BIOLOGICAL MONITORING OF CHAPEL HILL STREAMS, NORTH CAROLINA

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HOW TO READ THIS REPORT

This is the first report by Lenat Consulting on water quality and habitat quality of streams in Chapel Hill, North Carolina. It includes data on Bolin Creek, Booker Creek, Morgan Creek, Little Creek and their tributaries. A companion report also has been prepared for the Town of Carrboro, with information on Bolin Creek and selected tributaries. Data from three sites have been included in both reports: Morgan Creek at NC 54, Bolin Creek at Village Drive and Jolly Branch. There is some duplication between these reports, especially in the introduction, summary of flow data, methods, and summary of prior biological monitoring. Long lists of species are primarily confined to the appendices, but the reader will often find some species names used in the discussion, especially in regard to tolerant or intolerant species. In order to comprehend many of the summary tables, the reader should understand the terms “EPT taxa richness” and “biotic index”, and should understand how bioclassifications are assigned to streams (see Methods section). Given some familiarity with these terms, Tables 2 and 3 provide the quickest summary this study.

INTRODUCTION

Water quality in Chapel Hill was evaluated in March 2011 by sampling benthic macroinvertebrates at 18 sites: 2 Bolin Creek sites, Morgan Creek, Little Creek and 14 smaller tributaries.

There are several reasons for using biological surveys in monitoring water quality. Conventional water quality surveys do not integrate fluctuations in water quality between sampling periods. Therefore, short-term critical events may often be missed. The biota, especially benthic macroinvertebrates, reflect both long and short-term conditions. Since many species in a macroinvertebrate community have life cycles of a year or more, the effects of a short-term pollutant will generally not be overcome until the following generation appears.

Macroinvertebrates are useful biological monitors because they are found in all aquatic environments, they are less mobile than many other groups of organisms, and they are small enough to be easily collectable. Moreover, chemical and physical analysis for a complex mixture of pollutants is generally not feasible. The aquatic biota, however, show responses to a wide array of potential pollutants, including those with synergistic or antagonistic effects. Additionally, the use of benthic macroinvertebrates has been shown to be a cost-effective monitoring tool (Lenat 1988). The sedentary nature of the benthos ensures that exposure to a pollutant or stress reliably denotes local conditions, and allows for comparison of sites that are in close proximity (Engel and Voshell 2002).

Analysis of stream life is one way to detect water quality problems (Rosenberg et al 1986). Different kinds of stress will often produce different benthic macroinvertebrate communities. For example, the species associated with organic loading (and low dissolved oxygen) are well known. More recent studies have begun to identify the biological impacts of sedimentation and toxic stress. Identification at, or near, the species level is desirable for many groups of organisms (Resh and Unzicker 1975), and recent work by Lenat and Resh (2001) has shown the benefits of precise taxonomy for both pollution monitoring and conservation biology.

Organisms cannot always be identified at the species level, thus counts of the number of kinds of stream organisms often include identifications at higher levels (genus, family, etc.). Each different type of organism in these situations is called a “taxon” and the plural form of this word is “taxa”. Thus “taxa richness” is a count of the number of different types of organisms.

LITTLE CREEK CATCHMENT

The following overview of this catchment is modified from a report by North Carolina Department of Environment and Natural Resources (2003): Assessment Report - Biological Impairment in the Little Creek Watershed Cape Fear River Basin.

Located in Orange and Durham Counties, Little Creek flows into the New Hope arm of B. Everett Jordan Lake, draining a 24.6-square mile area in subbasin 03-06-06 of the Cape Fear River basin. Two major tributaries, Booker Creek and Bolin Creek, drain the majority of the Little Creek catchment. The watershed includes extensive areas of residential and commercial development, as well as a portion of the campus of the University of North Carolina at Chapel Hill (UNC). As of 1999, impervious areas such as roads and buildings covered approximately 15 percent of the study area. The upper three quarters of this area lies in the Carolina Slate Belt, and streams here exhibit the narrow valleys and rocky substrates associated with this geologic zone. Little Creek and the downstream reaches of Booker and Bolin Creek are located in a Triassic Basin and exhibit its characteristic broad floodplains and sandy substrates. Visual assessment suggests that most streams downstream of East Franklin Street were channelized (straightened and dredged) in the past. An OWASA (Orange Water and Sewer Authority) sewer easement follows Booker, Bolin and Little Creeks for much of their length.

Bolin Creek

The headwaters of Bolin Creek are located northwest of the intersection of Homestead Road (SR1777) and Old NC 86 (SR 1109), north of Carrboro. Bolin Creek is joined by the following named tributaries, in order from upstream to downstream: Jones Creek, Jolly Branch, Tanbark Branch, and Battle Branch. This report also includes information from some of the smaller tributaries, including an unnamed tributary at Severin Street, Tanyard Branch, Mill Race Branch, Cole Springs Branch, and Library Branch. Bolin Creek is dammed several times in its headwaters, most notably to form Lake Hogan, a 12-acre impoundment located just downstream of Old NC 86. Bolin Creek begins in a fairly undeveloped area and drains progressively more urban and developed areas in Carrboro and Chapel Hill as it flows towards its confluence with Booker Creek. Bolin Creek is approximately eleven miles long, mostly located within the planning jurisdiction of Carrboro. The 12-square mile watershed includes about half of Carrboro's downtown commercial district, the majority of Chapel Hill's central business district and approximately 146 acres of the University of North Carolina at Chapel Hill (UNC) campus (primarily draining to Battle Branch). The stream also drains a variety of residential areas in Chapel Hill and Carrboro, and the dense commercial district along Estes Drive near University Mall.

Booker Creek

The headwaters of Booker Creek rise southwest of the intersection of Martin Luther King Jr., Blvd. (NC 86) and Weaver Dairy Road in Chapel Hill. Booker Creek is joined by two named tributaries: Cedar Fork and Crow Branch. The mainstem of Booker Creek has been dammed to create Lake Ellen (surface area of seven acres, built in 1961) and, further downstream, Eastwood Lake. Unlike Bolin Creek, which drains progressively more developed areas as it flows downstream, most of the Booker Creek watershed is heavily developed.

MORGAN CREEK CATCHMENT

Morgan Creek originates in a rural and residential area west of Chapel Hill, although much of this area is undergoing further residential development. It is the major tributary of University Lake. Downstream of University Lake, the stream flows through residential areas in the southern part of Chapel Hill. Major tributaries downstream of University Lake include Fan Branch and Wilson Creek. Most of the Morgan Creek catchment is located in the Slate Belt ecoregion, producing rocky streams. The southern tributaries, however, had stream beds largely comprised of sand and gravel. These streams are similar to headwater tributaries of Pokeberry Creek in Chatham County (Lenat, unpublished data).

OTHER STREAMS
This report also includes data from Old Field Creek, which flows north into New Hope Creek.

METHODS

All collection methods are derived from techniques used by the NC Division of Water Quality (Lenat 1988). These methods have been in use by North Carolina since 1982, and have been thoroughly tested for accuracy and repeatability. More details can be found at their web site: http://portal.ncdenr.org/web/wq/ess/bau. Three of DWQ's collection methods have been used for the Bolin Creek study: intensive "Standard Qualitative" collections and more rapid "EPT" and "Qual-4" collections. These three methods are briefly described below.

Standard Qualitative Method – Overview [Bolin Creek sites 4 and 5, and Morgan Creek site 2]
The standard qualitative technique includes 10 separate samples and is designed to sample all habitats and all sizes of invertebrates. This collection technique consists of two kick net samples (kicks), three sweep-net samples (sweeps), one leaf-pack sample, two fine-mesh rock and/or log wash samples, one sand sample, and visual collections. Invertebrates are separated from the rest of the sample in the field ("picked") using forceps and white plastic trays, and preserved in glass vials containing 95% ethanol.

Organisms are picked roughly in proportion to their abundance, but no attempt is made to remove all organisms. If an organism can be reliably identified as a single taxon in the field, then no more than 10 individuals need to be collected. Some organisms are not picked, even if found in the samples, because abundance is difficult to quantify or because they are most often found on the water surface or on the banks and are not truly benthic.

Organisms are classified as Abundant if 10 or more specimens are collected, Common if 3-9 specimens are collected, and Rare if 1-2 specimens are collected.

EPT Method – Overview [Morgan Creek at NC 54]
The EPT method is a more rapid collection technique, limited to 4 samples: 1 kick, 1 bank sweep, 1 leaf pack and visuals. Furthermore, collections are limited to the most intolerant "EPT" groups: Ephemeroptera, Plecoptera and Trichoptera. Note that the EPT method is a subset of the standard qualitative method described above.

Qual-4 Method – Overview [Smaller tributary sites and Little Creek]
The Qual-4 method uses the same 4 samples as the EPT method, but all benthic macroinvertebrates are collected. DWQ uses this method to evaluate small streams (drainage area < 3 square miles) and assigns ratings based solely on the biotic index values. This method is intended for use, however, only in perennial streams.

Assigning Bioclassifications - Overview
The ultimate result of a benthos sample is a bioclassification. Bioclassifications used by NC DWQ are Excellent, Good, Good/Fair, Fair or Poor for standard qualitative samples; they are based on both EPT taxa richness and the biotic index values. A score (1-5) is assigned for both EPT taxa richness and the NC biotic index. The final site classification is based on the average of these two scores. In some situations, adjustments must be made for stream size or the season, but such adjustments were not required for this study.

