Triangle Expressway Southeast Extension project (TIP #s R-2721, R-2828, R-2829) was evaluated by The Catena Group Inc. (TCG) to establish a planning level baseline status of the freshwater mussel resources within the project study corridor, with particular emphasis on the federally protected Dwarf Wedgemussel and Tar River Spinymussel, and other mussel species with assigned conservation statuses in North Carolina of Endangered. Habitat evaluations and mussel surveys were performed in selected portions of perennial water bodies within the study corridor in an effort to identify particular streams that contain significant freshwater mussel populations, particularly those that support listed species.

A total of 110 separate stream reaches were evaluated for the presence of mussels (Figures 1 and 2, Appendix A), with 15 freshwater mussel species, as well as 2 freshwater clam species and 4 aquatic snail species found. For purposes of data analysis and discussion, the project study area was segmented into three sections based on general watersheds: Western Section (Middle Creek and tributaries), Central Section (Swift Creek and tributaries), and Eastern section (Neuse River and tributaries).

Western Section: Middle Creek drains the western section of the project corridor study area, and from a freshwater mussel standpoint, is the most significant water body in the Western section. Middle Creek was known to support several rare mussel species, including the Dwarf Wedgemussel; however, this species has not been detected during any survey effort since 1992, where it was found at the NC 50 crossing downstream of the study area in Johnston County. In addition, occurrences and numbers of other rare mussel species known from the stream have declined in recent years. The results of this survey effort further support this declining trend, as only very low numbers of four rare mussel species were found. Observations of habitat conditions also support the apparent decline.

The proposed project will cross Middle Creek in the upper limits of the watershed upstream of Sunset Lake. While it is possible that the Dwarf Wedgemussel still occurs in Middle Creek further downstream in Johnston County, the presence of Sunset Lake between the proposed crossing and potentially occupied habitat downstream makes the potential for any direct impacts very unlikely. No rare mussel species were found in any of the tributaries; however, some of these streams such as Basal Creek, Little Creek, and Guffy Branch support fairly high abundances of the Eastern Elliptio, and contain areas of "good" mussel habitat, which may be suitable for the Dwarf Wedgemussel.

Central Section: The Central section of the project study area drains to the Swift Creek Subbasin, which is considered an aquatic habitat of national significance, as it supports the Dwarf Wedgemussel. Historically, at least 18 species of freshwater mussels have been reported to occur in the Swift Creek subbasin. This study confirms the relatively high species diversity (for Atlantic Slope drainages) of this stream, as at least 14 species were collected. The study also confirms the persistence of the Dwarf Wedgemussel in Swift Creek below Lake Benson, as three individuals were found within the study corridor. In addition, two other individuals were found downstream of the project corridor, as part of a concurrent study carried out by TCG for the City of Raleigh. Other targeted mussel species, including the Atlantic Pigtoe and Yellow Lance, were also located along with several other rare mussel species. Thus, direct impacts to these species are possible from project construction within this section of Swift Creek.

Because of the existence of the Dwarf Wedgemussel in Swift Creek, the study corridor for this project was expanded to include an avoidance alternative (Red Route), which would cross Swift Creek upstream of Lake Benson. This section of Swift Creek is not believed to support the Dwarf Wedgemussel, and the results of this study further support this assumption, as it was not found, nor were any of the associate rare mussel species. In addition, Lake Benson occurs between this section of the creek and occupied habitat downstream. As such, direct impacts to the Dwarf Wedgemussel are unlikely to occur if the Red Corridor is constructed; however, conclusions regarding Indirect and Cumulative Impacts to the population cannot be determined at this time, and will need to be addressed with all alternates within the study area.

No rare mussel species were found in any of the tributaries to Swift Creek within the study area; however, both White Oak Creek and Little Creek are known to support Dwarf Wedgemussel and other rare species farther downstream of the study area. In both instances, artificial impoundments are present between any of the proposed crossing locations and occupied habitat downstream; therefore direct impacts are unlikely.

Eastern Section: The Eastern section of the project corridor drains to the Neuse River from the US 64/264 Bypass crossing of the river downstream to the vicinity of the Wake/Johnston County line. Tributaries to the Neuse River within this section include Walnut Creek and Beddingfield Creek to the south; Mango Creek, Unnamed Tributary (UT) to Neuse River, Poplar Creek, and Mark’s Creek to the north.

Historically, at least 18 species of freshwater mussels have been reported to occur in the mainstem of the Neuse River within the project study area. While this study indicates relatively high species diversity (for Atlantic Slope drainages) of this section of the river (10 species), including the targeted Green Floater, species like the Dwarf Wedgemussel, Atlantic Pigtoe, Yellow Lance and Notched Rainbow, which historically occurred in this area, were not found. The presence of the Green Floater is the first documented occurrence of this species in this section of the Neuse River since the early 1950’s.

While the Dwarf Wedgemussel is unlikely to still occur in this section of the Neuse River, the re-discovery of the Green Floater, which was believed to have extirpated from this area, may indicate that some of the other species formerly reported from this area may still exist in low numbers, as the Green Floater was obviously present, but in such low numbers that it was not found during surveys since that time. The presence of Green Floater at multiple sites (8) and the fact that the majority of individuals found were of the same size (age) class, suggest a recent population expansion. Additional surveys will need to be done once an alternate is chosen. No rare mussel species were found in any of the tributaries in this section. Habitat conditions are generally unsuitable for the Dwarf Wedgemussel; thus it is very unlikely to occur in any of the water bodies within this section of the study corridor.

TABLE OF CONTENTS

1.0 INTRODUCTION 1
2.0 MUSSEL SURVEY EFFORTS 2
2.1. Mussel Survey Methodology 2
2.2. Mussel Survey Results 3
2.2.1. Western Section 4
2.2.2. Central Section 13
2.2.3. Eastern Section 47
3.0 MUSSEL SPECIES DESCRIPTIONS 56
3.1. Federally Protected Species 56
3.1.1. *Alasmidonta heterodon* (Dwarf Wedgemussel) 56
3.1.2. *Elliptio steinstansana* (Tar River Spinymussel) 59
3.2. Target Federal Species of Concern (FSC) 60
3.2.1. *Elliptio lanceolata* (Yellow Lance) 60
3.2.2. *Fusconaia masoni* (Atlantic Pigtoe) 61
3.2.3. *Lasmigona subviridis* (Green Floater) 61
3.2.4. *Lampsilis cariosa* (Yellow Lampmussel) 62
3.3. Other Mussel Species Located 62
3.3.1 *Alasmidonta undulata* (Triangle Floater) 62
3.3.2 *Elliptio complanata* (Eastern Elliptio) 63
3.3.3 *Elliptio congarea* (Carolina Slabshell) 63
3.3.4 *Elliptio icterina* (Variable Spike) 63
3.3.5. *Elliptio mediocris* (No Common Name) 63
3.3.6. *Elliptio producta* (Atlantic Spike) 64
3.3.7. *Elliptio roanokensis* (Roanoke Slabshell) 64
3.3.8. *Lampsilis radiata* (Eastern Lampmussel) 64
3.3.9. *Pyganodon cataracta* (Eastern Floater) 65
3.3.10. *Strophitus undulatus* (Creeper) 65
3.3.11. *Utterbackia imbecillis* (Paper Pondshell) 66
4.0 DISCUSSION 66
4.1. Western Section 66
4.2. Central Section 67
4.3. Eastern Section 68
5.0 LITERATURE CITED 70

Table 1. Rare Aquatic Species Neuse River Basin in Wake/Johnston Counties 2
Table 2. Study Corridor: Mollusk Species Found 4
Table 3. Middle Creek Site-100428.1: Mollusk Species Found 5
Table 4. Middle Creek Site-100428.2: Mollusk Species Found 5
Table 5. Middle Creek Site-100428.3: Mollusk Species Found 6
Table 6. Middle Creek Site-100611.1: Mollusk Species Found 6
Table 7. Middle Creek Site-100616.2: Mollusk Species Found 7
Table 8. Middle Creek Site-100616.1: Mollusk Species Found 7
Table 9. Basal Creek Site-100623.3: Mollusk Species Found 8
Table 10. Basal Creek Site-100618.1: Mollusk Species Found 8
Table 11. UT Middle Creek Site-100507.2: Mollusk Species Found 8
Table 12. Rocky Branch Site-100507.1: Mollusk Species Found 9

Table 13. UT Middle Creek (Bell's Lake Creek) Site-100618.3: Mollusk Species Found 9
Table 14. Terrible Creek Site-100618.2: Mollusk Species Found...10
Table 15. Terrible Creek Site-100624.2: Mollusk Species Found...10
Table 16. Terrible Creek Site-100624.1: Mollusk Species Found...11
Table 17. Panther Branch Site-100611.3: Mollusk Species Found 11
Table 18. Little Creek Site-100623.1: Mollusk Species Found..12
Table 19. Little Creek Site-100623.2: Mollusk Species Found..12
Table 20. Guffy Branch Site-100623.4: Mollusk Species Found...12
Table 21. Guffy Branch Site-100623.5: Mollusk Species Found...13
Table 22. Buffalo Branch Site-100623.6: Mollusk Species Found 13
Table 23. Swift Creek Site-101124.4: Mollusk Species Found..14
Table 24. Swift Creek Site-101124.3: Mollusk Species Found..14
Table 25. Swift Creek Site-101124.2: Mollusk Species Found..15
Table 26. Swift Creek Site-101124.1: Mollusk Species Found..15
Table 27. Swift Creek Site-101123.6: Mollusk Species Found..15
Table 28. Swift Creek Site-101123.5: Mollusk Species Found..16
Table 29. Swift Creek Site-101123.4: Mollusk Species Found..16
Table 30. Swift Creek Site-101123.3: Mollusk Species Found..17
Table 31. Mahlers Creek Site-101124.5: Mollusk Species Found 17
Table 32. Mahlers Creek Site-101124.8: Mollusk Species Found 17
Table 33. Swift Creek Site-101124.6: Mollusk Species Found..18
Table 34. Swift Creek Site-101124.7: Mollusk Species Found..18
Table 35. Swift Creek Site-100708.5: Mollusk Species Found..19
Table 36. Swift Creek Site-100708.4: Mollusk Species Found..19
Table 37. Swift Creek Site-100708.3: Mollusk Species Found..20
Table 38. Swift Creek Site-100708.2: Mollusk Species Found..20
Table 39. Swift Creek Site-100708.1: Mollusk Species Found..21
Table 40. Swift Creek Site-101123.2: Mollusk Species Found..21
Table 41. Swift Creek Site-101123.1: Mollusk Species Found..22
Table 42. Swift Creek Site-101027.1: Mollusk Species Found..22
Table 43. Swift Creek Site-101027.4: Mollusk Species Found..23
Table 44. Swift Creek Site-101027.3: Mollusk Species Found..23
Table 45. Swift Creek Site-101027.2: Mollusk Species Found..23
Table 46. Swift Creek Site-101007.6: Mollusk Species Found..24
Table 47. Swift Creek Site-101007.5: Mollusk Species Found..24
Table 48. Swift Creek Site-101007.1: Mollusk Species Found..25
Table 49. Swift Creek Site-101007.4: Mollusk Species Found..25
Table 50. Swift Creek Site-101007.3: Mollusk Species Found..26
Table 51. Swift Creek Site-101007.2: Mollusk Species Found..26
Table 52. Swift Creek Site-101027.10: Mollusk Species Found..27
Table 53. Swift Creek Site-101027.9: Mollusk Species Found..27
Table 54. Swift Creek Site-101027.8: Mollusk Species Found..28
Table 55. Swift Creek Site-101027.7: Mollusk Species Found..28
Table 56. Swift Creek Site-101027.6: Mollusk Species Found..29
Table 57. Swift Creek Site-101027.5: Mollusk Species Found..29
Table 58. Swift Creek Site-101021.7: Mollusk Species Found..30
Table 59. Swift Creek Site-101021.6: Mollusk Species Found..30
Table 60. Swift Creek Site-101021.5: Mollusk Species Found..31
Table 61. Swift Creek Site-101021.4: Mollusk Species Found..31
Table 62. Swift Creek Site-101021.3: Mollusk Species Found..32
Table 63. Swift Creek Site-101021.2: Mollusk Species Found..32
Table 64. Swift Creek Site-101021.1: Mollusk Species Found..33
Table 65. Swift Creek Site-101012.8: Mollusk Species Found..33
Table 66. Swift Creek Site-101012.7: Mollusk Species Found..34
Table 67. Swift Creek Site-101012.6: Mollusk Species Found..34
Table 68. Swift Creek Site-101012.5: Mollusk Species Found..35
Table 69. Swift Creek Site-101012.4: Mollusk Species Found..35

Table 70. Swift Creek Site-101012.3: Mollusk Species Found....................36
Table 71. Swift Creek Site-101012.2: Mollusk Species Found....................36
Table 72. Swift Creek Site-101012.1: Mollusk Species Found....................37
Table 73. Swift Creek Site-100713.4: Mollusk Species Found....................37
Table 74. Swift Creek Site-101013.9: Mollusk Species Found....................38
Table 75. Swift Creek Site-101013.8: Mollusk Species Found....................38
Table 76. Swift Creek Site-101013.7: Mollusk Species Found....................39
Table 77. Swift Creek Site-101013.6: Mollusk Species Found....................39
Table 78. Swift Creek Site-101013.5: Mollusk Species Found....................40
Table 79. Swift Creek Site-101013.3: Mollusk Species Found....................40
Table 80. Swift Creek Site-101013.2: Mollusk Species Found....................41
Table 81. Swift Creek Site-101013.4: Mollusk Species Found....................41
Table 82. Swift Creek Site-101013.1: Mollusk Species Found....................42
Table 83. Swift Creek Site-101026.4: Mollusk Species Found....................42
Table 84. Swift Creek Site-101026.3: Mollusk Species Found....................43
Table 85. Swift Creek Site-101026.2: Mollusk Species Found....................43
Table 86. Swift Creek Site-101026.1: Mollusk Species Found....................44
Table 87. Swift Creek Site-101019.4: Mollusk Species Found....................44
Table 88. Swift Creek Site-101019.3: Mollusk Species Found....................45
Table 89. White Oak Creek Site-100722.1: Mollusk Species Found....................45
Table 90. White Oak Creek Site-100713.1: Mollusk Species Found....................46
Table 91. Little Creek Site-100720.4: Mollusk Species Found....................46
Table 92. Little Creek Site-100713.3: Mollusk Species Found....................47
Table 93. Big Branch Site-100722.2: Mollusk Species Found....................47
Table 94. Walnut Creek Site-100623.4: Mollusk Species Found....................48
Table 95. Neuse River Site-100726.1: Mollusk Species Found....................48
Table 96. Neuse River Site-100726.2: Mollusk Species Found....................49
Table 97. Neuse River Site-100726.3: Mollusk Species Found....................49
Table 98. Neuse River Site-100726.4: Mollusk Species Found....................50
Table 99. Neuse River Site-100726.5: Mollusk Species Found....................50
Table 100. Neuse River Site-100726.6: Mollusk Species Found....................51
Table 101. Neuse River Site-100726.7: Mollusk Species Found....................51
Table 102. Neuse River Site-100726.8: Mollusk Species Found....................52
Table 103. Neuse River Site-100726.9: Mollusk Species Found....................52
Table 104. Neuse River Site-100720.2: Mollusk Species Found....................53
Table 105. Neuse River Site-100720.1: Mollusk Species Found....................53
Table 106. Neuse River Site-100720.3: Mollusk Species Found....................54
Table 107. Mango Creek Site-100702.2: Mollusk Species Found....................54
Table 108. Mango Creek Site-100702.1: Mollusk Species Found....................55
Table 109. UT Neuse River Site-100722.3: Mollusk Species Found....................55
Table 110. Poplar Creek Site-100702.3: Mollusk Species Found....................56
Table 111. Marks Creek Site 100722.4: Mollusk Species Found....................56
Table 112. Mussel Species by Study Corridor Section....................66

1.0 INTRODUCTION

The North Carolina Turnpike Authority (NCTA) a division of the North Carolina Department of Transportation (NCDOT), proposes the construction of a new road corridor from NC-55 near Apex south and east to US-64/264 Bypass near Knightdale within Wake and Johnston Counties, referred to as the Triangle Expressway Southeast Extension. The entire project area occurs within the Neuse River Basin.

Two freshwater mussel species federally designated and protected as Endangered under the Endangered Species Act of 1973 as amended are known to occur within the Neuse River Basin in Wake and Johnston Counties, the Dwarf Wedgemussel (*Alasmidonta heterodon*) and the Tar River Spinymussel (*Elliptio steinstansana*). To assess the potential for these two species to occur within the project area, The Catena Group, Inc. (TCG) was retained by H.W. Lochner (Lochner), to gather updated mussel survey data for streams within the project corridor during the preliminary planning phase of the project in order to assist in selection of potential corridors and to initiate any potential consultation with the agencies as early as possible to avoid project delays.

In addition, four species listed as state Endangered and Federal Species of Concern (FSC), [1] the Atlantic Pigtoe (*Fusconaia masoni*), Green Floater (*Lasmigona subviridis*), Yellow Lampmussel (*Lampsillis cariosa*), and Yellow Lance (*Elliptio lanceolata*), have been previously documented in this portion of the Neuse River Basin, and were also targeted in this survey because the US Fish and Wildlife Service (USFWS) is in the process of putting together "Elevation to Candidate Species Status" packages for some these species as they may be formally listed as Threatened, or Endangered in the near future (John Fridell, USFWS Recovery Biologist, personal communication). In addition, The Center for Biological Diversity (CBD), a nonprofit conservation organization dedicated to the protection of endangered species and wild places (www.biologicaldiversity.org) recently petitioned the USFWS to list 404 aquatic species in the southeastern United States, including three of these four species as either Threatened or Endangered under the Endangered Species Act (CBD 2010). As such, it has been determined that it would be prudent to address these species during this phase of project planning in the event that they become federally listed as Threatened or Endangered. Several other mussel species that are considered to be rare in North Carolina and have assigned various conservation statuses are also known from this portion of the Neuse River Basin (Table 1).

[1] **Federal Species of Concern (FSC)** are defined as species that are under consideration for listing for which there is insufficient information to support listing. FSCs are not afforded federal protection under the Endangered Species Act and are not subject to any of its provisions, including Section 7, until they are formally proposed or listed as Threatened or Endangered. However, the status of these species is subject to change, and so should be included for consideration.

Table 1. Rare Aquatic Species Neuse River Basin in Wake/Johnston Counties

Scientific Name	Common Name	Federal Status	NC Status
Alasmidonta heterodon	Dwarf Wedgemussel	E	E
Alasmidonta undulata	Triangle Floater	~	T
Elliptio congarea	Carolina Slabshell	~	W3/W5
Elliptio lanceolata	Yellow Lance	FSC	E
Elliptio producta	Atlantic Spike	~	W3/W5
Elliptio roanokensis	Roanoke Slabshell	~	T
Fusconaia masoni	Atlantic Pigtoe	FSC	E
Lampsilis cariosa	Yellow Lampmussel	FSC	E
Lampsilis radiata	Eastern Lampmussel	~	T
Lasmigona subviridis	Green Floater	FSC	E
Strophitus undulatus	Creeper	~	T
Villosa constricta	Notched Rainbow	~	SC

See Appendix B for status designations

2.0 MUSSEL SURVEY EFFORTS

Portions of all perennial water bodies within the project study corridor were evaluated for the presence of freshwater mussels and other aquatic mussel species, with particular emphasis on the federally protected Dwarf Wedgemussel and Tar River Spinymussel, as well as four state Endangered /FSC mussel species, three of which have been included in a petition for consideration for federal listing as Endangered or Threatened.

2.1. Mussel Survey Methodology

Survey locations were chosen based on mapping as provided by Lochner, pre-survey investigations, accessibility, and appropriate habitat for the target species as determined in the field. Surveys were conducted by TCG personnel on the following dates in 2010:

- Tim Savidge: April 28; June 11, 16, 18, 23, 24; July 2, 8, 13, 20, 26; October 7, 12, 13, 21, 26, 27; November 23, 24
- Tom Dickinson: April 28; May 7; June 11, 16, 23; July 8, 22, 26; October 7, 19, 21, 26, 27; November 23, 24
- Chris Sheats: June 16, 18, 23; July 8, 20, 26; October 7, 12, 13, 19; November 23, 24
- Jonathan Hartsell: July 8
- Kate Montieth: May 7
- David Zitlow: July 8
- Daniel Savidge: June 23, 24; July 2, 8, 13; October 7, 26
- Ivy Kimbrough: July 20; October 7, 12, 13, 19, 21, 26, 27; November 24
- Maggie Griffin: October 19, 21, 26, 27; November 23, 24

The following non-TCG personnel assisted with the surveys on the following dates:

- Sarah McRae-USFWS: October 7
- John Fridell-USFWS: October 21, 26, 27
- Karen Lynch-NCDOT: October 27
- Jayson Mays-NCDOT: October 7, 21, 27

- Mike Sanderson-NCDOT: October 21, 27
- Logan Williams-NCDOT: October 27
- Hal Bain-RK&K: October 12, 13
- Matt Smith-ESI: November 24

In each stream segment, a habitat evaluation was first performed by accessing a specific stream or stream system downstream of the corridor and walking the drainage for at least 0.5 person-hour. If it was determined by professional judgment that further efforts were not warranted, then survey efforts were stopped. This decision by the respective investigator to discontinue survey effort on a particular stream was based on a lack of suitable habitat for freshwater mussels. Within the surveyed reaches, all habitat types (riffle, run, pool, slack-water, etc.) were sampled by a minimum of a two-person team. The survey team began at the downstream end of the survey reach and proceeded upstream with the team spread across the stream into survey lanes. A combination of visual using bathyscopes (glass-bottom view buckets) or mask and snorkle, and tactile methodologies were employed as appropriate. Upstream and downstream survey limits were recorded using a hand-held Garmin 12 or e-trex Vista GPS unit. Timed searches were employed in each reach to provide a catch per unit effort (CPUE). Searches were also conducted for relict shells. Presence of fresh shell material was equated with species presence, but was not factored into CPUE.

Relative abundance for freshwater snails and the freshwater clam species were estimated using the following criteria:

- Very abundant > 30 observed at survey station
- Abundant 16-30 observed at survey station
- Common 6-15 observed at survey station
- Uncommon 3-5 observed at survey station
- Rare 1-2 observed at survey station
- Patchy indicates an uneven distribution of the species within the sampled site.

2.2. Mussel Survey Results

A total of 111 separate stream reaches within the study corridor were evaluated for the presence of mussels (Figures 1 and 2, Appendix A), with 15 freshwater mussel species, as well as 2 freshwater clam species and 4 aquatic snail species being found (Table 2).

Stream survey segments are reported by USGS stream name, the date surveyed, and respective sequence within that date. Unnamed tributaries are noted as "UT" to the named receiving water body. Habitat descriptions and survey results are summarized below for each site in order from West to East. Site numbers (i.e., 101010.1) dictate the date in YYMMDD (year, month, day) format with survey sequence from that day of sampling listed after the decimal point. Survey segments are depicted in their respective figures in Appendix A.

Table 2. Study Corridor: Mollusk Species Found

Scientific Name	Common Name	# Sites Found	Conservation Status
Freshwater Mussels	~	~	~
Alasmidonta heterodon	Dwarf Wedgemussel	3	Federally E
Alasmidonta undulata	Triangle Floater	28	State T
Elliptio complanata	Eastern Elliptio	100	None
Elliptio congarea	Carolina Slabshell	43	State W
Elliptio icterina	Variable Spike	81	None
Elliptio lanceolata	Yellow Lance	8	State E
Elliptio mediocris	No Common Name	17	None
Elliptio producta	Atlantic Spike	8	State W
Elliptio roanokensis	Roanoke Slabshell	34	State T
Fusconaia masoni	Atlantic Pigtoe	23	State E
Lampsilis radiata	Eastern Lampmussel	44	State T
Lasmigona subviridis	Green Floater	8	State E
Pyganodon cataracta	Eastern Floater	24	None
Strophitus undulatus	Creeper	32	State T
Utterbackia imbecillis	Paper Pondshell	14	None
Freshwater Snails and Clams	~	~	~
Campeloma decisum	Pointed Campeloma	40	None
Corbicula fluminea	Asian Clam	101	Exotic
Helisoma anceps	Two-ridge Ram's Horn	2	Common
Physidae	A Physid Snail	4	None
Planorbella trivolvis	Marsh Ram's Horn	1	None
Sphaeriidae	A Sphaeriid Clam	2	None

For purposes of data analysis and discussion, the project study area was segmented into three sections based on general watersheds: Western Section (Middle Creek and tributaries), Central Section (Swift Creek and tributaries), and Eastern section (Neuse River and tributaries).

2.2.1. Western Section

The western section of the project corridor occurs within the Middle Creek Subbasin between NC 55 and NC 50. Six reaches of Middle Creek, were evaluated, as were portions of all perennial tributaries to Middle Creek within the study corridor (15 sites).

Middle Creek Site-100428.1

This section of Middle Creek was accessed off the Holly Springs Road (SR 1152) crossing. Channel width ranges from 4 to 5 meters with relatively stable 1-meter high banks. In order of dominance, substrate consists of sand, gravel, silt, cobble, and mud. Water levels were normal and water visibility was clear. A wastewater treatment plant (wwtp) discharge was noted and the smell of effluent was present. An extensive natural buffer surrounds the reach. Mussel surveys were conducted for a total of 3.07 person hours.

Table 3. Middle Creek Site-100428.1: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Elliptio complanata	Eastern Elliptio	96	31.27/hr
Elliptio icterina	Variable Spike	2	0.65/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common
Corbicula fluminea	Asian Clam	~	Abundant

Middle Creek Site-100428.2

This section of Middle Creek was accessed off Sunset Lake Road (SR 1301). Channel width ranges from 2 to 5 meters with 1-meter high banks showing some signs of erosion. In order of dominance, substrate consists of silt, sand, clay, gravel, and mud. The smell of wwtp effluent was noted. Surveys were conducted for a total of 1.40 person hours.

Table 4. Middle Creek Site-100428.2: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Elliptio complanata	Eastern Elliptio	8	5.71/hr
Elliptio icterina	Variable Spike	2	1.43/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon
Corbicula fluminea	Asian Clam	~	Abundant
Physella sp.	A Physid Snail	~	Patchy, Common

Middle Creek Site-100428.3

This section of Middle Creek was located within the tailrace of Sunset Lake. Channel width ranges from 6 to 10 meters with <1-meter high relatively stable banks. In order of dominance, substrate consists of boulder, gravel, sand, cobble, bedrock, and silt. Surveys were conducted for 1.00 person hour.

Table 5. Middle Creek Site-100428.3: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	6	6.00/hr
Lampsilis radiata	Eastern Lampmussel	2	2.00/hr
Pyganodon cataracta	Eastern Floater	0	Shell only
Utterbackia imbecillis	Paper Pondshell	0	Shell only
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common
Corbicula fluminea	Asian Clam	~	Abundant
Sphaeriidae	A Sphaeriid clam	~	Uncommon

Middle Creek Site-100611.1

This mid section of Middle Creek within the study area was accessed off the Lake Wheeler Road Crossing (SR 1371). Channel width ranges from 6 to 10 meters with 1- to 2-meter high moderately eroded banks. In order of dominance, substrate consists of sand, silt, gravel, clay, and cobble. Mussels were concentrated in small patches of suitable habitat. Surveys were conducted for 4.67 person hours.

Table 6. Middle Creek Site-100611.1: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.21/hr
Elliptio complanata	Eastern Elliptio	225	48.18/hr
Elliptio icterina	Variable Spike	154	32.98/hr
Strophitus undulatus	Creeper	2	0.43/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Middle Creek Site-100616.2

This section of Middle Creek occurs off the Old Stage Road (SR 1006) crossing. Channel width ranges from 10 to 12 meters with 2-meter high banks that range from fairly stable to moderately eroded. In order of dominance, substrate consists of sand, silt, clay, cobble, and boulder. Surveys were conducted for 5.15 person hours.

Table 7. Middle Creek Site-100616.2: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Elliptio complanata	Eastern Elliptio	241	46.80/hr
Elliptio icterina	Variable Spike	121	23.50/hr
Elliptio producta	Atlantic Spike	1	0.19/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Very Abundant

Middle Creek Site-100616.1

This most downstream section of Middle Creek within the study area was accessed off the Barber Bridge Road (SR 2739) crossing. Channel width ranges from 10 to 15 meters with 2-meter high banks that ranged from stable to severely eroded. In order of dominance, substrate consists of sand, clay, gravel, silt, and cobble. Mussels were fairly common in areas associated with stable clay and rock outcrops, and uncommon to absent in the rest. Surveys were conducted for 6.25 person hours.

Table 8. Middle Creek Site-100616.1: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Elliptio complanata	Eastern Elliptio	393	62.88/hr
Elliptio icterina	Variable Spike	146	23.36/hr
Lampsilis radiata	Eastern Lampmussel	1	0.16/hr
Strophitus undulatus	Creeper	1	0.16/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon
Corbicula fluminea	Asian Clam	~	Very Abundant

Basal Creek Site-100623.3

This section of Basal Creek upstream of Bass Lake was accessed off the NC 55 crossing. Channel width ranges from 3 to 6 meters with <1-meter high moderately eroded banks. In order of dominance, substrate consists of sand, gravel, silt, clay, cobble, and bedrock. There is an extensive wetland complex created by beaver (*Castor canadensis*) dams upstream of the reach. Surveys were conducted for 2.13 person hours.

Table 9. Basal Creek Site-100623.3: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	414	194.37/hr
Elliptio icterina	Variable Spike	139	65.26/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common
Corbicula fluminea	Asian Clam	~	Common

Basal Creek Site-100618.1

This section of Basal Creek extends from the Basal Creek arm of Sunset Lake upstream to the SR 1393 crossing just below the tailrace of Bass Lake. The stream consists of a series of braided channels within a floodplain wetland created by beaver dams. There is a large amount of detritus and woody debris. The channels range from 2 to 4 meters wide with <1-meter high banks. In order of dominance, substrate consists of sand, clay and gravel. Surveys were conducted for 4.0 person hours.

Table 10. Basal Creek Site-100618.1: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	51	12.75/hr
Pyganadon cataracta	Eastern Floater	2	0.50/hr
Utterbackia imbecillis	Paper Pondshell	2	0.50/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common
Corbicula fluminea	Asian Clam	~	Uncommon

UT to Middle Creek Site-100507.2

This section of a UT to Middle Creek was accessed from the Optimist Farm Road (SR 1390) crossing. Channel width ranges from 2 to 4 meters with 1-meter high banks that showed signs of erosion. In order of dominance, substrate consists of sand, gravel, and silt. A mixture of residential development and forested landscape occurs adjacent to this reach. Mussel surveys were conducted for 2.5 person hours.

Table 11. UT Middle Creek Site-100507.2: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	2	0.80/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Rare

Rocky Branch Site-100507.1

This section of Rocky Branch was accessed off the Optimist Farm Road (SR 1390) crossing. Channel width ranges from 2 to 4 meters with 1-meter high banks that showed signs of erosion. Surveys were conducted upstream of a section of the channel that was impounded by beavers. In order of dominance, substrate consists of gravel, sand, cobble, and boulder. Surveys were conducted for 2.17 person hours.

Table 12. Rocky Branch Site-100507.1: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Elliptio complanata	Eastern Elliptio	1	0.46/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common
Corbicula fluminea	Asian Clam	~	Rare

UT Middle Creek (Bell's Lake Creek) Site-100618.3

This stretch of UT to Middle Creek (Bell's Lake Creek) which originates from Bell's Lake extends from approximately 100 meters below the Optimist Farm Road (SR 1390) crossing to a point approximately 650 meters upstream. The channel ranges from 2 to 4 meters wide, with eroded banks 1 meter high. Substrate is dominated by sand, gravel and cobble. No mussels were located during the 1.5 person hours of search time.

Table 13. UT Middle Creek (Bell's Lake Creek) Site-100618.3: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
None	~	~	~
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Uncommon

Terrible Creek Site-100618.2

This section of Terrible Creek extends from approximately 0.5 mile downstream of the Johnson Pond Road (SR 1404) crossing upstream to the bridge. The channel, which ranges from 2 to 4 meters with <1-meter high banks, flows through a floodplain marsh wetland system, that appears to be a relict bed of a former impoundment. Numerous small beaver dams are present throughout. In order of dominance, substrate consists of sand, gravel, and cobble. Surveys were conducted for 2.67 person hours.

Table 14. Terrible Creek Site-100618.2: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Elliptio complanata	Eastern Elliptio	5	1.87/hr
Pyganodon cataracta	Eastern floater	7	2.62/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common
Corbicula fluminea	Asian Clam	~	Patchy, Common

Terrible Creek Site-100624.2

This section of Terrible Creek extends from the WWTP discharge in Terrible Creek above Hilltop Road (SR 2751) upstream to the US 401 crossing. The channel width ranges from 3 to 4 meters, and the fairly stable banks are between 1 and 1.5 meters high. The substrate is dominated by sand, cobble, and gravel. Fairly extensive woodland is present on both sides of the stream. Surveys were conducted for 2.73 person hours.

Table 15. Terrible Creek Site-100624.2: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Elliptio complanata	Eastern Elliptio	85	31.14/hr
Elliptio icterina	Varaible Spike	8	2.93/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Terrible Creek Site-100624.1

This section of Terrible Creek extends from the Hilltop Road (SR 2751) crossing upstream to the WWTP discharge point. The channel ranges from 3 to 4 meters wide, and the highly eroded banks are between 1 and 1.5 meters high. The substrate is dominated by sand, cobble, and silt. Fairly extensive woodland is present on both sides of the stream. Surveys were conducted for 0.8 person hour.

Table 16. Terrible Creek Site-100624.1: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	1	1.25/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

UT Middle Creek Site-100611.2

This UT to Middle Creek was accessed from its confluence with Middle Creek near the Lake Wheeler Road (SR 1371) crossing of Middle Creek. Channel is approximately 2 meters wide before it broadens into a larger inundated wetland system with no defined channel. The wetland complex also encompasses another UT to Middle Creek that flows into Middle Creek, approximately 160 meters upstream of this UT confluence. Substrate is dominated by silt and mud. No mollusks were located during the 0.5 person hour of search time. The survey endpoint depicted on Figure 2, Sheet 4 occurs within this wetland complex, and not within a defined channel.

Panther Branch Site-100611.3

This section of Panther Branch was accessed off the Old Stage Road (SR 1006) crossing. The incised channel ranges from 3 to 4 meters wide with unstable 2-meter high banks. In order of dominance, substrate consists of sand, gravel, silt, cobble, and clay. Surveys were conducted for 1.5 person hours.

Table 17. Panther Branch Site-100611.3: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio icterina	Variable Spike	38	25.33/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon

Little Creek Site-100623.1

This section of Little Creek was accessed off the NC 42 crossing. Channel width ranges from 3 to 5 meters with relatively stable 1- to 2-meter high banks. In order of dominance, substrate consists of sand, pebble, gravel, clay, silt, and cobble. Surveys were conducted for 4.33 person hours.

Table 18. Little Creek Site-100623.1: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	316	72.98/hr
Elliptio icterina	Variable Spike	173	39.95/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common
Corbicula fluminea	Asian Clam	~	Common

Little Creek Site-100623.2
This section of Little Creek is located just upstream of Site-100623.1. Channel width ranges from 2 to 5 meters with 1-meter high moderately eroded banks. In order of dominance, substrate consists of sand, pebble, gravel, clay, silt, and cobble. Surveys were conducted for 1.5 person hours.

Table 19. Little Creek Site-100623.2: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	143	95.33/hr
Elliptio icterina	Variable Spike	25	16.67/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common
Corbicula fluminea	Asian Clam	~	Common

Guffy Branch Site-100623.4
This section of Guffy Branch extends from the confluence with Little Creek upstream to the Saul's Road (SR 2727) crossing. The channel width ranges from 3 to 4 meters, and the slightly eroded banks are between 1 and 1.5 meters high. The substrate is dominated by sand, and cobble. A mixture of forest and pastureland occurs along the stream. Surveys were conducted for 3.0 person hours.

Table 20. Guffy Branch Site-100623.4: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	135	45.00/hr
Elliptio icterina	Variable Spike	14	4.67/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon
Corbicula fluminea	Asian Clam	~	Patchy, Common

Guffy Branch Site-100623.5

This section of Guffy Branch extends from the Saul's Road (SR 2727) crossing to a point approximately 600 meters upstream. The channel width ranges from 2 to 3 meters, and the fairly stable banks are 1 meter high. The substrate is dominated by sand, and cobble, with areas of bedrock interspersed. A mixture of forest and fallow agricultural land occurs along the stream. Surveys were conducted for 1.17 person hours.

Table 21. Guffy Branch Site-100623.5: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	95	81. 20/hr
Elliptio icterina	Variable Spike	21	11.95/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon
Corbicula fluminea	Asian Clam	~	Patchy, Common

Buffalo Branch Site-100623.6

This section of Buffalo Branch extends from the NC 50 crossing to a point approximately 450 meters upstream, near the Johnston/Wake County line. The channel width ranges from 3 to 4 meters, and the fairly stable banks are 1 meter high. The substrate is dominated by sand, and cobble. The surrounding landscape is forested. Surveys were conducted for 2.00 person hours.

Table 22. Buffalo Branch Site-100623.6: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	92	46.00/hr
Elliptio icterina	Variable Spike	14	7.00/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common
Corbicula fluminea	Asian Clam	~	Abundant

2.2.2. Central Section

The Central section of the project corridor occurs within the Swift Creek Subbasin between NC 50 and US 70. Two general areas of Swift Creek were evaluated: 1) Swift Creek between Lake Wheeler and Lake Benson (8 sites); and 2) Swift Creek between Lake Benson and the Cornwallis Road (SR 1525) crossing (55 Sites). Tributaries to Swift Creek that were evaluated include Mahler's Creek, UT to Swift Creek, White Oak Creek, and Little Creek (7 sites).

Swift Creek between Lake Wheeler and Lake Benson Site-101124.4
This section of Swift Creek extends from a point approximately 250 meters below the spillway of Lake Wheeler upstream to the spillway. The stream channel ranges from 8 to 10 meters wide, with relatively stable banks up to 2 meters high. The substrate is dominated by sand and gravel, with clay and silt along the banks. Surveys were conducted for 3.58 person hours.

Table 23. Swift Creek Site-101124.4: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	105	29.33/hr
Elliptio icterina	Variable Spike	9	2.51/hr
Utterbackia imbecillis	Paper Pondshell	5	1. 40/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Wheeler and Lake Benson Site-101124.3
This site occurs in an extensive riffle habitat in a bend of Swift Creek approximately halfway between the Lake Wheeler spillway and the US 401 crossing of the creek. The stream channel is 6 meters wide, with relatively stable banks 1 meter high. The substrate is dominated by cobble and gravel, with clay and silt along the banks. Surveys were conducted for 3.67 person hours.

Table 24. Swift Creek Site-101124.3: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	84	22.89/hr
Elliptio icterina	Variable Spike	33	8.99/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Wheeler and Lake Benson Site-101124.2
This site occurs in a long run and pool habitat sequence approximately 600 meters above the US 401 crossing of the creek. The stream channel is 6 to 9 meters wide, with relatively stable banks 1.5 meters high. The substrate is dominated by sand and gravel, with clay and silt along the banks. Surveys were conducted for 3.5 person hours.

Table 25. Swift Creek Site-101124.2: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	82	23.43/hr
Elliptio icterina	Variable Spike	17	4.86/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Wheeler and Lake Benson Site-101124.1

This site occurs in an extensive shallow run and riffle habitat approximately 400 meters above the US 401 crossing of the creek. The stream channel is 6 to 8 meters wide, with relatively stable banks 1.5 meters high. The substrate is dominated by sand and gravel, with clay and silt along the banks. Surveys were conducted for 3.08 person hours.

Table 26. Swift Creek Site-101124.1: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	54	17.53/hr
Elliptio icterina	Variable Spike	23	7.47/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Wheeler and Lake Benson Site-101123.6

This site occurs in a long run, pool and slack-water habitat sequence, approximately 200 meters below the CSX crossing of the creek near US 401. The stream channel is 7 to 9 meters wide, with moderately eroded banks 2 meters high. The substrate is dominated by unconsolidated sand with clay and silt banks. Surveys were conducted for 1.33 person hours.

Table 27. Swift Creek Site-101123.6: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	27	20.30/hr
Elliptio icterina	Variable Spike	7	5.26/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek between Lake Wheeler and Lake Benson Site-101123.5
This site occurs in a long pool and slack-water section with limited riffle and run habitat, approximately 1,050 meters above the Old Stage Road (SR 1006) crossing of the creek. The stream channel is 8 to 10 meters wide, with moderately eroded banks 2 meters high. The substrate is dominated by unconsolidated sand with clay and silt banks. Surveys were conducted for 2.13 person hours.

Table 28. Swift Creek Site-101123.5: Mollusk Species Found

Scientific Name	**Common Name**	**#**	**Abundance/ CPUE**
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	21	9.86/hr
Elliptio icterina	Variable Spike	11	5.16/hr
Elliptio producta	Atlantic Spike	1	0.47/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek between Lake Wheeler and Lake Benson Site-101123.4
This site occurs in a long (60 meter) extensive riffle and run habitat sequence approximately 650 meters above the Old Stage Road (SR 1006) crossing of the creek. The stream channel is 6 to 8 meters wide, with moderately eroded banks 2 meters high. The substrate is dominated by gravel and sand with clay banks. Surveys were conducted for 2.20 person hours.

Table 29. Swift Creek Site-101123.4: Mollusk Species Found

Scientific Name	**Common Name**	**#**	**Abundance/ CPUE**
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	75	34.09/hr
Elliptio icterina	Variable Spike	96	43.64/hr
Elliptio producta	Atlantic Spike	1	0.45/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek between Lake Wheeler and Lake Benson Site-101123.3
This site occurs in a long run, pool, and slack-water habitat sequence approximately 400 meters above the Old Stage Road (SR 1006) crossing of the creek. The stream channel is 8 to 10 meters wide, with moderately eroded banks 2 meters high. The substrate is dominated by unconsolidated sand, gravel, and cobble with clay banks. Surveys were conducted for 1.80 person hours.

Table 30. Swift Creek Site-101123.3: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	4	2.22/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Mahler's Creek Site-101124.5

This section of Mahler's Creek occurs in the vicinity of the New Bethel Church Road (SR 2708) crossing. The channel ranges from 2 to 4 meters wide with 1- to 2-meter high moderately eroded banks. The substrate is dominated by shifting sand and silt. Surveys were conducted for 1.5 person hours.

Table 31. Mahlers Creek Site-101124.5: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	2	1.33/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam		Uncommon

Mahler's Creek Site-101124.8

This section of Mahler's Creek extends from the confluence with Swift Creek to a point approximately 370 meters upstream. The channel ranges from 2 to 3 meters wide with 1- to 2-meter high severely eroded banks. The substrate is dominated by shifting sand and silt. Surveys were conducted for 1.5 person hours.

Table 32. Mahlers Creek Site-101124.8: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	6	4.0/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam		Patchy, Common

Swift Creek between Lake Benson and Cornwallis Road Site-101124.6

This site extends from the Mahler's Creek confluence upstream to a point approximately 250 meters below the NC 50 crossing of Swift Creek. The stream channel is 8 to 10 meters wide, with moderately eroded banks 2.5 meters high. A small beaver dam occurs within this reach, creating slack-water pool habitat. The substrate is dominated by sand and silt, with large amounts of detritus and woody debris. Surveys were conducted for 1.25 person hours.

Table 33. Swift Creek Site-101124.6: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	5	4.00/hr
Elliptio icterina	Variable Spike	1	0.80/hr
Elliptio mediocris	No Common Name	1	0.80/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek between Lake Benson and Cornwallis Road Site-101124.7

This site occurs in a shallow riffle habitat within an island channel on the left descending side of Swift Creek, approximately 50 meters in length just below the Mahler's Creek confluence. The island stream channel is 5 meters wide, with severely eroded banks 2.5 meters high. The substrate is dominated by shifting sand and pebble. Surveys were conducted for 1.0 person hour.

Table 34. Swift Creek Site-101124.7: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	6	6.00/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek between Lake Benson and Cornwallis Road Site-100708.5

This site occurs in a riffle/run/pool habitat sequence approximately 500 meters downstream of the Mahler's Creek confluence. The stream channel is 8 to 10 meters wide, with moderately eroded banks 2.5 meters high. The substrate is dominated by sand and gravel. Surveys were conducted for 2.08 person hours.

Table 35. Swift Creek Site-100708.5: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	110	52.88/hr
Elliptio icterina	Variable Spike	6	2.88/hr
Lampsilis radiata	Eastern Lampmussel	1	0.48/hr
Pyganodon cataracta	Eastern Floater	1	0.48/hr
Utterbackia imbecillis	Paper Pondshell	13	6.25/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek between Lake Benson and Cornwallis Road Site-100708.4
This site occurs in wide bend of Swift Creek, approximately 750 meters downstream of the Mahler's Creek confluence. The habitat consists of shallow sandbar/riffles grading to a deep scoured run. The stream channel is 8 to 10 meters wide, with moderately eroded banks 2.5 meters high. The substrate is dominated by sand and gravel, with clay banks. Surveys were conducted for 4.17 person hours.

Table 36. Swift Creek Site-100708.4: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	238	57.07/hr
Elliptio icterina	Variable Spike	4	0.96/hr
Pyganodon cataracta	Eastern Floater	1	0.24/hr
Utterbackia imbecillis	Paper Pondshell	16	3.84/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon
Corbicula fluminea	Asian Clam	~	Common

Swift Creek between Lake Benson and Cornwallis Road Site-100708.3
This site occurs in a shallow sandbar/riffle and run habitat, approximately 920 meters downstream of the Mahler's Creek confluence. The stream channel is 8 to 10 meters wide, with moderately eroded banks 2.5 meters high. The substrate is dominated by sand and pebble, with clay banks. Surveys were conducted for 4.17 person hours.

Table 37. Swift Creek Site-100708.3: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	575	137.89/hr
Elliptio congarea	Carolina Slabshell	1	0.24/hr
Elliptio icterina	Variable Spike	30	7.19/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.24/hr
Lampsilis radiata	Eastern Lampmussel	3	0.72/hr
Pyganodon cataracta	Eastern Floater	11	2.64/hr
Utterbackia imbecillis	Paper Pondshell	20	4.80/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Patchy, Common
Physella sp.	A Physid Snail	~	Patchy, Common
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-100708.2

This site occurs in a narrow riffle and run habitat, approximately 1,020 meters downstream of the Mahler's Creek confluence. The stream channel is 6 meters wide, with moderately eroded banks 2.5 meters high. The substrate is dominated by sand and pebble, with clay banks. Surveys were conducted for 3.0 person hours.

Table 38. Swift Creek Site-100708.2: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	250	83.33/hr
Elliptio congarea	Carolina Slabshell	1	0.33/hr
Elliptio icterina	Variable Spike	11	3.67/hr
Lampsilis radiata	Eastern Lampmussel	5	1.67/hr
Strophitus undulatus	Creeper	1	0.33/hr
Utterbackia imbecillis	Paper Pondshell	5	1.67/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-100708.1

This site occurs in a narrowly meandering section of the creek, approximately 1,350 meters downstream of the Mahler's Creek confluence. The stream channel is 6 to 10 meters wide, with moderately eroded banks 2.5 meters high. The habitat consists of a series of short riffle run sequences dominated by cobble, sand, and gravel substrate, with clay banks. Surveys were conducted for 2.92 person hours.

Table 39. Swift Creek Site-100708.1: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	307	105.14/hr
Elliptio congarea	Carolina Slabshell	3	1.03/hr
Elliptio icterina	Variable Spike	28	9.59/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.34/hr
Lampsilis radiata	Eastern Lampmussel	2	0.68/hr
Pyganodon cataracta	Eastern Floater	1	0.34/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101123.2
This site occurs in a long straight section of Swift Creek, approximately 1,800 meters downstream of the Mahler's Creek confluence. The stream channel is 10 to 12 meters wide, with moderately eroded banks 2 meters high. Habitat consists of a shallow run grading to a slackwater pool created by a small beaver dam. Substrate is dominated by sand, with clay along the banks. Surveys were conducted for 2.13 person hours.

Table 40. Swift Creek Site-101123.2: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	144	67.60/hr
Elliptio congarea	Carolina Slabshell	2	0.94/hr
Elliptio icterina	Variable Spike	20	9.39/hr
Elliptio mediocris	No Common Name	3	1.41/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.47/hr
Lampsilis radiata	Eastern Lampmussel	1	0.47/hr
Pyganodon cataracta	Eastern Floater	9	4.22/hr
Utterbackia imbecillis	Paper Pondshell	4	1.88/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101123.1
This site occurs adjacent to the Indian Overlook Residential Community and extends from the WWTP discharge point upstream for 167 meters. Habitat consists of a straight relatively shallow pool habitat, with small sandbar and log jam created riffles interspersed. The stream channel is 10 meters wide, with moderately eroded banks 2 meters high. Substrate is dominated by sand and gravel, with clay along the banks. Surveys were conducted for 8.53 person hours.

Table 41. Swift Creek Site-101123.1: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	578	67.76/hr
Elliptio congarea	Carolina Slabshell	6	0.70/hr
Elliptio icterina	Variable Spike	51	5.98/hr
Elliptio producta	Atlantic Spike	3	0.35/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.12/hr
Lampsilis radiata	Eastern Lampmussel	3	0.35/hr
Pyganodon cataracta	Eastern Floater	47	5.51/hr
Utterbackia imbecillis	Paper Pondshell	2	0.23/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101027.1

This site occurs adjacent to the Indian Overlook Residential Community and extends from a point approximately 167 meters downstream of the WWTP discharge point up to the discharge point. The site occurs in a broad bend of the creek, and contains shallow riffle and run habitats dominated by gravel, sand, and cobble substrate. The stream channel is 10 to 12 meters wide, with moderately eroded banks 2 meters high. Surveys were conducted for 10.58 person hours.

Table 42. Swift Creek Site-101027.1: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	185	17.48/hr
Elliptio icterina	Variable Spike	17	1.61/hr
Fusconaia masoni	Atlantic Pigtoe	2	0.19/hr
Lampsilis radiata	Eastern Lampmussel	1	0.09/hr
Pyganodon cataracta	Eastern Floater	83	7.84/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101027.4

This site occurs in short, cobble and gravel dominated, riffle habitat, in a narrow bend of the creek, approximately 180 meters below the Indian Overlook WWTP discharge. The stream channel is 8 meters wide, with moderately eroded banks 2 meters high. Surveys were conducted for 0.53 person hours.

Table 43. Swift Creek Site-101027.4: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	5	9.43/hr
Elliptio icterina	Variable Spike	1	1.89/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101027.3
This site occurs in wide straight section of the creek approximately 240 meters below the Indian Overlook WWTP discharge. The stream channel is 15 meters wide, with moderately eroded banks 2 meters high. Habitat consists of a series of small riffle, run, and pool habitats. Surveys were conducted for 1.0 person hour.

Table 44. Swift Creek Site-101027.3: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	61	61.00/hr
Elliptio icterina	Variable Spike	7	7.00/hr
Pyganodon cataracta	Eastern Floater	3	3.00/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101027.2
This site occurs in wide straight section of the creek approximately 470 meters below the Indian Overlook WWTP discharge. The stream channel is 15 meters wide, with severely eroded banks 2 meters high. Large sandbars and log jams occur throughout this reach, and the habitat consists of shallow runs dominated by shifting sand, and deep pools above the log jams with clay banks. Surveys were conducted for 1.47 person hours.

Table 45. Swift Creek Site-101027.2: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	29	19.73/hr
Elliptio icterina	Variable Spike	Shell	0.0/hr
Lampsilis radiata	Eastern Lampmussel	Shell	0.0/hr
Pyganodon cataracta	Eastern Floater	4	2.72/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101007.6

This site was accessed from the Garner WWTP Spray Field facility off Wrenn Road, and occurs in a narrow bend of the creek approximately 1,300 meters below the Indian Overlook WWTP discharge. The stream channel is 15 meters wide, with moderately eroded banks 1.5 meters high. Habitat consists of shallow riffles and runs dominated by sand with clay banks. Surveys were conducted for 2.67 person hours.

Table 46. Swift Creek Site-101007.6: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Alasmidonta undulata	Triangle Floater	3	1.12/hr
Elliptio complanata	Eastern Elliptio	219	82.02/hr
Elliptio congarea	Carolina Slabshell	1	0.37/hr
Elliptio icterina	Variable Spike	30	11.24/hr
Elliptio mediocris	No Common Name	1	0.37/hr
Lampsilis radiata	Eastern Lampmussel	1	0.37/hr
Pyganodon cataracta	Eastern Floater	1	0.37/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101007.5

This 30 meter long site was accessed from the Garner WWTP Spray Field facility off Wrenn Road, and occurs in a narrow, straight run habitat approximately 1,370 meters below the Indian Overlook WWTP discharge. The stream channel is 15 meters wide, with moderately eroded banks 1.5 meters high. Substrate is dominated by sand and pebble with clay banks. Surveys were conducted for 1.92 person hours.

Table 47. Swift Creek Site-101007.5: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	154	80.21/hr
Elliptio icterina	Variable Spike	40	20.83/hr
Fusconaia masoni	Atlantic Pigtoe	2	1.04/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101007.1

This 30-meter long site was accessed from the Garner WWTP Spray Field facility off Wrenn Road, and occurs in a bend with shallow riffle/run habitat approximately 1,630 meters below the Indian Overlook WWTP discharge. The stream channel is 15 meters wide, with moderately eroded banks 1.5 meters high. Substrate is dominated by sand and pebble with clay banks. Surveys were conducted for 3.13 person hours.

Table 48. Swift Creek Site-101007.1: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Elliptio complanata	Eastern Elliptio	211	67.41/hr
Elliptio icterina	Variable Spike	36	11.50/hr
Elliptio mediocris	No Common Name	1	0.32/hr
Elliptio producta	Atlantic Spike	1	0.32/hr
Strophitus undulatus	Creeper	1	0.32/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101007.4
This site was accessed from the Garner WWTP Spray Field facility off Wrenn Road, and occurs in a wide, straight section of the creek approximately 1,830 meters below the Indian Overlook WWTP discharge. The stream channel is 18 meters wide, with severely eroded banks 2 meters high. Habitat is classified as a shallow run dominated by sand and pebble with clay banks. A large amount of woody debris is present. Surveys were conducted for 2.06 person hours.

Table 49. Swift Creek Site-101007.4: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Elliptio complanata	Eastern Elliptio	113	54.85/hr
Elliptio icterina	Variable Spike	18	8.74/hr
Elliptio producta	Atlantic Spike	1	0.48/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.48/hr
Lampsilis radiata	Eastern Lampmussel	1	0.48/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101007.3
This site was accessed from the Garner WWTP Spray Field facility off Wrenn Road, and occurs in a narrow bend at the confluence with an intermittent tributary from the north, approximately 1,930 meters below the Indian Overlook WWTP discharge. The stream channel is 12 meters wide, with severely eroded banks 1.5 meters high. Habitat is classified as a shallow riffle/run dominated by sand and pebble with clay banks. A large amount of woody debris is present. Surveys were conducted for 2.75 person hours.

Table 50. Swift Creek Site-101007.3: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	280	101.82/hr
Elliptio congarea	Carolina Slabshell	3	1.09/hr
Elliptio icterina	Variable Spike	48	17.45/hr
Lampsilis radiata	Eastern Lampmussel	1	0.36/hr
Pyganodon cataracta	Eastern Floater	1	0.36/hr
Strophitus undulatus	Creeper	1	0.36/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101007.2
This site was accessed from the Garner WWTP Spray Field facility off Wrenn Road, and occurs in a long, straight section of the stream approximately 1,100 meters above the Wake/Johnston County line. The stream channel is 15 meters wide, with severely eroded banks 1.5 meters high. Habitat consists primarily of deep runs and pools with a few small riffle areas that have formed below fallen trees. The substrate is dominated by sand and pebble with clay banks. Surveys were conducted for 4.0 person hours.

Table 51. Swift Creek Site-101007.2: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	347	86.75/hr
Elliptio icterina	Variable Spike	14	3.50/hr
Pyganodon cataracta	Eastern Floater	1	0.25/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101027.10
This site was accessed from the I-40 crossing of the creek, and occurs in a wide section of the stream approximately 100 meters above the Wake/Johnston County line. The stream channel is 12 meters wide, with moderately eroded banks 2 meters high. Habitat consists primarily of deep runs and pools with a few small riffle areas that have formed below fallen trees. The substrate is dominated by sand and pebble with clay banks. Surveys were conducted for 2.33 person hours.

Table 52. Swift Creek Site-101027.10: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Alasmidonta undulata	Triangle Floater	2	0.86/hr
Elliptio complanata	Eastern Elliptio	221	94.85/hr
Elliptio congarea	Carolina Slabshell	1	0.43/hr
Elliptio icterina	Variable Spike	35	15.02/hr
Elliptio lanceolata	Yellow Lance	1	0.43/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.43/hr
Strophitus undulatus	Creeper	1	0.43/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101027.9

This site was accessed from the I-40 crossing of the creek, and occurs in a narrow straight section of the stream in the vicinity of the Wake/Johnston County line. The stream channel ranges from 8 to 10 meters wide, with moderately eroded banks 2 meters high. The site consists of a sequence of shallow glide, riffle, and run habitat sequences. The substrate is dominated by sand and gravel with clay banks. Surveys were conducted for 3.73 person hours.

Table 53. Swift Creek Site-101027.9: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.27/hr
Elliptio complanata	Eastern Elliptio	336	90.08/hr
Elliptio congarea	Carolina Slabshell	3	0.80/hr
Elliptio icterina	Variable Spike	50	13.40/hr
Lampsilis radiata	Eastern Lampmussel	Shell	0.0/hr
Pyganodon cataracta	Eastern Floater	2	0.54/hr
Strophitus undulatus	Creeper	2	0.54/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101027.8

This 30-meter long site was accessed from the I-40 crossing of the creek, and occurs in a broad bend of the stream approximately 280 meters downstream of the Wake/Johnston County line. The stream channel ranges from 6 to 10 meters wide, with moderately eroded banks 2 to 3-meters high. The site consists of a sequence of shallow, glide, riffle and run habitat sequences. The substrate is dominated by bedrock overlain with sand, gravel and cobble with clay banks. Surveys were conducted for 3.67 person hours.

Table 54. Swift Creek Site-101027.8: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Alasmidonta heterodon	Dwarf Wedgemussel	1	0.27/hr
Alasmidonta undulata	Triangle Floater	4	1.09/hr
Elliptio complanata	Eastern Elliptio	915	249.32/hr
Elliptio congarea	Carolina Slabshell	14	3.81/hr
Elliptio icterina	Variable Spike	133	36.24/hr
Elliptio lanceolata	Yellow Lance	1	0.27/hr
Elliptio roanokensis	Roanoke Slabshell	5	1.36/hr
Fusconaia masoni	Atlantic Pigtoe	2	0.54/hr
Lampsilis radiata	Eastern Lampmussel	1	0.27/hr
Strophitus undulatus	Creeper	2	0.54/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101027.7
This site was accessed from the I-40 crossing of the creek, and occurs in a narrow straight section between two bends of the stream in approximately 320 meters downstream of the Wake/Johnston County line. The stream channel ranges from 6 to 8 meters wide, with moderately eroded banks 2 meters high. The site contains a sequence of shallow, glide, riffle and run habitat sequences. The substrate is dominated by sand and pebble with clay banks. Surveys were conducted for 3.0 person hours.

Table 55. Swift Creek Site-101027.7: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Alasmidonta undulata	Triangle Floater	2	0.67/hr
Elliptio complanata	Eastern Elliptio	190	63.33/hr
Elliptio congarea	Carolina Slabshell	5	1.67/hr
Elliptio icterina	Variable Spike	17	5.67/hr
Elliptio mediocris	No Common Name	2	0.67/hr
Elliptio roanokensis	Roanoke Slabshell	3	1.00/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.33hr
Lampsilis radiata	Eastern Lampmussel	1	0.33/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101027.6
This site was accessed from the I-40 crossing of the creek, and occurs between two narrow bends approximately 300 meters upstream of I-40. The stream channel ranges from 6 to 8 meters wide, with moderately eroded banks 2 meters high. Habitat consists

primarily of runs and pools, with limited riffles. The substrate is dominated by sand and pebble with clay banks and scattered boulders. Surveys were conducted for 3.67 person hours.

Table 56. Swift Creek Site-101027.6: Mollusk Species Found

Scientific Name	**Common Name**	**#**	**Abundance/ CPUE**
Freshwater Mussels	~	~	**CPUE**
Alasmidonta undulata	Triangle Floater	2	0.54/hr
Elliptio complanata	Eastern Elliptio	284	77.38/hr
Elliptio congarea	Carolina Slabshell	11	3.00/hr
Elliptio icterina	Variable Spike	29	7.90/hr
Elliptio mediocris	No Common Name	2	0.54/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.27/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101027.5
This site was accessed from the I-40 crossing of the creek, and occurs in a long, straight, narrow section of the stream approximately 200 meters upstream of I-40. The stream channel ranges from 5 to 8 meters wide, with moderately eroded banks 2 meters high. Habitat consists primarily of runs and pools, with limited riffles. The substrate is dominated by sand and pebble with clay banks and scattered boulders. Surveys were conducted for 2.87 person hours.

Table 57. Swift Creek Site-101027.5: Mollusk Species Found

Scientific Name	**Common Name**	**#**	**Abundance/ CPUE**
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	63	21.95/hr
Elliptio congarea	Carolina Slabshell	3	1.04/hr
Elliptio icterina	Variable Spike	13	4.53/hr
Elliptio roanokensis	Roanoke Slabshell	2	0.70/hr
Lampsilis radiata	Eastern Lampmussel	2	0.70/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101021.7
This site occurs just below the I-40 crossing of the creek. The stream channel ranges from 8 to 10 meters wide, with severely eroded banks 2.5 meters high. Habitat consists primarily of runs and pools, with limited riffles created by sandbars and log jams. The substrate is dominated by shifting sand. Surveys were conducted for 2.92 person hours.

Table 58. Swift Creek Site-101021.7: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.34/hr
Elliptio complanata	Eastern Elliptio	55	18.84/hr
Elliptio congarea	Carolina Slabshell	5	1.71/hr
Elliptio icterina	Variable Spike	8	2.74/hr
Lampsilis radiata	Eastern Lampmussel	1	0.34/hr
Strophitus undulatus	Creeper	1	0.34/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101021.6

This site occurs approximately 380 meters below the I-40 crossing of the creek in a long straight section. The stream channel ranges from 8 to 10 meters wide, with moderately eroded banks 2.5 meters high. The site contains a sequence of shallow, glide, riffle and run habitat sequences. The substrate is dominated by sand and pebble with clay banks. Surveys were conducted for 6.42 person hours.

Table 59. Swift Creek Site-101021.6: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Alasmidonta undulata	Triangle Floater	2	0.31/hr
Elliptio complanata	Eastern Elliptio	200	31.15/hr
Elliptio congarea	Carolina Slabshell	1	0.16/hr
Elliptio icterina	Variable Spike	39	6.07/hr
Elliptio lanceolata	Yellow Lance	1	0.16/hr
Elliptio roanokensis	Roanoke Slabshell	3	0.47/hr
Fusconaia masoni	Atlantic Pigtoe	3	0.47/hr
Lampsilis radiata	Eastern Lampmussel	2	0.31/hr
Pyganodon cataracta	Eastern Floater	1	0.16/hr
Strophitus undulatus	Creeper	1	0.16/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101021.5

This site occurs approximately 480 meters below the I-40 crossing of the creek in a long straight run habitat. The stream channel ranges from 7 to 9 meters wide, with moderately eroded banks 2 meters high. The substrate is dominated by sand and gravel, with clay banks and occasional cobble and boulder. Surveys were conducted for 3.85 person hours.

Table 60. Swift Creek Site-101021.5: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	62	16.10/hr
Elliptio congarea	Carolina Slabshell	9	2.34/hr
Elliptio icterina	Variable Spike	16	4.16/hr
Elliptio roanokensis	Roanoke Slabshell	2	0.52/hr
Fusconaia masoni	Atlantic Pigtoe	2	0.52/hr
Pyganodon cataracta	Eastern Floater	1	0.26/hr
Strophitus undulatus	Creeper	1	0.26/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101021.4

This site occurs approximately 580 meters below the I-40 crossing of the creek in a long, straight section. The stream channel ranges from 8 to 10 meters wide, with moderately eroded banks 2.5 meters high. The site contains a sequence of shallow glide, riffle, and run habitat sequences. The substrate is dominated by sand and pebble with clay banks. Surveys were conducted for 3.25 person hours.

Table 61. Swift Creek Site-101021.4: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.31/hr
Elliptio complanata	Eastern Elliptio	231	71.08/hr
Elliptio congarea	Carolina Slabshell	10	3.08/hr
Elliptio icterina	Variable Spike	28	8.62/hr
Elliptio roanokensis	Roanoke Slabshell	2	0.62/hr
Fusconaia masoni	Atlantic Pigtoe	2	0.62/hr
Strophitus undulatus	Creeper	1	0.31/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Patchy, Common
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101021.3

This 30 meter long site occurs approximately 620 meters below the I-40 crossing of the creek in a long, straight section. The stream channel ranges from 8 to 10 meters wide, with moderately eroded banks 2.5 meters high. Habitat consists of a shallow riffle transitioning to a deep run. The substrate is dominated by sand and gravel with clay banks. Surveys were conducted for 2.83 person hours.

Table 62. Swift Creek Site-101021.3: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	126	44.52/hr
Elliptio congarea	Carolina Slabshell	2	0.71/hr
Elliptio icterina	Variable Spike	16	5.65/hr
Lampsilis radiata	Eastern Lampmussel	1	0.35/hr
Strophitus undulatus	Creeper	1	0.35/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Patchy, Common
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101021.2
This site occurs approximately 700 meters below the I-40 crossing of the creek in a long, straight, narrow section. The stream channel ranges from 6 to 8 meters wide, with fairly stable banks 2 meters high. The site contains a braided channel of shallow glide, riffle, and run habitat sequences created by sandbars. The substrate is dominated by sand and pebble with clay banks. Surveys were conducted for 4.67 person hours.

Table 63. Swift Creek Site-101021.2: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.21/hr
Elliptio complanata	Eastern Elliptio	234	50.11/hr
Elliptio congarea	Carolina Slabshell	4	0.86/hr
Elliptio icterina	Variable Spike	62	13.28/hr
Elliptio mediocris	No Common Name	1	0.21/hr
Elliptio roanokensis	Roanoke Slabshell	2	0.43/hr
Fusconaia masoni	Atlantic Pigtoe	2	0.43/hr
Lampsilis radiata	Eastern Lampmussel	4	0.86/hr
Strophitus undulatus	Creeper	8	1.71/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101021.1
This site occurs approximately 800 meters below the I-40 crossing of the creek in a long, straight section. The stream channel ranges from 8 to 10 meters wide, with fairly stable banks 2 meters high. The site contains riffle and run habitats. The substrate is dominated by sand and pebble with clay banks. Surveys were conducted for 3.5 person hours.

Table 64. Swift Creek Site-101021.1: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Alasmidonta undulata	Triangle Floater	2	0.57/hr
Elliptio complanata	Eastern Elliptio	147	42.00/hr
Elliptio congarea	Carolina Slabshell	4	1.14/hr
Elliptio icterina	Variable Spike	23	6.57/hr
Elliptio lanceolata	Yellow Lance	1	0.28/hr
Elliptio producta	Atlantic Spike	1	0.28/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.28/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.28/hr
Strophitus undulatus	Creeper	1	0.28/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101012.8
This site occurs approximately 1,000 meters below the I-40 crossing of the creek in a long straight run. The stream channel ranges from 6 to 8 meters wide, with moderately eroded banks 1.5 meters high. The substrate is dominated by sand and gravel with clay banks. Surveys were conducted for 1.33 person hours.

Table 65. Swift Creek Site-101012.8: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Alasmidonta undulata	Triangle Floater	3	2.26/hr
Elliptio complanata	Eastern Elliptio	140	105.26/hr
Elliptio congarea	Carolina Slabshell	1	0.75/hr
Elliptio icterina	Variable Spike	28	21.05/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.75/hr
Strophitus undulatus	Creeper	1	0.75/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek between Lake Benson and Cornwallis Road Site-101012.7
This site occurs approximately 1,100 meters below the I-40 crossing of the creek in a broad bend. The stream channel ranges from 6 to 8 meters wide, with eroded banks 2 meters high. Habitat consists of a shallow riffle grading into a deep run. The substrate is dominated by sand and gravel with clay banks. Surveys were conducted for 2.67 person hours.

Table 66. Swift Creek Site-101012.7: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Alasmidonta undulata	Triangle Floater	2	0.75/hr
Elliptio complanata	Eastern Elliptio	243	91.01/hr
Elliptio congarea	Carolina Slabshell	4	1.50/hr
Elliptio icterina	Variable Spike	21	7.86/hr
Elliptio mediocris	No Common Name	4	1.50/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.37/hr
Strophitus undulatus	Creeper	1	0.37/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek between Lake Benson and Cornwallis Road Site-101012.6
This site occurs approximately 800 meters above the NC 42 crossing of the creek in long straight pool and glide habitat. The stream channel ranges from 6 to 8 meters wide, with eroded banks 3 meters high. The substrate is dominated by sand and silt with clay banks and occasional boulders. Surveys were conducted for 1.62 person hours.

Table 67. Swift Creek Site-101012.6: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	112	69.14/hr
Elliptio icterina	Variable Spike	7	4.32/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.62/hr
Lampsilis radiata	Eastern Lampmussel	1	0.62/hr
Strophitus undulatus	Creeper	2	1.23/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek between Lake Benson and Cornwallis Road Site-101012.5
This site occurs approximately 700 meters above the NC 42 crossing of the creek in broad bend with glide, riffle, and run habitat sequences. The stream channel ranges from 6 to 8 meters wide, with moderately eroded banks 2 meters high. The substrate is dominated by sand with clay banks. Surveys were conducted for 1.67 person hours.

Table 68. Swift Creek Site-101012.5: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Elliptio complanata	Eastern Elliptio	91	54.49/hr
Elliptio icterina	Variable Spike	7	4.19/hr
Elliptio lanceolata	Yellow Lance	1	0.60/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.60/hr
Strophitus undulatus	Creeper	1	0.60/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek between Lake Benson and Cornwallis Road Site-101012.4
This site occurs approximately 600 meters above the NC 42 crossing of the creek in straight section between two bends with riffle and run habitats. The stream channel ranges from 6 to 8 meters wide, with moderately eroded banks 2 meters high. The substrate is dominated by sand with clay banks. Surveys were conducted for 2.0 person hours.

Table 69. Swift Creek Site-101012.4: Mollusk Species Found

Scientific Name	Common Name	#	Abundance /CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Elliptio complanata	Eastern Elliptio	88	44.00/hr
Elliptio congarea	Carolina Slabshell	3	1.50/hr
Elliptio icterina	Variable Spike	16	8.00/hr
Elliptio roanokensis	Roanoke Slabshell	2	1.00/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.50/hr
Lampsilis radiata	Eastern Lampmussel	2	1.00/hr
Strophitus undulatus	Creeper	1	0.50/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek between Lake Benson and Cornwallis Road Site-101012.3
This site occurs approximately 400 meters above the NC 42 crossing of the creek in straight section just below the confluence of an unnamed tributary to the north. The stream channel ranges from 6 to 8 meters wide, with severely eroded banks 2 meters high. Habitat consists of deep pool grading into a swift run. The substrate is dominated by shifting sand with clay banks. Surveys were conducted for 1.0 person hour.

Table 70. Swift Creek Site-101012.3: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	60	60.00/hr
Elliptio congarea	Carolina Slabshell	1	1.00/hr
Elliptio icterina	Variable Spike	6	6.00/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek between Lake Benson and Cornwallis Road Site-101012.2
This site occurs approximately 300 meters above the NC 42 crossing of the creek just above a narrow bend of the creek. The stream channel ranges from 6 to 8 meters wide, with severely eroded banks 2 meters high. Habitat consists of a shallow riffle grading into a swift run. The substrate is dominated by shifting sand with clay banks. Surveys were conducted for 1.0 person hour.

