Appendix A
The Duration of flow in Headwater Streams in North Carolina
NC Division of Water Quality

Some research has been done in North Carolina concerning the duration of flow in small, headwater streams in the state, which may be useful in the context of the recent Corps/EPA guidance on the Rapanos case. The most pertinent research was done by Ms. Nekesha Williams for her M.S. degree at NC State University (Williams 2005). The following description was taken from that thesis and the data presented therein. These data show that seven of eight intermittent streams that have long term monitoring data in the piedmont region of North Carolina have continuous flow for at least three months during the year.

Williams (2005) studied eight headwater streams in the central piedmont of North Carolina over an 18 month period from May 2003 to December 2004. The eight streams were in and near Raleigh, NC in small, forested watersheds in the Northern Outer Piedmont Level IV ecoregion (Griffith, et al. 2002). She collected flow data weekly at these eight streams with several observations at each stream in ephemeral, intermittent and perennial reaches. This work was done in conjunction with an aquatic macrobenthos study (see Appendix B) as well as ratings of the streams using DWQ's stream evaluation method (NC Division of Water Quality. 2005) to ensure that the streams were ephemeral, intermittent or perennial. Williams measured the depth to water table, depth of water flowing in the channel (if any) as well as depth of water in the nearest pool, riffle or run.

The following table was generated from the figures presented in her thesis (Table 1) in order to address the question whether ephemeral, intermittent and small perennial streams in this area have continuous flow for at least three months during the year. From these data, it is clear that ephemeral channels do not have three months of continuous flow, intermittent channels do have continuous flow for at least three months (usually from January to April) and small perennial streams do have continuous flow for at least three months (usually year-long). Therefore, intermittent streams in this part of the piedmont of NC meet the criteria in the Rapanos guidance for having continuous flow for at least three consecutive months and thereby meet a definition in that guidance as "relatively permanent water".

Table 1. Length of flow regimes in riffle/run segments in headwater streams in Piedmont North Carolina. (Data from Williams 2005; Data were collected from eight streams during the period May 2003 to December 2004)

	Flow regime		
Site name	**Ephemeral**	**Intermittent**	**Perennial**
Schenck	N	Y (Dec - April)	Y
Umstead 1	N	Y (all year)	Y
Umstead 2	N	Y (Jan - May)	Y
Falls 1	N	Y (Jan - April)	Y
Falls 2	N	N	Y
Falls 3	N	n/a [1]	Y
Falls 4	N	Y (Jan - April)	Y
Falls 5	N	Y (Dec - June)	Y

Y = flow occurred for at least three months during the year
N = flow occurred for a period less than three months
[1] No intermittent segment

References

Griffith, et. al. 2002. Ecoregions of North and South Carolina. Reston, VA. United States Geological Survey.

N.C. Division of Water Quality. 2005. Identification methods for the origins of intermittent and perennial streams. Version 3.1. Raleigh, NC.

Williams, N. B. 2005. Relationship between headwater streams and general macroinvertebrate abundance in piedmont region, North Carolina. M.S. Thesis, Natural Resources, Hydrology. North Carolina State University.

Appendix A.
Biological justification for significant nexus in streams in North Carolina

October 25, 2007

What is a stream?

The U.S. Army Corps of Engineers Jurisdictional Determination Form Instructional Guidebook on page 7 reads that the "agencies will assert jurisdiction over the following categories of water bodies: [Traditionally Navigable Waters] TNWs; all wetlands adjacent to TNWs; non-navigable tributaries of TNWs that are relatively permanent (i.e., tributaries that typically flow year-round or have continuous flow at least seasonally)." The definition is not clear about how much stream flow counts as flowing (e.g. 1 m/s, visible, interstitial) and how long of a flow duration is "seasonal". The second question is answered parenthetically on the bottom of page 6 of Appendix B (the JD Form) as "e.g. typically three months each year." This presumably would be the winter, when flows are at their highest. For the purpose of this discussion it will be assumed that the term "flow" means any visible flow, rather than any particular velocity, since none was stated in the guidance.

While a more definitive study of stream flow duration can be made using the data in Williams (2005), field notes from our studies of 18 headwater streams in the mountain, piedmont and coastal plain suggest that stream segments that flow for extended periods (very likely during the entire three month winter season) average 20 points (range 3-29 points), using the DWQ Stream Classification Form. It is important to note that using this form, 19 points is the lowest score for a stream to be classified as intermittent. Therefore by the definition of a stream in the Jurisdiction Determination Form (Appendix B), the Corps defines as Relatively Permanent Waters (RPW), all streams except ephemeral channels and the most marginal of intermittent systems, and may now (if they so choose) assert jurisdiction over them.

Significant Nexus Determination

On page 15 of the JD Instruction Guidebook, a Clean Water Act (CWA) jurisdiction determination can be made using the following logic: "The significant nexus evaluation will include …A consideration of ecologic factors such as: …-the ability of the tributary and its adjacent wetlands (if any) to provide aquatic habitat that supports biota of a traditional navigable water." In other words, if a non-navigable stream (or wetland) contains biota that also inhabit Traditionally Navigable Waters, a sufficiently significant nexus may exist to call that water jurisdictional under the CWA.