EPT Criteria
The simplest method of data analysis is the tabulation of species richness (number of species), and species richness is the most direct measure of biological diversity. The association of good water quality with high species (or taxa) richness has been thoroughly documented. Increasing levels of pollution gradually eliminate the more sensitive species, leading to lower and lower

species richness. A score from 1 to 5 is assigned to each site, with 1 for Poor EPT taxa richness and a 5 for Excellent EPT taxa richness (see below).

The relationship of total taxa richness to water quality is nonlinear, as this metric may increase with mild enrichment of nitrogen and/or phosphorus. Taxa richness for the most intolerant groups (Ephemeroptera + Plecoptera + Trichoptera) is more reliable, but must be adjusted for ecoregion. Piedmont criteria were used for the Bolin Creek study.

Biotic Index Criteria

To supplement EPT taxa richness criteria, the North Carolina Biotic Index (NCBI) was derived as another (independent) method of bioclassification to support water quality assessments (Lenat 1993). This index is similar to the Hilsenhoff Biotic Index (Hilsenhoff, 1987) with tolerance values derived from the NC database. Biotic indices are based on a 0-10 scale, where 0 represents the best water quality and 10 represents the worst. Abundance values used in the biotic index calculation are 10 for Abundant taxa, 3 for Common taxa, and 1 for Rare taxa. The highest values (>5.1) indicate the worst water quality and receive a score of 5; the lowest values indicate Excellent water quality and receive a score of 1 (see below)

NC Division of Water Quality: Scoring for Biotic Index and EPT taxa richness values for Piedmont streams

Score	BI Values	EPT Values
5	<5.14	>33
4.6	5.14-5.18	32-33
4.4	5.19-5.23	30-31
4	5.24-5.73	26-29
3.6	5.74-5.78	24-25
3.4	5.79-5.83	22-23
3	5.84-6.43	18-21
2.6	6.44-6.48	16-17
2.4	6.49-6.53	14-15
2	6.54-7.43	10-13
1.6	7.44-7.48	8-9
1.4	7.49-7.53	6-7
1	>7.53	0-5

Derivation of Final Bioclassification for Standard Qualitative Samples

For most mountain, piedmont and coastal plain (Coastal A) streams, equal weight should be given to both the NC Biotic Index value and EPT taxa richness value in assigning bioclassifications. For these metrics, bioclassifications are assigned from the following site scores:

Excellent: 5 Good: 4 Good-Fair: 3 Fair: 2 Poor: 1

"Borderline" values are assigned near half-step values (1.4. 2.6, etc.) and are defined as boundary EPT values ±1 (except coastal plain), and boundary biotic index values ±0.05. The two ratings are then averaged together, and rounded up or down to produce the final classification. When the EPT and BI score differ by exactly one unit, the EPT abundance value is used to decide on rounding up or rounding down.

SAMPLING SITES (Figure 1)

More detailed site descriptions (with photos) are presented in Appendices 3 and 4.

Table 1 gives data on habitat ratings and substrate composition at all sites sampled in March 2011. The habitat rating is based on standard Division of Water Quality procedures, and produces a value between 0 and 100. A higher value indicates better habitat quality. Many sites had problems with excessive algal growths. Spring months may produce abundant algal growths in most streams, due to rising temperatures and absence of shading before leaf-out. If coupled with high nutrient values, this spring growth of algae can grow over the entire stream bottom. Excessive algal growths affect the physical habitat by reducing habitat diversity; they affect the chemical environment by causing high variability in dissolved oxygen (DO) values. DO may be very high during the day (photosynthesis), but very low at night when respiration becomes more important.

Figure 1: 2011 Chapel Hill Benthic Macroinvertebrate Monitoring

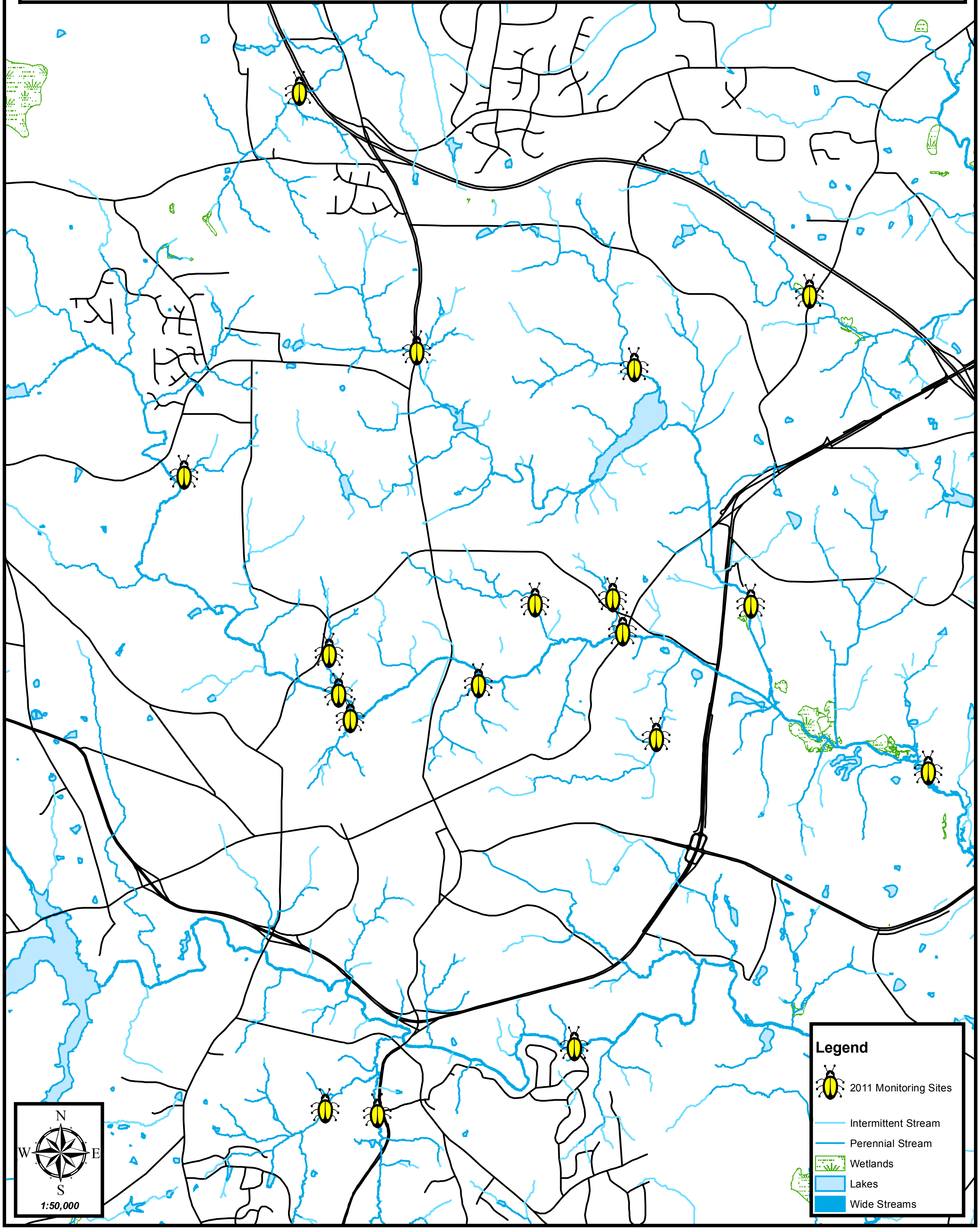

Table 1. Site characteristics, Chapel Hill Streams, March 2011, Orange County. Low scores (indicating habitat problems) are shown with yellow highlights.

Stream	CM	IH	BS	PV	RH	BSV	LP	RVZW	Total	Width	B	R	Gr	Sa	Si	Comments
	Habitat Scoring (0-100)										Substrate (%)					
Slate Belt (Rocky)																
Bolin Cr #4	4	18	8	6	7	6/3	7	3/1	63	7	30	30	15	25	Tr	Rocky, but with excessive filamentous algae.
Bolin Cr #5	4	8	3	4	5	3/3	2	1/1	34	6	5	10	25	60	Tr	Rocky near Franklin St, but sandy upstream. Poor bank habitat.
Morgan Cr	4	16	10	4	16	6/6	7	5/5	79	10	20	20	20	30	10	Sand deposited in pools, excessive algal growth with some floating mats.
Cedar Fk	4	14	8	6	10	7/7	10	5/5	76	3	40	30	10	10	10	Old neighborhood, but houses close to stream, excessive filamentous algae.
Old Field Cr	3	10	3	4	7	5/5	7	5/5	54	2.5	25	15	20	20	20	Lots of bedrock, Heavy Aufwuchs growth with silt deposition.
Booker Cr 1	5	10	6	4	3	5/5	10	3/5	46	2	10	20	20	30	20	Very homogenous habitat due to excessive filamentous algae, poor riffles, good root habitat.
Mill Race Br	4	10	6	4	10	6/3	10	3/2	58	2	1	25	20	45	Tr	Sandy, embedded substrate. Fauna sparse.
Tanyard Br	4	15	8	4	12	3/6	5	0/3	60	2	20	40	15	25	Tr	Fauna very sparse, heavily developed catchment.
Cole Springs Br	4	18	12	6	14	6/6	10	5/5	86	1.5	20	40	20	20	-	Old residential area, forested riparian, good habitat.
Jolly Br	5	16	11	4	16	2/2	10	5/5	76	1	15	40	25	15	5	Severe bank erosion, but largely forested. Good habitat.
Library Br	4	11	3	6	7	3/3	7	2/2	48	1	Tr	10	20	65	5	Largely residential area, fauna sparse. Small sandy stream.
UT Bolin	4	17	10	6	16	5/5	10	5/3	71	<1	40	40	10	10	-	Very small, just barely flowing. Fauna sparse.
Sandy Transition Streams																
Battle Br	5	12	4	6	9	3/3	7	1/4	54	2	Tr	15	35	45	5	Very sandy with eroding banks.
Wilson Cr	5	12	3	8	12	2/2	7	4/2	57	2	-	5	30	60	5	High density development at site, but older development upstream with large lots, mostly forested. Sandy with eroding banks. Lots of filamentous algae
Fan Br	5	7	3	6	16	3/3	10	4/5	62	1.5	-	Tr	20	80	Tr	High density development at site, but older development upstream with large lots.
Triassic (Clay/Sand)																
Little Cr	5	10	3	6	3	2/2	7	5/5	48	7	-	-	-	80	20	Sandy stream, but with good snag and leafpack habitat. Many seeps in area, swamp habitat.
Booker Cr 2	3	7	3	4	3	2/2	10	2/5	41	4.5	-	-	Tr	60	40	Poor habitat (sand/clay), excessive filamentous algae, entrenched. Prior records with high coliform counts.
Dry Cr	3	7	1	4	3	2/2	10	5/5	42	1	-	-	-	20	80	Poor habitat (mostly clay), but good riparian buffer. Many seeps in this area, swamp habitat upstream