Table 71. Swift Creek Site-101012.2: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	64	64.00/hr
Elliptio congarea	Carolina Slabshell	1	1.00/hr
Elliptio icterina	Variable Spike	12	12.00/hr
Elliptio roanokensis	Roanoke Slabshell	1	1.00/hr
Lampsilis radiata	Eastern Lampmussel	Shell	0.0/hr
Strophitus undulatus	Creeper	1	1.00/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek between Lake Benson and Cornwallis Road Site-101012.1
This site occurs approximately 200 meters above the NC 42 crossing of the creek in a narrow bend of the creek. The stream channel ranges from 5 to 6 meters wide, with severely eroded banks 2 meters high. Habitat consists of a shallow riffle grading into a swift run. The substrate is dominated by shifting sand with clay banks. Surveys were conducted for 1.5 person hours.

Table 72. Swift Creek Site-101012.1: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.67/hr
Elliptio complanata	Eastern Elliptio	116	77.33/hr
Elliptio congarea	Carolina Slabshell	1	0.67/hr
Elliptio icterina	Variable Spike	20	13.33/hr
Lampsilis radiata	Eastern Lampmussel	Shell	0.0/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

UT Swift Creek Site-100713.4

This UT to Swift Creek, which flows into Swift Creek approximately 400 meters upstream of NC 42, extends from the SR 1548 crossing of the stream to a point approximately 260 meters upstream. Numerous beaver dams within the stream and adjacent floodplain have created a braided channel wetland system. Substrate consists of sand and mud, with large amounts of detritus and aquatic vegetation. Surveys were conducted for a total of 1.00 person hour. No freshwater mussels were found; however, three aquatic snail species were common, and the Asian clam was also present.

Table 73. Swift Creek Site-100713.4: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
None	~	~	~
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common
Corbicula fluminea	Asian Clam	~	Uncommon
Helisoma anceps	Two-ridge Ram's Horn	~	Common
Physidae	A Physid Snail		Common

Swift Creek between Lake Benson and Cornwallis Road Site-101013.9

This site occurs approximately 100 meters below the NC 42 crossing of the creek in a narrow bend. The stream channel ranges from 5 to 6 meters wide, with relatively stable banks 2 meters high. Habitat consists of a shallow glide grading into a swift run. The substrate is dominated by gravel and sand with clay banks. Surveys were conducted for 2.0 person hours.

Table 74. Swift Creek Site-101013.9: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.50/hr
Elliptio complanata	Eastern Elliptio	251	125.50/hr
Elliptio congarea	Carolina Slabshell	2	1.00/hr
Elliptio icterina	Variable Spike	54	27.00/hr
Elliptio mediocris	No Common Name	2	1.00/hr
Elliptio roanokensis	Roanoke Slabshell	2	1.00/hr
Fusconaia masoni	Atlantic Pigtoe	2	1.00/hr
Lampsilis radiata	Eastern Lampmussel	1	0.50/hr
Pyganodon cataracta	Eastern Floater	1	0.50/hr
Strophitus undulatus	Creeper	5	2.50/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon
Corbicula fluminea	Asian Clam	~	Common

Swift Creek between Lake Benson and Cornwallis Road Site-101013.8
This site occurs in a long straight section of the stream below a broad bend approximately 170 meters below the NC 42 crossing of the creek. The stream channel ranges from 5 to 6 meters wide, with moderately eroded banks 2 meters high. Habitat consists of a long pool grading into a short riffle. The substrate is dominated by gravel and sand with clay banks. Surveys were conducted for 0.67 person hour.

Table 75. Swift Creek Site-101013.8: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Elliptio complanata	Eastern Elliptio	33	49.25/hr
Elliptio congarea	Carolina Slabshell	1	1.49/hr
Elliptio icterina	Variable Spike	5	7.46/hr
Elliptio mediocris	No Common Name	1	1.49/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek between Lake Benson and Cornwallis Road Site-101013.7
This site occurs in a long straight section of the stream below a broad bend approximately 200 meters below the NC 42 crossing of the creek. The stream channel ranges from 5 to 6 meters wide, with severely eroded banks 2 meters high. Habitat consists of a long pool grading into a short run. Large amounts of woody debris are present. The substrate is dominated by gravel and sand with clay banks. Surveys were conducted for 0.67 person hour.

Table 76. Swift Creek Site-101013.7: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Elliptio complanata	Eastern Elliptio	12	17.91/hr
Elliptio icterina	Variable Spike	2	2.98/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek between Lake Benson and Cornwallis Road Site-101013.6
This site occurs in a long, straight, constricted section of the stream approximately 230 meters below the NC 42 crossing of the creek. The stream channel ranges from 5 to 6 meters wide, with moderately eroded banks 2 meters high. Habitat consists of a riffle and run series. The substrate is dominated by gravel and sand with clay banks. Surveys were conducted for 1.33 person hours.

Table 77. Swift Creek Site-101013.6: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Alasmidonta undulata	Triangle Floater	3	2.26/hr
Elliptio complanata	Eastern Elliptio	137	103.00/hr
Elliptio congarea	Carolina Slabshell	1	0.75/hr
Elliptio icterina	Variable Spike	17	12.78/hr
Elliptio mediocris	No Common Name	1	0.75/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.75/hr
Lampsilis radiata	Eastern Lampmussel	1	0.75/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common
Corbicula fluminea	Asian Clam	~	Common

Swift Creek between Lake Benson and Cornwallis Road Site-101013.5
This site occurs in a long pool above a broad bend approximately 260 meters below the NC 42 crossing of the creek. The stream channel ranges from 5 to 6 meters wide, with severely eroded banks 2 meters high. The substrate is dominated by sand and silt with clay banks. A large amount of woody debris and detritus is present. Surveys were conducted for 1.0 person hour.

Table 78. Swift Creek Site-101013.5: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	96	96.00/hr
Elliptio congarea	Carolina Slabshell	4	4.00/hr
Elliptio icterina	Variable Spike	11	11.00/hr
Fusconaia masoni	Atlantic Pigtoe	1	1.00/hr
Utterbackia imbecillis	Paper Pondshell	1	1.00/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common
Corbicula fluminea	Asian Clam	~	Common

Swift Creek between Lake Benson and Cornwallis Road Site-101013.3

This site occurs in a broad bend approximately 660 meters below the NC 42 crossing of the creek. The stream channel ranges 6 to 7 meters wide, with relatively stable banks 2 meters high. Habitat consists of a shallow glide transitioning to a run. The substrate is dominated by sand and pebble with clay banks. Surveys were conducted for 2.88 person hours.

Table 79. Swift Creek Site-101013.3: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Alasmidonta undulata	Triangle Floater	4	1.39/hr
Elliptio complanata	Eastern Elliptio	425	147.57/hr
Elliptio congarea	Carolina Slabshell	1	0.35/hr
Elliptio icterina	Variable Spike	38	13.19/hr
Fusconaia masoni	Atlantic Pigtoe	3	1.04/hr
Lampsilis radiata	Eastern Lampmussel	6	2.08/hr
Strophitus undulatus	Creeper	4	1.39/hr
Utterbackia imbecillis	Paper Pondshell	1	0.35/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common
Corbicula fluminea	Asian Clam	~	Common

Swift Creek between Lake Benson and Cornwallis Road Site-101013.2

This site occurs in straight wide section approximately 700 meters below the NC 42 crossing of the creek. The stream channel ranges 8 to 9 meters wide, with moderately eroded banks 2 meters high. Habitat is characterized as a glide to riffle to run sequence, with sand and gravel substrate. Surveys were conducted for 1.33 person hours.

Table 80. Swift Creek Site-101013.2: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Alasmidonta undulata	Triangle Floater	3	2.26/hr
Elliptio complanata	Eastern Elliptio	121	90.98/hr
Elliptio congarea	Carolina Slabshell	1	0.75/hr
Elliptio icterina	Variable Spike	11	8.27/hr
Elliptio lanceolata	Yellow Lance	1	0.75/hr
Elliptio mediocris	No Common Name	3	2.26/hr
Lampsilis radiata	Eastern Lampmussel	6	4.51/hr
Strophitus undulatus	Creeper	2	1.50/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon
Corbicula fluminea	Asian Clam	~	Common
Physidae	A Physid Snail	~	Uncommon

Swift Creek between Lake Benson and Cornwallis Road Site-101013.4
This site occurs in small riffle section at the confluence of an intermittent channel from the south, approximately 730 meters below the NC 42 crossing of the creek. The stream channel ranges from 7 to 8 meters wide, with relatively stable banks 2 meters high. The substrate is dominated by sand and pebble with clay banks. Surveys were conducted for 0.58 person hour.

Table 81. Swift Creek Site-101013.4: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Alasmidonta undulata	Triangle Floater	1	1.72/hr
Elliptio complanata	Eastern Elliptio	25	43.10/hr
Elliptio icterina	Variable Spike	14	24.14/hr
Elliptio mediocris	No Common Name	1	1.72/hr
Lampsilis radiata	Eastern Lampmussel	1	1.72/hr
Strophitus undulatus	Creeper	2	3.45/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common
Corbicula fluminea	Asian Clam	~	Common

Swift Creek between Lake Benson and Cornwallis Road Site-101013.1
This site occurs in straight wide section approximately 750 meters below the NC 42 crossing of the creek. The stream channel ranges from 8 to 9 meters wide, with moderately eroded banks 2 meters high. Habitat is characterized as a glide to riffle to run sequence, with sand and gravel substrate. Surveys were conducted for 2.33 person hours.

Table 82. Swift Creek Site-101013.1: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Alasmidonta heterodon	Dwarf Wedgemussel	1	0.43/hr
Alasmidonta undulata	Triangle Floater	7	3.00/hr
Elliptio complanata	Eastern Elliptio	180	77.25/hr
Elliptio icterina	Variable Spike	28	12.02/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.43/hr
Lampsilis radiata	Eastern Lampmussel	1	0.43/hr
Strophitus undulatus	Creeper	2	0.86/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon
Corbicula fluminea	Asian Clam	~	Common
Planorbella trivolvis	Marsh Ram's Horn	~	Rare

Swift Creek between Lake Benson and Cornwallis Road Site-101026.4

This site occurs in straight wide section approximately 770 meters below the NC 42 crossing of the creek. The stream channel ranges from 8 to 10 meters wide, with moderately eroded banks 2 meters high. Habitat is characterized as a series of glide to riffle to run sequences, with sand and gravel substrate. Surveys were conducted for 6.50 person hours.

Table 83. Swift Creek Site-101026.4: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Alasmidonta heterodon	Dwarf Wedgemussel	1	0.15/hr
Alasmidonta undulata	Triangle Floater	11	1.69/hr
Elliptio complanata	Eastern Elliptio	489	75.23/hr
Elliptio congarea	Carolina Slabshell	8	1.23/hr
Elliptio icterina	Variable Spike	89	13.69/hr
Elliptio lanceolata	Yellow Lance	1	0.15/hr
Elliptio mediocris	No Common Name	9	1.38/hr
Elliptio producta	Atlantic Spike	1	0.15/hr
Elliptio roanokensis	Roanoke Slabshell	2	0.31/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.15/hr
Lampsilis radiata	Eastern Lampmussel	1	0.15/hr
Pyganodon cataracta	Eastern Floater	2	0.31/hr
Strophitus undulatus	Creeper	5	0.77/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101026.3
This site occurs in narrow bend approximately 950 meters below the NC 42 crossing of the creek. The stream channel ranges from 6 to 8 meters wide, with moderately eroded banks 2 meters high. Habitat is characterized as a riffle to run sequence, with sand and gravel substrate. Surveys were conducted for 5.58 person hours.

Table 84. Swift Creek Site-101026.3: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Alasmidonta undulataundulate	Triangle Floater	8	1.43/hr
Elliptio complanata	Eastern Elliptio	515	92.29/hr
Elliptio congarea	Carolina Slabshell	7	1.25/hr
Elliptio icterina	Variable Spike	173	31.00/hr
Elliptio mediocris	No Common Name	10	1.79/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.18/hr
Fusconaia masoni	Atlantic Pigtoe	6	1.08/hr
Pyganodon cataracta	Eastern Floater	1	0.18/hr
Strophitus undulatus	Creeper	6	1.08/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101026.2
This site occurs in a short run between two narrow bends approximately 980 meters below the NC 42 crossing of the creek. The stream channel ranges from 7 to 9 meters wide, with moderately eroded banks 2 meters high. Habitat consists of sand and pebble with clay banks. Surveys were conducted for 1.17 person hours.

Table 85. Swift Creek Site-101026.2: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.85/hr
Elliptio complanata	Eastern Elliptio	130	111.11/hr
Elliptio congarea	Carolina Slabshell	2	1.71/hr
Elliptio icterina	Variable Spike	23	19.66/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.85/hr
Lampsilis radiata	Eastern Lampmussel	2	1.71/hr
Strophitus undulatus	Creeper	2	1.71/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101026.1
This site occurs in straight section approximately 1,010 meters below the NC 42 crossing of the creek. The stream channel ranges from 8 to 10 meters wide, with moderately eroded banks 2 meters high. Habitat is characterized as a glide to riffle to run sequence, with sand and pebble substrate. Surveys were conducted for 3.75 person hours.

Table 86. Swift Creek Site-101026.1: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.27/hr
Elliptio complanata	Eastern Elliptio	257	68.53/hr
Elliptio congarea	Carolina Slabshell	5	1.33/hr
Elliptio icterina	Variable Spike	86	22.93/hr
Elliptio lanceolata	Yellow Lance	1	0.27/hr
Elliptio mediocris	No Common Name	4	1.07/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.27/hr
Fusconaia masoni	Atlantic Pigtoe	2	0.53/hr
Lampsilis radiata	Eastern Lampmussel	1	0.27/hr
Strophitus undulatus	Creeper	3	0.80/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Rare
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101019.4
This site occurs in narrow, straight section approximately 1,000 meters above the Cornwallis Road (SR 1525) crossing of the creek. The stream channel ranges from 8 to 10 meters wide, with moderately eroded banks 2 meters high. Habitat is characterized as a scoured run, with sand and pebble substrate with occasional cobble. Surveys were conducted for 3.73 person hours.

Table 87. Swift Creek Site-101019.4: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	246	65.95/hr
Elliptio icterina	Variable Spike	23	6.17/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.27/hr
Fusconaia masoni	Atlantic Pigtoe	2	0.54/hr
Strophitus undulatus	Creeper	2	0.54/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Rare
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek between Lake Benson and Cornwallis Road Site-101019.3
This site occurs in broad bend approximately 600 meters above the Cornwallis Road (SR 1525) crossing of the creek. The stream channel ranges from 8 to 10 meters wide, with moderately eroded banks 2 meters high. Habitat is characterized as a scoured run, with sand and pebble substrate with occasional cobble. Surveys were conducted for 4.0 person hours.

Table 88. Swift Creek Site-101019.3: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.25/hr
Elliptio complanata	Eastern Elliptio	291	72.75/hr
Elliptio congarea	Carolina Slabshell	2	0.50/hr
Elliptio icterina	Variable Spike	32	8.00/hr
Elliptio mediocris	No Common Name	1	0.25/hr
Lampsilis radiata	Eastern Lampmussel	2	0.50/hr
Strophitus undulatus	Creeper	3	0.75/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

White Oak Creek Site-100722.1
This section of White Oak Creek was accessed off the Raynor Road (SR 2555) crossing. Channel width ranged from 2 to 4 meters with relatively stable 1-meter high banks. In order of dominance, substrate consisted of sand, clay, silt, and pebble. Water levels were normal and water visibility was clear. Mussel surveys were conducted for a total of 1.83 person hours.

Table 89. White Oak Creek Site-100722.1: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	34	18.58/hr
Elliptio icterina	Variable Spike	2	1.09/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon

White Oak Creek Site-100713.1
This section of White Oak Creek extends from the SR 1550 (Winston Road) crossing of the creek to a point approximately 300 meters upstream. The poorly defined channel is approximately 1.5 meters wide and meanders through a marsh wetland system. The substrate consists of firm clay and sand. Surveys were conducted for a total of 2.00 person hours.

Table 90. White Oak Creek Site-100713.1: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
None	~	~	~
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Patchy Common
Corbicula fluminea	Asian Clam	~	Common

Little Creek Site-100720.4
This section of Little Creek occurs between a point approximately 200 meters upstream of the Amelia Church Road (SR 1553) crossing to a point approximately 600 meters upstream and was accessed off the Raynor Road (SR 2555) crossing. Channel width ranged from 3 to 4 meters with relatively stable 1-meter high banks. Habitat consists of shallow pool to riffle to run sequences, with sand and cobble dominated substrate. Surveys were conducted for a total of 3.0 person hours.

Table 91. Little Creek Site-100720.4: Mollusk Species Found

Scientific Name	Common Name	#	Abundance /CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Elliptio complanata	Eastern Elliptio	262	87.33/hr
Elliptio icterina	Variable Spike	10	3.33/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Patchy, Common
Corbicula fluminea	Asian Clam	~	Rare

Little Creek Site-100713.3
This section of Little Creek extends from the Amelia Church Road (SR 1553) crossing to a point approximately 200 meters upstream. Channel width ranged from 3 to 4 meters with relatively stable 1-meter high banks. Habitat consists of shallow pool to riffle to run sequences, with sand and cobble dominated substrate. Surveys were conducted for a total of 1.0 person hour.

Table 92. Little Creek Site-100713.3: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Elliptio complanata	Eastern Elliptio	78	78.00/hr
Elliptio icterina	Variable Spike	5	5.00/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Patchy, Common
Corbicula fluminea	Asian Clam	~	Rare

2.2.3. Eastern Section

The Eastern section of the project corridor occurs between Business 70 north to the US 64/US 264 Bypass, and drains to the Neuse River from the US 64/264 Bypass crossing of the river downstream to the vicinity of the Wake/Johnston County line. Tributaries to the Neuse River within this section include: Walnut Creek and Beddingfield Creek to the south; Mango Creek, Unnamed Tributary (UT) to Neuse River, Poplar Creek, and Mark's Creek to the north.

Big Branch Site-100722.2

This section of Big Branch, a tributary to Walnut Creek, was accessed off the Auburn Church Road (SR 2548) crossing. Channel width ranged from 3 to 5 meters with 1-meter high banks that showed signs of erosion. Substrate was dominated by a heavy load of unconsolidated sand. Water levels were normal and water visibility was clear. A few shells of Asian clam were the only evidence of mollusks found in 1.0 person hour.

Table 93. Big Branch Site-100722.2: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
None	~	~	~
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Rare

Walnut Creek Site-100623.4

This section of Walnut Creek extends from the Barwell Road (SR 2551) crossing to a point approximately 700 meters upstream. Channel width ranges from 10 to 12 meters with moderately eroded banks 2 to 3 meters high. Substrate consists of shifting sand with numerous boulders. No mussels were found in 2.5 person hours of survey time.

Table 94. Walnut Creek Site-100623.4: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
None	~	~	~
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Beddingfield Creek Site-100713.2
This section of Beddingfield Creek extends from approximately 30 meters below the Shotwell Road (SR 1553) crossing to a point approximately 400 meters upstream of the crossing. The channel width ranges from 3 to 4 meters with severely eroded banks 2 to 4 meters high. Substrate consists of shifting sand. No mollusk species were found in 1.5 person hours.

Neuse River Site-100726.1
This site occurs in a slack-water section of Neuse River approximately 50 meters upstream of the Poole Road (SR 1007) crossing at a canoe access. The river is approximately 40 meters wide with moderately eroded banks 2 to 3 meters high. Substrate consists of bedrock overlain with silt and sand. Surveys were conducted for 0.41 person hour.

Table 95. Neuse River Site-100726.1: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Elliptio complanata	Eastern Elliptio	25	60.98/hr
Elliptio roanokensis	Roanoke Slabshell	2	4.88/hr
Lasmigona subviridis	Green Floater	1 shell	0.0/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Neuse River Site-100726.2
This site occurs at the Poole Road (SR 1007) crossing of the Neuse River in a deep run habitat. The river is approximately 40 meters wide with moderately eroded banks 2 to 3 meters high. Substrate consists of sand and gravel with clay banks, and occasional boulders. Surveys were conducted for 1.05 person hours.

Table 96. Neuse River Site-100726.2: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Elliptio complanata	Eastern Elliptio	41	39.05/hr
Elliptio congarea	Carolina Slabshell	2	1.90/hr
Elliptio icterina	Variable Spike	2	1.90/hr
Elliptio roanokensis	Roanoke Slabshell	59	56.19/hr
Lampsilis radiata	Eastern Lampmussel	1	0.95/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Neuse River Site-100726.3

This site occurs approximately 300 meters below the Poole Road (SR 1007) crossing of the Neuse River in a riffle to run habitat sequence. The river is approximately 40 meters wide with moderately eroded banks 2 to 3 meters high. Substrate consists of sand and gravel with clay banks. Surveys were conducted for 2.25 person hours.

Table 97. Neuse River Site-100726.3: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Elliptio complanata	Eastern Elliptio	214	95.11/hr
Elliptio congarea	Carolina Slabshell	8	3.56/hr
Elliptio icterina	Variable Spike	16	7.11/hr
Elliptio roanokensis	Roanoke Slabshell	426	189.33/hr
Lampsilis radiata	Eastern Lampmussel	4	1.78/hr
Lasmigona subviridis	Green Floater	23	10.22/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Neuse River Site-100726.4

This site occurs approximately 200 meters below the Walnut Creek confluence with the river. The river is approximately 40 meters wide with moderately eroded banks 2 to 3 meters high. The habitat consists of a bedrock cascade and plunge pool. Mussels were mostly found within bedrock crevices and pockets of accumulated sand. Surveys were conducted for 1.0 person hour.

Table 98. Neuse River Site-100726.4: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Elliptio complanata	Eastern Elliptio	37	37.00/hr
Elliptio congarea	Carolina Slabshell	1 shell	0.0/hr
Elliptio roanokensis	Roanoke Slabshell	19	19.00/hr
Lasmigona subviridis	Green Floater	1	1.00/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Neuse River Site-100726.5

This site occurs approximately 600 meters below the Walnut Creek confluence with Neuse River in a run habitat. The river is approximately 26 meters wide with moderately eroded banks 2 to 3 meters high. Substrate consists of sand and gravel with clay banks. Surveys were conducted for 1.0 person hour.

Table 99. Neuse River Site-100726.5: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Elliptio complanata	Eastern Elliptio	66	66.00/hr
Elliptio congarea	Carolina Slabshell	1	1.00/hr
Elliptio icterina	Variable Spike	1	1.00/hr
Elliptio roanokensis	Roanoke Slabshell	26	26.00/hr
Lampsilis radiata	Eastern Lampmussel	1	1.00/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Neuse River Site-100726.6

This site occurs approximately 1,100 meters below the Walnut Creek confluence with the Neuse River in a riffle to run habitat sequence. The river is approximately 28 meters wide with moderately eroded banks 2 to 3 meters high. Substrate consists mostly of unconsolidated sand with clay banks, and occasional pockets of gravel in the thalweg. Surveys were conducted for 1.75 person hours.

Table 100. Neuse River Site-100726.6: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Alasmidonta undulata	Triangle Floater	2	1.14/hr
Elliptio complanata	Eastern Elliptio	197	112.57/hr
Elliptio congarea	Carolina Slabshell	2	1.14/hr
Elliptio icterina	Variable Spike	2	1.14/hr
Elliptio roanokensis	Roanoke Slabshell	211	120.57/hr
Lampsilis radiata	Eastern Lampmussel	1	0.57/hr
Lasmigona subviridis	Green Floater	5	2.86/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Neuse River Site-100726.7
This site occurs approximately in the middle of a large broad bend of the river, approximately 1,900 meters above the Auburn-Knightdale Road (SR 2555) crossing in a riffle to run habitat sequence. The river is approximately 28 meters wide with moderately eroded banks 2 to 3 meters high. Substrate consists of sand, gravel, and cobble with clay banks, and occasional boulders. A large sandbar occurs along the left descending bank, extending into the river for one-third the width. Surveys were conducted for 1.75 person hours.

Table 101. Neuse River Site-100726.7: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Elliptio complanata	Eastern Elliptio	107	61.14/hr
Elliptio congarea	Carolina Slabshell	2	1.14/hr
Elliptio icterina	Variable Spike	2	1.14/hr
Elliptio roanokensis	Roanoke Slabshell	57	32.57/hr
Lampsilis radiata	Eastern Lampmussel	2	1.14/hr
Lasmigona subviridis	Green Floater	5	2.86/hr
Strophitus undulatus	Creeper	1 shell	0.0/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Neuse River Site-100726.8
This site occurs in a straight section between two broad bends of the river, approximately 1,000 meters above the Auburn-Knightdale Road (SR 2555) crossing. The habitat consists of a riffle to run habitat sequence. The river is approximately 28 meters wide with moderately eroded banks 2 to 3 meters high. Substrate consists of sand, gravel, and cobble with clay banks and occasional boulders. Surveys were conducted for 1.75 person hours.

Table 102. Neuse River Site-100726.8: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	104	59.43/hr
Elliptio roanokensis	Roanoke Slabshell	219	125.14/hr
Lampsilis radiata	Eastern Lampmussel	1	0.57/hr
Lasmigona subviridis	Green Floater	1	0.57/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Neuse River Site-100726.9
This site occurs in a relatively narrow straight section of the river, approximately 300 meters above the Auburn-Knightdale Road (SR 2555) crossing. The river is approximately 24 meters wide with moderately eroded banks 2 to 3 meters high. The habitat consists of a bedrock cascade and plunge pool. Mussels were mostly found within bedrock crevices and pockets of accumulated sand. Surveys were conducted for 1.25 person hours.

Table 103. Neuse River Site-100726.9: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	18	14.40/hr
Elliptio roanokensis	Roanoke Slabshell	52	41.60/hr
Lampsilis radiata	Eastern Lampmussel	1	0.80/hr
Lasmigona subviridis	Green Floater	1	0.80/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Neuse River Site-100720.2
This site occurs in the vicinity of the Auburn-Knightdale Road (SR 2555) crossing, in a run and pool habitat sequence. The river is approximately 32 meters wide with moderately eroded banks 2 to 3 meters high. Substrate consists of sand and cobble with clay banks. The right descending bank has been stabilized with rip rap that extends into the channel. Surveys were conducted for 1.16 person hours.

Table 104. Neuse River Site-100720.2: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	55	47.41/hr
Elliptio roanokensis	Roanoke Slabshell	25	21.55/hr
Lampsilis radiata	Eastern Lampmussel	2	1.72/hr
Lasmigona subviridis	Green Floater	3	2.59/hr
Pyganodon cataracta	Eastern Floater	1	0.86/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Neuse River Site-100720.1

This site occurs approximately 220 meters below the Auburn-Knightdale Road (SR 2555) crossing in a deep run. A large sandbar extends from the left descending bank to the center of the channel. The river is approximately 30 meters wide with moderately eroded banks 2 to 3 meters high. Substrate consists of sand and gravel with some areas of exposed bedrock. Surveys were conducted for 2.83 person hours.

Table 105. Neuse River Site-100720.1: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	8	2.82/hr
Elliptio roanokensis	Roanoke Slabshell	188	66.43/hr
Lampsilis radiata	Eastern Lampmussel	1	0.35/hr
Utterbackia imbecillis	Paper Pondshell	1	0.35/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Neuse River Site-100720.3

This site occurs in the vicinity of the Mail Plantation Road (SR 2509) crossing in a small riffle to long, deep run habitat sequence. The river is approximately 34 meters wide with moderately eroded banks 2 to 3 meters high. Substrate consists of sand, gravel and cobble with clay banks. A large sandbar occurs along the left descending bank, extending into the river for one-quarter the width. Surveys were conducted for 2.5 person hours.

Table 106. Neuse River Site-100720.3: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.40/hr
Elliptio complanata	Eastern Elliptio	45	18.0/hr
Elliptio congarea	Carolina Slabshell	3	1.20/hr
Elliptio roanokensis	Roanoke Slabshell	18	7.20/hr
Lampsilis radiata	Eastern Lampmussel	2	0.80/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Mango Creek Site-100702.2

This site occurs approximately 100 meters downstream of the Hodge Road (SR 2516) crossing in a side channel 2 to 3 meters wide of Mango Creek created by a beaver dam across the main channel. Habitat is characterized as a shallow run with a sand and clay substrate. Surveys were conducted for 1.5 person hours.

Table 107. Mango Creek Site-100702.2: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Pyganodon cataracta	Eastern Flaoter	6	4.00/hr
Utterbackia imbecillis	Paper Pondshell	4	2.67/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common
Corbicula fluminea	Asian Clam	~	Abundant

Mango Creek Site-100702.1

This site extends from the Hodge Road (SR 2516) crossing to a point approximately 600 meters upstream. Habitat consists of a large, braided channel, beaver created, wetland complex. Substrate consists of sand, clay, mud, and detritus. Surveys were conducted for 3.0 person hours.

Table 108. Mango Creek Site-100702.1: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Pyganodon cataracta	Eastern Flaoter	12	4.0/hr
Utterbackia imbecillis	Paper Pondshell	4	1.33/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common
Corbicula fluminea	Asian Clam	~	Abundant
Helisoma anceps	Two-ridge Ram's Horn	~	Patchy, Common
Physidae	A Physid Snail	~	Patchy, Uncommon
Sphaeriidae	A Sphaeriid Clam	~	Uncommon

UT Neuse River Site-100722.3

This UT to the Neuse River was accessed off the Poole Road crossing. Channel width ranges from 1 to 2 meters with relatively unstable 1- to 2-meter high banks. In order of dominance, substrate consists of sand, clay, gravel, silt, and pebble. Mussel surveys were conducted for a total of 1.33 person hours.

Table 109. UT Neuse River Site-100722.3: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	~	~	**CPUE**
Elliptio complanata	Eastern Elliptio	6	4.51/hr
Freshwater Snails and Clams	~	~	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common
Corbicula fluminea	Asian Clam	~	Abundant
Helisoma anceps	Two-ridge Ram's Horn	~	Patchy, Common
Physidae	A Physid Snail	~	Patchy, Uncommon
Sphaeriidae	A Sphaeriid Clam	~	Uncommon

Poplar Creek Site-100702.3

This site extends from the Grasshopper Road (SR 2511) crossing upstream to the Poole Road (SR 1007) crossing. The channel ranges from 3 to 4 meters wide, with severely eroded banks 3 meters high. The substrate consists of unconsolidated sand with scattered cobble. A WWTP discharge is located near the Poole Road crossing. Surveys were conducted for 2.33 person hours.

Table 110. Poplar Creek Site-100702.3: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
None	~	~	~
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Marks Creek 100722.4
This section of Marks Creek was accessed off Marks Creek Road (SR 2234). Channel width ranges from 3 to 6 meters with 2-meter high banks that showed signs of erosion. In order of dominance, substrate consists of sand, silt, granitic bedrock, clay, and gravel. Surveys were conducted for a total of 1.0 person hour.

Table 111. Marks Creek Site 100722.4: Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels	**~**	**~**	**CPUE**
Elliptio complanata	Eastern Elliptio	12	12.00/hr
Freshwater Snails and Clams	**~**	**~**	**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common

3.0 MUSSEL SPECIES DESCRIPTIONS

Brief descriptions of the six targeted mussel species, four of which were found during this survey effort, are provided below as are descriptions of the 11 other mussel species found.

3.1. *Federally Protected Species*

The two federally endangered freshwater mussel species known to occur within the Neuse River Basin in Wake and Johnston Counties were the main focus of this study. Prior to these surveys, the Dwarf Wedgemussel had been found in Swift Creek and Middle Creek, and was historically known from the Neuse River in Wake County. The only known occurrence of the Tar River Spinymussel in the Neuse River Basin is from the Little River in Johnston County. This species has never been found in Swift Creek, and was not found during this study.

3.1.1. *Alasmidonta heterodon* (Dwarf Wedgemussel)

Characteristics

The Dwarf Wedgemussel was originally described as *Unio heterodon* (Lea 1829). Simpson (1914) subsequently placed it in the genus *Alasmidonta*. Ortmann (1914) placed it in a monotypic subgenus *Prolasmidonta*, based on the unique soft-tissue anatomy and conchology. Fuller (1977) believed the characteristics of *Prolasmidonta* warranted elevation to full generic rank and renamed the species *Prolasmidonta* *heterodon*. Clarke (1981) retained the genus name *Alasmidonta* and considered *Prolasmidonta* to be a subjective synonym of the subgenus *Pressodonta* (Simpson 1900).

The specific epithet *heterodon*, refers to the chief distinguishing characteristic of this species, which is the only North American freshwater mussel that consistently has two lateral teeth on the right valve and only one on the left (Fuller 1977). All other laterally dentate freshwater mussels in North America normally have two lateral teeth on the left valve and one on the right. The Dwarf Wedgemussel is generally small, with a shell length ranging between 25 mm and 38 mm. The largest specimen reported by Clarke (1981) was 56.5 mm long, taken from the Ashuelot River in New Hampshire. The periostracum is generally olive green to dark brown; nacre bluish to silvery white, turning to cream or salmon colored towards the umbonal cavities. Sexual dimorphism occurs in DWM, with the females having a swollen region on the posterior slope, and the males are generally flattened. Clarke (1981) provides a detailed description of the species.

Nearly all freshwater mussel species have similar reproductive strategies; a larval stage (glochidium) becomes a temporary obligatory parasite on a fish. Many mussel species have specific fish hosts, which must be present to complete their life cycle. Based upon laboratory infestation experiments, Michaelson and Neves (1995) determined that potential fish hosts for the Dwarf Wedgemussel in North Carolina include the tesselated darter (*Etheostoma olmstedi*) and the Johnny darter (*E. nigrum*). McMahon and Bogan (2001) and Pennak (1989) should be consulted for a general overview of freshwater mussel reproductive biology.

Distribution and Habitat Requirements

The historic range of the Dwarf Wedgemussel was confined to Atlantic slope drainages from the Peticodiac River in New Brunswick, Canada, south to the Neuse River, North Carolina. Occurrence records exist from at least 70 locations, encompassing 15 major drainages, in 11 states and 1 Canadian Province (USFWS 1993). When the recovery plan for this species was written, the Dwarf Wedgemussel was believed to have been extirpated from all but 36 localities, 14 of them in North Carolina (USFWS 1993). The most recent assessment (2007 5-Year Review) indicates that the Dwarf Wedgemussel is currently found in 15 major drainages, comprising approximately 70 "sites" (one site may have multiple occurrences). At least 45 of these sites are based on less than five individuals or solely on relict shells. It appears that the populations in North Carolina, Virginia, and Maryland are declining as evidenced by low densities, lack of reproduction, or inability to relocate any individuals in follow-up surveys. Populations in New Hampshire, Massachusetts, and Connecticut appear to be stable, while the status of populations in the Delaware River watershed affected by the recent floods of 2005 is uncertain (USFWS 2007).

Strayer et al. (1996) conducted range-wide assessments of remaining Dwarf Wedgemussel populations, and assigned a population status, to each of the populations. The status rating is based on range size, number of individuals and evidence of reproduction. Seven of the 20 populations assessed were considered “poor”, and two others are considered “poor to fair” and “fair to poor” respectively. In North Carolina, populations are found in portions of the Neuse and Tar River basins; however it is believed to have been extirpated from the main-stem of the Neuse River. It was found at 3 sites within the study area, all in Swift Creek.

The Dwarf Wedgemussel inhabits creeks and rivers of varying sizes (down to approximately two meters wide), with slow to moderate flow. A variety of preferred substrates have been described that range from coarse sand, to firm muddy sand to gravel (USFWS 1993). In North Carolina, Dwarf Wedgemussel often occur within submerged root mats along stable streambanks. The wide range of substrate types used by this species suggests that the stability of the substrate is likely as important as the composition.

Threats to Species

The cumulative effects of several factors, including sedimentation, point and non-point discharge, and stream modifications (impoundments, channelization, etc.), have contributed to the decline of this species throughout its range. With the exception of the Neversink River population in New York, which has an estimated population of over 80,000 Dwarf Wedgemussel individuals, all of the other populations are generally small in numbers and restricted to short reaches of isolated streams. The low numbers of individuals and the restricted range of most of the surviving populations make them extremely vulnerable to extirpation from a single catastrophic event or activity (Strayer et al. 1996). Catastrophic events may consist of natural events such as flooding or drought, as well as human influenced events such as toxic spills associated with highways, railroads, or industrial-municipal complexes.

Siltation resulting from substandard land-use practices associated with activities such as agricultural, forestry and land development has been recognized as a major contributing factor to degradation of mussel populations (USFWS 1996). Siltation has been documented to be extremely detrimental to mussel populations by degrading substrate and water quality, increasing potential exposure to other pollutants, and by direct smothering of mussels (Ellis 1936, Markings and Bills 1979). Sediment accumulations of less than 25 mm have been shown to cause high mortality in most mussel species (Ellis 1936). In Massachusetts, a bridge construction project decimated a population of the Dwarf Wedgemussel because of accelerated sedimentation and erosion (Smith 1981).

Sewage treatment effluent has been documented to significantly affect the diversity and abundance of mussel fauna (Goudreau et al. 1988). Goudreau et al. (1988) found that recovery of mussel populations may not occur for up to 3,218 meters (two miles) below points of chlorinated sewage effluent.

The impact of impoundments on freshwater mussels has been well documented (USFWS 1992a, Neves 1993). Construction of dams transforms lotic habitats into lentic habitats, which results in changes in aquatic community composition. The changes associated with inundation adversely affect both adult and juvenile mussels as well as fish community structure, which could eliminate possible fish hosts for upstream transport of glochidia. Muscle Shoals on the Tennessee River in northern Alabama, once the richest site for naiads (mussels) in the world, is now at the bottom of Wilson Reservoir and covered with 5.79 meters (19 feet) of muck (USFWS 1992b). Large portions of all of the river basins within the Dwarf Wedgemussel's range have been impounded and this is believed to be a major factor contributing to the decline of the species (Master 1986, USFWS 1993).

The introduction of exotic species such as the Asian Clam (*Corbicula fluminea*) and zebra mussel (*Dreissena polymorpha*) has also been shown to pose significant threats to native freshwater mussels. The Asian Clam is now established in most of the major river systems in the United States (Fuller and Powell 1973), including those streams still supporting surviving populations of the Dwarf Wedgemussel. Concern has been raised over competitive interactions for space, food and oxygen with this species and native mussels, possibly at the juvenile stages (Neves and Widlak 1987, Alderman 1995). The zebra mussel, native to the drainage basins of the Black, Caspian and Aral Seas, is an exotic freshwater mussel that was introduced into the Great Lakes in the 1980s and has rapidly expanded its range into the surrounding river basins, including those of the South Atlantic slope (O'Neill and MacNeill 1991). This species competes for food resources and space with native mussels, and is expected to contribute to the extinction of at least 20 freshwater mussel species if it becomes established throughout most of the eastern United States (USFWS 1992b). The zebra mussel is not currently known from any river supporting DWM populations.

3.1.2. *Elliptio steinstansana* (Tar River Spinymussel)

Characteristics

The Tar River Spinymussel grows to a maximum length of 60 millimeters. Short spines are arranged in a radial row anterior to the posterior ridge on one valve and symmetrical to the other valve. The shell is generally smooth in texture with as many as 12 spines that project perpendicularly from the surface and curve slightly ventrally. However, adult specimens tend to lose their spines as they mature (USFWS 1992a). The Tar River Spinymussel is distinguished by its shiny periostracum, parallel pseudocardinal teeth, and the linear ridges on the inside surface of the shell.

Little is known about the reproductive biology of the Tar River Spinymussel USFWS 1992c), however, nearly all freshwater mussel species have similar reproductive strategies, which involves a larval stage (glochidium), that becomes a temporary obligatory parasite on a fish. Many mussel species have specific fish hosts, which must be present to complete their life cycle. McMahon and Bogan (2001) and Pennak (1989) should be consulted for a general overview of freshwater mussel reproductive biology.

Distribution and Habitat Requirements

Previously this mussel was believed to be endemic to the Tar River system, currently occurring in relatively short stretches of the Tar River and three creeks (Shocco, Sandy/Swift and Fishing/Little Fishing) in the Tar drainage. Historically, the Tar River Spinymussel was collected in the Tar River from near Louisburg in Franklin County to Falkland in Pitt County, a range of approximately 125.5 kilometers (78 river miles). Clarke (1983) located Tar River Spinymussel in only a 19.31 km (12-mile) stretch of the Tar River in Edgecombe County. Since 1998, five individuals of this species have been found in the Little River of the Neuse River Basin in Johnston (NCWRC unpublished data). This species is also listed as being found in the Little River in site records of Clarke (1983), but was not mentioned in the report. The Tar River Spinymussel has never been found in any of the water bodies in the project area, nor was it found during this study.

The preferred habitat of the Tar River Spinymussel in Swift Creek of the Tar River Basin was described as relatively fast flowing, well oxygenated, circumneutral pH water in sites prone to significant swings in water velocity, with a substrate comprised of relatively silt-free loose gravel and/or coarse sand.

Threats to Species
The cumulative effects of several factors, including sedimentation, point and non-point discharge, and stream modifications (impoundments, channelization, etc.), have contributed to the decline of this species throughout its range. The remaining populations of Tar River Spinymusse are generally small in numbers. The low numbers of individuals and the restricted range of most of the surviving populations make them extremely vulnerable to extirpation from a single catastrophic event or activity (Strayer et al. 1996). Catastrophic events may consist of natural events such as flooding or drought, as well as human influenced events such as toxic spills associated with highways, railroads or industrial-municipal discharges. Other threats are similar to those described above for Dwarf Wedgemussel.

3.2.*Target Federal Species of Concern (FSC)*

The four FSC species targeted have been previously reported in the study area; however, prior to this survey, no recent records of the Green Floater, or Yellow Lampmussel were known.

3.2.1. Elliptio lanceolata (Yellow Lance)

Characteristics
The yellow lance was described from the Tar River at Tarboro, North Carolina by I. Lea in 1828. This species differs from other lance-shaped elliptios by having a “waxy” bright yellow periostracum that lacks rays. The posterior ridge is distinctly rounded and curves dorsally towards the posterior end.

Distribution and Habitat Requirements
This species is distributed from the Neuse River Basin north to the Rappahannock, but is not believed to occur in the Roanoke or James River Basin. It is in considerable decline throughout its range. Extant populations occur in the Neuse, Tar/Pamlico, Chowan and York River basins. This species is found in small streams to large rivers in substrates primarily consisting of clean sand, and occasionally gravel. It was found at 8 sites within Swift Creek during this study.

Threats to Species
Threats to this and many other freshwater mussel species are similar to those described above for the Dwarf Wedgemussel This species is a FSC and is listed as Endangered in North Carolina. Williams et al. (1993) list this species as Endangered. There appears to be sufficient data to warrant elevation of the yellow lance to Candidate status in the very near future (John Fridell, Recovery Biologist USFWS, Personal Communication).

3.2.2. *Fusconaia masoni* (Atlantic Pigtoe)

Characteristics

The Atlantic Pigtoe was described by Conrad (1834) from the Savannah River in Augusta, Georgia. Shells of the Atlantic pigtoe are subrhomboidal in outline, with a parchment-like yellow to dark brown periostracum. The posterior ridge is very distinct, and the umbos extend well above the dorsal margin.

The Atlantic pigtoe is a tachytictic (short-term) breeder, brooding young and releasing glochidia in early summer. The bluegill (*Lepomis macrochirus*) and shield darter (*Percina peltata*) have been identified as potential fish hosts for this species (O'Dee and Waters 2000).

Distribution and Habitat Requirements

The Atlantic Pigtoe ranges from the Ogeechee River Basin in Georgia north to the James River Basin in Virginia. It occurs in medium size streams to large rivers, but has experienced major declines throughout its entire range. The preferred habitat for this species is a substrate composed of gravel and coarse sand, usually at the base of riffles, however, it can be found in a variety of other substrates and habitat conditions (personal observations). It was found at 23 sites within Swift Creek during this study effort.

Threats to Species

Threats to this and many other freshwater mussel species are similar to those described above for the Dwarf Wedgemussel. This species is a FSC and is listed as Endangered in North Carolina. Williams et al. (1993) list this species as Endangered. There appears to be sufficient data to warrant elevation of the Atlantic pigtoe to Candidate status in the very near future (John Fridell, Recovery Biologist USFWS, Personal Communication).

3.2.3. *Lasmigona subviridis* (Green Floater)

Characteristics

The green floater was described by Conrad (1835) from the Schuykill River in Lancaster County, Pennsylvania. The small mussel species has a thin slightly inflated subovate shell that is narrower in front, higher behind. The dorsal margin forms a blunt angle with the posterior margin. The shell is dull yellow or tan to brownish green, usually with concentrations of dark green rays.

Distribution and Habitat Requirements

The Green Floater occurs along the Atlantic slope from the Savannah River in Georgia north to the Hudson River in New York, as well as in the "interior" basins (New, Kanawah, and Wataugua Rivers) of the Tennessee River basin. It occurs in small size streams to large rivers, in quiet waters such as pools, or eddies, with gravel and sand substrates. It has experienced major declines throughout its entire range. It was found at 8 sites within the Neuse River during this study.

Threats to Species

Threats to this and many other freshwater mussel species are similar to those described above for the Dwarf Wedgemussel This species is a FSC and is listed as Endangered in North Carolina. Williams et al. (1993) list this species as Threatened. Based on preliminary genetics research, the southern populations of the Green Floater (Tar

Pamlico, Neuse, and Yadkin/Pee Dee River Basins) appear to be genetically distinct from populations from the Roanoke River to the north and west (Morgan Railey and Arthur Bogan, North Carolina Museum of Natural Sciences, 2007 personal communication). Further research is needed to determine if these differences warrant classification of the southern populations as a distinct species.

3.2.4. *Lampsilis cariosa* (Yellow Lampmussel)

Characteristics

This species was described from the Schuylkill River near Philadelphia (Say 1817). The waxy-yellow shell is obovate in outline, with a rounded anterior margin and slightly curved posterior margin, and is rarely rayed. The shell thickness begins as thin in juveniles becoming thicker with age. The moderately inflated shell attains a length of 120 mm (Bogan 2002). Male shells are elliptical and somewhat elongate in outline with the ventral margin evenly convex. Female shells are subovate to obovate in outline with the ventral margin expanded near the posterior margin, sloping up to a very bluntly rounded posterior margin. Posterior ridge is poorly developed and rounded, posterior slope slightly convex to flat. Beaks moderately swollen but not elevated much above the hinge line, located anterior of the middle of the shell, beak sculpture consist of about five poorly defined bars, the first ridge concentric with the remainder slightly double-looped. The left valve has two compressed pseudocardinal teeth, the posterior tooth low and immediately under the umbo, and two delicate lateral teeth. The right valve has a single compressed pseudocardinal tooth, and a single lamellar lateral tooth. The pseudocardinal teeth tend to become more stumpy and ragged with age. The interdentum is practically absent, and the beak cavity is open and moderately deep. Older specimens become brownish and loose much of the luster. Nacre color is bluish-white, often tinged with cream or salmon.

Distribution and Habitat Requirements

The yellow lampmussel is found from the lower Ottawa River, Canada eastward to the Sydney River, Nova Scotia then south to the Ogeechee River Drainage Basin in Georgia (Johnson 1970). At one time this species probably ranged throughout most of the Atlantic drainages in North Carolina; however, historical records provided by Johnson (1970) and recent records (Bogan 2002, NCWRC Unpublished data) indicate the species occurs in the Catawba, Pee Dee, Waccamaw, Cape Fear, Neuse, Tar/Pamlico, and Chowan drainages.

Threats to Species

Threats to this and many other freshwater mussel species are similar to those described above for the Dwarf Wedgemussel. This species is a FSC and is listed as Endangered in North Carolina. Williams et al. (1993) also list this species as Endangered.

3.3. *Other Mussel Species Located*

3.3.1 Alasmidonta undulata (Triangle Floater)

This species was described from the Schuykill River near Philadelphia (Say 1817). Its range extends from the Catawba River in North Carolina north to the lower St. Lawrence River. The shell shape is subtriangular to ovate and inflated. The anterior and ventral shell margins are rounded. The periostracum is yellowish green with broad green or black rays. This species is considered Special Concern throughout its range (Williams et al. 1993). It is considered Threatened in North Carolina. This species was found at 1 site in Middle Creek, 28 sites in Swift Creek, and 2 sites in the Neuse River.

3.3.2 Elliptio complanata (Eastern Elliptio)

This species was described as *Mya complanata* from the Potomac River in Maryland (Lightfoot 1786). Shell characteristics are highly variable. Shell shape is typically trapezoidal to rhomboid and compressed to inflated. The usually straight ventral margin is mostly parallel with the dorsal margin and the posterior margin is broadly rounded. Shell thickness varies from thin to solid. This species is widely distributed along the Atlantic Slope from Altamaha River Basin in Georgia north to the St. Lawerence River Basin, and west to Lake Superior and parts of the Hudson Bay Basin. It can be found in a variety of habitats from large rivers and, lakes to small headwater streams. The species is widespread and common throughout its range and considered stable (Williams et al. 1993). It was found at 100 sites in all three watershed sections of the study area.

3.3.3 *Elliptio congarea* (Carolina Slabshell)

This species was described from the Congaree River, South Carolina by Lea (1831). The range of this species extends from the Ogeechee River, Georgia north to the Chowan River, North Carolina and Virginia. The shell is rhomboid and subcompressed with moderately full beaks. The front of the shell is wedge-shaped, with the posterior end obliquely truncate above and biangulate below. The posterior slope usually has numerous cross corrugations or wrinkles. The periostracum is greenish-yellow or tawny. (Williams et al. 1993) list this species as Special Concern. It is considered a Watch 2/Watch 5 species, which indicates that the species is rare to uncommon, but probably not in trouble (W2), but has known increasing threats to its habitat, whether populations are known to be declining or not (W5) (LeGrand et al. 2010). This species was found at 43 sites within Swift Creek and the Neuse River.

3.3.4 Elliptio icterina (Variable Spike)

Described from the Savannah River near Augusta Georgia (Conrad 1834), this highly variable species represents a complex of nearly 50 named species (Johnson 1970). The shell shape is oblong, subelliptical, or subrhomboid, with a prominent posterior ridge, and moderately elevated beaks. The periostracum is usually smooth and greenish yellow to tawny-brown. This species is considered common and currently stable throughout its range (Williams et al. 1993). It was found at 81 sites in all three watershed sections of the study area.

3.3.5. Elliptio mediocris (No Common Name)

This species was described from the Neuse River 6 miles east of Raleigh (Lea 1863). Although Johnson (1970) synonomized this into the *E. complanata* complex and even though there has been no subsequent publication recognizing it as a distinct species, most aquatic biologists working with freshwater mussels on the Atlantic slope recognize it as such. Shell shape is typically rhomboid, and inflated. The usually straight ventral margin is mostly parallel with the dorsal margin and the posterior margin is broadly rounded. Unlike most forms of E. complanata, the beaks are moderately full, and the periostrachum is covered with dark green rays of varying width that remain conspicuous even with older individuals. The posterior slope is high, but more rounded than *E. congarea*. This species was found at 17 sites only within Swift Creek.

3.3.6. *Elliptio producta* (Atlantic Spike)

This species was described from the Savannah River, Georgia by Conrad (1836). The range of this species extends from the Savannah River, Georgia north to the Potomac River Basin in Maryland and Virginia. The Atlantic spike was once synonymized with *Elliptio lanceolata* (Johnson 1970), but is now considered a separate species. The anterior shell margin is rounded and the posterior margin roundly pointed with the most posterior point slightly above the midline of the shell. The periostracum is often shiny, dark reddish brown to greenish brown, generally with out rays. Shell nacre is variable shades of purple. Williams et al. (1993) list this species as Special Concern. The Atlantic spike was found at two sites in Middle Creek and six sites in Swift Creek.

3.3.7. Elliptio roanokensis (Roanoke Slabshell)

The Roanoke slabshell was described from the Roanoke River (exact location unknown) by I. Lea (1838). The reported range of this species extends from the Connecticut River in Massachusetts south to the Savannah River in Georgia (Walter 1954). Based on shell morphologies, Johnson (1970) synominized this and 100 other species into the *Elliptio complanata* complex, however it is now widely recognized as being a valid species. The periostracum is generally very smooth, often with placations (furrows) and reddish yellow in color. Shells of this species reach lengths exceeding 150 mm. This species is listed as Threatened in North Carolina. Williams et al. (1993) list this species as Special Concern. This species was found at 22 sites in Swift Creek, and all 12 sites in the Neuse River sites in Swift Creek and the Neuse River

3.3.8. Lampsilis radiata (Eastern Lampmussel)

Lampsilis radiata radiata (eastern lampmussel) and *Lampsilis radiata conspicua* (Carolina fatmucket). Gmelin (1791) described *Mya radiata* and used Malabar, a region of southern India as the type locality. Ortmann (1919) reported this locality as incorrect and noted Lamarck (1819) had listed it from Saratoga Lake in New York and recommended "if there should not be any other earlier record, we might select this as the type locality." Simpson (1914) had earlier listed Virginia as the type locality, thus Johnson (1970) restricted the type locality to Potomac River, District of Columbia (approximately opposite, Farifax Co., Virginia). Lea (1872) described *Unio conspicuous* from the Yadkin River in Rowan County, North Carolina, which Simpson (1914) treated as a variety of *Lampsilis radiata radiata*, which Johnson (1970) agreed with.

This large mussel is subelliptical to subovate in outline. Shells are generally thick and solid, with rounded anterior and posterior margins and vary from hardly inflated to very inflated. The periostracum is usually yellowish or brownish green with dark green rays over the entire surface. Like other members of this genus, this species is sexually dimorphic, with the shells of the male being more elongate, and the females more rounded and swollen, particularly in the posterior margin. Left valve has two pseudocardinal teeth, the posterior one located under the umbo, and two straight lateral teeth. The right valve has two separate pseudocardinal teeth, the upper is smaller and compressed, and has a single straight lateral tooth. Interdentum is lacking, umbo cavity is shallow, compressed. Nacre color is white, may be tinged with pink or salmon or may be completely pink or salmon. Shells of the Carolina fatmucket are much larger and heavier than the shells of the Eastern lampmussel (Adams et al. 1990) and tend to be more shiny and smooth than the Eastern lampmussel, which is usually rough with close concentric wrinkles (Johnson, 1970, Timothy W. Savidge, personal observations). Also, the posterior ridge is much more broadly rounded in the Carolina fatmucket and, in general, the umbos are not as inflated. Adams et al. (1990) suggested that "because of these differences and because *L. r. radiata* is thought to parasitize an anadromous fish host and *L. r. conspicua* is found in areas without such fish species being present, it is possible that *L. r. radiata* and *L. r. conspicua* are separate species".

The taxonomic status of the *Lampsilis radiata* complex is still uncertain. Both the eastern lampmussel and the Carolina fatmucket forms are known to occur in the Neuse River basin. This large mussel is subelliptical to subovate in outline. Shells are generally thick and solid, with rounded anterior and posterior margins. The periostracum is usually yellowish or brownish green with dark green rays over the entire surface. Like other members of this genus, this species is sexually dimorphic, with the shells of the male being more elongate, and the females more rounded and swollen, particularly in the posterior margin. Williams et al. (1993) consider this species to be Stable; however, both the eastern lampmussel and the Carolina fatmucket are considered Threatened in North Carolina. This species was found at 44 sites, two within Middle Creek, 32 within Swift Creek, and 10 within the Neuse River.

3.3.9. Pyganodon cataracta (Eastern Floater)

Described by Say (1817) in the deep part of a milldam presumably near Philadelphia, this species is wide ranging in the Atlantic drainages from the lower St. Lawrence River Basin south to the Altamaha River Basin, Georgia, and in the Alabama-Coosa River drainage, and the Apalachicola and Coctawhatchee River Basins, Florida. The shells of this species are uniformly thin, and lack hinge teeth. The shell shape is ovate, subelliptical and elongate, with an evenly rounded anterior margin and a broadly rounded ventral margin. The periostracum is light to dark green with broad green rays on the posterior slope. Ortman (1919) recognized three generalized shell forms, the pond form, the creek/small river form and the big river form, that were related to environmental conditions. The pond form occurs in small ponds with muddy substrates, and is characterized by very thin elongate inflated shells. The creek form occurs in riffle-pool habitats in gravel substrates, and is much thicker and more compressed. The big river form is generally short and inflated and occurs in soft substrates. This species is considered common and currently stable throughout its range (Williams et al. 1993). It was found at 24 sites in all three watershed sections of the study area.

3.3.10. Strophitus undulatus (Creeper)

This mussel was described from the Schuylkill River near Philadelphia (Say 1817). Its range extends from throughout much of the Interior River Basin and Atlantic Slope regions. The shell is elliptical to rhomboid in outline and somewhat inflated. The anterior end is rounded, and the posterior end is bluntly pointed. The periostracum is yellowish green to brown, with dark green rays. Williams et al. (1993) consider this species to be Stable; however it is considered Threatened in North Carolina. It was found at two sites within Middle Creek, 29 sites in Swift Creek, and one site in the Neuse River.

3.3.11. *Utterbackia imbecillis* (Paper Pondshell)

Described from the Wabash River in Indiana (Say 1829), this mussel occurs throughout the Mississippi River and Great Lakes drainages, south to northeastern Mexico and east along the Gulf Coast to Florida, as well as along the Atlantic Slope. It has an extremely thin shell that is oblong and inflated. The dorsal and ventral margins are nearly straight and parallel. The periostracum is greenish yellow with fine green rays. This species is considered common throughout its range (Williams et al. 1993). It was found at 14 sites in all three watershed sections of the study area, although mostly within Swift Creek.

4.0 DISCUSSION

These survey efforts provide a comprehensive updated evaluation of freshwater mussel species occurring within the project study area. This information helps to identify which water bodies within the study area contain significant mussel faunas, and can then be used to minimize impacts to these resources. At least one freshwater mussel species was found in 102 of the 110 stream sites sampled. Four of the six targeted mussel species were found during this study, including: the federally Endangered Dwarf Wedgemussel, which was found only within Swift Creek; the FSC and North Carolina listed Endangered Atlantic Pigtoe (Swift Creek), Yellow Lance which were found only within Swift Creek; and the FSC and North Carolina listed Endangered Green Floater which was found only within the Neuse River. Neither the Tar River Spinymussel, nor the Yellow Lampmussel was found during this study, although habitat that could potentially support both species is present in much of the study area. The Tar River Spinymussel has only ever been found in the Little River in the Neuse River Basin. There are historic records of the Yellow Lampmussel from the Neuse River and an unnamed tributary to Swift Creek in Wake County (Johnson 1970); however, this species has not been found in these areas in recent years (NCWRC Unpublished Data).

Although significant freshwater mussel resources occur within all three sections of the study area, habitat degradation and low relative abundances and species diversity is evident in some areas, particularly in the Western Section. As depicted in Table 111, the highest species diversity and number of rare species (as identified in Table 1) occur in the Central Section (Swift Creek and tributaries), followed by the Eastern Section (Neuse River and tributaries) and then Western Section (Middle Creek and tributaries).

Table 112. Mussel Species by Study Corridor Section

Section	# Species	# Rare Species	# FSC Species	# Federal Species
Western	8	4	0	0
Central	14	9	2	1
Eastern	10	6	1	0

4.1. Western Section

Middle Creek drains the western section of the project corridor study area, and from a freshwater mussel standpoint, is the most significant water body in the Western section. Like Swift Creek, Middle Creek was known to support several rare mussel species, including the Dwarf Wedgemussel; however, this species has not been detected during any survey effort since 1992 (NCWRC unpublished data), where it was found at the NC 50 crossing downstream of the study area in Johnston County. In addition, occurrences and numbers of other rare mussel species known from the stream have declined in recent years (NCWRC Unpublished Database of Aquatic Species 2010). The results of this survey effort further support this declining trend, as only four rare mussel species were found in very low numbers (three Eastern Lampmussel, three Creeper, one Ttriangle Floater, and one Atlantic Spike). Observations of habitat conditions also support the apparent decline, as heavy sediment loads, stream-bed scour and stream-bank instability were evident at all sites sampled in Middle Creek. In addition, numerous WWTP discharges are located within the subbasin. The proposed project will cross Middle Creek in the upper limits of the watershed upstream of Sunset Lake. While it is possible that Dwarf Wedgemussel still occurs in Middle Creek further downstream in Johnston County, the presence of Sunset Lake between the proposed crossing and potentially occupied habitat downstream would eliminate the potential for any direct impacts to occur. Given the fact that the Tar River Spinymussel has never been found in Middle Creek and Swift Creek, despite multiple surveys throughout both stream systems, it is unlikely to occur in this section of the project.

No rare mussel species were found in any of the tributaries; however, some of these streams such as Basal Creek, Little Creek, and Guffy Branch support fairly high abundances of the Eastern Elliptio, and contain areas of “good” mussel habitat, which may be suitable for the Dwarf Wedgemussel. However, given the results of this study, and other survey efforts in these tributaries, its presence is unlikely.

4.2. Central Section

The Central section of the project study area drains to the Swift Creek Subbasin. The NCWRC identified the Swift Creek watershed as one of 25 areas in North Carolina considered essential for the continued survival of endangered or threatened aquatic wildlife species (Alderman et al. 1993). As required by the Nature Preserves Act (NCGS 113A-164 of Article 9), the North Carolina Natural Heritage Program (NHP) compiles the North Carolina Department of Environment and Natural Resources (DENR) priority list of “Natural Heritage Areas” in which natural areas (sites) are inventoried and evaluated on the basis of rare plant and animal species, rare or high quality natural communities, and geologic features occurring in the particular site. The sites are rated with regard to national, state and regional significance, and Swift Creek is rated as having “National Significance”, due to the presence of the Dwarf Wedgemussel. It is noted that sites on the list should be given priority for protection; however, it does not imply that all of the areas currently receive protection (NCDENR 2005).

Historically, at least 18 species of freshwater mussels have been reported to occur in the Swift Creek subbasin. This study confirms the relatively high species diversity (for Atlantic Slope drainages) of this stream, as at least 14 species were collected, including the Dwarf Wedgemussel. It is very possible that the *E. complanata* and *E. icterina* complexes are represented by several species, which would further raise the number of species in the subbasin. The only three species reported to occur in Swift Creek that were not found in this study are the Green Floater, Carolina lance (*Elliptio angustata*) and Notched Rainbow. The green floater was reported as occurring in Swift Creek by Walter

(1956) and one specimen was found by Alderman (1991); however, it has not been found in Swift Creek in subsequent surveys. Taxonomic uncertainties with lanceolate elliptios exist; thus, specimens reported as the Carolina lance in previous surveys may in fact be the same species as what is reported in this study as the Atlantic spike, or the northern lance, two other lanceolate elliptio species. The Notched Rainbow was found in the study area in 2007 (TCG 2008).

The results of this study confirm the persistence of the Dwarf Wedgemussel in Swift Creek below Lake Benson, as three individuals were found within the study corridor. In addition, two other individuals were found downstream of the project corridor, as part of a concurrent study carried out by TCG for the City of Raleigh. The targeted FSC Atlantic Pigtoe and Yellow Lance and several other rare mussel species were also confirmed to persist in this section of Swift Creek. Thus, direct impacts to these species are possible from project construction within this section of Swift Creek.

Because of the existence of the Dwarf Wedgemussel in Swift Creek, the study corridor for this project was expanded to include an avoidance alternative (Red Route), which would cross Swift Creek upstream of Lake Benson. This section of Swift Creek is not believed to support the Dwarf Wedgemussel, and the results of this study further support this assumption, as it was not found, nor were any of the associate rare mussel species. In addition, Lake Benson occurs between this section of the creek and occupied habitat located downstream. As such, direct impacts to the Dwarf Wedgemussel are unlikely to occur if the Red Corridor is constructed; however, conclusions regarding Indirect and Cumulative Impacts to the population cannot be determined at this time, and will need to be addressed with all alternates within the study area.

The Tar River Spinymussel was not found in Swift Creek during this study, and it has never been found in this subbasin, despite the presence of apparently suitable habitat. Given this, it is very unlikely to occur in this section of the project.

No rare mussel species were found in any of the tributaries to Swift Creek within the study area; however, both White Oak Creek and Little Creek are known to support Dwarf Wedgemussel and other rare species further downstream of the study area. In both instances artificial impoundments are present between any of the proposed crossing locations and occupied habitat downstream; therefore direct impacts are unlikely.

4.3. Eastern Section

The Eastern section of the project corridor drains to the Neuse River from the US 64/264 Bypass crossing of the river downstream to the vicinity of the Wake/Johnston County line. Tributaries to the Neuse River within this section include: Walnut Creek and Beddingfield Creek to the south; Mango Creek, Unnamed Tributary (UT) to Neuse River, Poplar Creek, and Mark’s Creek to the north.

Historically, at least 18 species of freshwater mussels have been reported to occur in the mainstem of the Neuse River within the project study area (Walter 1956, Johnson 1970), including the Dwarf Wedgemussel. While this study indicates relatively high species diversity (for Atlantic Slope drainages) of this section of the river (10 species), species like the Dwarf Wedgemussel, Atlantic Pigtoe, Yellow Lance and Notched Rainbow, which historically occurred in this area, were not found. The presence of the Green Floater is the first documented occurrence of this species in this section of the Neuse River since the early 1950's (Walter 1956).

The population of the Dwarf Wedgemussel in the main-stem of the Neuse River has long been considered extirpated (USFWS 1993). This section of the Neuse River is drained by an extensive urban area (City of Raleigh). Given this, and the fact that it has not been found in the Neuse River in recent years, including during this study, it is unlikely to still occur in this section of the Neuse River. However, the re-discovery of the targeted FSC Green Floater, which was also believed to have extirpated from this area, casts some uncertainty on this conclusion. Some of the other species formerly reported from this area like the Dwarf Wedgemussel and Atlantic Pigtoe (Johnson 1970) may still exist in low numbers, as the Green Floater was obviously present, but in such low numbers that it was not detected during surveys in recent years (NCWRC Unpublished Data). The presence of the Green Floater at multiple sites (8) and the fact that the majority of individuals found were of the same size (age) class, suggest a recent population expansion. Unless future surveys detect the Dwarf Wedgemussel in the Neuse River, it should still be considered a "Hitoric" population. However, intensive surveys will need to be conducted at the proposed Neuse River crossing once an alternate is chosen.

The Tar River Spinymussel was not found in the Neuse River during this study, nor has it ever been found in the Neuse River. As mentioned previously, the only population of this species in the Neuse River Basin is the Little River. As such, it is very unlikely that the Tar River Spinymussel occurs within the main-stem of the Neuse River in the study area.

No rare mussel species were found in any of the tributaries in this section. Habitat conditions in these tributaries are generally unsuitable for the Dwarf Wedgemussel, and Tar River Spinymussel, in that they are either highly degraded (Beddingfield Branch, Poplar Creek, Walnut Creek etc.), or they are more lentic (still water) in nature (Mango Creek) than lotic habitats (flowing water) where these species occur. Therefore, it is very unlikely that the Dwarf Wedgemussel, or Tar River Spinymussel occur in any of the Neuse River tributaries within this section of the study corridor.

5.0 LITERATURE CITED

Alderman, J. M. 1991. Annual Performance Report on North Carolina Mussels. In: Annual Report 1990-1991, Nongame and Endangered Wildlife Program, Division of Wildlife Management, North Carolina Wildlife Resources Commission> September 1991.

Alderman, J. M. (1995). Monitoring the Swift Creek Freshwater mussel community. Unpublished report presented at the UMRCC symposium on the Conservation and Management of Freshwater Mussels II Initiative for the Future. Rock Island, IL, UMRCC.

Alderman, J. M., R. C. Wilson and C. McGrath. 1993. Conservation of aquatic critical habitats in North Carolina. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 47:348-352.

Bogan, A. E. (2002). Workbook and key to the freshwater bivalves of North Carolina. North Carolina Freshwater Mussel Conservation Partnership, Raleigh, NC, 101 pp, 10 color plates.

Center for Biological Diversity. 2010. Petition To List 404 Aquatic, Riparian and Wetland Species From The Southeastern United States, As Threatened Or Endangered Under The Endangered Species Act. April 20, 2010, 1,145 pp. Available online at: http://sero.nmfs.noaa.gov/pr/esa/Candiate%20Spp/SE_Petition.pdf

Clarke, A. H. 1981. The Tribe Alasmidontini (Unionidae: Anodontinae), Part I: *Pegias*, *Alasmidonta*, and *Arcidens*. Smithsonian Contributions to Zoology, No. 326. 101 pp.

Clarke, A. H. 1983. Status survey of the Tar River spiny mussel. Final Report to U.S. Fish and Wildlife Service with supplement. 63 pp.

Conrad, T. A. (1834). "Descriptions of some new species of fresh water shells from Alabama, Tennessee, etc." American Journal of Science and Arts **25**(2): 338-343.

Conrad, T. A. (1835). Additions to, and corrections of, the Catalogue of species of American Naiades, with descriptions of new species and varieties of Fresh Water Shells. Pp. 1–8, pl. 9. Appendix to: *Synoptical table to New freshwater shells of the United States, with coloured illustrations; and a monograph of the genus Anculotus of Say; also a synopsis of the American naiades.* J. Dobson, 108 Chestnut Street, Philadelphia, Pennsylvania.

Ellis, M. M. (1936). Erosion Silt as a Factor in Aquatic Environments. Ecology 17: 29-42.

Gmelin, J. F. 1791. *Systema Naturae.* 13th edition. Leipzig. Vol.1 part 6:3021-3910.

Fuller, S. L. H. 1977. Freshwater and terrestrial mollusks. In: John E. Cooper, Sarah S.Robinson, John B. Fundeburg (eds.) *Endangered and Threatened Plants and Animals of North Carolina.* North Carolina State Museum of Natural History, Raleigh.

Fuller, S. L. H. and C. E. Powell (1973). Range extensions of *Corbicula manilensis* (Philippi) in the Atlantic drainage of the United States. Nautilus 87(2): 59.

Goudreau, S. E., R. J. Neves, and R. J. Sheehan (1988). Effects of Sewage Treatment Effluents on Mollusks and Fish of the Clinch River in Tazewell County, Virginia. USFWS: 128 pp.

Johnson, R. I. (1970). The Systematics and Zoogeography of the Unionidae (Mollusca: Bivalva) of the Southern Atlantic Slope Region. Bulletin of the Museum of Comparative Zoology 140(6): 263-449.

Lamarck, J. B. P. A. 1815–1822. Histoire naturelle des Animaux sans Vertébres. volumes.

Lea, I. 1829. Description of a new genus of the family of naïades, including eight species, four of which are new; also the description of eleven new species of the genus Unio from the rivers of the United States: with observations on some of the characters of the naïades. *Transactions of the American Philosophical Society* 3[New Series]:403–457, pls. 7–14.

Lea, I. 1831. Observations on the naïades, and descriptions of new species of that and other families. *Transactions of the American Philosophical Society* 4[New Series]:63–121, pls. 3–18.

Lea, I. 1834. Observations on the naïades; and descriptions of new species of that, and other families. Transactions of the American Philosophical Society 5[New Series]:23–119, pls. 1–19.

LeGrand, H. E., Jr., S. P. Hall, S. E. McRae, and J. T. Finnegan. 2010. Natural Heritage Program List of the Rare Animal Species of North Carolina. North Carolina Natural Heritage Program, Raleigh, North Carolina. 124 pp.

Lightfoot, J. (1786). A catalogue of the Portland Museum, lately the property of the duchess Dowager of Portland, deceased, which will be sold at auction by Mr. Skinner and Co. London. Vii = 194 pp.

Markings, L. L. and T. D. Bills (1979). Acute Effects of Silt and Sand Sedimentation on Freshwater Mussels. UMRCC Symposium on the Upper Mississippi River bivalve Mollusks, Rock Island, IL, UMRCC.

Master, L. 1986. Alasmidonta heterodon: results of a global status survey and proposal to list as an endangered species. A report submitted to Region 5 of the U.S. Fish and Wildlife Service. 10 pp. and appendices.

McMahon, R. F. and A. E. Bogan. (2001). Mollusca: Bivalvia. Pp. 331-429. IN: J.H. Thorpe and A.P. Covich. Ecology and classification of North American freshwater invertebrates. 2nd edition. Academic Press.

Michaelson, D.L. and R.J. Neves. 1995. Life history and habitat of the endangered dwarf wedgemussel *Alasmidonta heterodon* (Bivalvia: Unionidae). *Journal of the North American Benthological Society* 14(2):324-340.

NCDENR-Division of Parks and Recreation, 2005. North Carolina Natural Heritage Program Biennial Protection Plan, Natural Heritage Areas Priority List, Raleigh Dept. of Environment Health and Natural Resources, 115 pp.

Neves, R. J. and J. C. Widlak (1987). Habitat Ecology of Juvenile Freshwater Mussels (Bivalva: Unionidae) in a Headwater Stream in Virginia. American Malacological Bulletin 1(5): 1-7.

