ARCADIS

City of Raleigh 2007 Sampling and Monitoring Program Report

Appendix F

Swift Creek Freshwater Mussel Surveys for the Dempsey E. Benton Water Treatment Project, The Catena Group, March 2008

Swift Creek Freshwater Mussel Surveys for the Dempsey E. Benton Water Treatment Project

Wake and Johnston Counties, North Carolina

Prepared For:

Linda Diebolt, Senior Scientist
ARCADIS G&M of North Carolina, Inc.
801 Corporate Center Drive, Suite 300
Raleigh, NC 27607

Prepared By:

The Catena Group
410-B Millstone Drive
Hillsborough, NC 27278
919-732-1300

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Timothy W. Savidge

EXECUTIVE SUMMARY

The City of Raleigh is constructing the Dempsey E. Benton Water Treatment Plant (WTP) Project, a new 20 million-gallon-per-day (mgd) water treatment plant with ancillary facilities. The project involves reactivation of Lake Wheeler and Lake Benson as water supply sources, with an average water withdrawal of 14-mgd. The lakes, which were used as a water supply source from 1953 to 1987, occur on Swift Creek, a major tributary to the Neuse River. The proposed Project will serve as a secondary water supply source for the City of Raleigh and also assist in meeting the post-2010 water supply needs of the area.

The federally endangered dwarf-wedge mussel (*Alasmidonta heterodon*) is known to occur in the Neuse River Basin in Wake County in the Swift Creek and Little River watersheds. The U.S. Fish and Wildlife Service (USFWS) issued their Biological Opinion (BO), dated February 23, 2006, on the project and its potential effects on the dwarf-wedge mussel in accordance with Section 7 of the Endangered Species Act of 1973. Within the Terms and Conditions of the BO, Baseline Mussel Surveys (not to exceed 250 person hours), were required within Swift Creek prior to initiation of project construction. The BO also states that additional mussel surveys (not to exceed 40 person hours) will be conducted promptly after minimum flow releases are maintained at Tier III (1.0 cubic feet per second [cfs]) for more than 7 days, or more than 14 days in a 30 day period once the project is in operation. The Catena Group (TCG) was been retained by ARCADIS G&M of North Carolina, Inc. to conduct the Baseline Surveys.

The objectives of this study consisted of three components:

- Determine species composition and distribution within the study area
- Establishment of seven Tier III minimum flow monitoring stations
- Compare mussel bed abundance and diversity above and below the existing Wastewater Treatment Plant (WWTP) discharge into Swift Creek from the Indian Creek Overlook Home Park that will be taken offline as part of this project, in such a manner to allow for future monitoring once the discharge is taken offline.

Swift Creek originates in western Wake County near the town of Cary, and flows in a general southward direction. Middle Creek joins Swift Creek approximately one mile upstream of the confluence with the Neuse River just south of the town of Smithfield in central Johnston County. Total stream length is approximately 38 miles and the drainage area above Middle Creek is approximately 156 square miles.

This study encompassed the main channel of Swift Creek from the tailrace of Lake Benson downstream to the vicinity of the NC 210 crossing of the creek northwest of Smithfield (30.0 miles). In general, Swift Creek is characterized as slow moving, with a streambed gradient of 4.7 feet per mile. The channel in the study area is typically U-shaped, 30 to 40 feet wide and at least 1 to 3 feet deep. The substrate is highly variable throughout its course ranging from silt to sandy-gravel to cobble. The banks are mostly gently sloping, although some areas exhibit fairly steep topography.

Timed qualitative mussel surveys were performed at 63 stations in Swift Creek (Figures 1A-D) between November 2006 and October 2007. Site numbers (1-63) were assigned sequentially to each area surveyed. Sites 22 a-e and 22 f-j were established as WWTP discharge monitoring stations, and Sites 29, 31, 37, 39, 40, 43 and 49 were established as Tier III minimum flow monitoring stations. The general study area was divided into Upper, Middle and Lower segments. Survey sites were distributed throughout each segment to obtain a general representation of the habitat conditions and faunal assemblage. Specific survey sites were accessed by road crossings, utility corridors, or adjacent residential developments.

All habitat types (riffle, run, pool, slack water, etc.) within each site were sampled; however, Shallow Fast Coarse (SFC) or Deep Stream Margin Roots (DSMR) habitats, as described in the Biological Assessment for this project (Entrix 2005), were the primary focus as these are most likely to contain the dwarf wedgemussel. Mask/snorkel, bathyscope (glass-bottom view buckets), and tactile (hand grubbing) methodologies were used. Mussel shells were also searched for in over-wash areas, dewatered sections of the stream, and in muskrat (*Ondatra zibethicus*) shell middens. Each survey was timed, the amount of which was determined by survey conditions and concentration of mussels. Survey distances within and between sites varied, as sites were chosen based on best suitable habitat for the target species and accessibility. Mussels were collected and brought to the surface for identification and returned to the substrate. Nomenclature of mussels followed Turgeon et al. (1988). Catch per unit effort (CPUE) for each mussel species were calculated at each surveyed site. The presence of relict shells was equated with presence of that species, but was not factored into the CPUE. Representative photographs of each mussel species were taken when possible.

Tier III monitoring stations were established at seven of the 63 sites (Figure 2). Each station consisted of a 100 foot section of the stream that was divided into 4 survey lanes of equal width; right descending bank (RDB), right descending channel (RDC), left descending channel (LDC), and left descending bank (LDB). Mussels were collected from each survey lane, recorded, and returned to the same location. All species monitored by the NHP were measured and tagged. The tags (Hallprint Tags) are polyethylene, oval, and approximately 9 mm long by 4 mm wide. Each tag is colored (e.g., green) and also has a unique 4-character code, which begins with a letter followed by 3 numbers. The tags were applied to the mussel shells (both valves) using Instant Krazy Glue©. Tier III monitoring stations were selected based on prevalence of SFC and DSMR habitats, as well as other shallow habitats containing mussels that appeared to potentially be susceptible to dewatering during low flow periods.

As mentioned previously, the existing Indian Creek Overlook Home Park WWTP discharge into Swift Creek will be taken offline as part of this project. Two monitoring stations were set up in proximity to this discharge point to compare relative abundances of mussels downstream and upstream of the discharge. Stations consisted of 100 foot sections beginning 550 feet downstream of the discharge and extending 550 feet upstream of the discharge. Five 100-foot sections of the creek (Site 22 a-e) were surveyed below the discharge point, and five 100 foot sections (Site 22 f-j) were surveyed

above the discharge point (Figure 2). The 50 foot section of the creek immediately below the discharge is characterized as a deep scour pool, which would have require total immersion in the water using self-contained underwater breathing apparatus (SCUBA) to survey. Because of concerns with body exposure to wastewater, the 50 foot section immediately below the discharge was eliminated from sampling, and for consistency, the 50 foot section immediately above the discharge was also eliminated. Mussels were collected in each 100 foot section with sites 22 a-e located below the discharge, and 22 f-j above the discharge. As with the Tier III monitoring stations, the position within the channel of each mussel was recorded and individuals were returned to their locations.

A total of 22,152 live native freshwater mussels comprising at least 16 species were collected during the survey efforts. The total number of individuals found, number of sites where located, highest recorded CPUE for the species, and the site number where the highest CPUE was recorded for each species is listed in Table 3. Species numbers and CPUE for each site are provided in Appendix B.

Mussel distribution at the seven Tier III Minimum Flow Monitoring Sites is reflective of the heterogeneity of microhabitats within Swift Creek. Three of the seven dwarf-wedge mussel individuals found during this study occurred within one of the seven monitoring stations.

These surveys provide new and updated mussel distribution for the section of Swift Creek below Lake Benson, as well as establishing seven stations that can be monitored over time following Tier III (1 cfs) flow conditions, and two stations that can be monitored over time following removal of the existing Indian Creek Overlook Home Park WWTP discharge. Seven individuals of the endangered dwarf-wedge mussel were found at six locations, which resulted in an upstream extension (over 1 mile) of the known range of the species in Swift Creek. The majority of the "rare" mussel species occurred in the middle and upper segments of the study area.

Much of the survey effort took place during extreme low flow conditions, which aided in ease of detection, resulting in high CPUE. Although water levels were very low during much of the study, continual flow was observed throughout. As a result, the mussel fauna of Swift Creek did not appear to suffer as much mortality from exposure/desiccation as in other streams in the Piedmont of North Carolina (personal observations). Maintaining minimum flows as well as ground water input may be responsible for this.

TABLE OF CONTENTS

1.0 INTRODUCTION 1
1.1 Background and Objectives 1
2.0 STUDY AREA 2
3.0 METHODS 3
4.0 RESULTS 7
4.1 Habitat Conditions and Mussel Distribution 8
4.2 Tier III Minimum Flow Monitoring Stations 9
4.2.1 Site 29 9
4.2.2 Site 31 9
4.2.3 Site 37 10
4.2.4 Site 39 10
4.2.5 Site 40 11
4.2.6 Site 43 11
4.2.7 Site 49 12
4.3 Indian Creek Overlook WWTP Discharge Monitoring Stations 12
4.3.1 Site 22 a (550 feet to 450 feet below discharge) 13
4.3.2 Site 22 b (450 feet to 350 feet below discharge) 13
4.3.3 Site 22 c (350 feet to 250 feet below discharge) 13
4.3.4 Site 22 d (250 feet to 150 feet below discharge) 14
4.3.5 Site 22 e (150 feet to 50 feet below discharge) 14
4.3.6 Site 22 f (50 feet to 150 feet above discharge) 15
4.3.7 Site 22 g (150 feet to 250 feet above discharge) 15
4.3.8 Site 22h (250 feet to 350 feet above discharge) 15
4.3.9 Site 22 i (350 feet to 450 feet above discharge) 16
4.3.10 Site 22 j (450 feet to 550 feet above discharge) 16
5.0 DISCUSSION 16
5.1 The Mussel Fauna of Swift Creek 17
5.1.1 Mussel species found during the surveys 17
5.2 Tier III Minimum Flow Monitoring Stations 25
5.3 Indian Creek Overlook WWTP Discharge Monitoring Stations 25
6.0 REFERENCES 26

TABLES

Table 1. Rare Freshwater Mussel Species in Swift Creek 1
Table 2. Swift Creek Survey Sites 4
Table 3. Mussel Species Located 7
Table 4. Mussel Species Located at Tier III Monitoring Station: Site 29 9
Table 5. Mussel Species Located at Tier III Monitoring Station: Site 31 9
Table 6. Mussel Species Located at Tier III Monitoring Station: Site 37 10
Table 7. Mussel Species Located at Tier III Monitoring Station: Site 39 10
Table 8. Mussel Species Located at Tier III Monitoring Station: Site 40 11
Table 9. Mussel Species Located at Tier III Monitoring Station: Site 43 11
Table 10. Mussel Species Located at Tier III Monitoring Station: Site 49 12

Table 11. Mussel Species Located at WWTP Discharge Monitoring Station: Site 22a... 13
Table 12. Mussel Species Located at WWTP Discharge Monitoring Station: Site 22b... 13
Table 13. Mussel Species Located at WWTP Discharge Monitoring Station: Site 22c... 13
Table 14. Mussel Species Located at WWTP Discharge Monitoring Station: Site 22d... 14
Table 15. Mussel Species Located at WWTP Discharge Monitoring Station: Site 22e... 14
Table 16. Mussel Species Located at WWTP Discharge Monitoring Station: Site 22f... 15
Table 17. Mussel Species Located at WWTP Discharge Monitoring Station: Site 22g... 15
Table 18. Mussel Species Located at WWTP Discharge Monitoring Station: Site 22h... 15
Table 19. Mussel Species Located at WWTP Discharge Monitoring Station: Site 22i ... 16
Table 20. Mussel Species Located at WWTP Discharge Monitoring Station: Site 22j ... 16

APPENDICIES

APPENDIX A FIGURES. ... 30
APPENDIX B DEFINITIONS OF FEDERAL AND STATE LISTING CATEGORIES (FROM LEGRAND ET AL. 2006) ... 37
APPENDIX C MUSSEL SPECIES PER SITE ... 42
APPENDIX D SPECIES DISTRIBUTION IN SWIFT CREEK ... 51

1.0 INTRODUCTION

The City of Raleigh is constructing the Dempsey E. Benton Water Treatment Plant (WTP) Project, a new 20 million-gallon-per-day (mgd) water treatment plant with ancillary facilities. The project involves reactivation of Lake Wheeler and Lake Benson as water supply sources, with an average water withdrawal of 14-mgd. The lakes, which were used as a water supply source from 1953 to 1987, occur on Swift Creek, a major tributary to the Neuse River. The proposed Project will serve as a secondary water supply source for the City of Raleigh and also assist in meeting the post-2010 water supply needs of the area.

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1.1 Background and Objectives

Until the 1990's, 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 dwarf-wedge mussel at four stations. Since the discovery of dwarf-wedge mussel 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 Miller 1993) and various status/monitoring surveys by the North Carolina Wildlife Resources Commission (WRC) from 1992-2006, as well as comprehensive efforts in 1996 and 2003 undertaken by the North Caroline Department of Transportation (NCDOT) for the Clayton Bypass roadway project (NCDOT 2005a). In addition to the dwarf-wedge mussel, several other rare freshwater mussel species have been found in Swift Creek, all of which are presented in Table 1.

Table 1. Rare Freshwater Mussel Species in Swift Creek

Scientific Name	Common Name	NC Status*	Federal Status
Alasmidonta heterodon	dwarf-wedge mussel	E	E
Alasmidonta undulata	triangle floater	T	~
Elliptio lanceolata	yellow lance	E	FSC
Elliptio roanokensis	Roanoke slabshell	T	~
Fusconia masoni	Atlantic pigtoe	E	FSC
Lampsilis radiata	eastern lampmussel	T	~
Lasmigona subviridis	green floater	E	FSC

Scientific Name	Common Name	NC Status*	Federal Status
Strophitus undulatus	creeper	T	~
Villosa constricta	notched rainbow	SC	~

*E, T, and FSC denote Endangered, Threatened and Federal Species of Concern, respectively.

In addition to the mussels, the Carolina madtom (*Noturus furiosus*), a small member of the catfish family, and the Neuse River waterdog (Necturus lewisi), an aquatic salamander, have also been recorded from Swift Creek. Both species are endemic to the Neuse and Tar/Pamlico River basins in North Carolina and are listed as Special Concern (SC) in North Carolina (Legrand Jr. et al. 2006). Definitions of Federal and State protection status are listed in Appendix A.

The WRC 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 (NCDENR) 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". 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).

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2.0 STUDY AREA

Swift Creek originates in western Wake County near the town of Cary, and flows in a general southward direction. Middle Creek joins Swift Creek approximately one mile upstream of the confluence with the Neuse River just south of the town of Smithfield in central Johnston County. Total stream length is approximately 38 miles and the drainage area above Middle Creek is approximately 156 square miles.

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The survey crew varied between dates, and consisted of TCG personnel Tim Savidge (TS), Tom Dickinson (TD), Chris Sheats (CS), Shay Garriock (SG), John Lancaster (JL), Jennifer Logan (JLo), Kate Montieth (KM), Megan Euliano (ME), Jonathan Hartsell, (JH), Jessie Taylor (JT), Joshua Jones (JJ), Robert Moore (RM), Bryant Savidge (BS), Mike Callahan (MC), and Michael Wood (MW). In addition, John Fridell (JF) of the USFWS, Sarah McRae (SM) of the NHP and Logan Williams (LW) of NCDOT assisted with survey efforts on various dates. The individual dates, survey sites and personnel are shown in Table 2.

Table 2. Swift Creek Survey Sites

Site #	Date	Person Hours	Location	People
1	11-06-06	3	35.57487°N, -78.49854°W	TD,SG,JL
2	11-06-06	3.75	35.57171°N, -78.50395°W	TD,SG,JL
3	11-06-06	4.5	35.57529°N, -78.50597°W	TD,SG,JL
4	11-20-06	1.33	35.55169°N, -78.45992°W	TS,MW,JL,MC,JLo,KM
5	11-20-06	8.0	35.55214°N, -78.46088°W	TS,MW,JL,MC,JLo,KM
6	3-14-07	4.0	35.54502°N, -78.39850°W	TS,CS,KM,JLo
7	5-22-07	7.0	35.56977°N, -78.47150°W	TD,ME,JLo,JJ,RM,JT
8	5-22-07	15.5	35.56870°N, -78.47314°W	TD,ME,JLo,JJ,RM,JT
9	5-22-07	7.5	35.56521°N, -78.47438°W	TD,ME,JLo,JJ,RM,JT
10	6-01-07	5.5	35.55279°N, -78.45686°W	TD,JJ,JT

Site #	Date	Person Hours	Location	People
11	6-01-07	5.0	35.55340°N, -78.46134°W	TD,JJ,JT
12	6-08-07	3.75	35.60244°N, -78.52135°W	TD,JLo,ME
13	6-08-07	9.25	35.57367°N, -78.49929°W	TD,JLo,ME
14	7-11-07	3.75	35.61491°N, -78.54933°W	TD,CS,JJ
15	7-11-07	3	35.61627°N, -78.55009°W	TD,CS,JJ
16	7-11-07	3.5	35.61798°N, -78.55189°W	TD,CS,JJ
17	7-11-07	4	35.61848°N, -78.55269°W	TD,CS,JJ
18	7-13-07	3.33	35.61941°N, -78.55323°W	TD,CS,RM,JJ,JLo
19	7-13-07	2.08	35.61956°N, -78.55365°W	TD,CS,RM,JJ,JLo
20	7-13-07	6.67	35.61926°N, -78.55402°W	TD,CS,RM,JJ,JLo
21	7-13-07	5	35.62078°N, -78.55619°W	TD,CS,RM,JJ,JLo
22 a-e#	8-02-07	7.32	35.64597°N, -78.60184°W	TS,CS,JJ.JT,RM
22 f-j#	8-02-07	7.93	35.64821°N, -78.60372°W	TS,CS,JJ.JT,RM
23	8-02-07	2.5	35.64887°N, -78.60395°W	TS,CS,JJ,JT,RM
24	8-03-07	7.5	35.51823°N, -78.38260°W	TD,CS,JJ,JT,RM
25	8-03-07	10.83	35.52047°N, -78.37743°W	TD,CS,JJ,JT,RM
26	8-03-07	5	35.52203°N, -78.37600°W	TD,CS,JJ,JT,RM
27	8-03-07	5	35.54418°N, -78.39740°W	TD,CS,JJ,JT,RM
28	8-10-07	5.4	35.62755°N, -78.58482°W	TS,TD,CS,JH,JT
29*	8-10-07	2	35.62766°N, -78.58522°W	TS,TD,CS,JH,JT
30	8-10-07	2.5	35.62825°N, -78.58629°W	TS,TD,CS,JH,JT
31*	8-10-07	1.15	35.62928°N,	TS,TD,CS,JH,JT

Site #	Date	Person Hours	Location	People
			-78.58653°W	
32	8-10-07	1.5	35.62910°N, -78.58716°W	TS,CS,JT
33	8-29-07	3.33	35.60618°N, -78.54324°W	TS,BS,ME,JF,LW
34	8-29-07	4.0	35.60645°N, -78.54406°W	TS,BS,ME,JF,LW
35	8-29-07	2.5	35.60708°N, -78.54444°W	TS,BS,ME,JF,LW
36	8-29-07	1	35.60776°N, -78.54517°W	TS,BS,ME,JF,LW
37*	8-29-07	3.41	35.60788°N, -78.54532°W	TS,BS,ME,JF,LW
38	8-29-07	1	35.61120°N, -78.54772°W	TS,BS,ME,JF,LW
39*	8-29-07	5	35.62070°N, -78.55540°W	TD,CS,JT,JL,JLo
40*	8-29-07	5	35.62019°N, -78.56139°W	TD,CS,JT,JL,JLo
41	8-30-07	2.08	35.62239°N, -78.56789°W	TD,CS,JT,JL,JLo
42	8-30-07	2.67	35.62294°N, -78.56847°W	TD,CS,JT,JL,JLo
43*	8-30-07	7.08	35.62256°N, -78.57014°W	TD,CS,JT,JL,JLo
44	8-30-07	2.5	35.62275°N, -78.57055°W	TD,CS,JT,JL,JLo
45	8-30-07	2.92	35.66170°N, -78.61120°W	TD,CS,JT,JL,JLo
46	8-30-07	1	35.62048°N, -78.55709°W	TS,ME,JF,SM
47	8-30-07	1	35.61984°N, -78.55895°W	TS,ME,JF,SM
48	8-30-07	1.67	35.61995°N, -78.56014°W	TS,ME,JF,SM
49*	8-30-07	1.75	35.62076°N, -78.56266°W	TS,ME,JF,SM
50	8-30-07	2.67	35.62027°N, -78.56325°W	TS,ME,JF,SM
51	8-30-07	1	35.62068°N, -78.56424°W	TS,ME,JF,SM
52	10-23-07	1.67	35.60326°N, -78.52392°W	TS,TD,CS,SG,JL

Site #	Date	Person Hours	Location	People
53	10-23-07	1.67	35.60368°N, -78.52456°W	TS,TD,CS,SG,JL
54	10-23-07	1.58	35.60397°N, -78.52558°W	TS,TD,CS,SG,JL
55	10-23-07	1.08	35.60445°N, -78.52721°W	TS,TD,CS,SG,JL
56	10-23-07	1.67	35.60423°N, -78.52754°W	TS,TD,CS,SG,JL
57	10-23-07	1.67	35.60381°N, -78.52831°W	TS,TD,CS,SG,JL
58	10-23-07	1.67	35.60230°N, -78.52957°W	TS,TD,CS,SG,JL
59	10-23-07	1.67	35.60207°N, -78.53013°W	TS,TD,CS,SG,JL
60	10-23-07	1.67	35.60216°N, -78.53125°W	TS,TD,CS,SG,JL
61	10-23-07	1.67	35.60233°N, -78.52203°W	TS,TD,CS,SG,JL
62	10-23-07	1.0	35.60288°N, -78.52283°W	TS,TD,CS,SG,JL
	Total:	**236.64**	~	~

wastewater discharge monitoring sites
* low flow monitoring sites

4.0 RESULTS

A total of 22,152 live native freshwater mussels comprising at least 16 species were collected during the survey efforts. The total number of individuals found, number of sites where located, highest recorded CPUE for the species, and the site number where the highest CPUE was recorded for each species is listed in Table 3. Species numbers and CPUE for each site are provided in Appendix B.