Habitat Components: CM = Channel Modification (0-5), IH = Instream Habitat (0-20), BS = Bottom Substrate (1-15), PV = Pool Variety (0-10), RH = Riffle Habitats (0-16), BSV = Bank Stability and Vegetation (0-7 for both left and right banks), LP = Light Penetration (0-10), RVZM = Riparian Vegetative Zone Width (0-5 for both left and right banks). Substrate: Boulder (B), Rubble (R), Gravel (Gr), Sand (Sa), Silt (Si), Tr = Trace (<10%). Stream width is in meters.

FLOW DATA

The fauna of Chapel Hill streams have been frequently affected by droughts, with some streams becoming entirely dry during severe droughts. Changes due to water quality problems cannot be discerned without taking into consideration this natural stress. The data below is taken from the USGS web site, using data from 1999 to September 2010. The USGS measures daily flow at Morgan Creek at NC 54 and Cane Creek; both streams are in Orange County and both are similar in geology to the Bolin Creek catchment. These streams are of similar size relative to Bolin Creek, but note that the Bolin Creek catchment is slightly smaller than either Morgan Creek or Cane Creek catchments.

Mean Monthly flow (cfs) in streams most similar to Bolin Creek, 1999-2009.

Morgan Creek nr White Cross (Drainage area 8.3 square miles)

Year	Month:	1	2	3	4	5	6	7	8	9	10	11	12
1999		13	4	5	10	0.9	0.5	0.4	0.09	40	8	7	4
2000		11	15	7	11	3	4	12	4	3	1.3	1.7	2.2*
2001		2.4	6	17*	12	3	5*	1.1	0.6	0.2	0.1	0.1	0.3
2002		7	4	4	2	0.7	0.03	0.04	0.01	0.04	6	4	15
2003		6	20	32	39	11	7	6	3	2	2	2	5
2004		2	8	5	4	3	0.4	0.7	5	7	2	4	3
2005		7	7	15	6	2	0.7	0.3	0.2	0.01	0.2	0.6	7
2006		3	2	2	2	0.7	1.7	5	0.08	0.5	1.9	16	6
2007		13	7	9	12	1.8	0.6	0.2	0.002	0.000	0.008	0.003	0.2
2008		0.4	1.3	9	6	2	0.4	1.6	4	15	0.3	1.4	9
2009		5	3	19	6	3	4	0.4	0.2	0.05	0.05	7.7	18.7
2010		13	21	7	3	4	0.6	0.1	0.02	0.6			

Cane Creek nr Orange Grove (Drainage area 7.5 square miles)

Year	Month:	1	2	3	4	5	6	7	8	9	10	11	12
1999		14	4	3	6	1.1	0.5	0.2	0.09	18	4	6	4
2000		9	14	8	12	2	8	14	3	5	0.9	0.8	5*
2001		3	9	21	11	1.2	2*	0.4	0.1	0.1	0.1	0.06	0.2
2002		5	2	3	1.1	0.1	0.03	0.04	0.04	0.4	13	9	20
2003		6	20	34	37	17	8	5	4	1.3	0.7	0.7	6
2004		2	8	5	4	0.9	0.4	1.9	10	9	1.8	4	4
2005		7	6	15	6	2	0.8	0.3	0.3	0.000	0.03	0.5	8
2006		3	2	1.2	2	1.0	7	4	0.1	0.2	1.2	19	6
2007		11	8	12	12	0.9	0.2	0.03	0.00	0.00	0.005	0.000	0.08
2008		0.3	1.2	7	9	3	0.2	0.5	0.3	4	0.3	0.7	8
2009		4	1.7	18	5	0.9	8	0.2	0.08	0.03	0.01	10	21
2010		12	24	10	3	3	0.3	0.1	0.01	1.5			

Flow data from Morgan Creek at Chapel Hill (41 square miles) did not indicate any months with average flows less than 7 cfs (1999-2010). Low flows (less than 0.5 cfs) are highlighted in yellow; severe low flows (less than 0.1 cfs) are highlighted in red.

PRIOR BIOLOGICAL DATA

Benthic macroinvertebrates have been collected in Orange County for over 30 years. One of the first publications was a list of species found in Cane Creek, prior to the existence of the Cane Creek Reservoir (Lenat 1983). The NC Division of Water Quality has multiple collections from Morgan Creek and Bolin Creek, including both standard qualitative and EPT samples. EPT samples use a shorter 4-sample method (vs. 10 samples for the standard qualitative), and are limited to the Ephemeroptera, Plecoptera, and Trichoptera (see Methods).

The following data are taken from the Cape Fear River basin report (NC DWQ 2003):

<u>NC DWQ data, 1985-2003. Standard Qualitative and EPT samples</u>.

	Date	Total S	EPT S	BI	Bioclass*
Bolin Cr at SR 1777	7/01	87	24	5.96	Good-Fair
	2/01	82	17	6.40	Not Rated
	4/00	-	26	-	Good
	3/98	-	23	-	Good
	4/93	-	24	-	Good
Bolin Cr at Village Rd	3/02	40	7	7.00	Fair (follows Drought)
	7/01	52	9	6.6	Fair
	2/01	54	6	7.00	Poor
	2/98	59	26	5.1	Good
	4/93	-	24	-	Good-Fair
Bolin Cr, E Franklin St	7/01	41	4	6.9	Poor
	3/01	53	4	7.1	Poor
	3/98	37	13	6.3	Fair
	2/98	-	4	-	Poor
	2/93	32	8	6.5	Fair
	4/86	89	28	6.1	Good-Fair
Booker Cr, Piney Mtn Rd	7/01	35	4	6.1	Not Rated
	2/01	39	8	6.3	Not Rated
	3/98	-	10	-	Fair
Booker Cr, Barbara Ct	7/01	45	3	6.6	Not Rated
	2/01	31	4	7.3	Not Rated
Booker Ct, Walnut St	7/01	31	4	7.3	Not Rated
	2/01	51	7	6.9	Not Rated
Morgan Cr, NC 54	03/09	-	26	-	Good
	03/08	-	12	-	Not Rated (Drought)
	06/04	-	18	-	Good-Fair
	10/03	-	22	-	Good
	7/03	-	20	-	Good-Fair
	5/03	-	16	-	Good-Fair
	3/03	-	12	-	Not Rated (Drought)
	1/03	-	8	-	Not Rated (Drought)
	9/02	-	2	-	Not Rated (Drought)
	4/00	-	36	-	Excellent
	2/98	80	33	4.4	Excellent
	10/96	64	22	5.0	Good
	7/93	61	22	4.9	Good
	2/93	90	36	4.5	Excellent
	4/85	109	32	5.7	Good

Morgan Creek near the Botanical gardens	3/98	46	20	6.1	Good-Fair
	4/93	-	16	-	Fair
	2/93	71	26	6.0	Good-Fair
Little Cr at Pinehurst Dr	7/01	27	5	6.8	Not Rated
	3/01	45	3	7.3	Poor
	2/93	37	7	7.1	Fair

*DWQ did not assign ratings to streams in the Triassic basin, pending development of criteria for this ecoregion.

NC Department of Environment and Natural Resources (2003) provided the following summary of the Bolin Creek data:

> "When Bolin Creek was first sampled at East Franklin Street in 1986, the benthic community was reasonably diverse, and the stream, though showing indications of impact, was not considered impaired. Impairment was evident when the stream was next sampled in 1993 and has persisted at this downstream site. Upstream sites supported a reasonably intact benthic fauna until 2000, when impairment became evident as far upstream as Waterside Drive in Carrboro, located between Homestead Road and Estes Drive Extension. It is probably too soon to evaluate whether this decline in the benthic community is persistent, or was due to a specific perturbation from which this portion of the stream will yet recover. Currently, only the upper portion of Bolin Creek (Homestead Road) appears to support an adequate benthic fauna.
>
> The causes of impairment in the portion of Bolin Creek between Airport Road and Waterside Drive are less clear than in the downstream section of Bolin Creek. In-stream habitat is adequate. Some effects of toxicity and scour are likely, although these impacts appear less pronounced than in lower Bolin Creek, and likely decline significantly at the upstream end of this section."

DWQ collections from Morgan Creek in 2002 and 2003 were intended to show recovery from the 4- month drought. These data indicated that the stream took about one year to recover from extreme low flow. It had shown a decline over time, never attaining the very high EPT taxa richness values seen in 1985, 1993, 1998, and 2000.