Neves, R.J. 1993. A state of the Unionids address. Pp. 1-10 in K.S. Cummings, A.C. Buchanan, and L.M. Kooch, eds. Proc. of the UMRCC symposium on the Conservation and Management of Freshwater Mussels. UMRCC. Rock Island IL.189 pp.

O'Dee, S. H., and G. T. Watters. 2000. New or confirmed host identification for ten freshwater mussels. pp. 77-82 in R.A. Tankersley, D.I. Warmolts, G.T. Watters, B.J. Armitage, P.D. Johnson, and R.S. Butler (eds.). Freshwater Mollusk Symposia Proceedings. Part I. Proceedings of the Conservation, Captive Care and Propagation of Freshwater Mussels Symposium. Ohio Biological Survey Special Publication, Columbus.

O'Neill, C. R., Jr., and D. B. MacNeill. 1991. The zebra mussel (Dreissena polymorpha): an unwelcome North American invader. Sea Grant, Coastal Resources Fact Sheet. New York Sea Grant Extension. 12 pp.

Ortmann, A.E. 1919. A monograph of the naiades of Pennsylvania. Part III: Systematic account of the genera and species. *Memoirs of the Carnegie Museum* 8(1):xvi–384, 21 pls.

Pennak, R. W. (1989). Fresh-water Invertebrates of the United States, Protozoa to Mollusca. New York, John Wiley & Sons, Inc.

Savidge, Timothy W. Personal Observation. The Catena Group, Inc.

Say, T., Ed. (1817). Article Conchology. American Edition of the British Encyclopedia of Dictionary of Arts and Sciences, Comprising an Accurate and Popular View of the Present Improved State of Human Knowledge. Philadelphia, Samuel A. Mitchel and Horace Ames.

Say, T. (1829). Descriptions of some new terrestrial and fluviatile shells of North America. The Disseminator of Useful Knowledge; containing hints to the youth of the United States, from the School of Industry **2**(19-23): 291-356.

Simpson, C.T. 1900. Synopsis of the naiades, or pearly fresh-water mussels. Proceedings of the United States National Museum 22(1205):501–1044.

Simpson, C.T. 1914. A descriptive catalogue of the naiades, or pearly fresh-water mussels. Parts I–III. Bryant Walker, Detroit, Michigan, xii + 1540 pp.

Smith, D. 1981. Selected freshwater invertbrates proposed for special concern status in Massachussetts (Mollusca, Annelida, Arthropoda). MA Dept. of Env. Qual. Engineering, Div. of Water Pollution Control. 26 pp.

Strayer, D. L., S. J. Sprague and S. Claypool, 1996. A range-wide assessment of populations of Alasmidonta heterodon, an endangered freshwater mussel (Bivalva:Unionidae). J.N. Am. Benthol. Soc., 15(3):308-317.

The Catena Group Inc. 2008. Swift Creek Freshwater Mussel Surveys The Dempsey E.Benton Water Treatment Project: Wake and Johnston Counties, North Carolina.Unpublished Final Report prepared for Arcadis, Raleigh, North Carolina. 29 ppplus figures.

USFWS 1992a. Special report on the status of freshwater mussels.

USFWS 1992b. Endangered and Threatened species of the southeast United States (The Red Book). FWS, Ecological Services, Div. of Endangered Species, Southeast Region. Govt Printing Office, Wash, DC: 1,070.

U.S. Fish and Wildlife Service. 1992c. Tar River Spinymussel (*Elliptio (Cathyria) steinstansana)* Recovery Plan. Atlanta, Georgia. 34 pp.

U.S. Fish and Wildlife Service. 1993. Dwarf Wedgemussel Mussel (*Alasmidonta heterodon*) Recovery Plan. Hadley, Massachusetts. 527 pp.

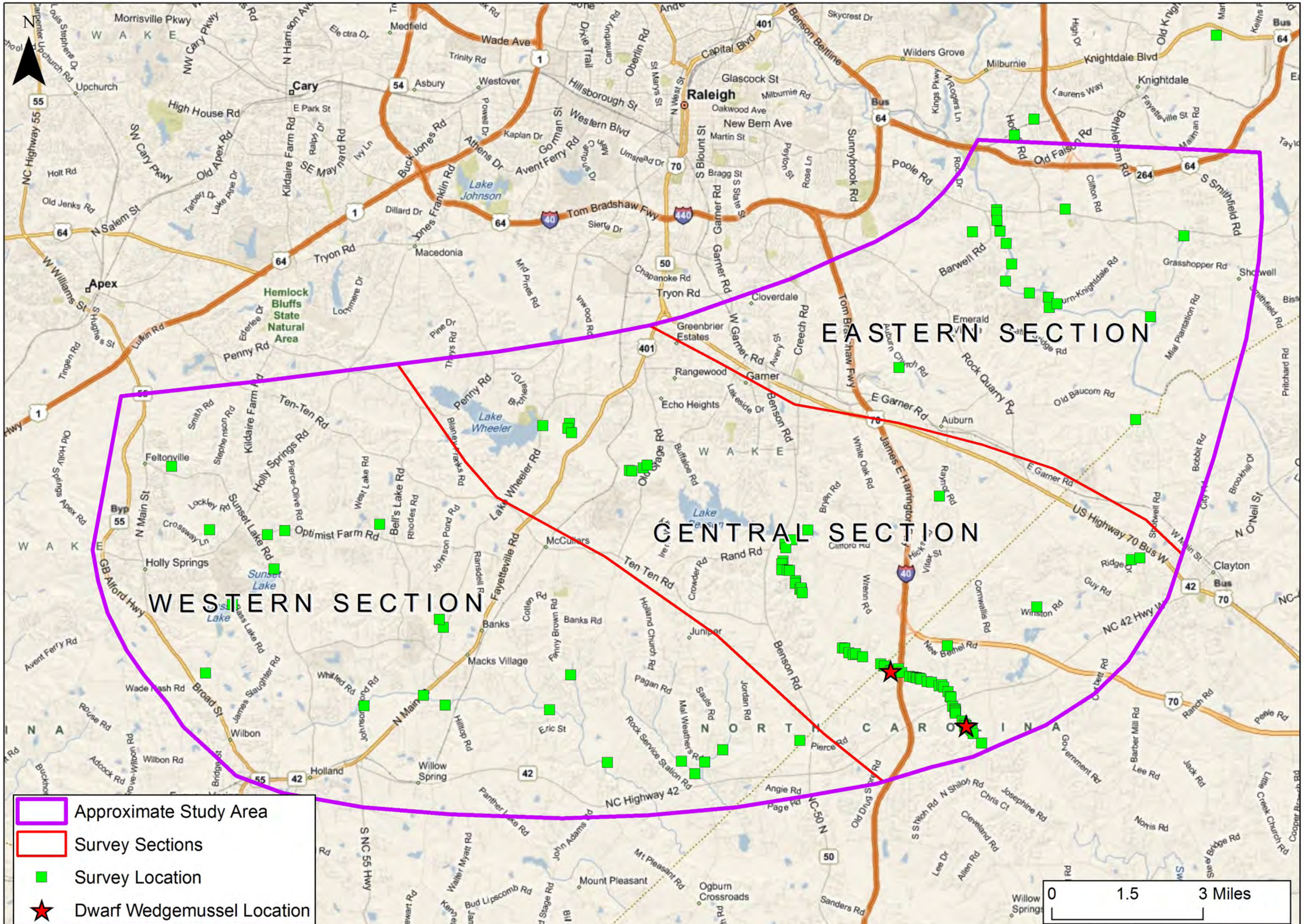
USFWS (1996). Revised Technical/Agency Draft Carolina Heelsplitter Recovery Plan, Atlanta, GA: 47.

Walter, W. M. (1954). Mollusca of the upper Neuse River basin, North Carolina. Durham, North Carolina, Duke University. **Ph. D. dissertation:** i-x + 220.

Walter, W. M. (1956). Mollusca of the upper Neuse River basin, North Carolina. Durham. J. of the Elisha Mitchell Scientific Society (72 (2):262-274.

Williams, J. D., M. L. Warren, Jr., K. S. Cummings, J. L. Harris, and R. J. Neves. (1993). Conservation status of the freshwater mussels of the United States and Canada. Fisheries 18 (9): 6-22.

APPENDIX A
PROJECT FIGURES/SURVEY LOCATION SHEETS



The Catena Group

Date: March 2011

Scale: As Shown

Job No.: 3271

Title: **Triangle Expressway Southeast Extension**

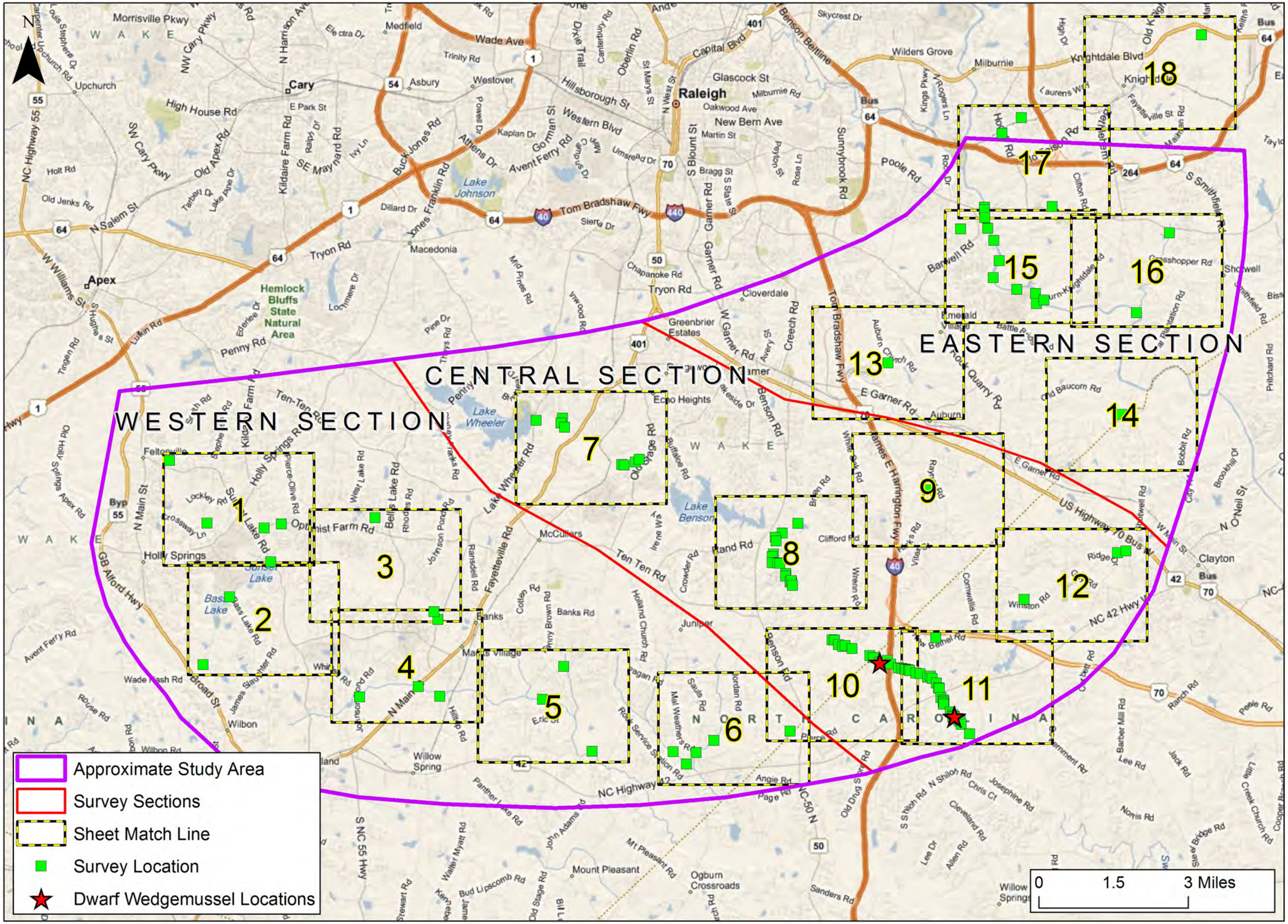
Freshwater Mussel Surveys

Wake and Johnston Counties, North Carolina

Client:

North Carolina Turnpike Authority

Figure 1



The Catena Group

Date: March 2011

Scale: As Shown

Job No.: 3271

Title: **Triangle Expressway Southeast Extension**

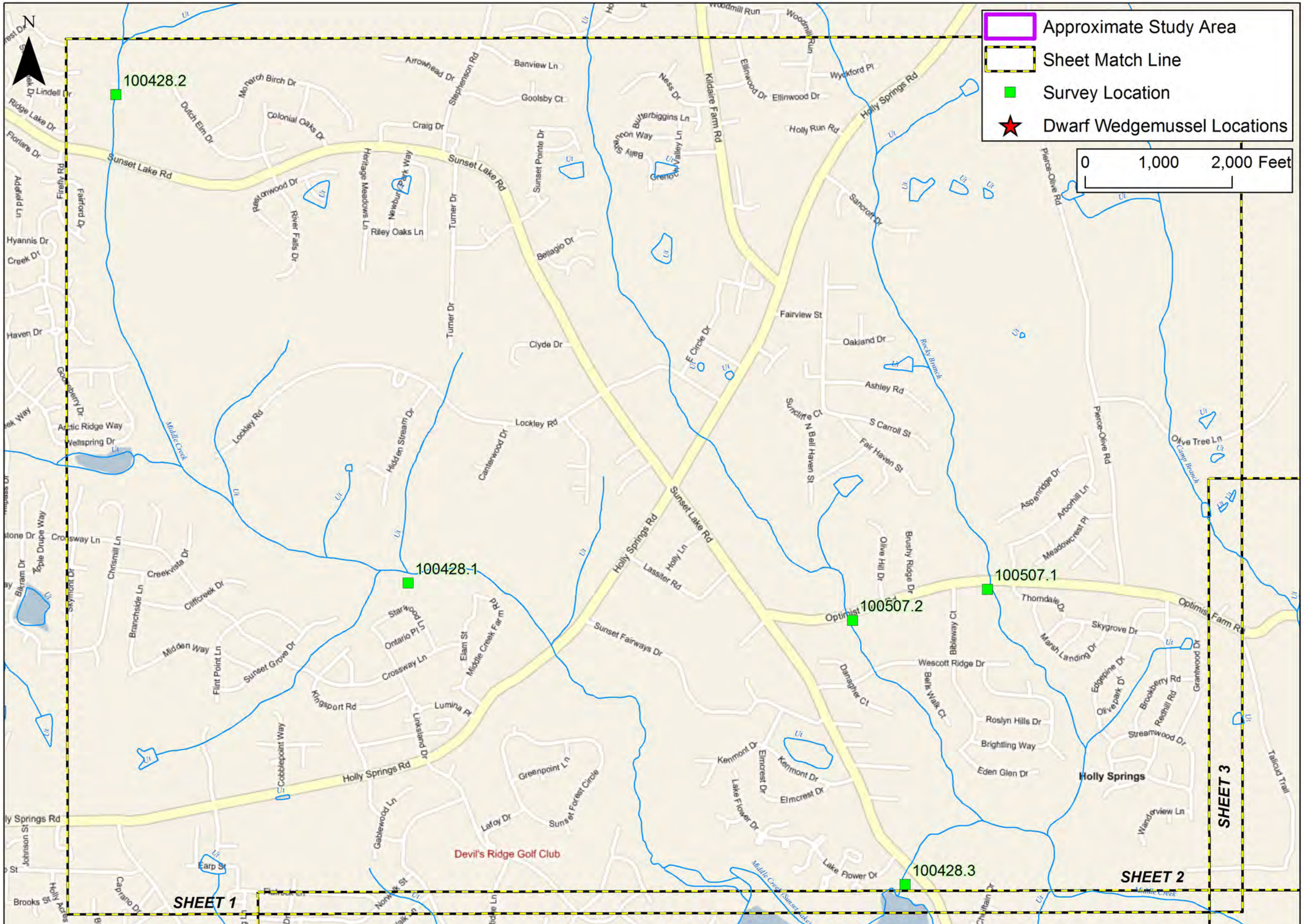
Freshwater Mussel Surveys

Wake and Johnston Counties, North Carolina

Client: North Carolina Turnpike Authority

Figure 2

Sheet Index



The Catena Group

Date: March 2011

Scale: As Shown

Job No.: 3271

Title: **Triangle Expressway Southeast Extension**

Freshwater Mussel Surveys

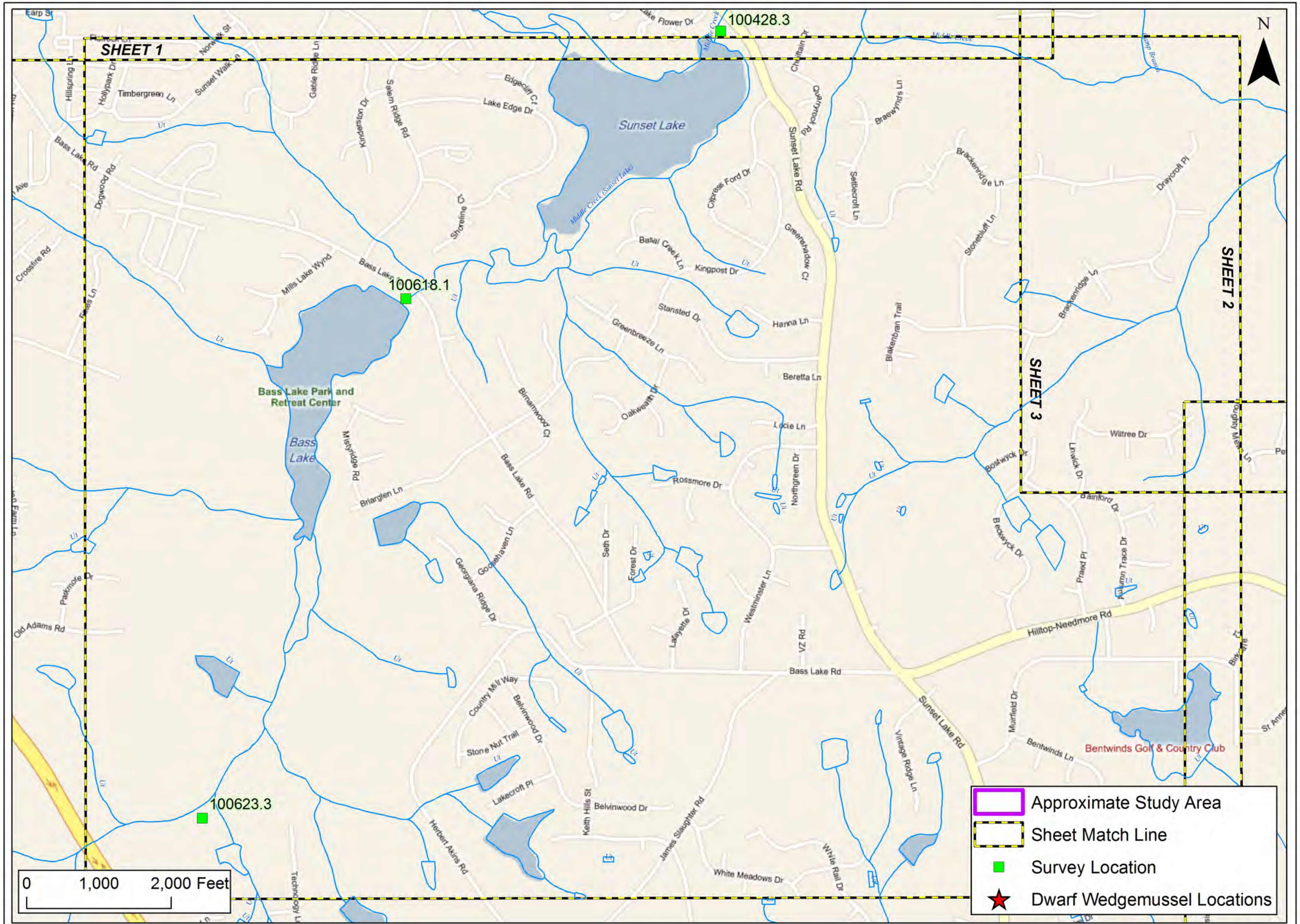
Wake and Johnston Counties, North Carolina

Client:

North Carolina Turnpike Authority

Figure 2

Sheet 1



The Catena Group

Date: March 2011

Scale: As Shown

Job No.: 3271

Title:
Triangle Expressway Southeast Extension

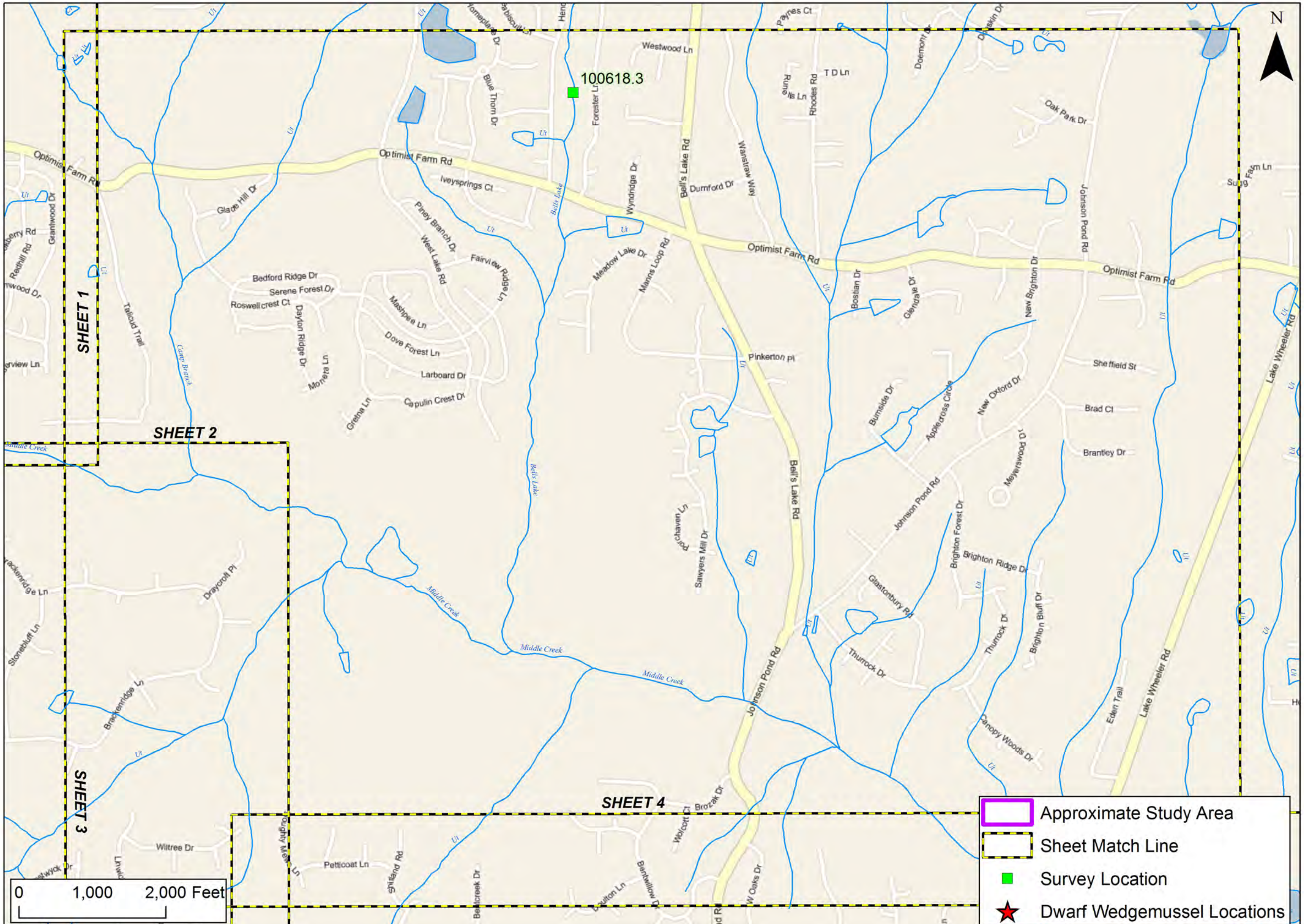
Freshwater Mussel Surveys

Wake and Johnston Counties, North Carolina

Client:

North Carolina Turnpike Authority

Figure 2
Sheet 2



The Catena Group

Date:
March 2011

Scale:
As Shown

Job No.:
3271

Title:
Triangle Expressway Southeast Extension

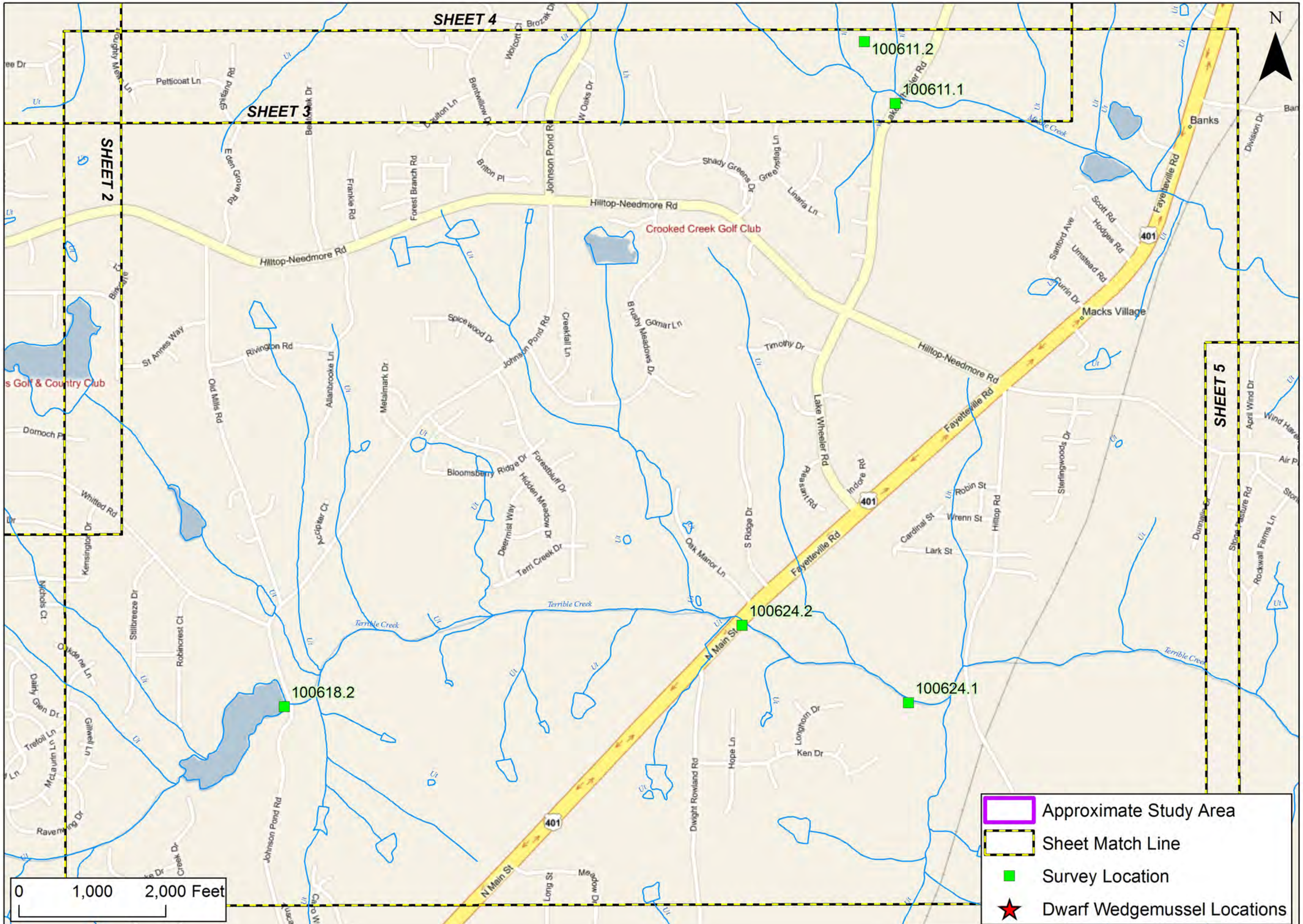
Freshwater Mussel Surveys

Wake and Johnston Counties, North Carolina

Client:

North Carolina Turnpike Authority

Figure
2
Sheet 3



The Catena Group

Date: March 2011

Scale: As Shown

Job No.: 3271

Title:

Triangle Expressway Southeast Extension

Freshwater Mussel Surveys

Wake and Johnston Counties, North Carolina

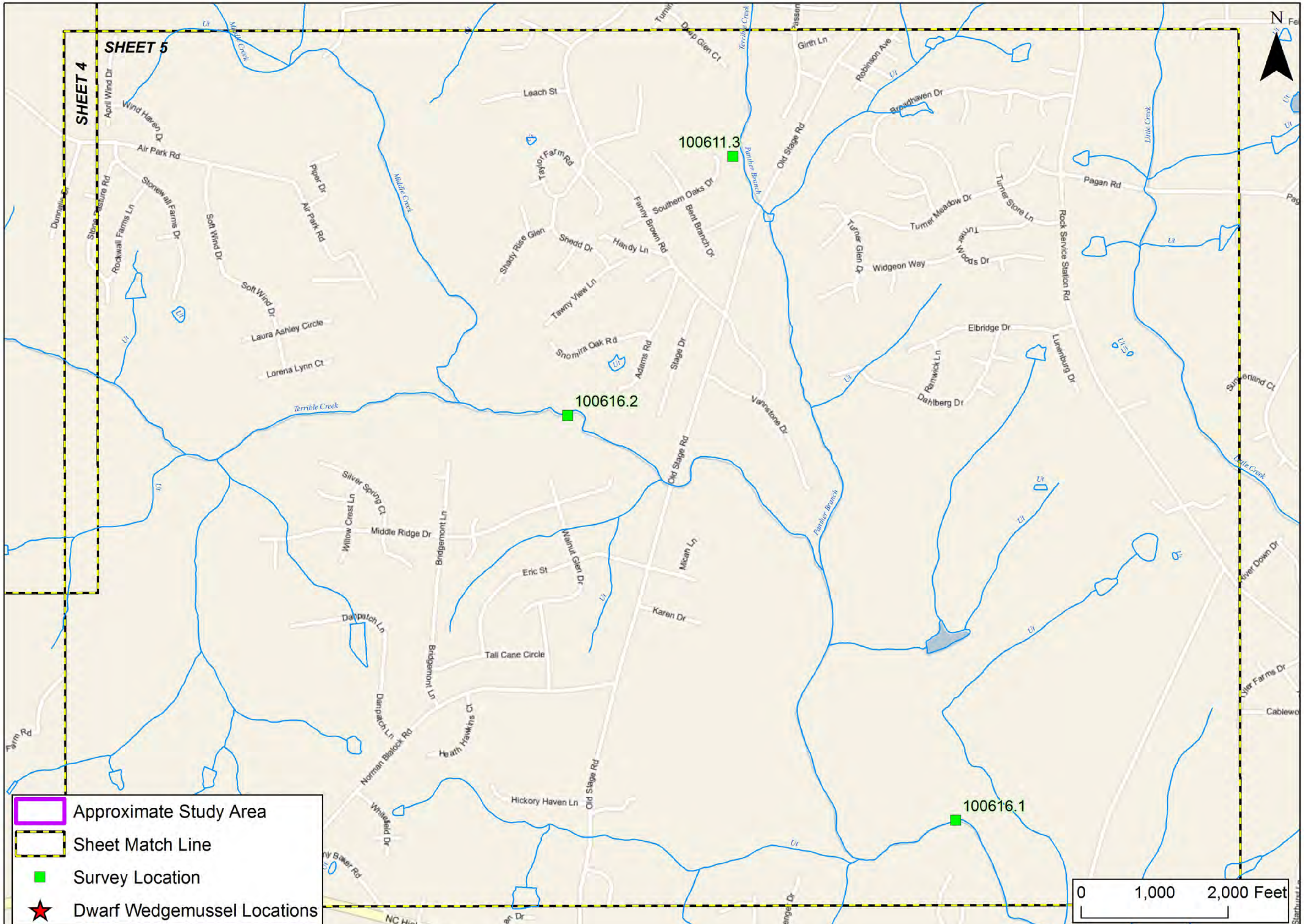
Client:

North Carolina Turnpike Authority

Figure

2

Sheet 4



The Catena Group

Date: March 2011

Scale: As Shown

Job No.: 3271

Title: **Triangle Expressway Southeast Extension**

Freshwater Mussel Surveys

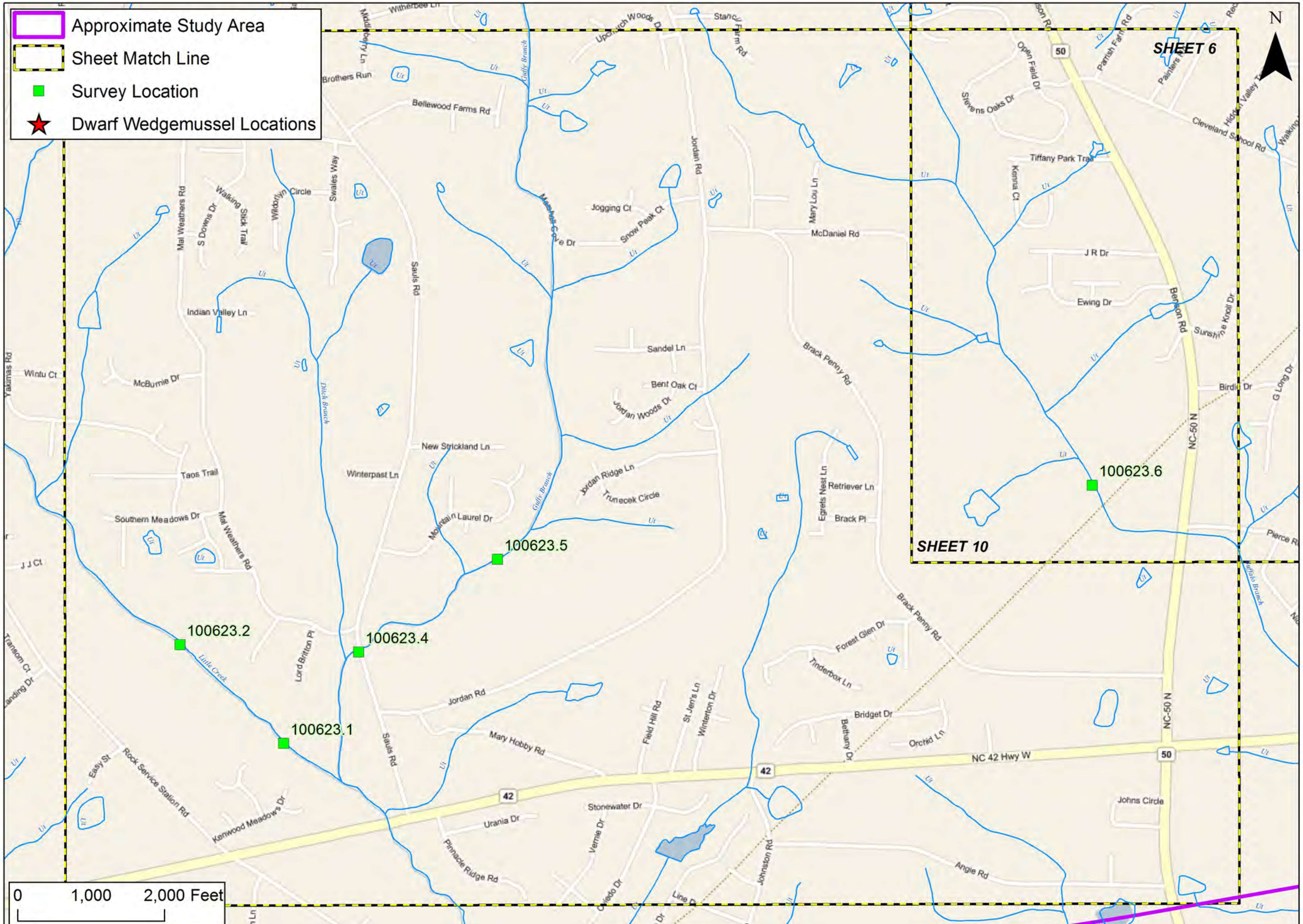
Wake and Johnston Counties, North Carolina

Client:

North Carolina Turnpike Authority

Figure **2**

Sheet 5



The Catena Group

Date: March 2011

Scale: As Shown

Job No.: 3271

Title: **Triangle Expressway Southeast Extension**

Freshwater Mussel Surveys

Wake and Johnston Counties, North Carolina

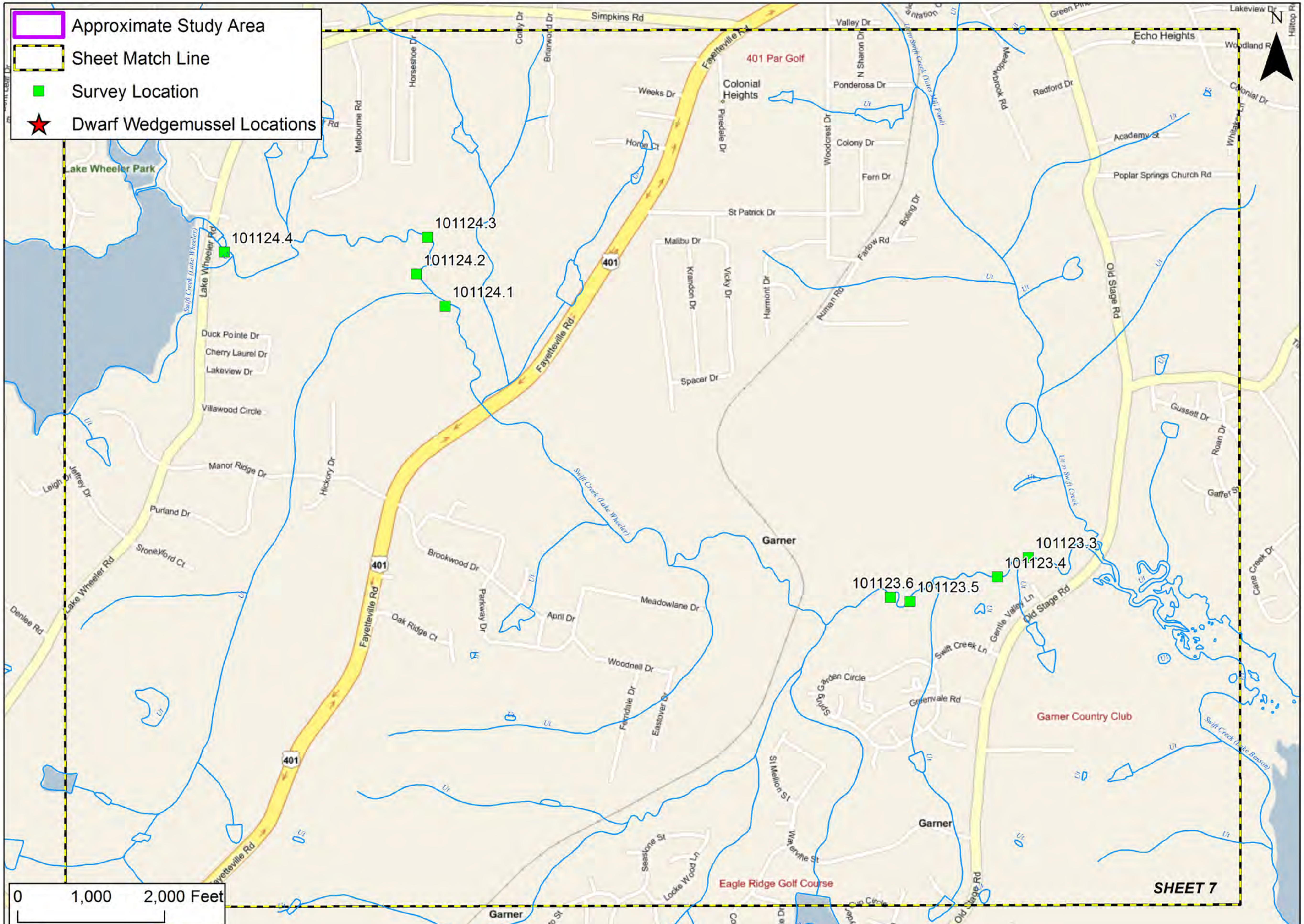
Client:

North Carolina Turnpike Authority

Figure

2

Sheet 6



The Catena Group

Date: March 2011

Scale: As Shown

Job No.: 3271

Title:
Triangle Expressway Southeast Extension

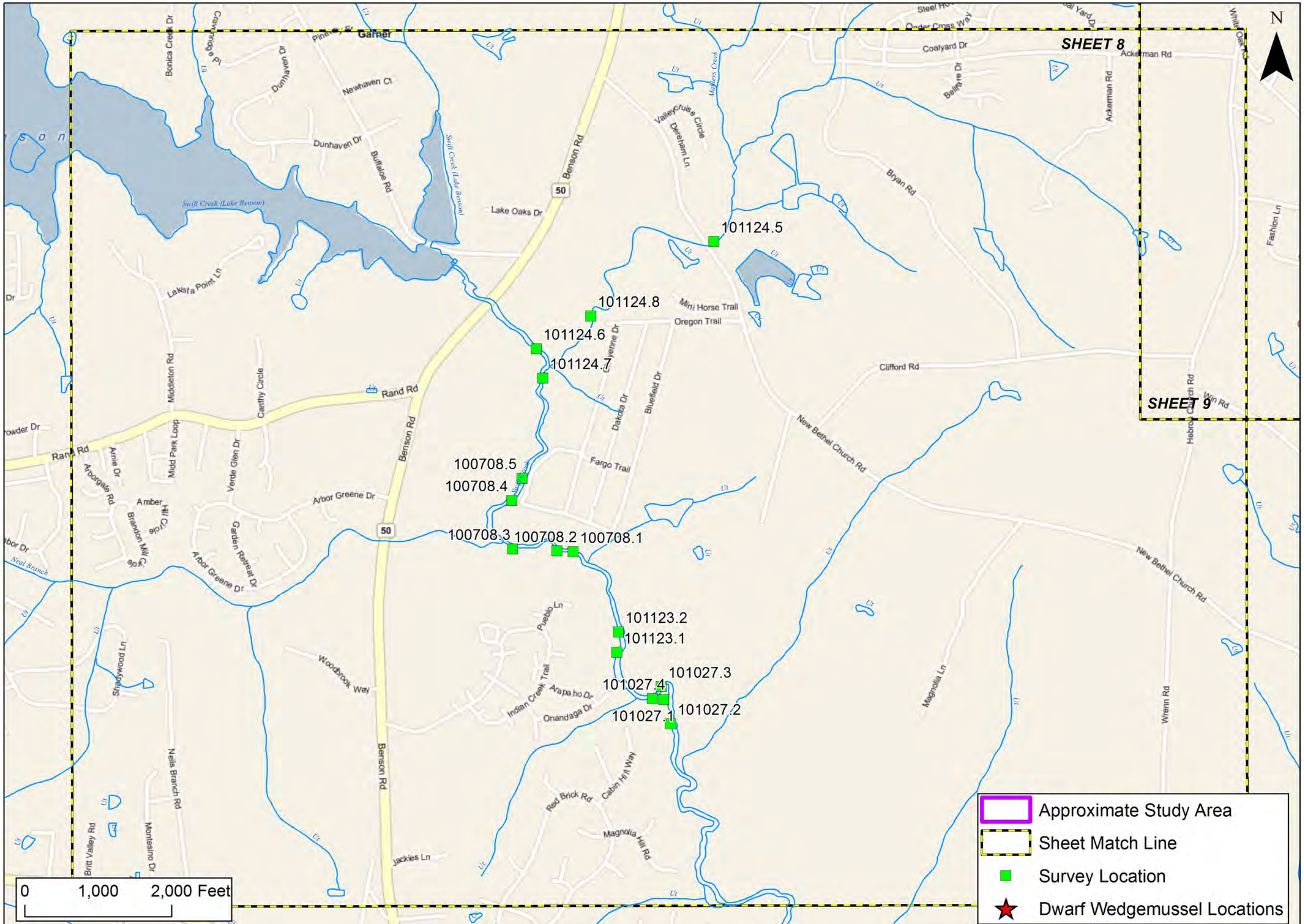
Freshwater Mussel Surveys

Wake and Johnston Counties, North Carolina

Client:

North Carolina Turnpike Authority

Figure 2
Sheet 7



The Catena Group

Date: March 2011

Scale: As Shown

Job No.: 3271

Title:
Triangle Expressway Southeast Extension

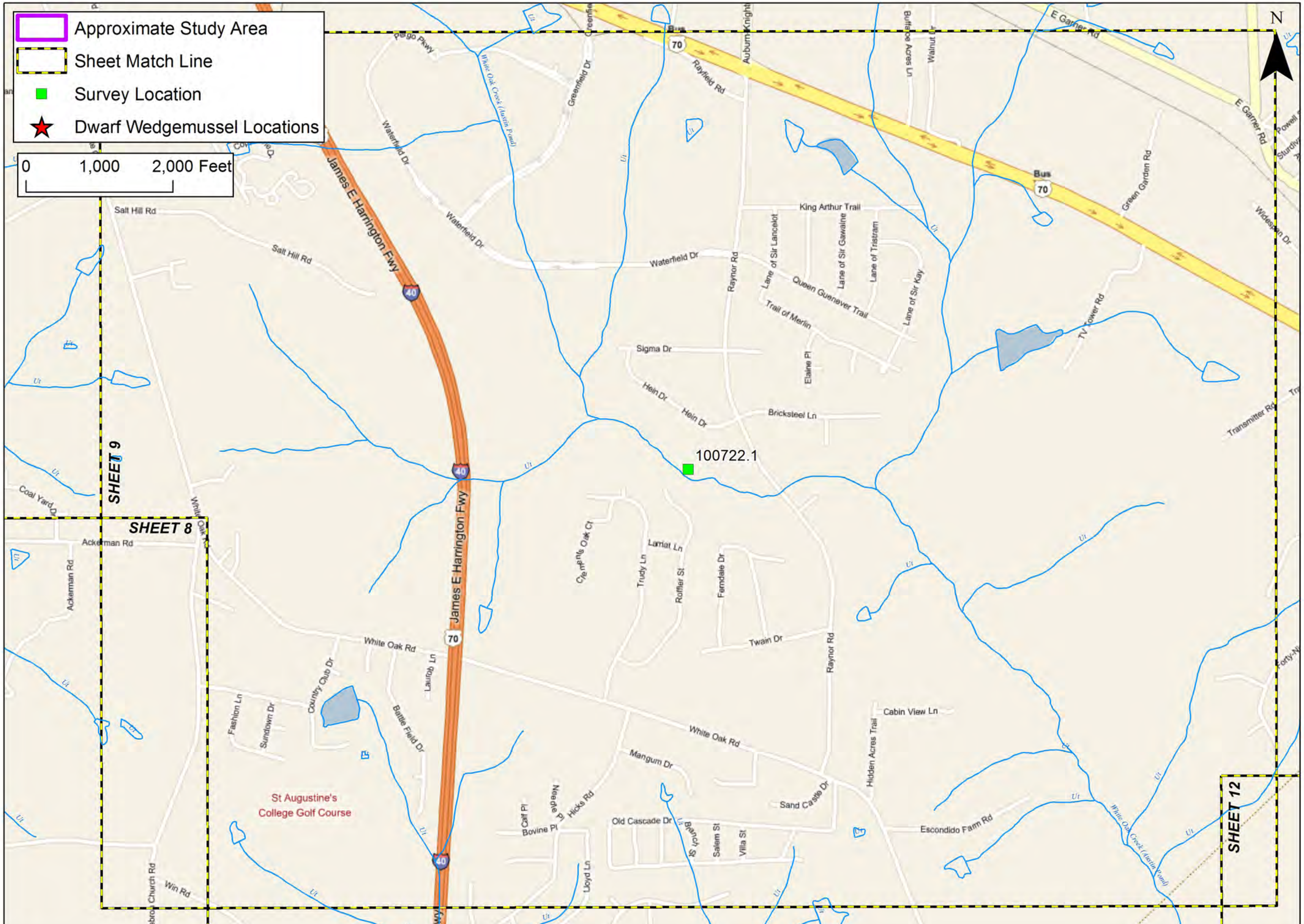
Freshwater Mussel Surveys

Wake and Johnston Counties, North Carolina

Client:

North Carolina Turnpike Authority

Figure
2
Sheet 8



The Catena Group

Date: March 2011

Scale: As Shown

Job No.: 3271

Title: **Triangle Expressway Southeast Extension**

Freshwater Mussel Surveys

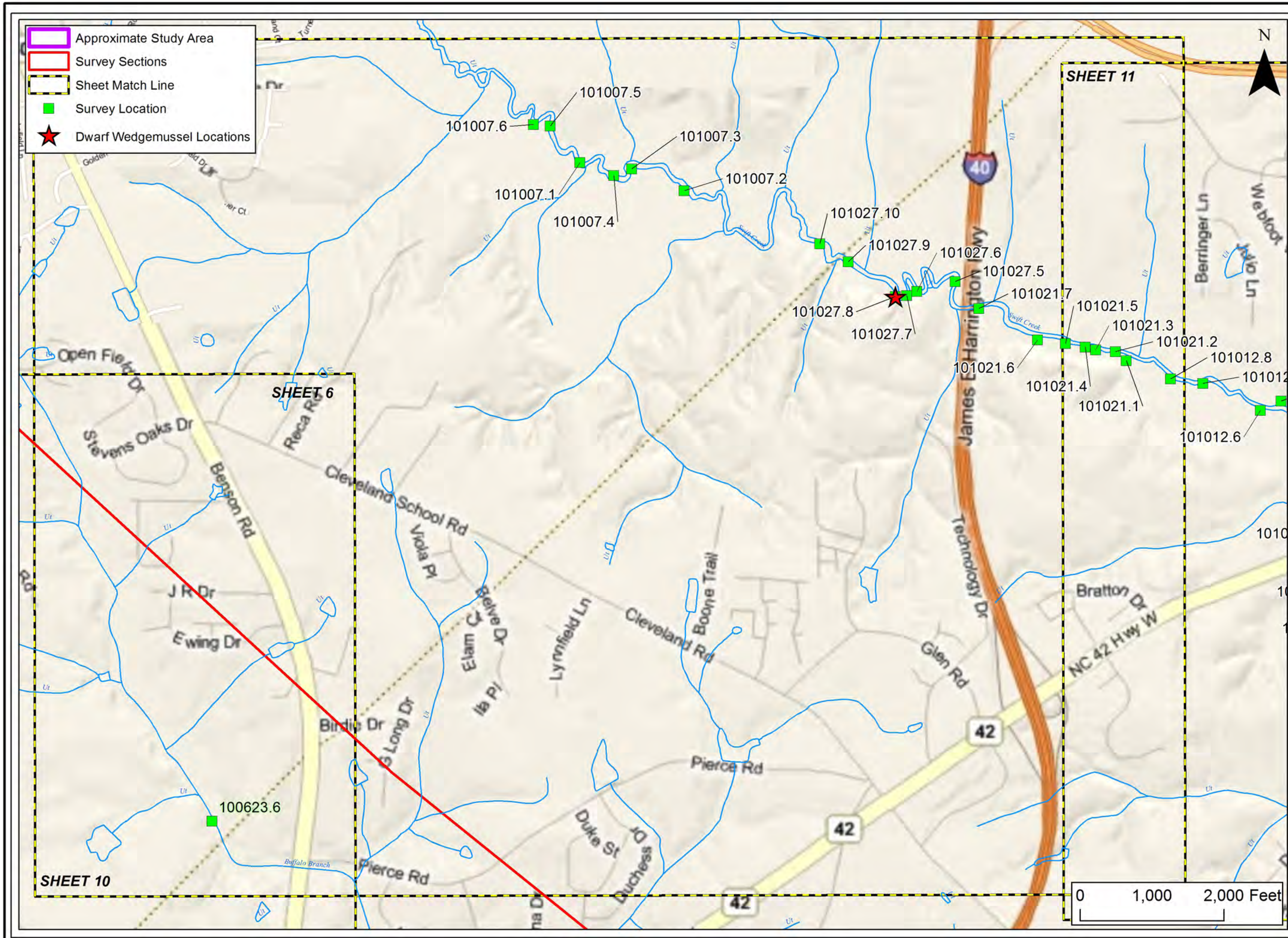
Wake and Johnston Counties, North Carolina

Client:

North Carolina Turnpike Authority

Figure **2**

Sheet 9



The Catena Group

Date: March 2011

Scale: As Shown

Job No.: 3271

Title:
Triangle Expressway Southeast Extension

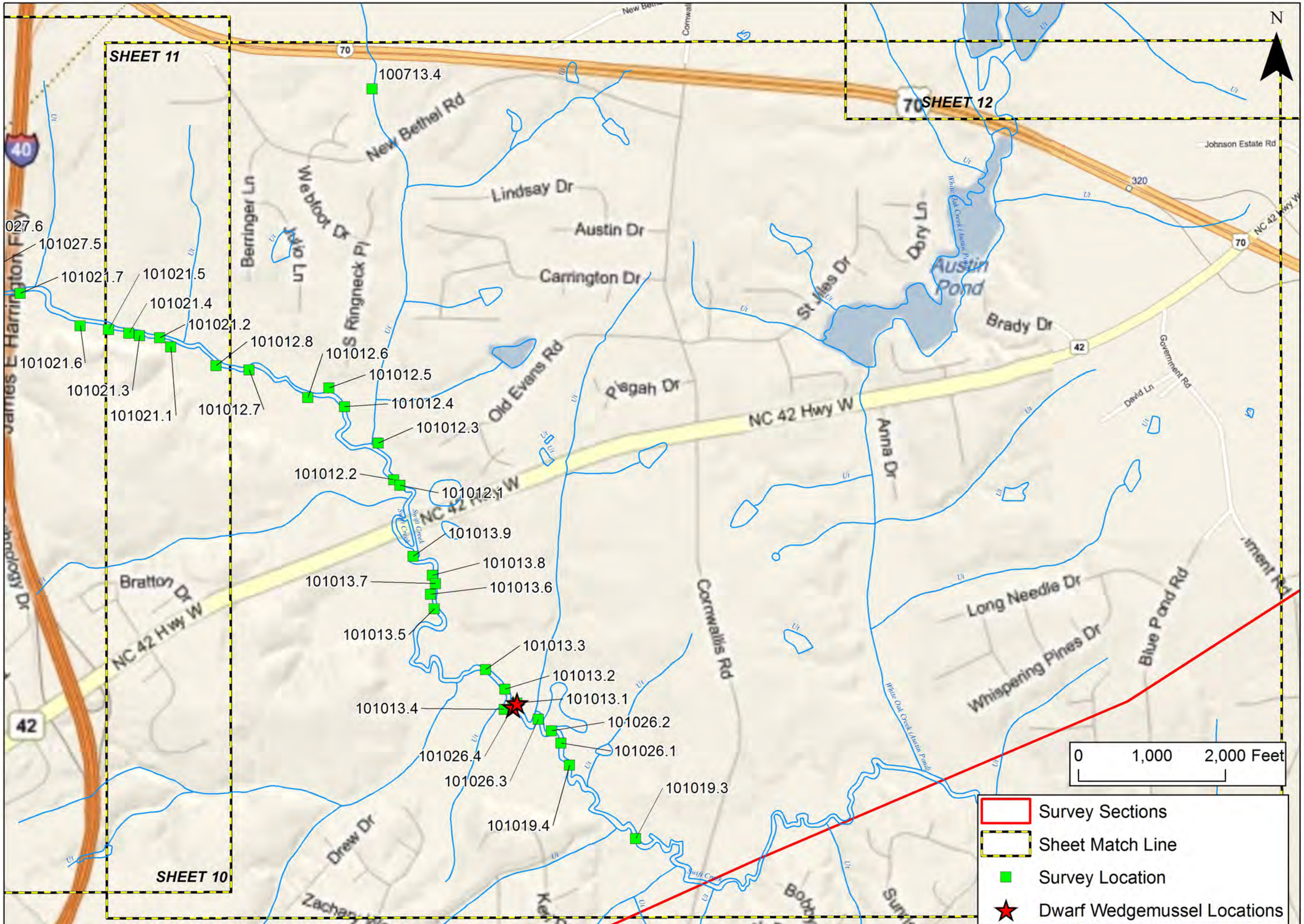
Freshwater Mussel Surveys

Wake and Johnston Counties, North Carolina

Client:

North Carolina Turnpike Authority

Figure
2
Sheet 10



The Catena Group

Date: March 2011

Scale: As Shown

Job No.: 3271

Title:

Triangle Expressway Southeast Extension

Freshwater Mussel Surveys

Wake and Johnston Counties, North Carolina

Client:

North Carolina Turnpike Authority

Figure 2

Sheet 11

The Catena Group

Date: March 2011

Scale: As Shown

Job No.: 3271

Title: **Triangle Expressway Southeast Extension**

Freshwater Mussel Surveys

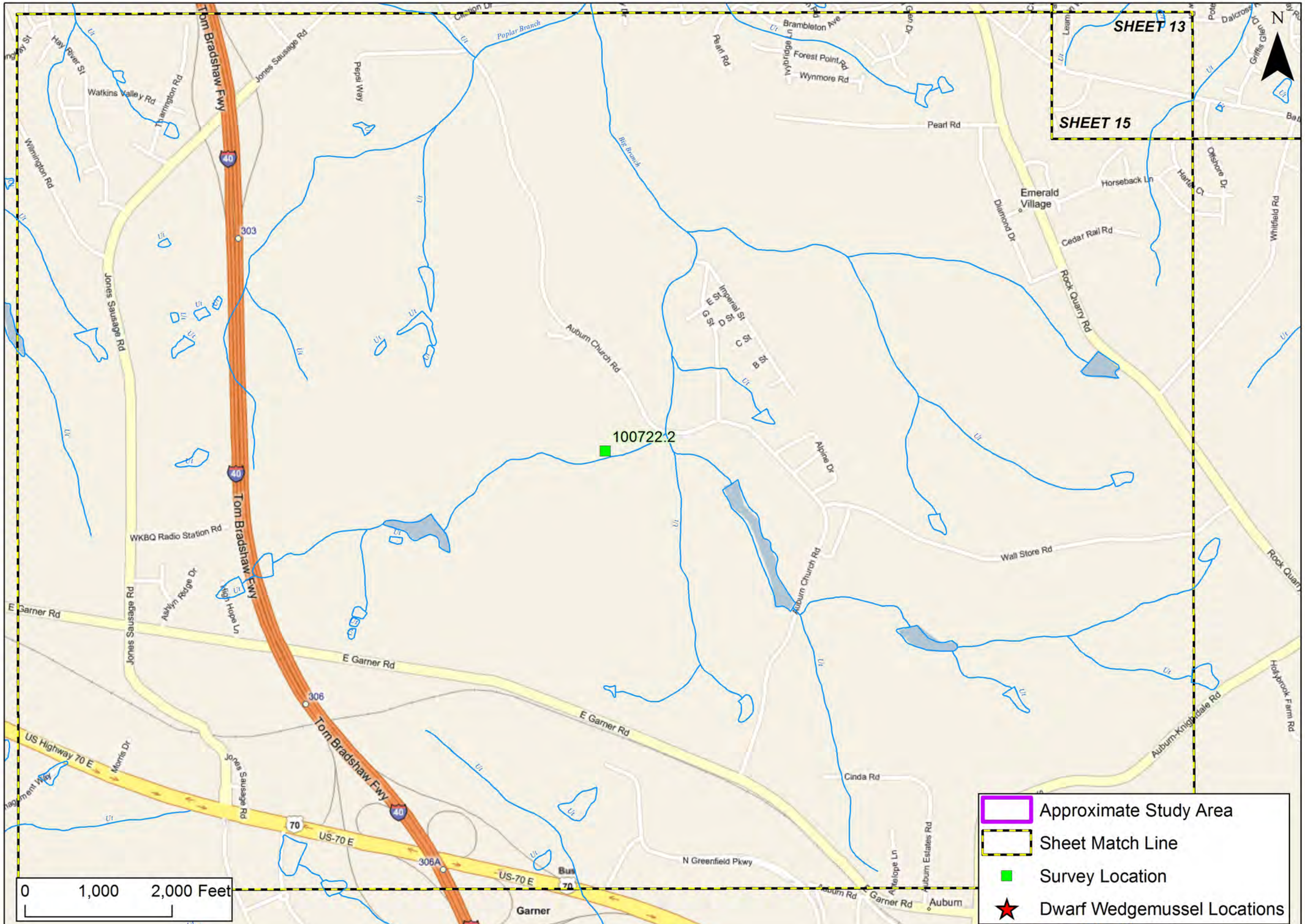
Wake and Johnston Counties, North Carolina

Client:

North Carolina Turnpike Authority

Figure 2

Sheet 12



The Catena Group

Date: March 2011

Scale: As Shown

Job No.: 3271

Title:
Triangle Expressway Southeast Extension

Freshwater Mussel Surveys

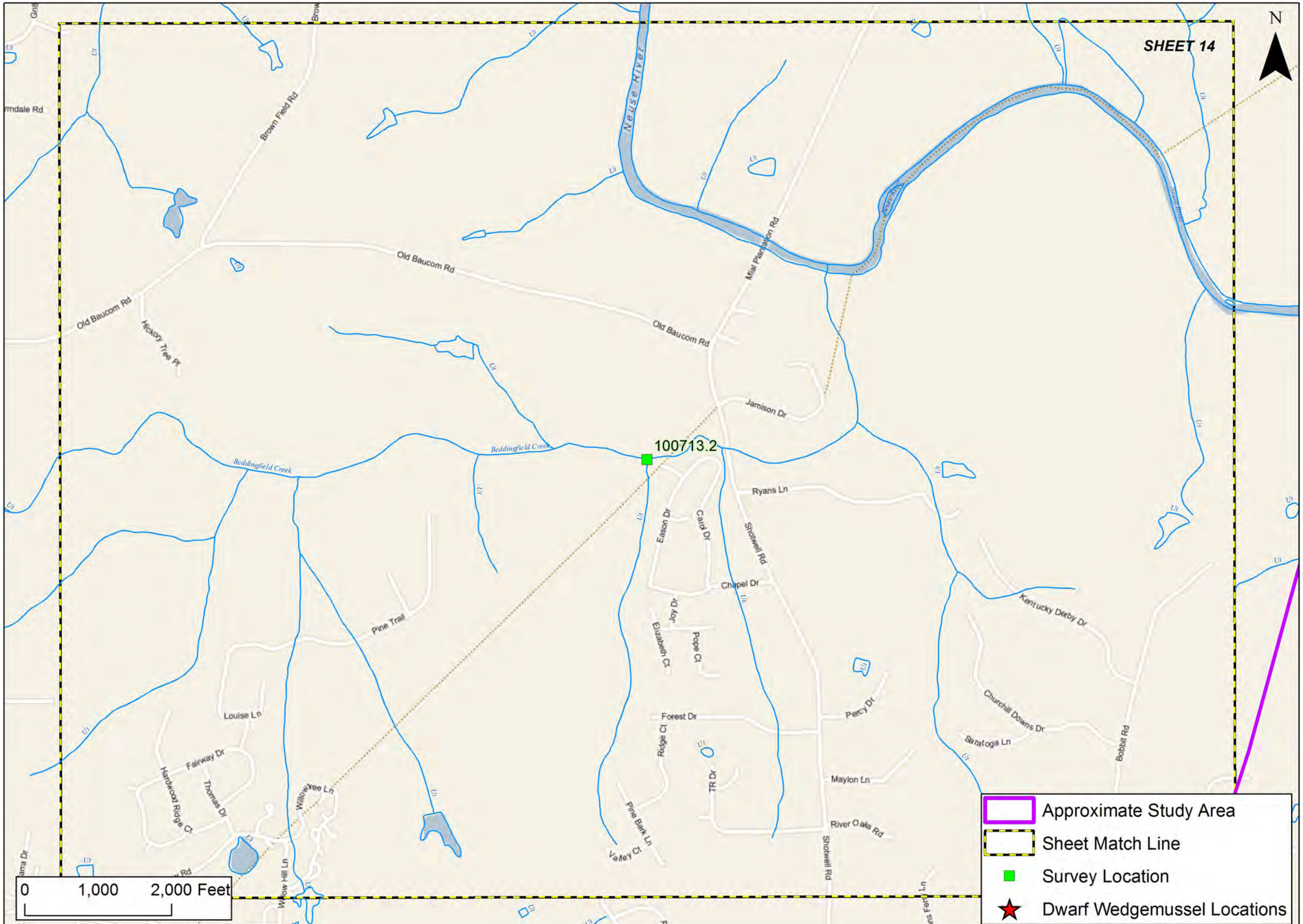
Wake and Johnston Counties, North Carolina

Client:

North Carolina Turnpike Authority

Figure 2

Sheet 13



The Catena Group

Date: March 2011

Scale: As Shown

Job No.: 3271

Title:
Triangle Expressway Southeast Extension

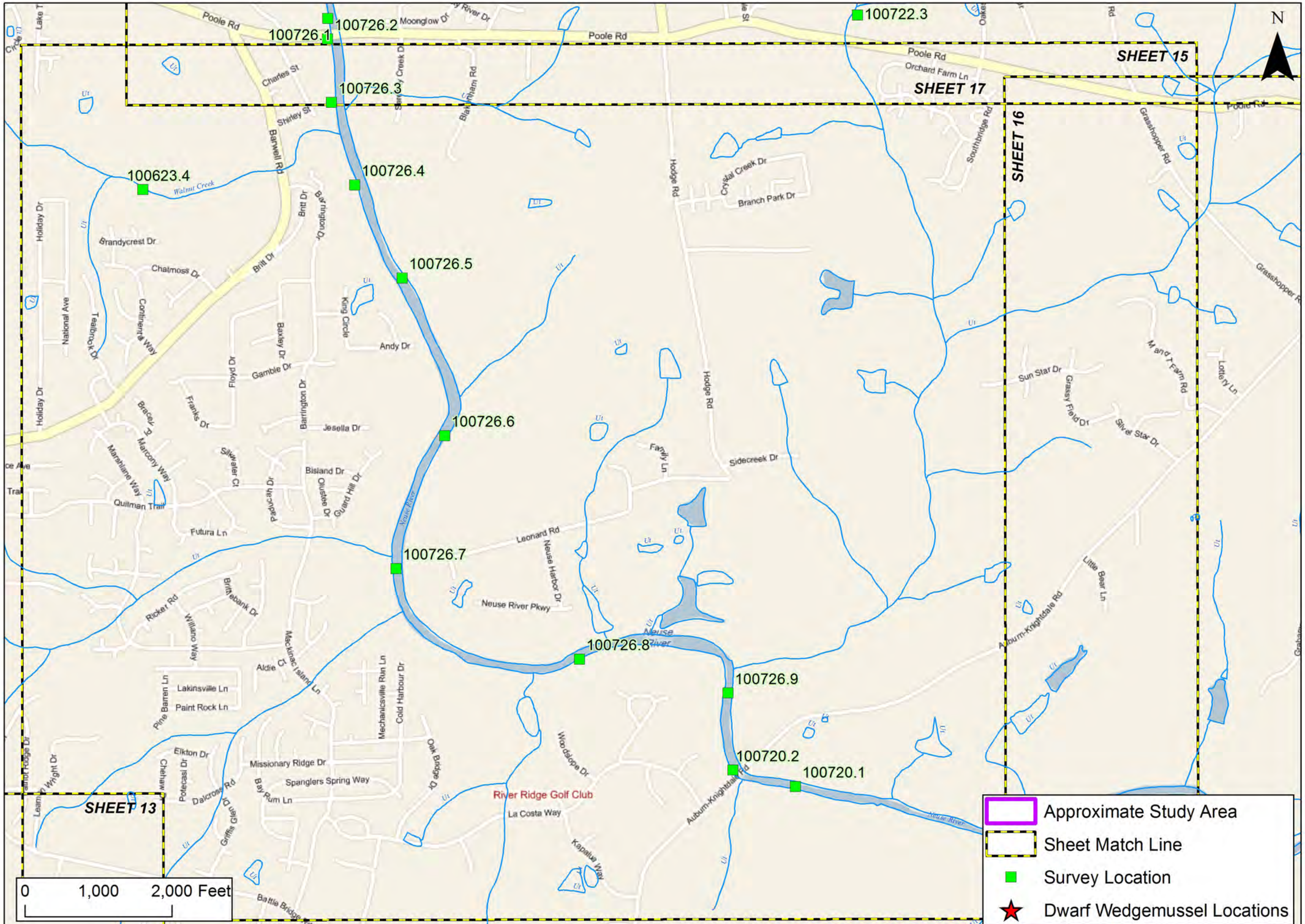
Freshwater Mussel Surveys

Wake and Johnston Counties, North Carolina

Client:

North Carolina Turnpike Authority

Figure
2
Sheet 14



Approximate Study Area

Sheet Match Line

Survey Location

Dwarf Wedgemussel Locations

The Catena Group

Date: March 2011

Scale: As Shown

Job No.: 3271

Title: **Triangle Expressway Southeast Extension**

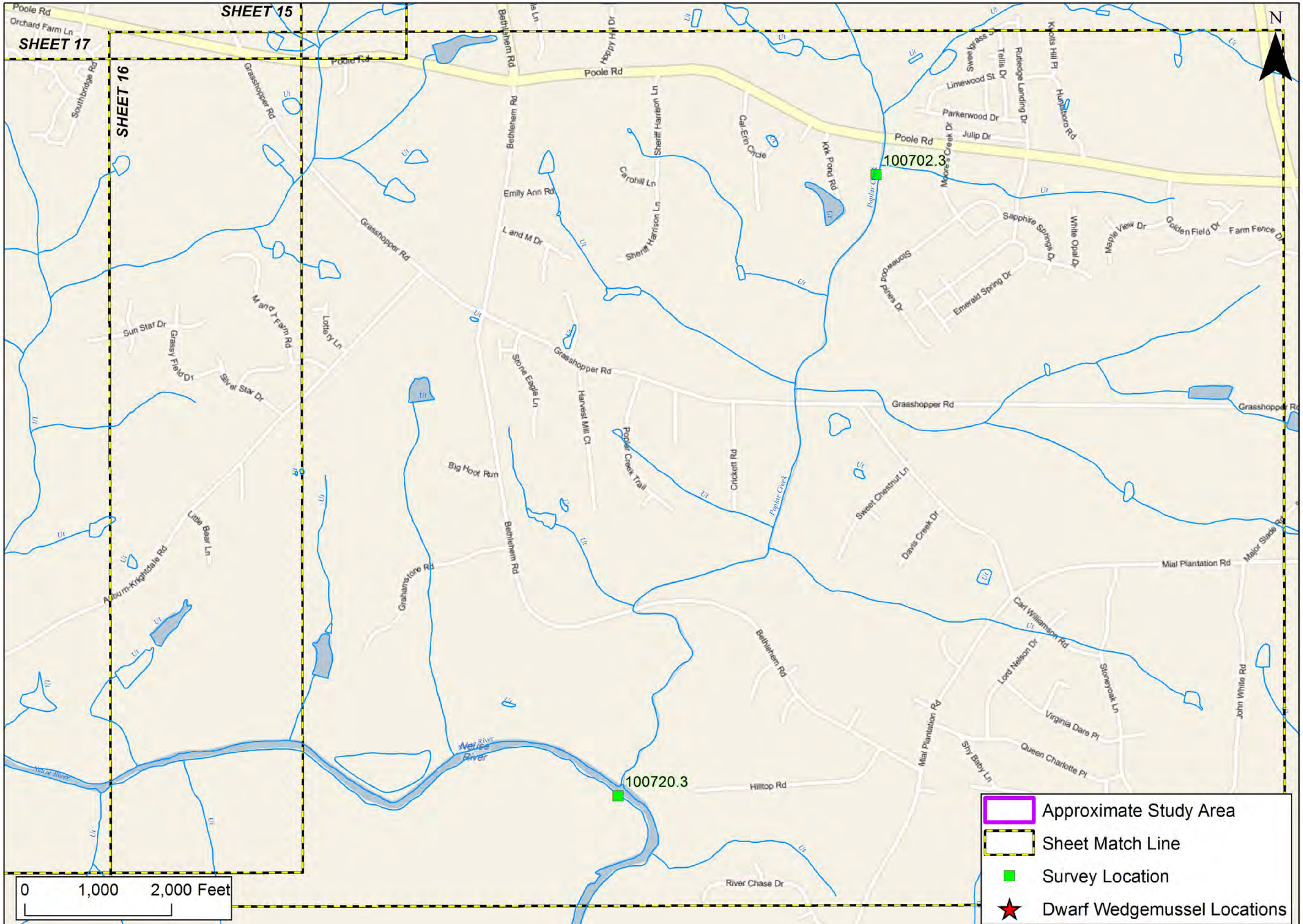
Freshwater Mussel Surveys

Wake and Johnston Counties, North Carolina

Client: North Carolina Turnpike Authority

Figure 2

Sheet 15



The Catena Group

Date: March 2011

Scale: As Shown

Job No.: 3271

Title: **Triangle Expressway Southeast Extension**

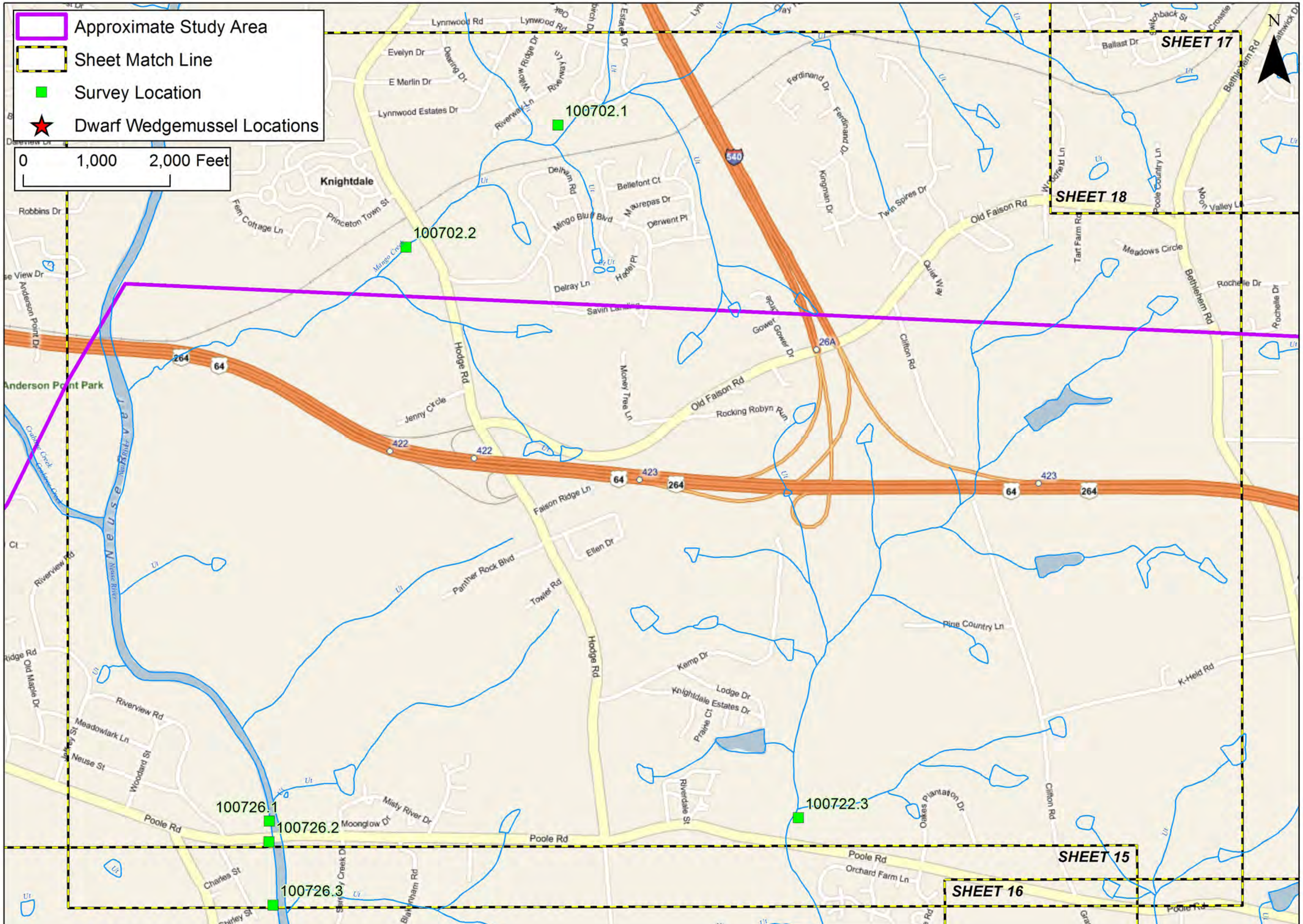
Freshwater Mussel Surveys

Wake and Johnston Counties, North Carolina

Client: North Carolina Turnpike Authority

Figure 2

Sheet 16



The Catena Group

Date: March 2011

Scale: As Shown

Job No.: 3271

Title:
Triangle Expressway Southeast Extension

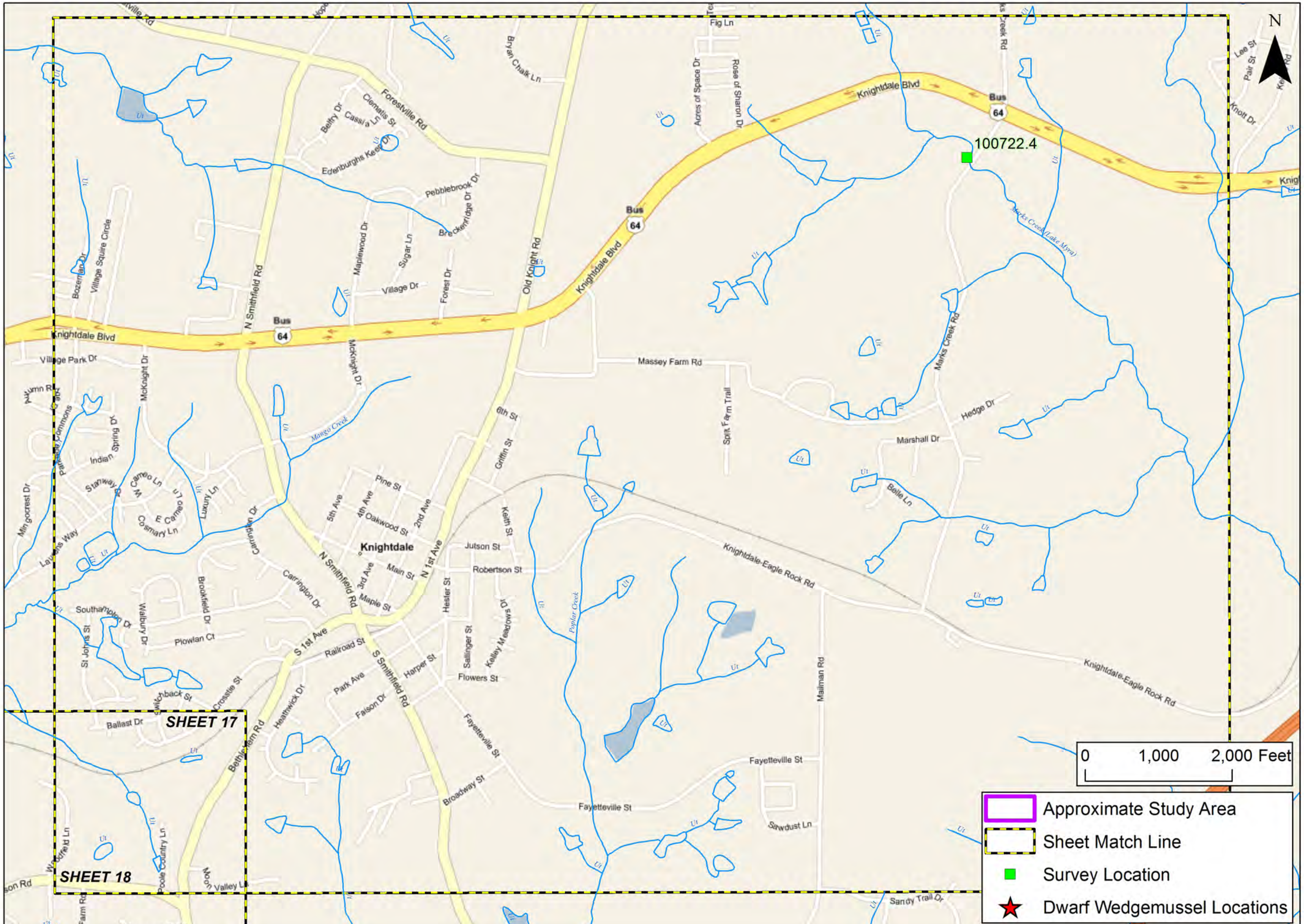
Freshwater Mussel Surveys

Wake and Johnston Counties, North Carolina

Client:

North Carolina Turnpike Authority

Figure
2
Sheet 17



The Catena Group

Date: March 2011

Scale: As Shown

Job No.: 3271

Title:
Triangle Expressway Southeast Extension

Freshwater Mussel Surveys

Wake and Johnston Counties, North Carolina

Client:

North Carolina Turnpike Authority

Figure
2
Sheet 18

APPENDIX B

DEFINITIONS OF FEDERAL AND STATE LISTING CATEGORIES
(FROM LEGRAND ET AL. 2010)

United States Status. This status is designated by the U.S. Fish and Wildlife Service. Federally listed Endangered and Threatened species are protected under the provisions of the Endangered Species Act of 1973, as amended through the 100th Congress. Unless otherwise noted, definitions are taken from the Federal Register, Vol. 56, No. 225, November 21, 1991 (50 CFR Part 17).