Table 3. Mussel Species Located

Species	# of Individuals Found	# of Sites Where Found	Site(s) w/Highest # Individuals (#)	Site # of Highest CPUE
Alasmidonta heterodon (dwarf-wedge mussel)	7	6	58 (2 individuals)	58 (1.20/hr)
Alasmidonta undulata (triangle floater)	121	44	8 (10 individuals)	36 (3.0/hr)
Elliptio complanata (eastern elliptio)	10,457	all*	28 (1,055 individuals)	47 (460.0/hr)
Elliptio congarea (Carolina slabshell)	325	27	6 (78 individuals)	6 (19.50/hr)
Elliptio icterina (variable spike)	1,373	all except #4*	37 (102 individuals)	47 (82/hr)

Species	# of Individuals Found	# of Sites Where Found	Site(s) w/Highest # Individuals (#)	Site # of Highest CPUE
Elliptio fisheriana (northern lance)	6	5	8, 10 (2 individuals)	7 (0.14/hr)
Elliptio lanceolata (yellow lance)	8	7	40 (3 individuals)	47 (2.0/hr)
Elliptio mediocris (no common name)	25	4	5 (15 individuals)	61 (4.79/hr)
Elliptio producta (Atlantic spike)	3	2	47 (2 individuals)	47 (2.0/hr)
Elliptio roanokensis (Roanoke slabshell)	303	27	13 (161 individuals)	13 (17.41/hr)
Elliptio spp.* (*E. complanata* and *E. icterina* complexes)	9,212	23	13 (829 individuals)	42 (195.13/hr)
Fusconaia masoni (Atlantic pigtoe)	71	35	22 f-j, 43 (5 individuals)	47 (3.0/hr)
Lampsilis radiata (eastern lampmussel)	72	33	22 f-j (12 individuals)	54 (2.53/hr)
Pyganodon cataracta (eastern floater)	70	16	22 a-e (36 individuals)	22a-e (4.92/hr)
Strophitus undulatus (creeper)	72	31	43 (7 individuals)	61 (3.59/hr)
Utterbackia imbecillis (paper pondshell)	34	9	22 a-e (16 individuals)	22a-e (2.19/hr)
Villosa constricta (notched rainbow)	3	1	2 (3 individuals)	2 (0.80/hr)

* in some instances *E. complanata* and *E. icterina* were recorded collectively as *E.* spp

The Asian clam (*Corbicula fluminea*) occurred at all of the sites and was the most abundant mollusk. Five species of aquatic snails were found sporadically throughout the study area, these include in order of frequency of encounter, the pointed campeloma (*Campeloma decisum*), the gravel elimia (*Elimia catenaria*), two ridge ram's horn (*Helisoma anceps*), a physid (*Physa* sp.), and the piedmont elimia (*Elimia virginica*).

4.1 Habitat Conditions and Mussel Distribution

Mussels were generally unevenly distributed across the stream channel, which is reflective of the distribution and quality of microhabitats at a particular site. In general, mussels were most abundant in the thalweg at the base of the stream bank, which is often associated with DSMR habitats, and rare to absent in the shifting sand dominated runs in the center of the channel. However, high numbers of mussels were occasionally found in SFC habitats of compact sand and/or gravel in the center of the channel. Although not quantified, mussel abundances in pool habitats appeared to be negatively affected by increasing amount of fine sediments and woody debris.

4.2 Tier III Minimum Flow Monitoring Stations

Mussel distribution at the seven Tier III Minimum Flow Monitoring Sites is reflective of the heterogeneity of microhabitats within Swift Creek. Three of the seven dwarf-wedge mussel individuals found during this study occurred within one of the seven monitoring stations. Habitat conditions and survey results for each station are summarized below. As previously noted, the stream was divided into four survey lanes; right descending bank (RDB), right descending channel (RDC), left descending channel (LDC), and left descending bank (LDB)

4.2.1 Site 29

This site occurs in a relatively straight, shallow to moderately deep run of the stream. Channel width is approximately 33 feet, with relatively stable banks 2 to 4 feet high. The channel is dominated by coarse sand, with clay banks. The RDB has a fairly compact substrate and contains significant DSRM habitats. A sand bar created by woody debris and associated SFC riffle habitat, occurs within the RDC. One individual dwarf-wedge mussel measuring 38 millimeters (mm) total length (TL) was found along the RDB.

Table 4. Mussel Species Located at Tier III Monitoring Station: Site 29

Survey Lane	Species (#)	CPUE all mussels	# rare mussels (species)
LDB	*E. complanata* (1)	3.03/hr	0
LDC	*E. complanata* (2)	6.06/hr	0
RDC	*E. complanata* (15), *E. icterina* (1)	48.48/hr	0
RDB	*A. heterodon* (1), *A. undulata* (2), *E. complanata* (162), *E. icterina* (6), *L. radiata* (1), *P. cataracta* (1), *U. imbecellis* (1)	174.0/hr	3 (3)
Total	***A. heterodon* (1), *A. undulata* (2), *E. complanata* (180), *E. icterina* (7), *L. radiata* (1), *P. cataracta* (1), *U. imbecellis* (1)**	**96.50/hr**	**4 (3)**

4.2.2 Site 31

This site consists of a shallow SFC sand/pebble riffle habitat along the LDB and LDC, and a moderately deep run with DSRM habitats along the RDB. Channel width is approximately 28 feet, with relatively stable banks 4 to 6 feet high.

Table 5. Mussel Species Located at Tier III Monitoring Station: Site 31

Survey Lane	Species (#)	CPUE all mussels	# rare mussels (species)
LDB	*E. complanata* (2)	12.90/hr	0
LDC	*E. complanata* (1)	6.45/hr	0
RDC	*E. complanata* (1)	6.45/hr	0
RDB	*A. undulata* (1), *E. complanata* (294), *E. icterina* (18), *F. masoni* (4), *S. undulatus* (1)	467.65/hr	6 (3)

Survey Lane	Species (#)	CPUE all mussels	# rare mussels (species)
Total	***A. undulata* (1), *E. complanata* (298), *E. icterina* (18), *F. masoni* (4), *S. undulatus* (1)**	**280.0/hr**	**6 (3)**

4.2.3 Site 37

This site consists of a shallow to moderately deep run with DSRM habitats along the LDB and a shallow SFC sand/pebble riffle habitat along the RDB and RDC. Channel width is approximately 28 feet, with relatively stable banks 2 to 4 feet high. The channel is dominated by coarse sand, with clay banks. One dwarf-wedge mussel measuring 45 mm TL was found along the LDB.

Table 6. Mussel Species Located at Tier III Monitoring Station: Site 37

Survey Lane	Species (#)	CPUE all mussels	# rare mussels (species)
LDB	*A. heterodon* (1), *A. undulata* (3), *E. complanata* (278), *E. icterina* (78), *L. radiata* (5), *P. cataracta* (1), *U. imbecellis* (3)	369.0/hr	9 (3)
LDC	*A. undulata* (2), *E. complanata* (28), *E. icterina* (15), *L. radiata* (1), *S. undulatus* (1)	47.0/hr	4 (3)
RDC	*E. complanata* (14), *E. icterina* (2), *L. radiata* (2), *S. undulatus* (1)	28.36/hr	3 (2)
RDB	*A. undulata* (2), *E. complanata* (12), *E. icterina* (7), *S. undulatus* (2)	34.33/hr	4 (2)
Total	***A. heterodon* (1), *A. undulata* (7), *E. complanata* (332), *E. icterina* (102), *L. radiata* (8), *P. cataracta* (1), *S. undulatus* (4), *U. imbecillis* (3)**	**134.31/hr**	**20 (4)**

4.2.4 Site 39

This site consists of a shallow to moderately deep run with DSRM habitats along the LDB and a shallow sandbar/pool habitat along the RDB and RDC. Channel width is approximately 30 feet, with relatively stable banks 2 to 4 feet high. The channel is dominated by coarse sand, with clay banks.

Table 7. Mussel Species Located at Tier III Monitoring Station: Site 39

Survey Lane	Species (#)	CPUE all mussels	# rare mussels (species)
LDB	*E. complanata* (162), *E. congaraea* (2), *E. icterina* (13), *S. undulatus* (2)	215.66/hr	2 (1)
LDC	*E. complanata* (74), *E. icterina* (8), *E. roanokensis* (1)	100.0/hr	1 (1)
RDC	*E. complanata* (2)	2.41/hr	0
RDB	*E. complanata* (6)	7.23/hr	0

Survey Lane	Species (#)	CPUE all mussels	# rare mussels (species)
Total	***E. complanata* (244), *E. congaraea* (2), *E. icterina* (21), *E. roanokensis* (1), *S. undulatus* (2)**	**54.0/hr**	**3 (2)**

4.2.5 Site 40

This site consists of a moderately deep run with DSRM habitats along the LDB and a sequence of short sandbar created riffle/pool habitats along the RDB and RDC. Channel width is approximately 40 feet, with relatively stable banks 2 to 4 feet high. The channel is dominated by coarse sand, with clay banks and pebble in the troughs along the LDB.

Table 8. Mussel Species Located at Tier III Monitoring Station: Site 40

Survey Lane	Species (#)	CPUE all mussels	# rare mussels (species)
LDB	*E. complanata* (311), *E. icterina* (34), *F. masoni* (1)	336.0/hr	1 (1)
LDC	*A. undulata* (4), *E. complanata* (114), *E. icterina* (17), *E. lanceolata* (1), *E. roanokensis* (2)	100.0/hr	7 (3)
RDC	*A. undulata* (2), *E. complanata* (30), *E. icterina* (2), *E. lanceolata* (1),	35.0/hr	3 (2)
RDB	*E. complanata* (151), *E. icterina* (5), *E. lanceolata* (1), *F. masoni* (1), *U. imbecellis* (1)	159.0/hr	2 (2)
Total	***A. undulata* (6), *E. complanata* (606), *E. icterina* (58), *E. lanceolata* (2), *E. roanokensis* (3), *F. masoni* (2), *U. imbecellis* (1)**	**135.0/hr**	**13 (4)**

4.2.6 Site 43

This site consists of a moderately deep run with DSRM habitats along the LDB and a sequence of short sandbar created riffle/pool habitats along the RDB and RDC. Channel width is approximately 40 feet, with relatively stable banks 2 to 4 feet high. The channel is dominated by coarse sand, with clay banks and pebble in the troughs along the LDB.

Table 9. Mussel Species Located at Tier III Monitoring Station: Site 43

Survey Lane	Species (#)	CPUE all mussels	# rare mussels (# rare species)
LDB	*E. complanata* (414), *E. icterina* (52), *S. undulatus* (1)	263.84/hr	1 (1)
LDC	*A. undulata* (5), *E. complanata* (338), *E. congaraea* (2), *E. icterina* (21), *F. masoni* (4), *L. radiata* (3), *S. undulatus* (2)	211.86/hr	14 (4)
RDC	*E. complanata* (83), *E. icterina* (2), *E. roanokensis* (2), *S. undulatus* (1)	49.71/hr	3 (2)

Survey Lane	Species (#)	CPUE all mussels	# rare mussels (# rare species)
RDB	*A. undulata* (2), *E. complanata* (101), *E. congaraea* (1), *E. icterina* (18), *E. roanokensis* (1), *F. masoni* (1), *S. undulatus* (3)	71.75/hr	7 (4)
Total	***A. undulata* (7), *E. complanata* (936), *E. congaraea* (3), *E. icterina* (93), *F. masoni* (5), *L. radiata* (3), *S. undulatus* (7), *E. roanokensis (3)***	**148.87/hr**	**25 (5)**

4.2.7 Site 49

This site consists of a moderately deep run with DSRM habitats along the LDB and a sequence of short logjam created riffle/pool habitats along the LDC. The RDC and RDB areas are shallow run/riffle/pool habitats with large accumulations of woody debris. Channel width is approximately 40 feet, with relatively stable banks 2 to 4 feet high. The channel is dominated by coarse sand, with clay banks and pebble in the troughs along the LDB. One individual dwarf-wedge mussel measuring 37 mm TL was found along the LDC in silt covered pool habitat, which is atypical for this species.

Table 10. Mussel Species Located at Tier III Monitoring Station: Site 49

Survey Lane	Species (#)	CPUE all mussels	# rare mussels (species)
LDB	*E. complanata* (131), *E. congaraea* (2), *E. icterina* (30), *S. undulatus* (3)	322.0/hr	3 (1)
LDC	*A. heterodon* (1), *E. complanata* (5), *E. icterina* (3)	21.95/hr	1 (1)
RDC	*A. undulata* (1), *E. complanata* (9), *E. icterina* (2)	29.27/hr	1 (1)
RDB	*E. complanata* (55), *E. icterina* (1)	136.59/hr	0
Total	***A. heterodon* (1), *A. undulata* (1), *E. complanata* (200), *E. congaraea* (2), *E. icterina* (36), *S. undulatus* (3)**	**138.86/hr**	**5 (3)**

4.3 Indian Creek Overlook WWTP Discharge Monitoring Stations

The existing discharge for the Indian Creek Overlook Home Park, is located along the RDB at the end of the development. The discharge consists of a straight pipe into a concrete step pool structure that directs the discharge flow towards the LDB. Five 100-foot sections of the creek (Sites 22 a-e) were surveyed below the discharge point, and five 100-foot sections (Sites 22 f-j) were surveyed above the discharge point. With the exception of the 50 foot scour pool immediately below the discharge, similar physical habitat characteristics occur above and below the discharge. Stream width is approximately 24 to 30 feet, and bank height is approximately 6 to 8 feet.

4.3.1 Site 22 a (550 feet to 450 feet below discharge)
This site occurs in a relatively straight, shallow run of the stream, with a large sand bar and associated SFC riffle habitat along the RDB and RDC. There is a shallow run with DSRM habitats along the LDB and a sequence of short logjam created riffle/pool habitats along the LDC. The substrate is dominated by gravel and coarse sand, with clay and mud banks. Stream width is approximately 24 feet, and bank height is approximately 6 feet.

Table 11. Mussel Species Located at WWTP Discharge Monitoring Station: Site 22a

Survey Lane	Species (#)	CPUE all mussels	# rare mussels (species)
LDB	*E. complanata* (4), *E. icterina* (1)	29.42/hr	0
LDC	None	0/hr	0
RDC	None	0/hr	0
RDB	*E. complanata* (19), *E. icterina* (4)	69.70/hr	0
Total	***E. complanata* (23), *E. icterina* (5)**	**33.73/hr**	**0**

4.3.2 Site 22 b (450 feet to 350 feet below discharge)
This site consists of a relatively straight, shallow gravel run habitat with a sand bar island in the center of the channel. Water levels were very low (<8 inches) on both sides of the island.

Table 12. Mussel Species Located at WWTP Discharge Monitoring Station: Site 22b

Survey Lane	Species (#)	CPUE all mussels	# rare mussels (species)
LDB	*E. icterina* (1)	5.88/hr	0
LDC	None	0/hr	0
RDC	None	0/hr	0
RDB	*E. complanata* (34)	103.03	0
Total	***E. complanata* (34), *E. icterina* (1)**	**42.17/hr**	**0**

4.3.3 Site 22 c (350 feet to 250 feet below discharge)
This site consists of a moderately deep flowing pool habitat created by the sandbar island located in Site 22 b. The substrate is dominated by gravel and coarse sand, with clay and mud banks.

Table 13. Mussel Species Located at WWTP Discharge Monitoring Station: Site 22c

Survey Lane	Species (#)	CPUE all mussels	# rare mussels (species)
LDB	*E. complanata* (3), *E. icterina* (1), *P. cataracta* (3), *U. imbecellis* (2)	15.52/hr	0
LDC	*F. masoni* (1)	2.0/hr	1 (1)
RDC	None	0/hr	0

Survey Lane	Species (#)	CPUE all mussels	# rare mussels (species)
RDB	*E. complanata* (169), *E. icterina* (9), *F. masoni* (1), *P. cataracta* (7), *U. imbecellis* (4)	327.59/hr	1 (1)
Total	***E. complanata* (172), *E. icterina* (10), *F. masoni* (2), *P. cataracta* (10), *U. imbecellis* (4)**	**95.19/hr**	**2 (1)**

4.3.4 Site 22 d (250 feet to 150 feet below discharge)
This site consists of a moderately deep run/pool habitat, with small SFC riffle habitats created by logjams. The substrate is dominated by gravel and coarse sand, with clay and mud banks.

Table 14. Mussel Species Located at WWTP Discharge Monitoring Station: Site 22d

Survey Lane	Species (#)	CPUE all mussels	# rare mussels (species)
LDB	*E. complanata* (4), *E. icterina* (3), *L. radiata* (1), *P. cataracta* (6), *U. imbecellis* (2)	32.0/hr	1 (1)
LDC	*E. complanata* (4), *P. cataracta* (13), *U. imbecellis* (1)	42.86/hr	0
RDC	*E. complanata* (57)	135.71/hr	0
RDB	*E. complanata* (67), *E. icterina* (4), *F. masoni* (1), *P. cataracta* (3), *U. imbecellis* (4)	158.0/hr	1 (1)
Total	***E. complanata* (132), *E. icterina* (7), *F. masoni* (1), *L. radiata* (1), *P. cataracta* (22), *U. imbecellis* (7)**	**89.01/hr**	**2 (2)**

4.3.5 Site 22 e (150 feet to 50 feet below discharge)
This site consists of a moderately deep pool habitat. The substrate is dominated by gravel and coarse sand, with clay and mud banks and a fairly large amount of silt deposition.

Table 15. Mussel Species Located at WWTP Discharge Monitoring Station: Site 22e

Survey Lane	Species (#)	CPUE all mussels	# rare mussels (species)
LDB	None	0/hr	0
LDC	None	0/hr	0
RDC	*P. cataracta* (1), *U. imbecellis* (2)	7.14/hr	0
RDB	*E. complanata* (78), *E. icterina* (3), *P. cataracta* (3), *U. imbecellis* (1)	146.55/hr	0
Total	***E. complanata* (78), *E. icterina* (3), *P. cataracta* (4), *U. imbecellis* (3)**	**52.69/hr**	**0**

4.3.6 Site 22 f (50 feet to 150 feet above discharge)
This site consists of a moderately deep pool habitat. The substrate is dominated by gravel and coarse sand, with clay and mud banks and a fairly large amount of silt deposition and woody debris.

Table 16. Mussel Species Located at WWTP Discharge Monitoring Station: Site 22f

Survey Lane	Species (#)	CPUE all mussels	# rare mussels (species)
LDB	*E. complanata* (14), *P. cataracta* (4), *U. imbecellis* (2)	47.62/hr	0
LDC	*E. complanata* (5)	11.90/hr	0
RDC	*E. complanata* (10), *F. masoni* (1), *P. cataracta* (4)	35.71/hr	1 (1)
RDB	*E. complanata* (18), *E. icterina* (1), *P. cataracta* (2)	50.0/hr	0
Total	***E. complanata* (47), *E. icterina* (1), *F. masoni* (1), *P. cataracta* (6), *U. imbecellis* (2)**	**34.13/hr**	**1 (1)**

4.3.7 Site 22 g (150 feet to 250 feet above discharge)
This site consists of a shallow sand dominated run and flowing pool habitat, with mud and clay banks.

Table 17. Mussel Species Located at WWTP Discharge Monitoring Station: Site 22g

Survey Lane	Species (#)	CPUE all mussels	# rare mussels (species)
LDB	*E. complanata* (40), *L. radiata* (2)	127.27/hr	2 (1)
LDC	*E. complanata* (40)	142.86/hr	0
RDC	*E. complanata* (15), *E. icterina* (3), *F. masoni* (1), *P. cataracta* (2)	63.64/hr	1 (1)
RDB	*E. complanata* (62)	206.67/hr	0
Total	***E. complanata* (157), *E. icterina* (3), *F. masoni* (1), *L. radiata* (2), *P. cataracta* (2)**	**132.0/hr**	**3 (2)**

4.3.8 Site 22h (250 feet to 350 feet above discharge)
This site consists of a shallow, sand and gravel dominated run and flowing pool habitat, with mud and clay banks.

Table 18. Mussel Species Located at WWTP Discharge Monitoring Station: Site 22h

Survey Lane	Species (#)	CPUE all mussels	# rare mussels (species)
LDB	*E. complanata* (30), *L. radiata* (2), *P. cataracta* (5)	88.09/hr	2 (1)
LDC	*E. complanata* (15), *E. icterina* (3)	42.86/hr	0
RDC	*E. complanata* (28), *F. masoni* (1)	69.05/hr	1 (1)
RDB	*E. complanata* (50), *E. icterina* (5), *U. imbecellis* (1)	133.33/hr	0

Survey Lane	Species (#)	CPUE all mussels	# rare mussels (species)
Total	***E. complanata* (123), *E. icterina* (8), *F. masoni* (1), *L. radiata* (2), *P. cataracta* (5), *U. imbecellis* (1)**	**83.83/hr**	**3 (2)**

4.3.9 Site 22 i (350 feet to 450 feet above discharge)
This site consists of a gravel dominated run and flowing pool habitat of moderate depth, with mud and clay banks.

Table 19. Mussel Species Located at WWTP Discharge Monitoring Station: Site 22i

Survey Lane	Species (#)	CPUE all mussels	# rare mussels (species)
LDB	*E. complanata* (25), *L. radiata* (2), *P. cataracta* (2), *U. imbecellis* (3)	76.19/hr	2 (1)
LDC	*E. complanata* (10), *E. icterina* (2), *L. radiata* (1),	30.95/hr	1(1)
RDC	*E. complanata* (31), *F. masoni* (1)	76.19/hr	1 (1)
RDB	*E. complanata* (40), *E. icterina* (8), *L. radiata* (1)	116.67/hr	1 (1)
Total	***E. complanata* (106), *E. icterina* (10), *F. masoni* (1), *L. radiata* (4), *P. cataracta* (2), *U. imbecellis* (3)**	**74.85/hr**	**5 (2)**

4.3.10 Site 22 j (450 feet to 550 feet above discharge)
This site consists of a gravel dominated run of moderate depth and a fairly deep flowing pool habitat.