RESULTS AND DISCUSSION (Tables 2-4, Appendices 1-2)

Early samples from Bolin Creek (prior to 2000) indicated Good water quality in the upper section, declining slightly to Good-Fair further downstream. Surveys in 2000, however, produced a Fair rating for sites at Waterside Drive (#3) and Estes Drive (#4). It appears that nonpoint source runoff had a significant negative effect on water quality in Bolin Creek between 1998 and 2000. Note that changes in habitat were not responsible for any these changes.

After August 2001, Bolin Creek was potentially affected by a series of severe droughts, with very low flows (see flow data for Cane Creek and Morgan Creek) in:

-Aug-Dec 2001 (6 months, with lowest flow in Nov)
-June-Sept 2002 (4 months with streams drying up much of this time)
-June 2004
Note that 2003-2004 would be expected to be a period of recovery.
-July-Oct 2005 (4 months with streams going dry in September)
-Aug-Sept 2006
-June-Dec 2007 (7-8 months, with streams going dry for 4-6 months)
-July-August + September 2008 – no streams went completely dry. Another period of possible recovery.
-July-September 2009 (4 months with severe drought for 2-3 months)

-June-August 2010 (3 months with severe drought in August)

These repeated shocks to the stream biota would be expected to severely affect the diversity of the stream fauna, and bioclassifications based on taxa richness counts might underestimate water quality conditions. The repeated Fair and Poor rating assigned to much of Bolin Creek in Carrboro during this period have been used to show that Bolin Creek does not support designated uses, but note that some intolerant species were still abundant at all Bolin sites in Carrboro through 2010. Morgan Creek at NC 54 (intended as a control site) has lost some components of a normal stream fauna (*Elimia*, *Maccafertium*, *Cheumatopsyche*, *Chimarra*), but still supports a community of highly intolerant aquatic species through 2011.

Routine sampling in Carrboro and Chapel Hill has been switched from summer months to winter/spring months (esp. March), to avoid these periods of extreme low flow. Much of Bolin Creek is functioning as an intermittent stream and may be difficult to evaluate using DWQ criteria for perennial streams. Taxa typical of temporary stream or smaller streams are increasing at Bolin Creek in Carrboro, especially the caddisflies *Rhyacophila fenestra* and *Ironoquia punctatissima*. Conversely some components of a normal stream fauna (esp. hydropsychid and philopotamid caddisflies) are declining in abundance at both Morgan Creek and upper Bolin Creek. The latter species are filter-feeders and they are highly dependent on the presence of flowing water. This pattern suggests that the continuing droughts are having an impact on the composition of the invertebrate fauna in Carrboro and Chapel Hill streams.

Tables 2 and 3 present a summary of the biological monitoring for Chapel Hill streams during March 2011. A list of selected intolerant species is presented in Table 4, producing a score (the "Sum" line) that is useful in comparing sites. Species are only included in table 4 that were Common or Abundant at one or more sites.

None of the Chapel Hill sites had a community that would indicate organic loading. Some sites, however, had fauna (especially the snail *Physa*) that suggested low dissolved oxygen concentrations. *Physa* was abundant at Cedar Fork, Tanyard Branch and Dry Creek; all of these sites had very high levels of filamentous algae. Such high levels of algae can cause oxygen supersaturation during the day, but low dissolved oxygen levels at night from respiration of this algae.

Site Evaluations

It is important to realize that stream flow conditions over the last few years make it difficult to accurately rate water quality in Chapel Hill streams. Repeated drought conditions have resulted in very low flow rates, with some streams going completely dry. This would be expected to reduce the diversity of the fauna, but would have less effect on the tolerance of the aquatic fauna. For this reason, more emphasis is placed on biotic index ratings than taxa richness ratings. The DWQ system for rating small piedmont and mountain streams relies entirely on biotic index values, but note that it is not intended to apply to intermittent streams.

Large Streams

<u>Bolin Creek Site 4 (Village Drive).</u> This site is intended to be equivalent to the Estes Drive site that has been monitored by the Town of Carrboro since 2000. The Estes Drive site usually received a Fair rating during drought years, but recovered to Good-Fair in 2008 in a period of higher summer flows. An unusual characteristic of this site was the continuing presence of two intolerant species; the caddisfly *Chimarra* and the stonefly *Acroneuria abnormis*, but these species were rare or absent at the Village Drive site in 2011. The biotic index for this segment of Bolin Creek was significantly higher (6.7) in 2011 relative to prior collections (5.8-6.4), suggesting a recent decline in water quality. The bioclassification, however, remained Fair in 2011. The abundance of the snail *Physa* indicates that this segment of Bolin Creek had experienced low

dissolved oxygen concentrations. Collections in a period of higher flow will be needed to determine the long-term trend in water quality at Bolin Creek Site 4.

<u>Bolin Creek Site 5 (Franklin Street)</u>. This site received a Poor bioclassification in 2011, similar to DWQ collections in 1998 and 2008. This site is quite sandy upstream of the bridge area, but DWQ collections in 1986 demonstrate that habitat for this site is capable of supporting a Good or Good-Fair aquatic fauna. Urban runoff (toxics) is the most likely cause of problems in lower Bolin Creek. This is a common pattern for streams draining major cities throughout North Carolina. One intolerant species was abundant at this site (*Chimarra*), suggesting that some improvement is possible in years with a more normal flow regime.

<u>Morgan Creek Site 1, NC 54</u>. This site has been used as a reference site for studies in Carrboro, and there also have been many collections by the Division of Water Quality. These collections have shown the loss of many species due to problems caused by repeated summer droughts. However, the benthic macroinvertebrate fauna of upper Morgan Creek is dominated by intolerant species, and this site still maintains a Good rating.

<u>Morgan Creek at Ashe Place (near Botanical Garden).</u> Prior DWQ sampling (1993, 1998) suggested this site should have a Good-Fair rating. Collections from March 2011 produced only a Fair bioclass, but the fauna had some common or abundant intolerant species, including *Isonychia*, *Chimarra*, and *Psephenus herricki*. Additionally, the mayflies *Maccafertium modestum* and *Eurylophella verisimilis* were abundant in this portion of Morgan Creek. This pattern suggests that a Good-Fair rating is likely under more normal flow conditions.

Morgan Creek was experiencing a bloom of bright green filamentous algae during the March 2011 collections. Floating mats of this algae were observed along most banks (especially in pool areas). Except in the areas of fastest current, the bottom was covered with heavy growths of this algae.

<u>Little Creek near Meadowmont Lane</u>. The geology of the Little Creek area is very different from the Morgan Creek and Bolin Creek catchments. The Triassic Basin geology here produces a sandy stream running through a swampy floodplain. Recent DWQ samples from Little Creek have been “Not Rated”, as adequate criteria have not been established for the Triassic ecoregion. The most recent DWQ collections in 2001 had 27-45 species, with 3-5 EPT taxa and a biotic index of 6.8-7.3. Our 2011 sample had a total taxa richness of 31, EPT taxa richness of 3, and a biotic index of 7.3. These values are similar to those obtained by DWQ, indicating no recent change in water quality. Rating this stream with normal Piedmont criteria would produce a Fair or Poor rating. The dominant fauna includes two very tolerant midges (*Cricotopus bicinctus* and *Polypedilum illinoense*) which generally would indicate problems with toxicity. Although Little Creek is very sandy, there is adequate habitat (banks, snags, leafpacks) to support a much more diverse benthic community. While the stream had a poor invertebrate community, the wide floodplain area supports diverse wlldlife.

Small Streams

Slate Belt (Rocky Streams)

-<u>Cedar Fork</u>. Cedar Fork is located in an older residential area with large lots, but the houses are often placed very close to the stream. There was much NC Department of Transportation work in this catchment in the last year, possibly adding sediment to the stream. Cedar Fork had excessive growth of filamentous algae, and the macroinvertebrate fauna indicated problems with low dissolved oxygen. This site received a Fair-Poor rating based on the high biotic index (7.3) and low EPT taxa richness (2).

-Old Field Creek. Old Field Creek runs north into New Hope Creek. A landfill is located within the Old Field catchment, although there is no current evidence that it is causing problems. Given fairly good habitat and the large amount of forested buffer at this site, it was surprising to see a very sparse fauna dominated by tolerant species. All metrics indicated Poor water quality at this site.

-Booker Creek 1 (MLK). Booker Creek also had a very sparse fauna, complicated by excessive algal growths. Comparisons with DWQ collections in 2001 suggest a recent decline from Fair to Poor. Over this same time period, there had been much construction and development in the Booker Creek catchment. Booker Creek, however, may become intermittent during the recent summer droughts.

-Mill Race Branch. All metrics indicate Poor water quality in Mill Race Branch, likely due to urban runoff. This catchment has poor riparian buffer zones with much bank erosion. The abundance of hydropsychid caddisflies suggested the Mill Race Branch is usually a perennial stream.

-Tanyard Branch. Like Mill Race Branch, Tanyard Branch had a very sparse fauna and appeared to have perennial flow. The majority of downtown Chapel Hill drains to this stream. The fauna at Tanyard Branch suggested problems with low dissolved oxygen concentrations. The slightly lower biotic index (7.2 here vs. 7.7 at Mill Race Branch) produced a Fair-Poor rating.

-Cole Springs Branch. Cole Springs Branch was located in a largely forested area; this older residential area has large lot sizes and a wide forested buffer zone adjacent to the stream. This combination resulted in much higher water quality as evidenced by the abundance of intolerant species, especially *Haploperla brevis* and *Neophylax consimilis*. This perennial stream received a Good rating.