STATUS CODE	STATUS	STATUS DEFINITION
E	Endangered	A taxon "which is in danger of extinction throughout all or a significant portion of its range" (Endangered Species Act, Section 3).
T	Threatened	A taxon "which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range" (Endangered Species Act, Section 3).
FSC	(Federal) Species of Concern [also known as Species at Risk]	"... the Service is discontinuing the designation of Category 2 species as candidates in this notice. The Service remains concerned about these species, but further biological research and field study are needed to resolve the conservation status of these taxa. Many species of concern will be found not to warrant listing, either because they are not threatened or endangered or because they do not qualify as species under the definition in the [Endangered Species] Act. Others may be found to be in greater danger of extinction than some present candidate taxa. The Service is working with the States and other private and public interests to assess their need for protection under the Act. Such species are the pool from which future candidates for listing will be drawn." (Federal Register, February 28, 1996). The Service suggests that such taxa be considered as "Species of Concern" or "Species at Risk", neither of which has official status. The N.C. Natural Heritage Program uses "(Federal) Species of Concern" in this document for those taxa formerly considered as Category 2.
P	Proposed	Species proposed in the Federal Register as a status different from its current Federal status.

STATUS CODE	STATUS	STATUS DEFINITION
T (S/A)	Threatened due to Similarity of Appearance	"Section 4 (e) of the [Endangered Species] Act authorizes the treatment of a species (subspecies or population segment) as endangered or threatened even though it is not otherwise listed as endangered or threatened if -- (a) the species so closely resembles in appearance an endangered or threatened species that enforcement personnel would have substantial difficulty in differentiating between the listed and unlisted species; (b) the effect of this substantial difficulty is an additional threat to an endangered or threatened species; and (c) such treatment of an unlisted species will substantially facilitate the enforcement and further the policy of the Act." (Federal Register, November 4, 1997). [The American Alligator is listed as T (S/A) due to Similarity of Appearance with other rare crocodilians, and the southern population of the Bog Turtle is listed as T (S/A) due to Similarity of Appearance with the northern population of the Bog Turtle (which is federally listed as Threatened and which does not occur in North Carolina).]
XN	Nonessential Experimental Population	"Section 10 (j) of the Endangered Species Act of 1973, as amended, provides for the designation of introduced populations of federally listed species as nonessential experimental. This designation allows for greater flexibility in the management of these populations by local, state, and Federal agencies. Specifically, the requirement for Federal agencies to avoid jeopardizing these populations by their actions is eliminated and allowances for taking the species are broadened." (U.S. Fish and Wildlife Service, 1995).
D	De-listed	Species has been proposed by the U.S. Fish and Wildlife Service for de-listing from the List of Endangered and Threatened Wildlife. However, at the present time, the species is still on the List of Endangered and Threatened Wildlife and is thus protected under the Endangered Species Act. Because such species still have legal Federal protection, the NHP will maintain existing records on the species, though new records might not necessarily be added. If the status becomes law prior to the next publication of the NHP Rare Animal List, the Program will remove the Federal designation from its database (and thus the species will no longer appear on printouts of Federally listed species). NHP may or may not continue to track the species, depending on its legal State status and other factors such as overall abundance and range in the state.

North Carolina Status. Endangered, Threatened, and Special Concern species of mammals, birds, reptiles, amphibians, freshwater fishes, freshwater and terrestrial mollusks, and crustaceans have legal protection status in North Carolina (Wildlife Resources Commission). In addition to the above categories, the Natural Heritage Program maintains computer and map files on Significantly Rare species, as well as species considered Extirpated. Paper files only are maintained for a few of the above species; these species are indicated by the phrase "not tracking."

STATUS CODE	STATUS	STATUS DEFINITION
E	Endangered	"Any native or once-native species of wild animal whose continued existence as a viable component of the State's fauna is determined by the Wildlife Resources Commission to be in jeopardy or any species of wild animal determined to be an 'endangered species' pursuant to the Endangered Species Act." (Article 25 of Chapter 113 of the General Statutes; 1987).
T	Threatened	"Any native or once-native species of wild animal which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range, or one that is designated as a threatened species pursuant to the Endangered Species Act." (Article 25 of Chapter 113 of the General Statutes; 1987).
SC	Special Concern	"Any species of wild animal native or once-native to North Carolina which is determined by the Wildlife Resources Commission to require monitoring but which may be taken under regulations adopted under the provisions of this Article." (Article 25 of Chapter 113 of the General Statutes; 1987).
P	Proposed	Species has been proposed by a Scientific Council as a status (Endangered, Threatened, Special Concern, Watch List, or for Delisting) that is different from the current status, but the status has not yet been adopted by the General Assembly as law. In the lists of rare species in this book, these proposed statuses are listed in parentheses below the current status. Only those proposed statuses that are different from the current statuses are listed.

STATUS CODE	STATUS	STATUS DEFINITION
SR	Significantly Rare	Any species which has not been listed by the N.C. Wildlife Resources Commission as an Endangered, Threatened, or Special Concern species, but which exists in the state in small numbers and has been determined by the N.C. Natural Heritage Program to need monitoring. (This is a N.C. Natural Heritage Program designation.) Significantly Rare species include "peripheral" species, whereby North Carolina lies at the periphery of the species' range (such as Hermit Thrush).
EX	Extirpated	A species which is no longer believed to occur in the state. (This is a N.C. Natural Heritage Program designation, though WRC also uses this status; the NHP list includes those on the WRC list.)
W	Watch List	Any other species believed to be of conservation concern in the state because of scarcity, declining populations, threats to populations, or inadequacy of information to assess its rarity (see page 59 for a more complete discussion). (This is a N.C. Natural Heritage Program designation.)
G		Species is a game animal, and therefore (by law) cannot be listed for State protection as E, T, or SC.

Environmental Baseline Additional Studies: Freshwater Mussel Surveys Targeting Dwarf Wedgemussel

Triangle Expressway Southeast Extension
(TIP No R-2721/R-2828/R-2829)

Wake and Johnston Counties, North Carolina

Prepared for:

H.W. Lochner, Inc.
2840 Plaza Place, Suite 202
Raleigh, NC 27612

Prepared by:

The Catena Group

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

February 8, 2012

EXECUTIVE SUMMARY

The freshwater mussel fauna within the project study corridor for the proposed Triangle Expressway Southeast Extension project (TIP #s R-2721, R-2828, R-2829) was evaluated in selected portions of perennial water bodies in 2010 by The Catena Group Inc. (Catena) to establish a planning level baseline status of the freshwater mussel resources, with particular emphasis on the federally protected Dwarf Wedgemussel (DWM) and Tar River Spinymussel (TSM), and other mussel species (Atlantic Pigtoe, Green Floater and Yellow Lance) with assigned conservation statuses in North Carolina of Endangered. The results of this comprehensive mussel survey effort, which documented the continued presence of the DWM in Swift Creek within the study corridor, were detailed in the final report submitted to Lochner on March 09, 2011.

The US Fish and Wildlife Service (USFWS) requested the North Carolina Turnpike Authority (NCTA) to provide an updated Environmental Baseline on the DWM population in Swift Creek in order to determine if the proposed action has the potential to jeopardize the continued existence of this species. The USFWS proposed a three-tiered study be implemented by the NCTA to develop this updated Environmental Baseline:

1. Provide an accounting (compliance/ implementation) of conservation measures that have been implemented in Swift Creek to protect the DWM
2. Assess the effectiveness of existing conservation measures and environmental protections in Swift Creek with regard to habitat and population stability
3. Assess historic trends, and current viability of the DWM population and its habitat in Swift Creek

Due to life history attributes of the DWM, gathering data to complete the population viability component of the third tier of this study is time sensitive, and it was determined that it would be prudent to gather baseline data quickly in order to maintain the current scheduling timeline for this project. As such, the population viability component of the third tier of this study (an assessment of historic trends, and current viability of the DWM population in Swift Creek) was implemented, the results of which are presented in this report.

As part of this analysis, a total of 85 separate sites were surveyed in 2011, encompassing 32 target sites with previously documented DWM, with 16 freshwater mussel species, as well as one freshwater clam species and three aquatic snail species found. DWM was located in low numbers at only three survey sites (3.53%), although appropriate habitat and the presence of rare associate species at many sites suggest its continued potential occupation at additional sites in the study area. The targeted Atlantic Pigtoe and Yellow Lance were found at 34 sites (40.0%), and 7 sites (8.24%), respectively. No TSM, Green Floater, or Yellow Lampmussel were found within the study area during the 2011 effort.

Preliminary analysis on mussel population trends within Swift Creek overtime indicate a decrease in relative abundances of the Elliptio fauna and the Atlantic Pigtoe, while an expansion in range and an increase in relative abundance was indicated for the Eastern Floater, a species that is considered tolerant of habitat modification and pollution. Further study and analysis of existing data, as well as incorporation of tiers 1 and 2, are needed to fully assess the continued viability of DWM and other freshwater mussel species in Swift Creek.

TABLE OF CONTENTS

1.0 INTRODUCTION 1
2.0 POPULATION VIABILITY STUDY EFFORTS 2
2.1 Mussel Survey Methodology 3
2.2 Mussel Survey Results 5
2.2.1 Section 1 Upper Swift Creek 6
2.2.2 Section 2 Middle Swift Creek 10
2.2.3 Section 3 Lower Swift Creek 30
2.3 White Oak Creek 34
2.4 Little Creek 36
2.5 Middle Creek 39
3.0 MUSSEL SPECIES DESCRIPTIONS 47
3.1 Federally Protected Species 47
3.1.1 Alasmidonta heterodon (Dwarf Wedgemussel) 47
3.1.1.1 Characteristics 47
3.1.1.2 Distribution and Habitat Requirements 48
3.1.1.3 Threats to Species 49
3.1.2 Elliptio steinstansana (Tar River Spinymussel) 50
3.1.2.1 Characteristics 50
3.1.2.2 Distribution and Habitat Requirements 50
3.1.2.3 Threats to Species 51
3.2 Target Federal Species of Concern (FSC) 51
3.2.1 Elliptio lanceolata (Yellow Lance) 51
3.2.1.1 Characteristics 51
3.2.1.2 Distribution and Habitat Requirements 51
3.2.1.3 Threats to Species 51
3.2.2 Fusconaia masoni (Atlantic Pigtoe) 52
3.2.2.1 Characteristics 52
3.2.2.2 Distribution and Habitat Requirements 52
3.2.2.3 Threats to Species 52
3.2.3 Lasmigona subviridis (Green Floater) 52
3.2.3.1 Characteristics 52
3.2.3.2 Distribution and Habitat Requirements 52
3.2.3.3 Threats to Species 53
3.2.4 Lampsilis cariosa (Yellow Lampmussel) 53
3.2.4.1 Characteristics 53
3.2.4.2 Distribution and Habitat Requirements 53
3.2.4.3 Threats to Species 53
3.3 Other Mussel Species Located During the 2011 Surveys 54
3.3.1 Alasmidonta undulata (Triangle Floater) 54
3.3.2 Elliptio complanata (Eastern Elliptio) 54
3.3.3 Elliptio congaraea (Carolina Slabshell) 54
3.3.4 Elliptio fisheriana (Northern Lance) 54
3.3.5 Elliptio icterina (Variable Spike) 55
3.3.6 Elliptio producta (Atlantic Spike) 55
3.3.7 Elliptio roanokensis (Roanoke Slabshell) 55
3.3.8 Elliptio sp. c.f. mediocris (No Common Name) 55
3.3.9 Lampsilis radiata (Eastern Lampmussel) 56
3.3.10 Pyganodon cataracta (Eastern Floater) 57
3.3.11 Strophitus undulatus (Creeper) 57

3.3.12 Utterbackia imbecillis (Paper Pondshell) ... 57
3.3.13 Villosa constricta (Notched Rainbow) ... 57
4.0 SURVEY DISCUSSION 2011 ... 58
4.1 Section 1 Upper Swift Creek ... 58
4.2 Section 2 Middle Swift Creek ... 58
4.3 Section 3 Lower Swift Creek ... 58
4.4 White Oak Creek ... 59
4.5 Little Creek ... 59
4.6 Middle Creek ... 59
5.0 DWM POPULATION VIABILITY ANALYSIS ... 59
5.1 Viability Measures of DWM Population ... 59
5.1.1 Length of occupied habitat criterion ... 60
5.1.2 Occur at 75% of sites within occupied habitat criterion ... 62
5.1.3 CPUE of $\geq$ 5 individuals per hour at 50% of sites criterion ... 62
5.1.4 Evidence of recent reproduction criterion ... 62
5.2 Swift Creek Mussel Population Trend Analysis ... 63
5.2.1 Relative Abundance Trends ... 63
5.2.1.1 Atlantic Pigtoe ... 64
5.2.1.2 Elliptio Species ... 64
5.2.1.3 Eastern Floater ... 65
5.2.1.4 Paper Pondshell ... 66
5.2.2 Age Class Distribution ... 66
6.0 CONCLUSIONS ... 66
7.0 LITERATURE CITED ... 67

Appendix A ... 72

LIST OF CHARTS AND FIGURES

Figure 1 ... 61
Chart 1. CPUE of Atlantic Pigtoe ... 64
Chart 2. CPUE of Elliptio Species ... 65
Chart 3. CPUE of Eastern Floater ... 65
Chart 4. CPUE of Paper Pondshell ... 66

LIST OF TABLES

Table 1. Rare Aquatic Species Neuse River Basin in Wake/Johnston Counties ... 2
Table 2. Dwarf Wedgemussel Locations in Swift Creek Subbasin 1991-2010 ... 3
Table 3. Study Corridor: Mollusk Species Found 2011 ... 5
Table 4. Swift Creek Site- 110509.1ted (Additional): Mollusk Species Found ... 6
Table 5. Swift Creek Site- 110509.2ted (980602.7jaj): Mollusk Species Found ... 7
Table 6. Swift Creek Site- 110509.3ted (980602.4jaj): Mollusk Species Found ... 7
Table 7. Swift Creek Site- 110509.4ted (960520.7jma): Mollusk Species Found ... 8
Table 8. Swift Creek Site- 110509.5ted (070810.2tws): Mollusk Species Found ... 8
Table 9. Swift Creek Site- 110607.1ted (Additional): Mollusk Species Found ... 9
Table 10. Swift Creek Site- 110607.2ted (070830.2ted): Mollusk Species Found ... 9
Table 11. Swift Creek Site- 110607.3ted (101027.8ted and 920914.1jma): Mollusk Species Found ... 10
Table 12. Swift Creek Site- 110607.4ted (Additional): Mollusk Species Found ... 10
Table 13. Swift Creek Site- 110407.1Catena (101026.4tcg): Mollusk Species Found ... 11
Table 14. Swift Creek Site- 110407.2Catena (Additional): Mollusk Species Found ... 11
Table 15. Swift Creek Site- 110407.3Catena (Additional): Mollusk Species Found ... 12

Table 16. Swift Creek Site- 110407.4Catena (101013.1tcg): Mollusk Species Found 12
Table 17. Swift Creek Site- 110407.5Catena (070829.5tws): Mollusk Species Found 13
Table 18. Swift Creek Site- 110407.6Catena (Additional): Mollusk Species Found 13
Table 19. Swift Creek Site- 110426.1tws (Additional): Mollusk Species Found 14
Table 20. Swift Creek Site- 110426.2tws (Additional): Mollusk Species Found 14
Table 21. Swift Creek Site- 110426.1ted (940901.0jma): Mollusk Species Found 15
Table 22. Swift Creek Site- 110426.2ted (Additional): Mollusk Species Found 15
Table 23. Swift Creek Site- 110426.3ted (101109.4tcg): Mollusk Species Found 16
Table 24. Swift Creek Site- 110426.4ted (Additional): Mollusk Species Found 16
Table 25. Swift Creek Site- 110426.5ted (920319.2jma): Mollusk Species Found 17
Table 26. Swift Creek Site- 110427.1ted (031105.4tws): Mollusk Species Found 17
Table 27. Swift Creek Site- 110427.2ted (960521.3jma): Mollusk Species Found 18
Table 28. Swift Creek Site- 110427.3ted (Additional): Mollusk Species Found 18
Table 29. Swift Creek Site- 110427.4ted (971013.1jaj and 970729.3jaj): Mollusk Species Found 19
Table 30. Swift Creek Site- 110427.5ted (970729.2jaj; 981124.1jaj; 070830.4tws): Mollusk Species Found 19
Table 31. Swift Creek Site- 110427.6ted (960521.1jma): Mollusk Species Found 20
Table 32. Swift Creek Site- 110510.5ted (910411.1jma): Mollusk Species Found 20
Table 33. Swift Creek Site- 110513.1tws (970728.4jaj): Mollusk SpeciesFound 21
Table 34. Swift Creek Site- 110513.2tws (Additional): Mollusk Species Found 21
Table 35. Swift Creek Site- 110513.3tws (Additional): Mollusk Species Found 22
Table 36. Swift Creek Site- 110513.4tws (Additional): Mollusk Species Found 22
Table 37. Swift Creek Site- 110615.3Catena (Flowers 1992.22): Mollusk Species Found 23
Table 38. Swift Creek Site- 110615.4Catena (Additional): Mollusk Species Found 23
Table 39. Swift Creek Site- 110615.5Catena (Additional) Mollusk Species Found 24
Table 40. Swift Creek Site- 110615.6Catena (Additional) Mollusk Species Found 24
Table 41. Swift Creek Site- 110615.7Catena (Additional) Mollusk Species Found 25
Table 42. Swift Creek Site- 110621.1tws (Additional) Mollusk Species Found 25
Table 43. Swift Creek Site- 110621.1Catena (Additional) Mollusk Species Found 26
Table 44. Swift Creek Site- 110621.2Catena (Additional) Mollusk Species Found 26
Table 45. Swift Creek Site- 110621.3Catena (Flowers 1992.23) Mollusk Species Found 27
Table 46. Swift Creek Site- 110621.4Catena (Additional) Mollusk Species Found 27
Table 47. Swift Creek Site- 110628.1Catena (Additional) Mollusk Species Found 28
Table 48. Swift Creek Site- 110628.2Catena (Additional) Mollusk Species Found 28
Table 49. Swift Creek Site- 110628.3Catena (Additional) Mollusk Species Found 29
Table 50. Swift Creek Site- 110628.4Catena (Additional) Mollusk Species Found 29
Table 51. Swift Creek Site- 110628.5Catena (Additional) Mollusk Species Found 30
Table 52. Swift Creek Site- 110427.1tws (Additional): Mollusk Species Found 30
Table 53. Swift Creek Site- 110427.2tws (Additional): Mollusk Species Found 31
Table 54. Swift Creek Site- 110510.1ted (Additional): Mollusk Species Found 31
Table 55. Swift Creek Site- 110607.5tws (Additional): Mollusk Species Found 32
Table 56. Swift Creek Site- 110607.6tws (Additional): Mollusk Species Found 32
Table 57. Swift Creek Site- 110615.1Catena (910327.1jma): Mollusk Species Found 33
Table 58. Swift Creek Site- 110615.2Catena (Additional): Mollusk Species Found 33
Table 59. Swift Creek Site-110603.6tws (Additional): Mollusk Species Found 34
Table 60. White Oak Creek Site- 110420.1Catena (940915.7jma): Mollusk Species Found 34
Table 61. White Oak Creek Site- 110420.2Catena (940420.1jma): Mollusk Species Found 35
Table 62. White Oak Creek Site- 110420.3Catena (Additional): Mollusk SpeciesFound 35
Table 63. White Oak Creek Site- 110420.4Catena (Additional): Mollusk Species Found 36

Table 64. Little Creek Site- 110414.1ted (030724.5tws): Mollusk Species Found 36
Table 65. Little Creek Site- 110414.2ted (030724.6tws): Mollusk Species Found 37
Table 66. Little Creek Site- 110414.3ted (Additional): Mollusk Species Found 37
Table 67. Little Creek Site- 110426.3tws (Additional): Mollusk Species Found 37
Table 68. Little Creek Site- 110427.3tws (Additional): Mollusk Species Found 38
Table 69.Little Creek Site- 110510.2ted (Additional): Mollusk Species Found.. 38
Table 70. Little Creek Site- 110510.3ted (Additional): Mollusk Species Found 38
Table 71. Little Creek Site- 110510.4ted (Additional): Mollusk Species Found 39
Table 72. Middle Creek Site- 110526.1tws (Additional): Mollusk Species Found 39
Table 73. Middle Creek Site- 110526.2tws (Additional): Mollusk Species Found 40
Table 74. Middle Creek Site- 110526.3tws (Additional): Mollusk Species Found 40
Table 75. Middle Creek Site- 110603.1tws (Additional): Mollusk Species Found 41
Table 76. Middle Creek Site- 110603.2tws (Additional): Mollusk Species Found 41
Table 77. Middle Creek Site- 110603.3tws (Additional): Mollusk Species Found 42
Table 78. Middle Creek Site- 110603.4tws (Additional): Mollusk Species Found 42
Table 79. Middle Creek Site- 110603.5tws (Additional): Mollusk Species Found 43
Table 80. Middle Creek Site- 110607.1tws (Additional): Mollusk Species Found 43
Table 81. Middle Creek Site- 110607.2tws (Additional): Mollusk Species Found 44
Table 82. Middle Creek Site- 110607.3tws (Additional): Mollusk Species Found 44
Table 83. Middle Creek Site- 110607.4tws (Additional): Mollusk Species Found 45
Table 84. Middle Creek Site- 110609.1ted (920910.5jma): Mollusk Species Found 45
Table 85. Middle Creek Site- 110609.2ted (920518.1jma): Mollusk Species Found 46
Table 86. Middle Creek Site- 110609.3ted (Additional): Mollusk Species Found..................................... 46
Table 87. Middle Creek Site- 110609.4ted (Additional): Mollusk Species Found..................................... 47
Table 88. Middle Creek Site- 110621.5Catena (Additional) Mollusk Species Found................................ 47

1.0 INTRODUCTION

The North Carolina Turnpike Authority (NCTA) a division of the North Carolina Department of Transportation (NCDOT), proposes the construction of a new road corridor from NC-55 near Apex south and east to US-64/264 Bypass near Knightdale within Wake and Johnston Counties, referred to as the Triangle Expressway Southeast Extension. The project will impact streams within the Neuse River Basin.

Two freshwater mussel species federally designated and protected as Endangered under the Endangered Species Act of 1973, as amended, are known to occur within the Neuse River Basin in Wake and Johnston Counties, the Dwarf Wedgemussel (*Alasmidonta heterodon*, DWM) and the Tar River Spinymussel (*Elliptio steinstansana*, TSM). To assess the potential for these two species to occur within the project area, The Catena Group, Inc. (Catena) was retained by H.W. Lochner (Lochner), to gather updated mussel survey data for streams within the project corridor during the project preliminary planning phase to assist in selection of potential corridors and to initiate coordination with the agencies early in the process in an effort to avoid project delays.

The results of these updated, project specific surveys, which were conducted in 2010, were presented in a final report submitted to Lochner on March 09, 2011. These surveys documented the continued presence of the DWM in Swift Creek within the study corridor. These surveys did not document the presence of TSM in streams within the project corridor.

In addition, the state Endangered /Federal Species of Concern (FSC)[1] Atlantic Pigtoe (*Fusconaia masoni*), and Yellow Lance (*Elliptio lanceolata*) were also documented to be extant within the study corridor in Swift Creek, and the state Endangered/FSC Green Floater (*Lasmigona subviridis*) was found in the Neuse River. Additional rare species found during this study include Creeper (*Strophitus undulatus*), Eastern Lampmussel (*Lampsilis radiata*), Roanoke Slabshell (*Elliptio roanokensis*), and Triangle Floater (*Alasmidonta undulata*). The Creeper, Eastern Lampmussel, Roanoke Slabshell and Triangle Floater are considered threatened in North Carolina[2].

Three of the species found, Atlantic Pigtoe, Yellow Lance, and Green Floater, are being considered for elevation to candidate species status. As such, the USFWS has advised NCTA to gather as much information on these species as possible during this phase of project planning in the event that they become federally listed as Threatened or Endangered. Several other mussel species that are considered to be rare in North Carolina and have been assigned various

---

[1] **Federal Species of Concern (FSC)** is defined as a species that is under consideration for listing for which there is insufficient information to support listing. FSCs are not afforded federal protection under the Endangered Species Act and are not subject to any of its provisions, including Section 7, until they areformally proposed or listed as Threatened or Endangered. However, the status of these species is subject to change, and so should be included for consideration.

[2] **North Carolina Endangered, Threatened and Special Concern** species have legal protection status in North Carolina under the State Endangered Species Act administered and enforced by the North Carolina Wildlife Resources Commission. Species listed as Significantly Rare are not afforded any protection

conservation statuses are also known from this portion of the Neuse River Basin (Table 1).

Table 1. Rare Aquatic Species Neuse River Basin in Wake/Johnston Counties

Scientific Name	Common Name	Federal Status	NC Status
Alasmidonta heterodon	Dwarf Wedgemussel	E	E
Alasmidonta undulata	Triangle Floater	~	T
Elliptio congaraea	Carolina Slabshell	~	W3/W5
Elliptio lanceolata	Yellow Lance	FSC	E
Elliptio producta	Atlantic Spike	~	W3/W5
Elliptio roanokensis	Roanoke Slabshell	~	T
Fusconaia masoni	Atlantic Pigtoe	FSC	E
Lampsilis cariosa	Yellow Lampmussel	FSC	E
Lampsilis radiata	Eastern Lampmussel	~	T
Lasmigona subviridis	Green Floater	FSC	E
Strophitus undulatus	Creeper	~	T
Villosa constricta	Notched Rainbow	~	SC

See Appendix A for status designations

Since the federally endangered DWM is present within the proposed action area, all potential direct, indirect and cumulative impacts to this species will need to be fully assessed and disclosed as required by Section 7 of the Endangered Species Act of 1973, as amended. Additionally, the Swift Creek population of the DWM has been identified as essential for the recovery of the species (USFWS 1993).

In a letter to the NCTA on February 17, 2011, the US Fish and Wildlife Service (USFWS) indicated that an updated Environmental Baseline on the DWM population in Swift Creek will be needed to determine if the proposed action has the potential to jeopardize the continued existence of this species. The USFWS proposed a three-tiered study to be implemented by the NCTA to develop this updated Environmental Baseline:

1. Provide an accounting (compliance/ implementation) of conservation measures that have been implemented in Swift Creek to protect the DWM
2. Assess the effectiveness of existing conservation measures and environmental protections in Swift Creek with regard to habitat and population stability
3. Assess historic trends, and current viability of the DWM population and habitat conditions in Swift Creek

Due to life history attributes of the DWM, gathering data to complete the population viability component of the third tier of this study is time sensitive, and it was determined that it would be prudent to gather baseline data quickly in order to maintain the current scheduling timeline for this project. As such, the population viability component of the third tier of this study (an assessment of historic trends, and current viability of the DWM population in Swift Creek) was implemented, the results of which are presented in this report.

2.0 POPULATION VIABILITY STUDY EFFORTS

This portion of the study consists of two components; a desktop evaluation of existing data to determine population trends over time, and an in-stream survey to gather site specific information to determine the current viability of the DWM population in Swift Creek. As the desktop evaluation is on-going and will be incorporated into further study analyses, this report focuses on the in-stream survey componment already conducted.

Based on evaluation of existing data, 43 live and eight relict shells of the DWM have been found in the Swift Creek subbasin since 1991. This includes 37 live and eight relict shells at 31 sites distributed within a greater than 21-mile reach of Swift Creek, three live individuals at two sites in Middle Creek, two live individuals at two sites in Little Creek, and one live individual in White Oak Creek. Based on the most recent survey efforts from 2007-2010, 12 live individuals were found at 11 of the sites within a 11-mile reach.

To further examine viability, Catena conducted specific surveys targeting the DWM at the majority of locations known to support this species within the Swift Creek watershed as well as locations where survey gaps existed in the watershed.

2.1 Mussel Survey Methodology

A three-person team experienced with the DWM and its habitat performed timed surveys targeting this species at 27 of the 31 locations within Swift Creek, and the five locations collectively in the tributaries (White Oak Creek, Little Creek, and Middle Creek), where DWM species had previously been recorded (Table 2). Each survey site consisted of a stream reach 200 linear feet in length. The GPS coordinates of the occurrence locations were generally used to center the point of respective sites, with a few exceptions due to overlapping of sites, inaccurate coordinates (coordinates off of channel) and/or significantly altered habitat conditions. In these instances a center point was chosen based on the most suitable habitat conditions in the general area.

Table 2. Dwarf Wedgemussel Locations in Swift Creek Subbasin 1991-2010

Location	GPS Coordinates	Date	Site ID #	# of DWM
Swift Creek	35.54522°N, -78.39826°W	03-27-1991	910327.1jma	1 live
Swift Creek	35.57402°N, -78.49949°W	04-11-1991	910411.1jma	1 shell
Swift Creek	35.57302°N, -78.50005°W	03-19-1992	920319.2jma	2 live
Swift Creek	35.5890°N, -78.52000°W	08-10-1992	Flowers-1992-22	2 shells
Swift Creek	35.5950°N, -78.5220°W	08-10-1992	Flowers-1992-23	2 shells
Swift Creek	35.62221°N, -78.57060°W	09-14-1992	920914.1jma	1 shell
Swift Creek	35.60840°N, -78.54901°W	09-01-1994	940901.0jma	1 live
Swift Creek	35.59997°N, -78.53665°W	09-01-1994	940901.4jma*	1 live
Swift Creek @ White Oak Creek	35.60393°N, -78.52627°W	09-15-1994	940915.7jma	1 live
Swift Creek	35.62623°N, -78.57930°W	05-20-1996	960520.7jma	1 live
Swift Creek	35.62117°N, -78.56474°W	05-21-1996	960521.1jma	1 live
Swift Creek	35.61951°N, -78.55847°W	05-21-1996	960521.3jma	1 live
Swift Creek	35.60173°N, -78.53853°W	07-28-1997	970728.4jaj	3 live
Swift Creek	35.62050°N, -78.56202°W	07-29-1997	970729.2jaj	2 live, 1 shell
Swift Creek	35.62035°N, -78.56087°W	07-29-1997	970729.3jaj	2 live
Swift Creek	35.62050°N, -78.56202°W	10-13-1997	971013.1jaj	4 live
Swift Creek	35.62563°N, -78.57858°W	06-02-1998	980602.4jaj	1 live, 1 shell
Swift Creek	35.62540°N, -78.57657°W	06-02-1998	980602.7jaj	1 live
Swift Creek	35.62020°N, -78.56193°W	11-24-1998	981124.1jaj	2 live
Swift Creek	35.62032°N, -78.55640°W	11-05-2003	031105.4tws	1 live

Location	GPS Coordinates	Date	Site ID #	# of DWM
Swift Creek	35.62766°N, -78.58522°W	08-10-2007	070810.2tws	1 live
Swift Creek	35.60788°N, -78.54517°W	08-29-2007	070829.5tws	1 live
Swift Creek	35.62294°N, -78.56847°W	08-30-2007	070830.2ted	1 live
Swift Creek	35.62078°N, -78.56266°W	08-30-2007	070830.4tws	1 live
Swift Creek	35.60423°N, -78.52754°W	10-23-2007	071023.5tws*	1 live
Swift Creek	35.60230°N, -78.52957°W	10-23-2007	071023.7tws*	2 live
Swift Creek	35.60662°N, -78.54391°W	10-13-2010	101013.1tcg	1 live
Swift Creek	35.60647°N, -78.54409°W	10-26-2010	101026.4tcg	1 live
Swift Creek	35.62249°N, -78.57048°W	10-27-2010	101027.8tcg	1 live
Swift Creek	35.60226°N, -78.53124°W	11-01-2010	101101.5tcg*	1 live
Swift Creek	35.57189°N, -78.50263°W	11-09-2010	101109.4tcg	1 live
Middle Creek	35.56741°N, -78.59562°W	05-18-1992	920518.1jma	2 live
Middle Creek	35.52112°N, -78.48501°W	09-10-1992	920910.5jma	1 live
White Oak Creek	35.60618°N, -78.52709°W	04-20-1992	920420.1jma	1 live
Little Creek	35.58039°N, -78.44558°W	07-24-2003	030724.5tws	1 live
Little Creek	35.58097°N, -78.44619°W	07-24-2003	030724.6tws	1 live

* Not targeted during the 2011 surveys

Additionally, 53 other sites were surveyed in areas where little or no previous survey data existed. These locations were chosen based on pre-survey investigations that identified gaps, accessibility, and appropriate habitat for the target species as determined in the field. A minimum two-person survey team familiar with the DWM and its habitat performed these additional surveys.

Surveys were conducted by Catena personnel on the following dates in 2011:

- Tim Savidge (Team Lead): April 7, 20, 26, 27; May 13, 26; June 4, 7, 15, 21, 28
- Tom Dickinson (Team Lead): April 7, 14, 20, 26, 27; May 9, 10; June 7, 9, 15,21, 28
- Chris Sheats: April 7, 14, 20, 26, 27; May 9, 10; June 4, 7, 9, 15
- Daniel Savidge: April 26, 27; May 13, June 15, 21
- Ivy Kimbrough: April 14, 20, 26, 27; May 9, 26; June 4, 7, 15, 21, 28
- Jonathan Hartsell: April 20, 26, 27; June 7, 9
- John Roberts: June 4

The following non-Catena personnel assisted with the surveys on the following dates:

- Kevin Markham-ESI: June 28
- Kiersten Giugno-HNTB: June 28

Visual surveys using glass bottom view buckets (bathyscopes) and/or mask/snorkel, along with tactile methods were utilized at all of the sampled sites. The surveys began at the downstream end of the survey site and proceeded upstream. Upstream and downstream survey limits were recorded using a hand-held Garmin 12 or e-Trex Vista GPS unit. Timed searches were employed in each reach to provide a catch per unit effort (CPUE). Searches were also conducted for relict shells. Presence of fresh shell material was equated with species presence, but was not factored into CPUE. The survey team focused their efforts in microhabitats associated with DWM and other rare target species.

Each individual DWM and FSC (Atlantic Pigtoe, Yellow Lance) collected was measured, photographed, checked for reproductive condition, tagged (to allow for future monitoring), and returned to the substrate. Individual state listed species were treated in the same manner, but not tagged. Individuals of all other mussel species encountered were counted and returned to the substrate.

Relative abundance for freshwater snails and the freshwater clam species were estimated using the following criteria:

- Very abundant > 30 observed at survey station
- Abundant 16-30 observed at survey station
- Common 6-15 observed at survey station
- Uncommon 3-5 observed at survey station
- Rare 1-2 observed at survey station
- Patchy indicates an uneven distribution of the species within the sampled site.

2.2 Mussel Survey Results

A total of 85 separate stream reaches within the study corridor were surveyed with 16 freshwater mussel species, one freshwater clam species, and three aquatic snail species found (Table 3).

Table 3. Study Corridor: Mollusk Species Found 2011

Scientific Name	Common Name	# Sites Found	Conservation Status
Freshwater Mussels			
Alasmidonta heterodon	Dwarf Wedgemussel	3	Federally E
Alasmidonta undulata	Triangle Floater	43	State T
Elliptio complanata	Eastern Elliptio	85	None
Elliptio congarea	Carolina Slabshell	65	State W
Elliptio fisheriana	Northern Lance	6	None
Elliptio icterina	Variable Spike	82	None
Elliptio lanceolata	Yellow Lance	7	State E
Elliptio producta	Atlantic Spike	9	State W
Elliptio roanokensis	Roanoke Slabshell	28	State T
Elliptio sp. c.f. mediocris	No Common Name	57	None
Fusconaia masoni	Atlantic Pigtoe	34	State E
Lampsilis radiata	Eastern Lampmussel	44	State T
Pyganodon cataracta	Eastern Floater	21	None
Strophitus undulatus	Creeper	43	State T
Utterbackia imbecillis	Paper Pondshell	10	None
Villosa constricta	Notched Rainbow	2	State SC
Freshwater Snails and Clams			
Campeloma decisum	Pointed Campeloma	19	None
Corbicula fluminea	Asian Clam	85	Exotic
Elimia catenaria	Gravel Elimia	7	None
Helisoma anceps	Two-ridge Ram's Horn	2	None

For purposes of data reporting, analysis, and discussion, the project study area was segmented into a total of six sections; three in Swift Creek based on general habitat divisions and one each for White Oak Creek, Little Creek, and Middle Creek.

The general study area of Swift Creek is divided into three sections of unequal length to account for these general habitat conditions as follows:

1. Upper (Lake Benson to I-40),
2. Middle (I-40 to Barber Mill Road)
3. Lower (Barber Mill Road to NC 210)

Stream survey segments are reported by USGS stream name, the date surveyed, and respective sequence within that date. Habitat descriptions and survey results are summarized below for each site in order by section. Site numbers (i.e., 101010.1) indictate the date in YYMMDD (year, month, day) format and are listed in sequence. Initials indicate the survey team lead (*i.e.*, tws for Tim Savidge, ted for Tom Dickinson, and Catena when both present). If the site contained a previous DWM record, the corresponding site number follows the 2011 site number.

2.2.1 Section 1 Upper Swift Creek

Section 1 of the Swift Creek study area occurs between Lake Benson and I-40. Nine sites were surveyed in this section, six of which were sites with previous records of DWM.

Swift Creek Site-110509.1ted

Swift Creek was accessed from the Wake County WWTP sprayfields off Wrenn Road. Channel width was approximately 10 meters with relatively stable 1.5 meter high banks. In order of dominance, substrate consisted of sand, consolidated clay banks, and silt. Water levels were low and water visibility was clear. A wide natural buffer surrounds the reach. Mussel surveys were conducted for 4.25 person hours.

Table 4. Swift Creek Site- 110509.1ted (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	3	0.71/hr
Elliptio complanata	Eastern Elliptio	899	211.53/hr
Elliptio congaraea	Carolina Slabshell	2	0.47/hr
Elliptio icterina	Variable Spike	157	36.94/hr
Elliptio sp. cf. mediocris	n/a	3	0.71/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.24/hr
Lampsilis radiata	Eastern Lampmussel	4	0.94/hr
Pyganodon cataracta	Eastern Floater	5	1.18/hr
Strophitus undulatus	Creeper	3	0.71/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek Site-110509.2ted (980602.7jaj)

This targeted site was a location of a previous DWM find in 1998. Channel width was approximately 10 meters with relatively stable 2 meter high banks. In order of dominance, substrate consisted of sand, consolidated clay banks, and silt. Water levels were low and water visibility was clear. A wide natural buffer surrounds the reach. Mussel surveys were conducted for 2.45 person hours.

Table 5. Swift Creek Site- 110509.2ted (980602.7jaj): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	4	1.63/hr
Elliptio complanata	Eastern Elliptio	419	171.02/hr
Elliptio congaraea	Carolina Slabshell	1	0.41/hr
Elliptio icterina	Variable Spike	72	29.39/hr
Elliptio sp. cf. mediocris	n/a	1	0.41/hr
Fusconaia masoni	Atlantic Pigtoe	3	1.22/hr
Lampsilis radiata	Eastern Lampmussel	7	2.86/hr
Pyganodon cataracta	Eastern Floater	1	0.41/hr
Strophitus undulatus	Creeper	1	0.41/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek Site-110509.3ted (980602.4jaj)

This targeted site was a location of a previous DWM find in 1998. Channel width was approximately 10 meters with 2 meter high eroded banks. The site was relatively shallow with significant riffle and run habitat and heavy woody debris. In order of dominance, substrate consisted of sand, consolidated clay banks, and silt. Water levels were low and water visibility was clear. A wide natural buffer surrounds the reach. Mussel surveys were conducted for 2.57 person hours.

Table 6. Swift Creek Site- 110509.3ted (980602.4jaj): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	2	0.78/hr
Elliptio complanata	Eastern Elliptio	330	128.40/hr
Elliptio icterina	Variable Spike	136	52.92/hr
Elliptio lanceolata	Yellow Lance	1	0.39/hr
Elliptio producta	Atlantic Spike	1	0.39/hr
Elliptio sp. cf. mediocris	n/a	3	1.17/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.39/hr
Lampsilis radiata	Eastern Lampmussel	2	0.78/hr
Strophitus undulatus	Creeper	2	0.78/hr
Freshwater Snails and Clams			**Relative Abundance**

Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek Site-110509.4ted (960520.7jma)

This targeted site was a location of previous DWM find in 1996. Channel width ranged from 9 to 12 meters with relatively unstable 2 meter high banks. In order of dominance, substrate consisted of sand, consolidated clay banks, and silt. Water levels were low and water visibility was clear. Mussel surveys were conducted for 2.05 person hours.

Table 7. Swift Creek Site- 110509.4ted (960520.7jma): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.49/hr
Elliptio complanata	Eastern Elliptio	197	96.10/hr
Elliptio icterina	Variable Spike	56	27.32/hr
Lampsilis radiata	Eastern Lampmussel	2	0.98/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek Site-110509.5ted (070810.2tws)

This targeted site was a location of a previous DWM find in 2007. Channel width ranged from 8 to 10 meters with relatively unstable 2 meter high banks. In order of dominance, substrate consisted of unconsolidated sand, clay banks, and silt. Water levels were low and water visibility was clear. Mussel surveys were conducted for 1.40 person hours.

Table 8. Swift Creek Site- 110509.5ted (070810.2tws): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.71/hr
Elliptio complanata	Eastern Elliptio	131	93.57/hr
Elliptio icterina	Variable Spike	17	12.14/hr
Elliptio roanokensis	Roanoke Slabshell	2	1.43/hr
Strophitus undulatus	Creeper	2	1.43/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek Site-110607.1ted

This section of Swift Creek was accessed from I-40. At this site, channel width was approximately 10 meters with relatively stable 1 to 2 meter high banks. In order of dominance, substrate consisted of unconsolidated sand, clay banks, silt, and pebble. Water levels were very low and water visibility was clear. Mussel surveys were conducted for 2.75 person hours.

Table 9. Swift Creek Site- 110607.1ted (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	176	64.00/hr
Elliptio congaraea	Carolina Slabshell	13	4.73/hr
Elliptio icterina	Variable Spike	59	21.45/hr
Elliptio producta	Atlantic Spike	1	0.36/hr
Elliptio roanokensis	Roanoke Slabshell	2	0.73/hr
Elliptio sp. cf. mediocris	n/a	2	0.73/hr
Fusconaia masoni	Atlantic Pigtoe	2	0.73/hr
Strophitus undulatus	Creeper	1	0.36/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek Site-110607.2ted (070830.2ted)

This targeted site was the location of a previous DWM find in 2007. Channel width was approximately 10 meters with relatively stable 1 to 2 meter high banks. In order of dominance, substrate consisted of unconsolidated sand, clay banks, boulder, and silt. Water levels were very low and water visibility was clear. Mussel surveys were conducted for 2.02 person hours.

Table 10. Swift Creek Site- 110607.2ted (070830.2ted): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	2	0.99/hr
Elliptio complanata	Eastern Elliptio	132	65.35/hr
Elliptio congaraea	Carolina Slabshell	2	0.99/hr
Elliptio icterina	Variable Spike	75	37.13/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.50/hr
Elliptio sp. cf. mediocris	n/a	2	0.99/hr
Lampsilis radiata	Eastern Lampmussel	1	0.50/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek Site-110607.3ted (101027.8ted and 920914.1jma)

This targeted site was the location of a previous DWM find in 1992 and 2010. Channel width ranged from 8 to 10 meters with mostly stable approximately 2 meter high banks. In order of dominance, substrate consisted of gravel, unconsolidated sand, clay banks, silt, and cobble, and bedrock. Water levels were very low and water visibility was clear. Mussel surveys were conducted for 3.83 person hours.

Table 11. Swift Creek Site- 110607.3ted (101027.8ted and 920914.1jma): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	5	1.31/hr
Elliptio complanata	Eastern Elliptio	681	177.81/hr
Elliptio congaraea	Carolina Slabshell	9	2.35/hr
Elliptio icterina	Variable Spike	88	22.98/hr
Elliptio roanokensis	Roanoke Slabshell	6	1.57/hr
Fusconaia masoni	Atlantic Pigtoe	4	1.04/hr
Lampsilis radiata	Eastern Lampmussel	4	1.04/hr
Strophitus undulatus	Creeper	3	0.78/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek Site-110607.4ted

At this additional site, the channel width was approximately 10 meters with eroded 1 to 2 meter high banks. In order of dominance, substrate consisted of unconsolidated sand, clay banks, silt, and cobble. Heavy woody debris was present at this site. Water levels were very low and water visibility was clear. Mussel surveys were conducted for 1.80 person hours.

Table 12. Swift Creek Site- 110607.4ted (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	201	111.67/hr
Elliptio congaraea	Carolina Slabshell	2	1.11/hr
Elliptio icterina	Variable Spike	33	18.33/hr
Lampsilis radiata	Eastern Lampmussel	1	0.56/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

2.2.2 Section 2 Middle Swift Creek

Section 2 of the project corridor occurs within the Swift Creek Subbasin between I-40 and Barber Mill Road. The section contained the highest concentration of previous DWM sites (12) and the corresponding highest quality mussel habitat observed in the subbasin in 2011. A total of 39 sites were evaluated.

Swift Creek-110407.1Catena (101026.4tcg)

This targeted site was the location of a previous DWM find in 2010. The stream channel ranged from 8 to 10 meters wide, with relatively stable banks up to 2 meters high. The substrate was dominated by sand and gravel, with clay and silt along the banks. Surveys were conducted for 3.90 person hours.

Table 13. Swift Creek Site- 110407.1Catena (101026.4tcg): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	11	2.82/hr
Elliptio complanata	Eastern Elliptio	321	82.31/hr
Elliptio congaraea	Carolina Slabshell	3	0.77/hr
Elliptio icterina	Variable Spike	152	38.97/hr
Elliptio producta	Atlantic Spike	1	0.26/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.26/hr
Elliptio sp. cf. mediocris	n/a	4	1.03/hr
Lampsilis radiata	Eastern Lampmussel	2	0.51/hr
Pyganodon cataracta	Eastern Floater	2	0.51/hr
Strophitus undulatus	Creeper	2	0.51/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Present
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek-110407.2Catena

At this additional site, the channel ranged from 8 to 10 meters wide, with 2 meter high banks exhibiting moderate erosion. The substrate was dominated by sand and gravel/pebble, with clay and silt along the banks. Surveys were conducted for 3.00 person hours.

Table 14. Swift Creek Site- 110407.2Catena (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	2	0.67/hr
Elliptio complanata	Eastern Elliptio	242	80.67/hr
Elliptio congaraea	Carolina Slabshell	3	1.00/hr
Elliptio icterina	Variable Spike	116	38.67/hr
Elliptio lanceolata	Yellow Lance	1	0.33/hr
Elliptio roanokensis	Roanoke Slabshell	3	1.00/hr
Elliptio sp. cf. mediocris	n/a	3	1.00/hr
Fusconaia masoni	Atlantic Pigtoe	3	1.00/hr
Lampsilis radiata	Eastern Lampmussel	2	0.67/hr
Pyganodon cataracta	Eastern Floater	1	0.33/hr
Strophitus undulatus	Creeper	2	0.67/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant
Helisoma anceps	Two-ridge Rams-horn	~	Present

Swift Creek-110407.3Catena

At this additional site, the channel ranged from 8 to 10 meters wide, with relatively stable 2 meter high banks. The substrate was dominated by sand and gravel, with clay and silt along the banks. Surveys were conducted for 1.75 person hours.

Table 15. Swift Creek Site- 110407.3Catena (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	5	2.86/hr
Elliptio complanata	Eastern Elliptio	136	77.71/hr
Elliptio congaraea	Carolina Slabshell	1	0.57/hr
Elliptio icterina	Variable Spike	66	37.71/hr
Elliptio lanceolata	Yellow Lance	1	0.57/hr
Elliptio sp. cf. mediocris	n/a	5	2.86/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.57/hr
Lampsilis radiata	Eastern Lampmussel	1	0.57/hr
Strophitus undulatus	Creeper	3	1.71/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek-110407.4Catena-(101013.1tcg)

This targeted site was the location of a previous DWM find in 2010. The stream channel ranged from 8 to 10 meters wide, with relatively stable banks up to 2 meters high. The substrate was dominated by sand, gravel and clay banks. Surveys were conducted for 2.70 person hours.

Table 16. Swift Creek Site- 110407.4Catena (101013.1tcg): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	9	3.33/hr
Elliptio complanata	Eastern Elliptio	245	90.74/hr
Elliptio congaraea	Carolina Slabshell	1	0.37/hr
Elliptio icterina	Variable Spike	97	35.93/hr
Elliptio sp. cf. mediocris	n/a	3	1.11/hr
Lampsilis radiata	Eastern Lampmussel	4	1.48/hr
Strophitus undulatus	Creeper	5	1.85/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek-110407.5Catena-(070829.5tws)

At this targeted site, the channel ranged from 5 to 8 meters wide, with relatively stable 1 meter high banks. Habitat consisted of shallow riffle/run, and the substrate was dominated by coarse sand and pea gravel, with clay and silt along the banks. Surveys were conducted for 1.75 person hours.

Table 17. Swift Creek Site- 110407.5Catena (070829.5tws): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.57/hr
Elliptio complanata	Eastern Elliptio	127	72.57/hr
Elliptio icterina	Variable Spike	144	82.29/hr
Elliptio lanceolata	Yellow Lance	1	0.57/hr
Elliptio producta	Atlantic Spike	1	0.57/hr
Elliptio sp. cf. mediocris	n/a	1	0.57/hr
Fusconaia masoni	Atlantic Pigtoe	3	1.71/hr
Lampsilis radiata	Eastern Lampmussel	3	1.71/hr
Strophitus undulatus	Creeper	2	1.14/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek-110407.6Catena

At this additional site, the channel ranged from 5 to 8 meters wide, with relatively stable 1 meter high banks. Habitat consisted of shallow riffle/run, and the substrate was dominated by sand, gravel, and silt. Surveys were conducted for 0.83 person hour.

Table 18. Swift Creek Site- 110407.6Catena (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	1.20/hr
Elliptio complanata	Eastern Elliptio	86	103.61/hr
Elliptio congaraea	Carolina Slabshell	2	2.41/hr
Elliptio icterina	Variable Spike	80	96.39/hr
Elliptio producta	Atlantic Spike	1	1.20/hr
Fusconaia masoni	Atlantic Pigtoe	2	2.41/hr
Lampsilis radiata	Eastern Lampmussel	3	3.61/hr
Pyganodon cataracta	Eastern Floater	3	3.61/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek-110426.1tws

At this additional site, the channel was approximately 7 meters wide, with 1.5 meter high banks exhibiting some erosion/undercutting. The substrate was dominated by sand and clay. Surveys were conducted for 1.65 person hours.

Table 19. Swift Creek Site- 110426.1tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	159	96.36/hr
Elliptio congaraea	Carolina Slabshell	4	2.42/hr
Elliptio icterina	Variable Spike	34	20.61/hr
Elliptio sp. cf. mediocris	n/a	1	0.61/hr
Lampsilis radiata	Eastern Lampmussel	2	1.21/hr
Pyganodon cataracta	Eastern Floater	1	0.61/hr
Strophitus undulatus	Creeper	1	0.61/hr
Utterbackia imbecillis	Paper Pondshell	1	0.61/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek-110426.2tws

At this additional site, the channel ranged from 5 to 6 meters wide, with 1.5 meter high banks exhibiting some erosion/undercutting. The substrate was dominated by sand and pebble. Surveys were conducted for 3.40 person hours.

Table 20. Swift Creek Site- 110426.2tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.29/hr
Elliptio complanata	Eastern Elliptio	396	116.47/hr
Elliptio congaraea	Carolina Slabshell	17	5.00/hr
Elliptio icterina	Variable Spike	127	37.35/hr
Elliptio producta	Atlantic spike	1	0.29/hr
Elliptio sp. cf. mediocris	n/a	4	1.18/hr
Fusconaia masoni	Atlantic Pigtoe	4	1.18/hr
Lampsilis radiata	Eastern Lampmussel	2	0.59/hr
Pyganodon cataracta	Eastern Floater	7	2.06/hr
Strophitus undulatus	Creeper	3	0.88/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek-110426.1ted (940901.0jma)

This targeted site was the location of a previous DWM find in 1994. The stream channel ranged from 8 to 10 meters wide, with banks up to 2 meters high that exhibited moderate erosion. The substrate was dominated by sand and silt with heavy woody debris.

Surveys were conducted for 1.50 person hours.

Table 21. Swift Creek Site- 110426.1ted (940901.0jma): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	100	66.67/hr
Elliptio icterina	Variable Spike	12	8.00/hr
Elliptio sp. cf. mediocris	n/a	1	0.67/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.67/hr
Lampsilis radiata	Eastern Lampmussel	1	0.67/hr
Strophitus undulatus	Creeper	1	0.67/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek-110426.2ted

At this additional site, the channel ranged from 8 to 10 meters wide, with banks up to 2 meters high that exhibited moderate erosion. The substrate was dominated by sand and gravel. Surveys were conducted for 2.10 person hours.

Table 22. Swift Creek Site- 110426.2ted (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	52	24.76/hr
Elliptio icterina	Variable Spike	16	7.62/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.48/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek-110426.3ted (101109.4tcg)

This targeted site was the location of a previous DWM find in 2010. The stream channel ranged from 10 to 12 meters wide, with banks up to 2.5 meters high that exhibited moderate erosion. The substrate was dominated by sand, gravel, silt, and clay banks. Surveys were conducted for 2.05 person hours.

Table 23. Swift Creek Site- 110426.3ted (101109.4tcg): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	93	45.37/hr
Elliptio congaraea	Carolina Slabshell	1	0.49/hr
Elliptio icterina	Variable Spike	46	22.44/hr
Elliptio sp. cf. mediocris	n/a	6	2.93/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.49/hr
Strophitus undulatus	Creeper	1	0.49/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek-110426.4ted

At this additional site, the channel ranged from 8 to 10 meters wide, with banks up to 2 meters high that exhibited moderate erosion. The substrate was dominated by sand and rocky cobble over clay. Surveys were conducted for 1.60 person hours.

Table 24. Swift Creek Site- 110426.4ted (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	3	1.88/hr
Elliptio complanata	Eastern Elliptio	70	43.75/hr
Elliptio icterina	Variable Spike	38	23.75/hr
Elliptio sp. cf. mediocris	n/a	4	2.50/hr
Fusconaia masoni	Atlantic Pigtoe	2	1.25/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek-110426.5ted (920319.2jma)

At this targeted site, the channel was approximately 10 meters wide, with relatively stable banks. The substrate was dominated by sand and gravel. Surveys were conducted for 2.00 person hours.

Table 25. Swift Creek Site- 110426.5ted (920319.2jma): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	3	1.50/hr
Elliptio complanata	Eastern Elliptio	274	137.00/hr
Elliptio congaraea	Carolina Slabshell	4	2.00/hr
Elliptio icterina	Variable Spike	123	61.50/hr
Elliptio roanokensis	Roanoke Slabshell	5	2.50/hr
Elliptio sp. cf. mediocris	n/a	8	4.00/hr
Fusconaia masoni	Atlantic Pigtoe	3	1.50/hr
Strophitus undulatus	Creeper	4	2.00/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek-110427.1ted (031105.4tws)

This targeted site was the location of a previous DWM find in 2003. The stream channel ranged from 8 to 10 meters wide, with banks up to 2 meters high that exhibited moderate erosion. The substrate was dominated by sand, pebble, and clay banks with high woody debris. Surveys were conducted for 1.40 person hours.

Table 26. Swift Creek Site- 110427.1ted (031105.4tws): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	125	89.29/hr
Elliptio congaraea	Carolina Slabshell	3	2.14/hr
Elliptio icterina	Variable Spike	41	29.29/hr
Lampsilis radiata	Eastern Lampmussel	2	1.43/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek-110427.2ted (960521.3jma)

This targeted site was the location of a previous DWM find in 1996. The stream channel ranged from 8 to 10 meters wide, with banks up to 2 meters high that exhibited moderate erosion. The substrate was dominated by sand, pebble, and clay banks. Surveys were conducted for 2.35 person hours.

Table 27. Swift Creek Site- 110427.2ted (960521.3jma): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.43/hr
Elliptio complanata	Eastern Elliptio	81	34.47/hr
Elliptio congaraea	Carolina Slabshell	4	1.70/hr
Elliptio icterina	Variable Spike	102	43.40/hr
Elliptio lanceolata	Yellow Lance	1	0.43/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.43/hr
Elliptio sp. cf. mediocris	n/a	2	0.85/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek-110427.3ted

At this additional site, the stream channel ranged from 8 to 10 meters wide, with banks up to 2 meters high that exhibited moderate erosion. The substrate was dominated by sand, pebble, and clay banks. Surveys were conducted for 1.00 person hour.

Table 28. Swift Creek Site- 110427.3ted (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	1.00/hr
Elliptio complanata	Eastern Elliptio	91	91.00/hr
Elliptio congaraea	Carolina Slabshell	2	2.00/hr
Elliptio icterina	Variable Spike	41	41.00/hr
Elliptio roanokensis	Roanoke Slabshell	2	2.00/hr
Lampsilis radiata	Eastern Lampmussel	2	2.00/hr
Pyganodon cataracta	Eastern Floater	2	2.00/hr
Strophitus undulatus	Creeper	3	3.00/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek-110427.4ted (971013.1jaj and 970729.3jaj)

This targeted site was the location of a previous DWM find in 1997. The stream channel ranged from 8 to 10 meters wide, with banks up to 2 meters high that exhibited moderate erosion. The substrate was dominated by sand, gravel, silt, and clay banks. Surveys were conducted for 1.90 person hours.

Table 29. Swift Creek Site- 110427.4ted (971013.1jaj and 970729.3jaj): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.53/hr
Elliptio complanata	Eastern Elliptio	240	126.32/hr
Elliptio congaraea	Carolina Slabshell	3	1.58/hr
Elliptio icterina	Variable Spike	142	74.74/hr
Elliptio sp. cf. mediocris	n/a	3	1.58/hr
Fusconaia masoni	Atlantic Pigtoe	2	1.05/hr
Lampsilis radiata	Eastern Lampmussel	1	0.53/hr
Strophitus undulatus	Creeper	3	1.58/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek-110427.5ted (970729.2jaj; 981124.1jaj; 070830.4tws)

This targeted site was the location of previous DWM finds on three occasions: in 1997, 1998, and 2007. The stream channel ranged from 8 to 10 meters wide, with banks up to 2 meters high that exhibited some erosion. The substrate consisted of coarse sand, gravel, cobble, boulder, silt and clay banks. Surveys were conducted for 3.25 person hours.

Table 30. Swift Creek Site- 110427.5ted (970729.2jaj; 981124.1jaj; 070830.4tws): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	5	1.54/hr
Elliptio complanata	Eastern Elliptio	351	108.00/hr
Elliptio congaraea	Carolina Slabshell	3	0.92/hr
Elliptio icterina	Variable Spike	143	44.00/hr
Elliptio lanceolata	Yellow Lance	shell only	n/a
Elliptio sp. cf. mediocris	n/a	4	1.23/hr
Fusconaia masoni	Atlantic Pigtoe	4	1.23/hr
Lampsilis radiata	Eastern Lampmussel	1	0.31/hr
Strophitus undulatus	Creeper	1	0.31/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek-110427.6ted (960521.1jma)

This targeted site was the location of a previous DWM find in 1996. The stream channel ranged from 8 to 10 meters wide, with banks up to 2 meters high that exhibited some erosion. The substrate was dominated by sand, gravel, and clay banks. Surveys were conducted for 2.10 person hours.

Table 31. Swift Creek Site- 110427.6ted (960521.1jma): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	180	85.71/hr
Elliptio congaraea	Carolina Slabshell	5	2.38/hr
Elliptio icterina	Variable Spike	81	38.57/hr
Elliptio sp. cf. mediocris	n/a	3	1.43/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.48/hr
Lampsilis radiata	Eastern Lampmussel	1	0.48/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek-110510.5ted (910411.1jma)

This targeted site was the location of a previous DWM find in 1991. The stream channel was approximately 12 meters wide, with banks from 2-3 meters high that exhibited moderate erosion. The substrate was dominated by sand, gravel, cobble, and clay banks. Surveys were conducted for 1.85 person hours.

Table 32. Swift Creek Site- 110510.5ted (910411.1jma): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	shell only	n/a
Elliptio complanata	Eastern Elliptio	223	120.54/hr
Elliptio congaraea	Carolina Slabshell	37	20.00/hr
Elliptio icterina	Variable Spike	30	16.22/hr
Elliptio roanokensis	Roanoke Slabshell	65	35.14/hr
Elliptio sp. cf. mediocris	n/a	20	10.81/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.54/hr
Lampsilis radiata	Eastern Lampmussel	1	0.54/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek-110513.1tws (970728.4jaj)

At this targeted site, the channel was approximately 8 meters wide, with 2 meter high banks exhibiting some erosion/undercutting. The substrate was dominated by sand and gravel. Surveys were conducted for 2.00 person hours.

Table 33. Swift Creek Site- 110513.1tws (970728.4jaj): Mollusk SpeciesFound

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	2	1.00/hr
Elliptio complanata	Eastern Elliptio	90	45.00/hr
Elliptio congaraea	Carolina Slabshell	3	1.50/hr
Elliptio icterina	Variable Spike	17	8.50/hr
Elliptio roanokensis	Roanoke Slabshell	2	1.00/hr
Elliptio sp. cf. mediocris	n/a	4	2.00/hr
Strophitus undulatus	Creeper	2	1.00/hr
Utterbackia imbecillis	Paper Pondshell	1	0.50/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Present
Corbicula fluminea	Asian Clam	~	Common

Swift Creek-110513.2tws

At this additional site, the channel was approximately 8 meters wide, with 2 meter high banks exhibiting some erosion/undercutting. The substrate was dominated by sand and clay. Surveys were conducted for 2.00 person hours.

Table 34. Swift Creek Site- 110513.2tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	128	64.00/hr
Elliptio congaraea	Carolina Slabshell	1	0.50/hr
Elliptio icterina	Variable Spike	17	8.50/hr
Elliptio sp. cf. mediocris	n/a	2	1.00/hr
Lampsilis radiata	Eastern Lampmussel	2	1.00/hr
Pyganodon cataracta	Eastern Floater	1	0.50/hr
Utterbackia imbecillis	Paper Pondshell	2	1.00/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek-110513.3tws

At this additional site, the channel was approximately 8 meters wide, with 2 meter high banks exhibiting some erosion/undercutting. The substrate was dominated by sand and clay. Surveys were conducted for 2.00 person hours.

Table 35. Swift Creek Site- 110513.3tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.50/hr
Elliptio complanata	Eastern Elliptio	111	55.50/hr
Elliptio congaraea	Carolina Slabshell	6	3.00/hr
Elliptio icterina	Variable Spike	20	10.00/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.50/hr
Elliptio sp. cf. mediocris	n/a	17	8.50/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.50/hr
Strophitus undulatus	Creeper	1	0.50/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek-110513.4tws

At this additional site, the channel was approximately 8 meters wide, with 2 meter high banks exhibiting some erosion/undercutting. The substrate was dominated by sand and clay. Surveys were conducted for 2.00 person hours.