Table 20. Mussel Species Located at WWTP Discharge Monitoring Station: Site 22j

Survey Lane	Species (#)	CPUE all mussels	# rare mussels (species)
LDB	*E. complanata* (58), *E. icterina* (3), *L. radiata* (2)	150.0/hr	2 (1)
LDC	*E. complanata* (46), *E. icterina* (3), *F. masoni* (1)	119.05/hr	1 (1)
RDC	*E. complanata* (31), *E. icterina* (7), *E. roanokensis* (1), *L. radiata* (1)	95.24/hr	2 (2)
RDB	*E. complanata* (70), *E. icterina* (4), *L. radiata* (1)	178.57/hr	1 (1)
Total	***E. complanata* (205), *E. icterina* (17), *F. masoni* (1), *L. radiata* (4), *E. roanokensis* (1)**	**136.53/hr**	**6 (3)**

5.0 DISCUSSION

These surveys provide new and updated mussel distribution for the section of Swift Creek below Lake Benson, as well as establishing seven stations that can be monitored over time following Tier III (1 cfs) flow conditions, and two stations that can be monitored over time following removal of the existing Indian Creek Overlook Home Park WWTP discharge. Seven individuals of the endangered dwarf-wedge mussel were found at six locations, which resulted in an upstream extension (over 1 mile) of the

known range of the species in Swift Creek. The majority of the "rare" mussel species occurred in the middle and upper segments of the study area.

Much of the survey effort took place during extreme low flow conditions, which aided in ease of detection, resulting in high CPUE. Although water levels were very low during much of the study, continual flow was observed throughout. As a result, the mussel fauna of Swift Creek did not appear to suffer as much mortality from exposure/desiccation as in other streams in the Piedmont of North Carolina (personal observations). Maintaining minimum flows as well as ground water input may be responsible for this.

5.1 The Mussel Fauna of Swift Creek

Historically, at least 18 species of freshwater mussels have been reported to occur in the Swift Creek subbasin. This study confirms the high species diversity (for Atlantic Slope drainages) of this stream, as at least 16 species were collected. 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 two species reported to occur in Swift Creek that were not found in this study are the green floater (*Lasmigona subviridis*) and the Carolina lance (*Elliptio angustata*). 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.

5.1.1 Mussel species found during the surveys

Brief descriptions of each of the mussel species found in Swift Creek are provided below. The original species descriptions along with Bogan (2002) and Johnson (1970) should be consulted for more detailed descriptions. Maps showing distribution within the study area for each species are included in Appendix C Figures 1-17.

5.1.1.1 *Alasmidonta heterodon* (dwarf-wedge mussel)

Originally described as *Unio heterodon* (Lea 1829), the dwarf-wedge mussel was listed as federally endangered on March 14, 1990. 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 TL. The largest specimen ever recorded was 56.5 mm long, taken from the Ashuelot River in New Hampshire (Clarke 1981). 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, 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.

The historic range of the dwarf-wedge mussel 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). It is currently believed to have been extirpated from all but 36 localities, 14 of them in North Carolina (USFWS 1993). The dwarf-wedge mussel inhabits creeks and rivers of varying sizes (down to approximately 6.6 feet 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, the dwarf-wedge mussel often occurs within submerged root mats along stable streambanks (DSRM). The wide range of substrate types used by this species suggests that the stability of the substrate is likely as important as the composition.

Seven individuals were found ranging in size from 24 to 45 mm TL, with 3 to 4 size classes (age classes) present. Although only 7 individuals were found, this is the highest number recorded in Swift Creek in any given year. The occurrence at site 29 represents an upstream extension of the known range in Swift Creek of 1 mile. The accepted extent of occupied habitat in Swift Creek was reported to have declined from 20.5 miles in 1991 to 9.3 miles in 1996 (NCDOT 2005b) and then to 5 miles in 2002 (USFWS 2002). This study establishes an occupied range within Swift Creek of 6 miles.

5.1.1.2 *Alasmidonta undulata* (triangle floater)
This species was described from the Schuylkill River near Philadelphia (Say 1817). Its range extends from the Savannah River in South Carolina/Georgia 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 dull yellowish green with distinct green rays of varying width and length. This species is considered special concern throughout its range (Williams et al. 1993), and is listed as Threatened in North Carolina.

This species can occur in a variety of habitats in small streams to large rivers, usually in quiet waters with some current in a variety of substrates. This species ranged throughout the entire study area with 121 individuals being found at 44 of the 63 sites. It occurred in fairly low numbers, with a maximum of 10 individuals at a particular site (Site 8); however, multiple age classes were observed, with a size range of 25.5mm to 81 mm TL.

5.1.1.3 *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. Johnson (1970) synonomized the following species described from the Neuse River Basin with *E. complanata*: *Unio (=Elliptio macer), U. neusensis, U. exactus, U. raleighensis, U. aberrans, U. quadrilatterus, U. idefinitus, U. cisteliformis, U. protensus and U. ratus*. This species is widely distributed along the Atlantic Slope from the Altamaha River Basin in Georgia north to the St. Lawrence 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).

This species occurred at all of the sites sampled and was the most abundant. Multiple age classes were observed ranging in size from 20 mm to 107 mm TL. Several forms occurred throughout the study area, often within a particular site. This species generally occupied multiple habitat types within a particular site. However, due to time constraints and not being the focus of this study, efforts to correlate different forms with different habitat types were not attempted. It is unclear whether the variations in shell morphology within the study area, as well as within particular sites, represent ecophenotypic or genotypic variability.

5.1.1.4 *Elliptio congaraea* (Carolina slabshell)
This species was described from the Congaree River, South Carolina by Lea (1831). Five species (*E. sordidis*, *E. gibbesianus*, *E. rufusculus*, *E. forbesianus*, and *E. buxeus*) described from the Savannah River Basin (Lea 1852) were synonomized with *E. congaraea* (Johnson 1970). The range of this species extends from the Ogeechee River, Georgia north to the Chowan River, North Carolina. 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 is moderately sharp and usually has numerous cross corrugations or wrinkles. The periostracum is greenish-yellow or tawny. Williams et al. (1993) lists this species as Special Concern, and it is on the Watch list in North Carolina.

The Carolina slabshell was found at 27 sites, usually in run habitats dominated by coarse sand/ gravel, and fairly swift flow. Although it essentially occupies the entire study area, it occurred more often and in higher numbers in the middle and lower segments. A total of 325 individuals were found, but with the exception of Sites 6, 26, 27, 25 and 31 (78, 40, 40, 35 and 31 individuals respectively), numbers were fairly low. The population appears to be represented mainly by large (old) individuals.

5.1.1.5 *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 in low numbers (maximum 2 individuals) at five sites in shallow, bank habitats with soft substrates. Two of the sites where this species occurred were 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 very is rare for these two species to occur in the same area (personal observations). This phenomenon is not understood.

5.1.1.6 *Elliptio icterina* (variable spike)
Described from the Savannah River near Augusta Georgia (Conrad 1834), this highly variable species represents a complex of nearly 50 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).

Like the eastern elliptio, the variable spike was a common find at all of the surveyed sites, with the exception of Site 4, where only two individual mussels were found. This was the second most abundant species encountered, and like the eastern elliptio, multiple age classes were observed (20-85 mm TL). This species was found in multiple habitat types within the study area; however, it appeared to be most prevalent in riffle and flowing run habitats with coarse sand and gravel substrates. Due to time constraints and not being the focus of this study, efforts to correlate different forms with different habitat types were not attempted. It is unclear whether the variations in shell morphology within the study area, as well as within particular sites, represent ecophenotypic or genotypic variability.

5.1.1.7 *Elliptio lanceolata* (yellow lance)
Described from the Tar River at Tarboro, North Carolina by Lea (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. This species is distributed from the Neuse River Basin north to the Rappahannock, but is in considerable decline throughout its range. Extant populations occur in the Neuse, Tar/Pamlico, Chowan and York River basins. This species is a Federal Species of Concern and is listed as Endangered in North Carolina. Williams et al. (1993) list this species as Endangered, and it is listed as Endangered in North Carolina.

This species was found at 7 sites in very low numbers (8 individuals), with two of the sites represented only by relict shell material. The 8 individuals, which range in size from 44-53 mm TL, were found exclusively in SFC habitats associated with sandbars in the channel. Although the range of this species appears to be similar to what was reported in the 1990’s, abundances (#s and CPUE) have declined drastically (WRC database, personal observation).

5.1.1.8 *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. congerea*.

This species was found at 4 sites, mainly in the middle segment and the lower portion of the upper segment. A total of 25 individuals were found, with 15 individuals found at Site 5.

5.1.1.9 *Elliptio producta* (Atlantic spike)
Described from the Savannah River, Georgia by Conrad (1836), 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* (Johnston 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, and it is on the Watch list in North Carolina.

Only 3 individuals of the Atlantic spike were found at two sites. This species is typically uncommon in the Neuse River Basin, and is common in river basins to the south (personal observations).

5.1.1.10 *Elliptio roanokensis* (Roanoke slabshell)
The Roanoke slabshell was described from the Roanoke River (exact location unknown) by Lea (1838). The reported range extends from the Connecticut River in Massachusetts south to the Savannah River in Georgia (Walter 1954)). Based on shell morphologies, Johnson (1970) synonymized 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. Williams et al. (1993) list this species as Special Concern and it is listed as Threatened in North Carolina.

The Roanoke slabshell was found at 27 sites, usually in run habitats dominated by coarse sand/ gravel, and fairly swift flow. Although it essentially occupies the entire study area, it occurred more often and in higher numbers in the middle and lower segments. A total of 303 individuals were found, but with the exception of Site 13 (161 individuals),

numbers were fairly low. The population appears to be represented mainly by large (old) individuals.

5.1.1.11 *Elliptio* spp. (*E. complanata* and *E. icterina* complexes)
Mussels in the genus Elliptio were the most common species found throughout the study area. Based on shell morphologies, Johnson (1970) synonymized nearly 150 named species into two complexes: *E. complanata* and *E. icterina* respectively (102 and 47). Many of these species were described in the Carolinas. Preliminary genetic research suggests that some of these may be valid species. In some of the streams surveyed for this project, there appeared to be several forms of Elliptios, with gradation between each form, making separation difficult and subjective. A number of distinct "forms" of *E. complanata* and *E. icterina* were consistently noted during this study. Unfortunately time constraints did not allow for, nor did the scope of this study intend to separate each form at each site, and assign a former species name to the elliptio fauna found. In many instances, separation into the two species complexes was determined to be too time consuming which would have resulted in excessive exposure (time out of the water) of individual mussels; thus, they were lumped into 1 group (*Elliptio* spp.). A total of 9,212 elliptio mussels were lumped into the *E*. spp. When separation to species complex was made, the ratio of *E. complanata* to *E. icterina* was estimated at 7.6 to 1. Thus, it is estimated that the *E*. spp. consisted of approximately 8,142 *E. complanata* and 1,070 *E. icterina*.

5.1.1.12 *Fusconaia masoni* (Atlantic pigtoe)
The Atlantic pigtoe was described by Conrad (1834) from the Savannah River in Augusta, Georgia. Its range extends from the Ogeechee River Basin in Georgia north to the James River Basin in Virginia (Johnson 1970). The Atlantic pigtoe occurs in medium size streams to large rivers, but has experienced major declines throughout its entire range. The preferred habitat 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). Shells of the Atlantic pigtoe are subrhomboidal in outline, with a parchment, or cloth-like yellow to dark brown periostracum. The posterior ridge is very distinct, and the umbos extend well above the dorsal margin. The dorsal margin is also marked by a short, thick hinge ligament. Williams et al. (1993) list this species as endangered. It is considered Endangered in North Carolina and is a Federal Species of Concern.

A total of 71 individuals were found at 35 sites distributed throughout the entire study area in fairly low numbers (maximum of 5 individuals at a site). Gravid (females holding young) were observed during the surveys in June. Size range in the population was from 34 to 67 mm TL; however, only 5 of the 71 individuals collected were under 40 mm TL, suggesting an aging population with limited recruitment.

5.1.1.13 *Lampsilis radiata radiata* (eastern lampmussel) and *Lampsilis radiata conspicua* (Carolina fatmucket)
The eastern lampmussel was described from Saratoga Lake in New York by Lamarck (1819). Carolina fatmucket was described from the Yadkin/Pee Dee River Basin in

North Carolina as *Unio conspicuus* by Lea (1874). Simpson (1914) considered it to be a variety of *L. radiata radiata* (eastern lampmussel). The Carolina fatmucket was synonomized with *L. radiata radiata* by Johnson (1970). 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 complex was found at 32 sites throughout the study area, usually in bank habitats. With the exception of Site 22 f-j (12 individuals) and Site 37 (8 individuals), it was found in fairly low numbers (1-3 individuals). Due to the taxonomic uncertainty of this species complex, attempts were not made to distinguish between *L. radiata radiata* and *L. radiata conspicua*; however, both forms were noted. Although not recorded, it appeared that the eastern lampmussels found in the upper segments resembled *L. radiata conspicua* while the ones in the lower segment resembled *L. radiata radiata*, with gradation between forms in the middle segment. Multiple size classes of this species complex were observed (34-141 mm TL); however, the majority of individuals comprised larger (older) size classes.

5.1.1.14 *Pyganadon 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).

This species was found at 16 sites mainly in the upper portion of the study area. With the exception of the two sites associated with the Indian Creek Overlook Home Park WWTP discharge (Sites 22 a-e and 22 f-j) where 36 and 17 individuals were found respectively, all other sites had only 1, or 2 individuals. The relatively low numbers at most sites is likely attributable to its preferred slackwater habitats being minimally sampled. The

relatively large numbers at the two sites near the discharge are discussed further in Section 5.3.

5.1.1.15 *Strophitus undulatus* (creeper)

This species was described from the Schuylkill River near Philadelphia (Say, 1817). Its range extends 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. This species occupies a variety of habitats, from high-gradient small streams, to larger rivers. Williams et al. (1993), considers it Special Concern and it is listed as Threatened in North Carolina.

This species was found in fairly low numbers (1-7 individuals) at 31 sites primarily in the middle segment of the study area in a variety of habitats. The 72 individuals ranged in size from 30 to 74 mm TL, with multiple size (age) classes observed.

5.1.1.16 *Utterbackia imbecillis* (paper pondshell)
Described from the Wabash River in Indiana (Say 1829), this mussel occurs throughout the Mississippi River and Great Lakes drainages, as well as sporadically 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).

This species was found at 9 sites mainly in the upper portion of the study area. With the exception of the two sites associated with the Indian Creek Overlook Home Park WWTP discharge (Sites 22 a-e and 22 f-j where 19 and 6 individuals were found respectively), all other sites had only 1-3 individuals. The relatively low numbers at most sites is likely attributable to its preferred slackwater habitats being minimally sampled. The relatively large numbers at the two sites near the discharge are discussed further in Section 5.3.

5.1.1.17 *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.

This species occurred at only 1 site (Site 2), with 3 individuals being found. This species is present near the headwaters of Swift Creek upstream of Lake Wheeler, but it had not been recorded below Lake Benson in recent surveys (NCDOT 2005a).

5.2 Tier III Minimum Flow Monitoring Stations

The seven Tier III minimum flow monitoring stations were selected based on the presence of SFC and DSRM habitats. The presence of these habitat proved to be reliable indicators for the presence of dwarf-wedge mussel as 3 of the 7 individuals found during this study occurred within a monitoring station. In addition, these sites were also good indicators of other rare mussel species, as 23.6 %, 19.8%, 17.4% and 14.1% respectively of the total number of creeper, triangle floater, eastern lampmussel and Atlantic pigtoe were found, though the monitoring sites only accounted for only 11% of the sites sampled. The sites were sampled in August in the middle of the severity of the drought. Water levels were very low, but continual flow was being maintained. In addition, although no monitoring stations were sampled, continual flow was observed in Swift Creek during the peak of the drought on October 23, 2007. Many of the mussels found at these stations would have been exposed if water levels were any lower. Thus, monitoring of these sites will be sufficient in determining the effects of prolonged Tier III minimum flows on the freshwater mussel fauna of Swift Creek.

5.3 Indian Creek Overlook WWTP Discharge Monitoring Stations

The relative abundances of mussels based on CPUE were significantly lower below the discharge as opposed to above (70.6/hr vs. 93.4/hr). Although there were no differences in species diversity (7 species above and below), only four individuals of "rare" mussel species were found below the discharge as opposed to 18 found above. In addition, the highest numbers and CPUE for the eastern floater and paper pondshell occurred at Site 22 a-e just below the discharge (Section 5.1.1). Both of these species are considered to be more tolerant of toxicants than many other freshwater mussel species (Millam et al. 2005, Metcalfe-Smith et al. 1997).

The most dramatic difference observed upstream and downstream of the discharge pertains to distribution of mussels across the channel. Mussels were more evenly distributed across the channel upstream of the discharge than downstream, as 78.9% of the mussels found downstream of the discharge occurred in the RDB survey lane, as opposed to only 36.7% in the RDB upstream. Many factors influence distribution of mussels in a stream (substrate, water depth, flow, water quality etc.), thus mussels are rarely distributed evenly across a stream channel. However, it seems apparent that the discharge is affecting the distribution of mussels in this section of the stream and may also be affecting abundances.

As mentioned in Section 4.3, the wastewater is directed towards the center of the channel and LDB. The discharged water was clearly distinguishable from the rest of the flow in Swift Creek (visual observation), downstream at least 400 feet (Site 22 b). The ability to observe this was likely aided by the low flow conditions of the creek at the time of the site visit. Thus, the RDB habitat does not appear to be receiving much of the wastewater at least during low flow periods. When the RDB survey lane data is eliminated, the CPUE of mussels upstream vs. downstream is even more dramatic (77.4/hr versus 22.0/hr).

More robust data analysis (water chemistry data, flow pattern analysis etc.) is needed to fully understand the dynamics and magnitude of the discharge's impact of the freshwater mussel fauna; however, the baseline data established above and below the discharge are sufficient to determine changes in abundances and distribution once the discharge is taken offline.

6.0 REFERENCES

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., 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 Museum of Natural Sciences Special Publication 101 pp.

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

Clarke, A. H. 1985. The tribe Alasmidontini (Unionidae: Anodontinae), Part II: Lasmigona and Simpsonaias.

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. 1836. 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. 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.

Conrad, T. A. 1838. Monography of the Family Unionidae, or naiads of Lamarck (freshwater bivalve shells) of North America, illustrated by figures drawn on stone from nature. 10:81-94, plates 46-51.

Entrix. 2005. Biological Assessment for Dwarf Wedgemussel (*Alasmidonta heterodon*) Prepared in Support of the Dempsey E. Benton Water Treatment Plant Project June 2005.

Flowers, J.R. and G.C. Miller. 1993. Molluscs from Swift Creek, Wake and Johnston counties, North Carolina. Proc. of the 47th Annual Conference, Southeastern Association of Fish and Wildlife Agencies. 47:359-365.

Fuller, S. L. H. 1977. Freshwater and Terrestrial Mollusks. Endangered and Threatened Plants and Animals of North Carolina. J. E. Cooper, S. S. Robinson and J. B. Funderburg. Raleigh, North Carolina, NC State Museum of Natural History: 143-194.

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.

Lea, I. 1828. Description of six new species of the genus Unio, embracing the anatomy of the oviduct of one of them, together with some anatomical observations on the genus. Transactions of the American Philosophical Society 3[New Series]: 259-273, pls. 3-6.

Lea, I. 1829. Description of a new genus of the family of naïades, including eight new 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): 403-456, 8 plates.

Lea, I. 1831. Observations of the Naiades, and descriptions of new species of that and other families. Transactions of the American Philosophical Society 5 (new series)): 23-119, pls. 1-19.

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. 1852. Description of a new species of the family Unionidae. Transactions of the American Philosophical Society 10: 253-294.

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. 1874. "Descriptions of fifty-two species of Unionidae." Journal of the Academy of Natural Sciences of Philadelphia 8: 5-54, pls 1-18.

LeGrand, H. E., S.E. McRae, S.P. Hall, and J.T. Finnegan. 2006. Natural Heritage Program List of the Rare Animal Species of North Carolina. NCDENR, 104pp.

Lightfoot, J. 1786. A Catalogue of the Portland Museum, Lately the Property of the Duchess of Dowager of Portland, deceased, which will be sold at auction by Mr. Skinner and Co. London. Vii: 194.

Metcalfe-Smith, J. L., S. K. Staton, G. L. Mackie, and N. M. Lane. 1997. Biodiversity of freshwater mussels in the lower Great Lakes Drainage Basin. Plenary presentation at the 3rd National EMAN Meeting, Saskatoon, Saskatchewan, 24 January 1997

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 (Unionida). Archives of Environmental Contamination and Toxicology, 48 (2) 166-173.

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.

North Carolina Department of Transportation. 2005a. Data from the Swift Creek, Little Creek, White Oak Creek, and Copper Branch dwarf wedgemussel survey.

North Carolina Department of Transportation. 2005b. Addendum to the Biological Assessment, Clayton Bypass, Johnston and Wake County, North Carolina (R-2552). March 2005.

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.

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. 1914. A descriptive catalogue of the naiades or pearly freshwater mussels. 1-3.

Turgeon, D. D., A. E. Bogan, E. V. Coan, W. K. Emerson, W. G. Lyons, W. L. Pratt, C. F. E. Roper, A. Scheltema, F. G. Thompson, and J. J. Williams 1988. Common and scientific names of aquatic invertebrates from the United States and Canada: Mollusks. American Fisheries Society, Special Publication 16: 277, 12 pls.