-Jolly Branch. Jolly Branch is located near the Carrboro/Chapel Hill boundary; it has been included in the reports to both towns. The lack of some expected species (for example all heptagenid mayflies and hydropsychid caddisflies) clearly indicated stream flow has been intermittent in recent years. The abundance of several intolerant species (*Ameletus lineatus, Amphinemura*) suggested there are no serious water quality problems. This site was tentatively given a Good-Fair rating.

-Library Branch. This very small stream had evidence of sediment inputs. The fauna was sparse, but contained a few intolerant species. This site also was tentatively given a Good-Fair rating, although water quality and habitat quality were significantly worse than at Jolly Branch.

-Unnamed Trirbutary to Bolin Creek at Severin. This minute stream had barely visible flow; much of the flow may have been subsurface. However, it contained a good number of very intolerant species and was given a Good rating using small-stream criteria. Like Cole Springs Branch, this site has a forested buffer zone and was located in an older residential area.

Transitional Area Streams (Sandy)

-Wilson Creek and Fan Branch. These two streams appear to be affected by sedimentation, but the sand/gravel substrate may actually reflect local geology. Similar streams have been observed a little further south in the headwaters of Pokeberry Creek in Chatham County (Lenat, unpublished). Both sites were located in a high-density residential area, but most of the catchment is comprised of heavily forested older residential areas with large lot sizes. There is more bank erosion in the Fan Branch catchment. Wilson Creek and Fan Branch had the most diverse fauna in our survey on small Chapel Hill streams. Using small-stream criteria, a Good rating was given to Fan Branch and a Good-Fair rating to Wilson Creek.

-Battle Branch. Battle Branch had instream habitat similar to Wilson Creek and Fan Branch, but the fauna indicated much worse water quality. This site was given a Fair rating using small-stream criteria and had very low total taxa richness (11). The only positive sign was the presence of an intolerant caddisfly (*Chimarra*).

Triassic Basin Streams

-Booker Creek 2 (Willow Drive). Booker Creek is a channelized stream in a heavily developed catchment. Abundant filamentous algae and silt covered most of the stream bottom. DWQ collected twice at a site near Willow Drive in 2001 (Walnut St), obtained total taxa richness of 31-51, EPT taxa richness of 4-7, and a biotic index of 6.9-7.3. The March 2011 collections indicate a substantial decline in water quality, with only 1 EPT species and an extremely high biotic index (8.2). Using Piedmont criteria, this site would have received a Poor rating.

-Dry Creek. Upper Dry Creek is too small to receive a rating, and likely goes dry during drought periods. It was dominated by tolerant species (biotic index = 7.9) and had a fauna typical of swamp streams. The abundance of the caddisfly *Ironoquia punctatissima* suggested that this stream is frequently dry; the abundance of the snail *Physa* suggested that this stream has low dissolved oxygen concentrations.

SUMMARY

Although this is the 1st survey of Chapel Hill streams by the town of Chapel Hill, it is possible to evaluate some long-term trends using data from both the North Carolina Division of Water Quality (DWQ) and the Town of Carrboro. Long-term (20-year) data indicated a major decline in water quality for lower Bolin Creek (Good-Fair → Poor), during a time when Chapel Hill was rapidly developing. Smaller declines in water quality have been seen in recent years for Bolin Creek and Booker Creek, but this trend may be partially related to the repeated summer droughts observed over the last two years. Carrboro data from Bolin Creek showed some recovery in a year (2008) with higher flows. Collections during a year with a more normal flow regime are needed to determine how much recovery might be seen for Chapel Hill streams.

No sites had indications of organic loading problems, but several sites showed symptoms of low dissolved oxygen: Bolin Creek at Village Drive, Cedar Fork, Tanyard Branch and Dry Creek. These sites also had very high levels of filamentous algae in March 2011, so the low dissolved oxygen may be the result of nighttime respiration by this algae. High levels of attached algae are often observed in streams as temperatures rise in spring, but excessive growths are likely associated with nutrient inputs.

Although many of the larger streams in Chapel Hill have water-quality problems, tributary sites may support more intolerant aquatic communities. Good water quality was observed in Cole Springs Branch, an unnamed tributary of Bolin Creek at Severin Street, and Fan Branch. Good-Fair ratings were assigned to Jolly Branch, Library Branch, and Wilson Creek. Morgan Creek near the Botanical Garden was assigned a Fair rating in 2011, but the fauna suggests a Good-Fair rating would be assigned under more normal flow conditions.

Streams with Good or Good-Fair ratings often were associated with older developments and forested buffer zones. It is encouraging to see that such areas of higher water quality can still be maintained within the city limits.

Urban runoff caused Fair conditions in Bolin Creek at Village Drive and Battle Branch. A Poor (or Fair-Poor) was given to Bolin Creek at Franklin Street, Old Field Creek, Booker Creek (2 sites), Mill Race Branch, and Tanyard Branch. The NC Division of water Quality uses Fair ratings to indicate streams that are partially supporting designated uses, while a Poor rating is used to indicate streams that do not support designated uses.

Table 2. Taxa richness and summary parameters, Bolin Creek, Morgan Creek and Little Creek, Chapel Hill, North Carolina, March 2011.

Site:	Bolin 4	Bolin 5	Morgan 1*	Morgan 2	Little Cr
Ephemeroptera	4	1	9	7	-
Plecoptera	1	-	6	-	-
Trichoptera	3	3	3	5	3
Coleoptera	2	-		6	1
Odonata	2	6		3	1
Megaloptera	-	-		1	-
Diptera; Misc.	8	6		5	3
Diptera: Chironomidae	22	20		23	14
Oligochaeta	8	6		3	2
Crustacea	4	2		3	3
Mollusca	4	4		5	4
Other	1	2		2	-
Total Taxa Richness	59	50		63	31
EPT Taxa Richness	8	4	21*	12	3
EPT Abundance	21	26	67	74	5
EPT Score	1.6	1	3	2	1
NC Biotic Index	6.7	7.0	-	6.7	7.3
BI Score	2	2	-	2	2
Site Score	1.8	1.5	3-4?	2	1.5
Rating	Fair	Poor	Good?	Fair	Not Rated (Poor or Fair?)

*EPT sample only, EPT taxa richness count corrected to predicted 10-sample value

Table 3. Taxa richness and summary parameters, smaller streams, Chapel Hill, North Carolina, March 2011.

	CFk	OF	BK1	MR	Tan	Cole	Jolly	Libr	UTB	Battle	Wils	Fan	BK2	Dry
				Slate Belt							Transition		Triassic	
Site:	CFk	OF	BK1	MR	Tan	Cole	Jolly	Libr	UTB	Battle	Wils	Fan	BK2	Dry
Width (m):	3	2.5	2	2	2	1.5	1	1	<1	2	2	1.5	4.5	
Ephemeroptera	-	-	-	-	-	2	3	1	3	-	8	5	-	1
Plecoptera	-	-	-	-	-	1	2	2	2	-	4	4	1	-
Trichoptera	2	1	2	3	2	5	3	3	4	4	5	5	-	1
Coleoptera	-	1	1	2	1	3	2	3	2	2	4	2	-	1
Odonata	-	2	-	2	-	3	2	1	1	-	4	2	3	-
Megaloptera	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Diptera; Misc.	1	2	1	2	-	2	5	1	1	1	3	3	-	1
Diptera: Chironomidae	11	5	9	5	3	8	9	4	3	6	14	12	17	7
Oligochaeta	1	7	2	1	--	2	4	4	2	1	-	-	6	3
Crustacea	2	1	2	1	-	1	3	2	3	1	1	1	1	2
Mollusca	2	2	2	2	1	2	-	2	-	1	1	1	2	1
Other	1	-	1	-	-	-	-	1	-	1	1	-	1	1
Abundance of indicators														
Low DO (Physa)	+				+									+
Hydropsychids/Elimia	+			+	+	+		+				+		
Total Taxa Richness	20	22	20	18	7	29	33	24	21	11	45	35	31	18
EPT Taxa Richness	2	1	2	3	2	8	8	6	9	4	17	14	1	2
EPT Score	1	1	1	1	1	1.6	1.6	1.4	1.6	1	2.6	2.4	1	1
NC Biotic Index	7.3	7.6	7.5	7.7	7.2	4.6	6.2	5.6	5.1	6.7	6.0	5.4	8.2	7.9
BI Score (Normal Stream)	2	1	1.4	1	2	5	3	4	5	2	3	4	1	1
BI Rating Small Streams**	P	P	P	P	P	G	F	G-F	G	F	G-F	G	P	P
Flow*	P?	I	P/I	P	P	P/I	I	P/I	P/I	P/I	P/I	P	P/I	I
Combined Site Score (Mean of EPT and BI Score)	1.5	1	1.2	1	1.5	3.3	2.3	2.7	3.3	1.5	2.8	3.2	1	1
Overall Rating (Bioclass)	F-P	P	P	P	F-P	G	G-F	G-F	G	F	G-F	G	P?	Not Rated

*Flow: P = Perennial, I = intermittent (Based on faunal composition)
**Rating: G = Good, G-F = Good-Fair, F = Fair, P = Poor. Small stream criteria may not work for Intermittent streams. Fair and Poor ratings are used to designate streams that do not support designated uses.

Site abbreviations: CFk = Cedar Fork, OF = Old Field Creek, Bk1 = Booker Cr #1, MR = Mill Race Branch, Tan = Tanyard Branch, Coles = Cole's Spring Branch, Jolly = Jolly Branch, Libr = Library Branch, UTB = Unnamed tributary Bolin Creek, Batt = Battle Branch, Wils = Wilson Creek, Fan = Fan Branch, Bk2 = Booker Creek #2, Dry = Dry Creek

Table 4. Selected intolerant species at Chapel Hill streams, March 2011; species must be Common or Abundant at one or more sites.