Table 36. Swift Creek Site- 110513.4tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	3	1.50/hr
Elliptio complanata	Eastern Elliptio	137	68.50/hr
Elliptio congaraea	Carolina Slabshell	8	4.00/hr
Elliptio icterina	Variable Spike	40	20.00/hr
Elliptio sp. cf. mediocris	n/a	9	4.50/hr
Lampsilis radiata	Eastern Lampmussel	1	0.50/hr
Strophitus undulatus	Creeper	3	1.50/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek-110615.3Catena (Flowers 1992.22)

This targeted site was the location of a previous DWM find in 1992. The stream channel was approximately 12 meters wide, with banks up to 2 meters high that exhibited some erosion. The substrate was dominated by sand, gravel, silt, and clay banks with well established root mats. Surveys were conducted for 3.00 person hours.

Table 37. Swift Creek Site- 110615.3Catena (Flowers 1992.22): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.33/hr
Elliptio complanata	Eastern Elliptio	378	126.00/hr
Elliptio congaraea	Carolina Slabshell	5	1.67/hr
Elliptio icterina	Variable Spike	159	53.00/hr
Elliptio sp. cf. mediocris	n/a	20	6.67/hr
Fusconaia masoni	Atlantic Pigtoe	2	0.67/hr
Pyganodon cataracta	Eastern Floater	3	1.00/hr
Strophitus undulatus	Creeper	3	1.00/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek-110615.4Catena

At this additional site, the stream channel was approximately 12 meters wide, with banks up to 2 meters high that exhibited some erosion. The substrate was dominated by sand, gravel, silt, and clay banks. Surveys were conducted for 1.33 person hours.

Table 38. Swift Creek Site- 110615.4Catena (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.75/hr
Elliptio complanata	Eastern Elliptio	45	33.83/hr
Elliptio icterina	Variable Spike	3	2.26/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.75/hr
Pyganodon cataracta	Eastern Floater	1	0.75/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek-110615.5Catena

At this additional site, the stream channel ranged from 10 to12 meters wide, with banks up to 2 meters high that exhibited some erosion. The substrate was dominated by coarse sand, pebble, silt, and clay banks with well established root mats. Surveys were conducted for 2.83 person hours. This was the site of the only live DWM found in 2011. The individual was located with several other rare juvenile mussels along the edge of a coarse sand/pebble bar.

Table 39. Swift Creek Site- 110615.5Catena (Additional) Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta heterodon	Dwarf Wedgemussel	1	0.35/hr
Alasmidonta undulata	Triangle Floater	3	1.06/hr
Elliptio complanata	Eastern Elliptio	187	66.08/hr
Elliptio congaraea	Carolina Slabshell	5	1.77/hr
Elliptio icterina	Variable Spike	66	23.32/hr
Elliptio producta	Atlantic Spike	1	0.35/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.35/hr
Elliptio sp. cf. mediocris	n/a	7	2.47/hr
Fusconaia masoni	Atlantic Pigtoe	2	0.71/hr
Lampsilis radiata	Eastern Lampmussel	1	0.35/hr
Pyganodon cataracta	Eastern Floater	2	0.71/hr
Strophitus undulatus	Creeper	2	0.71/hr
Utterbackia imbecillis	Paper Pondshell	1	0.35/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek-110615.6Catena

At this additional site, the stream channel ranged from 10 to15 meters wide, with banks up to 2 meters high that exhibited some erosion. The substrate consisted of sand, pebble, cobble, silt, and clay banks with root mats. Surveys were conducted for 4.75 person hours.

Table 40. Swift Creek Site- 110615.6Catena (Additional) Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	5	1.05/hr
Elliptio complanata	Eastern Elliptio	504	106.11/hr
Elliptio congaraea	Carolina Slabshell	31	6.53/hr
Elliptio icterina	Variable Spike	114	24.00/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.21/hr
Elliptio sp. cf. mediocris	n/a	26	5.47/hr
Fusconaia masoni	Atlantic Pigtoe	3	0.63/hr
Lampsilis radiata	Eastern Lampmussel	3	0.63/hr
Pyganodon cataracta	Eastern Floater	1	0.21/hr
Strophitus undulatus	Creeper	8	1.68/hr
Freshwater Snails and Clams			**Relative bundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek-110615.7Catena

At this additional site, the stream channel ranged from 8 to12 meters wide, with banks up to 2 meters high that exhibited some erosion. The substrate consisted of sand, pebble, silt, and clay banks. Surveys were conducted for 1.50 person hours.

Table 41. Swift Creek Site- 110615.7Catena (Additional) Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	4	2.67/hr
Elliptio complanata	Eastern Elliptio	239	159.33/hr
Elliptio congaraea	Carolina Slabshell	26	17.33/hr
Elliptio icterina	Variable Spike	66	44.00/hr
Elliptio producta	Atlantic Spike	1	0.67/hr
Elliptio roanokensis	Roanoke Slabshell	6	4.00/hr
Elliptio sp. cf. mediocris	n/a	15	10.00/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.67/hr
Lampsilis radiata	Eastern Lampmussel	4	2.67/hr
Pyganodon cataracta	Eastern Floater	3	2.00/hr
Strophitus undulatus	Creeper	1	0.67/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Present
Corbicula fluminea	Asian Clam	~	Common

Swift Creek-110621.1tws

At this additional site, the stream channel was approximately 10 meters wide, with banks up to 2 meters high that exhibited some erosion. The substrate consisted of coarse sand, pebble, silt, and clay banks. Surveys were conducted for 0.17 person hour.

Table 42. Swift Creek Site- 110621.1tws (Additional) Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	5.88/hr
Elliptio complanata	Eastern Elliptio	11	64.71/hr
Elliptio congaraea	Carolina Slabshell	2	11.76/hr
Elliptio roanokensis	Roanoke Slabshell	3	17.65/hr
Fusconaia masoni	Atlantic Pigtoe	1	5.88/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek-110621.1Catena

At this additional site, the stream channel ranged from 10 to 12 meters wide, with banks up to 2 meters high that exhibited some erosion. The substrate consisted of coarse sand, pebble, silt, and clay banks with root mats. Surveys were conducted for 3.20 person hours.

Table 43. Swift Creek Site- 110621.1Catena (Additional) Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	3	0.94/hr
Elliptio complanata	Eastern Elliptio	380	118.75/hr
Elliptio congaraea	Carolina Slabshell	11	3.44/hr
Elliptio icterina	Variable Spike	89	27.81/hr
Elliptio roanokensis	Roanoke Slabshell	2	0.63/hr
Elliptio sp. cf. mediocris	n/a	8	2.50/hr
Fusconaia masoni	Atlantic Pigtoe	4	1.25/hr
Lampsilis radiata	Eastern Lampmussel	7	2.19/hr
Pyganodon cataracta	Eastern Floater	4	1.25/hr
Strophitus undulatus	Creeper	3	0.94/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek-110621.2Catena

At this additional site, the stream channel was approximately 10 meters wide, with banks up to 2 meters high that exhibited some erosion. The substrate consisted of coarse sand, pebble, silt, and clay banks with root mats. Surveys were conducted for 4.33 person hours.

Table 44. Swift Creek Site- 110621.2Catena (Additional) Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	4	0.92/hr
Elliptio complanata	Eastern Elliptio	312	72.06/hr
Elliptio congaraea	Carolina Slabshell	2	0.46/hr
Elliptio icterina	Variable Spike	46	10.62/hr
Elliptio producta	Atlantic Spike	1	0.23/hr
Elliptio roanokensis	Roanoke Slabshell	5	1.15/hr
Elliptio sp. cf. mediocris	n/a	2	0.46/hr
Fusconaia masoni	Atlantic Pigtoe	2	0.46/hr
Lampsilis radiata	Eastern Lampmussel	5	1.15/hr
Pyganodon cataracta	Eastern Floater	2	0.46/hr
Strophitus undulatus	Creeper	7	1.62/hr
Utterbackia imbecillis	Paper Pondshell	4	0.92/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek-110621.3Catena (Flowers 1992.23)

This targeted site was the location of a previous DWM find in 1992. The stream channel was approximately 10 meters wide, with banks up to 2 meters high that exhibited some erosion. The substrate was dominated by sand, pebble, silt, and clay banks with root mats. Significant woody debris was present. Surveys were conducted for 3.27 person hours.

Table 45. Swift Creek Site- 110621.3Catena (Flowers 1992.23) Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	451	137.92/hr
Elliptio congaraea	Carolina Slabshell	21	6.42/hr
Elliptio icterina	Variable Spike	82	25.08/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.31/hr
Elliptio sp. cf. mediocris	n/a	22	6.73/hr
Fusconaia masoni	Atlantic Pigtoe	2	0.61/hr
Lampsilis radiata	Eastern Lampmussel	9	2.75/hr
Utterbackia imbecillis	Paper Pondshell	8	2.45/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek-110621.4Catena

At this additional site, the stream channel was approximately 15 meters wide, with 2 to 3 meter high unstable banks. The substrate was dominated by sand, silt, pebble, and claybanks with root mats. Heavy woody debris was present. Surveys were conducted for 2.47 person hours.

Table 46. Swift Creek Site- 110621.4Catena (Additional) Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	85	34.41/hr
Elliptio congaraea	Carolina Slabshell	10	4.05/hr
Elliptio icterina	Variable Spike	24	9.72/hr
Elliptio roanokensis	Roanoke Slabshell	2	0.81/hr
Elliptio sp. cf. mediocris	n/a	5	2.02/hr
Lampsilis radiata	Eastern Lampmussel	3	1.21/hr
Pyganodon cataracta	Eastern Floater	1	0.40/hr
Utterbackia imbecillis	Paper Pondshell	6	2.43/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek-110628.1Catena

At this additional site, the stream channel was approximately 10 meters wide, with banks up to 2 meters high that exhibited some erosion. The substrate was dominated by sand and clay banks with root mats. Moderate woody debris was present. Surveys were conducted for 5.75 person hours and a relict shell of DWM was found.

Table 47. Swift Creek Site- 110628.1Catena (Additional) Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta heterodon	Dwarf Wedgemussel	1 shell	n/a
Alasmidonta undulata	Triangle Floater	2	0.35/hr
Elliptio complanata	Eastern Elliptio	232	40.35/hr
Elliptio congaraea	Carolina Slabshell	6	1.04/hr
Elliptio icterina	Variable Spike	81	14.09/hr
Elliptio sp. cf. mediocris	n/a	8	1.39/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.17/hr
Strophitus undulatus	Creeper	1	0.17/hr
Villosa constricta	Notched Rainbow	1 shell	n/a
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Present
Corbicula fluminea	Asian Clam	~	Common

Swift Creek-110628.2Catena

At this additional site, the stream channel ranged from 12 to 15 meters wide, with banks up to 2 meters high that exhibited some erosion. The substrate was dominated by sand, silt, and clay banks with root mats. An outcrop of bedrock and associated cobble was also present. Surveys were conducted for 5.25 person hours.

Table 48. Swift Creek Site- 110628.2Catena (Additional) Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.19/hr
Elliptio complanata	Eastern Elliptio	371	70.67/hr
Elliptio congaraea	Carolina Slabshell	15	2.86/hr
Elliptio icterina	Variable Spike	112	21.33/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.19/hr
Elliptio sp. cf. mediocris	n/a	15	2.86/hr
Fusconaia masoni	Atlantic Pigtoe	1 shell	n/a
Lampsilis radiata	Eastern Lampmussel	2	0.38/hr
Pyganodon cataracta	Eastern Floater	1	0.19/hr
Strophitus undulatus	Creeper	1	0.19/hr
Villosa constricta	Notched Rainbow	1 shell	n/a
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek-110628.3Catena

At this additional site, the stream channel ranged from 8 to 10 meters wide, with banks from 2 to 3 meters high that exhibited significant erosion. The substrate was dominated by gravel and sand, with some cobble and clay banks with occasional root mats. Surveys were conducted for

5.50 person hours.

Table 49. Swift Creek Site- 110628.3Catena (Additional) Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	2	0.36/hr
Elliptio complanata	Eastern Elliptio	279	50.73/hr
Elliptio congaraea	Carolina Slabshell	40	7.27/hr
Elliptio icterina	Variable Spike	189	34.36/hr
Elliptio roanokensis	Roanoke Slabshell	2	0.36/hr
Elliptio sp. cf. mediocris	n/a	1	0.18/hr
Fusconaia masoni	Atlantic Pigtoe	2	0.36/hr
Strophitus undulatus	Creeper	2	0.36/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common
Elimia catenaria	Gravel Elimia	~	Uncommon

Swift Creek-110628.4Catena

At this additional site, the stream channel was approximately 10 meters wide, with banks up to 2 meters high that exhibited significant erosion. The substrate was dominated by sand, silt, clay, pebble, and shell. Surveys were conducted for 4.08 person hours.

Table 50. Swift Creek Site- 110628.4Catena (Additional) Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta heterodon	Dwarf Wedgemussel	1 shell	n/a
Alasmidonta undulata	Triangle Floater	2 shell	n/a
Elliptio complanata	Eastern Elliptio	332	81.37/hr
Elliptio congaraea	Carolina Slabshell	10	2.45/hr
Elliptio icterina	Variable Spike	51	12.50/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.25/hr
Elliptio sp. cf. mediocris	n/a	5	1.23/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.25/hr
Lampsilis radiata	Eastern Lampmussel	2	0.49/hr
Strophitus undulatus	Creeper	3	0.74/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek-110628.5Catena

At this additional site, the stream channel was approximately 12 meters wide, with banks up to 2 meters high that exhibited significant erosion. The substrate was dominated by sand, silt, clay, pebble, and detritus. Heavy woody debris was present. Surveys were conducted for 3.40 person hours.

Table 51. Swift Creek Site- 110628.5Catena (Additional) Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	229	67.35/hr
Elliptio congaraea	Carolina Slabshell	2	0.59/hr
Elliptio icterina	Variable Spike	33	9.71/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.29/hr
Elliptio sp. cf. mediocris	n/a	3	0.88/hr
Strophitus undulatus	Creeper	2	0.59/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

2.2.3 Section 3 Lower Swift Creek

Section 3 encompasses Swift Creek from the Barber Mill Road crossing to the NC 210 Crossing. When beginning this study, two sites within this section were identified as containing records of DWM; however, upon examining the raw data, it was discovered that the three DWM reported at site 020717.7jnb, were actually three Triangle Floater entered incorrectly as DWM. Thus, only one valid record of DWM exists in this section. A total of eight sites were sampled, one of which contained a previous record of DWM.

Swift Creek Site-110427.1tws

At this additional site, the channel was approximately 12 meters wide with 2 to 3 meter high banks exhibiting significant erosion/undercutting. The substrate was dominated by unconsolidated sand and heavy woody debris. Surveys were conducted for 1.75 person hours.

Table 52. Swift Creek Site- 110427.1tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	7	4.00/hr
Elliptio icterina	Variable Spike	1	0.57/hr
Elliptio sp. cf. mediocris	n/a	1	0.57/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek Site-110427.2tws

At this additional site, the channel was approximately 12 meters wide with 2 meter high banks exhibiting erosion/undercutting. The substrate was dominated by sand, boulder, and cobble. Surveys were conducted for 4.00 person hours.

Table 53. Swift Creek Site- 110427.2tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	67	16.75/hr
Elliptio congaraea	Carolina Slabshell	15	3.75/hr
Elliptio sp. cf. mediocris	n/a	3	0.75/hr
Lampsilis radiata	Eastern Lampmussel	2	0.50/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Swift Creek Site-110510.1ted

At this additional site near the confluence with Little Creek, the channel ranged from 12 to 15 meters wide with 2 to 3 meter high relatively stable stream banks. Substrate was dominated by sand and gravel. Surveys were conducted for 2.75 person hours.

Table 54. Swift Creek Site- 110510.1ted (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	49	17.82/hr
Elliptio congaraea	Carolina Slabshell	2	0.73/hr
Elliptio icterina	Variable Spike	14	5.09/hr
Elliptio sp. cf. mediocris	n/a	24	8.73/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon
Corbicula fluminea	Asian Clam	~	Common
Elimia catenaria	Gravel Elimia	~	Common

Swift Creek Site-110607.5tws

At this additional site, the channel was approximately 10 meters wide with 2 meter high very stable stream banks. The substrate was dominated by boulder and cobble. Surveys were conducted for 2.25 person hours. The Atlantic Pigtoe collected was an individual tagged in 2007 as part of the mussel population monitoring associated with the Dempsey Benton Waste Water Treatment Plant (The Catena Group 2008).

Table 55. Swift Creek Site- 110607.5tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	56	24.89/hr
Elliptio congaraea	Carolina Slabshell	17	7.56/hr
Elliptio icterina	Variable Spike	10	4.44/hr
Elliptio sp. cf. mediocris	n/a	32	14.22/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.44/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Patchy Common
Corbicula fluminea	Asian Clam	~	Abundant
Elimia catenaria	Gravel Elimia	~	Patchy Common

Swift Creek Site-110607.6tws

At this additional site, the channel was approximately 10 meters wide with 2 meter high banks with some erosion/undercutting. The substrate was dominated by gravel and cobble. Surveys were conducted for 1.00 person hour.

Table 56. Swift Creek Site- 110607.6tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	1.00/hr
Elliptio complanata	Eastern Elliptio	92	92.00/hr
Elliptio congaraea	Carolina Slabshell	30	30.00/hr
Elliptio fisheriana	Northern Lance	4	4.00/hr
Elliptio icterina	Variable Spike	25	25.00/hr
Elliptio roanokensis	Roanoke Slabshell	1	1.00/hr
Elliptio sp. cf. mediocris	n/a	15	15.00/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Patchy Common
Corbicula fluminea	Asian Clam	~	Abundant
Elimia catenaria	Gravel Elimia	~	Patchy Common

Swift Creek Site-110615.1Catena (910327.1jma)

This targeted site was the location of a DWM find in 1991. The channel ranged from 10-15 meters wide with 2 meter high banks exhibiting some erosion/undercutting. The substrate was dominated by sand, gravel, and clay bank. Surveys were conducted for1.95 person hours.

Table 57. Swift Creek Site- 110615.1Catena (910327.1jma): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	2	1.03/hr
Elliptio complanata	Eastern Elliptio	108	55.38/hr
Elliptio congaraea	Carolina Slabshell	27	13.85/hr
Elliptio icterina	Variable Spike	10	5.13/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.51/hr
Elliptio sp. cf. mediocris	n/a	9	4.62/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Patchy Common
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek Site-110615.2Catena

This additional site had a channel that ranged from 10 to 15 meters wide with 2 meter high banks exhibiting some erosion/undercutting. The substrate was dominated by sand, gravel, and clay bank. Surveys were conducted for 1.63 person hours.

Table 58. Swift Creek Site- 110615.2Catena (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	17	10.43/hr
Elliptio congaraea	Carolina Slabshell	9	5.52/hr
Elliptio icterina	Variable Spike	1	0.61/hr
Elliptio sp. cf. mediocris	n/a	2	1.23/hr
Lampsilis radiata	Eastern Lampmussel	1	0.61/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Swift Creek Site-110603.6tws

This site occurs extends from approximately 400 meters downstream of the NC 210 crossing upstream to the road. The stream channel ranges from 12-14 meters wide, with highly eroded clay banks 3 meters high. Habitat consists of a series of runs and pools. The substrate is predominately unconsolidated sand, with pockets of gravel and bedrock. The majority of mussels occurred in these pockets. Surveys were conducted for 3.67 person hours.

Table 59. Swift Creek Site-110603.6tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.27/hr
Elliptio complanata	Eastern Elliptio	55	14.99/hr
Elliptio congarea	Carolina Slabshell	20	5.45/hr
Elliptio icterina	Variable Spike	16	4.36/hr
Elliptio roanokensis	Roanoke Slabshell	4	1.09/hr
Elliptio sp. cf. mediocris	n/a	38	10.35/hr
Lampsilis radiata	Eastern Lampmussel	1	0.27/hr
Freshwater Snails and Clams			**Relative Abundance**
Elimia catenaria	Gravel Elimia	~	Uncommon
Campeloma decisum	Pointed Campeloma	~	Uncommon
Corbicula fluminea	Asian Clam	~	Abundant

2.3 White Oak Creek

The portion of White Oak Creek in this study occurs downstream of Austin Pond, with most sites concentrated near its confluence with Swift Creek. A total of four sites were surveyed, two of which had previous records of DWM.

White Oak Creek Site-110420.1Catena (940915.7jma)

This targeted site was the location of a DWM find in 1994, where a single individual was found at the mouth of White Oak Creek within Swift Creek. The survey limits extended from the mouth of Swift Creek to a point 200 feet upstream. The channel ranged from 4 to 6 meters wide with approximately 1 meter high banks exhibiting some erosion/undercutting. The substrate was dominated by sand and clay bank. High woody debris was noted. Surveys were conducted for 5.10 person hours.

Table 60. White Oak Creek Site- 110420.1Catena (940915.7jma): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	163	31.96/hr
Elliptio icterina	Variable Spike	14	2.75/hr
Pyganodon cataracta	Eastern Floater	1	0.20/hr
Utterbackia imbecillis	Paper Pondshell	1	0.20/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Present
Corbicula fluminea	Asian Clam	~	Abundant

White Oak Creek Site-110420.2Catena-(940420.1jma)

This targeted site was the location of a DWM find in 1994. The channel ranged from 2 to 2.5 meters wide with approximately 0.5 meter high banks exhibiting some erosion/undercutting. This small braided channel occurred in a recently breeched beaver impoundment off the main channel of White Oak Creek. The substrate was dominated by clay and sand. Surveys were conducted for 1.30 person hours.

Table 61. White Oak Creek Site- 110420.2Catena (940420.1jma): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	shell only	n/a
Elliptio icterina	Variable Spike	shell only	n/a
Pyganodon cataracta	Eastern Floater	1	0.77/hr
Utterbackia imbecillis	Paper Pondshell	1	0.77/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common
Helisoma anceps	Two-ridge Rams-horn	~	Uncommon

White Oak Creek Site-110420.3Catena

At this additional site, the stream channel ranged from 4 to 6 meters wide with approximately 1 meter high banks exhibiting some erosion/undercutting. The substrate was dominated by sand and clay bank. High woody debris was present. Surveys were conducted for 2.50 person hours.

Table 62. White Oak Creek Site- 110420.3Catena (Additional): Mollusk SpeciesFound

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	22	8.80/hr
Elliptio icterina	Variable Spike	5	2.00/hr
Lampsilis radiata	Eastern Lampmussel	1	0.40/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Present
Corbicula fluminea	Asian Clam	~	Abundant

White Oak Creek Site-110420.4Catena

At this additional site, the stream channel ranged from 4-6 meters wide with approximately 1 meter high banks exhibiting some erosion/undercutting. The substrate was dominated by sand, gravel, and clay bank with root mats. Surveys were conducted for 6.25 person hours.

Table 63. White Oak Creek Site- 110420.4Catena (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	258	41.28/hr
Elliptio congaraea	Carolina Slabshell	5	0.80/hr
Elliptio icterina	Variable Spike	92	14.72/hr
Lampsilis radiata	Eastern Lampmussel	1	0.16/hr
Pyganodon cataracta	Eastern Floater	shell only	n/a
Utterbackia imbecillis	Paper Pondshell	7	1.12/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Present
Corbicula fluminea	Asian Clam	~	Abundant

2.4 Little Creek

A total of eight sites were surveyed in Little Creek as part of this study, two of which contained previous records of DWM.

Little Creek Site-110414.1ted (030724.5tws)

This targeted site was the location of a DWM find in 2003. The channel ranged from 5 to 7 meters wide with approximately 2 meter high banks exhibiting some erosion/ undercutting. The substrate was dominated by sand, quartz pebble, and clay banks. Surveys were conducted for 3.45 person hours.

Table 64. Little Creek Site- 110414.1ted (030724.5tws): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	107	31.01/hr
Elliptio congaraea	Carolina Slabshell	3	0.87/hr
Elliptio icterina	Variable Spike	52	15.07/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Present
Corbicula fluminea	Asian Clam	~	Abundant

Little Creek Site-110414.2ted (030724.6tws)

This targeted site was the location of a DWM find in 2003. The channel ranged from 5 to 8 meters wide with approximately 2 meter high banks exhibiting some erosion/undercutting. The substrate was dominated by sand, cobble, pebble, and clay banks with root mats. Surveys were conducted for 3.70 person hours.

Table 65. Little Creek Site- 110414.2ted (030724.6tws): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	141	38.11/hr
Elliptio congaraea	Carolina Slabshell	2	0.54/hr
Elliptio icterina	Variable Spike	37	10.00/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Present
Corbicula fluminea	Asian Clam	~	Abundant

Little Creek Site-110414.3ted

At this additional site, the channel ranged from 4 to 6 meters wide with approximately 2 meter high banks exhibiting some erosion/undercutting. The substrate was dominated by sand, quartz pebble, and clay banks with root mats. Surveys were conducted for 2.05 person hours.

Table 66. Little Creek Site- 110414.3ted (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	109	53.17/hr
Elliptio icterina	Variable Spike	25	12.20/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Little Creek Site-110426.3tws

At this additional site, the channel ranged from 3 to 4 meters wide with approximately 1 meter high banks exhibiting some erosion/undercutting. The substrate was dominated by sand and cobble. Surveys were conducted for 1.00 person hour.

Table 67. Little Creek Site- 110426.3tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	1.00/hr
Elliptio complanata	Eastern Elliptio	106	106.00/hr
Elliptio icterina	Variable Spike	20	20.00/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Little Creek Site-110427.3tws

At this additional site, the channel ranged from 3 to 4 meters wide with approximately 1 meter high stable banks. The substrate was dominated by sand and cobble. Surveys were conducted for 1.00 person hour.

Table 68. Little Creek Site- 110427.3tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	27	27.00/hr
Elliptio icterina	Variable Spike	14	14.00/hr
Strophitus undulatus	Creeper	1	1.00/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Little Creek Site-110510.2ted

At this additional site, the channel ranged from 4 to 6 meters wide with approximately 1 meter high banks that exhibited some erosion. The substrate was dominated by sand, silt, pebble, and cobble. Surveys were conducted for 2.65 person hours.

Table 69.Little Creek Site- 110510.2ted (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	49	18.49/hr
Elliptio icterina	Variable Spike	11	4.15/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Little Creek Site-110510.3ted

At this additional site, the channel ranged from 4 to 6 meters wide with approximately 1 meter high banks that exhibited some erosion. The substrate was dominated by sand and gravel. Surveys were conducted for 2.15 person hours.

Table 70. Little Creek Site- 110510.3ted (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	123	57.21/hr
Elliptio icterina	Variable Spike	28	13.02/hr
Elliptio sp. cf. mediocris	n/a	1	0.47/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Little Creek Site-110510.4ted

At this additional site, the channel ranged from 4 to 6 meters wide with approximately 1 meter high banks that exhibited some erosion. The substrate was dominated by sand, silt, pebble, and cobble. Surveys were conducted for 1.60 person hours.

Table 71. Little Creek Site- 110510.4ted (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	88	55.0/hr
Elliptio icterina	Variable Spike	17	10.63/hr
Strophitus undulatus	Creeper	1	0.63/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

2.5 Middle Creek

A total of seventeen sites were surveyed in Middle Creek as part of this study, two of which contained previous records of DWM.

Middle Creek Site-110526.1tws

This additional site extends from the NC 42 crossing to a point approximately 400 meters upstream. The channel was approximately 10 meters wide with approximately 1.5 meter high banks that exhibited some erosion. The substrate was dominated by cobble, sand, and gravel. Surveys were conducted for 1.00 person hour.

Table 72. Middle Creek Site- 110526.1tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	43	43.00/hr
Elliptio congaraea	Carolina Slabshell	1	1.00/hr
Elliptio icterina	Variable Spike	31	31.00/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Middle Creek Site-110526.2tws

This additional site extends from the SR 1330 crossing to a point approximately 1,000 meters upstream. The channel ranged between 10 and 15 meters wide with approximately 1.5 to 3.0 meter high banks meter high banks that exhibited some erosion. Habitat in this reach consisted of long deep pools, with short shallow riffles and runs. The substrate was dominated by sand and gravel, with large boulders scattered throughout. Much of the substrate in the pool habitats was covered with detritus and silt. Surveys focused largely on the shallow habitats and were conducted for 2.67 person hours.

Table 73. Middle Creek Site- 110526.2tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	2	0.75/hr
Elliptio complanata	Eastern Elliptio	311	116.48/hr
Elliptio congaraea	Carolina Slabshell	2	0.75/hr
Elliptio icterina	Variable Spike	41	15.36/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Middle Creek Site-110526.3tws

This additional site extended from the SR 1507 crossing to a point approximately 450 meters upstream. The channel ranged between 8 and 10 meters wide with approximately 2.0 meter high banks meter high banks that exhibited some erosion. Habitat in this reach consisted of a series of riffle/run/pool sequences. The substrate was dominated by sand and gravel, with occasional patches of cobble. Surveys were conducted for 3.00 person hours.

Table 74. Middle Creek Site- 110526.3tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.33/hr
Elliptio complanata	Eastern Elliptio	414	138.00/hr
Elliptio congaraea	Carolina Slabshell	6	2.00/hr
Elliptio fisheriana	Northern Lance	21	7.00/hr
Elliptio icterina	Variable Spike	71	23.67/hr
Elliptio lanceolata	Yellow Lance	1	0.33/hr
Elliptio mediocris	No Common Name	4	1.33/hr
Lampsilis radiata	Eastern Lampmussel	5	1.67/hr
Strophitus undulatus	Creeper	4	1.33/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Middle Creek Site-110603.1tws

This additional site occurs in the vicinity of a remnanent milldam just above the SR 1504 crossing. The channel ranged between 10 and 12 meters wide with approximately 2.0 meter high banks meter high banks that exhibited some erosion. Habitat in this reach consisted of a riffle/run/pool sequence with a midchannel sandbar. The substrate was dominated by bedrock overlain with cobble and gravel, and sand. Surveys were conducted for 3.00 person hours.

Table 75. Middle Creek Site- 110603.1tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	43	14.33/hr
Elliptio congaraea	Carolina Slabshell	5	1.67/hr
Elliptio icterina	Variable Spike	3	1.00/hr
Elliptio sp. cf. mediocris	n/a	6	2.00/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Middle Creek Site-110603.2tws

This additional site occurs in a long straight run upstream of the SR 1504 crossing. The channel ranged between 8 and 10 meters wide with approximately 2.0 meter high banks meter high banks that exhibited some erosion. The substrate was dominated by shifting sand and clay banks. Surveys were conducted for 3.00 person hours.

Table 76. Middle Creek Site- 110603.2tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	237	79.00/hr
Elliptio congaraea	Carolina Slabshell	3	1.00/hr
Elliptio icterina	Variable Spike	71	23.67/hr
Elliptio sp. cf. mediocris	n/a	5	1.67/hr
Lampsilis radiata	Eastern Lampmussel	1	0.33/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Middle Creek Site-110603.3tws

This additional site occurs within a large glide-riffle habitat sequence above the SR 1504 crossing. The channel was approximately 10 meters wide with approximately 2.0 meter high banks meter high banks that exhibited some erosion. The substrate was dominated by gravel and sand with clay banks. Surveys were conducted for 3.67 person hours.

Table 77. Middle Creek Site- 110603.3tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	158	43.05/hr
Elliptio congaraea	Carolina Slabshell	14	3.81/hr
Elliptio icterina	Variable Spike	16	4.36/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.27/hr
Elliptio sp. cf. mediocris	n/a	13	3.54/hr
Lampsilis radiata	Eastern Lampmussel	1	0.27/hr
Strophitus undulatus	Creeper	1	0.27/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Middle Creek Site-110603.4tws

This additional site occurs within a long deep pool, with short shallow riffles created by log jams. The substrate was dominated by sand, with clay banks. Much of the substrate in the pool habitats was covered with detritus and silt. The channel was approximately 10 meters wide with approximately 2.0 meter high banks that exhibited some erosion. Surveys were conducted for 2.33 person hours.

Table 78. Middle Creek Site- 110603.4tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	75	32.19/hr
Elliptio congaraea	Carolina Slabshell	1	0.43/hr
Elliptio icterina	Variable Spike	4	1.72/hr
Elliptio sp. cf. mediocris	n/a	4	1.72/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Middle Creek Site-110603.5tws

This additional site extends from the NC 210 crossing to a point approximately 650 meters upstream. Habitat consists of a long deep pool, with short shallow riffles created by log jams. The substrate was dominated by sand, with clay banks. Much of the substrate in the pool habitats was covered with detritus and silt. The channel was approximately 13 meters wide with approximately 2.0-3.0 meter high banks that exhibited some erosion. Surveys were conducted for 2.00 person hours.

Table 79. Middle Creek Site- 110603.5tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	16	8.00/hr
Elliptio sp. cf. mediocris	n/a	1	0.50/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common
Elimia catenaria	Gravel Elimia	~	Patchy Uncommon

Middle Creek Site-110607.1tws

At this additional site, the channel was approximately 13 meters wide with approximately 2.5 meter high banks that exhibited some erosion. The substrate was dominated by sand and pebble. Surveys were conducted for 2.50 person hours.

Table 80. Middle Creek Site- 110607.1tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	94	37.60/hr
Elliptio congaraea	Carolina Slabshell	6	2.40/hr
Elliptio fisheriana	Northern Lance	18	7.20/hr
Elliptio icterina	Variable Spike	20	8.00/hr
Strophitus undulatus	Creeper	1	0.40/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Middle Creek Site-110607.2tws

At this additional site, the channel was approximately 12 meters wide with approximately 2.5 meter high banks that exhibited some erosion. The substrate was dominated by sand and clay. Surveys were conducted for 1.15 person hours.

Table 81. Middle Creek Site- 110607.2tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	49	42.61/hr
Elliptio congaraea	Carolina Slabshell	1	0.87/hr
Elliptio fisheriana	Northern Lance	3	2.61/hr
Elliptio icterina	Variable Spike	5	4.35/hr
Elliptio sp. cf. mediocris	n/a	1	0.87/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Rare
Corbicula fluminea	Asian Clam	~	Abundant

Middle Creek Site-110607.3tws

At this additional site, the channel was approximately 12 meters wide with approximately 2.5 meter high banks that exhibited some erosion. The substrate was dominated by sand, bedrock, and pebble. Surveys were conducted for 2.50 person hours.

Table 82. Middle Creek Site- 110607.3tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	64	25.60/hr
Elliptio congaraea	Carolina Slabshell	3	1.20/hr
Elliptio fisheriana	Northern Lance	1	0.40/hr
Elliptio icterina	Variable Spike	5	2.00/hr
Elliptio sp. cf. mediocris	n/a	2	0.80/hr
Strophitus undulatus	Creeper	1	0.40/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Middle Creek Site-110607.4tws

At this additional site, the channel was approximately 12 meters wide with approximately 0.5-1 meter high banks that exhibited some erosion. The substrate was dominated by sand and gravel. Surveys were conducted for 1.00 person hour.

Table 83. Middle Creek Site- 110607.4tws (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	13	13.00/hr
Elliptio congaraea	Carolina Slabshell	1	1.00/hr
Elliptio icterina	Variable Spike	2	2.00/hr
Elliptio sp. cf. mediocris	n/a	2	2.00/hr
Strophitus undulatus	Creeper	1	1.00/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Middle Creek Site-110609.1ted-(920910.5jma)

This targeted site was the location of a DWM find in 1992. The channel ranged from 5 to 10 meters wide with approximately 1 meter high banks that exhibited some erosion. The substrate was dominated by sand and gravel. Surveys were conducted for 3.50 person hours.

Table 84. Middle Creek Site- 110609.1ted (920910.5jma): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	2	0.57/hr
Elliptio complanata	Eastern Elliptio	157	44.86/hr
Elliptio congaraea	Carolina Slabshell	23	6.57/hr
Elliptio fisheriana	Northern Lance	5	1.43/hr
Elliptio icterina	Variable Spike	16	4.57/hr
Lampsilis radiata	Eastern Lampmussel	2	0.57/hr
Strophitus undulatus	Creeper	4	1.14/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Patchy Common
Corbicula fluminea	Asian Clam	~	Abundant

Middle Creek Site-110609.2ted-(920518.1jma)

This targeted site was the location of a DWM find in 1992. The channel ranged from 10 to 12 meters wide with approximately 1 meter high banks that exhibited some erosion. The substrate was dominated by sand, gravel, cobble, and clay bank. High woody debris was noted. Surveys were conducted for 3.60 person hours.

Table 85. Middle Creek Site- 110609.2ted (920518.1jma): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	185	51.39/hr
Elliptio congaraea	Carolina Slabshell	2	0.56/hr
Elliptio icterina	Variable Spike	57	15.83/hr
Elliptio sp. cf. mediocris	n/a	3	0.83/hr
Lampsilis radiata	Eastern Lampmussel	1	0.28/hr
Strophitus undulatus	Creeper	3	0.83/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Patchy Uncommon
Corbicula fluminea	Asian Clam	~	Abundant

Middle Creek Site-110609.3ted

At this additional site, the channel was approximately 7 meters wide with approximately 1 meter high banks that exhibited significant erosion. The substrate was dominated by sand and pebble. Surveys were conducted for 2.00 person hours.

Table 86. Middle Creek Site- 110609.3ted (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	73	36.50/hr
Elliptio icterina	Variable Spike	18	9.00/hr
Elliptio congaraea	Carolina Slabshell	3	1.50/hr
Strophitus undulatus	Creeper	3	1.50/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Middle Creek Site-110609.4ted

At this additional site, the channel was approximately 8 meters wide with approximately 1 meter high banks that exhibited some erosion. The substrate was dominated by sand, rocky cobble, and clay banks. Surveys were conducted for 1.50 person hours.

Table 87. Middle Creek Site- 110609.4ted (Additional): Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	106	70.67/hr
Elliptio congaraea	Carolina Slabshell	4	2.67/hr
Elliptio icterina	Variable Spike	18	12.00/hr
Strophitus undulatus	Creeper	5	3.33/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

Middle Creek Site-110621.5Catena

At this additional site, the channel ranged from 10 to 12 meters wide with approximately 2 meter high banks that exhibited some erosion. The substrate was dominated by sand and clay banks. Surveys were conducted for 3.00 person hours.

Table 88. Middle Creek Site- 110621.5Catena (Additional) Mollusk Species Found

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	59	19.67/hr
Elliptio congaraea	Carolina Slabshell	11	3.67/hr
Elliptio icterina	Variable Spike	4	1.33/hr
Lampsilis radiata	Eastern Lampmussel	1	0.33/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Present
Corbicula fluminea	Asian Clam	~	Common
Elimia catenaria	Gravel Elimia		Present

3.0 MUSSEL SPECIES DESCRIPTIONS

Brief descriptions of the three target mussel species found during this survey effort, are provided below as are descriptions of the 13 other mussel species found. Additional target species not found, but potentially present, are included for information purposes.

3.1 Federally Protected Species

Prior to these surveys, the DWM had been found in Swift Creek, Little Creek, White Oak Creek and Middle Creek, and was historically known from the Neuse River in Wake County. The only known occurrence of the TSM in the Neuse River Basin is from the Little River in Johnston County. This species has never been found in Swift Creek, and was not found during this study.

3.1.1 Alasmidonta heterodon (Dwarf Wedgemussel)

3.1.1.1 Characteristics

The DWM was originally described as *Unio heterodon* (Lea 1829). Simpson (1914) subsequently placed it in the genus *Alasmidonta*. Ortmann (1914) placed it in a monotypic subgenus *Prolasmidonta*, based on the unique soft-tissue anatomy and conchology. Fuller (1977) believed the characteristics of *Prolasmidonta* warranted elevation to full generic rank and renamed the species *Prolasmidonta heterodon*. Clarke (1981) retained the genus name *Alasmidonta* and considered *Prolasmidonta* to be a subjective synonym of the subgenus *Pressodonta* (Simpson 1900). Based on recent DNA analyses, it is suggested that the species *A. heterodon* should be moved to a genus separate from *Alasmidonta*. This new placement would be *Pressodonta heterodon* (Bogan et al. 2008).

The specific epithet *heterodon*, refers to the chief distinguishing characteristic of this species, which is the only North American freshwater mussel that consistently has two lateral teeth on the right valve and only one on the left (Fuller 1977). All other laterally dentate freshwater mussels in North America normally have two lateral teeth on the left valve and one on the right. The DWM is generally small, with a shell length ranging between 25 mm and 38 mm. The largest specimen reported by Clarke (1981) was 56.5 mm long, taken from the Ashuelot River in New Hampshire. The periostracum is generally olive green to dark brown; nacre bluish to silvery white, turning to cream or salmon colored towards the umbonal cavities. Sexual dimorphism occurs in DWM, with the females having a swollen region on the posterior slope, and the males are generally flattened. Clarke (1981) provides a detailed description of the species.

Nearly all freshwater mussel species have similar reproductive strategies; a larval stage (glochidium) becomes a temporary obligatory parasite on a fish. Many mussel species have specific fish hosts, which must be present to complete their life cycle. Based upon laboratory infestation experiments, Michaelson and Neves (1995) determined that potential fish hosts for the DWM in North Carolina include the Tesselated Darter (*Etheostoma olmstedi*) and the Johnny Darter (*E. nigrum*). McMahon and Bogan (2001) and Pennak (1989) should be consulted for a general overview of freshwater mussel reproductive biology.

3.1.1.2 Distribution and Habitat Requirements

The historic range of the DWM was confined to Atlantic slope drainages from the Peticodiac River in New Brunswick, Canada, south to the Neuse River, North Carolina. Occurrence records exist from at least 70 locations, encompassing 15 major drainages, in 11 states and one Canadian Province (USFWS 1993). When the recovery plan for this species was written, the DWM was believed to have been extirpated from all but 36 localities, 14 of them in North Carolina (USFWS 1993). The most recent assessment (2007 5-Year Review) indicates that the DWM is currently found in 15 major drainages, comprising approximately 70 "sites" (one site may have multiple occurrences). At least 45 of these sites are based on less than five individuals or solely on relict shells. It appears that the populations in North Carolina, Virginia, and Maryland are declining as evidenced by low densities, lack of reproduction, or inability to relocate any individuals in follow-up surveys. Populations in New Hampshire, Massachusetts, and Connecticut appear to be stable, while the status of populations in the Delaware River watershed affected by the recent floods of 2005 is uncertain (USFWS 2007).

Strayer *et al*. (1996) conducted range-wide assessments of remaining DWM populations, and assigned a population status to each. The status rating is based on range size, number of individuals and evidence of reproduction. Seven of the 20 populations assessed were considered "poor", and two others are considered "poor to fair" and "fair to poor" respectively. In North Carolina, populations are found in portions of the Neuse and Tar River basins; however it is believed to have been extirpated from the main-stem of the Neuse River. It was found at 3 sites within the study area in 2011, all in Swift Creek.

The DWM inhabits creeks and rivers of varying sizes (down to approximately two meters wide), with slow to moderate flow. A variety of preferred substrates have been described that range from coarse sand, to firm muddy sand to gravel (USFWS 1993). In North Carolina, DWM often occur within submerged root mats along stable streambanks. The wide range of substrate types used by this species suggests that the stability of the substrate is likely as important as the composition.

3.1.1.3 Threats to Species

The cumulative effects of several factors, including sedimentation, point and non-point discharge, and stream modifications (impoundments, channelization, *etc.*), have contributed to the decline of this species throughout its range. With the exception of the Neversink River population in New York, which has an estimated population of over 80,000 DWM individuals, all of the other populations are generally small in numbers and restricted to short reaches of isolated streams. The low numbers of individuals and the restricted range of most of the surviving populations make them extremely vulnerable to extirpation from a single catastrophic event or activity (Strayer *et al*. 1996). Catastrophic events may consist of natural events such as flooding or drought, as well as human influenced events such as toxic spills associated with highways, railroads, or industrial- municipal complexes.

Siltation resulting from substandard land-use practices associated with activities such as agricultural, forestry and land development has been recognized as a major contributing factor to degradation of mussel populations (USFWS 1996). Siltation has been documented to be extremely detrimental to mussel populations by degrading substrate and water quality, increasing potential exposure to other pollutants, and by direct smothering of mussels (Ellis 1936, Markings and Bills 1979). Sediment accumulations of less than 25 mm have been shown to cause high mortality in most mussel species (Ellis 1936). In Massachusetts, a bridge construction project decimated a population of the DWM because of accelerated sedimentation and erosion (Smith 1981).

Sewage treatment effluent has been documented to significantly affect the diversity and abundance of mussel fauna (Goudreau *et al*. 1988). Goudreau *et al*. (1988) found that recovery of mussel populations may not occur for up to 3,218 meters (two miles) below points of chlorinated sewage effluent.

The impact of impoundments on freshwater mussels has been well documented (USFWS 1992a, Neves 1993). Construction of dams transforms lotic habitats into lentic habitats, which results in changes in aquatic community composition. The changes associated with inundation adversely affect both adult and juvenile mussels as well as fish community structure, which could eliminate possible fish hosts for upstream transport of glochidia. Muscle Shoals on the Tennessee River in northern Alabama, once the richest site for naiads (mussels) in the world, is now at the bottom of Wilson Reservoir and covered with 5.79 meters (19 feet) of muck (USFWS 1992b). Large portions of all of the river basins within the DWM's range have been impounded and this is believed to be a major factor contributing to the decline of the species (Master 1986, USFWS 1993).

The introduction of exotic species such as the Asian Clam (*Corbicula fluminea*) and Zebra Mussel (*Dreissena polymorpha*) has also been shown to pose significant threats to native freshwater mussels. The Asian Clam is now established in most of the major river systems in the United States (Fuller and Powell 1973), including those streams still supporting surviving populations of the DWM. Concern has been raised over competitive interactions for space, food and oxygen with this species and native mussels, possibly at the juvenile stages (Neves and Widlak 1987, Alderman 1995). The Zebra Mussel, native to the drainage basins of the Black, Caspian and Aral Seas, is an exotic freshwater mussel that was introduced into the Great Lakes in the 1980s and has rapidly expanded its range into the surrounding river basins, including those of the South Atlantic slope (O'Neill and MacNeill 1991). This species competes for food resources and space with native mussels, and is expected to contribute to the extinction of at least 20 freshwater mussel species if it becomes established throughout most of the eastern United States (USFWS 1992b). The Zebra Mussel is not currently known from any river supporting DWM populations.

3.1.2 Elliptio steinstansana (Tar River Spinymussel)

3.1.2.1 Characteristics

The TSM grows to a maximum length of 60 millimeters. Short spines are arranged in a radial row anterior to the posterior ridge on one valve and symmetrical to the other valve. The shell is generally smooth in texture with as many as 12 spines that project perpendicularly from the surface and curve slightly ventrally. However, adult specimens tend to lose their spines as they mature (USFWS 1992a). The TSM is distinguished by its shiny periostracum, parallel pseudocardinal teeth, and the linear ridges on the inside surface of the shell.

Little is known about the reproductive biology of the TSM (USFWS 1992c), however, nearly all freshwater mussel species have similar reproductive strategies, which involves a larval stage (glochidium) that becomes a temporary obligatory parasite on a fish. Many mussel species have specific fish hosts, which must be present to complete their life cycle. McMahon and Bogan (2001) and Pennak (1989) should be consulted for a general overview of freshwater mussel reproductive biology.

3.1.2.2 Distribution and Habitat Requirements

This species was believed to be endemic to the Tar River system, when it was listed as endangered in 1985; however since then it has also been found in the Neuse River Basin. Historically, the TSM was collected in the Tar River from near Louisburg in Franklin County to Falkland in Pitt County, a range of approximately 125.5 kilometers (78 river miles). Clarke (1983) located TSM in only a 19.31 km (12-mile) stretch of the Tar River in Edgecombe County. Currently it is believed to be occurring in relatively short stretches of the Tar River and three creeks (Shocco, Sandy/Swift and Fishing/Little Fishing) in the Tar drainage. Since 1998, five individuals of this species have been found in the Little River of the Neuse River Basin in Johnston (NCWRC unpublished data). This species is also listed as being found in the Little

River in site records of Clarke (1983), but was not mentioned in the report. The TSM has never been found in any of the water bodies in the project area, nor was it found in the project corridor streams during the 2011 effort.

The preferred habitat of the TSM in Swift Creek of the Tar River Basin was described as relatively fast flowing, well oxygenated, circumneutral pH water in sites prone to significant swings in water velocity, with a substrate comprised of relatively silt-free loose gravel and/or coarse sand.

3.1.2.3 Threats to Species

The cumulative effects of several factors, including sedimentation, point and non-point discharge, and stream modifications (impoundments, channelization, *etc*.), have contributed to the decline of this species throughout its range. The remaining populations of TSM are generally small in numbers. The low numbers of individuals and the restricted range of most of the surviving populations make them extremely vulnerable to extirpation from a single catastrophic event or activity (Strayer *et al*. 1996). Catastrophic events may consist of natural events such as flooding or drought, as well as human influenced events such as toxic spills associated with highways, railroads or industrial- municipal discharges. Other threats are similar to those described above for DWM.

3.2 Target Federal Species of Concern (FSC)

The four FSC species targeted have been previously reported in the study area; however, prior to this effort, no recent records of the Green Floater, or Yellow Lampmussel were known.

3.2.1 Elliptio lanceolata (Yellow Lance)

3.2.1.1 Characteristics

The Yellow Lance was described from the Tar River at Tarboro, North Carolina by I. Lea in 1828. This species differs from other lance-shaped elliptios by having a “waxy” bright yellow periostracum that lacks rays. The posterior ridge is distinctly rounded and curves dorsally towards the posterior end.

3.2.1.2 Distribution and Habitat Requirements

This species is distributed from the Neuse River Basin north to the Rappahannock, but is not believed to occur in the Roanoke or James River Basin. It is in considerable decline throughout its range. Extant populations occur in the Neuse, Tar/Pamlico, Chowan and York River basins. This species is found in small streams to large rivers in substrates primarily consisting of clean sand, and occasionally gravel. It was found at six sites within Swift Creek and one site in Middle Creek during the 2011 surveys.

3.2.1.3 Threats to Species

Threats to this and many other freshwater mussel species are similar to those described above for the DWM. The Yellow Lance species is a FSC and is listed as Endangered in North Carolina. Williams *et al*. (1993) list this species as Endangered. There appears to be sufficient data to warrant elevation of the Yellow Lance to Candidate status in the very near future (John Fridell, Recovery Biologist USFWS, Personal Communication).

3.2.2 *Fusconaia masoni (Atlantic Pigtoe)*

3.2.2.1 Characteristics

The Atlantic Pigtoe was described by Conrad (1834) from the Savannah River in Augusta, Georgia. Shells of the Atlantic pigtoe are subrhomboidal in outline, with a parchment-like yellow to dark brown periostracum. The posterior ridge is very distinct, and the umbos extend well above the dorsal margin.

The Atlantic Pigtoe is a tachytictic (short-term) breeder, brooding young and releasing glochidia in early summer. The Bluegill (*Lepomis macrochirus*) and Shield Darter (*Percina peltata*) have been identified as potential fish hosts for this species (O'Dee and Watters 2000).

3.2.2.2 Distribution and Habitat Requirements

The Atlantic Pigtoe ranges from the Ogeechee River Basin in Georgia north to the James River Basin in Virginia. It occurs in medium size streams to large rivers, but has experienced major declines throughout its entire range. The preferred habitat for this species is a substrate composed of gravel and coarse sand, usually at the base of riffles, however, it can be found in a variety of other substrates and habitat conditions (personal observations). It was found at 34 sites within Swift Creek during the 2011 effort.

3.2.2.3 Threats to Species

Threats to this and many other freshwater mussel species are similar to those described above for the DWM. This species is a FSC and is listed as Endangered in North Carolina. Williams *et al*. (1993) list this species as Endangered. There appears to be sufficient data to warrant elevation of the Atlantic pigtoe to Candidate status in the very near future (John Fridell, Recovery Biologist USFWS, Personal Communication).

3.2.3 *Lasmigona subviridis (Green Floater)*

3.2.3.1 Characteristics

The Green Floater was described by Conrad (1835) from the Schuykill River in Lancaster County, Pennsylvania. The small mussel species has a thin slightly inflated subovate shell that is narrower in front, higher behind. The dorsal margin forms a blunt angle with the posterior margin. The shell is dull yellow or tan to brownish green, usually with concentrations of dark green rays.

3.2.3.2 Distribution and Habitat Requirements

The Green Floater occurs along the Atlantic slope from the Savannah River in Georgia north to the Hudson River in New York, as well as in the "interior" basins (New, Kanawah, and Watauga Rivers) of the Tennessee River basin. It occurs in small size streams to large rivers, in quiet waters such as pools, or eddies, with gravel and sand substrates. It has experienced major declines throughout its entire range. It was not found in the study area during the 2011 surveys, and has not been found in Swift Creek since the early 1990's.

3.2.3.3 Threats to Species

Threats to this and many other freshwater mussel species are similar to those described above for the DWM. This species is a FSC and is listed as Endangered in North Carolina. Williams *et al.* (1993) list this species as Threatened. Based on preliminary genetics research, the southern populations of the Green Floater (Tar Pamlico, Neuse, and Yadkin/Pee Dee River Basins) appear to be genetically distinct from populations from the Roanoke River to the north and west (Morgan Railey and Arthur Bogan, North Carolina Museum of Natural Sciences, 2007 Personal Communication). Further research is needed to determine if these differences warrant classification of the southern populations as a distinct species.

3.2.4 Lampsilis cariosa (Yellow Lampmussel)

3.2.4.1 Characteristics

This species was described from the Schuylkill River near Philadelphia (Say 1817). The waxy-yellow shell is obovate in outline, with a rounded anterior margin and slightly curved posterior margin, and is rarely rayed. The shell thickness begins as thin in juveniles becoming thicker with age. The moderately inflated shell attains a length of 120 mm (Bogan 2002). Male shells are elliptical and somewhat elongate in outline with the ventral margin evenly convex. Female shells are subovate to obovate in outline with the ventral margin expanded near the posterior margin, sloping up to a very bluntly rounded posterior margin. Posterior ridge is poorly developed and rounded, posterior slope slightly convex to flat. Beaks moderately swollen but not elevated much above the hinge line, located anterior of the middle of the shell, beak sculpture consist of about five poorly defined bars, the first ridge concentric with the remainder slightly double-looped. The left valve has two compressed pseudocardinal teeth, the posterior tooth low and immediately under the umbo, and two delicate lateral teeth. The right valve has a single compressed pseudocardinal tooth, and a single lamellar lateral tooth. The pseudocardinal teeth tend to become more stumpy and ragged with age. The interdentum is practically absent, and the beak cavity is open and moderately deep. Older specimens become brownish and loose much of the luster. Nacre color is bluish-white, often tinged with cream or salmon.

3.2.4.2 Distribution and Habitat Requirements

The Yellow Lampmussel is found from the lower Ottawa River, Canada eastward to the Sydney River, Nova Scotia then south to the Ogeechee River Drainage Basin in Georgia (Johnson 1970). At one time this species probably ranged throughout most of the Atlantic drainages in North Carolina; however, historical records provided by Johnson (1970) and recent records (Bogan 2002, NCWRC Unpublished Data) indicate the species occurs in the Catawba, Pee Dee, Waccamaw, Cape Fear, Neuse, Tar/Pamlico, and Chowan drainages. It was not found in the study area in 2011, and has only ever been recorded from one location in the Swift Creek subbasin, an unnamed tributary to Swift Creek in Wake County (Johnson 1970).

3.2.4.3 Threats to Species

Threats to this and many other freshwater mussel species are similar to those described above for the DWM. This species is a FSC and is listed as Endangered in North Carolina. Williams *et al.* (1993) also list this species as Endangered.

3.3 Other Mussel Species Located During the 2011 Surveys

3.3.1 Alasmidonta undulata (Triangle Floater)

This species was described from the Schuylkill River near Philadelphia (Say 1817). Its range extends from the Catawba River in North Carolina north to the lower St. Lawrence River. The shell shape is subtriangular to ovate and inflated. The anterior and ventral shell margins are rounded. The periostracum is yellowish green with broad green or black rays. This species is considered Special Concern throughout its range (Williams *et al*. 1993). It is considered Threatened in North Carolina. This species was found at 39 sites in Swift Creek, 3 sites in Middle Creek, and 1 site in Little Creek during the 2011 effort.

3.3.2 Elliptio complanata (Eastern Elliptio)

This species was described as *Mya complanata* from the Potomac River in Maryland (Lightfoot 1786). Shell characteristics are highly variable. Shell shape is typically trapezoidal to rhomboid and compressed to inflated. The usually straight ventral margin is mostly parallel with the dorsal margin and the posterior margin is broadly rounded. Shell thickness varies from thin to solid. This species is widely distributed along the Atlantic Slope from Altamaha River Basin in Georgia north to the St. Lawerence River Basin, and west to Lake Superior and parts of the Hudson Bay Basin. It can be found in a variety of habitats from large rivers and, lakes to small headwater streams. The species is widespread and common throughout its range and considered stable (Williams *et al*. 1993). It was found at all 85 sites during the 2011 effort.

3.3.3 Elliptio congaraea (Carolina Slabshell)

This species was described from the Congaree River, South Carolina by Lea (1831). The range of this species extends from the Ogeechee River, Georgia north to the Chowan River, North Carolina and Virginia. The shell is rhomboid and subcompressed with moderately full beaks. The front of the shell is wedge-shaped, with the posterior end obliquely truncate above and biangulate below. The posterior slope usually has numerous cross corrugations or wrinkles. The periostracum is greenish-yellow or tawny. (Williams *et al*. 1993) list this species as Special Concern. It is considered a Watch2/Watch 5 species, which indicates that the species is rare to uncommon, but probably not in trouble (W2), but has known increasing threats to its habitat, whether populations are known to be declining or not (W5) (LeGrand et al. 2010). This species was found at 65 sites in the study corridor during the 2011 effort.

3.3.4 Elliptio fisheriana (Northern Lance)

This species was described from the Chester River in Maryland (Lea 1838). The shell is more than twice as long as high coming to a posterior point, usually at or above the midline between the dorsal and ventral margins. The dorsal ridge is angled. The smooth periostracum of the northern lance is usually yellowish-green with darker green rays, becoming black with age. Johnson (1970) synonymized this species and 25 other named species of lance-shaped elliptio mussels into *Elliptio lanceolata*. Recent genotypic and phenotypic analysis suggests that some of these formally described species are valid, including "true" *Elliptio lanceolata* (type locality, Tar River). Northern populations are thinner and more elongate than those from the south. The nacre may be purple or white. The northern lance likely encompasses several lanceolate elliptios, with similar characteristics that were described from a number of river basins along the Atlantic Slope. Included in this is *Elliptio viridula* from the Neuse River Basin. The name *E.*

fisheriana is used for these forms as it is the oldest one. Because of taxonomic uncertainty, the status of this species is undetermined.

The northern lance was found at five sites in Middle Creek and one site in Swift Creek. It was typically found in shallow, bank habitats with soft substrates, and with the exception of two sites in Middle Creek, 110526.3tws and 110607.1tws (21 and 18 individuals) it occurred in relatively low numbers. One of the sites where this species occurred (110526.3tws) was also occupied by the yellow lance. Even though habitat preferences of the northern lance are very different (bank habitats with soft substrates as opposed to SFC riffle habitats), it is very rare for these two species to occur in the same area (personal observations). This phenomenon is not understood.

3.3.5 *Elliptio icterina (Variable Spike)*

Described from the Savannah River near Augusta, Georgia (Conrad 1834), this highly variable species represents a complex of nearly 50 named species (Johnson 1970). The shell shape is oblong, subelliptical, or subrhomboid, with a prominent posterior ridge, and moderately elevated beaks. The periostracum is usually smooth and greenish yellow to tawny-brown. This species is considered common and currently stable throughout its range (Williams *et al*. 1993). It was found at 82 sites in the study corridor during the 2011 effort.

3.3.6 *Elliptio producta (Atlantic Spike)*

This species was described from the Savannah River, Georgia by Conrad (1836). The range of this species extends from the Savannah River, Georgia north to the Potomac River Basin in Maryland and Virginia. The Atlantic Spike was once synonymized with *Elliptio lanceolata* (Johnson 1970), but is now considered a separate species. The anterior shell margin is rounded and the posterior margin roundly pointed with the most posterior point slightly above the midline of the shell. The periostracum is often shiny, dark reddish brown to greenish brown, generally with out rays. Shell nacre is variable shades of purple. Williams *et al*. (1993) list this species as Special Concern. The Atlantic spike was found at nine sites in the study corridor during the 2011 effort.

3.3.7 *Elliptio roanokensis (Roanoke Slabshell)*

The Roanoke Slabshell was described from the Roanoke River (exact location unknown) by I. Lea (1838). The reported range of this species extends from the Connecticut River in Massachusetts south to the Savannah River in Georgia (Walter 1954). Based on shell morphologies, Johnson (1970) synominized this and 100 other species into the *Elliptio complanata* complex, however it is now widely recognized as being a valid species. The periostracum is generally very smooth, often with plications (furrows) and reddish yellow in color. Shells of this species reach lengths exceeding 150 mm. This species is listed as Threatened in North Carolina. Williams *et al*. (1993) list this species as Special Concern. This species was found at 28 sites in the study corridor during the 2011 effort.

3.3.8 *Elliptio sp. c.f. mediocris (No Common Name)*

This species was described from the Neuse River 6 miles east of Raleigh (Lea 1863). Although Johnson (1970) synonomized this into the *E. complanata* complex and even though there has been no subsequent publication recognizing it as a distinct species, most aquatic biologists working with freshwater mussels on the Atlantic slope recognize it as such. Shell shape is typically rhomboid, and inflated. The usually straight ventral margin is mostly parallel with the dorsal margin and the posterior margin is broadly rounded. Unlike most forms of *E. complanata*, the beaks are moderately full, and the periostracum is covered with dark green rays of varying width that remain conspicuous even with older individuals. The posterior slope is high, but more rounded than *E. congarea*. This species was found at 57 sites in the study corridor during the 2011 effort.

3.3.9 Lampsilis radiata (Eastern Lampmussel)

Lampsilis radiata radiata (Eastern Lampmussel) and *Lampsilis radiata conspicua* (Carolina Fatmucket). Gmelin (1791) described *Mya radiata* and used Malabar, a region of southern India as the type locality. Ortmann (1919) reported this locality as incorrect and noted Lamarck (1819) had listed it from Saratoga Lake in New York and recommended "if there should not be any other earlier record, we might select this as the type locality." Simpson (1914) had earlier listed Virginia as the type locality, thus Johnson (1970) restricted the type locality to Potomac River, District of Columbia (approximately opposite Fairfax Co., Virginia). Lea (1872) described *Unio conspicuous* from the Yadkin River in Rowan County, North Carolina, which Simpson (1914) treated as a variety of *Lampsilis radiata radiata*, with which Johnson (1970) agreed.

This large mussel is subelliptical to subovate in outline. Shells are generally thick and solid, with rounded anterior and posterior margins and vary from hardly inflated to very inflated. The periostracum is usually yellowish or brownish green with dark green rays over the entire surface. Like other members of this genus, this species is sexually dimorphic, with the shells of the male being more elongate, and the females more rounded and swollen, particularly in the posterior margin. Left valve has two pseudocardinal teeth, the posterior one located under the umbo, and two straight lateral teeth. The right valve has two separate pseudocardinal teeth, the upper is smaller and compressed, and has a single straight lateral tooth. Interdentum is lacking, umbo cavity is shallow, compressed. Nacre color is white, may be tinged with pink or salmon or may be completely pink or salmon. Shells of the Carolina fatmucket are much larger and heavier than the shells of the Eastern lampmussel (Adams *et al*. 1990) and tend to be more shiny and smooth than the Eastern lampmussel, which is usually rough with close concentric wrinkles (Johnson, 1970, Timothy W. Savidge, Personal Observations). Also, the posterior ridge is much more broadly rounded in the Carolina fatmucket and, in general, the umbos are not as inflated. Adams *et al*. (1990) suggested that "because of these differences and because *L. r. radiata* is thought to parasitize an anadromous fish host and *L. r. conspicua* is found in areas without such fish species being present, it is possible that *L. r. radiata* and *L. r. conspicua* are separate species".

The taxonomic status of the *Lampsilis radiata* complex is still uncertain. Both the eastern lampmussel and the Carolina fatmucket forms are known to occur in the Neuse River basin. This large mussel is subelliptical to subovate in outline. Shells are generally thick and solid, with rounded anterior and posterior margins. The periostracum is usually yellowish or brownish green with dark green rays over the entire surface. Like other members of this genus, this species is sexually dimorphic, with the shells of the male being more elongate, and the females more rounded and swollen, particularly in the posterior margin. Williams *et al*. (1993) consider this species to be Stable; however, both the eastern lampmussel and the Carolina fatmucket are considered Threatened in North Carolina. This species was found at 44 sites in the study corridor during the 2011 effort.

3.3.10 Pyganodon cataracta (Eastern Floater)

Described by Say (1817) in the deep part of a milldam presumably near Philadelphia, this species is wide ranging in the Atlantic drainages from the lower St. Lawrence River Basin south to the Altamaha River Basin, Georgia, and in the Alabama-Coosa River drainage, and the Apalachicola and Coctawhatchee River Basins, Florida. The shells of this species are uniformly thin, and lack hinge teeth. The shell shape is ovate, subelliptical and elongate, with an evenly rounded anterior margin and a broadly rounded ventral margin. The periostracum is light to dark green with broad green rays on the posterior slope. Ortman (1919) recognized three generalized shell forms, the pond form, the creek/small river form and the big river form, that were related to environmental conditions. The pond form occurs in small ponds with muddy substrates, and is characterized by very thin elongate inflated shells. The creek form occurs in riffle-pool habitats in gravel substrates, and is much thicker and more compressed. The big river form is generally short and inflated and occurs in soft substrates. This species is considered common and currently stable throughout its range (Williams *et al*. 1993). It was found at 21 sites in the study corridor during the 2011 effort.

3.3.11 Strophitus undulatus (Creeper)

This mussel was described from the Schuylkill River near Philadelphia (Say 1817). Its range extends from throughout much of the Interior River Basin and Atlantic Slope regions. The shell is elliptical to rhomboid in outline and somewhat inflated. The anterior end is rounded, and the posterior end is bluntly pointed. The periostracum is yellowish green to brown, with dark green rays. Williams *et al*. (1993) consider this species to be Stable; however it is considered Threatened in North Carolina. It was found at nine sites within Middle Creek, 32 sites in Swift Creek, and two sites in Little Creek during the 2011 effort.

3.3.12 Utterbackia imbecillis (Paper Pondshell)

Described from the Wabash River in Indiana (Say 1829), this mussel occurs throughout the Mississippi River and Great Lakes drainages, south to northeastern Mexico and east along the Gulf Coast to Florida, as well as along the Atlantic Slope. It has an extremely thin shell that is oblong and inflated. The dorsal and ventral margins are nearly straight and parallel. The periostracum is greenish yellow with fine green rays. This species is considered common throughout its range (Williams *et al*. 1993). It was found at 10 sites.

3.3.13 Villosa constricta (Notched Rainbow)

Described by Conrad (1838) from the North River in Rockbridge County, Virginia, it is reported to occur from the James River Basin in Virginia south to the Catawba River Basin in North Carolina (Johnson 1970). The shell is fairly small and short, and subelliptical in outline. The beaks are generally not elevated. The periostracum is shiny yellowish green to black occasionally having dark green rays. Like other members of the genus, the notched rainbow is sexually dimorphic; however, the marsupial swelling of the females is generally small compared to other species. Williams *et al*. (1993) lists this species as Special Concern. It is listed as Special Concern in North Carolina. It was found at 2 sites in Section 2 of Swift Creek during the

2011 effort; however, it was only represented by fresh shells.

4.0 SURVEY DISCUSSION 2011

These survey efforts provide a comprehensive, updated evaluation of freshwater mussel species occurring within habitats known to be occupied or to have been recently occupied by the DWM. At least one freshwater mussel species was found in all of the sites sampled. Three of the six potential federally protected or likely candidate mussel species were found during this study: the federally Endangered DWM, and the FSC and North Carolina listed Endangered Atlantic Pigtoe and Yellow Lance. These three species were found within Swift Creek and Yellow Lance was also found in Middle Creek. TSM, Yellow Lampmussel, and Green Floater were not found during the 2011 study, although habitat that could potentially support these species is present in much of the study area, based on the lack of any recent records, these three species are unlikely to occur in the study area. DWM was located in low numbers at only three survey sites (3.53%), although appropriate habitat and the presence of rare associate species at multiple sites suggest it may be present at other sites in low numbers. The Atlantic Pigtoe was found at 34 sites (40.0%), often represented by juvenile individuals, and the Yellow Lance was found at 7 sites (8.24%).

Although significant freshwater mussel resources occur within all three sections of the study area, habitat degradation and a decline in the relative abundances and species diversity is evident in some sections. The following discusses these habitat differences and results by section.

4.1 Section 1 Upper Swift Creek

Nine sites including seven DWM target sites were surveyed in Section 1; however, no DWM were found in 2011. Habitat conditions appear to be declining in recent years, with heavier sediment loads, streambed scour and streambank instability more evident in this section during the 2010 and 2011 surveys compared to surveys conducted in 2007 (Catena personal observations). Atlantic Pigtoe is persistant in this reach, occurring at five of the nine sites. Yellow Lance was found at one of nine sites in this reach. Other mussels found in this reach include Triangle Floater, Carolina Slabshell, Atlantic Spike, Roanoke Slabshell, Eastern Lampmussel, and Creeper.

4.2 Section 2 Middle Swift Creek

A total of 39 sites consisting of 12 DWM target sites were surveyed in Section 2. While no DWM were located within these target sections, the species was located at three of the additional Section 2 sites (total of 1 live and 2 shells). While signs of degradation (sediment load, eroded banks *etc*.) are evident, high quality mussel habitat consisting of a variety of microhabitats is present throughout this section. Atlantic Pigtoe is persistent in this reach, occurring at 28 of the 39 sites. Yellow Lance was found at five of 39 sites in this reach. Other mussels found in this reach include Triangle Floater, Carolina Slabshell, Atlantic Spike, Roanoke Slabshell, Eastern Lampmussel, Creeper and Notched Rainbow.

4.3 Section 3 Lower Swift Creek

Seven sites including one DWM target site were surveyed in Section 3 and no DWM were found. Much of the substrate in this section consists of shifting coarse sand, although small sections of cobble and gravel are also present. Atlantic Pigtoe was found at only one of the eight Section 3 survey sites. Yellow Lance was not found at any of the eight sites in this reach. Other mussels found in this reach include Triangle Floater, Carolina Slabshell, Northern Lance (one site), Roanoke Slabshell, and Eastern Lampmussel.

4.4 White Oak Creek

Four sites including two DWM target sites were surveyed in White Oak Creek and no DWM found. Habitat conditions were significantly different than what was reported at the previously known DWM sites, as one of these DWM target sites occurred in a separate channel that had been inundated by a recent beaver impoundment. The only rare mussel species found was a single Eastern Lampmussel.

4.5 Little Creek

Eight sites including two DWM target sites were surveyed in Little Creek and no DWM were found. Habitat conditions appear relatively stable and similar to those observed when DWM was found in 2003, so the species may persist in Little Creek. Rare species found in 2011 included Triangle Floater and Creeper.

4.6 Middle Creek

Seventeen sites including two DWM target sites were surveyed in Middle Creek and no DWM were found. Five rare species, the Yellow Lance, Triangle Floater, Eastern Lampmussel, Roanoke Slabshell and Creeper were found in Middle Creek in low numbers. Two other rare species known from previous surveys in Middle Creek, the Atlantic Pigtoe and the Notched Rainbow were not located. While an in depth analysis of mussel population trends in Middle Creek was not undertaken as part of this study, the lack of the Atlantic Pigtoe, and Notched Rainbow, as well as the relatively low numbers of the other rare species in the 2011 surveys compared with previous surveys (NCWRC Unpublished Database of Aquatic Species 2010) may indicate a declining trend in the species diversity, and number of rare species in Middle Creek. Habitat conditions with heavy sediment loads, stream-bed scour and stream-bank instability were evident at nearly all sites.

5.0 DWM POPULATION VIABILITY ANALYSIS

The overall goal of this study is to assess the viability of the DWM in Swift Creek. This species has consistently been rare in Swift Creek since its discovery in 1991 (Alderman 1991). As with many rare species, it is often necessary to evaluate more common associate species to serve as surrogates in the analyses. Therefore, this analysis will focus on trend data specific to the DWM, while also considering the entire mussel fauna in Swift Creek.

5.1 Viability Measures of DWM Population

The recovery goal identified for the DWM (USFWS 1993) is “to restore and maintain viable populations …to a significant portion of its historical range in order to remove the species from the Federal list of endangered and threatened species.” The maintenance of a viable population in Swift Creek is listed as a recovery objective (USFWS 1993). The recovery plan defines a viable population as “a population containing a sufficient number of reproducing adults to maintain genetic variability and in which annual recruitment is adequate to maintain a stable population." While the definition of what constitutes a viable population is clear, a quantifiable measure of population viability has been difficult to determine.