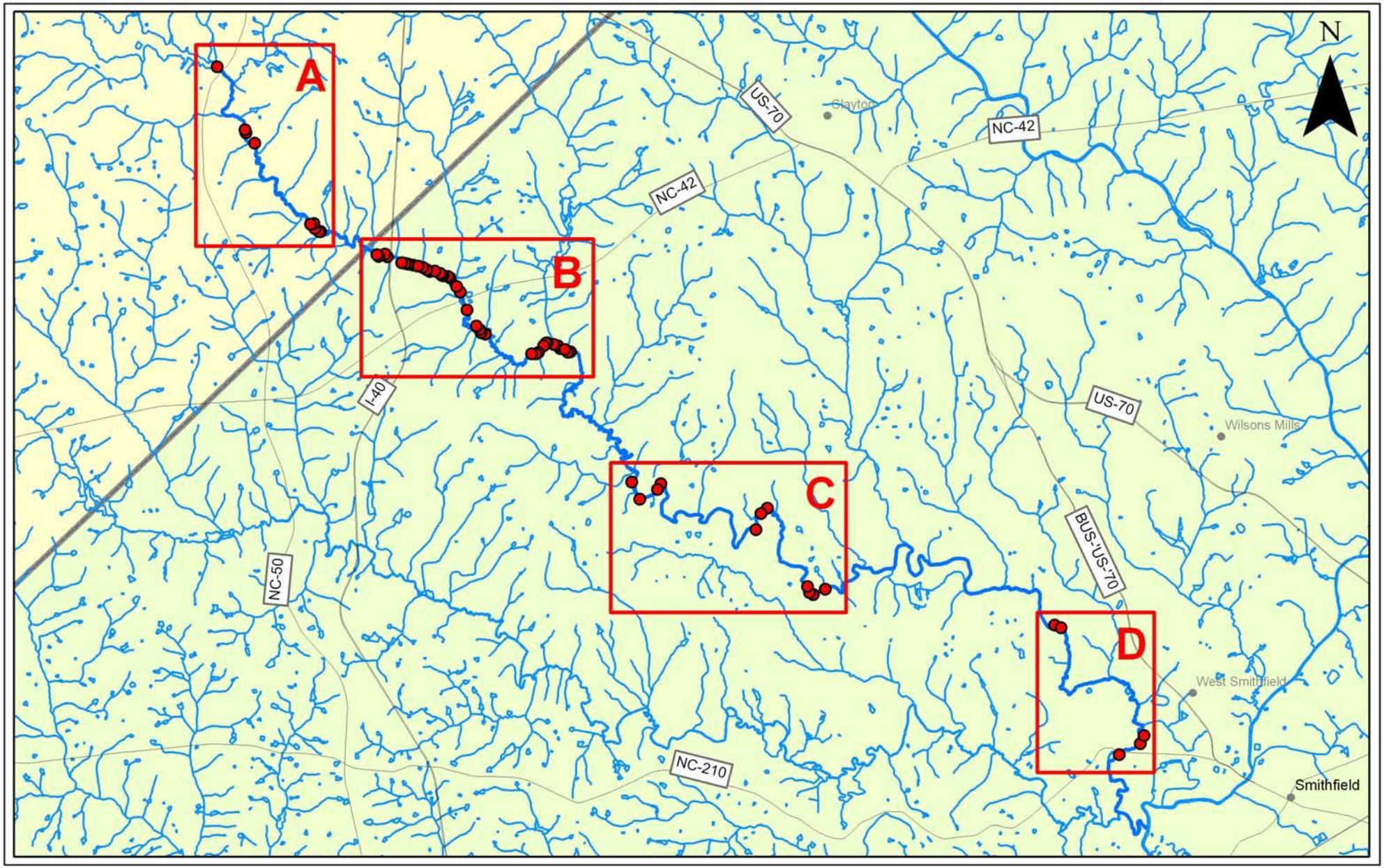
U.S. Fish and Wildlife Service. 1993. Dwarf Wedgemussel Mussel (*Alasmidonta heterodon*) Recovery Plan. Hadley, Massachusetts. 527 pp.

U.S. Fish and Wildlife Service. 2002. Dwarf Wedgemussel (*Alasmidonta heterodon)* Sites – 2002. Unpublished. Table Prepared by Susi vonOettingen, FWS Hadley, MA.

Walter, W. M. 1956. Molluscs of the upper Neuse River basin, North Carolina. J. of the Elisha Mitchell Scientific Society (72 (2):262-274.

Williams, J. D., M. L. Warren, Cummings, K.S., Harris, J.L., and Neves, R.J. 1993. Conservation Status of the Freshwater Mussels of the United States and Canada. Fisheries 18(9): 6-22.

APPENDIX A.
FIGURES



The Catena Group

Client:

ARCADIS
Infrastructure, environment, facilities

Dempsey E. Benton Water Treatment Plant: Swift Creek Mussel Surveys

Survey Locations

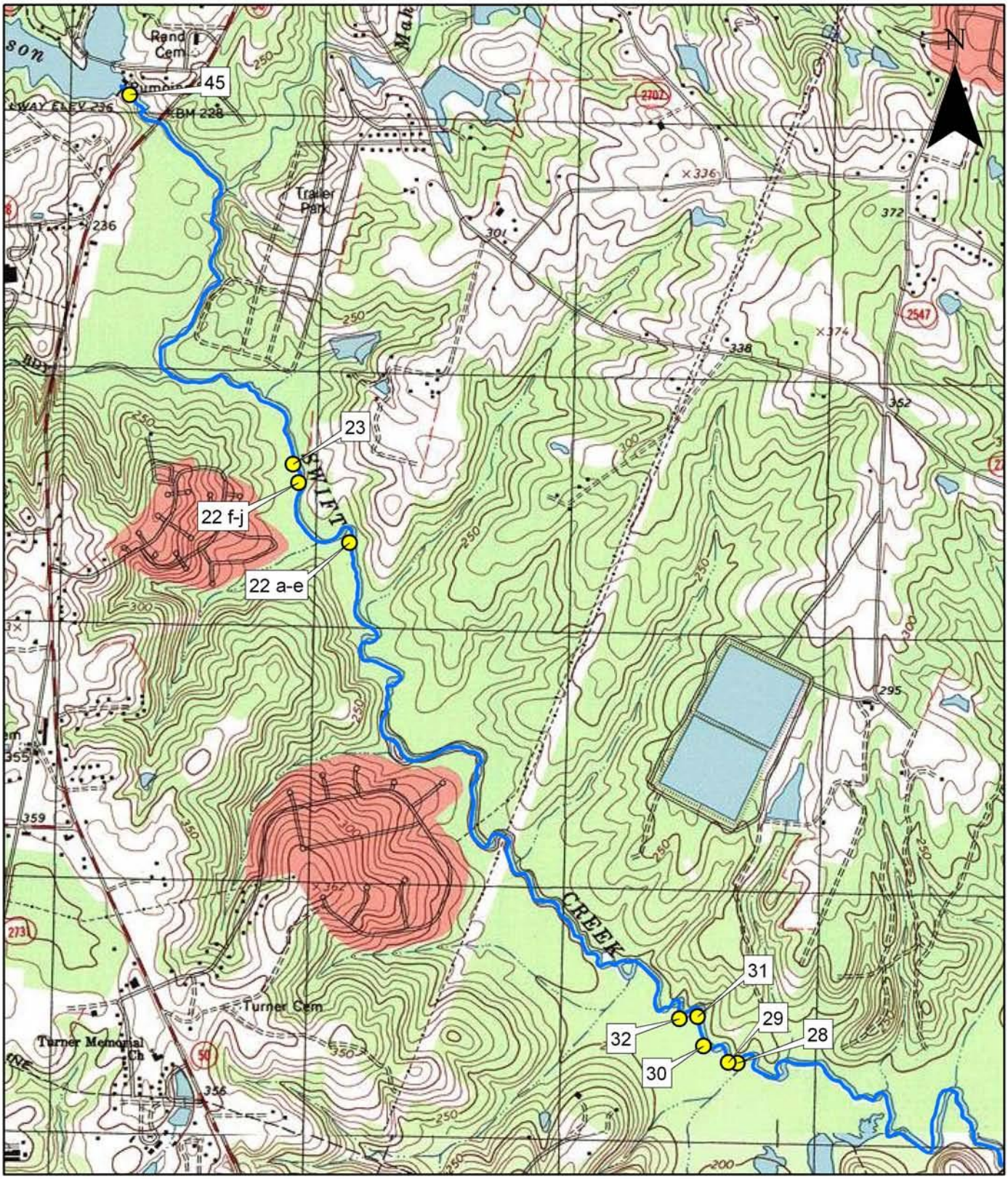
Wake and Johnston Counties, North Carolina

Date: February 2008

Scale: 0 0.5 1 Miles

Job No.: 3190

Figure 1



The Catena Group

Dempsey E. Benton Water Treatment Plant: Swift Creek Mussel Surveys

Survey Locations

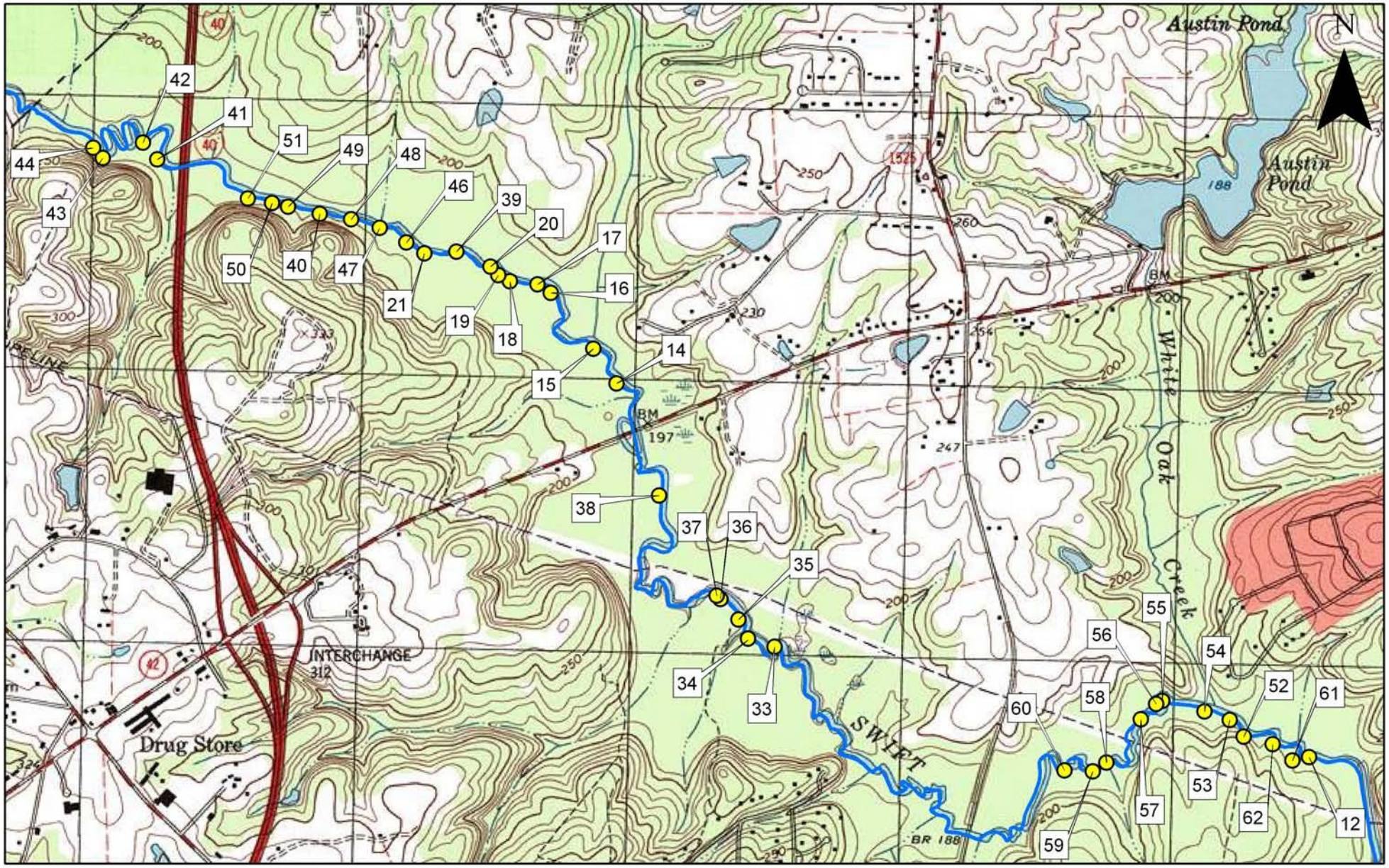
Wake and Johnston Counties, North Carolina

Date: February 2008

Scale: 0 500 1,000 Feet

Job No.: 3190

Figure 1A



The Catena Group

Client:

ARCADIS
Infrastructure, environment, facilities

Dempsey E. Benton Water Treatment Plant: Swift Creek Mussel Surveys

Survey Locations

Wake and Johnston Counties, North Carolina

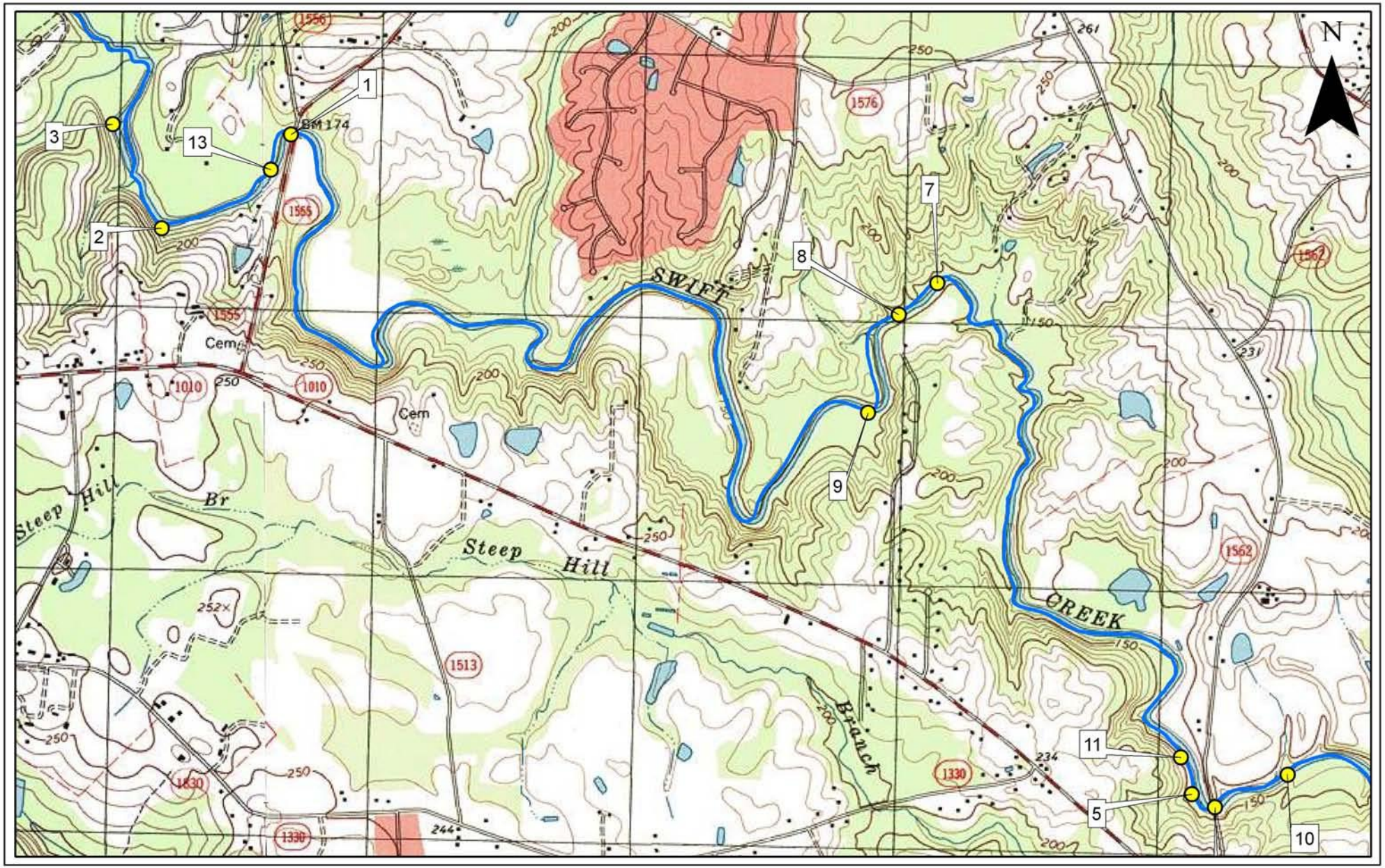
Date: February 2008

Scale: 0 500 1,000 Feet

Job No.: 3190

Figure

1B



The Catena Group

Client:

ARCADIS
Infrastructure, environment, facilities

Dempsey E. Benton Water Treatment Plant: Swift Creek Mussel Surveys

Survey Locations

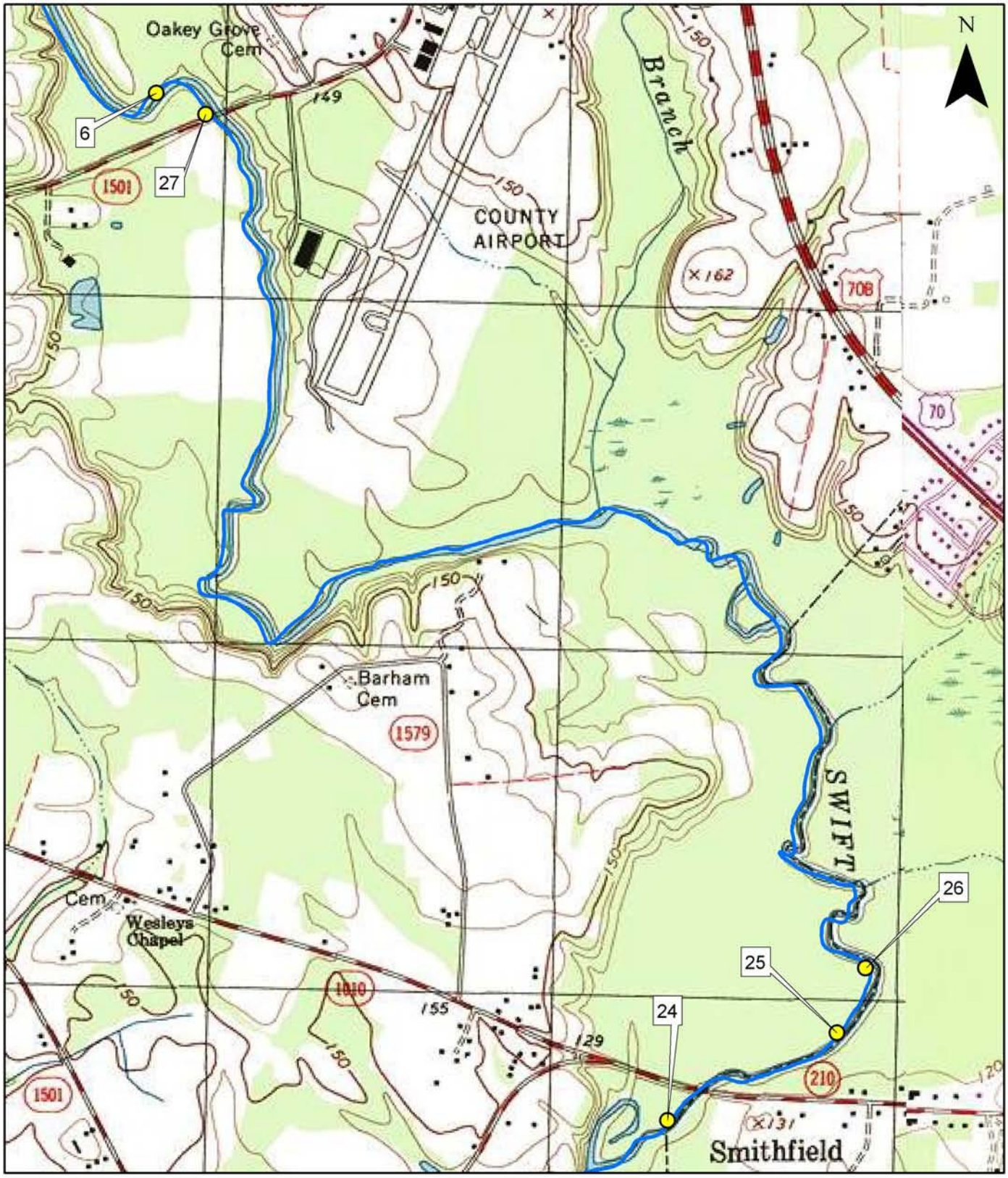
Wake and Johnston Counties, North Carolina

Date: February 2008

Scale: 0 750 1,500 Feet

Job No.: 3190

Figure 1C



The Catena Group

Dempsey E. Benton Water Treatment Plant: Swift Creek Mussel Surveys

Survey Locations

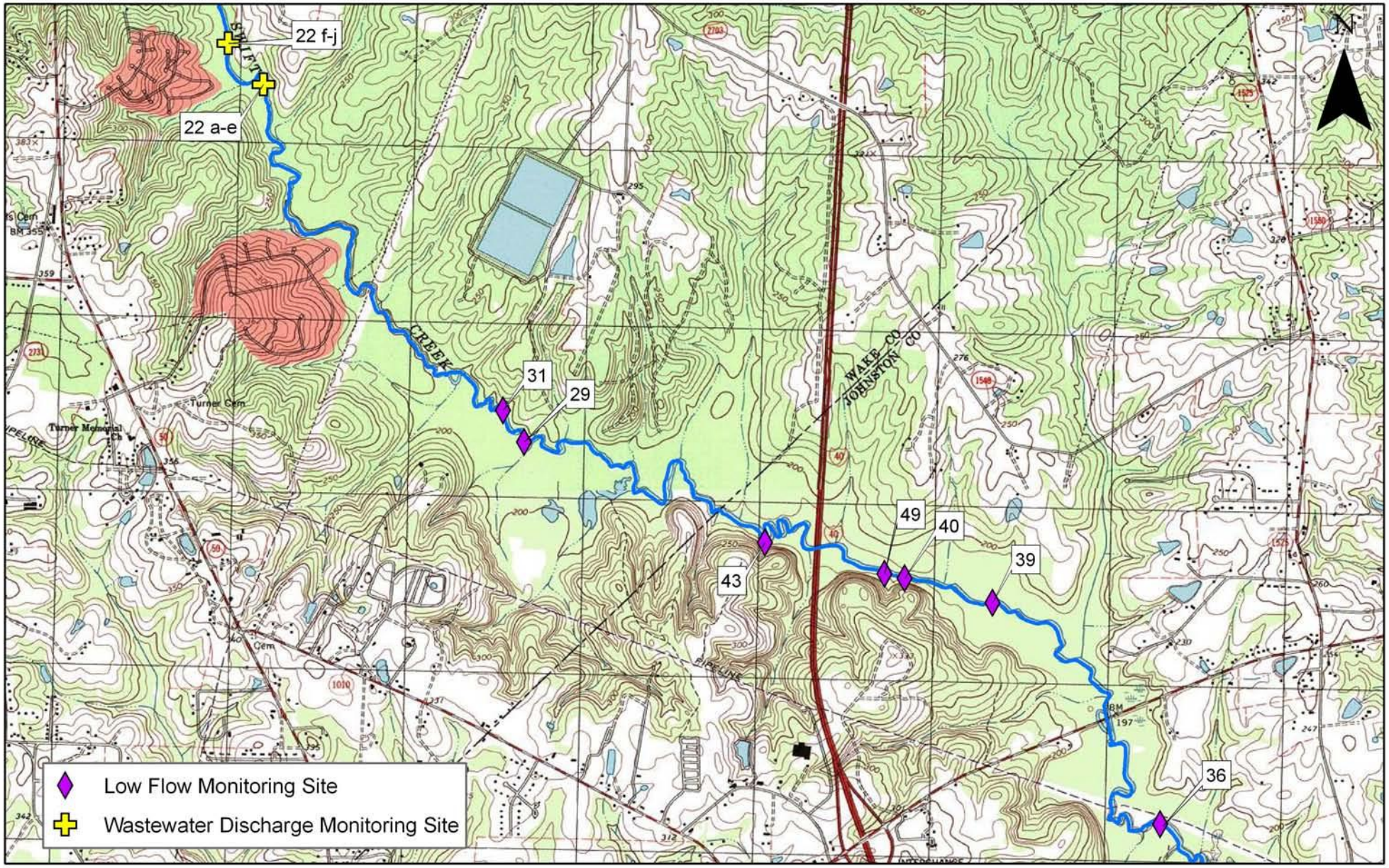
Wake and Johnston Counties, North Carolina

Date: February 2008

Scale: 0 500 1,000 Feet

Job No.: 3190

Figure 1D



The Catena Group

Client:

ARCADIS
Infrastructure, environment, facilities

Dempsey E. Benton Water Treatment Plant: Swift Creek Mussel Surveys
Monitoring Station Locations
Wake and Johnston Counties, North Carolina

Date: February 2008

Scale: 0 1,000 2,000 Feet

Job No.: 3190

Figure 2

APPENDIX B

DEFINITIONS OF FEDERAL AND STATE LISTING CATEGORIES
(FROM LEGRAND ET AL. 2006)

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.