Site:	Bolin 4	Bolin 5	Morgan 1	Morgan 2	Little
Leucrocuta aphrodite	-	-	C	-	-
Ameletus lineatus	-	-	C	-	-
Isonychia spp	-	-	-	A	-
Paraleptophlebia sp	-	-	C	-	-
Isoperla namata gr	-	-	A	-	-
Clioperla clio	-	-	A	-	-
Chimarra sp	R	A	-	A	-
Rhyacophila fenestra	-	-	C	-	-
Psephenus herricki	A	-		C	-
Elimia sp	C	-		-	-
Sum*	14	10	29	23	0

Site[1]:	CFk	OF	Bk1	MR	Tan	Cole	Jolly	Libr	UTB	Batt	Wils	Fan	Bk2	Dry
Ameletus lineatus	-	-	-	-	-	-	C	R	C	-	C	-	-	-
Paraleptophlebia sp	-	-	-	-	-	-	-	-	C	-	R	-	-	-
Haploperla brevis	-	-	-	-	-	A	-	R	-	-	R	C	-	-
Isoperla namata gr	-	-	-	-	-	-	-	-	-	-	C	C	-	-
Amphinemura sp	-	-	-	-	-	-	A	R	A	-	A	A	R	-
Chimarra sp	-	-	C	-	-	-	-	-	-	C	R	R	-	-
Diplectrona modesta	-	-	-	R	-	R	-	R	R	-	C	R	-	-
Rhyacophila fenestra	-	-	-		-	-	A	-	R	-	-	A	-	-
Neophylax oligius	-	-	-	-	-	A	-	-	-	-	-	-	-	-
Neophylax consimils	-	-	-	-	-	-	R	-	A	-	-	-	-	-
Psephenus herricki	-	-	-	-	R	C	-	-	R	R	C	-	-	-
Elimia sp	-	-	-	-	-	A	-	A	-	-	-	A	-	-
Sum*	0	0	3	1	1	34	24	14	28	4	22	38	1	0

*Using Rare = 1, Common = 3, and Abundant = 10.

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Appendix 1. Benthic macroinvertebrates collected from Bolin Creek, Morgan Creek and Little Creek, Chapel Hill,, March 2011. R=Rare, C=Common, A=Abundant. Upstream Morgan Creek collections (M1: NC 54) limited to most intolerant (EPT) groups. Blue highlights indicate most intolerant species; red highlights indicate most tolerant species.

Site:	Bolin 4	Bolin 5	Morgan 1	Morgan 2	Little
EPHEMEROPTERA					
Maccaffertium modestum	-	C	R	A	-
Stenonema femoratum	-	-	C	-	-
Stenacron interpunctatum	C	-	-	A	-
Leucrocuta aphrodite	-	-	C	-	-
Plauditus dubius gr	-	-	A	R	-
Centroptilum triangulifer	A	-	-	R	-
Acentrella ampla	-	-	A	-	-
Siphlonurus sp	R	-	R	-	-
Caenis spp	-	-	C	A	
Eurylophella spp	R	-	R	-	-
Ameletus lineatus	-	-	C	-	-
Isonychia spp	-	-	-	A	-
Paraleptophlebia sp	-	-	C	-	-
PLECOPTERA					
Isoperla namata gr	-	-	A	-	-
I. burkesi	-	-	R	-	-
Clioperla clio	-	-	A	-	-
Amphinemura sp	R	-	-	-	-
Leuctra sp	-	-	R	-	-
TRICHOPTERA					
Cheumatopsyche spp	C	A	-	A	R
Hydropsyche betteni	R	C	-	A	C
Chimarra sp	R	A	-	A	-
Polycentropus sp	-	-	-	R	-
Rhyacophila fenestra	-	-	C	-	-
Neophylax oligius	-	-	R	-	-
Triaenodes ignitus	-	-	-	R	-
Ironoquia punctatissima	-	-	C	-	R
COLEOPTERA					
Ancyronyx variegata	-	-		R	-
Macronychus glabratus	-	-		-	R
Dubiraphia sp	-	-		R	-
Stenelmis crenata	R	-		C	-
Psephenus herricki	A	-		C	-
Helichus spp	-	-		R	-
Neoporus mellitus gr	-	-		R	-
Peltodytes sp					
ODONATA					
Argia spp	-	R		-	-
Calopteryx sp	-	C		R	R
Enallagma spp	R	C		A	-
Gomphus sp	-	R		R	-
Progomphus obscurus	-	A		-	-
Pachydiplax longipennis	R	-		-	-
Somatochlora sp	-	R		-	-
Tetragoneuria sp					

Site:	Bolin 4	Bolin 5	Morgan 1	Morgan 2	Little
MEGALOPTERA					
Sialis sp	-	-		R	-
DIPTERA: MISC.					
Antocha spp	R	-		R	-
Pseudolimnophila sp					
Tipula spp	R	C		C	C
Palpomyia complex	R	-		R	-
Cnephia mutata	C	-		-	-
Prosimulium spp	C	-		A	-
Simulium spp	A	C		A	R
DIPTERA: CHIRONOMIDA					
Ablabesmyia janta/parajanta	-	-		C	-
Ablabesmyia mallochi	A	A		A	A
Clinotanypus pinguis	-	-		R	-
Conchapelopia group	C	R		R	R
Procladius sp	R	-		C	R
Cardiocladius sp	-	C		-	-
Corynoneura spp	R	R		R	-
Thienemaniella spp	-	-		C	R
Cricotopus bicinctus	A	-		A	A
Diplocladius cultriger	R	R		R	-
Eukiefferiella claripennis gr	R	R		R	-
Hydrobaenus sp	-	C		C	-
Nanocladius spp	C	R		-	-
Orthocladius spp					
O. obumbratus	A	A		A	-
O. dorenus	A	A		A	-
O. oliveri	-	-		A	-
O. (Eud.) dubitatus	-	R		R	-
Parametriocnemus lundbecki	R	-		-	-
Paraphaenocladius sp	-	R		-	-
Rheocricotopus robacki	-	-		R	-
Tvetenia bavarica gr	C	-	-	-	-
Diamesa sp	C	-		-	-
Potthastia longimanus	R	R		C	C
Chironomus sp	C	-		-	-
Cryptochironomus spp		C		C	-
Dicrotendipes spp	R	-		-	R
Microtendipes spp	C	R		-	-
Paratendipes sp	R	-		R	-
Phaenopsectra spp	-	R		R	-
Phaenopsectra flavipes gr	C	-		-	C
Polypedilum convictum	C	R		A	A
Polypedilum illinoense	-	A		A	A
Polypedilum scalaenum	-	-		-	R
Stenochironomus sp	-	-		-	R
Tribelos sp	-	R		-	-
Rheotanytarsus spp	-	-		R	-
Tanytarsus spp	A	R		-	R

Site:	Bolin 4	Bolin 5	Morgan 1	Morgan 2	Little
OLIGOCHAETA					
Limnodrilus spp	C	C		-	R
Ilyodrilus templetoni	R	-		-	-
Spirosperma nikolsyii	R	-		-	-
Nais spp	-	R		R	-
Dero sp	C	-		-	-
Stylaria lacustris	R	R		C	-
Slavinia appendiculata	-	R		-	-
Haplotaxis gordioides	-	-		-	R
Ecclipidrilus spp	R	-		-	-
Lumbriculus variegatus	C	R		-	-
Megadriles	C	R		-	-
CRUSTACEA					
Crangonyx spp	C	-		C	R
Hyallela azteca	A	-		-	-
Caecidotea sp	R	R		C	-
Cambarus spp	C	C		A	C
Procambarus acutus	-	-		-	R
MOLLUSCA					
Elimia sp	C	-		-	-
Campeloma decisum	R	-		-	R
Physella sp	A	C		C	R
Helisoma anceps	C	R		R	-
Menetus dilatatus	-	-		C	-
Laevapex fuscus	-	-		R	-
Pisidium spp	-	R		R	R
Corbicula fluminea	-	R		-	-
OTHER					
Turbellaria					
Dugesia tigrina	R	-		C	-

Appendix 2. Benthic macroinvertebrates collected at small stream in Chapel Hill, March 2001. Streams are grouped by geologic region, then by size within each region. R = Rare, C = Commonn, A = Abundant.