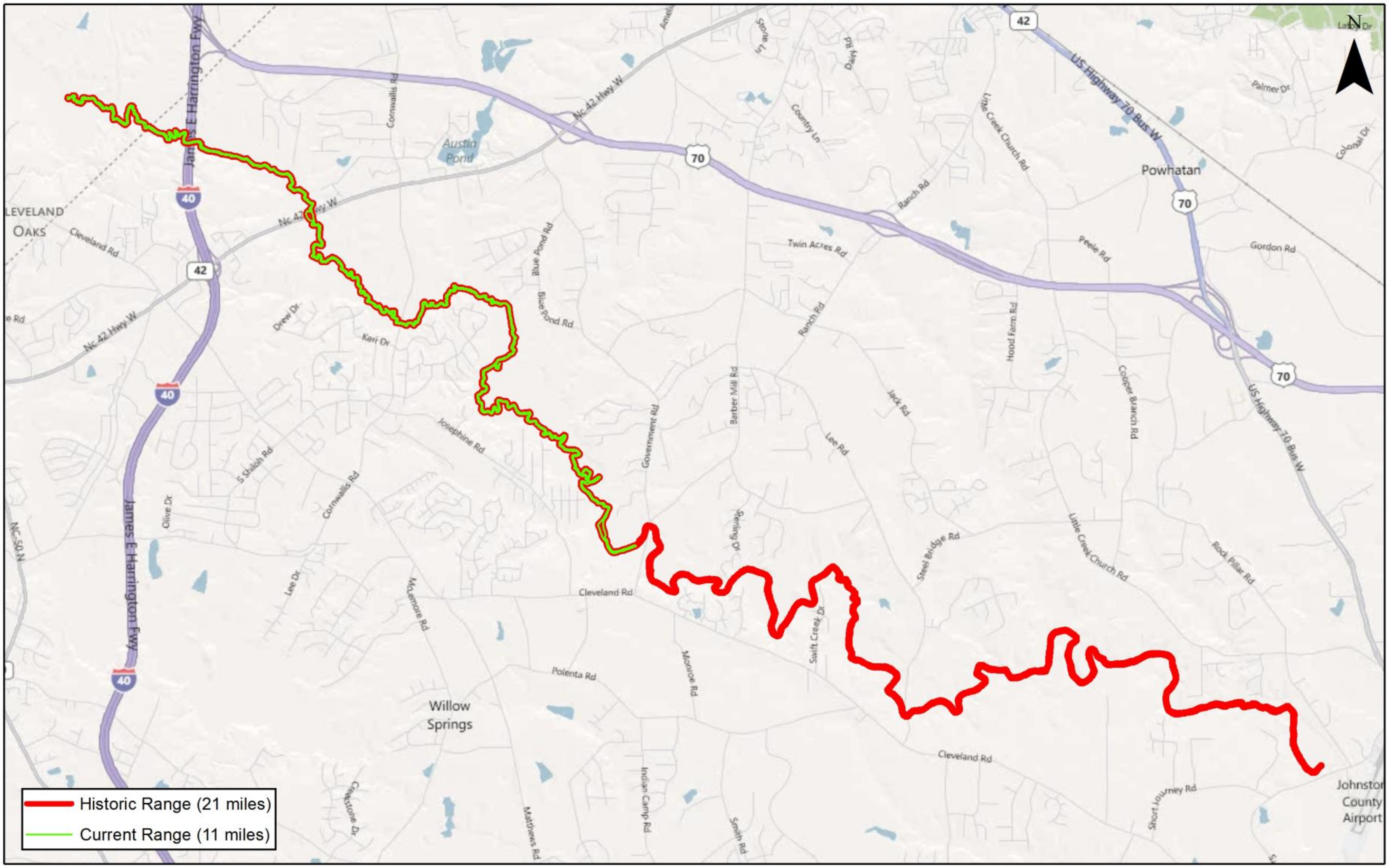
The Scientific Council on Freshwater and Terrestrial Mollusks (The Council), which currently consists of 17 scientists recognized for their respective knowledge on the status of mollusk species in North Carolina, was assembled by the North Carolina Nongame Wildlife Advisory Committee, an advisory committee that reports to the North Carolina WRC, to evaluate status listings of the rare, threatened, and endangered mollusks of North Carolina. The Council recognized a need to develop a quantitative ranking system to use as a tool for determining imperiled status of species that will lessen the subjective biases of existing ranking systems. One component of developing such a ranking system is determining population viability. As such, the Council suggested the following quantifiable criterion to measure population viability, the species should:

- Occupy between 10 to 20 miles of continuous habitat if dendritic (occurring in main stem and tributaries), or greater than 20 miles if linear, with no gaps greater than 2 miles of unoccupied habitat.
- Occur at 75% of sites within occupied habitat.
- Have a relative abundance as measured by CPUE of $\geq$ 5 individuals per hour at 50% of sites within occupied habitat.
- Exhibit evidence of reproduction (contain gravid individuals, and/or multiple size classes, including younger individuals.

These criteria have not been tested on mussel populations in the state, but were based on the collective opinions of the Council, and will likely need to be adjusted as these methods are applied and more information becomes available. While these measures of viability have not been officially adopted, they were incorporated into the study design to provide the basis for a specific and repeatable survey protocol targeting the DWM in Swift Creek watershed and for evaluating the resulting study data. The results of these survey efforts, coupled with the population trend analysis, will allow for some quantifiable gauge of the current population viability as it relates to these criteria, and whether they are appropriate measures of population viability.

5.1.1 Length of occupied habitat criterion

The historic range of the DWM population in Swift Creek is approximately 21 miles (Figure 1). Considering the occurrences of DWM in the tributaries White Oak Creek, Little Creek, and Middle Creek, and the fact that there are no known barriers that would limit connectivity (thus creating > two miles of unoccupied habitat), the assumed historic occupied habitat would be approximately 53.7 miles. This 53.7 miles was derived by adding the historic 21 mile range in Swift Creek to the combined distances of the most upstream DWM records in the respective tributaries to the respective confluences with Swift Creek (0.2 mile in White Oak Creek, 2.0 miles in Little Creek and 25.0 miles in Middle Creek), plus an additional 5.5 miles of Swift Creek from the most downstream historic occurrence to the confluence of Middle Creek. The survey efforts of 2007, 2010, and 2011 establish a current occupied range of at least 11 miles (Figure 1) in Swift Creek, with no gaps of unoccupied habitat greater than two miles. This is at the lower limits of the first population criterion.



The Catena Group

Client:

North Carolina Turnpike Authority

Triangle Expressway Southeast Extension

Dwarf Wedgemussel Historic and Current Occupied Range

Wake and Johnston Counties, North Carolina

Date: December 2011

Scale: 0 0.5 1 Miles

Job No.: 3297

Figure

1

While the species was not found in Little Creek during the 2011 surveys, habitat conditions appear relatively stable and are similar to those observed when DWM was found in 2003, suggesting that the species may still persist in Little Creek. Based on the assumption, it is unclear if this would constitute a separate population since there is greater than two miles with no recent DWM records between the downstream limits of the current 11 mile occupied range in Swift Creek and the confluence of Little Creek, or if it would represent a dendriditic expansion of the 11 miles of occupied habitat (assuming DWM is present in the greater than 2-mile gaps). More intensive surveys at various time intervals are needed in Little Creek as well as within Swift Creek near the confluence with Little Creek to determine DWM occupancy.

5.1.2 Occur at 75% of sites within occupied habitat criterion

In the recent surveys, within the 11 miles of Swift Creek believed to be occupied (47 of the 85 sites surveyed in 2011), the DWM was found at 6 of 62 sites (9.67%) in 2007, 5 of 83 sites (6.02%) in 2010, and 3 of 47 sites (6.38%) in 2011. The low number of occupied sites and extremely low CPUE during both studies are reflective of the rarity of this species in Swift Creek, and both of these metrics are substantially lower than the viability metrics suggested for this criterion.

5.1.3 CPUE of $\geq$ 5 individuals per hour at 50% of sites criterion

The CPUE for DWM has consistently been very low since its discovery in Swift Creek. During the 2007 and 2010 surveys, the overall CPUE of the DWM was 0.03/hr and 0.02/hr respectively. One of the hypotheses for the low CPUE of DWM at occupied sites was attributed to non-specific survey methods to detect all mussel species rather than specifically targeted DWM. As such, very habitat specific surveys targeting DWM were performed by experienced mussel surveyors at all of the known DWM sites in the Swift Creek watershed as part of this study. The theory was that the CPUE for DWM would be higher in occupied areas applying these targeted methodologies. However, these targeted surveys failed to detect the DWM at any of the previously known sites, further demonstrating its rarity in Swift Creek. The reasons for not detecting this species at any of the target sites are unclear, as many of these sites still contain the microhabitats associated with DWM. In addition, numerous mussels of other species that were tagged at some sites in 2007 were recovered in the same locations in 2011, which suggests a relatively stable habitat.

5.1.4 Evidence of recent reproduction criterion

Evidence of recent reproduction within a population can be determined by either finding gravid (holding progeny) individuals, and/or finding multiple size classes, including younger individuals. In the southern portion of its range, the period of gravidity reported for DWM is from November through April. In order to evaluate evidence of recent reproduction, the 2011 surveys were initially designed to be performed during the later portion of the gravidity period, more specifically late March to late April. While these months are only a portion of the period of gravidity, survey conditions (amount of daylight, water levels and temperatures *etc.*) would allow for maximum survey efficiency. However, due to weather patterns, all of the surveys could not be performed during this time frame.

The surveys began on April 07; however, a heavy rain event on the April 08 left stream conditions un-workable until April 14. Another rain event moved through on April 15, and again conditions were not workable. Surveys were conducted on April 20, but conditions were only workable in White Oak Creek. Conditions became favorable on April 26 and 27. However, another large rain event came through and conditions were not surveyable until May 9-10. Surveys resumed on May 13 and 26. Since many individuals of the Creeper, and Triangle Floater, which are closely related to the DWM were observed to be gravid in late May, it was hypothesized that the period of gravidity for DWM may be later than usual in 2011. Additionally, analysis of past survey data for Swift Creek Subbasin indicated that the majority (81%) of DWM were collected between Mid-May and October, which suggests that at least in Swift Creek, the DWM may be most detectable during periods when it is not gravid. Rather than delay efforts until November, the surveys continued through June since optimal survey conditions existed and the fact that evidence of reproduction can also be determined by the presence of young age classes.

While overall numbers of DWM in Swift Creek are very low, the 2007, 2010, and 2011 surveys indicate some recent reproduction, as young size-class individuals were found. It is unclear whether this reproduction is sufficient to maintain population viability over time, particularly when considering the indication of declines in relative abundances of the mussel fauna overtime (Section 5.2).

5.2 Swift Creek Mussel Population Trend Analysis

The other aspect of the viability component of this study is to conduct an analysis of population trends of the mussel species in Swift Creek. This analysis focuses on relative abundances (as measured by CPUE) of each species over time, and age class distribution (as inferred from size class data) over time for particular species which size class data is available.

5.2.1 Relative Abundance Trends

In the examples provided below in this report, to be repeated for additional species during subsequent study and analysis, Atlantic Pigtoe, a composite of several *Elliptio* species, Eastern Floater, and Paper Pondshell were evaluated for CPUE over time with the available data.

The available data sets contain enough information pertaining to relative abundances (CPUE) that mussel occurrence can be divided into the following five time periods:

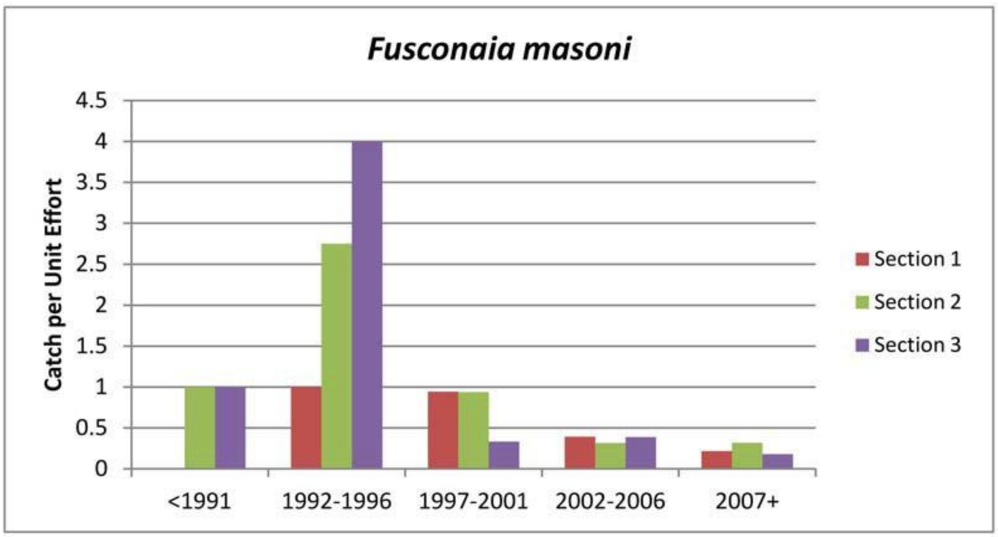
- <1991
- 1992-1996
- 1997-2001
- 2002-2006
- 2007+

It is important to note that each of these periods contains variability in data collection as to methods, level of effort, survey site location, *etc*. Many of the survey sites, particularly in the first three time periods, focused on the best habitat for rare species, such as the DWM, Atlantic Pigtoe and Yellow Lance, while later surveys were more comprehensive of a variety of habitat conditions with the stream. As such, conlusions based on apparent trends, particularly for habitat specialists like the Atlantic Pigtoe need to account for variability in survey methodologies over time. Variability in survey methodologies is less likely to be a factor when evaluating trends with habitat generalists such as the *Elliptio* species.

5.2.1.1 Atlantic Pigtoe

The Atlantic Pigtoe has been found in all three sections of Swift Creek in every sampling period, with the exception of <1991 being reported only in Section 2. This is likely due to a limited amount of survey effort during this sampling period. Chart 1 indicates a declining trend of Atlantic Pigtoe catch since the creek was intensively surveyed in 1992-1996 period.

Chart 1. CPUE of Atlantic Pigtoe

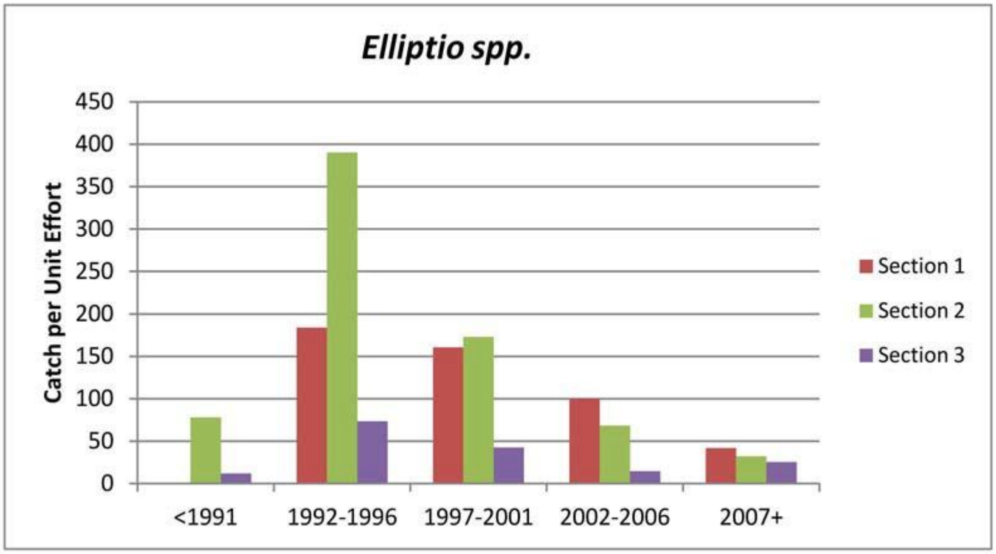


5.2.1.2 Elliptio Species

This composite of *Elliptio* species represents at least 3 species (*E. complanata* complex, *E. icterina* complex and *E. congerea*). Due to plasticity of shell morphologies and taxonomic uncertainties within the genus discrepacies regarding species identification exist within the dataset. For example, the Box Spike (*E. cistelliformis*) is reported from Swift Creek. This species, which was described from the Neuse River Basin was synomonized with *E. complanata* (Johnson 1970). Thus, some surveyors in Swift Creek may have recognized the *E. cistelliformis* form as separate from *E. complanata*, while others may have lumped them together. To account for this, all *Elliptio* species excluding *E. lanceolata*, *E. roanokensis* and various lanceolate *Elliptio* forms (*E. fisheriana*, *E. producta*, *E.* spp. c.f. lance and *E. viridula*), were grouped together for this analysis. *Elliptio* species generally account for the highest percentage of the freshwater mussel fauna in most Southern Atlantic Slope streams (Johnson 1970), which is the case within Swift Creek.

As with the Atlantic Pigtoe, a declining trend in relative abundance of the *Elliptio* species is evident since the 1992-1996 period in all three sections of Swift Creek (Chart 2). This decline is even more dramatic.

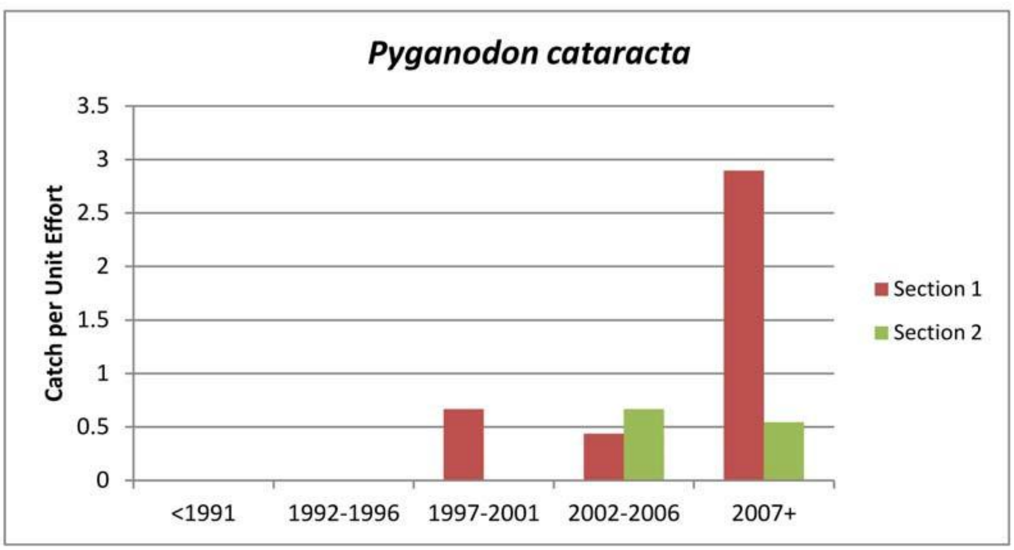
Chart 2. CPUE of Elliptio Species



5.2.1.3 Eastern Floater

The Eastern Floater is a wide-ranging, common species throughout the Southern Atlantic Slope and is considered more tolerant than most mussel species of habitat modification and many forms of pollution (Connecticut Dept. Envromental Protection 2011). This species was not detected in Swift Creek in surveys prior to the third sampling period (1997-2001), where it was found in low numbers in Section 1 (Chart 3). Since this time it appears that this species is expanding its range in Swift Creek, as it was found in Section 1 and 2 during the fourth (2002-2006) and fifth sampling periods (2007+), with an apparent increase in relative abundace in Section 1 in the fifth sampling period. This increase in range and relative abundance of this species may be indicative of continuing habitat modification in the stream.

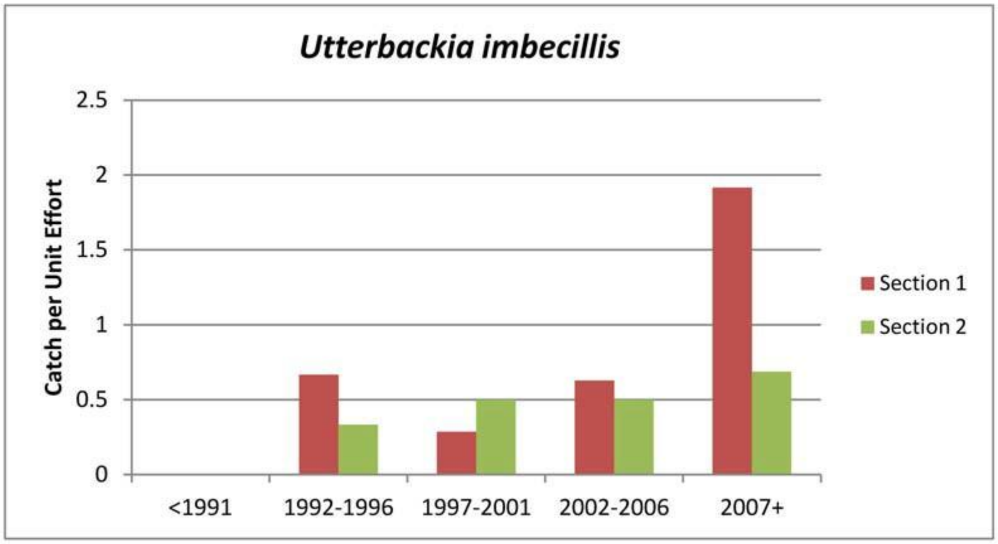
Chart 3. CPUE of Eastern Floater



5.2.1.4 Paper Pondshell

Similar to the Eastern Floater, the Paper Pondshell is a wide-ranging, common species throughout the Southern Atlantic Slope and is considered more tolerant than most mussel species of habitat modification (Williams *et. al* 2008). As with the Eastern Floater, this species has only been found in Section 1 and 2 of Swift Creek (Chart 4). There appears to be a slight increase in relative abundance in Section 1 during the fifth sampling period.

Chart 4. CPUE of Paper Pondshell



5.2.2 Age Class Distribution

Size class data is available for sampling periods four and five for the following species:

a. Dwarf Wedgemussel
b. Triangle Floater
c. Yellow Lance
d. Atlantic Pigtoe
e. Eastern Lampmussel
f. Creeper
g. Notched Rainbow

Some size class data also exists for these species for earlier sampling periods, but is not readily available in the database format. Catena is in the process of compiling this data, and will evaluate the trends in age class distribution overtime once all data has been compiled.

6.0 CONCLUSIONS

The recent surveys indicate that at least some of the proposed measures of population viability are met for the DWM in Swift Creek (length of occupied range, and evidence of recent reproduction). The other viability criterion of 75% of occupied sites within range and CPUE of $\geq$ 5 individuals per hour at 50% of sites within occupied habitat are far from being met in Swift Creek. However, analysis of past survey data indicate that these criteria have not been met at any time since the discovery of DWM in Swift Creek in 1991. The fact that the DWM still persists in Swift Creek, and evidence of recent reproduction, may suggest that these two metrics are not applicable to DWM in Swift Creek. Thus, when conducting the assessment of the Triangle Expressway Southeast Extension project, the various viability criteria need to be discussed in further detail with the USFWS when considering the long term viability of the DWM population in Swift Creek.

Further study and analysis of existing data as well as incorporation of study tiers 1 and 2 requested by USFWS are needed to fully assess the continued viability of DWM and other freshwater mussel species in Swift Creek.

7.0 LITERATURE CITED

Adams, W. F., J. M. Alderman, R. G. Biggins, A. G. Gerberich, E. P. Keferl, H. J. Porter, and A. S. Van Devender. 1990. A report on the conservation status of North Carolina's freshwater and terrestrial molluscan fauna. N.C. Wildlife Resources Commission, Raleigh. 246 pp, Appendix A, 37 pp.

Alderman, J. M. 1991. Annual Performance Report on North Carolina Mussels. In: Annual Report 1990-1991, Nongame and Endangered Wildlife Program, Division of Wildlife Management, North Carolina Wildlife Resources Commission, September 1991.

Alderman, J. M. 1995. Monitoring the Swift Creek Freshwater mussel community.

Unpublished report presented at the UMRCC symposium on the Conservation and Management of Freshwater Mussels II Initiative for the Future. Rock Island, IL, UMRCC.

Alderman, J. M., R. C. Wilson and C. McGrath. 1993. Conservation of aquatic critical habitats in North Carolina. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 47:348-352.

Bogan, A. E., Y. Huang, M. Raley, J. F. Levine 2008. Intraspecific phylogenetic relationships in the freshwater bivalve genus *Alasmidonta* (Bivalvia: Unionidae). Final Report. Submitted to: North Carolina Department of Transportation (Project Number: HWY-0754), 30 pp.

Bogan, A. E. 2002. Workbook and key to the freshwater bivalves of North Carolina. North Carolina Freshwater Mussel Conservation Partnership, Raleigh, NC, 101 pp, 10 color plates.

Clarke, A. H. 1981. The Tribe Alasmidontini (Unionidae: Anodontinae), Part I: *Pegias*, *Alasmidonta*, and *Arcidens*. Smithsonian Contributions to Zoology, No. 326. 101 pp.

Clarke, A. H. 1983. Status survey of the Tar River spiny mussel. Final Report to U.S. Fish and Wildlife Service with supplement. 63 pp.

Conrad, T. A. 1834. "Descriptions of some new species of fresh water shells from Alabama, Tennessee, etc." American Journal of Science and Arts **25**(2): 338-343.

Conneticut Department of Environmental Protection. 2011. The Freshwater Mussels of Conniticut. Accessed online at ttp://www.ct.gov/dep/cwp/view.asp?A=2723&Q=325906

Conrad, T. A. 1835. Additions to, and corrections of, the Catalogue of species of American Naiades, with descriptions of new species and varieties of Fresh Water Shells. Pp. 1–8, pl. 9. Appendix to: *Synoptical table to New freshwater shells of the United States, with coloured illustrations; and a monograph of the genus Anculotus of Say; also a synopsis of the American naiades.* J. Dobson, 108 Chestnut Street, Philadelphia, Pennsylvania.

Conrad, T.A. 1835b–1840. *Monography of the Family Unionidae, or naiades of Lamarck, (fresh water bivalve shells) or North America, illustrated by figures drawn on stone from nature.* J. Dobson, 108 Chestnut Street, Philadelphia, Pennsylvania. 1835, 1:1–12, [pp. 13–16 not published], pls. 1– 5; 1836, 2:17–24, pls. 6–10; 1836, 3:25–32, pls. 11–15; 1836, 4:33–40, pls. 16–19; 1836, 5:41–48, pls. 21–25; 1836, 6:49–56, pls. 26–30; 1836, 7:57–64, pls. 32–36; 1837, 8:65–72, pls. 36–40; 1837, 9:73–80, pls. 41–45; 1838, 10:81–94, 2i, pls. 46–51; 1838, 11:95–102, pls. 52–57; 1840, 12:103–110, pls. 58–60; [1840], 13:111–118, pls. 61–65.

Ellis, M. M. 1936. Erosion Silt as a Factor in Aquatic Environments. Ecology 17: 29- 42.

Fuller, S. L. H. 1977. Freshwater and terrestrial mollusks. In: J.E. Cooper, S.S.Robinson, J.B. Fundeburg (eds.) *Endangered and Threatened Plants and Animals of North Carolina.* North Carolina State Museum of Natural History, Raleigh.

Fuller, S. L. H. and C. E. Powell. 1973. Range extensions of *Corbicula manilensi* (Philippi) in the Atlantic drainage of the United States. Nautilus 87(2): 59.

Gmelin, J. F. 1791. *Systema Naturae.* 13th edition. Leipzig. Vol.1 part 6:3021-3910.

Goudreau, S. E., R. J. Neves, and R. J. Sheehan. 1988. Effects of Sewage Treatment Effluents on Mollusks and Fish of the Clinch River in Tazewell County, Virginia. USFWS: 128 pp.

Johnson, R. I. 1970. The Systematics and Zoogeography of the Unionidae (Mollusca: Bivalva) of the Southern Atlantic Slope Region. Bulletin of the Museum of Comparative Zoology 140(6): 263-449.

Lamarck, J. B. P. A. 1815–1822. Histoire naturelle des Animaux sans Vertébres. volumes.

Lea, I. 1829. Description of a new genus of the family of naïades, including eight species, four of which are new; also the description of eleven new species of the genus Unio from the rivers of the United States: with observations on some of the characters of the naïades. *Transactions of the American Philosophical Society* 3[New Series]:403–457, pls. 7–14.

Lea, I. 1831. Observations on the naïades, and descriptions of new species of that and other families. *Transactions of the American Philosophical Society* 4[New Series]:63–121, pls. 3–18.

Lea, I. 1838. Description of new freshwater and land shells. *Transactions of the American Philosophical Society* 6[New Series]:1–154, pls. 1–24.

Lea, I. 1863. Descriptions of twenty-four new species of Unionidae of the United States. *Proceedings of the Academy of Natural Sciences of Philadelphia* 15:191-194.

Lea, I. 1872. Observations on the genus *Unio*. Philadelphia, Penn., **1-13**.

LeGrand, H. E., Jr., S. P. Hall, S. E. McRae, and J. T. Finnegan. 2010. Natural HeritageProgram List of the Rare Animal Species of North Carolina. North Carolina Natural Heritage Program, Raleigh, North Carolina. 124 pp.

Lightfoot, J. 1786. A catalogue of the Portland Museum, lately the property of the duchess Dowager of Portland, deceased, which will be sold at auction by Mr. Skinner and Co. London. Vii = 194 pp.

Markings, L. L. and T. D. Bills. 1979. Acute Effects of Silt and Sand Sedimentation on Freshwater Mussels. UMRCC Symposium on the Upper Mississippi River bivalve Mollusks, Rock Island, IL, UMRCC.

Master, L. 1986. Alasmidonta heterodon: results of a global status survey and proposal to list as an endangered species. A report submitted to Region 5 of the U.S. Fish and Wildlife Service. 10 pp. and appendices.

McMahon, R. F. and A. E. Bogan. 2001. Mollusca: Bivalvia. Pp. 331-429. IN: J.H. Thorpe and A.P. Covich. Ecology and classification of North American freshwater invertebrates. 2nd edition. Academic Press.

Michaelson, D.L. and R.J. Neves. 1995. Life history and habitat of the endangered dwarf wedgemussel *Alasmidonta heterodon* (Bivalvia: Unionidae). *Journal of the North American Benthological Society* 14(2):324-340.

Neves, R. J. and J. C. Widlak. 1987. Habitat Ecology of Juvenile Freshwater Mussels (Bivalva: Unionidae) in a Headwater Stream in Virginia. American Malacological Bulletin 1(5): 1-7.

Neves, R.J. 1993. A state of the Unionids address. Pp. 1-10 in K.S. Cummings, A.C. Buchanan, and L.M. Kooch, eds. Proc. of the UMRCC symposium on the Conservation and Management of Freshwater Mussels. UMRCC. Rock Island IL. 189 pp.

O'Dee, S. H., and G. T. Watters. 2000. New or confirmed host identification for ten freshwater mussels. Pp. 77-82 in R.A. Tankersley, D.I. Warmolts, G.T. Watters, B.J. Armitage, P.D. Johnson, and R.S. Butler (eds.). Freshwater Mollusk Symposia Proceedings. Part I. Proceedings of the Conservation, Captive Care and Propagation of Freshwater Mussels Symposium. Ohio Biological Survey Special Publication, Columbus.

O'Neill, C. R., Jr., and D. B. MacNeill. 1991. The zebra mussel (Dreissena polymorpha): an unwelcome North American invader. Sea Grant, Coastal Resources Fact Sheet. New York Sea Grant Extension. 12 pp.

Ortmann, A.E. 1914. Studies in najades. Nautilus 28:41-47.

Ortmann, A.E. 1919. A monograph of the naiades of Pennsylvania. Part III: Systematic account of the genera and species. *Memoirs of the Carnegie Museum* 8(1):xvi–384, 21 pls.

Pennak, R. W. 1989. Fresh-water Invertebrates of the United States, Protozoa to Mollusca. New York, John Wiley & Sons, Inc.

Savidge, Timothy W. Personal Observation. The Catena Group, Inc.

Say, T., Ed. 1817. Article Conchology. American Edition of the British Encyclopedia of Dictionary of Arts and Sciences, Comprising an Accurate and Popular View of the Present Improved State of Human Knowledge. Philadelphia, Samuel A. Mitchel and Horace Ames.

Say, T. 1829. Descriptions of some new terrestrial and fluviatile shells of North America. The Disseminator of Useful Knowledge; containing hints to the youth of the United States, from the School of Industry **2**(19-23): 291-356.

Simpson, C.T. 1900. Synopsis of the naiades, or pearly fresh-water mussels. Proceedings of the United States National Museum 22(1205):501–1044.

Simpson, C.T. 1914. A descriptive catalogue of the naiades, or pearly fresh-water mussels. Parts I–III. Bryant Walker, Detroit, Michigan. xii + 1540 pp.

Smith, D. 1981. Selected freshwater invertbrates proposed for special concern status in Massachussetts (Mollusca, Annelida, Arthropoda). MA Dept. of Env. Qual. Engineering, Div. of Water Pollution Control. 26 pp.

Strayer, D. L., S. J. Sprague and S. Claypool. 1996. A range-wide assessment of populations of Alasmidonta heterodon, an endangered freshwater mussel (Bivalva:Unionidae). J.N. Am. Benthol. Soc., 15(3):308-317.

The Catena Group Inc. 2008. Swift Creek Freshwater Mussel Surveys The Dempsey E.Benton Water Treatment Project: Wake and Johnston Counties, North Carolina. Unpublished Final Report prepared for Arcadis, Raleigh, North Carolina. 29 pp plus figures.

U.S. Fish and Wildlife Service. 1992a. Special report on the status of freshwater mussels.

U.S. Fish and Wildlife Service. 1992b. Endangered and Threatened species of the southeast United States (The Red Book). FWS, Ecological Services, Div. of Endangered Species, Southeast Region. Govt Printing Office, Wash, DC: 1,070.

U.S. Fish and Wildlife Service. 1992c. Tar River Spinymussel (*Elliptio (Cathyria) steinstansana)* Recovery Plan. Atlanta, Georgia. 34 pp.

U.S. Fish and Wildlife Service. 1993. Dwarf Wedgemussel Mussel (*Alasmidonta heterodon*) Recovery Plan. Hadley, Massachusetts. 527 pp.

U.S. Fish and Wildlife Service. 1996. Revised Technical/Agency Draft Carolina Heelsplitter Recovery Plan. Atlanta, GA: 47.

U.S. Fish and Wildlife Service. 2007. Dwarf Wedgemussel (*Alasmidonta heterodon*) 5-Year Review: Summary and Evaluation, Susi vonOettingen, FWS Hadley, MA.

Walter, W. M. 1954. Mollusca of the upper Neuse River basin, North Carolina. Durham, North Carolina, Duke University. Ph. D. dissertation: i-x + 220.

Walter, W. M. 1956. Mollusca of the upper Neuse River basin, North Carolina. Durham. J. of the Elisha Mitchell Scientific Society (72 (2):262-274.

Williams, J. D., M. L. Warren, Jr., K. S. Cummings, J. L. Harris, and R. J. Neves. 1993. Conservation status of the freshwater mussels of the United States and Canada. Fisheries 18 (9): 6-22.

Appendix A

DEFINITIONS OF FEDERAL AND STATE LISTING CATEGORIES

(FROM LEGRAND ET AL. 2010)

United States Status. This status is designated by the U.S. Fish and Wildlife Service.

Federally listed Endangered and Threatened species are protected under the provisions of the Endangered Species Act of 1973, as amended through the 100th Congress. Unless otherwise noted, definitions are taken from the Federal Register, Vol. 56, No. 225, November 21, 1991 (50 CFR Part 17).

STATUS CODE		
E	Endangered	A taxon "which is in danger of extinction throughout all or a significant portion of its range" (Endangered Species Act, Section 3).
T	Threatened	A taxon "which is likely to become an endangered species within the foreseeable future throughout all or a significant
FSC	(Federal) Species of Concern [also known as Species at Risk]	"... the Service is discontinuing the designation of Category 2 species as candidates in this notice. The Service remains concerned about these species, but further biological research and field study are needed to resolve the conservation status of these taxa. Many species of concern will be found not to warrant listing, either because they are not threatened or endangered or because they do not qualify as species under the definition in the [Endangered Species] Act. Others may be found to be in greater danger of extinction than some present candidate taxa. The Service is working with the States and other private and public interests to assess their need for protection under the Act. Such species are the pool from which future candidates for listing will be drawn." (Federal Register, February 28, 1996). The Service suggests that such taxa be considered as "Species of Concern" or "Species at Risk", neither of which has official status. The N.C. Natural Heritage Program uses
P	Proposed	Species proposed in the Federal Register as a status

STATUS CODE		
T (S/A)	Threatened due to Similarity of Appearance	"Section 4 (e) of the [Endangered Species] Act authorizes the treatment of a species (subspecies or population segment) as endangered or threatened even though it is not otherwise listed as endangered or threatened if -- (a) the species so closely resembles in appearance an endangered or threatened species that enforcement personnel would have substantial difficulty in differentiating between the listed and unlisted species; (b) the effect of this substantial difficulty is an additional threat to an endangered or threatened species; and (c) such treatment of an unlisted species will substantially facilitate the enforcement and further the policy of the Act." (Federal Register, November 4, 1997). [The American Alligator is listed as T (S/A) due to Similarity of Appearance with other rare crocodilians, and the southern population of the Bog Turtle is listed as T
XN	Nonessential Experimental Population	"Section 10 (j) of the Endangered Species Act of 1973, as amended, provides for the designation of introduced populations of federally listed species as nonessential experimental. This designation allows for greater flexibility in the management of these populations by local, state, and Federal agencies. Specifically, the requirement for Federal agencies to avoid jeopardizing these populations by their
D	De-listed	Species has been proposed by the U.S. Fish and Wildlife Service for de-listing from the List of Endangered and Threatened Wildlife. However, at the present time, the species is still on the List of Endangered and Threatened Wildlife and is thus protected under the Endangered Species Act. Because such species still have legal Federal protection, the NHP will maintain existing records on the species, though new records might not necessarily be added. If the status becomes law prior to the next publication of the NHP Rare Animal List, the Program will remove the Federal designation from its database (and thus the species will no longer appear on printouts of Federally listed species). NHP may or may not continue to track the species, depending

North Carolina Status. Endangered, Threatened, and Special Concern species of mammals, birds, reptiles, amphibians, freshwater fishes, freshwater and terrestrial mollusks, and crustaceans have legal protection status in North Carolina (Wildlife Resources Commission). In addition to the above categories, the Natural Heritage Program maintains computer and map files on Significantly Rare species, as well as species considered Extirpated. Paper files only are maintained for a few of the above species; these species are indicated by the phrase "not tracking."

STATUS CODE		
E	Endangered	"Any native or once-native species of wild animal whose continued existence as a viable component of the State's fauna is determined by the Wildlife Resources Commission to be in jeopardy or any species of wild animal determined to be an 'endangered species' pursuant to the Endangered
T	Threatened	"Any native or once-native species of wild animal which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range, or one that is designated as a threatened species pursuant to the Endangered Species Act." (Article 25 of Chapter
SC	Special Concern	"Any species of wild animal native or once-native to North Carolina which is determined by the Wildlife Resources Commission to require monitoring but which may be taken under regulations adopted under the provisions of this Article." (Article 25 of Chapter 113 of the General
P	Proposed	Species has been proposed by a Scientific Council as a status (Endangered, Threatened, Special Concern, Watch List, or for Delisting) that is different from the current status, but the status has not yet been adopted by the General Assembly as law. In the lists of rare species in this book, these proposed statuses are listed in parentheses below the current status. Only those proposed statuses that are different from the current statuses are listed.

STATUS CODE		
SR	Significantly Rare	Any species which has not been listed by the N.C. Wildlife Resources Commission as an Endangered, Threatened, or Special Concern species, but which exists in the state in small numbers and has been determined by the N.C. Natural Heritage Program to need monitoring. (This is a N.C. Natural Heritage Program designation.) Significantly Rare species include "peripheral" species, whereby North Carolina lies at
EX	Extirpated	A species which is no longer believed to occur in the state. (This is a N.C. Natural Heritage Program designation, though WRC also uses this status; the NHP list includes those on the WRC list.)
W	Watch List	Any other species believed to be of conservation concern in the state because of scarcity, declining populations, threats to populations, or inadequacy of information to assess its rarity (see page 59 for a more complete discussion). (This is a N.C. Natural
G		Species is a game animal, and therefore (by law)

Environmental Baseline Additional Studies: 2012
Freshwater Mussel Surveys Targeting Dwarf Wedgemussel
Interim Report

Triangle Expressway Southeast Extension
(TIP No R-2721/R-2828/R-2829)

Wake and Johnston Counties, North Carolina

Prepared for:

H.W. Lochner, Inc.
2840 Plaza Place, Suite 202
Raleigh, NC 27612

Prepared by:

The Catena Group

410-B Millstone Drive
Hillsborough, NC 27278

July 24, 2012

1.0 INTRODUCTION

The North Carolina Turnpike Authority (NCTA) of the North Carolina Department of Transportation (NCDOT) proposes construction of the new road corridor from NC-55 (Apex) to US-64 Bypass (Knightdale). The Dwarf Wedgemussel (*Alasmidonta heterodon*, DWM), which is listed by the US Fish and Wildlife Service (USFWS) as a federally endangered species, occurs in Swift Creek within the proposed action area of the project. It was first documented to occur in Swift Creek in 1991.

The Swift Creek population of the DWM has been identified as essential for the recovery of the species (USFWS 1993). Since the DWM is present within the proposed action area, potential direct, indirect and cumulative impacts to this species will need to be assessed as required by Section 7 of the Endangered Species Act of 1973, as amended.

In a letter to the NCTA on February 17, 2011, the USFWS indicated that an updated Environmental Baseline on the DWM population in Swift Creek would be needed to determine if the proposed action could have the potential to jeopardize the continued existence of this species. The USFWS proposed a three-tiered study to be implemented by the NCTA to develop the updated Environmental Baseline:

1. Provide an accounting (compliance/success) of conservation measures that have been implemented in Swift Creek to protect the DWM
2. Assess the effectiveness of existing conservation measures and environmental protections in Swift Creek with regard to habitat and population stability
3. Assess historic trends and current viability of the DWM population, and its habitat, in Swift Creek

The Catena Group Inc. (Catena) developed a detailed study design addressing these three components. This study was implemented in March 2012, and is in various stages of completion. This Interim Report provides the data gathered from mussel surveys conducted from March to May 2012.

2.0 MUSSEL SURVEY DESIGN-2012

The overall goal of this larger study is to assess the viability of DWM in Swift Creek by examining numerous attributes, such as population density, distribution within Swift Creek, and habitat suitability. It is apparent that the DWM has always been rare in Swift Creek since it was first discovered in 1991, thus population data on this species is limited. As such, one metric to gauge the viability of the DWM population is to evaluate population trends of all mussel species that occur in Swift Creek over time. With regards to the freshwater mussel fauna, Swift Creek is one of the most species rich and extensively surveyed water-bodies in North Carolina. However, nearly all of the surveys employed an “informal” sampling design using timed qualitative searches for mussels at various locations. The primary objective of this type of sampling is to determine presence/absence of a particular species, and is not recommended for population density studies, or long term monitoring (Strayer and Smith 2003). Thus, conclusions on population trends derived by simply analyzing the existing dataset without accounting for sampling variance would have inherent flaws as the dataset provides no measure of uncertainty, such as survey effort, seasonality, surveyor experience, and survey conditions (water depth, visibility, flow etc.). To account for this, a probability-based design that involved a number of repeat surveys at selected sites was incorporated into the 2012 mussel surveys to develop detection probabilities for the mussel species occurring in Swift Creek. These detection probabilities will assist in making inferences of trends from previous survey data. While this will not totally eliminate the unknown biases of the informally sampled dataset, it will strengthen assumptions made with regard to previous survey data being representative of the overall population.

This 2012 sampling design consisted of three components, surveying specific locations where DWM was known to occur (including Little Creek, a tributary to Swift Creek), conducting timed qualitative surveys near the DWM sites, and conducting surveys in sections where prior survey data was limited (Data Gap Surveys), as detailed below.

Previous DWM Locations

Eleven distinct sites in Swift Creek where DWM had previously been collected were surveyed for a length of 200 feet, with the channel being segmented into three survey lanes (right, center, left). The number of each species collected and survey time was recorded for each survey lane. Five of these sites were then randomly selected, and repeat surveys were conducted on different dates. The two sites in Little Creek where DWM was found in 2003 were also surveyed in this Manner; however, they were not selected to be surveyed twice, as they had been surveyed in late 2011, and did not yield DWM.

Qualitative Surveys near DWM sites

Timed qualitative surveys were conducted in stream reaches of varying length near specific DWM locations. These qualitative surveys were conducted as the survey teams were moving from one DWM site to another. The survey lengths of these sites were determined in the field, with the starting and ending points recorded using GPS. The number of each mussel species collected was recorded, as were habitat conditions (substrate, depth etc.). Nine sites in Swift Creek and one site in Little Creek were surveyed in this manner

Data Gap Surveys

Despite the extensive surveys that have been conducted in Swift Creek, fairly large reaches existed (1-2 miles) where little or no surveys had been conducted. These gaps in survey data primarily occurred within two general reaches of Swift Creek: between Cornwallis Road and Barber Mill Road and between Barber Mill Road and Steel Bridge (Lee) Road. Timed qualitative surveys were conducted at 15 selected locations within these two general reaches, with starting and end points, species collected, and habitat data recorded. Four of these sites were randomly selected and re-surveyed on a different date. These re-surveys, as with the re-surveys of DWM sites, will factor into the generation of detection probabilities.

The surveys were conducted by Catena personnel on the following dates in 2012:

- Tim Savidge: March 02, 14, 15, 29; April 04, 09; May 02
- Tom Dickinson: March 14, 15; May 02
- Ivy Kimbrough: March 02, 15, 29; April 04, 09, 16; May 02
- Chris Sheats: March 02, 15; April 09; May 02
- John Roberts: March 14, 15, 29; April 04, 16
- Michael Wood: March 15; April 16; May 02
- Kate Montieth: May 02
- Nancy Roberts: May 02

The scientific names of all freshwater mussel species mentioned in this report follow Turgeon et al. 1998). The common names also follow this reference, with the exception of capitalization of common names. For consistency, all common names in this report are capitalized. Williams et al. (2008) provides a justification for capitalizing common names stating "Capitalization helps avoid confusion by identifying standardized common names". They explain that reference to a 'fragile papershell' could apply to a number of thin-shelled (freshwater mussel) species or to *Leptodea fragilis*; by capitalizing Fragile Papershell, it can easily be recognized as the common name for a distinct species (Williams et al. 2008).

3.0 RESULTS

A total of 47 sites (35 in Swift Creek, nine of which were surveyed twice, and three in Little Creek) were surveyed for a total of 121.50 person hours of survey time. Fifteen species were found, including six live, and two relict shells of the DWM. Two of the six DWM were gravid. The Notched Rainbow was represented by shell material only. The total number and overall catch per unit effort (CPUE) of each species found is shown in Table 1, and the results for each individual site are provided in Appendix A in sequential order.

Table 1. Mussel Species Found 2012 Swift Creek Surveys

Scientific Name	Common Name	#	Abundance/ CPUE
Alasmidonta heterodon	Dwarf Wedgemussel	6 live, 2 shells	0.05/hr
Alasmidonta undulata	Triangle Floater	43	0.35/hr
Elliptio complanata	Eastern Elliptio	8,637	71.09/hr
Elliptio congarea	Carolina Slabshell	451	3.71/hr
Elliptio icterina	Variable Spike	1,996	16.43/hr
Elliptio lanceolata	Yellow Lance	4	0.03/hr
Elliptio sp. cf. mediocris	n/a	224	1.84/hr
Elliptio sp. cf. producta	Atlantic Spike	10	0.08/hr
Elliptio roanokensis	Roanoke Slabshell	42	0.35/hr
Fusconaia masoni	Atlantic Pigtoe	36	0.30/hr
Lampsilis radiata	Eastern Lampmussel	63	0.52/hr
Pyganadon cataracta	Eastern Floater	19	0.16/hr
Strophitus undulatus	Creeper	68	0.56/hr

Utterbackia imbecillis	Paper Pondshell	1	0.01/hr
Villosa constricta	Notched Rainbow	shell	0.00/hr

4.0 DISCUSSION

The brief analysis summarized below is cursory at this point, as the data collected during the 2012 surveys will be added to the existing 22 year dataset for further analyses that will be part of the later reports. As discussed earlier, detection probabilities will be generated for each mussel species occurring in Swift Creek. Population and habitat trends will be analyzed in detail and provided in the future final report that covers all aspects of this larger study of Swift Creek.

As with previous survey efforts, the Eastern Elliptio and Variable Spike were the two most abundant mussel species found, and the DWM was detected in low numbers. Other "rare" mussel species occurring in Swift Creek, the Atlantic Pigtoe, Creeper, Eastern Lampmussel, Triangle Floater and Yellow Lance, were found in relatively low numbers, as they were in previous survey efforts.

Two of the 11 previous DWM sites surveyed in 2012 yielded evidence (live or shell) of DWM, where one of the sites yielded a relict shell, and the other site yielded two live DWM, with one found on the first survey, and a different individual found on the re-survey.

The population viability metric of recent reproduction and recruitment can be demonstrated by observing gravid individuals (reproduction) and multiple age classes, including young individuals (recruitment). While determining the exact age of an individual mussel in the field is difficult, age can be estimated by size (total length) and growth rests. The six live DWM individuals were 25, 28, 36, 38, 38 and 45 mm long and the two relict shells were both 34 mm. Based on age determinations of 43 DWM from the upper Tar River in North Carolina by Michaelson (1995), the DWM found in Swift Creek during the 2012 surveys likely represent at least three age classes, including relatively young (3-4 year old) individuals (Table 2). Aging individuals greater than 37 mm and 6 years old is difficult, as growth rates decline as individuals age (Michaelson 1995).

Table 2. Percent Composition in Age Groups (yr) adapted from Michaelson (1995)

Length (mm)	1 yr	2 yr	3 yr	4 yr	5 yr	6 yr	> 6 yr
9.0-12.9	80	20	~	~	~	~	~
13-.0-16.9	75	25	~	~	~	~	~
17.0-20.9	~	100	~	~	~	~	~
21.0-24.9	~	22.2	77.78	~	~	~	~
25.0-28.9	~	~	27.27	63.3	9.1	~	~
29.0-32.9	~	~	~	20	60	20	~
33.0-36.9	~	~	~	~	~	100	~

N =	7	12	10	8	4	2	0

5.0 LITERATURE CITED

Michaelson, D.L. and R.J. Neves. 1995. Life History and Habitat of the Endangered Dwarf Wedgemussel (*Alasmidonta heterodon*) (Bivalvia: Unionidae). *Journal of the North American Benthological Society* 14(2):324-340.

Strayer, D. L., and D. R. Smith. 2003. A Guide to Sampling Freshwater Mussel Populations. American Fisheries Society, Monograph 8, Bethesda, Maryland.

Turgeon, D.D., J.F. Quinn, Jr., A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P.M. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G. Thompson, M. Vecchione, and J.D. Williams. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: Mollusks. 2nd Edition. American Fisheries Society Special Publication 26, Bethesda, Maryland: 526 pp.

U.S. Fish and Wildlife Service. 1993. Dwarf Wedgemussel (*Alasmidonta heterodon*) Recovery Plan. Hadley, Massachusetts. 527 pp.

Williams, J.D., A.E. Bogan, and J.T. Garner. 2008. Freshwater Mussels of Alabama and the Mobile Basin in Georgia, Mississippi and Tennessee. University of Alabama Press, Tuscaloosa.

APPENDIX A SURVEY RESULTS BY SITE

120302.1tws 4.0 p-h 35.60647, -78.54409 TS, CS, IK

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta heterodon	Dwarf Wedgemussel	1	0.25/hr
Alasmidonta undulata	Triangle Floater	3	0.75/hr
Elliptio complanata	Eastern Elliptio	288	72.00/hr
Elliptio congarea	Carolina Slabshell	5	1.25/hr
Elliptio icterina	Variable Spike	79	19.75/hr
Elliptio sp. cf. mediocris	n/a	2	0.50/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.25/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.25/hr
Lampsilis radiata	Eastern Lampmussel	2	0.50/hr
Strophitus undulatus	Creeper	3	0.75/hr

120302.2tws 3.65 p-h 35.60662, -78.54391 TS, CS, IK

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	5	1.37/hr
Elliptio complanata	Eastern Elliptio	275	75.34/hr
Elliptio congarea	Carolina Slabshell	8	2.19/hr
Elliptio icterina	Variable Spike	74	20.27/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.27/hr
Lampsilis radiata	Eastern Lampmussel	5	1.37/hr
Pyganodon cataracta	Eastern Floater	1	0.27/hr
Strophitus undulatus	Creeper	1	0.27/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

120302.3tws 1.25 p-h 35.60782, -78.54639 TS, CS, IK

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.80/hr
Elliptio complanata	Eastern Elliptio	88	70.4/hr
Elliptio icterina	Variable Spike	37	29.60/hr
Fusconaia masoni	Atlantic Pigtoe	1 shell	~
Lampsilis radiata	Eastern Lampmussel	1	0.80/hr
Strophitus undulatus	Creeper	1	0.80/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon
Corbicula fluminea	Asian Clam	~	Common

120314.1tcg 3.9 p-h 35.58972, -78.51962 TS, TD, JR

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.26/hr
Elliptio complanata	Eastern Elliptio	307	78.72/hr
Elliptio congarea	Carolina Slabshell	51	13.08/hr
Elliptio icterina	Variable Spike	57	14.62/hr
Elliptio sp. cf. mediocris	n/a	14	3.59/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.26/hr
Pyganodon cataracta	Eastern Floater	3	0.77/hr
Strophitus undulatus	Creeper	6	1.54/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

120314.2tcg 2.05 p-h 35.59041, -78.52123 TS, TD, JR

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	91	44.39/hr
Elliptio congarea	Carolina Slabshell	18	8.78/hr
Elliptio icterina	Variable Spike	47	22.93/hr
Elliptio sp. cf. mediocris	n/a	15	7.32/hr
Elliptio sp. cf. producta	n/a	1	0.49/hr
Lampsilis radiata	Eastern Lampmussel	1	0.49/hr
Strophitus undulatus	Creeper	1	0.49/hr

120314.3tcg 3.5 p-h 35.59018, -78.52123 TS, TD, JR

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	2 shells	~
Elliptio complanata	Eastern Elliptio	138	39.43/hr
Elliptio congarea	Carolina Slabshell	14	4.00/hr
Elliptio icterina	Variable Spike	78	22.29/hr
Elliptio sp. cf. mediocris	n/a	26	7.43/hr
Elliptio sp. cf. producta	n/a	1	0.29/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.29/hr
Lampsilis radiata	Eastern Lampmussel	4	1.14/hr
Pyganodon cataracta	Eastern Floater	3	0.86/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Rare
Corbicula fluminea	Asian Clam	~	Very abundant

120314.4tcg 2.1 p-h 35.58892, -78.52244 TS, TD, JR

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.48/hr
Elliptio complanata	Eastern Elliptio	111	52.86/hr
Elliptio congarea	Carolina Slabshell	23	10.95/hr
Elliptio icterina	Variable Spike	28	13.33/hr
Elliptio sp. cf. mediocris	n/a	4	1.90/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.48/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.48/hr
Lampsilis radiata	Eastern Lampmussel	1	0.48/hr
Pyganodon cataracta	Eastern Floater	2	0.95/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

120314.5tcg 2.75 p-h 35.54061, -78.52412 TS, TD, JR

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	3	1.09/hr
Elliptio complanata	Eastern Elliptio	102	37.09/hr
Elliptio congarea	Carolina Slabshell	17	6.18/hr
Elliptio icterina	Variable Spike	27	9.82/hr
Elliptio sp. cf. mediocris	n/a	2	0.73/hr
Lampsilis radiata	Eastern Lampmussel	2	0.73/hr

Scientific Name	Common Name	#	Abundance/ CPUE
Pyganodon cataracta	Eastern Floater	4	1.45/hr
Strophitus undulatus	Creeper	3	1.09/hr

120315.1ted 3.95 p-h 35.58368, -78.50912 TD, CS, MW

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.25/hr
Elliptio complanata	Eastern Elliptio	496	125.57/hr
Elliptio congarea	Carolina Slabshell	18	4.56/hr
Elliptio icterina	Variable Spike	67	16.96/hr
Elliptio sp. cf. mediocris	n/a	20	5.06/hr
Elliptio roanokensis	Roanoke Slabshell	2	0.51/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.25/hr
Lampsilis radiata	Eastern Lampmussel	2	0.51/hr
Strophitus undulatus	Creeper	3	0.76/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common

120315.2ted 2.45 p-h 35.58447 -78.50989 TD, CS, MW

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta heterodon	Dwarf Wedgemussel	1 shell	~
Alasmidonta undulata	Triangle Floater	1	0.41/hr
Elliptio complanata	Eastern Elliptio	146	59.59/hr
Elliptio congarea	Carolina Slabshell	18	7.35/hr
Elliptio icterina	Variable Spike	51	20.82/hr
Elliptio sp. cf. mediocris	n/a	16	6.53/hr
Elliptio roanokensis	Roanoke Slabshell	2	0.82/hr
Fusconaia masoni	Atlantic Pigtoe	2	0.82/hr
Lampsilis radiata	Eastern Lampmussel	1	0.41/hr
Strophitus undulatus	Creeper	1	0.41/hr
Villosa constricta	Notched Rainbow	2 shells	~
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

120315.3ted 3.33 p-h 35.35.58441, -78.51064 TD, CS, MW

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	4	1.20/hr
Elliptio complanata	Eastern Elliptio	138	41.44/hr
Elliptio congarea	Carolina Slabshell	30	9.01/hr
Elliptio icterina	Variable Spike	168	50.45/hr
Elliptio sp. cf. mediocris	n/a	20	6.01/hr
Elliptio sp. cf. producta	n/a	1	0.30/hr
Elliptio roanokensis	Roanoke Slabshell	3	0.90/hr
Fusconaia masoni	Atlantic Pigtoe	3	0.90/hr
Lampsilis radiata	Eastern Lampmussel	1	0.30/hr
Pyganodon cataracta	Eastern Floater	1	0.30/hr
Strophitus undulatus	Creeper	4	1.20/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon
Corbicula fluminea	Asian Clam	~	Abundant

120315.4ted 0.8 p-h 35.58566, -78.512542 TD, CS, MW

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta heterodon	Dwarf Wedgemussel	1	1.25/hr
Elliptio complanata	Eastern Elliptio	29	36.25/hr
Elliptio congarea	Carolina Slabshell	1	1.25/hr
Elliptio icterina	Variable Spike	4	5.00/hr

120315.5ted 2.17 p-h 35.58591, -78.51254 TD, CS, MW

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	170	78.34/hr
Elliptio congarea	Carolina Slabshell	6	2.76/hr
Elliptio icterina	Variable Spike	33	15.21/hr
Elliptio sp. cf. mediocris	n/a	3	1.38/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.46/hr
Lampsilis radiata	Eastern Lampmussel	1	0.46/hr

120315.6ted 2.0 p-h 35.58694, -78.51470 TD, CS, MW

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	166	83.00/hr
Elliptio icterina	Variable Spike	23	11.50/hr
Elliptio sp. cf. mediocris	n/a	5	2.50/hr
Elliptio roanokensis	Roanoke Slabshell	2	1.00/hr
Lampsilis radiata	Eastern Lampmussel	2	1.00/hr

120315.1tws 1.7 p-h 35.58745, -78.5157 TS, IK, JR

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	74	43.53/hr
Elliptio congarea	Carolina Slabshell	5	2.94/hr
Elliptio icterina	Variable Spike	18	10.59/hr
Elliptio sp. cf. mediocris	n/a	4	2.35/hr
Elliptio sp. cf. producta	n/a	1	0.59/hr
Fusconaia masoni	Atlantic Pigtoe	1 shell	~
Pyganodon cataracta	Eastern Floater	1	0.59/hr
Strophitus undulatus	Creeper	2	1.18/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon
Corbicula fluminea	Asian Clam	~	Abundant

120315.2tws 2.75 p-h 35.58772, -78.51623 TS, IK, JR

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta heterodon	Dwarf Wedgemussel	1	0.36/hr
Alasmidonta undulata	Triangle Floater	3	1.09/hr
Elliptio complanata	Eastern Elliptio	346	125.81/hr
Elliptio congarea	Carolina Slabshell	18	6.55/hr
Elliptio icterina	Variable Spike	58	21.09/hr
Elliptio sp. cf. mediocris	n/a	20	7.27/hr
Elliptio sp. cf. producta	n/a	1	0.36/hr
Elliptio roanokensis	Roanoke Slabshell	4	1.45/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.36/hr
Lampsilis radiata	Eastern Lampmussel	1	0.36/hr
Strophitus undulatus	Creeper	2	0.73/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

120315.3tws 1.6 p-h 35.58876, -78.51743 TS, IK, JR

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.63/hr
Elliptio complanata	Eastern Elliptio	127	79.38/hr
Elliptio congarea	Carolina Slabshell	10	6.25/hr
Elliptio icterina	Variable Spike	15	9.38/hr
Elliptio sp. cf. mediocris	n/a	4	2.50/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.63/hr
Pyganodon cataracta	Eastern Floater	2	1.25/hr
Strophitus undulatus	Creeper	1	0.63/hr

120315.4tws 1.2 p-h 35.58957, -78.51954 TS, IK, JR

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	48	40.00/hr
Elliptio congarea	Carolina Slabshell	7	5.83/hr
Elliptio icterina	Variable Spike	13	10.83/hr
Elliptio sp. cf. mediocris	n/a	6	5.00/hr
Lampsilis radiata	Eastern Lampmussel	1 shell	~
Strophitus undulatus	Creeper	1	0.83/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

120315.5tws 1.35 p-h 35.56868, -78.48563 TS, IK, JR

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	16	11.85/hr
Elliptio congarea	Carolina Slabshell	5	3.70/hr
Elliptio icterina	Variable Spike	7	5.19/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.74/hr
Strophitus undulatus	Creeper	1 shell	~
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common
Elimia catenaria	Gravel Elimia	~	Common

120329.1tws 2.3 p-h 35.58039, -78.44558 TS, IK, JR

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	81	35.22/hr
Elliptio congarea	Carolina Slabshell	2	0.87/hr
Elliptio icterina	Variable Spike	10	4.35/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common
Corbicula fluminea	Asian Clam	~	Common

120329.2tws 2.55 p-h 35.58097, -78.44619 TS, IK, JR

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	78	30.59/hr
Elliptio icterina	Variable Spike	10	3.92/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common
Corbicula fluminea	Asian Clam	~	Common

120329.3tws 5.0 p-h 35.58215, -78.44753 TS, JR, IK

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	246	49.2/hr
Elliptio congarea	Carolina Slabshell	1	0.20/hr
Elliptio icterina	Variable Spike	36	7.20/hr
Strophitus undulatus	Creeper	1	0.20/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Common
Corbicula fluminea	Asian Clam	~	Common

120404.1tws 1.5 p-h 35.57445, -78.50588 TS, IK, JR

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta heterodon	Dwarf Wedgemussel	1	0.67/hr
Elliptio complanata	Eastern Elliptio	66	44.0/hr
Elliptio congarea	Carolina Slabshell	3	2.00/hr
Elliptio icterina	Variable Spike	8	5.33/hr

Scientific Name	Common Name	#	Abundance/ CPUE
Elliptio sp. cf. mediocris	n/a	2	1.33/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.67/hr
Lampsilis radiata	Eastern Lampmussel	1	0.67/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Patchy Common
Corbicula fluminea	Asian Clam	~	Common
Elimia catenaria	Gravel Elimia	~	Rare

120404.2tws 1.65 p-h 35.57601, -78.50533 TS, IK, JR

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	155	93.94/hr
Elliptio congarea	Carolina Slabshell	3	1.82/hr
Elliptio icterina	Variable Spike	8	4.85/hr
Lampsilis radiata	Eastern Lampmussel	1	0.61/hr
Strophitus undulatus	Creeper	1	0.61/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Patchy Common
Corbicula fluminea	Asian Clam	~	Abundant

120402.3tws 2.2 p-h 35.57948, -78.50827 TS, IK, JR

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	3 shells	~
Elliptio complanata	Eastern Elliptio	86	39.1/hr
Elliptio congarea	Carolina Slabshell	1	0.45/hr
Elliptio icterina	Variable Spike	10	4.55/hr
Elliptio sp. cf. mediocris	n/a	1	0.45/hr
Lampsilis radiata	Eastern Lampmussel	1	0.45/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Patchy Common
Corbicula fluminea	Asian Clam	~	Abundant

120404.4tws 2.35 p-h 35.58073, -78.5077 TS, IK, JR

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	131	55.74/hr

Scientific Name	Common Name	#	Abundance/ CPUE
Elliptio congarea	Carolina Slabshell	28	11.91/hr
Elliptio icterina	Variable Spike	33	14.04/hr
Elliptio sp. cf. mediocris	n/a	4	1.70/hr
Lampsilis radiata	Eastern Lampmussel	1	0.43/hr
Strophitus undulatus	Creeper	1	0.43/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon
Corbicula fluminea	Asian Clam	~	Common

120404.5tws 4.15 p-h 35.57336, -78.50532 TS, IK, JR

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	255	61.45/hr
Elliptio congarea	Carolina Slabshell	28	6.75/hr
Elliptio icterina	Variable Spike	65	15.66/hr
Elliptio sp. cf. mediocris	n/a	2	0.48/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.24/hr
Lampsilis radiata	Eastern Lampmussel	2	0.48/hr
Strophitus undulatus	Creeper	2	0.48/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon
Corbicula fluminea	Asian Clam	~	Abundant
Elimia catenaria	Gravel Elimia	~	Rare

120409.1tws 2.35 p-h 35.62032, -78.55640 TS, CS, IK

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.43/hr
Elliptio complanata	Eastern Elliptio	155	65.96/hr
Elliptio congarea	Carolina Slabshell	7	2.98/hr
Elliptio icterina	Variable Spike	18	7.66/hr
Elliptio sp. cf. mediocris	n/a	1	0.43/hr
Elliptio roanokensis	Roanoke Slabshell	2	0.85/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.43/hr
Pyganodon cataracta	Eastern Floater	1	0.43/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

120409.2tws 2.2 p-h 35.62032, -78.55640 TS, CS, IK

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	138	62.73/hr
Elliptio congarea	Carolina Slabshell	4	1.82/hr
Elliptio icterina	Variable Spike	23	10.45/hr
Elliptio roanokensis	Roanoke Slabshell	2	0.91/hr
Lampsilis radiata	Eastern Lampmussel	2	0.91/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

120409.3tws 4.25 p-h 35.62011, -78.5594 TS, CS, IK

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	2	0.47/hr
Elliptio complanata	Eastern Elliptio	225	52.94/hr
Elliptio congarea	Carolina Slabshell	4	0.94/hr
Elliptio icterina	Variable Spike	87	20.47/hr
Elliptio lanceolata	Yellow Lance	1	0.24/hr
Elliptio sp. cf. producta	n/a	1	0.24/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.24/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.24/hr
Lampsilis radiata	Eastern Lampmussel	9	2.12/hr
Strophitus undulatus	Creeper	3	0.71/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

120409.4tws 2.85 p-h 35.62011, -78.5594 TS, CS, IK

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.35/hr
Elliptio complanata	Eastern Elliptio	178	62.46/hr
Elliptio congarea	Carolina Slabshell	1	0.35/hr
Elliptio icterina	Variable Spike	29	10.18/hr
Fusconaia masoni	Atlantic Pigtoe	2	0.70/hr
Lampsilis radiata	Eastern Lampmussel	2	0.70/hr
Pyganodon cataracta	Eastern Floater	1	0.35/hr
Strophitus undulatus	Creeper	4	1.40/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

120409.5tws 3.0 p-h 35.62035, -78.56087 TS, CS, IK

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	2	0.67/hr
Elliptio complanata	Eastern Elliptio	405	135.00/hr
Elliptio congarea	Carolina Slabshell	2	0.67/hr
Elliptio icterina	Variable Spike	56	18.67/hr
Elliptio lanceolata	Yellow Lance	1	0.33/hr
Fusconaia masoni	Atlantic Pigtoe	2	0.67/hr
Lampsilis radiata	Eastern Lampmussel	1	0.33/hr
Strophitus undulatus	Creeper	6	2.00/hr

120409.6tws 1.67 p-h 35.62027, -78.56172 TS, CS, IK

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	140	83.83/hr
Elliptio icterina	Variable Spike	12	7.19/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.60/hr
Lampsilis radiata	Eastern Lampmussel	1	0.60/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

120416.1tcg 3.5 p-h 35.60604, -78.54325 MW, JR, IK

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	2	0.57/hr
Elliptio complanata	Eastern Elliptio	160	45.71/hr
Elliptio congarea	Carolina Slabshell	8	2.29/hr
Elliptio icterina	Variable Spike	61	17.43/hr
Fusconaia masoni	Atlantic Pigtoe	4	1.14/hr
Strophitus undulatus	Creeper	2	0.57/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

120416.2tcg 2.5 p-h 35.60647, -78.54409 MW, JR, IK

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta heterodon	Dwarf Wedgemussel	1	0.40/hr
Elliptio complanata	Eastern Elliptio	264	105.60/hr
Elliptio icterina	Variable Spike	32	12.80/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.40/hr
Lampsilis radiata	Eastern Lampmussel	1	0.40/hr
Strophitus undulatus	Creeper	3	1.20/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

120416.3tcg 2.75 p-h 35.60617, -78.54383 MW, JR, IK

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	3	1.09/hr
Elliptio complanata	Eastern Elliptio	158	57.45/hr
Elliptio icterina	Variable Spike	61	22.18/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.36/hr
Lampsilis radiata	Eastern Lampmussel	1	0.36/hr
Strophitus undulatus	Creeper	3	1.09/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

120416.4tcg 1.75 p-h 35.61032, -78.54772 MW, JR, IK

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	150	85.71/hr
Elliptio icterina	Variable Spike	40	22.86/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.57/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.57/hr
Utterbackia imbecillis	Paper Pondshell	1	0.57/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

120416.5tcg 1.50 p-h 35.60864, -78.54846 MW, JR, IK

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	106	70.67/hr
Elliptio icterina	Variable Spike	12	8.00/hr

120502.1tws 4.08 p-h 35.57189, -78.50263 TS, CS, IK

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta heterodon	Dwarf Wedgemussel	1 shell	~
Alasmidonta undulata	Triangle Floater	1	0.25/hr
Elliptio complanata	Eastern Elliptio	315	77.21/hr
Elliptio congarea	Carolina Slabshell	20	4.90/hr
Elliptio icterina	Variable Spike	99	24.26/hr
Elliptio sp. cf. mediocris	n/a	11	2.70/hr
Elliptio sp. cf. producta	n/a	1	0.25/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.25/hr
Fusconaia masoni	Atlantic Pigtoe	3	0.74/hr
Lampsilis radiata	Eastern Lampmussel	1	0.25/hr
Strophitus undulatus	Creeper	1	0.25/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon
Corbicula fluminea	Asian Clam	~	Common
Elimia catenaria	Gravel Elimia	~	Uncommon

120502.2tws 2.25 p-h 35.57293, -78.50549 TS, CS, IK

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta heterodon	Dwarf Wedgemussel	1	0.44/hr
Alasmidonta undulata	Triangle Floater	1	0.44/hr
Elliptio complanata	Eastern Elliptio	174	77.33/hr
Elliptio congarea	Carolina Slabshell	12	5.33/hr
Elliptio icterina	Variable Spike	42	18.67/hr
Elliptio sp. cf. mediocris	n/a	3	1.33/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.44/hr
Fusconaia masoni	Atlantic Pigtoe	2	0.89/hr
Lampsilis radiata	Eastern Lampmussel	3	1.33/hr
Strophitus undulatus	Creeper	2	0.89/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Patchy Common
Corbicula fluminea	Asian Clam	~	Common

120502.3tws 1.75 p-h 35.587521, -78.50612 TS, CS, IK

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	59	33.71/hr
Elliptio congarea	Carolina Slabshell	10	5.71/hr
Elliptio icterina	Variable Spike	17	9.71/hr
Elliptio sp. cf. mediocris	n/a	2	1.14/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.57/hr
Lampsilis radiata	Eastern Lampmussel	1	0.57/hr
Strophitus undulatus	Creeper	1	0.57/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Rare
Corbicula fluminea	Asian Clam	~	Common