APPENDIX C:
MUSSEL SPECIES PER SITE

SITE	DATE	COORDINATES	SCIENTIFIC NAME	#	CPUE (#/ph)
1	11/06/2006	35.57487°N, -78.49854°W	*Alasmidonta undulata*	1	0.33
			Elliptio complanata	153	51.00
			Elliptio icterina	8	2.67
			Elliptio roanokensis	12	4.00
			Fusconaia masoni	2 shells	~
2	11/06/2006	35.57171°N, -78.50395°W	*Alasmidonta undulata*	2	0.53
			Elliptio complanata	229	61.06
			Elliptio icterina	47	12.53
			Elliptio roanokensis	1	0.27
			Fusconaia masoni	1 shell	~
			Lampsilis radiata	3	0.80
			Villosa constricta	3	0.80
3	11/06/2006	35.57529°N, -78.50597°W	*Elliptio* spp.	241	53.55
			Fusconaia masoni	1	0.22
4	11/20/2006	35.55169°N, -78.45992°W	*Elliptio complanata*	1	0.75
			Elliptio congaraea	1	0.75
5	11/20/2006	35.55214°N, -78.46088°W	*Elliptio complanata*	97	12.13
			Elliptio congaraea	9	1.13
			Elliptio icterina	19	2.38
			Elliptio mediocris	15	1.88
			Strophitus undulatus	1	0.13
6	3/14/2007	35.54502°N, -78.39850°W	*Elliptio complanata*	98	24.50
			Elliptio congaraea	78	19.50
			Elliptio icterina	19	4.75
			Elliptioroanokensis	10	2.50
7	5/22/2007	35.56977°N, -78.47150°W	*Alasmidonta undulata*	3	0.43
			Elliptio fisheriana	1	0.14
			Elliptio roanokensis	5	0.63
			Elliptio spp.	99	14.14
			Fusconaia masoni	1	0.14
			Lampsilis radiata	1	0.14
			Strophitus undulatus	1	0.14
8	5/22/2007	35.56870°N, -78.47314°W	*Alasmidonta undulata*	10	0.65
			Elliptio fisheriana	2	0.13
			Elliptio roanokensis	17	1.10
			Elliptio spp.	729	47.03
			Fusconaia masoni	2	0.13
			Strophitus undulatus	2	0.13
9	5/22/2007	35.56521°N, -78.47438°W	*Elliptio roanokensis*	4	0.53
			Elliptio spp.	333	44.40
			Strophitus undulatus	1	0.13
10	6/01/2007	35.55279°N, -78.45686°W	*Alasmidonta undulata*	3	0.55
			Elliptio fisheriana	2	0.10
			Elliptio roanokensis	9	1.64
			Elliptio spp.	589	107.09
			Fusconaia masoni	2	0.10

SITE	DATE	COORDINATES	SCIENTIFIC NAME	#	CPUE (#/ph)
11	6/01/2007	35.55340°N, -78.46134°W	*Alasmidonta undulata*	1	0.20
			Elliptio fisheriana	1	0.20
			Elliptio lanceolata	1	0.20
			Elliptio roanokensis	2	0.40
			Elliptio spp.	488	97.60
			Fusconaia masoni	2	0.40
			Lampsilis radiata	1	0.20
12	6/08/2007	35.60244°N, -78.52135°W	*Alasmidonta undulata*	1	0.27
			Elliptio spp	106	28.27
			Lampsilis radiata	1	0.27
13	6/08/2007	35.57367°N, -78.49929°W	*Elliptio roanokensis*	161	17.41
			Elliptio spp.	829	89.62
			Fusconaia masoni	1	0.11
			Lampsilis radiata	1	0.11
14	7/11/2007	35.61491°N, -78.54933°W	*Elliptio congaraea*	1	0.27
			Elliptio spp	206	54.93
			Fusconaia masoni	2	0.53
			Lampsilis radiata	1	0.27
			Strophitus undulatus	4	1.07
15	7/11/2007	35.61627°N, -78.55009°W	*Elliptio* spp	269	89.67
			Fusconaia masoni	1	0.33
			Lampsilis radiate	2	0.67
16	7/11/2007	35.61798°N, -78.55189°W	*Elliptio* spp	365	104.29
			Strophitus undulatus	1	0.29
			Utterbackia imbecillis	1	0.29
17	7/11/2007	35.61848°N, -78.55269°W	*Alasmidonta undulata*	3	0.75
			Elliptio spp	617	154.25
			Fusconaia masoni	1	0.25
			Pyganadon cataracta	1	0.25
			Strophitus undulates	3	0.75
18	7/13/2007	35.61941°N, -78.55323°W	*Alasmidonta undulata*	1 shell	~
			Elliptio roanokensis	2	0.60
			Elliptio spp	458	137.54
			Fusconaia masoni	2	0.60
			Lampsilis radiata	1	0.30
			Strophitus undulatus	1	0.30
19	7/13/2007	35.61956°N, -78.55365°W	*Alasmidonta undulata*	2	0.96
			Elliptio congaraea	3	1.44
			Elliptio roanokensis	2	0.96
			Elliptio spp	384	184.62
			Fusconaia masoni	2	0.96
			Pyganodon cataracta	1	0.48
20	7/13/2007	35.61926°N, -78.55402°W	*Alasmidonta undulata*	6	0.90
			Elliptio congaraea	2	0.30
			Elliptio spp	359	53.82
			Fusconaia masoni	1	0.15
			Lampsilis radiate	1 shell	~
			Pyganodon cataracta	1	0.15
21	7/13/2007	35.62078°N, -78.55619°W	*Elliptio* spp	439	87.80

SITE	DATE	COORDINATES	SCIENTIFIC NAME	#	CPUE (#/ph)
			Fusconaia masoni	4	0.80
			Pyganodon cataracta	2	0.40
			Strophitus undulatus	2	0.40
22 a-e#	8/02/2007	35.64597°N, -78.60184°W	*Alasmidonta undulata*	1	0.14
			Elliptio complanata	436	59.56
			Elliptio icterina	24	3.28
			Fusconaia masoni	3	0.41
			Lampsilis radiata	1	0.14
			Pyganodon cataracta	36	4.92
			Utterbackia imbecillis	16	2.19
22 f-j#	8/02/2007	35.64821°N, -78.60372°W	*Elliptio complanata*	661	83.35
			Elliptio icterina	39	4.92
			Elliptio roanokensis	1	0.13
			Fusconaia masoni	5	0.63
			Lampsilis radiata	12	1.51
			Pyganodon cataracta	17	2.14
			Utterbackia imbecillis	6	0.76
23	8/02/2007	35.64887°N, -78.60395°W	*Elliptio complanata*	378	151.20
			Elliptio icterina	25	10.0
			Elliptio roanokensis	1	0.40
			Lampsilis radiata	2	0.80
			Pyganodon cataracta	2	0.80
			Utterbackia imbecillis	2	0.80
24	8/03/2007	35.51823°N, -78.38260°W	*Alasmidonta undulata*	4	0.53
			Elliptio congaraea	31	4.13
			Elliptio roanokensis	1	0.13
			Elliptio spp.	180	24
			Fusconaia masoni	1	0.13
			Lampsilis radiate	1	0.13
25	8/03/2007	35.52047°N, -78.37743°W	*Alasmidonta undulata*	3	0.28
			Elliptio congaraea	35	3.23
			Elliptio roanokensis	9	0.83
			Elliptio spp.	437	40.35
			Lampsilis radiata	1	0.09
26	8/03/2007	35.52203°N, -78.37600°W	*Alasmidonta undulata*	2	0.40
			Elliptio congaraea	40	8.0
			Elliptio roanokensis	11	2.20
			Elliptio spp.	325	65.0
			Fusconaia masoni	2	0.40
27	8/03/2007	35.54418°N, -78.39740°W	*Alasmidonta undulata*	4	0.80
			Elliptio congaraea	40	8.0
			Elliptio roanokensis	16	3.20
			Elliptio spp.	496	99.20
			Fusconaia masoni	3	0.60
28	8/10/2007	35.62755°N, -78.58482°W	*Alasmidonta undulata*	1	0.19
			Elliptio complanata	1,055	195.37
			Elliptio congaraea	4	0.74
			Elliptio icterina	64	11.85
			Elliptio roanokensis	1	0.19

SITE	DATE	COORDINATES	SCIENTIFIC NAME	#	CPUE (#/ph)
			Fusconaia masoni	1	0.19
			Pyganodon cataracta	1	0.19
			Strophitus undulatus	1	0.19
29*	8/10/2007	35.62766°N, -78.58522°W	*Alasmidonta heterodon*	1	0.50
			Alasmidonta undulata	2	1.0
			Elliptio complanata	180	90.0
			Elliptio icterina	7	3.50
			Lampsilis radiata	1	0.50
			Pyganodon cataracta	1	0.50
			Utterbackia imbecillis	1	0.50
30	8/10/2007	35.62825°N, -78.58629°W	*Elliptio complanata*	386	154.40
			Elliptio icterina	8	3.20
			Fusconaia masoni	2	0.80
			Lampsilis radiata	2	0.80
31*	8/10/2007	35.62928°N, -78.58653°W	*Alasmidonta undulata*	1	0.87
			Elliptio complanata	298	259.13
			Elliptio icterina	18	15.65
			Fusconaia masoni	4	3.48
			Strophitus undulatus	1	0.87
32	8/10/2007	35.62910°N, -78.58716°W	*Elliptio complanata*	190	126.67
			Elliptio icterina	3	2.0
			Strophitus undulatus	1	0.67
33	8/29/2007	35.60618°N, -78.54324°W	*Alasmidonta undulata*	9	2.70
			Elliptio complanata	312	93.69
			Elliptio congaraea	2	0.60
			Elliptio icterina	92	27.63
			Elliptio mediocris	1	0.30
			Elliptio roanokensis	1	0.30
			Fusconaia masoni	4	1.20
			Lampsilis radiata	1	0.30
			Strophitus undulatus	5	1.50
34	8/29/2007	35.60645°N, -78.54406°W	*Alasmidonta undulata*	5	1.25
			Elliptio complanata	224	44.80
			Elliptio icterina	78	15.20
			Elliptio laceolata	1	0.20
			Elliptio roanokensis	1	0.20
			Lampsilis radiate	1	0.20
			Strophitus undulatus	3	0.60
35	8/29/2007	35.60708°N, -78.54444°W	*Alasmidonta undulata*	4	1.60
			Elliptio complanata	105	42.0
			Elliptio icterina	30	12.0
			Elliptio producta	1	0.40
			Lampsilis radiata	2	0.80
			Pyganadon cataracta	2	0.80
			Strophitus undulatus	1	0.40
36	8/29/2007	35.60776°N, -78.54517°W	*Alasmidonta undulata*	3	3.0
			Elliptio complanata	77	77.0
			Elliptio icterina	9	9.0
			Lampsilis radiata	3	3.0

SITE	DATE	COORDINATES	SCIENTIFIC NAME	#	CPUE (#/ph)
37*	8/29/2007	35.60788°N, -78.54532°W	*Alasmidonta heterodon*	1	0.29
			Alasmidonta undulata	7	2.05
			Elliptio complanata	332	97.36
			Elliptio icterina	102	29.91
			Lampsilis radiata	8	2.34
			Pyganadon cataracta	1	0.29
			Strophitus undulatus	4	1.17
			Utterbackia imbecillis	3	0.88
38	8/29/2007	35.61120°N, -78.54772°W	*Elliptio complanata*	50	50.0
			Elliptio icterina	9	9.0
39*	8/29/2007	35.62070°N, -78.55540°W	*Elliptio complanata*	244	48.80
			Elliptio congaraea	3	0.60
			Elliptio icterina	21	4.20
			Elliptio roanokensis	1	0.20
			Strophitus undulatus	2	0.40
40*	8/29/2007	35.62019°N, -78.56139°W	*Alasmidonta undulata*	1	0.20
			Elliptio complanata	606	121.20
			Elliptio icterina	58	11.60
			Elliptio laceolata	3	0.60
			Elliptio roanokensis	2	0.40
			Fusconaia masoni	2	0.40
			Utterbackia imbecillis	1	0.20
41	8/30/2007	35.62239°N, -78.56789°W	*Alasmidonta undulata*	1	0.48
			Elliptio congaraea	4	1.92
			Elliptio roanokensis	2	0.92
			Elliptio spp.	298	143.27
42	8/30/2007	35.62294°N, -78.56847°W	*Alasmidonta heterodon*	1	0.37
			Alasmidonta undulata	1	0.37
			Elliptio spp.	521	195.13
			Fusconaia masoni	1	0.37
			Lampsilis radiata	1	0.37
			Pyganadon cataracta	1	0.37
43*	8/30/2007	35.62256°N, -78.57014°W	*Alasmidonta undulata*	7	0.99
			Elliptio complanata	936	132.20
			Elliptio congaraea	3	0.42
			Elliptio icterina	93	13.14
			Elliptio roanokensis	3	0.42
			Fusconaia masoni	5	0.71
			Lampsilis radiata	3	0.42
			Strophitus undulatus	7	0.99
44	8/30/2007	35.62275°N, -78.57055°W	*Alasmidonta undulata*	6	2.40
			Elliptio spp.	444	177.60
			Strophitus undulatus	2	0.80
45	8/30/2007	35.66170°N, -78.61120°W	*Elliptio complanata*	185	63.36
			Elliptio icterina	1	0.34
			Lampsilis radiata	1	0.34
			Utterbackia imbecillis	2	0.68
46	8/30/2007	35.62048°N, -78.55709°W	*Alasmidonta undulata*	1	1.0
			Elliptio complanata	116	116.0

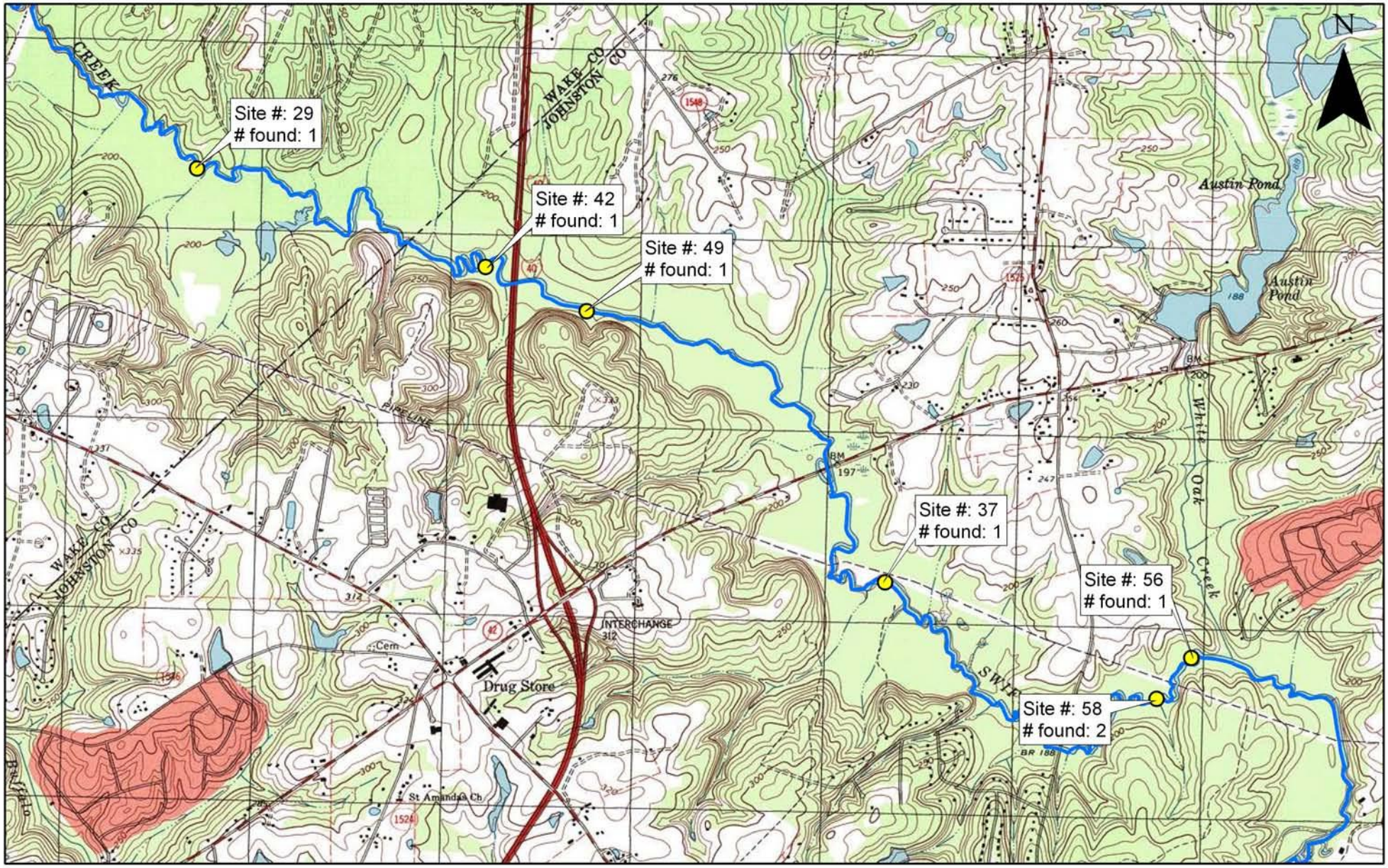
SITE	DATE	COORDINATES	SCIENTIFIC NAME	#	CPUE (#/ph)
			Elliptio congaraea	1	1.0
			Elliptio icterina	30	30.0
			Elliptio mediocris	1	1.0
47	8/30/2007	35.61984°N, -78.55895°W	*Alasmidonta undulata*	1	1.0
			Elliptio complanata	460	460.0
			Elliptio congaraea	4	4.0
			Elliptio icterina	82	82.0
			Elliptio laceolata	2	2.0
			Elliptio producta	2	2.0
			Fusconaia masoni	3	3.0
			Lampsilis radiata	2	2.0
			Pyganadon cataracta	1	1.0
48	8/30/2007	35.61995°N, -78.56014°W	*Alasmidonta undulata*	3	1.80
			Elliptio complanata	254	152.10
			Elliptio congaraea	1	0.60
			Elliptio icterina	29	17.37
			Fusconaia masoni	1	0.60
			Lampsilis radiata	3	1.80
			Pyganadon cataracta	1	0.60
			Strophitus undulatus	1	0.60
49*	8/30/2007	35.62076°N, -78.56266°W	*Alasmidonta heterodon*	1	0.57
			Alasmidonta undulata	1	0.57
			Elliptio complanata	229	130.86
			Elliptio congaraea	1	0.57
			Elliptio icterina	36	20.57
			Strophitus undulatus	3	1.71
50	8/30/2007	35.62027°N, -78.56325°W	*Alasmidonta undulata*	2	0.75
			Elliptio complanata	306	114.61
			Elliptio congaraea	7	2.62
			Elliptio icterina	49	18.35
			Fusconaia masoni	1	0.37
			Lampsilis radiata	3	1.12
			Pyganadon cataracta	1	0.37
			Strophitus undulatus	6	2.25
51	8/30/2007	35.62068°N, -78.56424°W	*Elliptio complanata*	196	196.0
			Elliptio congaraea	8	8.0
			Elliptio icterina	47	47.0
			Strophitus undulatus	1	1.0
52	10/23/2007	35.60326°N, -78.52392°W	*Alasmidonta undulata*	4	2.40
			Elliptio complanata	90	53.89
			Elliptio icterina	17	10.18
			Elliptio lanceolata	1 shell	~
			Fusconaia masoni	2	1.20
			Lampsilis radiata	2	1.20
			Pyganadon cataracta	1	0.60
			Strophitus undulatus	2	1.20
53	10/23/2007	35.60368°N, -78.52456°W	*Alasmidonta undulata*	2	1.20
			Elliptio complanata	55	32.93
			Elliptio icterina	7	4.19