	Slate Belt									Transition			Triassic	
Site[1]:	CFk	OF	Bk1	MR	Tan	Cole	Jolly	Libr	UTB	Batt	Wils	Fan	Bk2	Dry
Width (m):	3	2.5	2	2	2	1.5	1	1	<1	2	2	1.5	4.5	1
EPHEMEROPTERA														
Plauditus dubius gr	-	-	-	-	-	-	R	-	-	-	A	R	-	-
Centroptilum triangulifer	-	-	-	-	-	-	R	-	-	-	-	-	-	-
Acentrella ampla	-	-	-	-	-	-	-	-	-	-	R	-	-	-
Siphlonurus sp	-	-	-	-	-	-	-	-	-	-	R	C	-	-
Caenis spp	-	-	-	-	-	-	-	-	-	-	C	R	-	-
Ephemerella dorothea	-	-	-	-	-	-	-	-	-	-	A	A	-	-
Eurylophella spp	-	-	-	-	-	-	-	-	R	-	-	-	-	R
Ameletus lineatus	-	-	-	-	-	-	C	R	C	-	C	-	-	-
Paraleptophlebia sp	-	-	-	-	-	-	-	-	C	-	R	-	-	-
Maccaffertium modestum	-	-	-	-	-	C	-	-	-	-	R	A	-	-
Stenonema femoratum	-	-	-	-	-	R	-	-	-	-	-	-	-	-
PLECOPTERA														
Perlesta sp	-	-	-	-	-	-	A	-	R	-	R	R	-	-
Haploperla brevis	-	-	-	-	-	A	-	R	-	-	R	C	-	-
Isoperla namata gr	-	-	-	-	-	-	-	-	-	-	C	C	-	-
Amphinemura sp	-	-	-	-	-	-	A	R	A	-	A	A	R	-
TRICHOPTERA														
Cheumatopsyche spp	A	-	-	C	A	C	-	R	-	C	R	R	-	-
Hydropsyche betteni	-	-	-	A	R	A	-	-	-	C	R	-	-	-
Diplectrona modesta	-	-	-	R	-	R	-	R	R	-	C	R	-	-
Chimarra sp	-	-	C	-	-	-	-	-	-	C	R	R	-	-
Rhyacophila fenestra	-	-	-		-	-	A	-	R	-	-	A	-	-
Neophylax oligius	-	-	-	-	-	A	-	-	-	-	-	-	-	-
Neophylax consimils	-	-	-	-	-	-	R	-	A	-	-	-	-	-
Psilotreta sp	-	R	-	-	-	-	-	-	-	-	-	-	-	-
Ironoquia punctatissima	C	-	R	-	-	R	A	R	C	C	C	A	-	A
Lepidostoma sp	-	-	-	-	-	R	-	-	-	-	-	-	-	-
COLEOPTERA														
Dubiraphia sp	-	-	-	-	-	-	-	-	-	-	R	-	-	-
Stenelmis crenata	-	R	C	C	-	R	C	R	-	C	R	-	-	-
Microcycloepus pusillus														
Psephenus herricki	-	-	-	-	R	C	-	-	R	R	C	-	-	-
Ectopria nervosa	-	-	-	R	-	-	-	-	R	-	-	-	-	-
Helichus spp	-	-	-	-	-	R	R	R	-	-	-	C	-	C
Neoporus spp	-	-	-	-	-	-	-	R	-	-	R	-	-	-
Copelatus sp	-	-	-	-	-	-	-	-	-	-	-	R	-	-
ODONATA														
Argia spp	-	-	-	A	-	-	-	-	-	-	C	-	-	-
Calopteryx sp	-	-	-	R	-	C	R	R	-	-	-	R	-	-
Enallagma spp	-	-	-	-	-	-	-	-	-	-	R	-	-	-
Ischnura sp	-	-	-	-	-	-	-	-	-	-	-	-	C	-
Cordulegaster sp	-	R	-	-	-	-	-	-	-	-	-	-	-	-
Gomphus sp	-	-	-	-	-	-	-	-	-	-	R	-	-	-
Stylogomphus albistylus	-	-	-	-	-	R	-	-	-	-	-	-	-	-
Pachydiplax longipennis	-	-	-	-	-	-	-	-	-	-	-	-	R	-
Somatochlora sp	-	R	-	-	-	R	C	-	R	-	R	-	-	-
Tetragoneuria sp	-	-	-	-	-	-	-	-	-	-	-	-	R	-
Boyeria vinosa	-	-	-	-	-	-	-	-	-	-	-	R	-	-
MEGALOPTERA														
Nigronia serricornis	-	R	-	-	-	-	-	-	-	-	-	-	-	-

	Slate Belt									Transition			Triassic	
	CFk	OF	Bk1	MR	Tan	Cole	Jolly	Libr	UTB	Batt	Wils	Fan	Bk2	Dry
DIPTERA: MISC.														
Dixella indiana	-	-	-	-	-	-	R	-	-	-	-	-	-	-
Antocha spp	-	-	-	-	-	R	-	-	-	-	-	-	-	-
Limonia sp	-	-	-	R	-	-	-	-	-	-	-	-	-	-
Tipula sp	-	R	-	C	-	-	R	C	R	A	-	R	-	R
Palpomyia complex	-	C	R	-	-	-	R	-	-	-	-	-	-	-
Cnephia mutata	-	-	-	-	-	-	R	-	-	-	A	R	-	-
Prosimulium spp	-	-	-	-	-	-	-	-	-	-	R	-	-	-
Simulium spp	R	-	-	-	-	R	C	-	-	-	C	C	-	-
DIPTERA: CHIRONOMIDA														
Ablabesmyia mallochi	R	-	-	-	-	R	-	-	-	-	C	R	A	R
Conchapelopia group	-	R	-	R	-	-	R	R	-	-	-	R	C	-
Natarsia sp	-	-	-	-	-	-	-	-	-	-	-	-	-	A
Paramerina sp	-	-	-	-	-	R	-	-	-	-	-	-	-	-
Zavrelimyia sp	-	R	-	R	-	-	R	-	R	R	-	-	-	-
Corynoneura spp	-	-	-	-	-	-	C	R	-	-	-	-	R	-
Cricotopus bicinctus	C	-	-	-	-	-	-	-	-	-	A	-	-	R
Diplocladius cultriger	A	R	-	-	R	C	-	-	-	A	-	-	-	-
Eukiefferiella claripennis gr	-	-	-	-	-	R	-	-	-	R	-	R	R	-
Eukiefferiella brevicalcar gr	-	-	-	-	-	-	-	-	-	-	-	R	-	-
Hydrobaenus sp	-	A	A	-	-	-	A	-	C	-	-	C	-	-
Nanocladius sp	-	-	R	-	-	-	-	-	-	-	-	-	C	R
Orthocladius spp														
O. obumbratus	A	R	A	A	A	-	-	R	R	-	A	A	C	-
O. dorenus	A	-	-	R	A	A	A	-	-	A	A	-	-	-
O. robacki	-	C	-	-	-	-	A	-	-	-	A	A	-	-
O. (Eud.) dubitatus	C	-	-	-	-	-	-	-	-	-	-	-	-	-
Paraphaenocladius sp	R	-	-	-	-	R	-	R	-	R	-	-	-	-
Parametriocnemus lundbecki	-	R	R	R	-	-	C	-	-	-	C	-	-	-
Rheocricotopus robacki	-	-	-	-	-	-	-	-	-	-	R	C	-	-
Symposiocladius lignicola	-	-	-	-	-	-	-	-	-	-	-	R	-	-
Diamesa sp	C	-	R	-	-	R	-	-	-	-	-	-	-	-
Potthastia longimanus	C	-	-	-	-	-	-	-	-	-	R	-	-	-
Cryptochironomus spp	-	-	-	-	-	-	-	-	-	-	-	-	C	-
Dicrotendipes spp	-	-	-	-	-	-	-	-	-	-	-	-	R	-
Glyptotendipes sp	-	-	-	-	-	-	-	-	-	-	-	-	R	-
Microtendipes spp	-	-	R	-	-	-	-	-	-	-	-	-	-	-
Paratendipes sp	-	R	-	-	-	-	-	-	-	-	-	-	-	-
Phaenopsectra spp	-	-	-	-	-	-	-	-	-	-	-	-	R	-
Phaenopsectra flavipes gr	-	-	-	-	-	-	R	-	-	-	R	R	-	-
Polypedilum convictum	-	R	-	-	-	-	-	-	-	-	-	-	-	-
Polypedilum aviceps	C	-	-	-	-	C	-	-	-	-	C	A	-	-
Polypedilum halterale	-	R	-	-	-	-	-	-	-	-	-	-	-	-
Polypedilum illinoense	-	-	-	-	-	-	-	-	-	-	-	-	A	-
Polypedilum fallax	-	-	R	-	-	-	-	-	-	-	-	-	R	-
Polypedilum scalaenum	-	-	R	-	-	-	-	-	-	-	-	-	A	-
Tribelos sp	-	-	-	-	-	-	-	-	-	-	-	-	R	-
Rheotanytarsus spp	-	-	-	-	-	-	-	-	-	-	-	C	-	-
Tanytarsus spp	-	-	C	-	-	-	-	-	-	-	C	-	C	-

	Slate Belt									Transition			Triassic	
	CFk	OF	Bk1	MR	Tan	Cole	Jolly	Libr	UTB	Batt	Wils	Fan	Bk2	Dry
OLIGOCHAETA														
Limnodrilus spp	-	-	-	-	-	-	-	-	-	R	-	-	R	-
Ilyodrilus templetoni	-	-	-	C	-	R	R	R	-	-	-	-	C	-
Spirosperma nikolsyii	-	-	-	-	-	-	-	-	-	-	-	-	-	R
Nais spp	-	R	C	C	-	-	C	R	-	-	-	-	A	C
Dero sp	-	-	-	-	-	-	-	-	-	-	-	-	C	-
Slavina appendiculata	-	-	-	R	-	-	-	-	-	-	-	-	-	-
Stylaria lacustris	-	-	-	-	-	-	-	-	-	-	-	-	A	-
Haplotaxis gordioides	-	R	-	R	-	-	-	-	-	-	-	-	-	-
Ecclipidrilus spp	R	-	R	R	-	-	R	C	R	-	-	-	R	-
Megadriles	-	-	-	R	-	R	-	C	R	-	-	-	-	-
Enchytraeidae	-	-	-	-	-	-	R	-	-	-	-	-	-	-
CRUSTACEA														
Crangonyx spp	A	R	A	-	-	-	A	R	A	R	-	-	-	A
Caecidotea sp	C	R	A	-	-	-	A	-	A	-	-	-	-	A
Cambarus sp	-	C	C	R	-	R	R	R	C	-	C	C	-	-
Procambarus acutus	-	-	-	-	-	-	-	-	-	-	-	-	R	-
MOLLUSCA														
Elimia sp	-	-	-	-	-	A	-	A	-	-	-	A	-	-
Physella sp	A	C	-	R	A	-	-	-	-	C	R	-	R	A
Menetus dilatatus	R	R	C	R	-	-	-	-	-	-	-	-	-	-
Ferrissia sp	-	-	R	-	-	R	-	R	-	-	-	-	-	-
Pisidium spp	-	-	-	-	-	-	-	-	-	-	-	-	R	-
OTHER														
Prostoma graecens	R	R	-	-	-	-	-	R	-	-	-	-	-	-
Dugesia tigrina	-	-	R	-	-	-	-	-	-	R	R	-	R	R