120502.4tws 1.77 p-h 35.57521, -78.50612 TS, CS, IK

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	174	98.31/hr
Elliptio congarea	Carolina Slabshell	13	7.34/hr
Elliptio icterina	Variable Spike	16	9.04/hr
Elliptio sp. cf. mediocris	n/a	6	3.39/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.56/hr
Lampsilis radiata	Eastern Lampmussel	2	1.13/hr

Scientific Name	Common Name	#	Abundance/ CPUE
Strophitus undulatus	Creeper	1	0.56/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Patchy Common
Corbicula fluminea	Asian Clam	~	Common

120502.5tws 2.65 p-h 35.58772, -78.51622 TS, CS, IK

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	2	0.75/hr
Elliptio complanata	Eastern Elliptio	450	169.81/hr
Elliptio congarea	Carolina Slabshell	38	14.34/hr
Elliptio icterina	Variable Spike	88	33.21/hr
Elliptio sp. cf. mediocris	n/a	20	7.55/hr
Elliptio roanokensis	Roanoke Slabshell	6	2.26/hr
Fusconaia masoni	Atlantic Pigtoe	2	0.75/hr
Lampsilis radiata	Eastern Lampmussel	4	1.51/hr
Strophitus undulatus	Creeper	3	1.13/hr
Freshwater Snails and Clams			**Relative Abundance**
Campeloma decisum	Pointed Campeloma	~	Uncommon
Corbicula fluminea	Asian Clam	~	Abundant

120502.1ted 3.5 p-h 35.62031, -78.55709 TD, MW, KM, NS

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	140	40.00/hr
Elliptio icterina	Variable Spike	17	4.86/hr
Elliptio sp. cf. producta	n/a	1	0.29/hr
Lampsilis radiata	Eastern Lampmussel	1	0.29/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

120502.2ted 3.55 p-h 35.62035, -78.56087 TD, MW, KM, NS

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	1	0.28/hr
Elliptio complanata	Eastern Elliptio	480	135.21/hr
Elliptio congarea	Carolina Slabshell	2	0.56/hr

Scientific Name	Common Name	#	Abundance/ CPUE
Elliptio icterina	Variable Spike	88	24.79/hr
Elliptio lanceolata	Yellow Lance	2	0.56/hr
Elliptio sp. cf. mediocris	n/a	5	1.41/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.28/hr
Fusconaia masoni	Atlantic Pigtoe	2	0.56/hr
Lampsilis radiata	Eastern Lampmussel	1	0.28/hr
Strophitus undulatus	Creeper	4	1.13/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Abundant

120502.3ted 2.18 p-h 35.62020, -78.56193 TD, MW, KM, NS

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Elliptio complanata	Eastern Elliptio	130	59.63/hr
Elliptio icterina	Variable Spike	29	13.30/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.46/hr
Strophitus undulatus	Creeper	1	0.46/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

120502.4ted 3.25 p-h 35.62252, -78.57016 TD, MW, KM, NS

Scientific Name	Common Name	#	Abundance/ CPUE
Freshwater Mussels			**CPUE**
Alasmidonta undulata	Triangle Floater	3	0.92/hr
Elliptio complanata	Eastern Elliptio	382	117.54/hr
Elliptio congarea	Carolina Slabshell	10	3.08/hr
Elliptio icterina	Variable Spike	105	32.31/hr
Elliptio sp. cf. mediocris	n/a	6	1.85/hr
Elliptio sp. cf. producta	n/a	2	0.62/hr
Elliptio roanokensis	Roanoke Slabshell	4	1.23/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.31/hr
Lampsilis radiata	Eastern Lampmussel	3	0.92/hr
Freshwater Snails and Clams			**Relative Abundance**
Corbicula fluminea	Asian Clam	~	Common

Chart 1. CPUE of Dwarf Wedgemussel

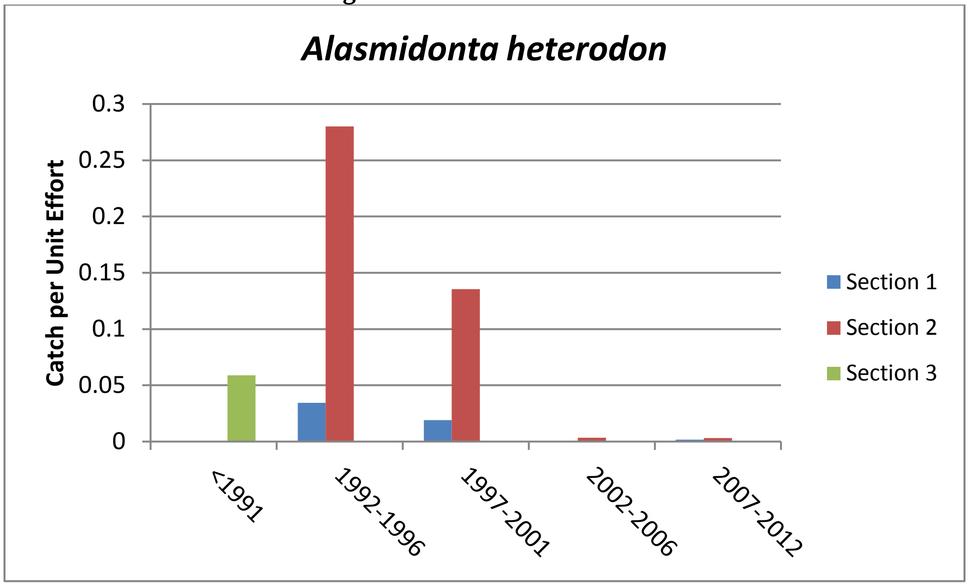


Chart 2. CPUE of Atlantic Pigtoe

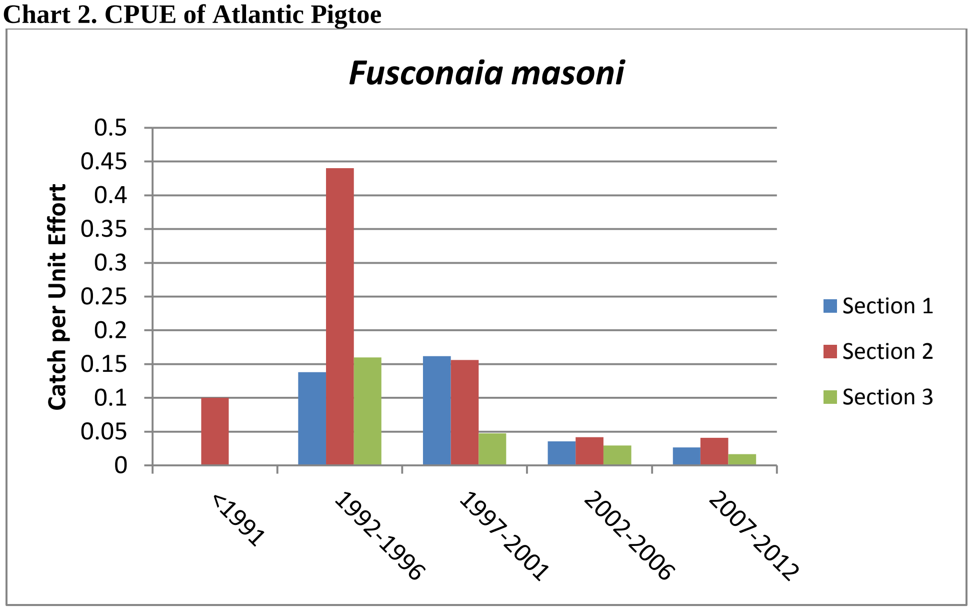


Chart 3. CPUE of Elliptio Species

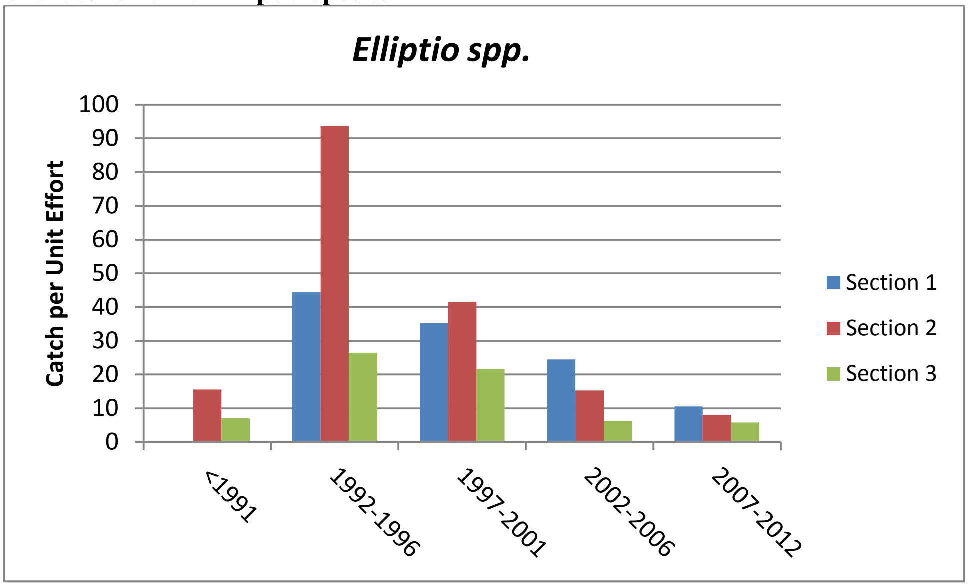


Chart 4. CPUE of Notched Rainbow

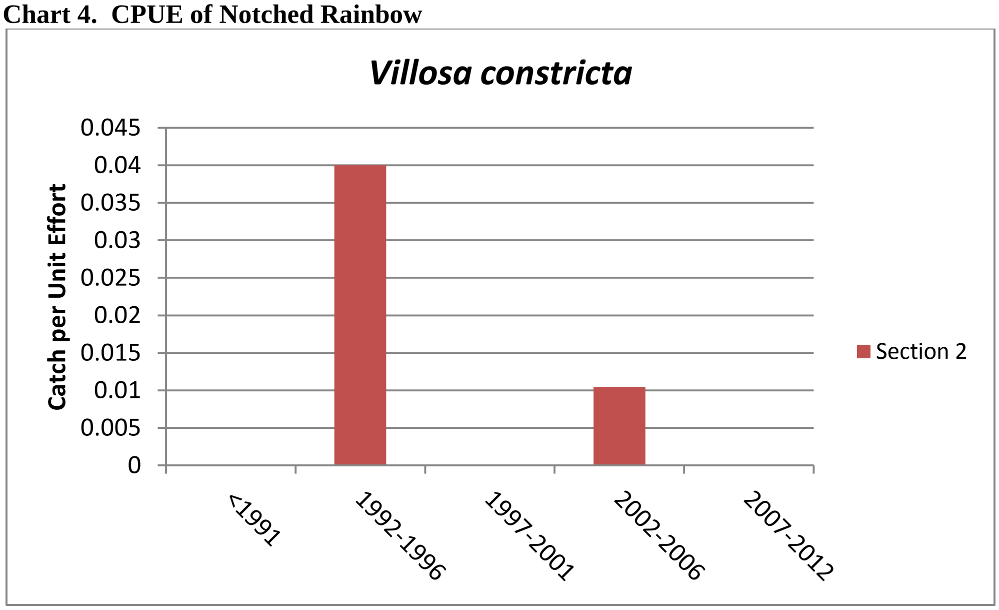


Chart 5. CPUE of Triangle Floater

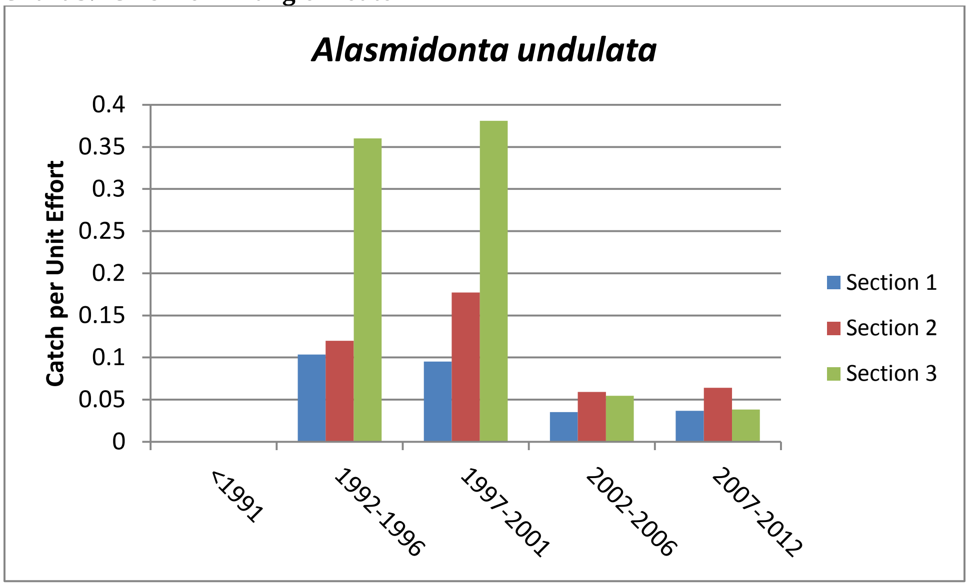


Chart 6. CPUE of Yellow Lance

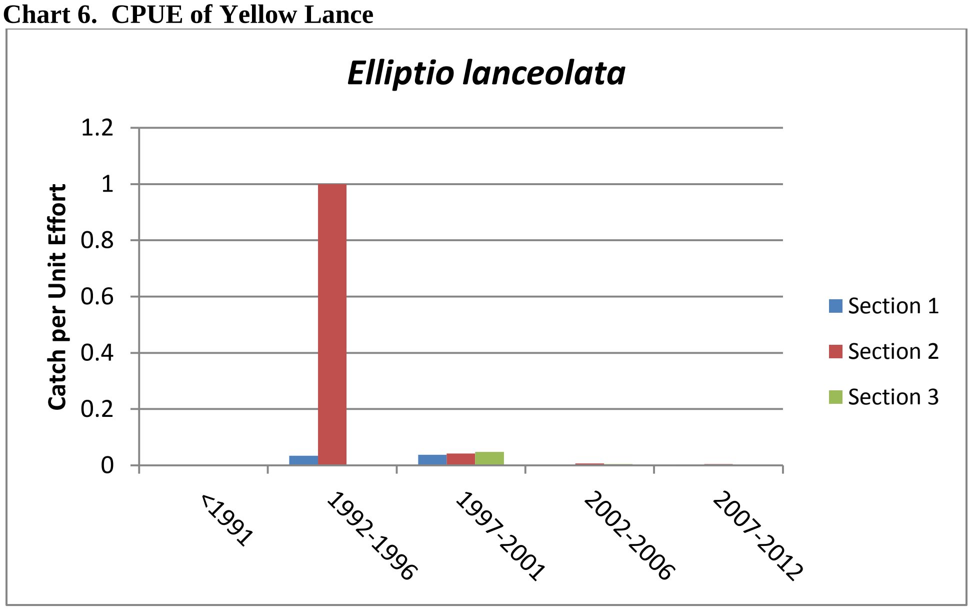


Chart 7. CPUE of Eastern Lampmussel

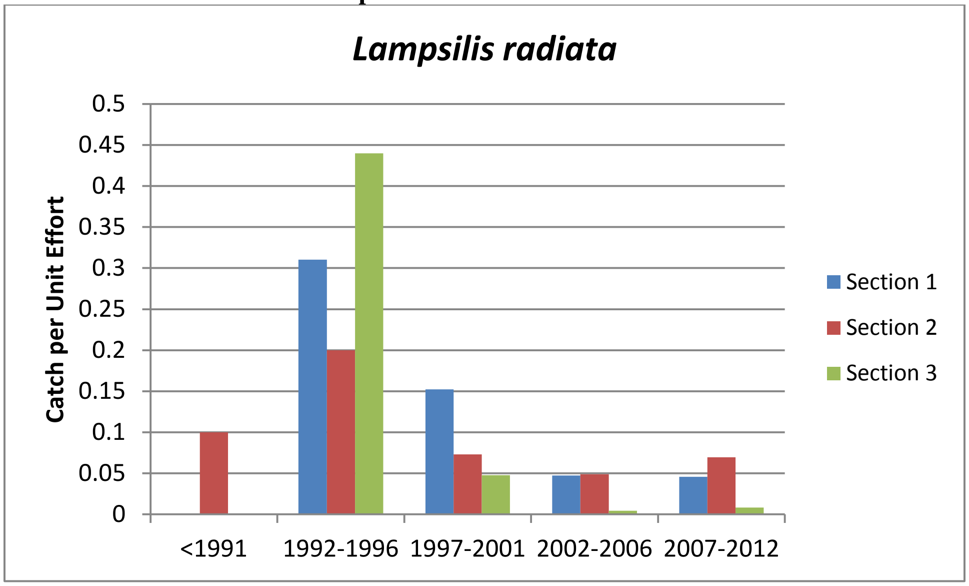


Chart 8. CPUE of Creeper

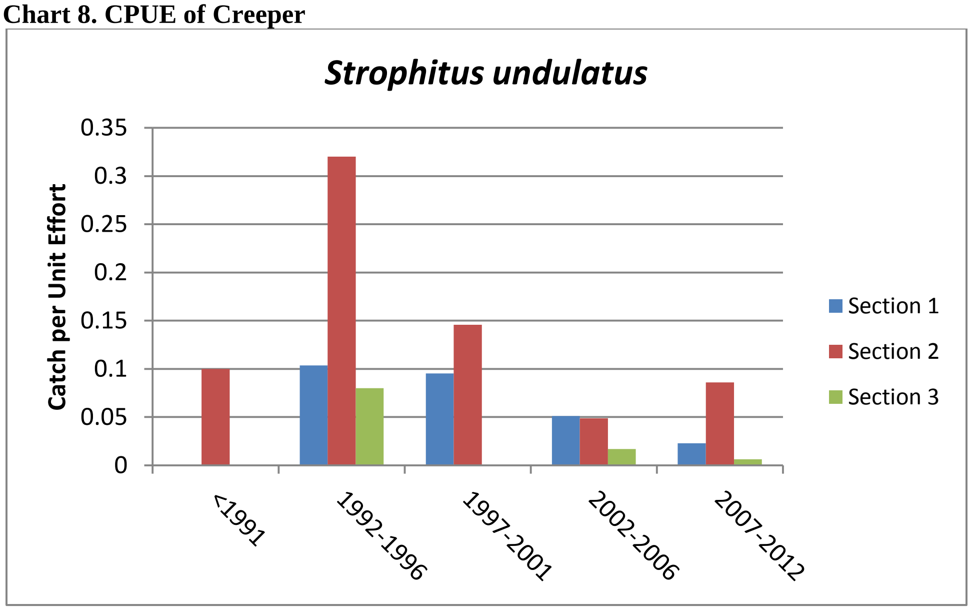


Chart 9. CPUE of Roanoke Slabshell

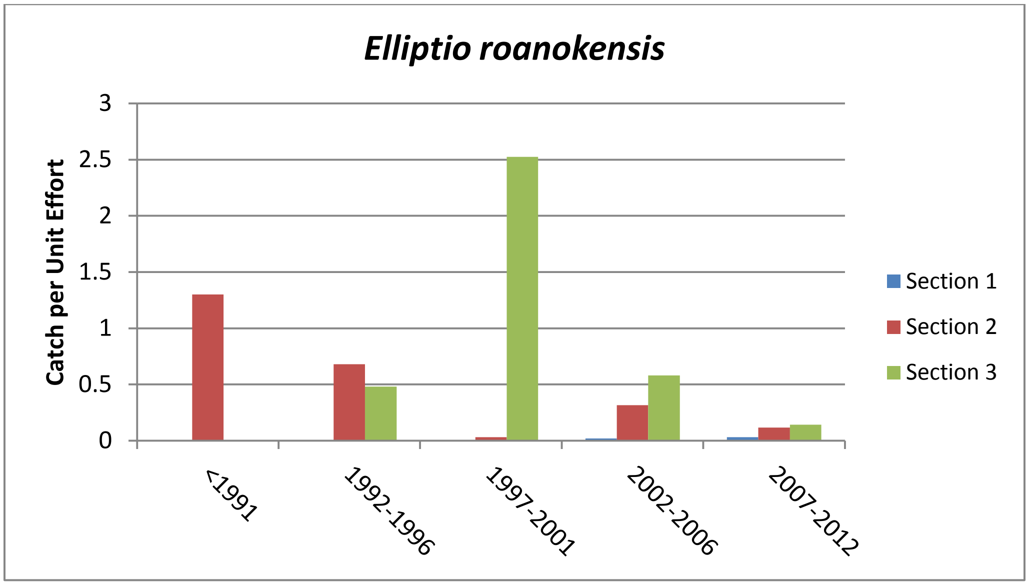


Chart 10. CPUE of Eastern Floater

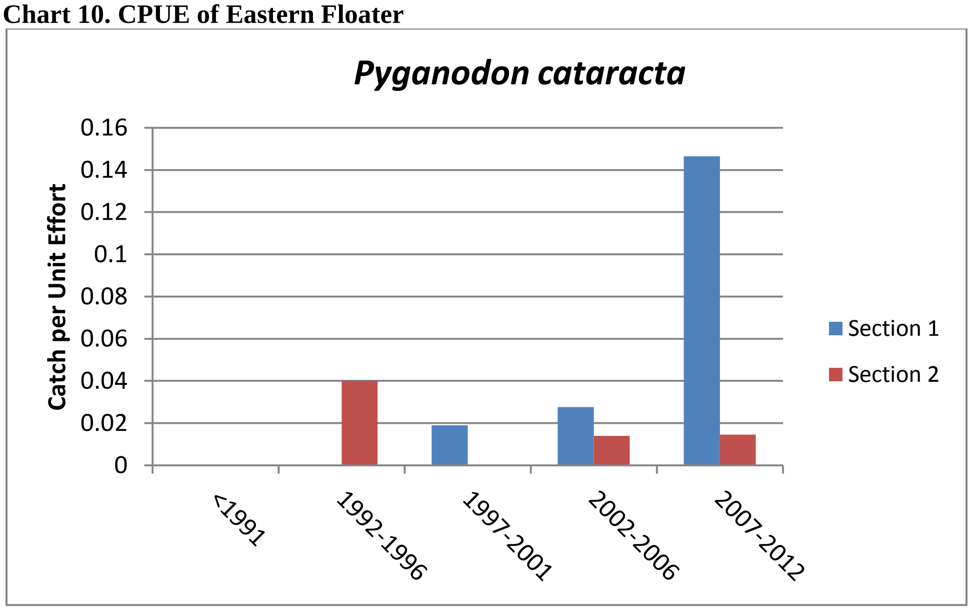


Chart 11. CPUE of Paper Pondshell

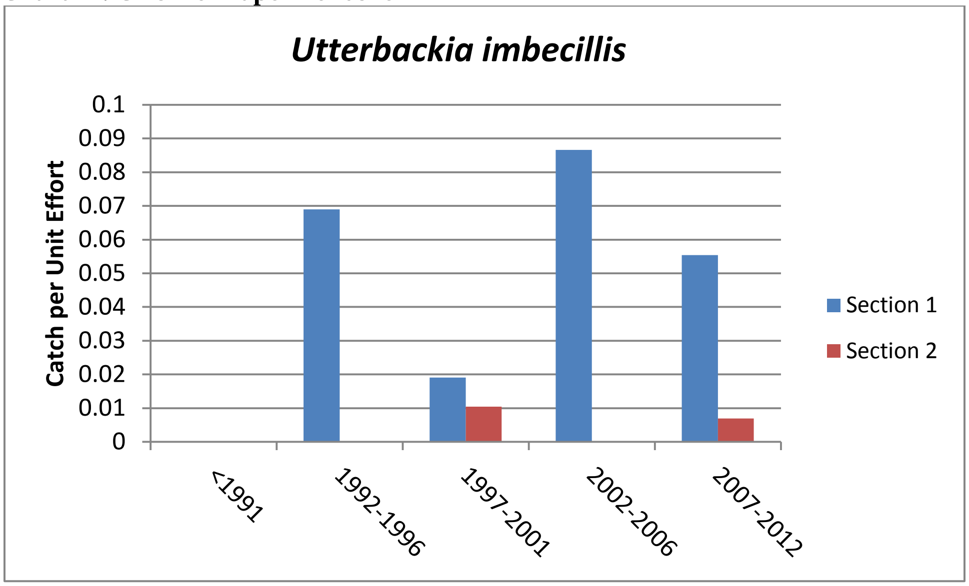


Table 1. Repeat Survey Site 1 Currently Occupied DWM site

		Survey 1: 120302.1tws-4.0 ph		Survey 2: 120416.2tcg-2.5 ph	
Scientific Name	Common Name	#	Abundance/ CPUE	#	Abundance/ CPUE
Alasmidonta heterodon	Dwarf Wedgemussel	1	0.25/hr	1*	0.4/hr
Alasmidonta undulata	Triangle Floater	3	0.75/hr	~	~
Elliptio complanata	Eastern Elliptio	288	72.0/hr	264	105.6/hr
Elliptio congarea	Carolina Slabshell	5	1.25/hr	~	~
Elliptio icterina	Variable Spike	79	19.75/hr	32	12.8/hr
Elliptio sp. cf. mediocris	n/a	2	0.5/hr	~	~
Elliptio roanokensis	Roanoke Slabshell	1	0.25/hr	~	~
Fusconaia masoni	Atlantic Pigtoe	1	0.25/hr	1	0.4/hr
Lampsilis radiata	Eastern Lampmussel	2	0.5/hr	1	0.4/hr
Strophitus undulatus	Creeper	3	0.75/hr	3	1.2/hr

*not same individual

Table 2. Repeat Survey Site 2 Currently Occupied DWM site

		Survey 1: 120302.2tws-3.65 ph		Survey 2: 120416.3tcg-2.75 ph	
Scientific Name	Common Name	#	Abundance/ CPUE	#	Abundance/ CPUE
Alasmidonta undulata	Triangle Floater	5	1.37/hr	3	1.09/hr
Elliptio complanata	Eastern Elliptio	275	75.34/hr	158	57.45/hr
Elliptio congarea	Carolina Slabshell	8	2.19/hr	~	~
Elliptio icterina	Variable Spike	74	20.27/hr	61	24.4/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.27/hr	1	0.36/hr
Lampsilis radiata	Eastern Lampmussel	5	1.37/hr	1	0.36/hr
Pyganodon cataracta	Eastern Floater	1	0.27/hr	~	~
Strophitus undulatus	Creeper	1	0.27/hr	3	1.09/hr

Table 3. Repeat Survey Site 3- Currently Occupied DWM site

		Survey 1: 120314.1tcg-3.90 ph		Survey 2: 120315.3tws-1.60 ph	
Scientific Name	Common Name	#	Abundance/ CPUE	#	Abundance/ CPUE
Alasmidonta undulata	Triangle Floater	1	0.26/hr	1	0.63/hr
Elliptio complanata	Eastern Elliptio	307	78.72/hr	127	79.34/hr
Elliptio congarea	Carolina Slabshell	51	13.08/hr	10	6.25/hr
Elliptio icterina	Variable Spike	57	14.62/hr	15	9.38/hr
Elliptio sp. cf. mediocris	n/a	14	3.59/hr	4	2.5/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.26/hr	1	0.63/hr
Pyganodon cataracta	Eastern Floater	3	0.77/hr	2	1.25/hr
Strophitus undulatus	Creeper	6	1.54/hr	1	0.63/hr

Table 4. Repeat Survey Site 4-Randomly Selected site with no previous surveys

		Survey 1: 120315.2tws-2.75 ph		Survey 2:120502.5tws-2.65 ph	
Scientific Name	Common Name	#	Abundance/ CPUE	#	Abundance/ CPUE
Alasmidonta heterodon	Dwarf Wedgemussel	1	0.36/hr	~	~
Alasmidonta undulata	Triangle Floater	3	1.09/hr	2	0.75/hr
Elliptio complanata	Eastern Elliptio	346	125.81/hr	450	169.81/hr
Elliptio congarea	Carolina Slabshell	18	6.55/hr	38	14.34/hr
Elliptio icterina	Variable Spike	58	21.09/hr	88	33.21/hr
Elliptio sp. cf. mediocris	n/a	20	7.27/hr	20	7.55/hr
Elliptio sp. cf. producta	n/a	1	0.36/hr	~	~
Elliptio roanokensis	Roanoke Slabshell	4	1.45/hr	6	2.26/hr
Fusconaia masoni	Atlantic Pigtoe	1	0.36/hr	2	0.75/hr
Lampsilis radiata	Eastern Lampmussel	1	0.36/hr	4	1.51/hr
Strophitus undulatus	Creeper	2	0.73/hr	3	1.13/hr

Table 5. Repeat Survey Site 5- Randomly Selected site with no previous surveys

		Survey 1: 120404.1tws-1.50 ph		Survey 2: 120502.3tws-1.75 ph	
Scientific Name	Common Name	#	Abundance/ CPUE	#	Abundance/ CPUE
Alasmidonta heterodon	Dwarf Wedgemussel	1	0.67/hr	~	~
Elliptio complanata	Eastern Elliptio	66	44.0/hr	59	33.71/hr
Elliptio congarea	Carolina Slabshell	3	2.0/hr	10	5.71/hr
Elliptio icterina	Variable Spike	8	5.33/hr	17	9.71/hr
Elliptio sp. cf. mediocris	n/a	2	1.33/hr	2	1.14/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.67/hr	1	0.57/hr
Lampsilis radiata	Eastern Lampmussel	1	0.67/hr	1	0.57/hr
Strophitus undulatus	Creeper	~	~	1	0.57/hr

Table 6. Repeat Survey Site 6 Randomly Selected site with no previous surveys

		Survey 1: 120404.2tws-1.65 ph		Survey 2: 120502.4tws-1.77 ph	
Scientific Name	Common Name	#	Abundance/ CPUE	#	Abundance/ CPUE
Elliptio complanata	Eastern Elliptio	155	93.94/hr	174	98.31/hr
Elliptio congarea	Carolina Slabshell	3	1.82/hr	13	7.34/hr
Elliptio icterina	Variable Spike	8	4.85/hr	16	9.04/hr
Elliptio sp. cf. mediocris	n/a	~	~	6	3.39/hr
Elliptio roanokensis	Roanoke Slabshell	~	~	1	0.56/hr
Lampsilis radiata	Eastern Lampmussel	1	0.61/hr	2	1.13/hr
Strophitus undulatus	Creeper	1	0.61/hr	1	0.56/hr

Table 7. Repeat Survey Site 7- Previously Known DWM site-no longer occupied

		Survey 1: 120409.1tws-2.35 ph		Survey 2: 120502.1ted-3.50 ph	
Scientific Name	Common Name	#	Abundance/ CPUE	#	Abundance/ CPUE
Alasmidonta undulata	Triangle Floater	1	0.43/hr	~	~
Elliptio complanata	Eastern Elliptio	155	65.96/hr	140	40.0/hr
Elliptio congarea	Carolina Slabshell	7	2.98/hr	~	~
Elliptio icterina	Variable Spike	18	7.66/hr	17	4.56/hr
Elliptio sp. cf. mediocris	n/a	1	0.43/hr	~	~
Elliptio sp. cf. producta	n/a	~	~	1	0.29/hr
Lampsilis radiata	Eastern Lampmussel	~	~	1	0.29/hr
Elliptio roanokensis	Roanoke Slabshell	2	0.85/hr	~	~
Fusconaia masoni	Atlantic Pigtoe	1	0.43/hr	~	~
Pyganodon cataracta	Eastern Floater	1	0.43/hr	~	~

Table 8. Repeat Survey Site 8- Previously Known DWM site-possibly still occupied

		Survey 1: 120409.5tws-3.0 ph		Survey 2: 120502.2ted-3.55 ph	
Scientific Name	Common Name	#	Abundance/ CPUE	#	Abundance/ CPUE
Alasmidonta undulata	Triangle Floater	2	0.67/hr	1	0.28/hr
Elliptio complanata	Eastern Elliptio	405	135.0/hr	480	135.21/hr
Elliptio congarea	Carolina Slabshell	2	0.67/hr	2	0.56/hr
Elliptio icterina	Variable Spike	56	18.67/hr	88	24.79/hr
Elliptio lanceolata	Yellow Lance	1	0.33/hr	2	0.56/hr
Elliptio sp. cf. mediocris	n/a	~	~	5	1.41/hr
Elliptio roanokensis	Roanoke Slabshell	~	~	1	0.28/hr
Fusconaia masoni	Atlantic Pigtoe	2	0.67/hr	2	0.56/hr
Lampsilis radiata	Eastern Lampmussel	1	0.33/hr	1	0.28/hr
Strophitus undulatus	Creeper	6	2.0/hr	4	1.13/hr

Table 9. Repeat Survey Site 9- Previously Known DWM site-No longer occupied

		Survey 1: 120409.6tws-1.67 ph		Survey 2: 120502.3ted-2.18 ph	
Scientific Name	Common Name	#	Abundance/ CPUE	#	Abundance/ CPUE
Elliptio complanata	Eastern Elliptio	140	83.83/hr	130	59.63/hr
Elliptio icterina	Variable Spike	12	7.19/hr	29	13.30/hr
Elliptio roanokensis	Roanoke Slabshell	1	0.6/hr	~	~
Fusconaia masoni	Atlantic Pigtoe	~	~	1	0.46/hr
Lampsilis radiata	Eastern Lampmussel	1	0.6/hr	~	~
Strophitus undulatus	Creeper	~	~	1	0.46/hr

Periods of Extreme Low Flows Swift Creek (2008-2013) (208773375)

Year	Date Range	Consecutive Days at or Below 1cfs	Consecutive Days at or Below 5cfs
2009	10/23-10/26		4
2011	7/15-7/23		9
2011	7/30		1
2011	9/16-9/17		2
2012	8/18		1
2012	11/12		1

Periods of Extreme Low Flows Middle Creek (1939-2013) (2088000)

Year	Date Range	Consecutive Days at or Below 1cfs	Consecutive Days at or Below 5cfs
1940	10/1		1
1940	10/13-10/18		6
1940	10/20-10/25		6
1940	10/7-10/8		2
1940	7/22-7/26		5
1940	7/29-8/8		11
1940	8/11-8/12		2
1941	10/10-10/27		18
1941	9/18-9/25		8
1945	6/7		1
1945	6/19		1
1948	7/10		1
1948	7/13		1
1948	8/18		1
1948	8/26-9/8		14
1948	9/13-9/27		15
1951	11/2		1
1951	10/6-10/10	5	
1951	6/23-6/26		4
1951	7/8-7/15		8
1951	8/1-8/2		2
1951	8/19-8/23		5
1951	8/28-9/14		18
1951	9/22-10/31		40
1952	7/22-7/30		9
1953	10/3-11/5		34
1953	7/27-8/1		6
1953	8/23-9/6		15
1953	9/11-9/26		16

1953	9/17-9/26	10	
1954	6/30-7/3		4
1954	7/5-7/15		8
1954	8/1-8/2		2
1954	8/23-10/14		53
1954	8/9-8/17		9
1954	9/3-9/4	2	
1954	9/7-10/14	38	
1955	8/10		1
1955	6/15-6/19		5
1955	7/3-7/4		2
1956	9/18-9/20		3
1957	8/12-8/17		6
1966	9/11-9/13		3
1968	10/6	1	
1968	9/11-11/4		80
1968	9/9-10/4	26	
1969	7/18-7/24		7
1970	9/2		1
1970	6/19-6/21		3
1970	7/18-7/20		3
1970	7/8-7/9		2
1970	9/12-9/27		16
1970	9/30-10/17		18
1973	10/23		1
1973	10/18-10/20		3
1973	11/20-11/21		2
1973	11/25-12/6		12
1973	11/3-11/15		13
1974	7/16-7/20		5
1976	8/12-8/24		13
1976	8/26-9/10		16
1976	8/6-8/7		2
1976	9/13-9/14		2
1976	9/19-9/25		7
1976	9/30-10/8		9
1977	10/6-10/8		3
1977	6/19-6/25		7
1977	6/28-7-9		12
1977	7/12-8/1		21
1977	7/17-7/31	15	

1977	8/13-8/18		6
1977	8/21-9/7		19
1977	8/27-9/7	11	
1977	9/28-10-3		6
1978	10/15-10/9		5
1978	9/20-10-1		12
1979	8/10-8/12		3
1980	8/16		1
1980	9/2	1	
1980	10/10		1
1980	11/9-11/15		7
1980	7/30-7/31		2
1980	8/25-8/31		12
1980	8/8-8/12		5
1980	9/1-9/5		5
1980	9/20-9/23		4
1980	9/8-9/17		10
1981	6/16-7/2		17
1981	7/16-7/19	4	
1981	7/23-8/11		20
1981	7/8-7/20		13
1981	8/1-8/8	8	
1981	8/31-10/23		40
1981	8/31-9/4		5
1982	10/1-10/8	8	
1982	10/19-10/21		3
1982	9/7-10/12		36
1983	12/1-12/2		2
1983	7/18-7/21		4
1983	7/31-11/1		94
1983	8/15-8/23	9	
1983	8/37-9/14	19	
1983	9/18-9/20	3	
1983	9/26-10/13	18	
1984	9/20-9/29		10
1985	6/11		1
1985	10/19	1	
1985	10/28-11/1	5	
1985	11/6-11/20		15
1985	11/7-11/20	14	
1985	5/30-6/5		7

1985	6/23-6/30		8
1985	7/10-7/11		2
1985	7/15-7/24		10
1985	8/13-11/3		61
1985	8/13-8/17		5
1985	9/22-10/3	12	
1986	5/29-6/1		4
1986	5/3-5/19		17
1986	6/22-7/28	37	
1986	6/4-8/12		70
1986	7/31-8/4	5	
1986	8/8-8/12	5	
1986	9/15-11/11		58
1986	9/26-10/26	31	
1987	6/26		1
1987	11/17		1
1987	10/14-10/25		12
1987	10/4-10/7		4
1987	11/24-11/25		2
1987	6/19-6/21		3
1987	6/28-7/2		5
1987	7/17-8/7		22
1987	7/26-8/6	15	
1987	7/4-7/11		8
1987	8/10-9/8		30
1987	8/12-8/19	8	
1987	8/23-9/8	17	
1987	9/18-9/19		2
1987	9/21-9/30		10
1988	6/17		1
1988	6/20		1
1988	8/5		1
1988	10/9-10/18		10
1988	6/28-7/13		16
1988	7/9-7/12	4	
1988	8/17-8/20		4
1988	8/23-8/28		6
1988	9/16-9/17		2
1988	9/30-10-3		4
1988	9/3-9/4		2
1990	8/6		1

1990	10/29-11/5		8
1990	11/1-11/3	3	
1990	9/13-10/1		19
1990	9/3-9/10		8
1999	8/4-8/8		5
2007	9/9		1

Discharge measurements from Swift Creek at NC-42 (1988-1997) (208772185)

Date	Discharge (cfs)
3/14/1988	50.1
5/9/1988	28.2
8/4/1988	9.48
11/10/1988	24.8
1/25/1989	22.4
4/27/1989	133
7/25/1989	60.8
11/14/1989	42.2
2/23/1990	160
8/8/1990	5.9
3/22/1991	77.9
6/6/1991	8.29
9/24/1991	8.6
5/21/1992	12.6
9/28/1992	8.44
12/17/1992	47.3
4/29/1994	16.4
11/15/1994	10.5
1/4/1995	21.2
5/15/1995	44.9
7/28/1995	16.3
10/20/1995	38.1
1/24/1996	99.4
5/1/1996	796
9/26/1996	34.1
11/19/1996	56.5
2/19/1997	135
4/15/1997	64.7

Complete 540 – Triangle Expressway Southeast Extension
Dwarf Wedgemussel Habitat Assessment
Survey Report

Wake and Johnston County, North Carolina

Survey site RS-3 where Dwarf Wedgemussel is present.

Prepared for:

LOCHNER

H.W. Lochner, Inc.
2840 Plaza Place, Suite 202
Raleigh, NC 27612

Prepared by:

The Catena Group

410B Millstone Drive
Hillsborough, NC 27278

December 2013

Table of Contents

1.0 INTRODUCTION 1

1.1 Habitat Assessment 1

2.0 METHODOLOGIES 2

2.1 Longitudinal Profile 2

2.2 Cross-sectional Profile 2

2.3 Particle Size Distribution Analysis 3

2.4 Channel Classification.. 3

2.5 Bankfull Discharge.. 3

3.0 SURVEY RESULTS 3

3.1 Currently Occupied Sites (1-3) 3

3.2 Previously Occupied Sites (1-3)... 4

3.3 Randomly Selected Sites (1-3)... 5

4.0 DISCUSSION.. 6

5.0 REFERENCES 9

Table of Tables

Table 1. Habitat Assessment Survey Sites.. 2

Table 2. Stream Attributes for Previously Surveyed DWM Sites in Swift Creek......................... 8

1.0 INTRODUCTION

In an effort to update the environmental baseline for the Dwarf Wedgemussel (*Alasmidonta heterodon*, DWM) population in Swift Creek, a multi-tier study is being conducted to determine the viability of this population. This component of the study addresses the current habitat conditions in Swift Creek and its ability to continue to support the DWM.

Survey efforts in Swift Creek during 2007, 2010, 2011 and 2012 established a current occupied range of at least 11 miles (Figure 1), with no gaps of unoccupied habitat greater than two miles. Habitat requirements for the DWM are still poorly understood. This wide ranging species historically occurred discontinuously from the Peticodiac River Basin in New Brunswick Canada, south to the Neuse River Basin in North Carolina (Johnson 1970). It has been recorded from very large rivers, like the Connecticut, Delaware, and Susquehanna Rivers (USFWS 1993), to first order streams like Maple Branch and Fox Creek in the Tar River Basin (NCWRC unpublished database). A variety of substrates including firm sand, clay banks, muddy sand, sand, mixed sand, gravel, and cobble (Johnson 1970, USFWS 1993) have been reported. In the southern portion of its range, it is often found near embedded logs and/or submerged root mats in shallow water along stable stream banks (USFWS 1993; Catena, pers. observ.). Two habitat types, Shallow Fast Coarse (SFC) or Deep Stream Margin Roots (DSMR) habitats were identified as primarily supporting this species in Swift Creek (Entrix 2005). In addition to the main objective of determining current habitat conditions and suitability in Swift Creek, this component of the study focuses on specific microhabitat parameters that are important in supporting this species.

1.1 Habitat Assessment

Habitat assessment and characterization was conducted in Swift Creek on January 31, February 6, and February 15, 2013 in locations that had previously been surveyed for freshwater mussels, with DWM as the target species (Table 1, Figure 1). The goal was to identify good and poor habitat attributes for the DWM. Stream reaches with relatively stable banks, substrate particle size diversity, and relatively high mussel fauna abundance and/or diversity were defined as good habitat. Stream reaches with unstable banks, unstable substrate that was usually sand dominated, and comparatively lower mussel fauna and diversity were defined as poor habitat. Nine locations were selected for this analysis from three categories:

1) Three sites currently occupied by DWM (CO-1-3)
2) Three sites previously occupied by DWM (PO-1-3)
3) Three randomly selected sites that were surveyed for mussels in 2012 (RS-1-3).

Currently occupied (CO) sites have records of DWM presence within the past 5 years (NCWRC unpublished database). Previously occupied (PO) sites have been surveyed within the past year but DWM has not been recorded there for over five years (PO1 and PO3 > 10 years), and habitat was characterized by the surveyors as degraded and likely no longer occupied. Randomly selected (RS) sites were chosen from a group of survey 15 sites that had no record of freshwater mussel surveys previous to 2012. Timed mussel surveys were conducted in 200 foot sections at eight of the nine sites in 2012; PO-2 had been surveyed in this manner in 2011 and those results were used in this analysis.

Table 1. Habitat Assessment Survey Sites

Survey Site ID	**Latitude**	**Longitude**
PO-2	35.62766	-78.58522
PO-3	35.6195	-78.55474
PO-1	35.60838	-78.54858
CO-1	35.60624	-78.54378
RS-2	35.58785	-78.51584
RS-1	35.58582	-78.51255
CO-3	35.57531	-78.50605
RS-3	35.57293	-78.50549
CO-2	35.57245	-78.50076

2.0 METHODOLOGIES

The assessment consisted of stream cross sectional profiles, longitudinal profiles, particle size distribution analyses, and qualitative analyses accompanied by photo documentation for each site. USGS stream gauge #0208773375 (Swift Creek at 1555 near Clayton, NC) was checked before each field visit to ensure appropriate water levels for data collection (Figure 2). Water levels ranged from 25-50 cubic feet per second (cfs) during the data collection period (USGS 2013).

2.1 Longitudinal Profile

For each site, a stream longitudinal profile of 200 feet was conducted using a survey grade laser level to identify the stream slope, bed features, and a general description of sediment composition along the stream thalweg. Measurements were taken along the thalweg to depict the micro-topographic relief of the stream channel.

2.2 Cross-sectional Profile

A cross sectional profile was surveyed for each site using a survey grade laser level. Cross sectional data were extracted based on a linear alignment between the end pins. Metrics collected include the stream cross-sectional area, width/depth ratio, bankfull width, and wetted width.

2.3 Particle Size Distribution Analysis

The Wolman pebble count procedure was used to determine the particle size distribution for each survey site (Wolman 1954). The procedure was used to measure the diameter of the intermediate axis of 100 randomly selected stones along transects located at the nine designated sites. The pebble count method is modified to target the low flow, wetted channel width where the mussels reside, rather than bankfull width. The resulting data yield a size distribution for the bed surface deposits. The observer walks perpendicularly across the wetted width along the cross section of the stream and back again, in the downstream direction, until a minimum of 100 pebbles have been randomly selected, measured, and recorded. Particle sizes smaller than 2 mm are classified as sand or silt based on feel. The representative grain size for each site is expressed as D50 and D84 in mm (50% and 84% of the sampled particles is equal to or finer than the representative particle diameter).

2.4 Channel Classification

Swift Creek classifies as a "C4 and C5" channel with mostly sand dominated substrate. C channels are riffle/pool streams with a well-developed floodplain, meanders, and point bars. These streams are wide with a width/depth ratio greater than 12. Type "C" streams are moderately entrenched and use their floodplain during large storm events. The channel material is generally sand dominated with some areas of gravel and cobble accumulations. Eroding streambanks are typical for this stream type unless in an area with extensive riparian vegetation (Rosgen, 1996). The "4" in the classification describes the channel further as a gravel bed stream, while the "5" indicates a sandbed stream.

2.5 Bankfull Discharge

The Swift Creek drainage areas for the survey sites range from approximately 77 to 131 square miles. Land use consists of wooded terrain, farmlands, and residential developments. Bankfull was located at or near the top of bank along the entire reach. Bankfull verification was completed with a comparison of field surveyed cross sections along the streams to typical bankfull width, area, depth, and discharge relationships. The watershed predicted discharges were compared with the bankfull channel capacities for verification. The Regional Curves developed by the North Carolina State University (NCSU) Water Quality Group were used to verify acceptable limits of morphological characteristics based on a hydro-physiographic region and drainage area. The average bankfull discharges, cross sectional areas, bankfull widths, and depth for Swift Creek fell within the confidence limits of these curves.

3.0 SURVEY RESULTS

3.1 Currently Occupied Sites (1-3)

These sites were relatively shallow runs with a heterogeneous distribution of sand, course sand, pea gravel, and gravel typical of runs and riffles, which is reflected in the D50 and D84 results

(Table 2). These sites reflect a coarser, more consolidated stable substrate as compared to the other less stable sand dominated stream reaches that were previously occupied by DWM. The stream banks consisted of stable clay with little detritus accumulation along the banks. The adjacent land use consists mostly of a wooded floodplain with a system of oxbow channels throughout the floodplain of Swift Creek. Longitudinal profiles show some fluctuation in the streambed elevation with a channel slope <0.1%. Mussel survey results from 2012 yielded the greatest catch per unit effort (CPUE) from these sites (105-111 mussels/hr) as well as species diversity ranging from 8-11 species per site.

Photo 1. Dwarf wedgemussel found at Site CO-1 during 2012 surveys

3.2 Previously Occupied Sites (1-3)

These sites consisted of a deeper run/pool complex with a dominant shifty sand substrate. The channel banks were unstable and steep in areas throughout these reaches. Further indicators of an unstable channel such as excess woody debris and detritus, and the dynamic nature of the mid-channel bar formations, are also evident. Adjacent land use consisted of extensive oxbow wetland complexes. Streambank substrate was dominated by clay with some silt accumulations. Longitudinal profiles show some fluctuation in the streambed elevation with a channel slope <0.05%. Mussel survey results from 2012 (2011 for PO-2) yielded a CPUE of 77, 109, and 58 mussels/hr for Sites PO-1, PO-2, and PO-3 respectively. PO-1 had a low diversity with a total of two species. PO-2 and PO-3 had a diversity of five and ten species respectively.

Photo 2. Eroding banks and woody debris within Site PO-3.

3.3 Randomly Selected Sites (1-3)

These 3 sites were randomly selected from 15 sites that were surveyed for the first time in 2012. The DWM was found at sites RS-1 and RS-3. RS-1 is a sand dominated pool/glide complex with high amounts of large woody debris. Adjacent land use is mainly floodplain with a large wetland system that flows into the RS-1 stream reach. Water levels are deep throughout, and the DWM was observed in 2012. RS-1 had a CPUE of 43 mussels/hr with a low diversity of 4 species. RS-2 is approximately 1,000ft upstream of RS-1. This site is very similar to RS-1 with a deeper run/ pool complex containing large amounts of woody debris with pockets of detritus dominated substrate. The substrate is mainly dominated by sand with clay banks. RS-2 had a CPUE of 61 mussels/hr with a diversity of 8 species. RS-3 is approximately 1 mile downstream of RS-2. This stream reach is a run/pool complex dominated by sand with silt accumulations along the base of the clay banks. Woody debris appears to be at appropriate natural levels. Adjacent land use consists of a forested riparian buffer with a cutover forest community beyond a 200 buffer on both sides of the creek. RS-3 had a CPUE of 107 mussels/hr with a diversity of 10 species, including the DWM.

Photo 3. Site RS-3 with relatively stable streambanks where DWM was found.

4.0 DISCUSSION

Throughout all of the survey sites, Swift Creek is a low gradient, meandering, point-bar, riffle/pool dominated stream type that has alluvial channels within broad well defined floodplains. In general, the CO sites are located towards the middle portion of Swift Creek between Lake Benson and the Neuse River while the PO sites are in the upper portion. Therefore, the drainage area, wetted width, bankfull width, bankfull width/depth ratio, and bankfull cross sectional area are larger in the CO sites.

Of the nine sites surveyed, five have current records of DWM. The survey results reveal a pattern of larger substrate size correlating with current DWM presence. Three of the five CO sites contained a gravel component ranging from 21-45% of the substrate within the cross section (Table 2). Data for the remaining two DWM sites (RS-1 and RS-3) reflected a clay/sand substrate. However, observations within site RS-3 noted a gravel trough within the thalweg of the cross section located left of center in the channel. This gravel component wasn't reflected in the data due to a coating of a silt/clay component on the gravel which was recorded instead during data collection. Even though DWM was found in RS-1, RS-1 is still considered an outlier. The RS-1 stream reach was largely composed of a sand dominant pool habitat, however, there was small, stable microhabitat of stream bank that supported one young DWM (~2-3 yrs old). Survey sites without current records of DWM presence trend toward a finer silt/sand dominated substrate, with the exception of site RS-2. RS-2 has a gravel component, but DWM was not found. However, given that only one survey has ever been conducted in this location, the species may be present but not detected.

Based on these results, evidence shows a correlation in DWM presence and substrate particle size. While the sites where the DWM occurs generally have gravel dominated substrate, the species is often found within small microhabitats of clay. These data could be further expanded with additional transects throughout each survey sites to accurately depict habitat conditions in order to better understand habitat needs of the DWM. The three previously occupied sites occur within the upper portion of the DWM range in Swift Creek. A likely reason these areas are no longer occupied is due to a shifting sand substrate, which is generally indicative of unstable conditions. Further study of the relationship between substrate particle size and the presence of DWM is needed along with in-stream habitat monitoring (particularly in the upper sections) to fully understand the persistence of DWM in Swift Creek.

Table 2. Stream Attributes for Previously Surveyed DWM Sites in Swift Creek.

Cross Section ID (Site order based on drainage area size)	**PO-2**	**PO-3***	**PO-1**	**CO-1**	**RS-2**	**RS-1**	**CO-3**	**RS-3**	**CO-2**
Drainage Area (sq mi)	77.5	81	86*	86.5	103	111	117	124	131
Wetted Width (ft)	44.2	30.2	23	40.8	45.8	37.9	57.5	43.5	48.9
Bankfull Width (ft)	59	49	66	62	59	73	98	74	96
Bankfull Width-Depth Ratio	21.1	9.1	17.1	27.2	15.7	22	19.9	23.7	18.7
Bankfull Cross Sectional Area (ft^2)	368.6	297.2	257.5	390.4	304	319.2	481	337.5	487.8
Bankfull Discharge Rate (cfs)	3479.6	1288.4	603.2	2428	2871.4	2562.3	1652.3	798.2	1276.9
D50 Particle Size (mm)	0.23	0.26	0.30	0.61	0.48	0.37	0.78	0.062	0.52
D84 Particle Size (mm)	0.40	0.54	0.65	6.60	0.94	0.73	20.00	0.59	5.80
Wolman Particle Size Distribution (%)	31% Clay, 69% Sand	42% Clay, 58% Sand	27% Clay, 73% sand	4% Clay, 60% Sand; 36% Gravel	13% Clay, 74% Sand, 13% Gravel	21% Clay; 79% Sand	16% Clay, 39% Sand, 45% Gravel	57% Clay; 43% Sand	19% Clay, 60% Sand, 21% Gravel
Water Surface Slope ft/ft	0.15	0.03	0.01	0.13	0.15	0.12	0.04	0.01	0.015
Channel Classification	C5	C5	C5	C5	C5	C5	C4	C5	C5
DWM Presence	No	No	No	Yes	No	Yes	Yes	Yes	Yes
# Species	5	10	2	10	8	4	8	10	11
CPUE All Mussels (#/hr)	109.28	58.97	78.67	105.69	61.76	43.75	53.23	107.11	111.03
General Habitat Condition**	Poor	Poor	Poor	Good	Marginal	Poor	Good	Marginal	Good

*Site on one of two channels that rejoin downstream
**Based on Best Professional Judgment

5.0 REFERENCES

ENTRIX. 2005. Biological Assessment for Dwarf Wedgemussel (*Alasmidonta heterodon*) (June 2005). ENTRIX, Inc., Atlanta, Georgia.

Johnson, R. I. 1970. The Systematics and Zoogeography of the Unionidae (Mollusca: Bivalva) of the Southern Atlantic Slope Region. Bulletin of the Museum of Comparative Zoology 140(6): 263-449.

Rosgen, Dave 1996. Applied River Morphology. Second Addition

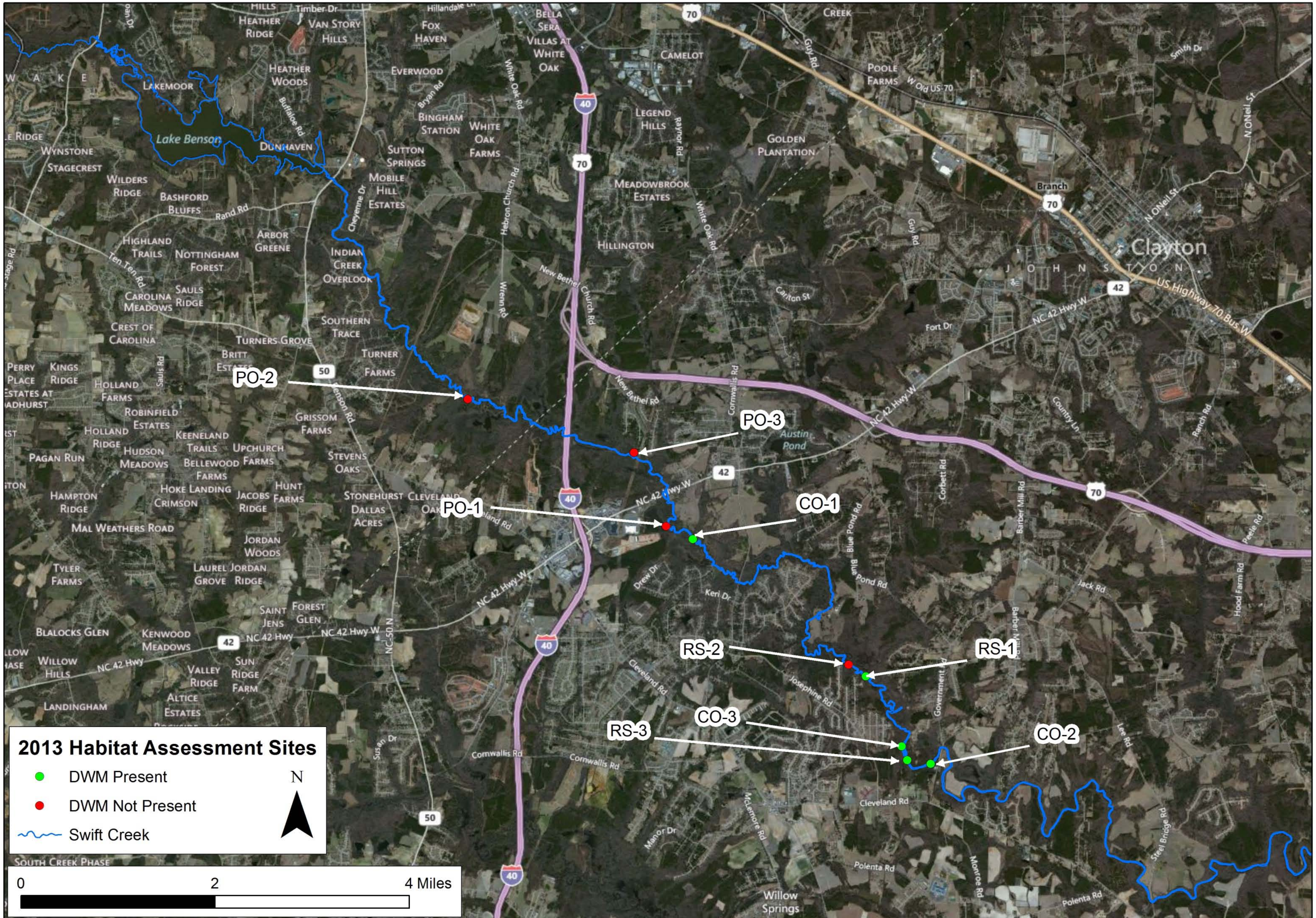
Savidge, Timothy W. Personal Observation. The Catena Group, Inc.

U.S. Fish and Wildlife Service. 1993. Dwarf Wedgemussel Mussel (*Alasmidonta heterodon*) Recovery Plan. Hadley, Massachusetts. 527 pp.

USGS 2013. National Water Information System: Web Interface USGS 0208773375 SWIFT CREEK AT SR1555 NEAR CLAYTON, NC (http://waterdata.usgs.gov/nc/nwis/uv/?site_no=0208773375&PARAmeter_cd=00065,00060)

Wolman, M.G. 1954. A method of sampling course river-bed material. Transactions of American Geophysical Union 35. 951-956.

Appendix I



The Catena Group

Date: December 2013

Scale: As Shown

Job No.: 1154

Title:

Swift Creek DWM Habitat Assessment Sites

Wake and Johnston Counties, North Carolina

Client:

Figure 1

Currently Occupied Site-1

The Catena Group

Date: December 2013

Scale: As Shown

Job No.: 1154

Title:

Swift Creek DWM Habitat Assessment Sites

Wake and Johnston Counties, North Carolina

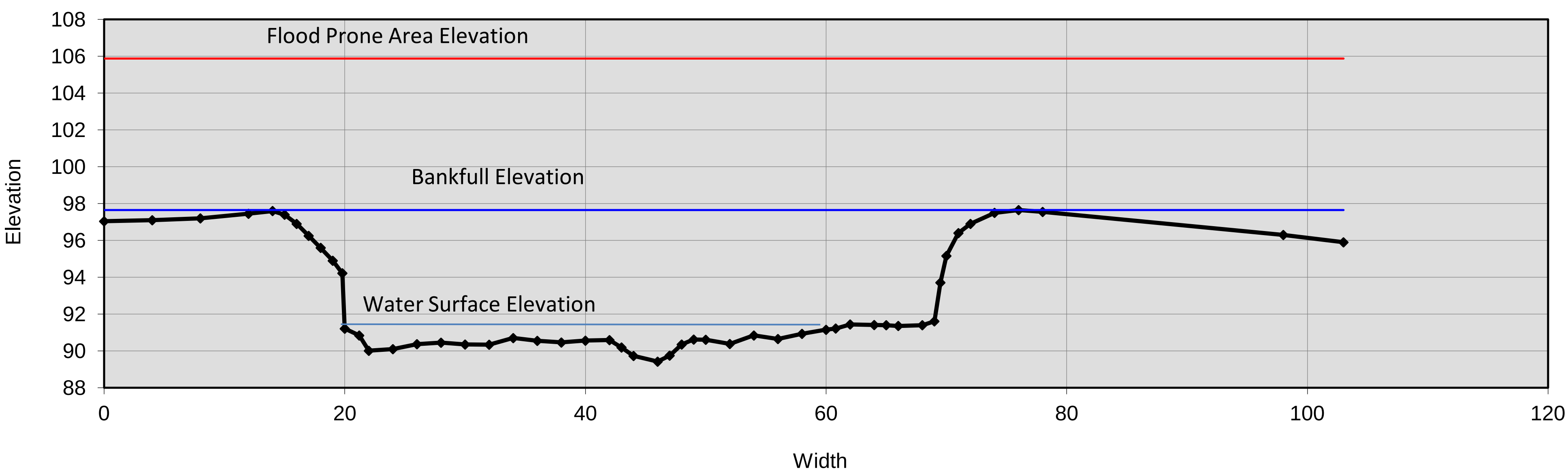
Client:

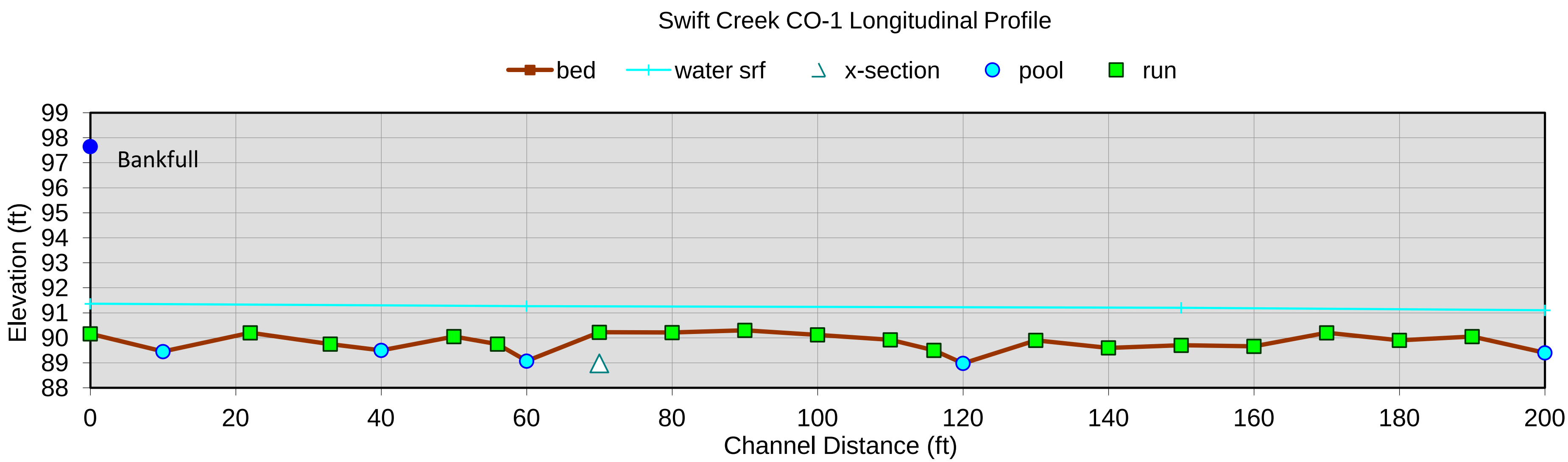
State of North Carolina Department of Transportation

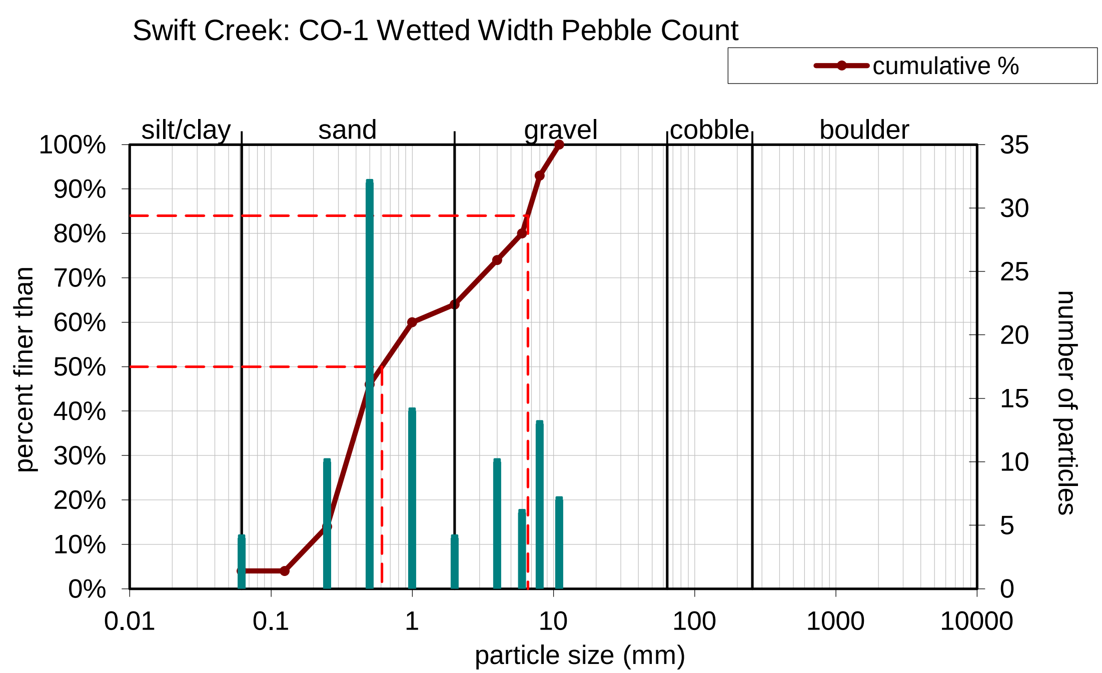
Figure

2

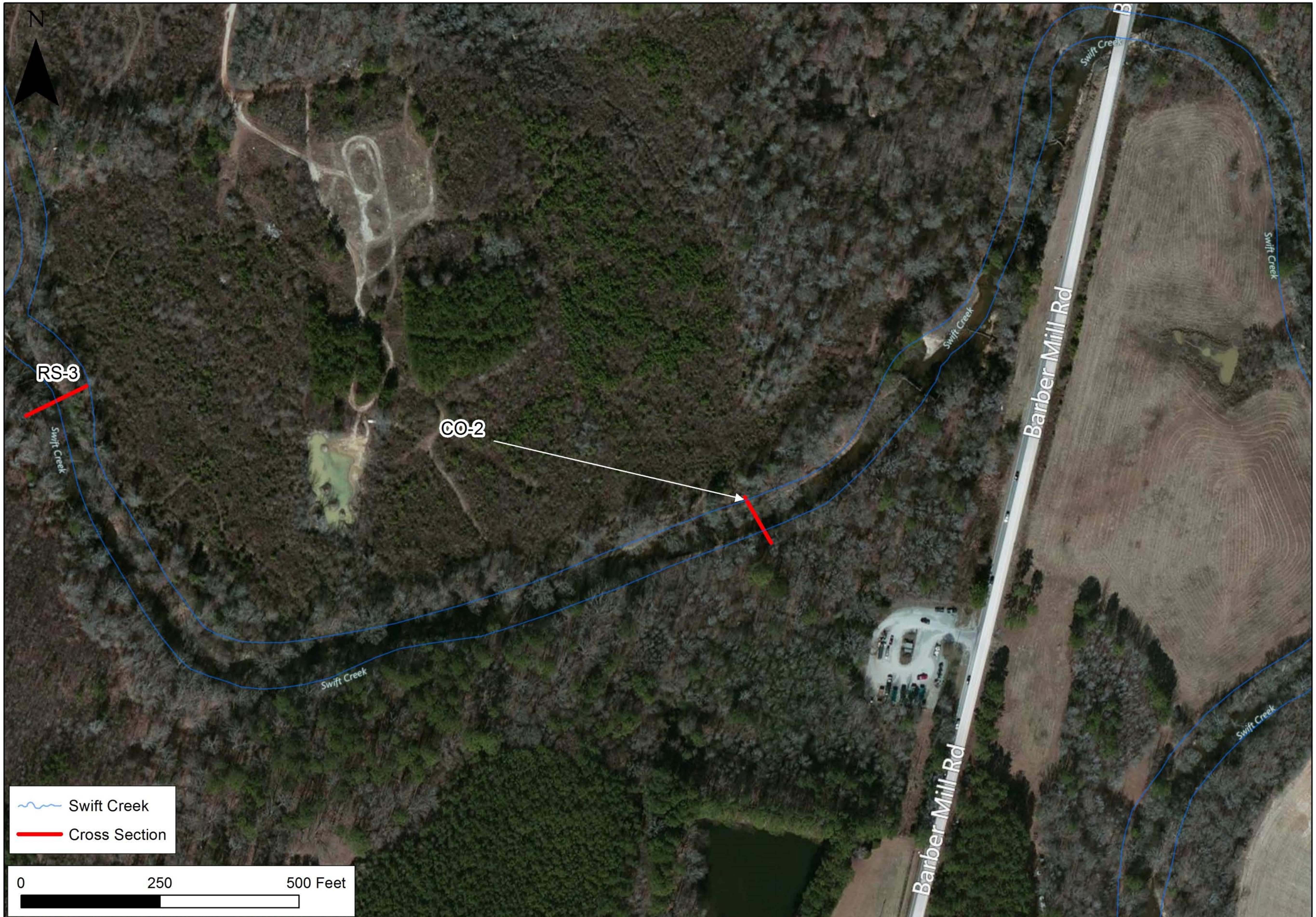
Swift Creek: CO-1 Cross Section, Downstream Facing View




Swift Creek CO-1 Longitudinal Profile
bed
water srf
x-section
pool
run
Bankfull
Elevation (ft)
Channel Distance (ft)
99
98
97
96
95
94
93
92
91
90
89
88
0
20
40
60
80
100
120
140
160
180
200


Swift Creek: CO-1 Wetted Width Pebble Count
cumulative %
silt/clay
sand
gravel
cobble
boulder
percent finer than
number of particles
particle size (mm)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
35
30
25
20
15
10
5
0
0.01
0.1
1
10
100
1000
10000

Currently Occupied Site-2



The Catena Group

Date:
December 2013

Scale:
As Shown

Job No.:
1154

Title:

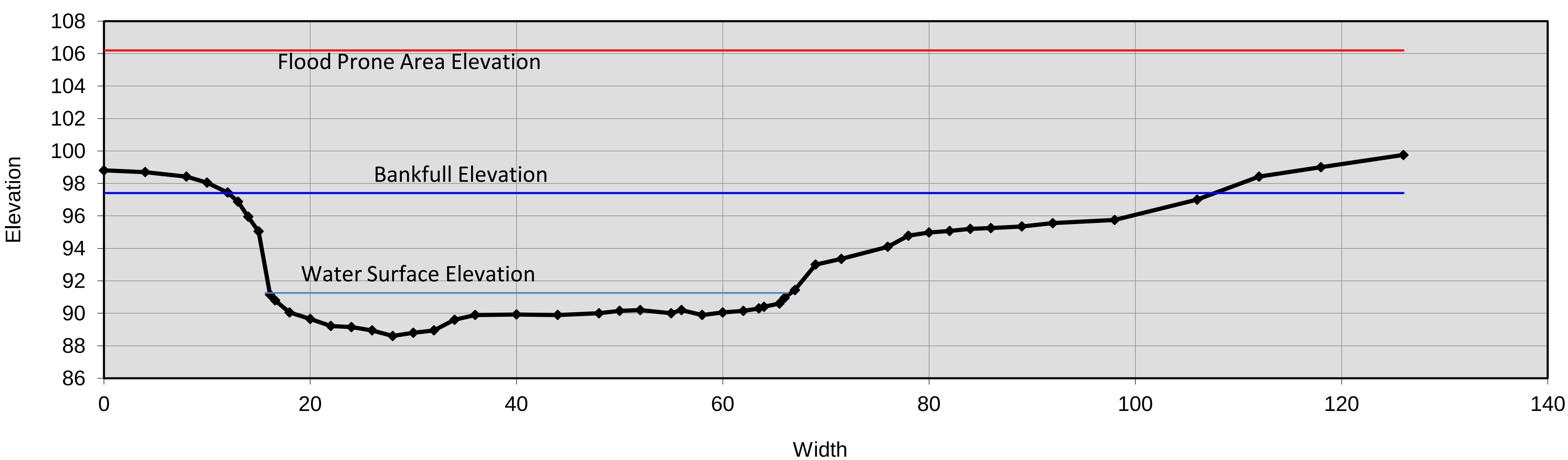
Swift Creek DWM Habitat Assessment Sites