SITE	DATE	COORDINATES	SCIENTIFIC NAME	#	CPUE (#/ph)
			Lampsilis radiata	2	1.20
			Strophitus undulatus	2	1.20
54	10/23/2007	35.60397°N, -78.52558°W	*Alasmidonta undulata*	1	0.63
			Elliptio complanata	47	29.75
			Elliptio icterina	6	3.80
			Lampsilis radiata	4	2.53
			Strophitus undulatus	2	1.27
			Utterbackia imbecillis	2	1.27
55	10/23/2007	35.60445°N, -78.52721°W	*Elliptio complanata*	35	32.41
			Elliptio congaraea	1	0.93
			Elliptio icterina	4	3.70
			Elliptio roanokensis	1	0.93
56	10/23/2007	35.60423°N, -78.52754°W	*Alasmidonta heterodon*	1	0.60
			Alasmidonta undulata	3	1.80
			Elliptio complanata	189	113.17
			Elliptio congaraea	14	8.38
			Elliptio icterina	52	31.14
			Elliptio roanokensis	2	1.20
			Lampsilis radiata	2	1.20
			Strophitus undulatus	2	1.20
57	10/23/2007	35.60381°N, -78.52831°W	*Alasmidonta undulata*	3 shells	~
			Elliptio complanata	181	108.38
			Elliptio congaraea	2	1.20
			Elliptio icterina	34	20.36
			Lampsilis radiata	1	0.60
			Strophitus undulatus	1	0.60
58	10/23/2007	35.60230°N, -78.52957°W	*Alasmidonta heterodon*	2	1.20
			Alasmidonta undulata	2	1.20
			Elliptio complanata	261	156.29
			Elliptio congaraea	8	4.79
			Elliptio icterina	87	52.09
			Elliptio lanceolata	1	0.60
			Fusconaia masoni	1	0.60
59	10/23/2007	35.60207°N, -78.53013°W	*Alasmidonta undulata*	2 shells	~
			Elliptio complanata	241	144.31
			Elliptio congaraea	8	4.79
			Elliptio icterina	41	24.55
			Elliptio fisheriana	1 shell	~
			Elliptio lanceolata	1 shell	~
			Fusconaia masoni	3	1.80
			Strophitus undulatus	1	0.60
60	10/23/2007	35.60216°N, -78.53125°W	*Alasmidonta undulata*	2	1.20
			Elliptio complanata	198	118.56
			Elliptio icterina	36	21.56
			Strophitus undulatus	2	1.20
61	10/23/2007	35.60233°N, -78.52203°W	*Alasmidonta undulata*	4	2.40
			Elliptio complanata	321	192.22
			Elliptio congaraea	14	8.38
			Elliptio icterina	31	18.56

SITE	DATE	COORDINATES	SCIENTIFIC NAME	#	CPUE (#/ph)
			Elliptio mediocris	8	4.79
			Elliptio roanokensis	24	14.37
			Fusconaia masoni	2	1.20
			Lampsilis radiata	2	1.20
			Pyganadon cataracta	1	0.60
			Strophitus undulatus	6	3.59
62	10/23/2007	35.60288°N, -78.52283°W	*Alasmidonta undulata*	1	1.0
			Elliptio complanata	46	46.0
			Elliptio icterina	11	11.0
			Fusconaia masoni	1	1.0

#wastewater discharge monitoring sites
*low flow monitoring sites

APPENDIX D:
SPECIES DISTRIBUTION IN SWIFT CREEK



The Catena Group

Client:

ARCADIS
Infrastructure, environment, facilities

Dempsey E. Benton Water Treatment Plant: Swift Creek Mussel Surveys

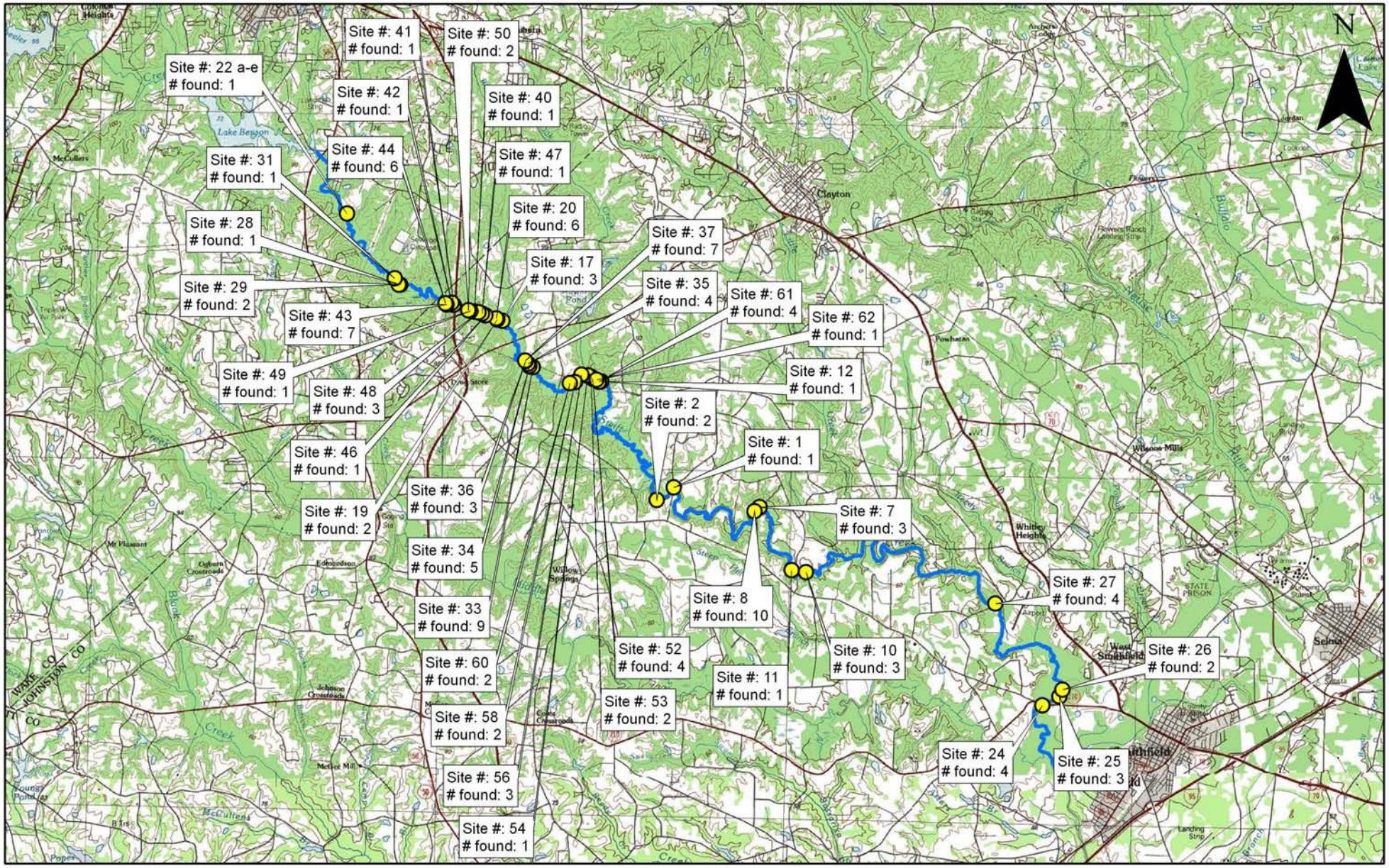
Alasmidonta heterodon
(Dwarf wedgemussel) Locations
Wake and Johnston Counties,North Carolina

Date: February 2008

Scale: 0 1,000 2,000 Feet

Job No.: 3190

Figure
1



The Catena Group

Client:

ARCADIS
Infrastructure, environment, facilities

Dempsey E. Benton Water Treatment Plant: Swift Creek Mussel Surveys

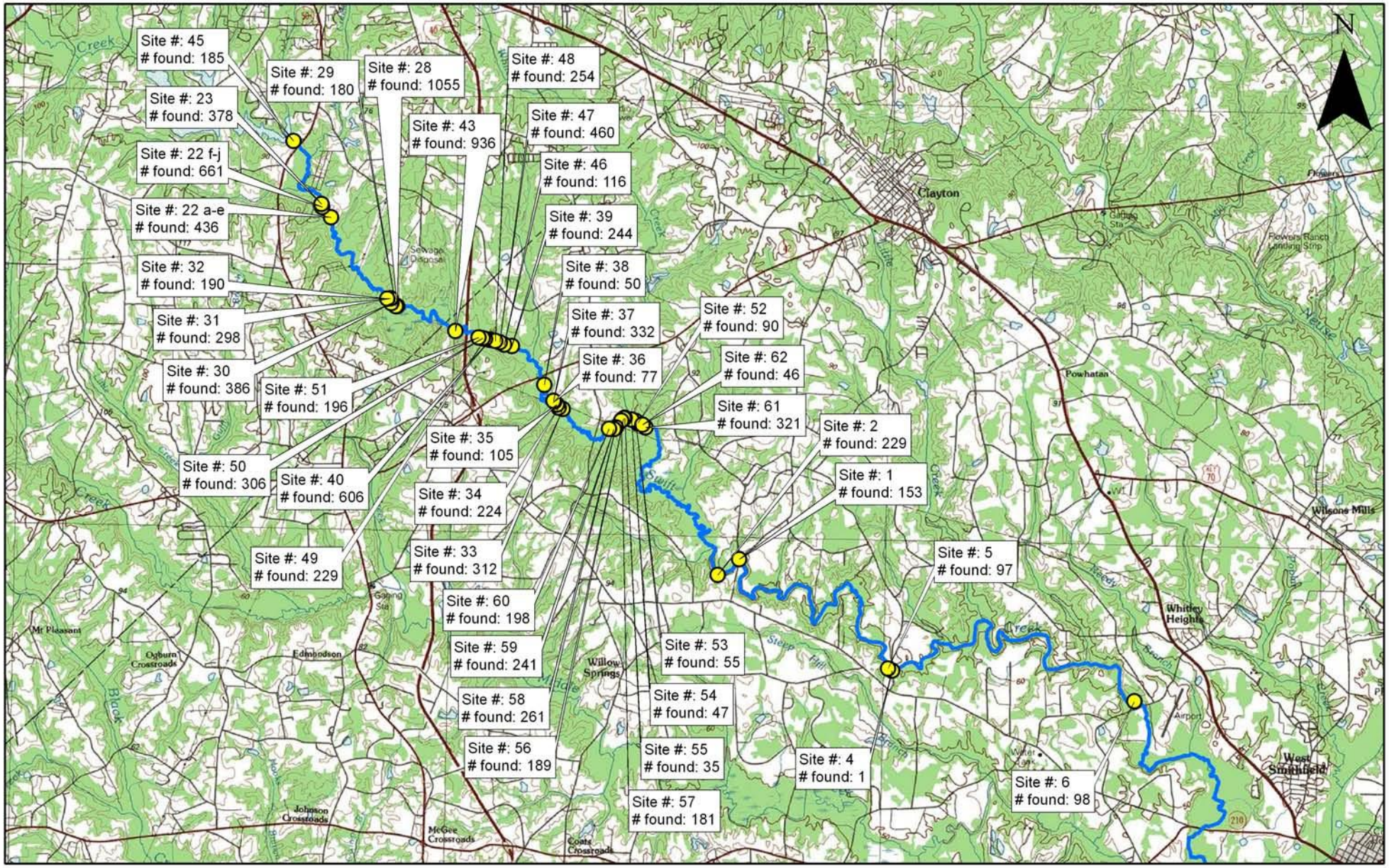
Alasmidonta undulata
(Triangle floater) Locations
Wake and Johnston Counties, North Carolina

Date: February 2008

Scale: 0 1 2 Miles

Job No.: 3190

Figure
2



The Catena Group

Client:

ARCADIS
Infrastructure, environment, facilities

Dempsey E. Benton Water Treatment Plant: Swift Creek Mussel Surveys

Elliptio complanata

(Eastern elliptio) Locations

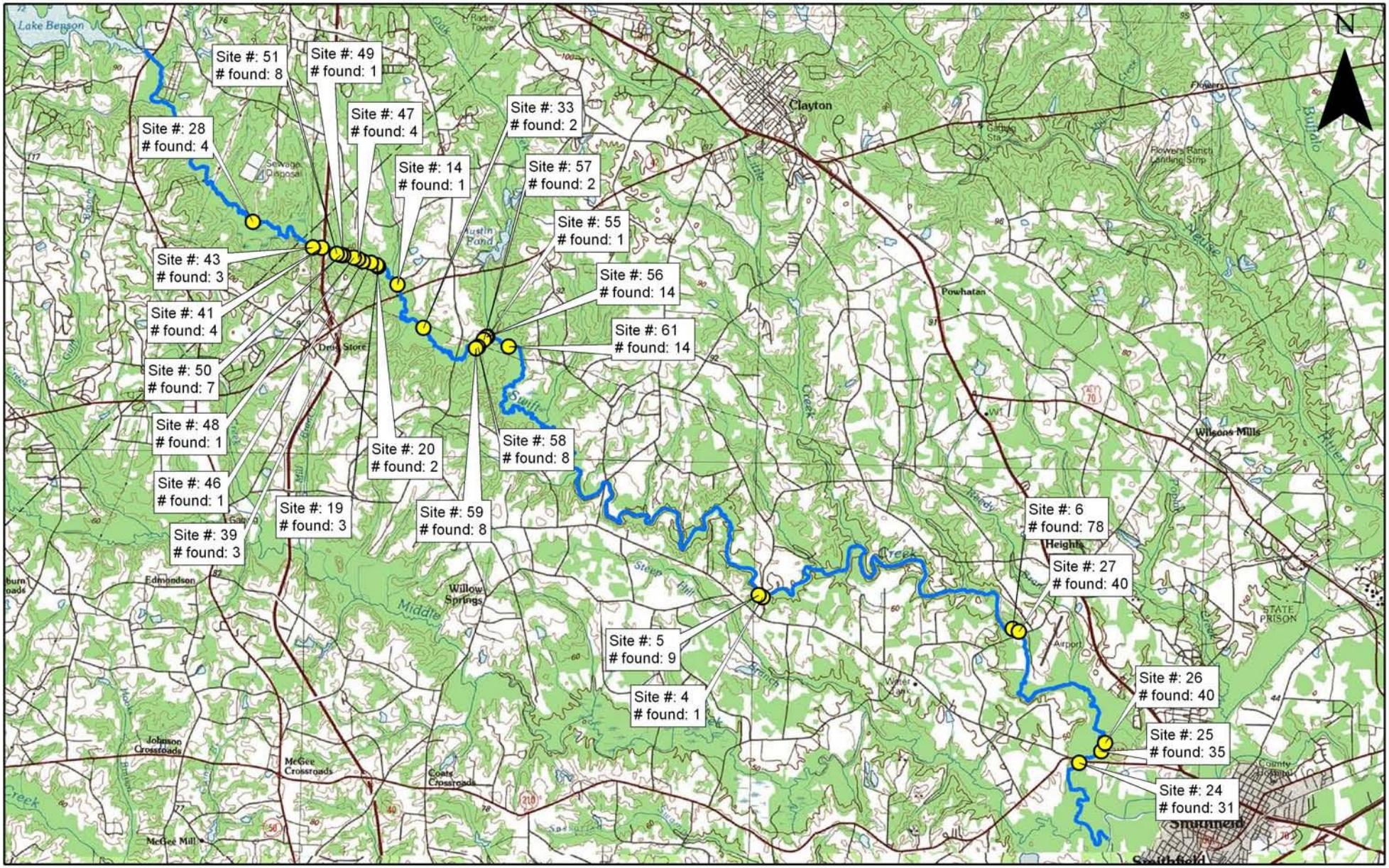
Wake and Johnston Counties, North Carolina

Date: February 2008

Scale: 0 1 2 Miles

Job No.: 3190

Figure 3



The Catena Group

Client:

ARCADIS
Infrastructure, environment, facilities

Dempsey E. Benton Water Treatment Plant: Swift Creek Mussel Surveys

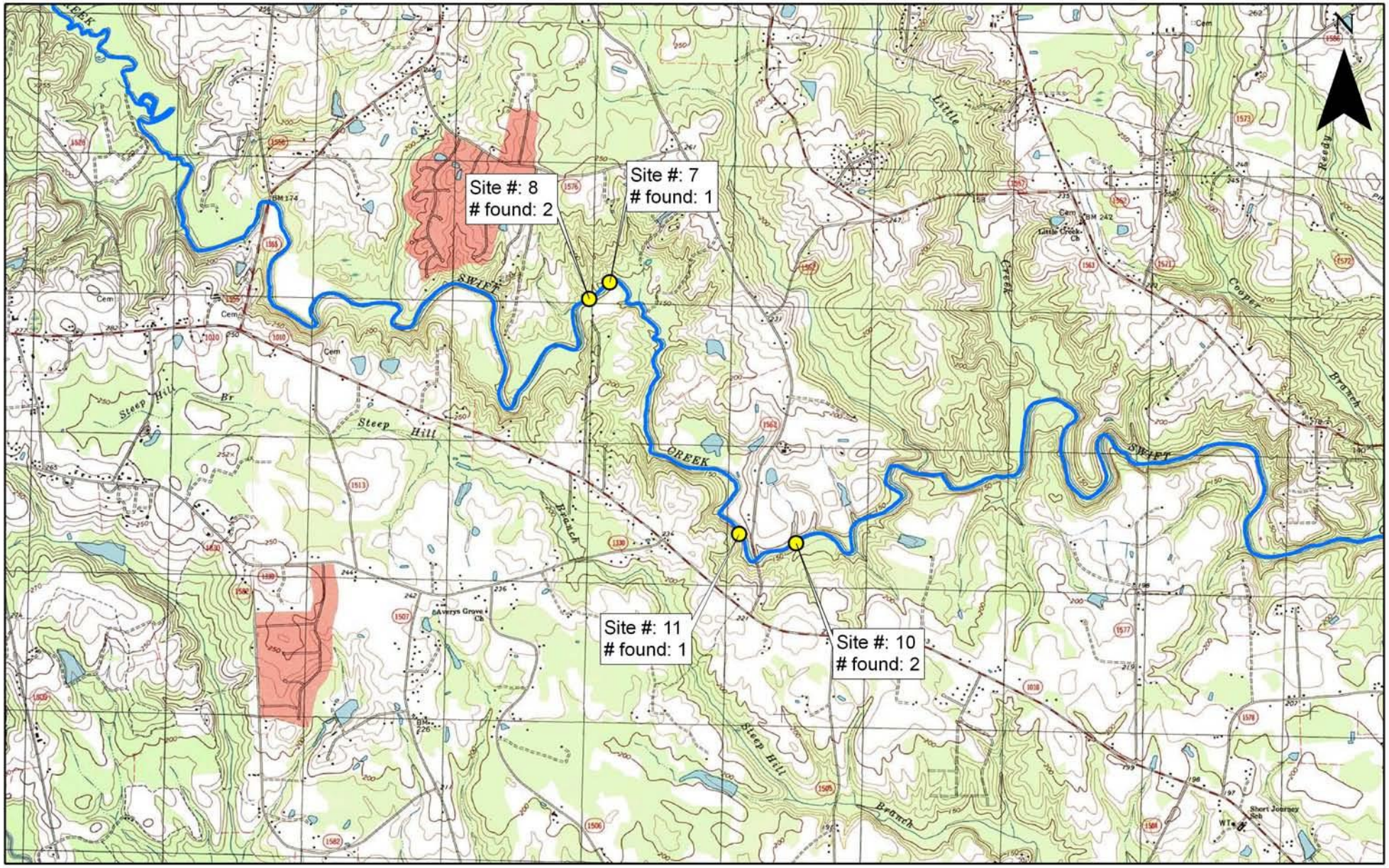
Elliptio congaraea
(Carolina slabshell) Locations
Wake and Johnston Counties, North Carolina

Date: February 2008

Scale: 0 1 2 Miles

Job No.: 3190

Figure 4



The Catena Group

Client:

ARCADIS
Infrastructure, environment, facilities

Dempsey E. Benton Water Treatment Plant: Swift Creek Mussel Surveys

Elliptio fisheriana

(Northern lance) Locations

Wake and Johnston Counties, North Carolina

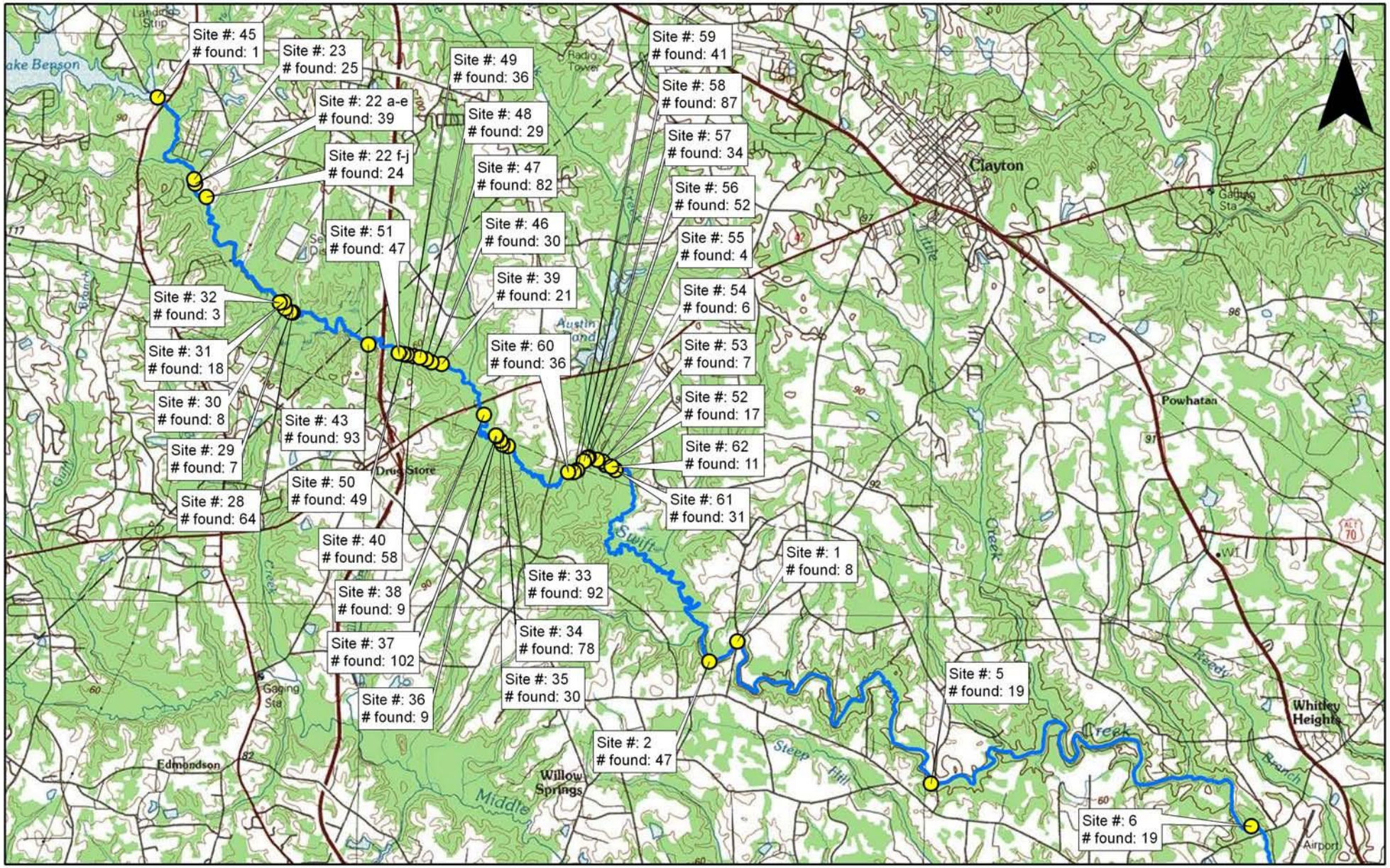
Date: February 2008

Scale: 0 1,250 2,500 Feet

Job No.: 3190

Figure

5



The Catena Group

Client:

ARCADIS
Infrastructure, environment, facilities

Dempsey E. Benton Water Treatment Plant: Swift Creek Mussel Surveys

Elliptio icterina

(Variable spike) Locations

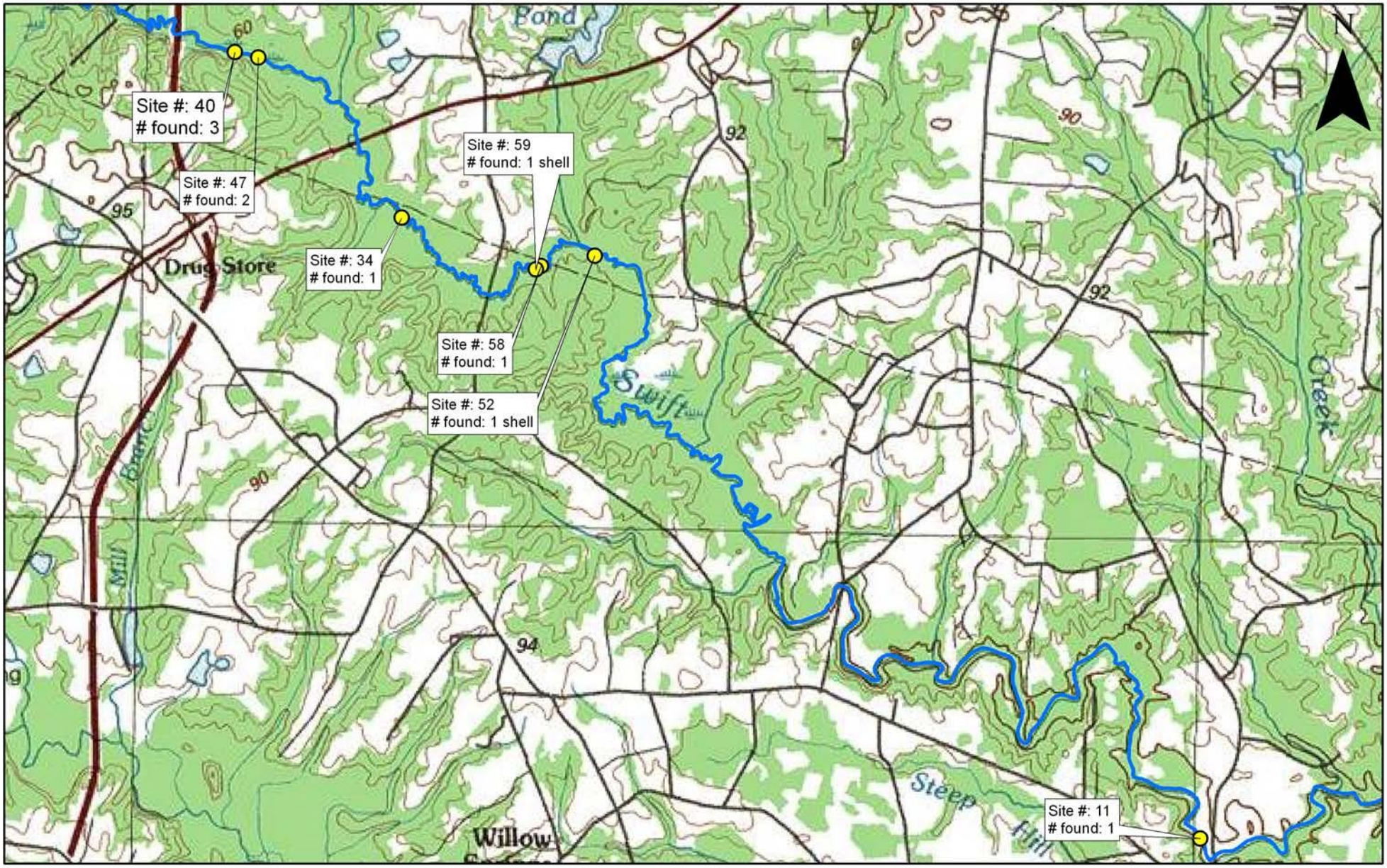
Wake and Johnston Counties, North Carolina

Date: February 2008

Scale: 0 0.5 1 Miles

Job No.: 3190

Figure 6



The Catena Group

Client:

ARCADIS
Infrastructure, environment, facilities

Dempsey E. Benton Water Treatment Plant: Swift Creek Mussel Surveys

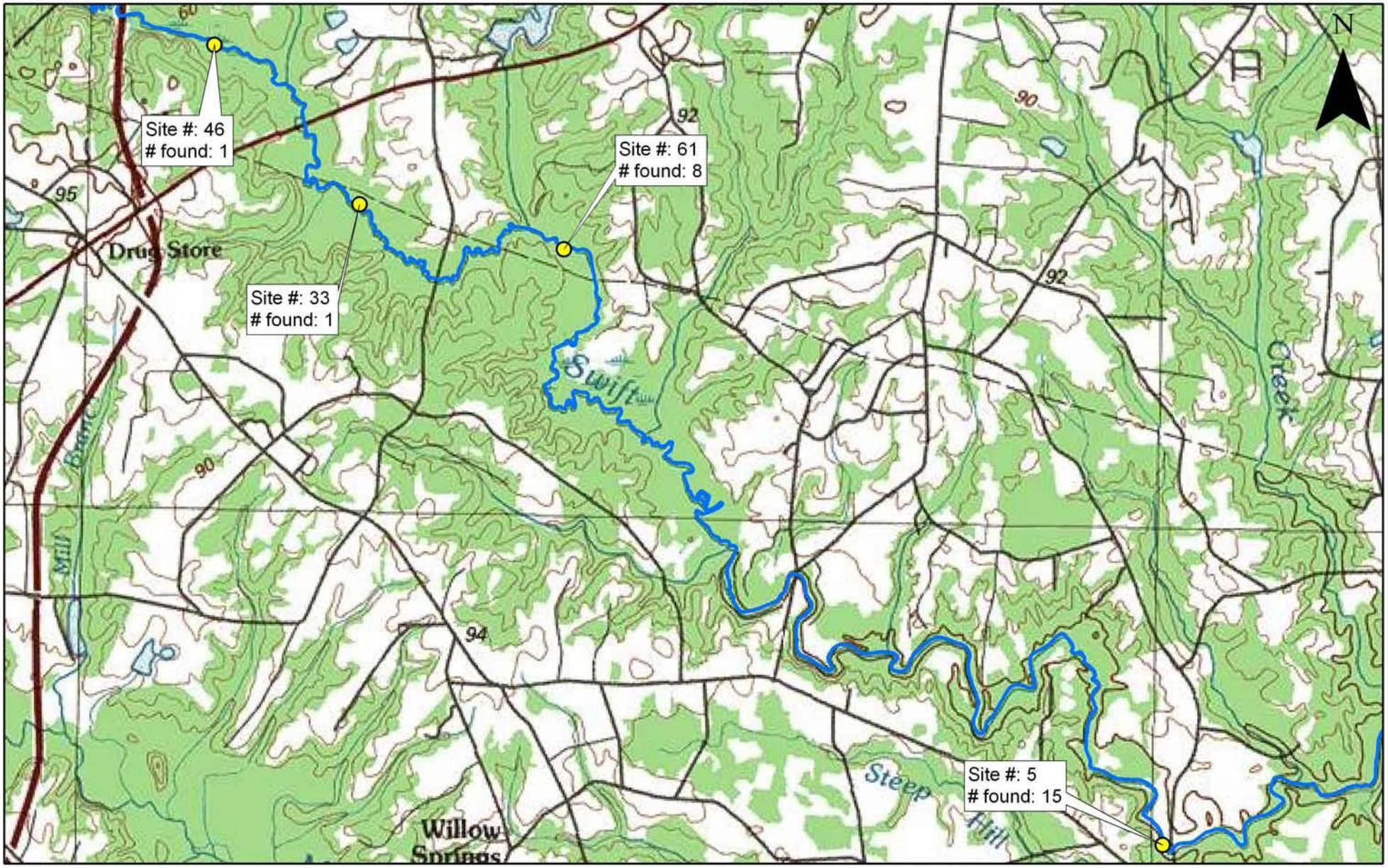
Elliptio lanceolata
(Yellow lance) Locations
Wake and Johnston Counties, North Carolina

Date: February 2008

Scale: 0 0.25 0.5 Miles

Job No.: 3190

Figure 7



The Catena Group

Client:

ARCADIS
Infrastructure, environment, facilities

Dempsey E. Benton Water Treatment Plant: Swift Creek Mussel Surveys

Elliptio mediocris

Locations

Wake and Johnston Counties, North Carolina

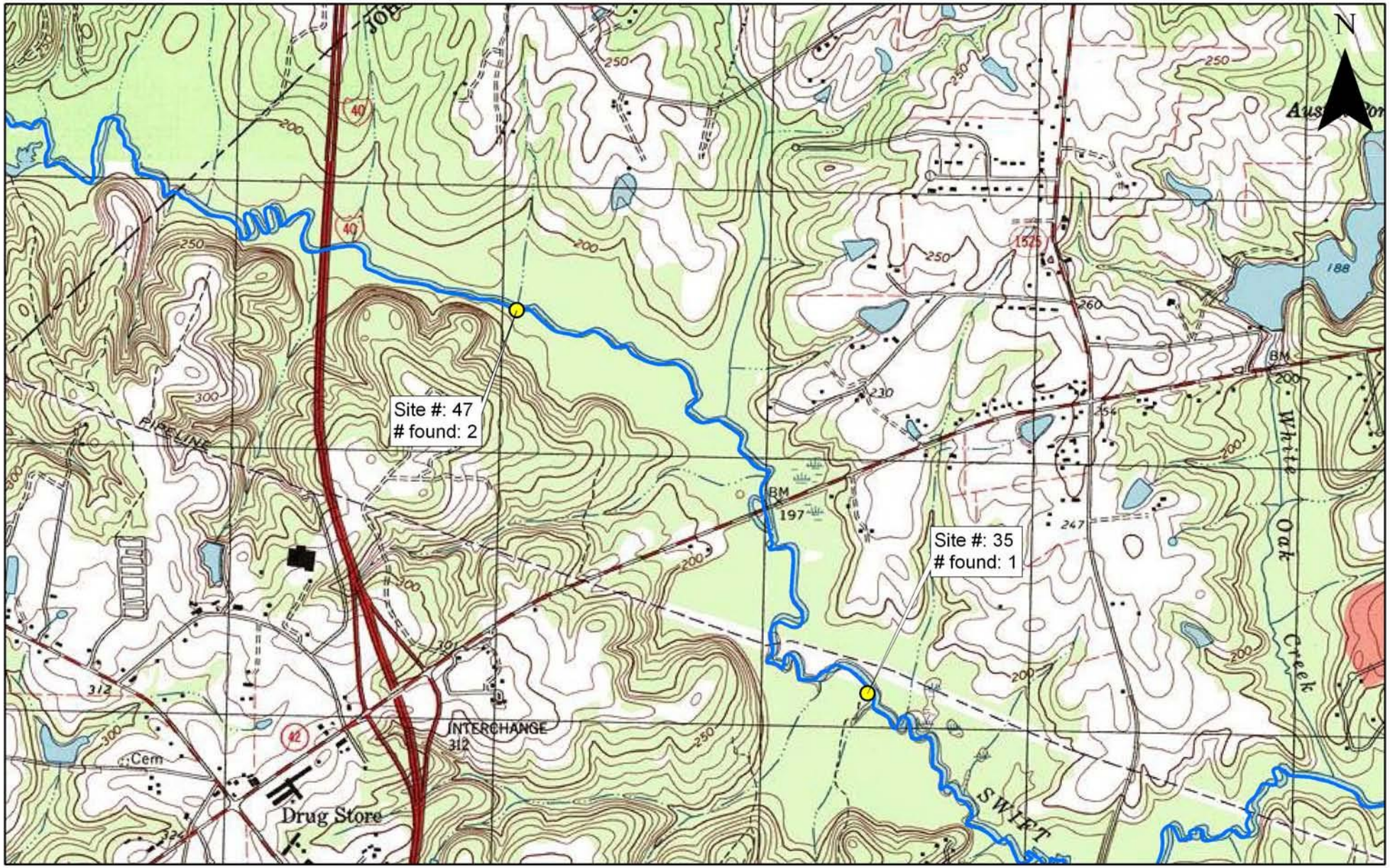
Date: February 2008

Scale: 0 0.25 0.5 Miles

Job No.: 3190

Figure

8



The Catena Group

Client:

ARCADIS
Infrastructure, environment, facilities

Dempsey E. Benton Water Treatment Plant: Swift Creek Mussel Surveys

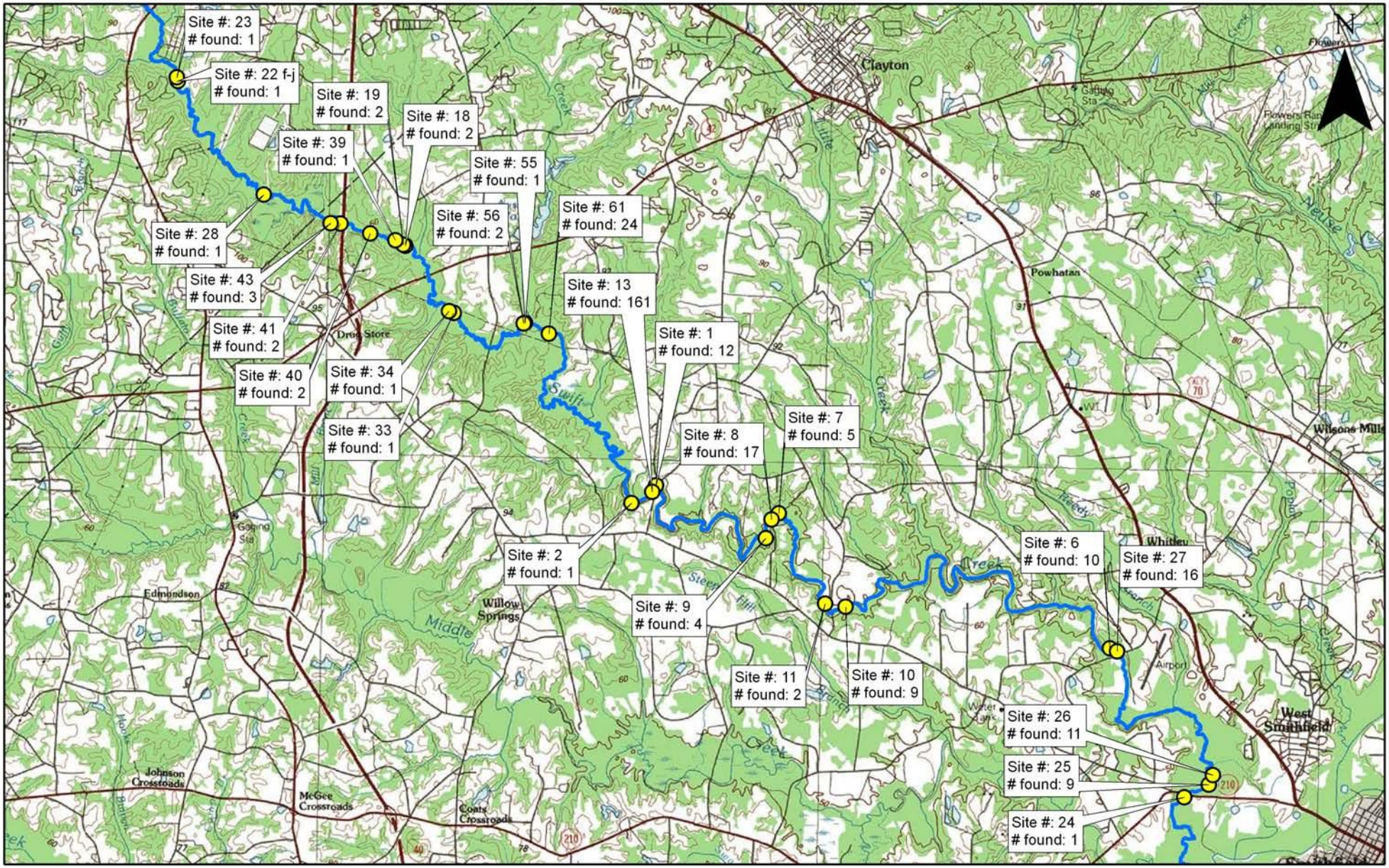
Elliptio producta
(Atlantic spike) Locations
Wake and Johnston Counties, North Carolina

Date: February 2008

Scale: 0 500 1,000 Feet

Job No.: 3190

Figure
9



The Catena Group

Client:

ARCADIS
Infrastructure, environment, facilities

Dempsey E. Benton Water Treatment Plant: Swift Creek Mussel Surveys

Elliptio roanokensis (Roanoke slabshell) Locations

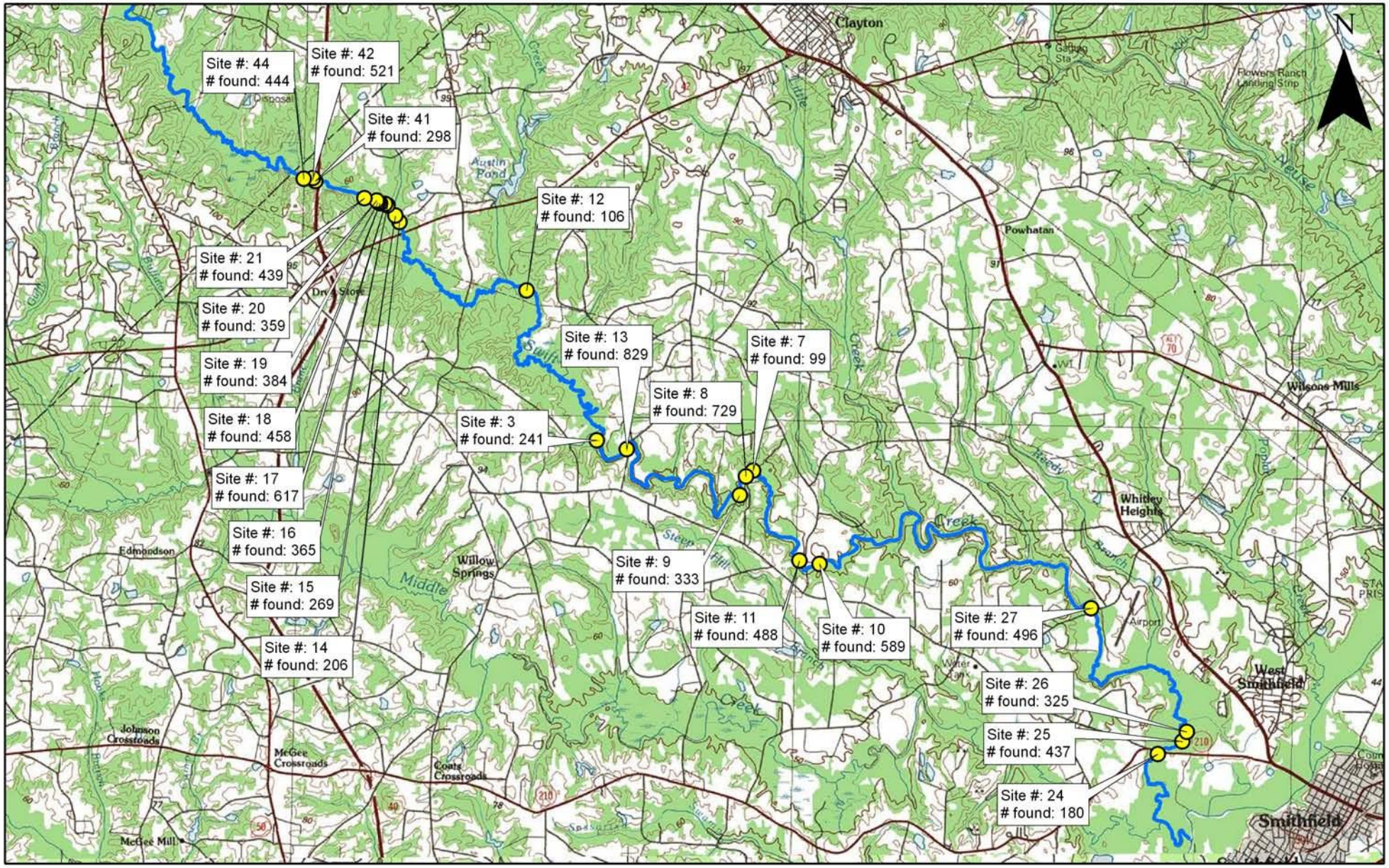
Wake and Johnston Counties, North Carolina