[1]Site abbreviations: CFk = Cedar Fork, OF = Old Field Creek, Bk1 = Booker Cr #1, MR = Mill Race Branch, Tan = Tanyard Branch, Coles = Cole's Spring Branch, Jolly = Jolly Branch, Libr = Library Branch, UTB = Unnamed tributary Bolin Creek, Batt = Battle Branch, Wils = Wilson Creek, Fan = Fan Branch, Bk2 = Booker Creek #2, Dry = Dry Creek

Appendix 3. Chapel Hill Large Stream Sites, March 2011

Bolin Creek sites are numbered from most upstream (Site 1) to most downstream (Site 5). Sites 1-3 are in Carrboro and are not included in this report. Site 4 was moved from Estes Drive (at the town boundary) to Village Drive in Chapel Hill. Bolin Creek sites are largely in the Slate Belt geologic region and are expected to have a very rocky stream bottom. Little Creek, however, is in the Triassic Basin and would be expected to have a sand/clay stream bottom. The lower Bolin Creek site may have characteristics of both ecoregions.

<u>Bolin Creek 4 (Village Drive)</u>. This portion of Bolin Creek is in a largely residential area; the catchment also drains most of Carrboro. The substrate was largely boulder and rubble, but some sand was being deposited in pools.

Bolin Creek Site 4 (Village Dr), March 2011.

There were abundant growths of filamentous algae at this site, which may have interfered with the growth of macroinvertebrates. This algae also tended to homogenize all microhabitats.

<u>Bolin Creek 5 (Franklin St)</u>. Bolin Creek has good rocky substrate near the bridge, but the stream bottom is mostly sand further upstream. A greenway path parallels Bolin Creek in this area.

Bolin Creek Site 5 (Franklin) , March 2010.

This site drains a heavily developed catchment, including the downtown areas of both Carrboro and Chapel Hill.

<u>Morgan Creek 1 (NC 54)</u>. Morgan Creek has been used as a reference site for Carrboro surveys, although this stream is freaquently affected by droughts. Prior surveys by the NC Division of Water Quality generally produced a Good or Excellent bioclassification for this site.

Morgan Cr Site 1 (NC 54), March 2011.

This catchment has a largely rural character, although the amount of residential land use has been increasing. Habitat quality, stream width and substrate composition are similar to Bolin Creek.

Morgan Creek 2 (Ashe St). This site is located near the Arboretum and it is downstream of University Lake. Although this part of Morgan Creek is located in a residential area, there is a forested buffer zone along most of the stream.

There was good rocky substrate in the riffles, but pools areas were being filled-in by sand deposition. There were very abundant growths of bright green filamentous algae at this site, often forming floating mats along the banks.

Morgan Creek Site 2 (Ashe), March 2011.

Algae at Morgan Creek Site 2 (Ashe), March 2011.

Little Creek. Samples were taken near Meadowmont lane, following the greenway trail 200 meters upstream. Little Creek is located in the Triassic geological region, and runs through an area of sand and clay. The surrounding area is very swampy, with many small seeps running through the floodplain.

This floodplain appeared to be excellent habitat for birds and other wildlife.

Little Creek, March 2011.

There were no rocky riffles, but snags and leaf-packs offered good habitat for macroinvertebrates.

Appendix 4. Chapel Hill Small Stream Sites, March 2011

These streams are grouped into 3 categories, according to local geology. Slate Belt streams are expected to have a very rocky substrate and are located in the western part of Chapel Hill. Triassic streams naturally have a stream bottom of sand and clay and are located in the eastern part of Chapel Hill. Some "Transition" stream share characters of both geologic zone, although the substrate is largely sand and gravel. Within each of these three groups, streams have been sorted by size (as measured by stream width). Slate Belt stream usually have a boulder-rubble substrate, although the more developed area have sandy pools and/or embedded riffles. Triassic site are largely sand and clay, with a very swampy floodplain. The Transitional sites are very sandy, with gravel/rubble riffles.

Most sites had unusually abundant growths of filamentous algae, which may have been stimulated by rising temperatures and/or low flow rates. We would expect less algae at other times of the year, or in a year with greater scour. Inputs of nutrients (nonpoint runoff or leaking sewers) may have exacerbated this problem.

SLATE BELT STREAMS

Cedar Fork. Cedar Fork is located in the northern section of Chapel Hill; it is one of the largest tributaries of Booker Creek (3 meters wide). The stream was sampled off Brookview Street, just above a small lake.

Cedar Fork, March 2011.

The surrounding land is an older residential area with large lots. Many of the houses, however, are placed very close to the stream. The substrate was rocky, but there were very abundant growths of filamentous algae in March.

Old Field Creek. Old Field Creek was sampled north of town, near the Chapel Hill Operations Center. The surrounding area is largely forested, but there is some development (including a landfill) further upstream.

Old Field Creek, March 2011.

The stream is very rocky (often having extensive areas of bedrock), but there was a layer of silt and algae over most of the stream bottom. The composition of the fauna suggested that this stream is intermittent.

Booker Creek 1 (Above MLK Blvd). Booker Creek had a heavy layer of filamentous algae over all surfaces in March 2011. The surrounding area provided a forested buffer next to the stream, but it drains a largely residential area.

Booker Creek Site 1 (MLK) March 2011.

Mill Race Branch. Mill Race Branch is located in a largely residential area; it was sampled off Bolinwood Drive just above its confluence with Bolin Creek. The substrate was largely gravel and sand, but with small rocky riffles areas.

Mill Race Branch, March 2011.

Tanyard Branch. Tanyard Branch is a small stream (2 meters wide) that was sampled near the end of Carver Street. There is a forested riparian zone, but the stream runs through a heavily developed residential area. The stream substrate was rocky, but 40-80% embedded with sand.

Tanyard Branch, March 2011

Cole Springs Branch. Cole Springs Branch was sampled near the end of Cedar Drive. This stream drains an older residential area with large lots; the area sampled was largely forest. This rocky stream had excellent habitat for aquatic fauna.

Cole Springs Branch, March 2011.

Jolly Branch near SR 1777 (just downstream of Bolin Creek 3). This site was accessed by walking about 100 meters downstream of SR 1777 (Homestead), crossing Bolin Creek, and going about 30 meters upstream on Jolly Branch. This small stream (1 meter wide) had good rocky habitat, but showed severe bank erosion in many places.

The surrounding area was largely forested, although there are residential areas further upstream. The aquatic life at Jolly Branch indicates that it may stop flowing (or go dry) during drought periods.

Jolly Branch, March 2011.

Library Branch. Library Branch was sampled downstream of Library Road. This very small stream (1 meter wide) had poor habitat due to the largely sand substrate. The abundance of the snail (*Elimia*), however, suggests that this stream does not dry up during drought periods.

Library Branch, March 2011.

UT Bolin Creek. This very small stream (<1 meter wide) was sampled at the end of Severin Street. It is located in an older residential area with a forested buffer zone adjacent to the stream. The substrate was primarily boulder/rubble, with barely perceptible flow that may be largely subsurface. The fauna was very sparse, but dominated by intolerant species.

UT Bolin Creek, March 2011.

TRANSITION STREAMS

Battle Branch. Battle Branch was sampled near Glendale Road. This stream is located in an older residential area, with forest and hiking paths next to the stream. The substrate is largely sand and gravel, with occasional rubble riffles. Battle Branch was entrenched with severely eroding banks.

Battle Branch, March 2011.

Wilson Creek. Wilson Creek was sampled at Arlen Park Drive, in a new residential area. The upstream area, however, is an older residential area (mostly forest) with large lot sizes.

Wilson Creek, March 2011.

Although this small stream was very sandy (95 % gravel, sand and silt), it supported a surprisingly diverse invertebrate community. Filamentous algae were very abundant at Wilson Creek.

<u>Fan Branch</u>. Fan Branch also was sampled in newer high-density residential development (at Parkview Crescent), but the upstream area is comprised of an older residential development with large lot sizes.

Like Wilson Creek, this is a very sandy stream (100% sand and gravel), but supports a surprisingly diverse invertebrate community. Both Wilson Creek and Fan Branch appears to be perennial streams based on the abundance of the snail *Elimia* and the presence of filter-feeding caddsiflies.

Fan Branch, March 2011.

TRIASSIC STREAMS

<u>Booker Creek 2 (Willow Drive)</u>. This segment of Willow drains a largely residential catchment. The stream appears to have been channelized at some time, with a very entrenched channel. The substrate is entirely sand and clay, but was mostly covered by a layer of filamentous algae.

Booker Creek 2, March 2011.

<u>Dry Creek</u>. This very small stream (1 meter wide) was sampled upstream of Erwin Road. The substrate was mostly clay/silt, likely due to the Triassic Basin geology. Roots and logs were the most important habitat for the aquatic fauna.

Dry Creek, March 2011.

The stream was entrenched near the road, but was more swamp-like further upstream. The riparian zone had many small seeps.