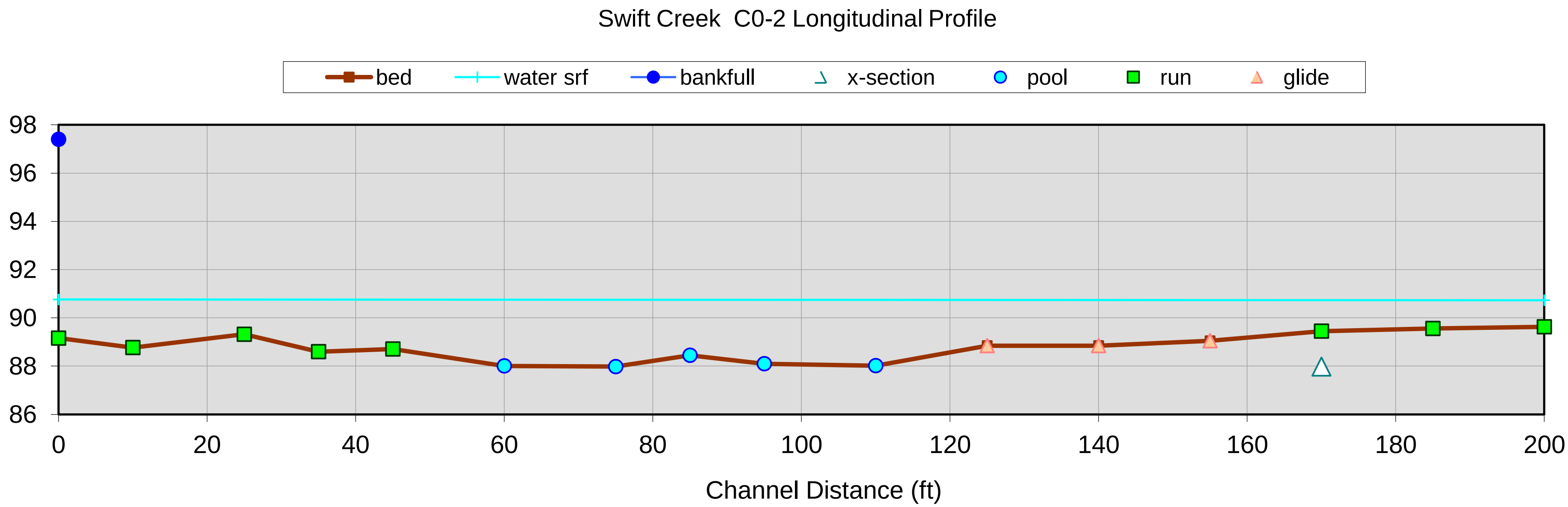
Wake and
Johnston Counties,
North Carolina

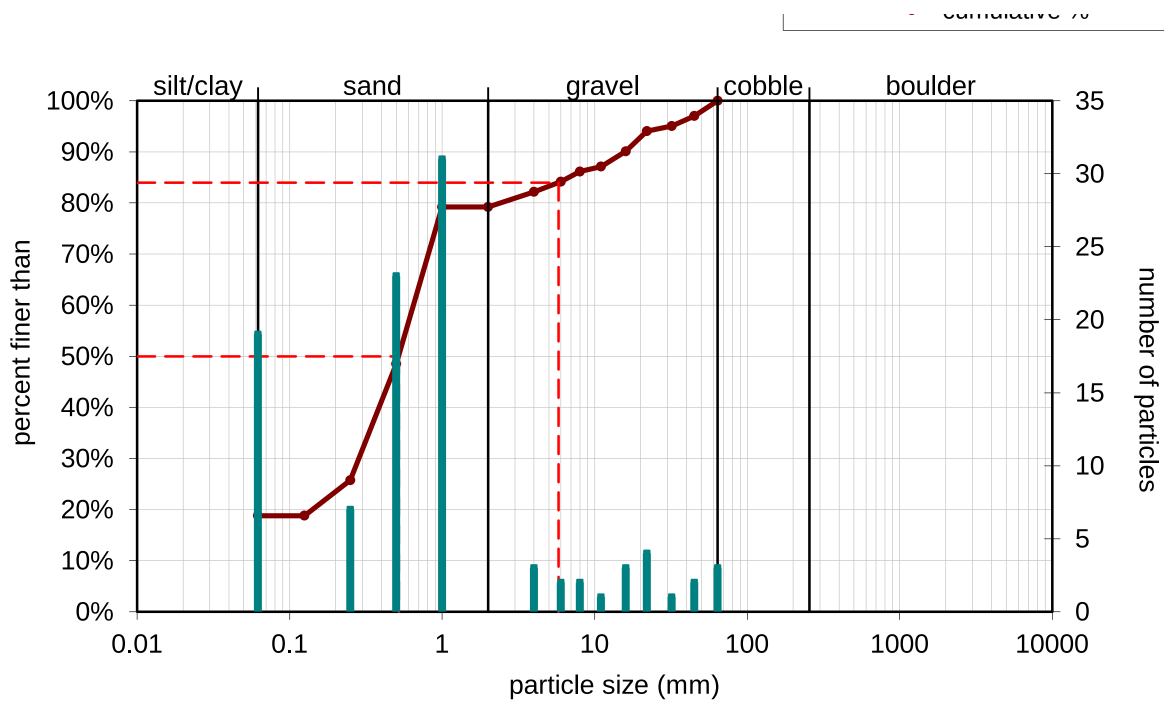
Client:

Figure
3

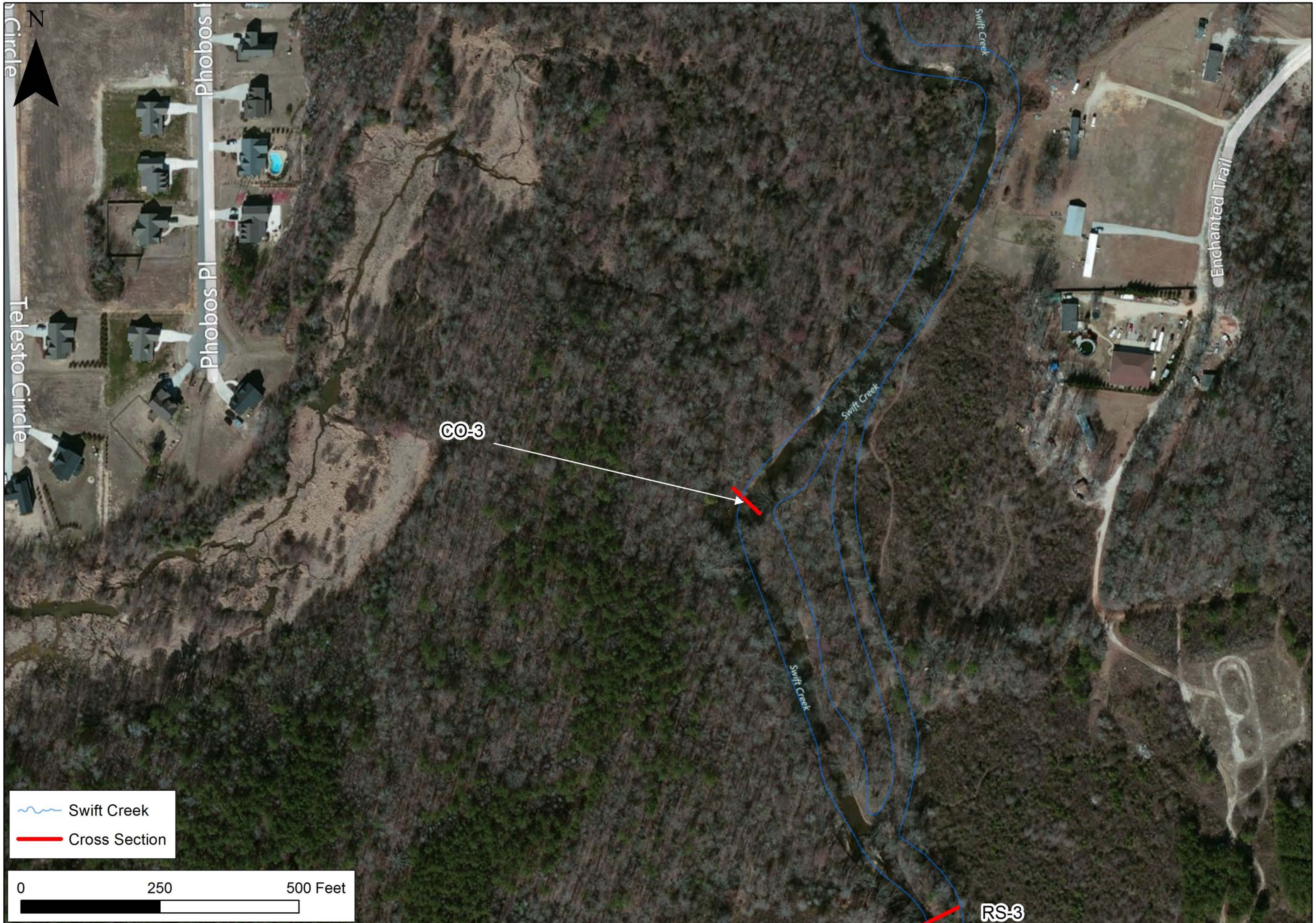
Swift Creek: CO-2 Cross Section, Downstream Facing View




Swift Creek C0-2 Longitudinal Profile
bed
water srf
bankfull
x-section
pool
run
glide
98
96
94
92
90
88
86
0
20
40
60
80
100
120
140
160
180
200
Channel Distance (ft)


silt/clay
sand
gravel
cobble
boulder
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
percent finer than
35
30
25
20
15
10
5
0
number of particles
0.01
0.1
1
10
100
1000
10000
particle size (mm)

Currently Occupied Site-3



The Catena Group

Date: December 2013

Scale: As Shown

Job No.: 1154

Title:

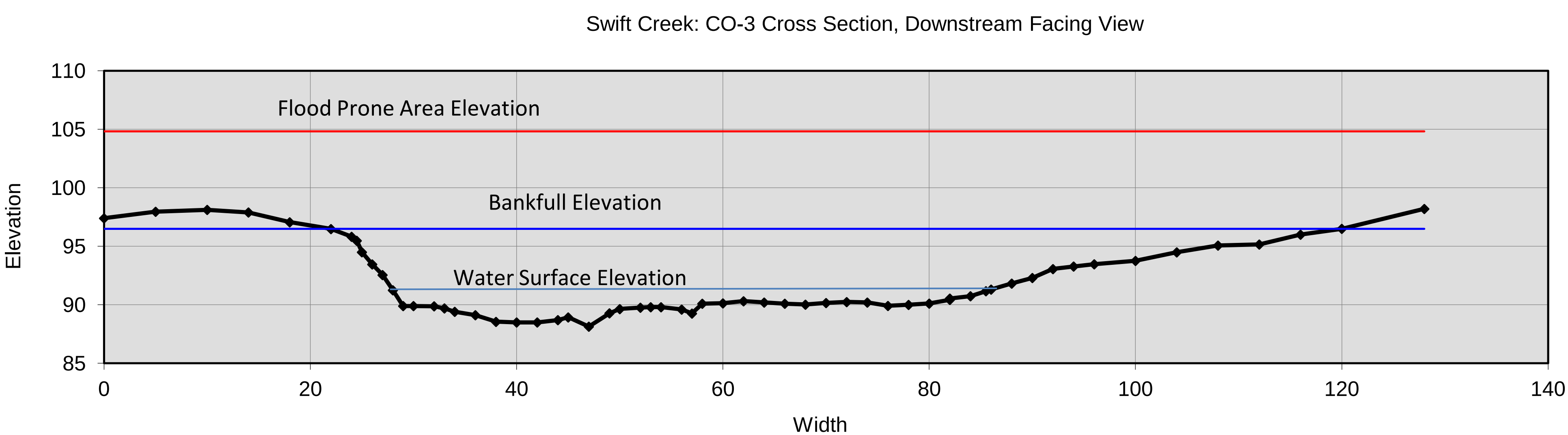
Swift Creek DWM Habitat Assessment Sites

Wake and Johnston Counties, North Carolina

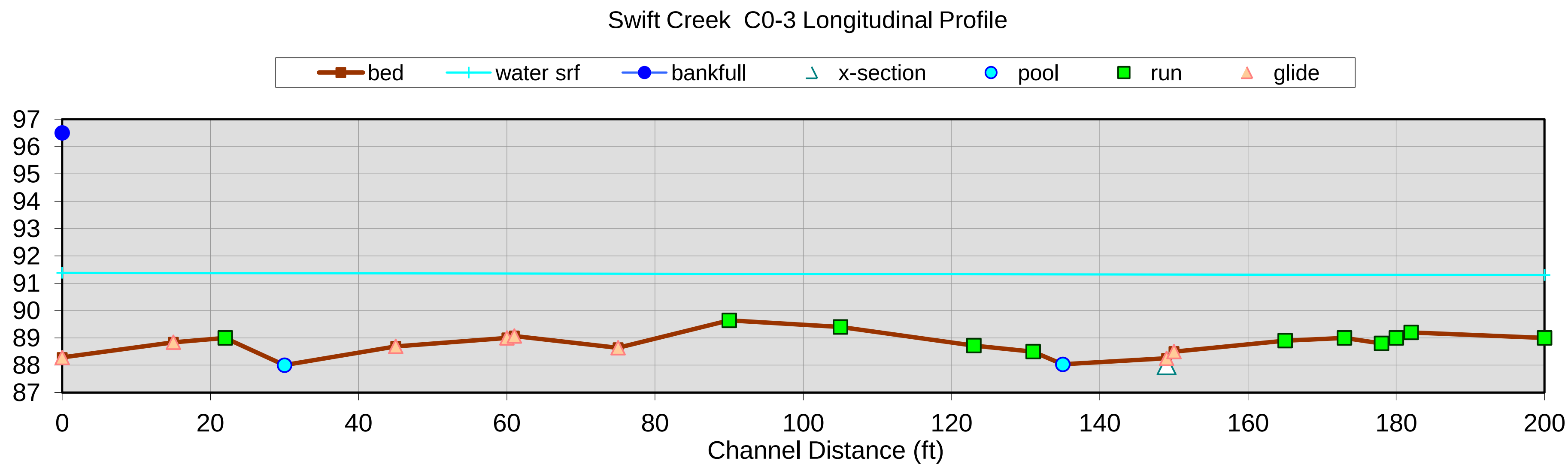
Client:

STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

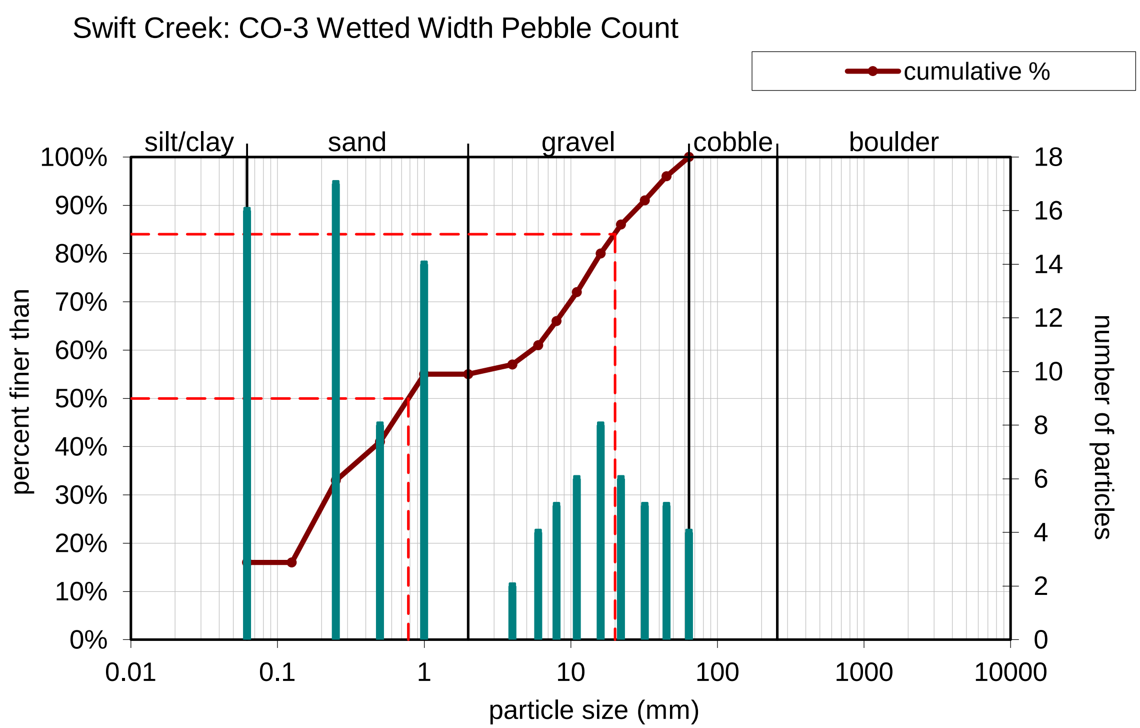
Figure 4



Swift Creek: CO-3 Cross Section, Downstream Facing View
Flood Prone Area Elevation
Bankfull Elevation
Water Surface Elevation
Elevation
Width
110
105
100
95
90
85
0
20
40
60
80
100
120
140



Swift Creek C0-3 Longitudinal Profile
bed
water srf
bankfull
x-section
pool
run
glide
97
96
95
94
93
92
91
90
89
88
87
0
20
40
60
80
100
120
140
160
180
200
Channel Distance (ft)



Swift Creek: CO-3 Wetted Width Pebble Count
cumulative %
silt/clay
sand
gravel
cobble
boulder
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
percent finer than
18
16
14
12
10
8
6
4
2
0
number of particles
0.01
0.1
1
10
100
1000
10000
particle size (mm)

Previously Occupied Site-1

The Catena Group

Date: December 2013

Scale: As Shown

Job No.: 1154

Title:

Swift Creek DWM Habitat Assessment Sites

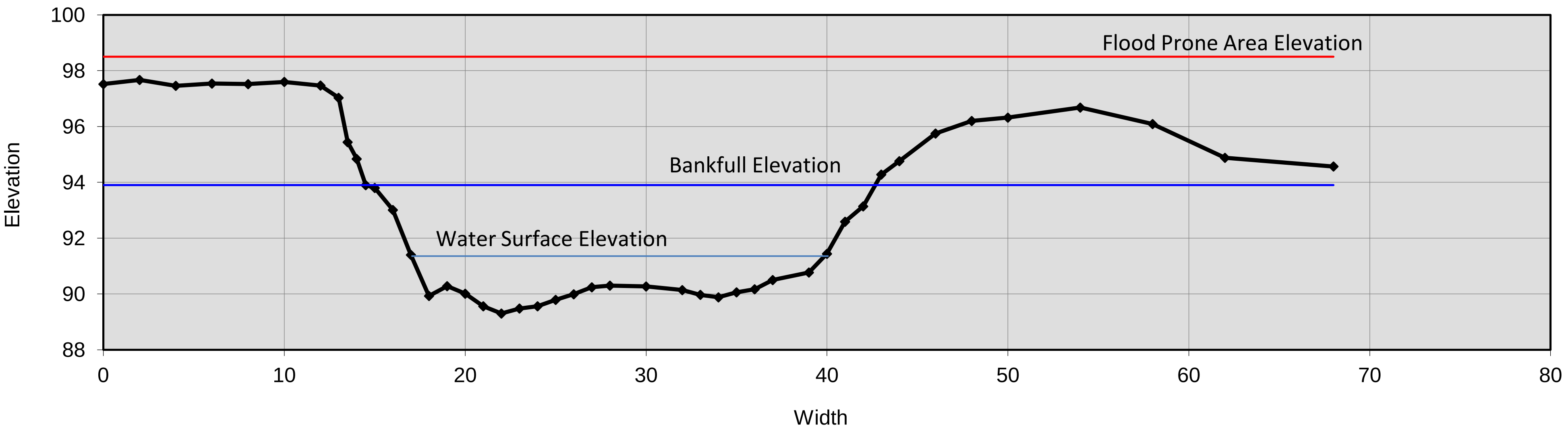
Wake and Johnston Counties, North Carolina

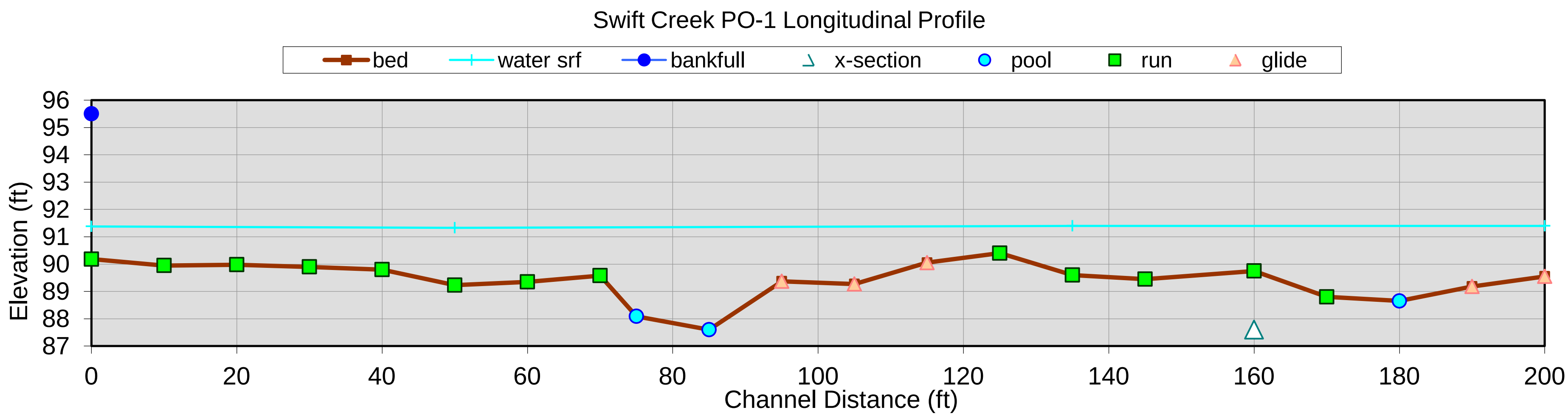
Client:

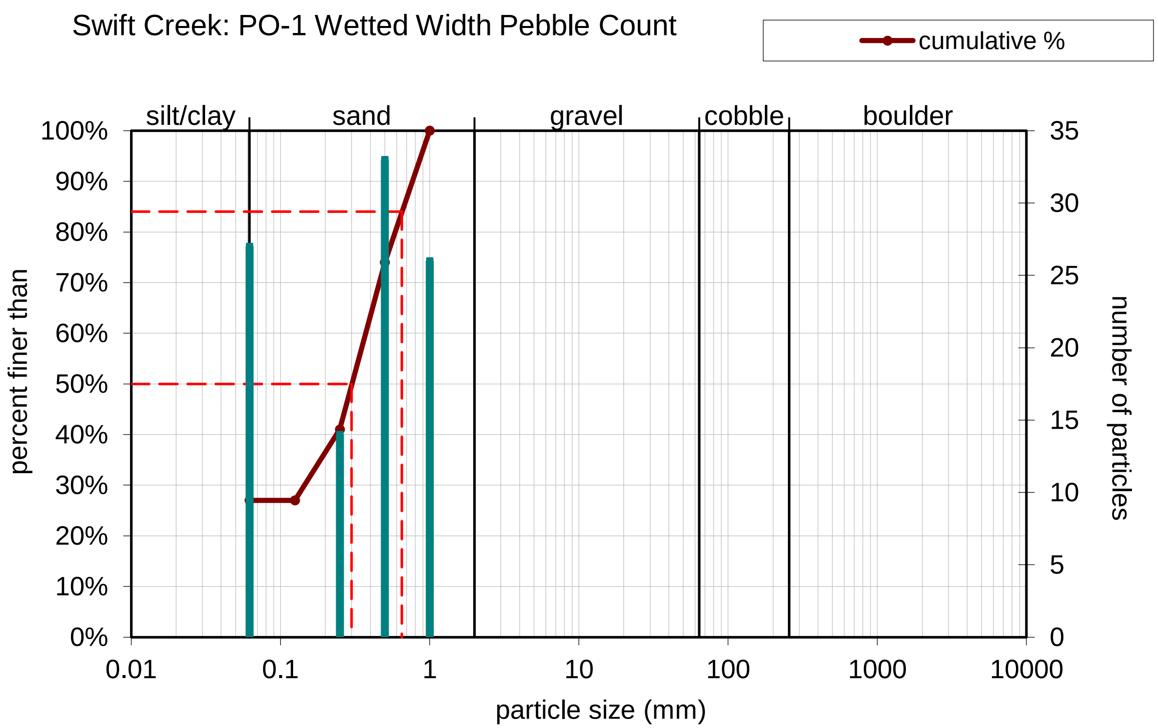
State of North Carolina Department of Transportation

Figure 5

Swift Creek: PO-1 Cross Section, Downstream Facing View




Swift Creek PO-1 Longitudinal Profile
bed
water srf
bankfull
x-section
pool
run
glide
Elevation (ft)
96
95
94
93
92
91
90
89
88
87
0
20
40
60
80
100
120
140
160
180
200
Channel Distance (ft)


Swift Creek: PO-1 Wetted Width Pebble Count
cumulative %
silt/clay
sand
gravel
cobble
boulder
percent finer than
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
35
30
25
20
15
10
5
0
number of particles
0.01
0.1
1
10
100
1000
10000
particle size (mm)

Previously Occupied Site-2

The Catena Group

Date: December 2013

Scale: As Shown

Job No.: 1154

Title:

Swift Creek DWM Habitat Assessment Sites

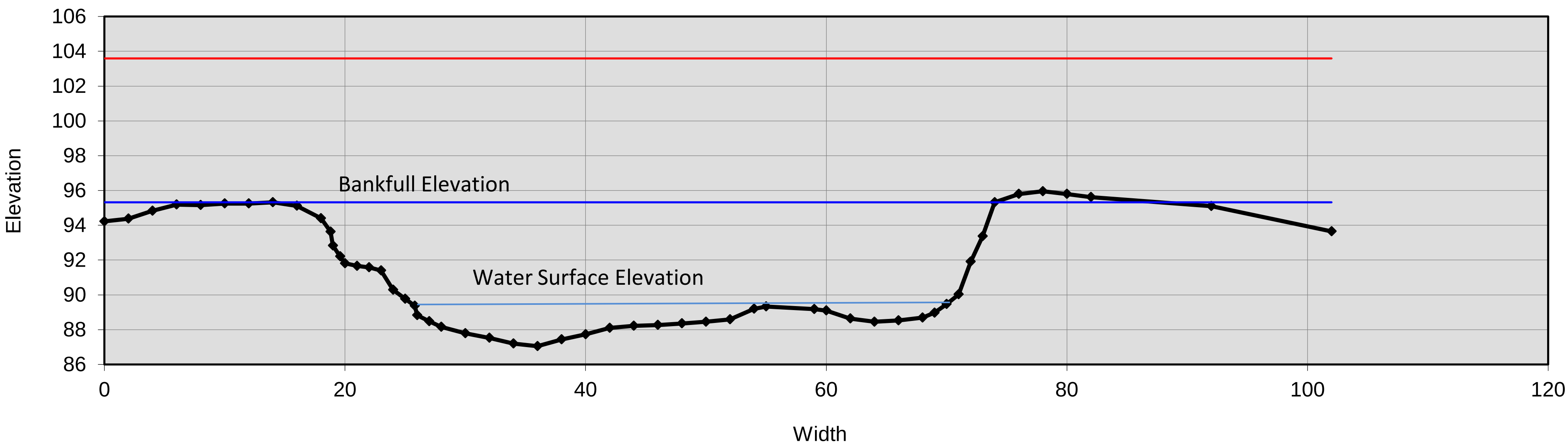
Wake and Johnston Counties, North Carolina

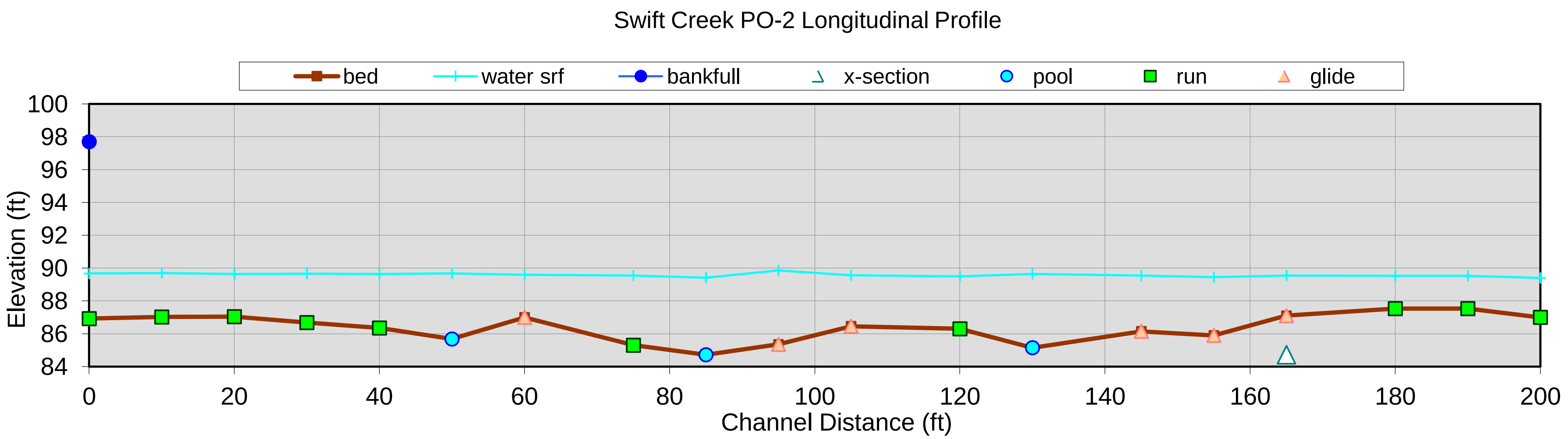
Client:

STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

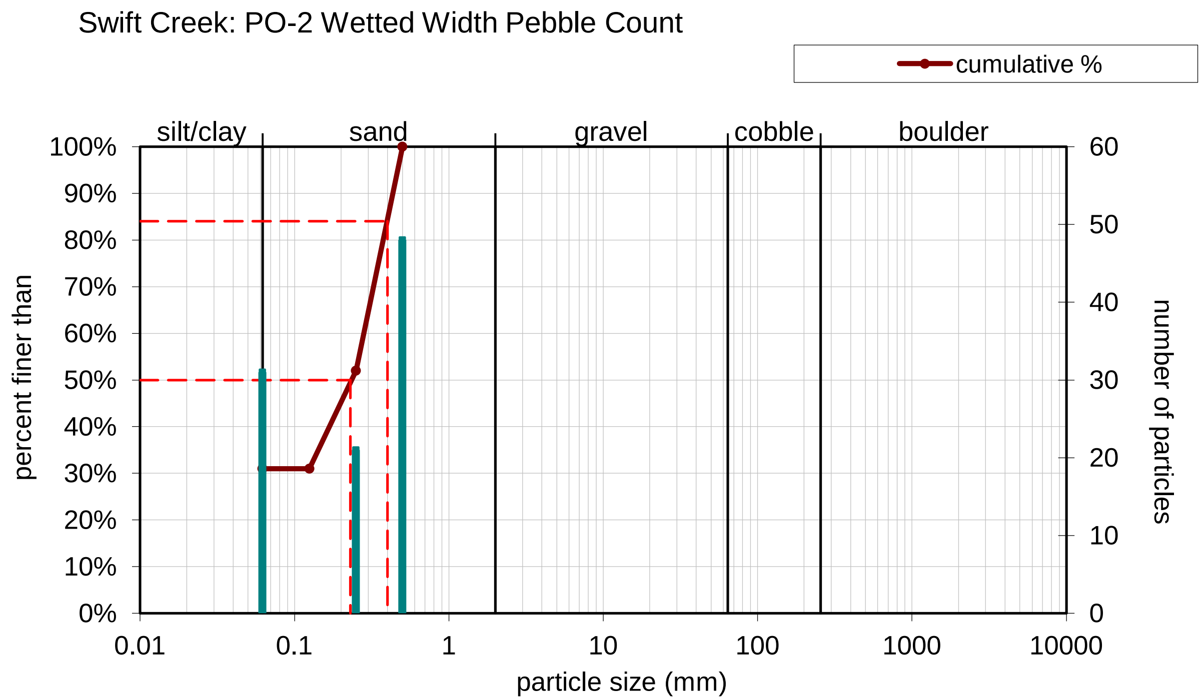
Figure 6

Swift Creek: PO-2 Cross Section, Downstream Facing View





Swift Creek PO-2 Longitudinal Profile
bed
water srf
bankfull
x-section
pool
run
glide
Elevation (ft)
100
98
96
94
92
90
88
86
84
0
20
40
60
80
100
120
140
160
180
200
Channel Distance (ft)



Swift Creek: PO-2 Wetted Width Pebble Count
cumulative %
silt/clay
sand
gravel
cobble
boulder
percent finer than
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
60
50
40
30
20
10
0
number of particles
0.01
0.1
1
10
100
1000
10000
particle size (mm)

Previously Occupied Site-3

The Catena Group

Date: December 2013

Scale: As Shown

Job No.: 1154

Title:

Swift Creek DWM Habitat Assessment Sites

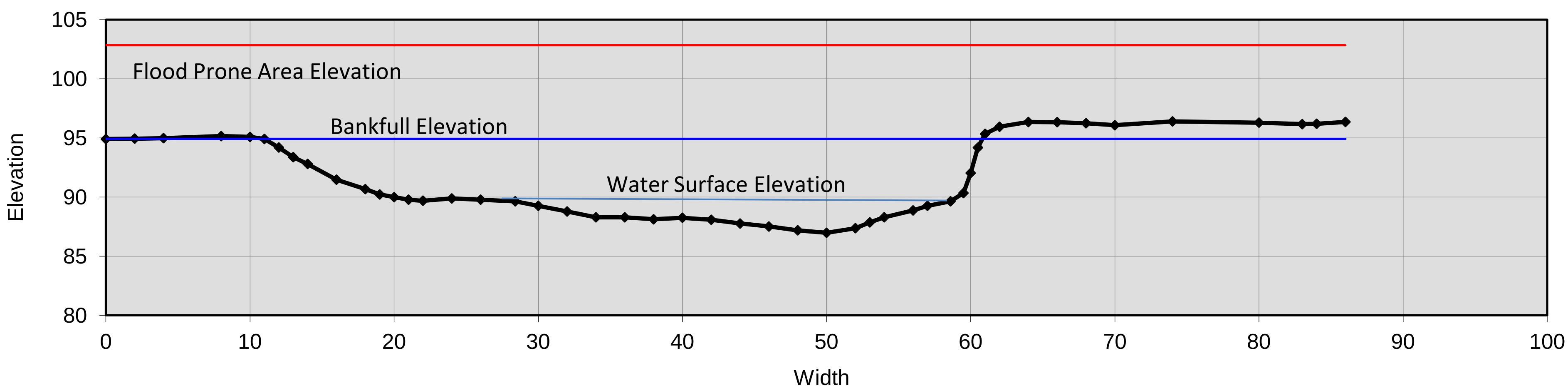
Wake and Johnston Counties, North Carolina

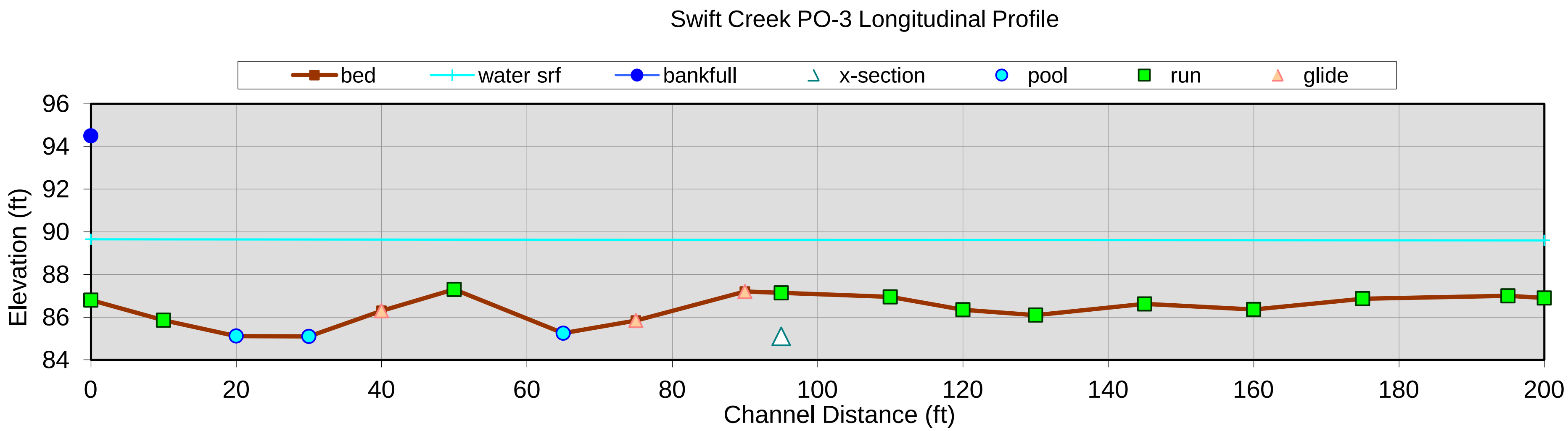
2010 Aerial Orthophotography Source: NCDOT

Client:

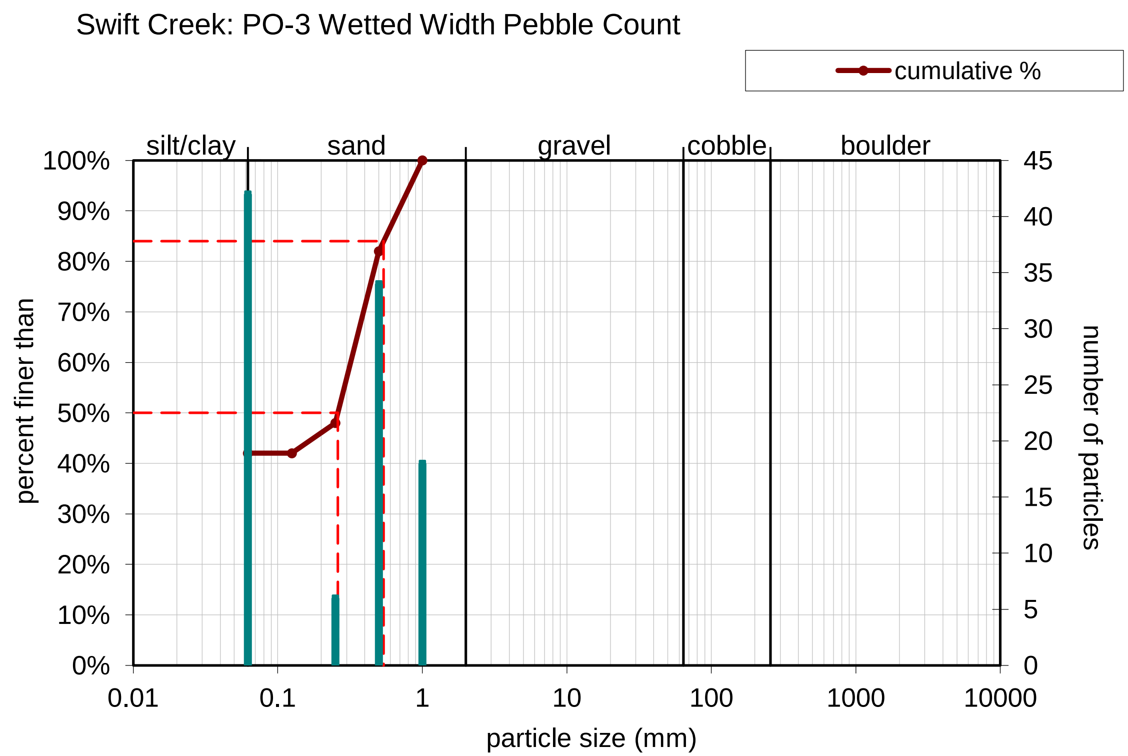
Figure 7

Swift Creek: PO-3 Cross Section, Downstream Facing View



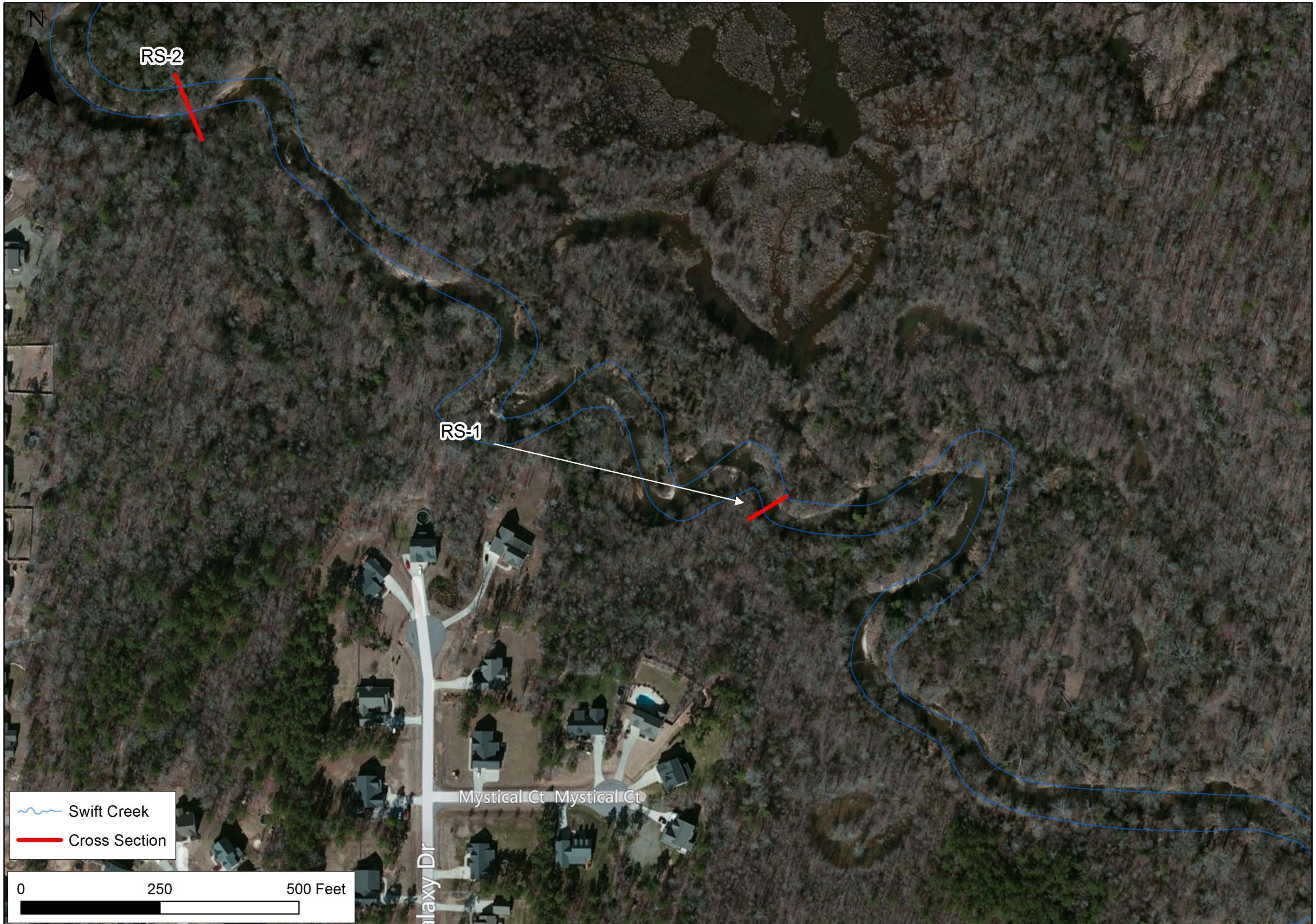


Swift Creek PO-3 Longitudinal Profile
bed
water srf
bankfull
x-section
pool
run
glide
Elevation (ft)
96
94
92
90
88
86
84
0
20
40
60
80
100
120
140
160
180
200
Channel Distance (ft)



Swift Creek: PO-3 Wetted Width Pebble Count
cumulative %
silt/clay
sand
gravel
cobble
boulder
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
percent finer than
45
40
35
30
25
20
15
10
5
0
number of particles
0.01
0.1
1
10
100
1000
10000
particle size (mm)

<u>Randomly Selected Site-1</u>



The Catena Group

Date: December 2013

Scale: As Shown

Job No.: 1154

Title:

Swift Creek DWM Habitat Assessment Sites

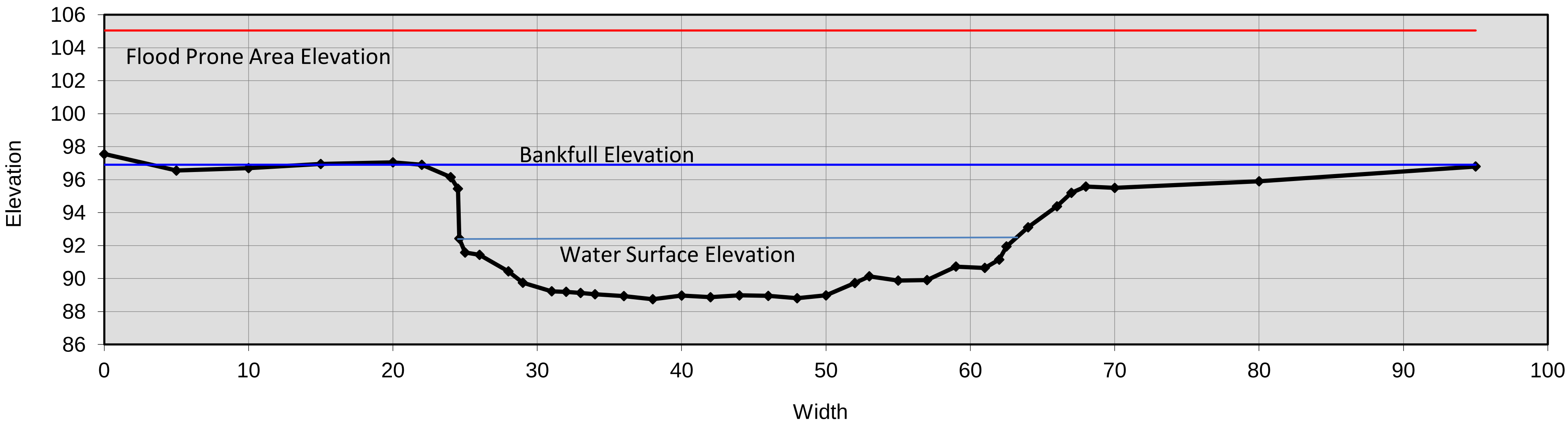
Wake and Johnston Counties, North Carolina

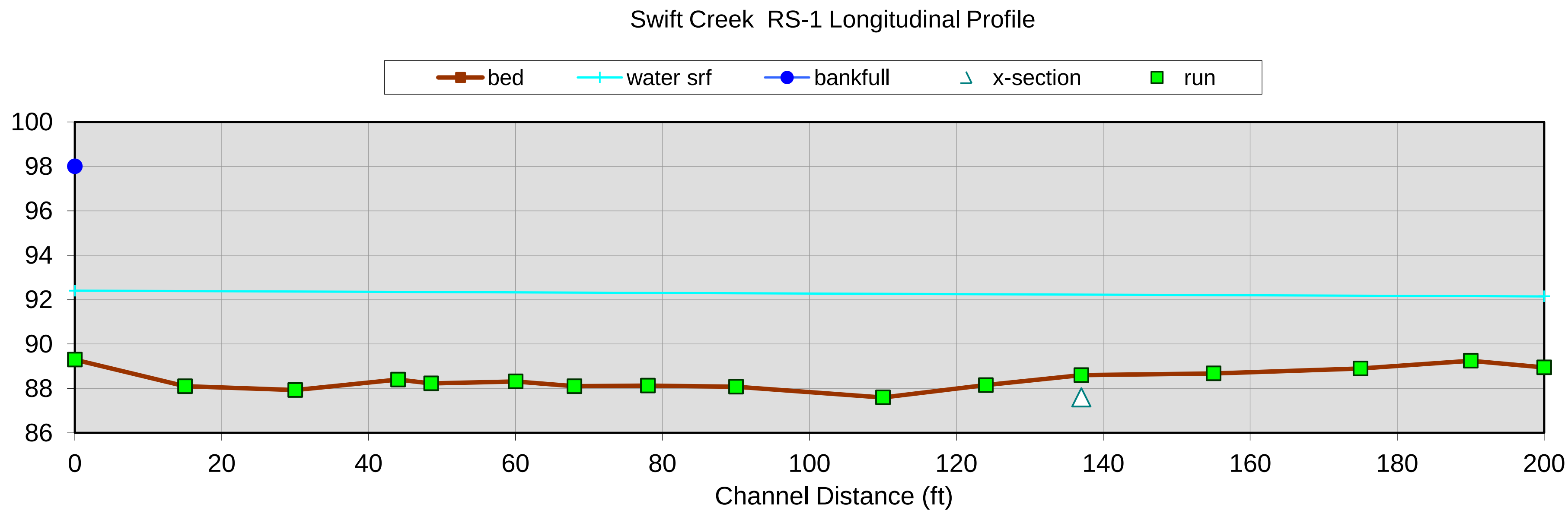
2010 Aerial Orthophotography Source: NCDOT

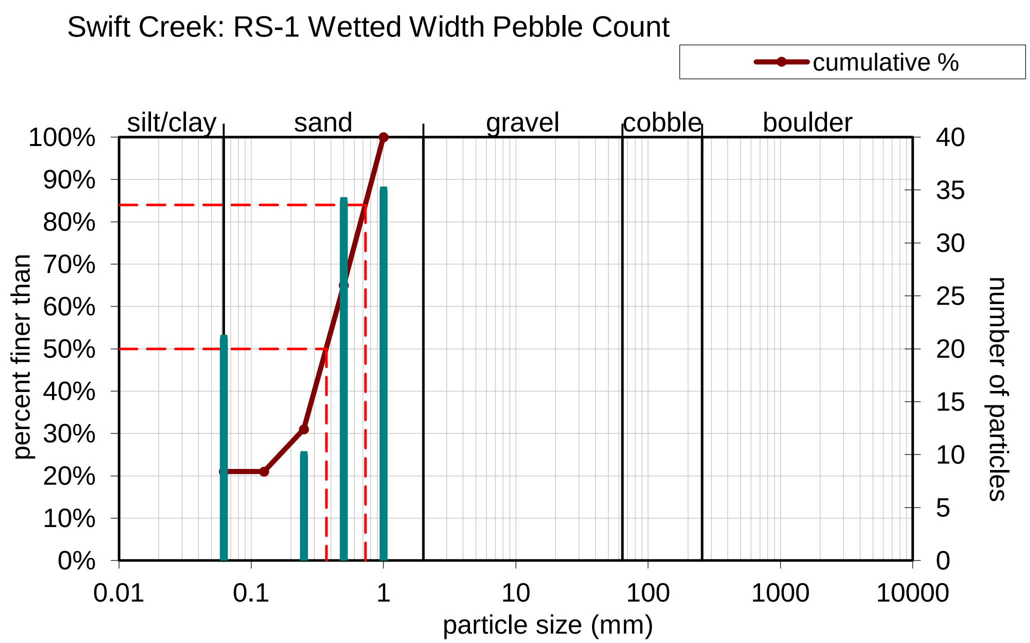
Client:

Figure 8

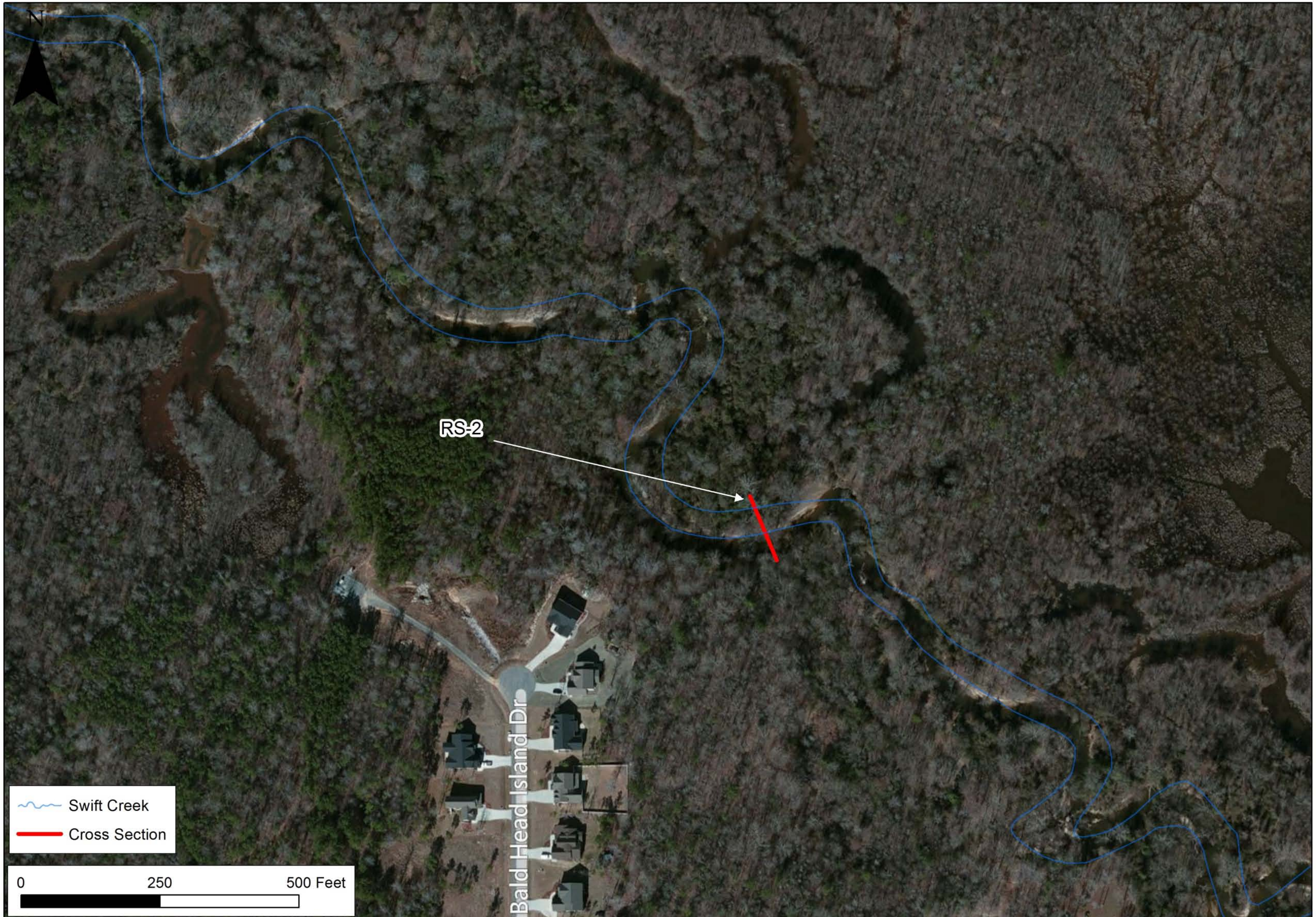
Swift Creek: RS-1 Cross Section, Downstream Facing View




Swift Creek RS-1 Longitudinal Profile
bed
water srf
bankfull
x-section
run
100
98
96
94
92
90
88
86
0
20
40
60
80
100
120
140
160
180
200
Channel Distance (ft)


Swift Creek: RS-1 Wetted Width Pebble Count
cumulative %
silt/clay
sand
gravel
cobble
boulder
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
percent finer than
40
35
30
25
20
15
10
5
0
number of particles
0.01
0.1
1
10
100
1000
10000
particle size (mm)

Randomly Selected Site-2



The Catena Group

Date: December 2013

Scale: As Shown

Job No.: 1154

Title:

Swift Creek DWM Habitat Assessment Sites

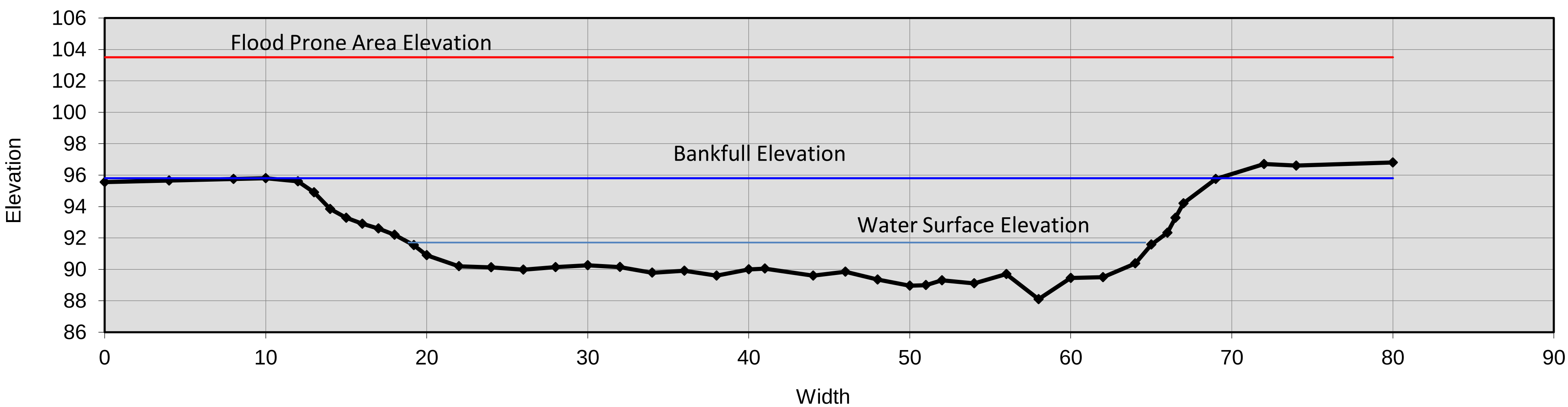
Wake and Johnston Counties, North Carolina

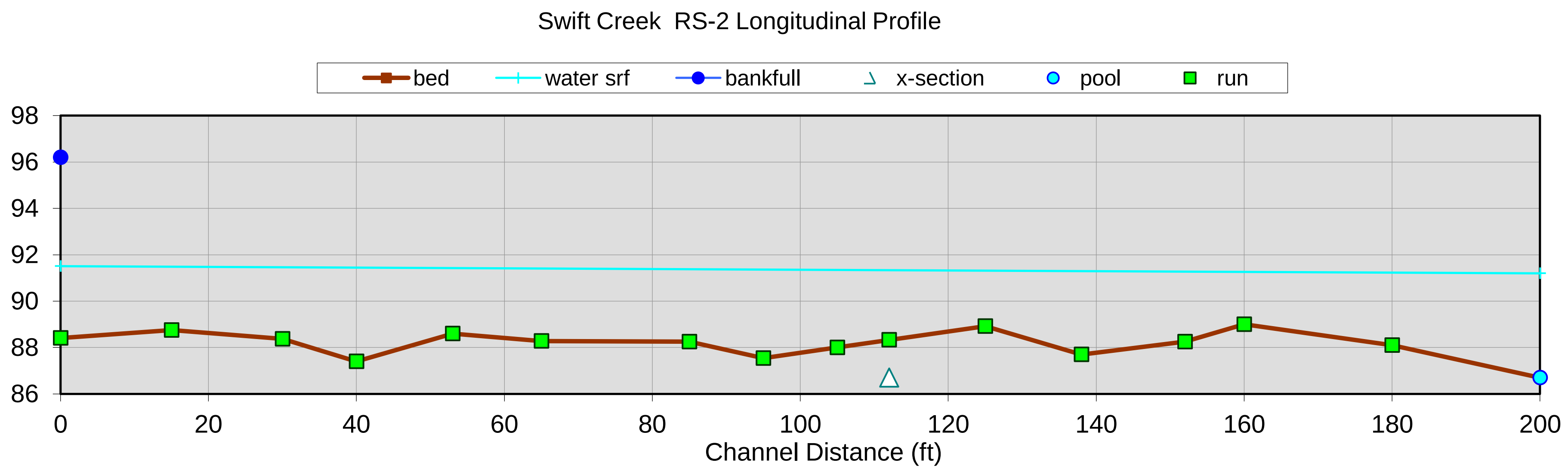
Client:

STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

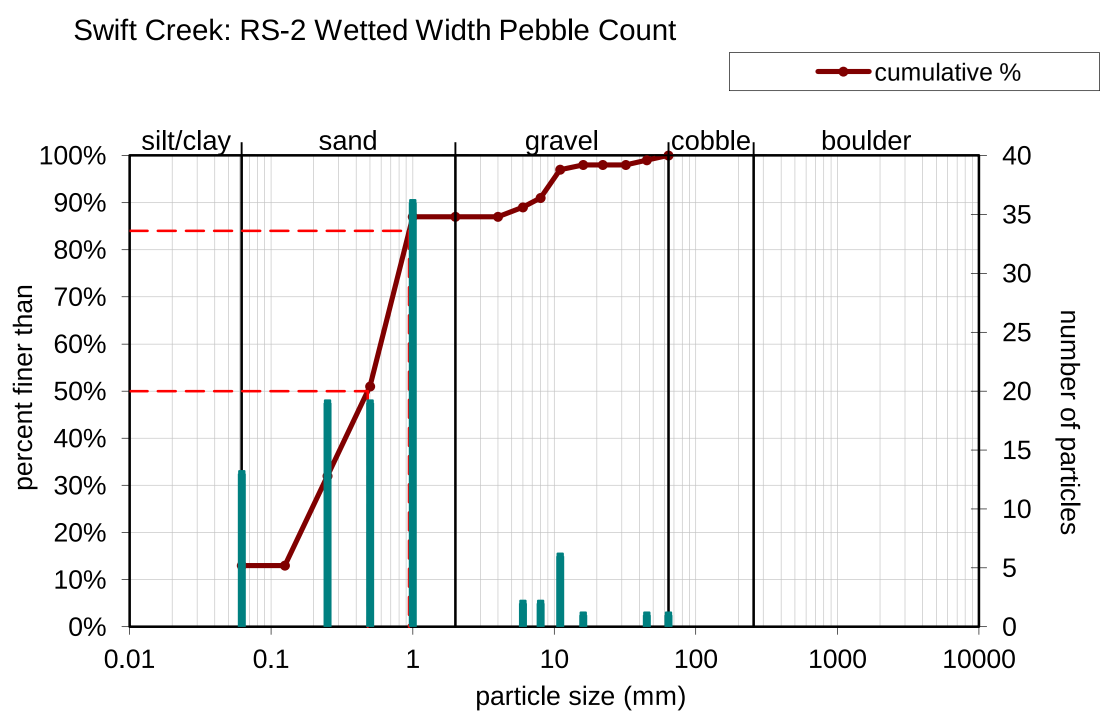
Figure 9

Swift Creek: RS-2 Cross Section, Downstream Facing View





Swift Creek RS-2 Longitudinal Profile
bed
water srf
bankfull
x-section
pool
run
98
96
94
92
90
88
86
0
20
40
60
80
100
120
140
160
180
200
Channel Distance (ft)



Swift Creek: RS-2 Wetted Width Pebble Count
cumulative %
silt/clay
sand
gravel
cobble
boulder
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
percent finer than
40
35
30
25
20
15
10
5
0
number of particles
0.01
0.1
1
10
100
1000
10000
particle size (mm)

<u>Randomly Selected Site-3</u>

The Catena Group

Date: December 2013

Scale: As Shown

Job No.: 1154

Title:

Swift Creek DWM Habitat Assessment Sites

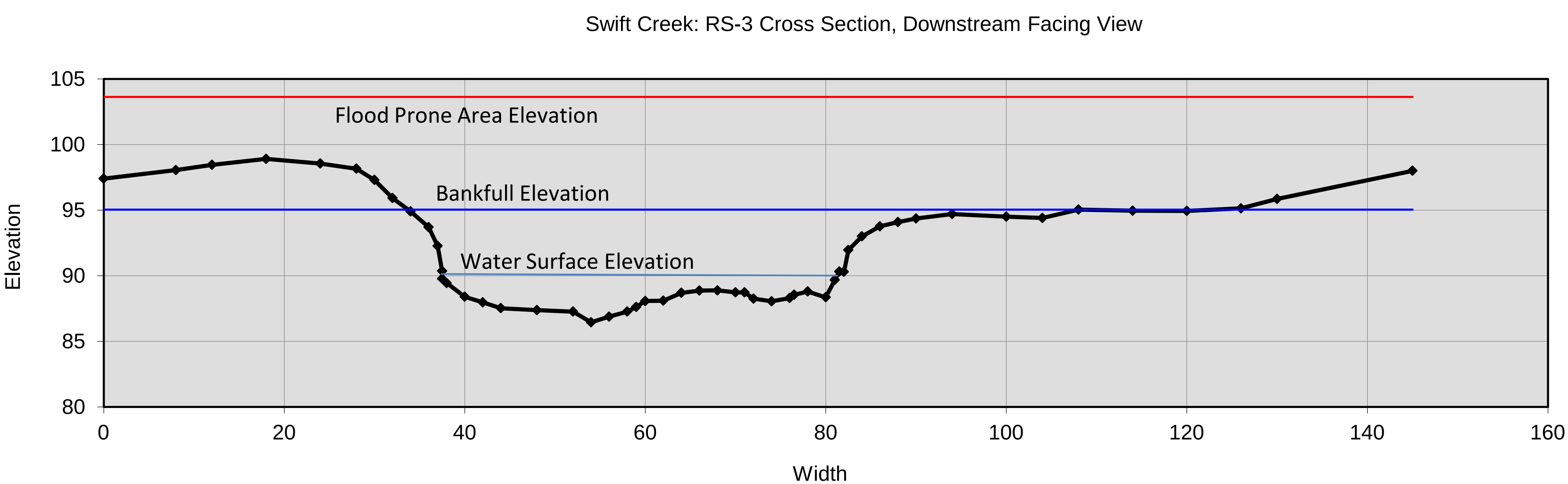
Wake and Johnston Counties, North Carolina

Client:

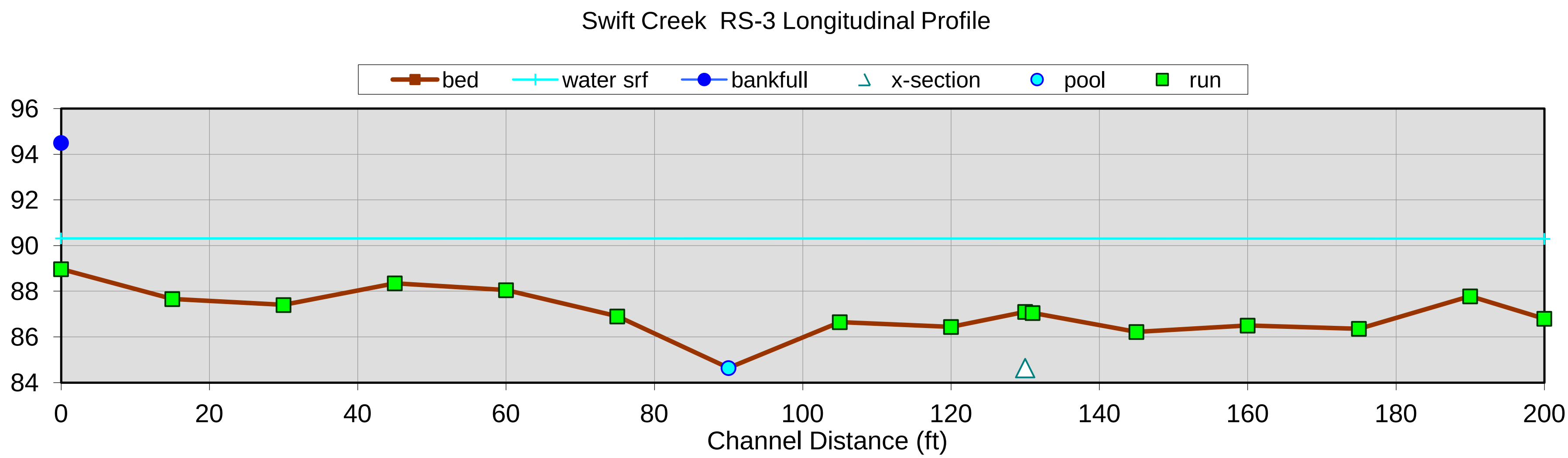
STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

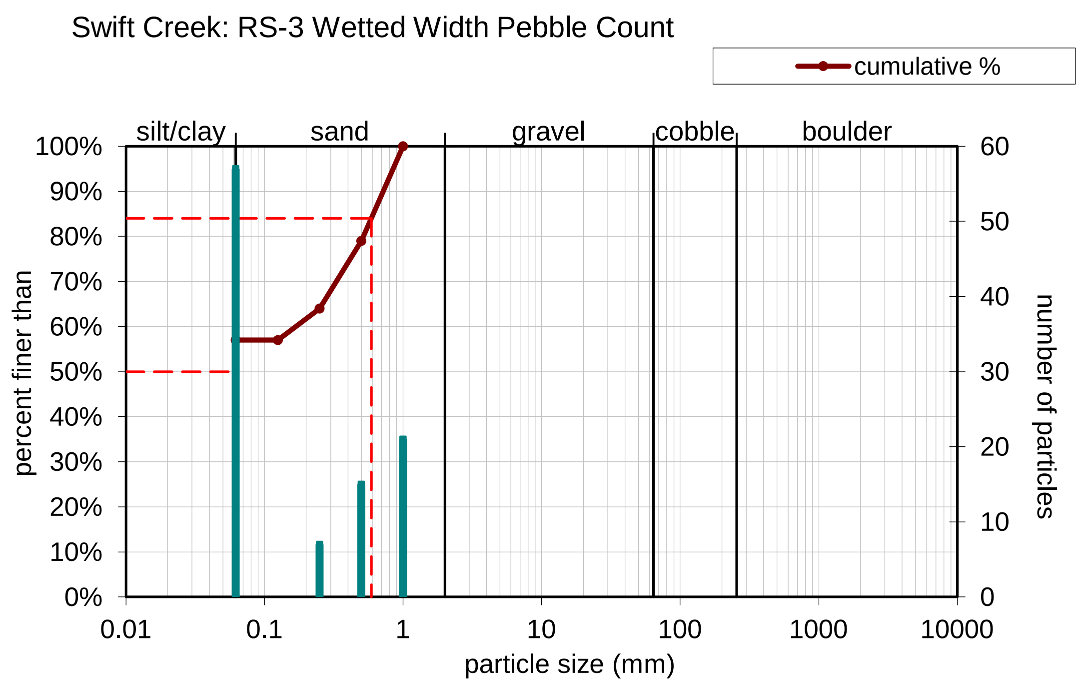
Figure

10



Swift Creek: RS-3 Cross Section, Downstream Facing View
Flood Prone Area Elevation
Bankfull Elevation
Water Surface Elevation
Elevation
Width
105
100
95
90
85
80
0
20
40
60
80
100
120
140
160


Swift Creek RS-3 Longitudinal Profile
bed
water srf
bankfull
x-section
pool
run
96
94
92
90
88
86
84
0
20
40
60
80
100
120
140
160
180
200
Channel Distance (ft)


Swift Creek: RS-3 Wetted Width Pebble Count
cumulative %
silt/clay
sand
gravel
cobble
boulder
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
percent finer than
60
50
40
30
20
10
0
number of particles
0.01
0.1
1
10
100
1000
10000
particle size (mm)