Date: February 2008

Scale: 0 0.5 1 Miles

Job No.: 3190

Figure 10



The Catena Group

Client:

ARCADIS
Infrastructure, environment, facilities

Dempsey E. Benton Water Treatment Plant: Swift Creek Mussel Surveys

Elliptio spp

Locations

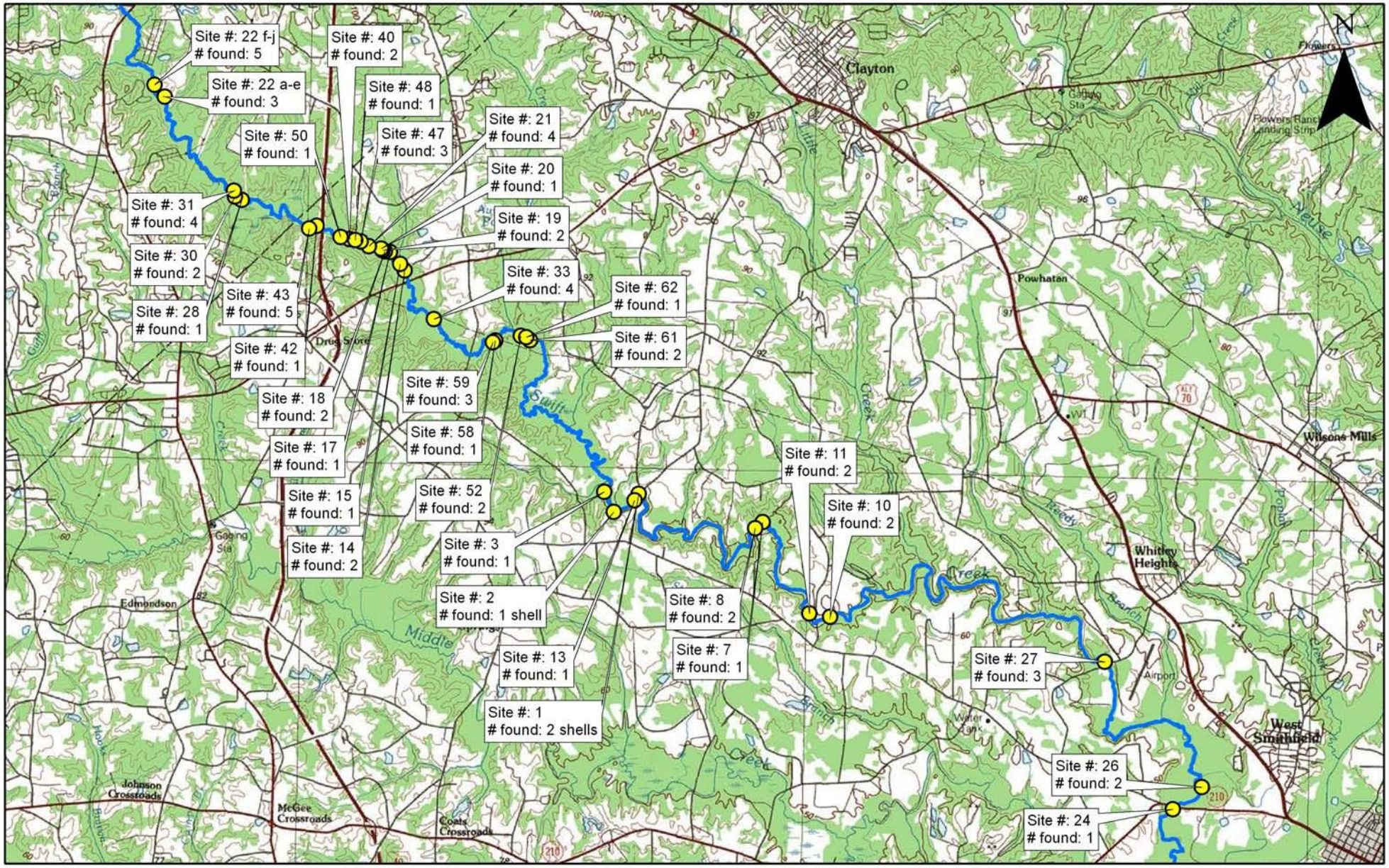
Wake and Johnston Counties, North Carolina

Date: February 2008

Scale: 0 0.5 1 Miles

Job No.: 3190

Figure 11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Site #: 20
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Clayton
Powhatan
Wilsons Mills
Whitley Heights
West Smithfield
Edmondson
Johnson Crossroads
McGee Crossroads
Coats Crossroads
Swift
Middle
Creek
Drug Store
Airport
Water Tank
Flowers
Flowers Ranch Landing Strip
Gaging Sta
Neuse
Poplar
Kennedy
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Hooks
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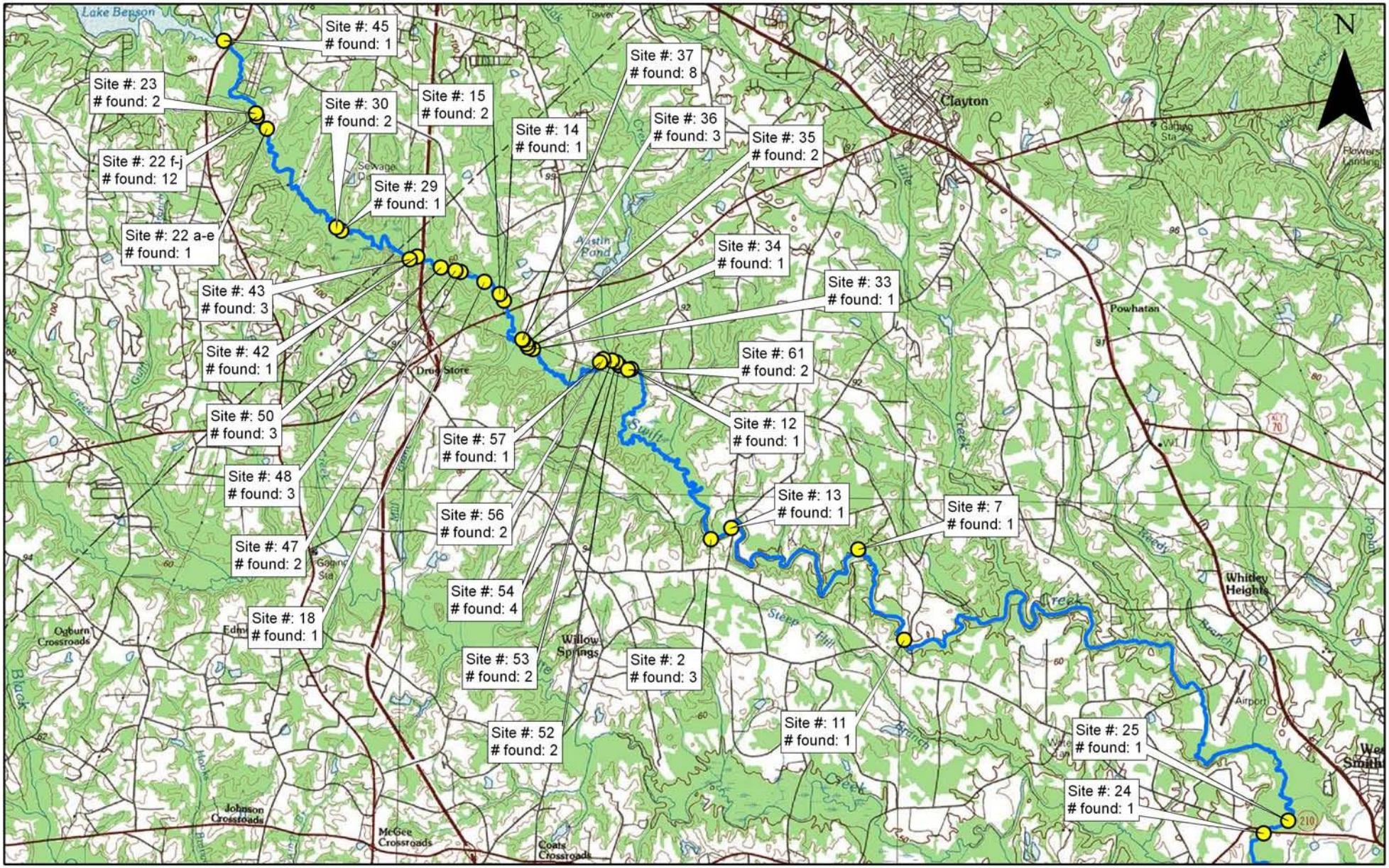
Little
Auburn
Cliff
Branch
Creek
Branch
Creek
Branch
Creek



The Catena Group

Client:

ARCADIS
Infrastructure, environment, facilities

Dempsey E. Benton Water Treatment Plant: Swift Creek Mussel Surveys

Lampsilis radiata

(Eastern lampmussel) Locations

Wake and Johnston Counties, North Carolina

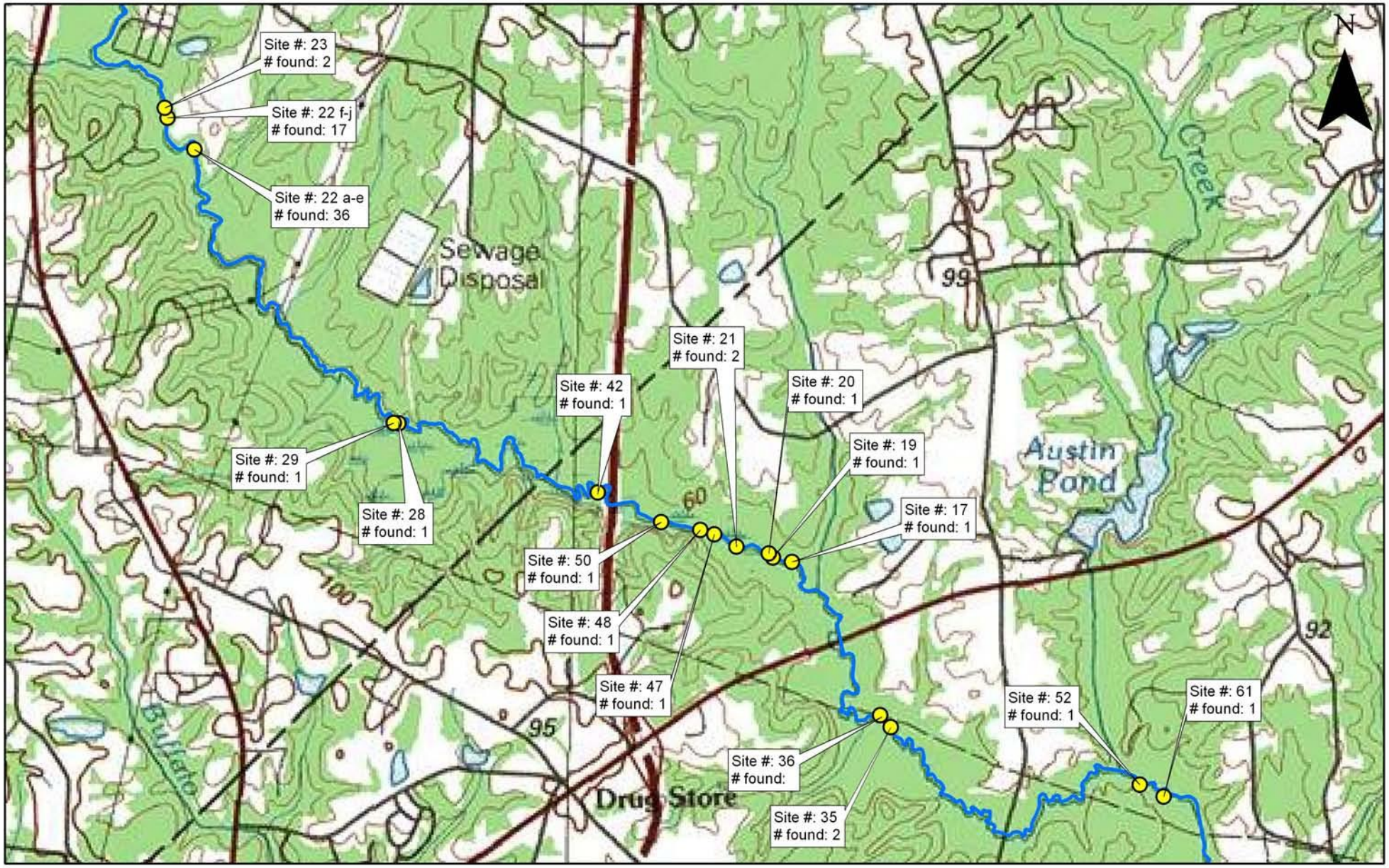
Date: February 2008

Scale: 0 0.5 1 Miles

Job No.: 3190

Figure

13



The Catena Group

Client: ARCADIS Infrastructure, environment, facilities

Dempsey E. Benton Water Treatment Plant: Swift Creek Mussel Surveys

Pyganodon cataracta (Eastern floater) Locations

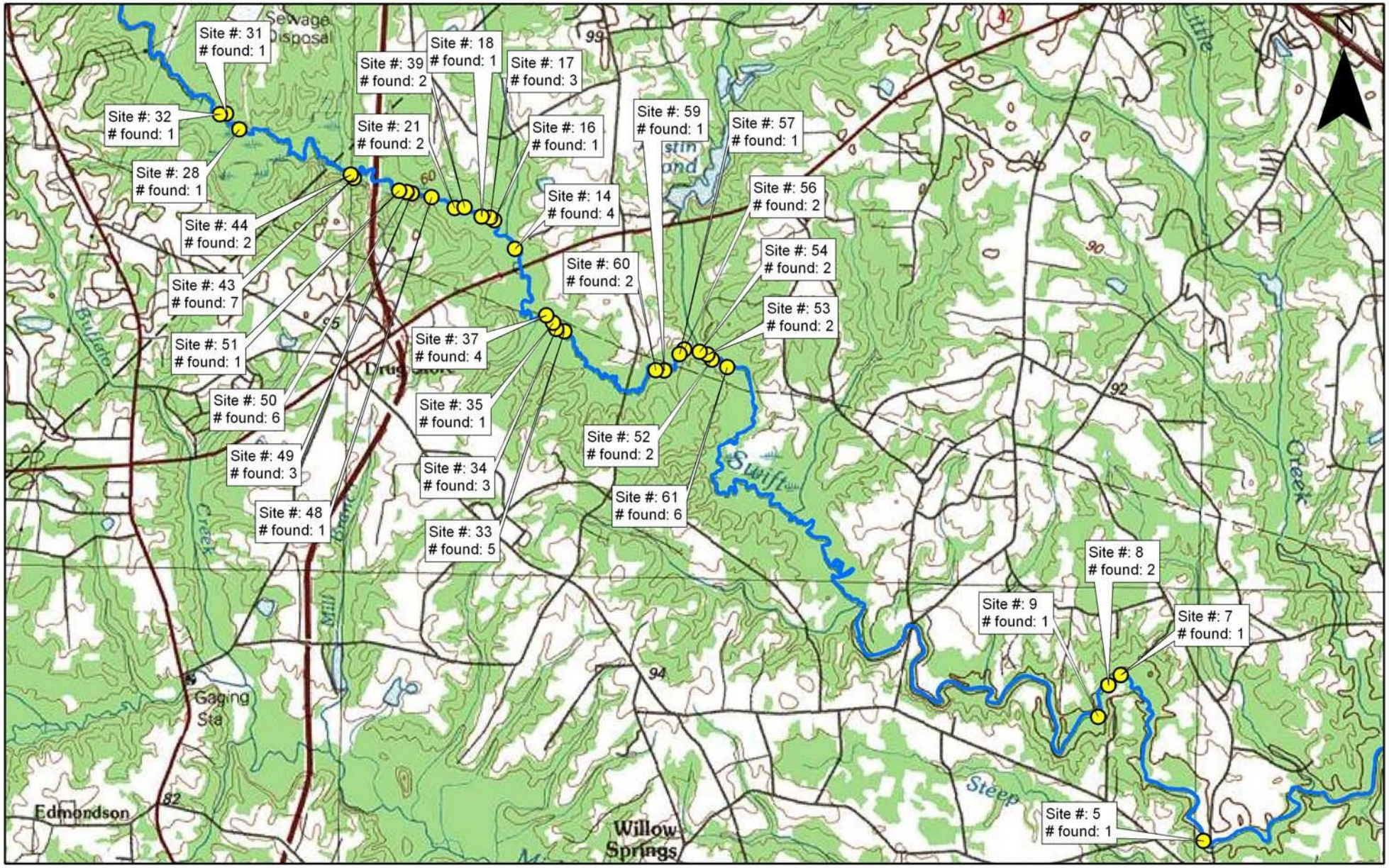
Wake and Johnston Counties, North Carolina

Date: February 2008

Scale: 0 1,000 2,000 Feet

Job No.: 3190

Figure 14



The Catena Group

Client:

ARCADIS
Infrastructure, environment, facilities

Dempsey E. Benton Water Treatment Plant: Swift Creek Mussel Surveys

Strophitus undulatus (Creeper) Locations

Wake and Johnston Counties, North Carolina

Date: February 2008

Scale: 0 2,000 4,000 Feet

Job No.: 3190

Figure 15

The Catena Group

Client:

ARCADIS
Infrastructure, environment, facilities

Dempsey E. Benton Water Treatment Plant: Swift Creek Mussel Surveys

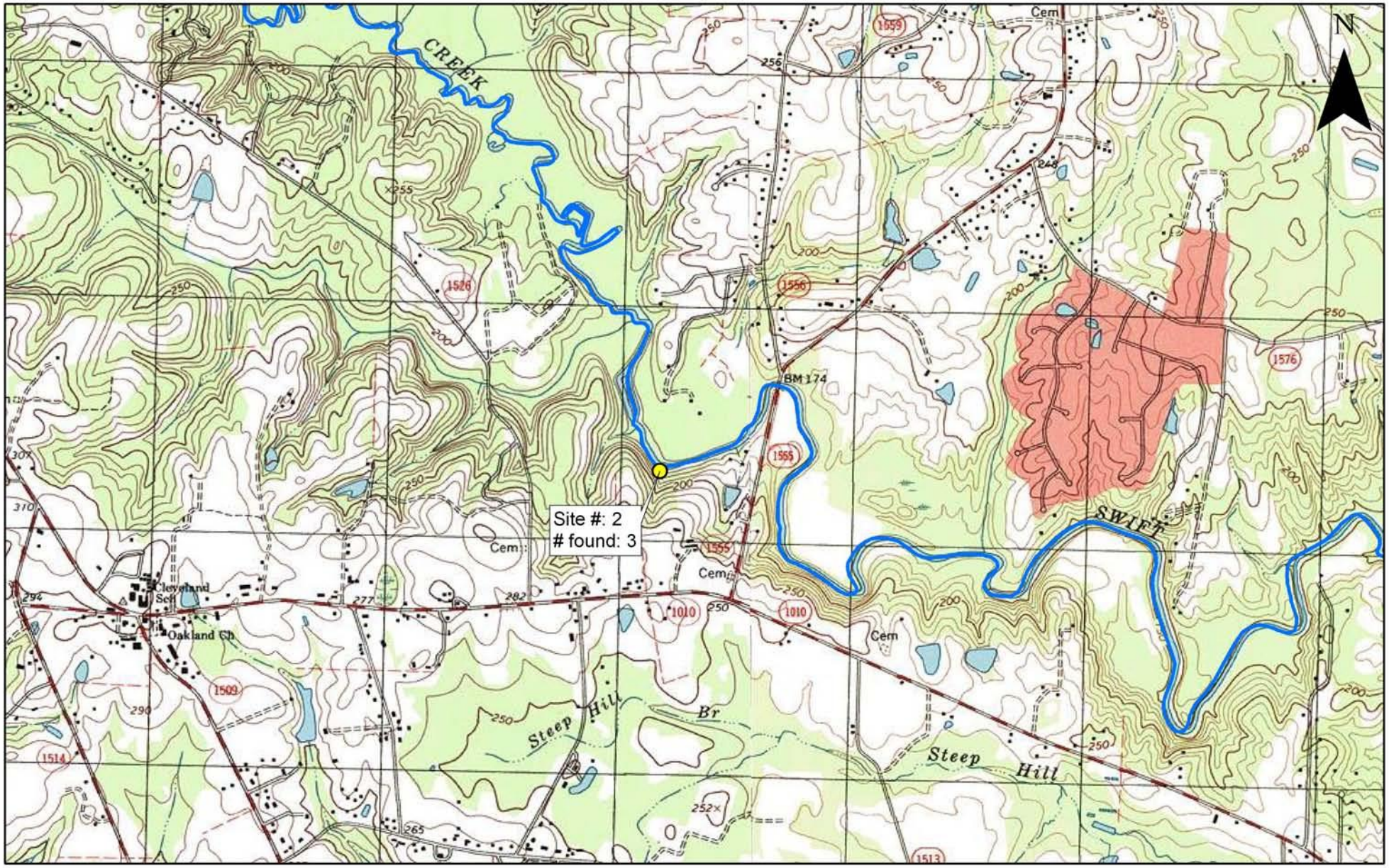
Utterbackia imbecillis
(Paper pondshell) Locations
Wake and Johnston Counties, North Carolina

Date: February 2008

Scale: 0 1,500 3,000 Feet

Job No.: 3190

Figure 16



The Catena Group

Client:

ARCADIS
Infrastructure, environment, facilities

Dempsey E. Benton Water Treatment Plant: Swift Creek Mussel Surveys

Villosa constricta

(Notched rainbow) Locations

Wake and Johnston Counties, North Carolina

Date: February 2008

Scale: 0 750 1,500 Feet

Job No.: 3190

Figure

17