Table 3 is a list of the 800 taxa collected in the freshwater TNWs in the State as identified by Tom Welborn (USACE), which were primarily the mainstems of the major rivers in the State (Chowan, Roanoke, Tar/Pamlico, Neuse, Cape Fear, French Broad) and some larger tributaries. Comparing this list with taxa collected from ephemeral, intermittent and perennial portions of headwater streams across the State finds that at least one, and usually several, of the taxa found in TNW's are found in all headwater perennial and intermittent reaches and nearly 2/3 of the ephemeral reaches. Based on this information, it appears that most headwater tributaries support biota found in TNWs, that on this basis a Significant Nexus would exist between these tributaries and their TNWs, and therefore the Corps may assert jurisdiction over them.

Biological overview of headwater streams

Streams appear to form in North Carolina in three different ways. They either originate from a hillside as an intermittent or perennial stream, they form when enough surface runoff erodes a channel to concentrate and convey the water or they form as an outlet from a wetland. Spring-fed streams tend to have little to no ephemeral or intermittent segments, whereas streams starting in wetlands have a small ephemeral reach, but a very long intermittent reach. Finally, while streams forming from overland flow can have short to long ephemeral reaches and short intermittent reaches (except for streams in the Triassic basin and slate belt, where intermittent reaches tend to be longer due to different geology). While all three methods occur in all three major ecoregions in the State, in general, mountain streams tend to start from springs, piedmont streams tend to start as overland flow concentration and unditched coastal plain streams tend to start as outlets from wetlands. It is unclear if ecoregion (geology, slope and groundwater levels) or headwater type drives the size of the watershed required to form a stream (Winter 2007).

Headwater streams deliver water, nutrients, carbon (organic and inorganic, dissolved and particulate), invertebrates (terrestrial and aquatic) and wood (Coarse Particualte Organic Matter – CPOM) to downstream aquatic systems (Triska et. al. 2007; Wipfli et. al. 2007). The aquatic life in headwater streams exists along a gradient (Boulton and Lake 1992; del Rosario and Resh 2000; Feminella 1996), which is in keeping with the way streams, and their ecology, change on a large scale (Vannote et al, 1980). In North Carolina streams (Eaton and Penrose, unpublished data), most of the taxa collected in the channels that only receive stormwater runoff (ephemeral), are terrestrial in origin (ants, spiders, millipedes, earthworms, earwigs, semi-aquatic midges, etc). In the portion of the stream that has water (and possibly flow) for several months but is also dry for a period (intermittent), aquatic taxa with short life spans can be found (amphipods, isopods, dytiscid beetles, true bugs, midges and other fly larvae, winter stoneflies, etc). In the section of the stream with water, and when you go far enough downstream, year round flow, (perennial) all of the taxa collected in the intermittent can be found plus species that require water for their entire one year larval life spans (mayflies, caddisflies, stoneflies, dragon and damselflies, riffle beetles and water pennies, mollusks, salamanders, fish etc). Table 1 summarizes the major taxa or groups in each type of stream.

The progression of the taxa occurrence gradient is fairly predictable; where that gradient lies on the landscape varies with rainfall. In wet years the gradient moves uphill and in dry years it moves downhill. This is demonstrated by Figure 1, which shows how the taxa richness changes in the ephemeral and intermittent segments between 2002, a record dry year, and 2003, a wetter-than-average year. In summer 2002, both ephemeral and intermittent - and some upper perennial - segments were dry. There was very little, but still some (3-6 taxa), aquatic life compared to the perennial segments (24 taxa). In summer 2003, a year after the drought ended, water filled the intermittent channels, and even a few of the lower ephemeral. As a result the number of taxa in intermittent segments that had been wet for a year (29) were similar to taxa richness in perennial segments in summer 2002 (24) and 2003 (27).

Intermittent stream segments in both the Piedmont and the Mountains have about half of the aquatic taxa and 57% of the aquatic abundance of small perennial streams (Table 2). Ephemeral reaches only support approximately 10% of the aquatic life of the perennial stream. This could be due to the effects of drying, reduced habitat heterogeneity, or both.

Table1. Taxa usually found in each stream type.

Terrestrial Taxa	***Intermittent taxa***	***Intermittent or Perennial Taxa***	***Perennial Taxa***
Terrestrial Diptera (flies)	Diptera - Dasyhela	Crayfish	Ephemeropetera
Terrestrial Beetles	Helichus larvae	Sphaerid Clams	Plecoptera (NOT Winter)
Terrestrial Snails		Amphipods	Trichoptera
Terrestrial Isopods (pillbugs)		Isopods	Aquatic Beetles
Spiders		Dytiscid Beetles	Helichus, Elmidae
Centipedes		Winter Stoneflies (Nemouridae	Anchytarsus bicolor
Millipedes		Capnidae, Taeniopterygidae	Megaloptera
Termites		Perennial taxa (Young of Year)	Odonata
Springtails		Most Diptera	Salamanders
Ants		Mosquitofish (Gambusia)	Ranid Tadpoles
Chironomidae - Georthocladius			Diptera - Ptychopteridae
Chironomidae - Smittia			Shrimp
Oligochaeta - Terrestrial			Fish (except Gambusia)
Oligochaeta - Enchytraeidae			

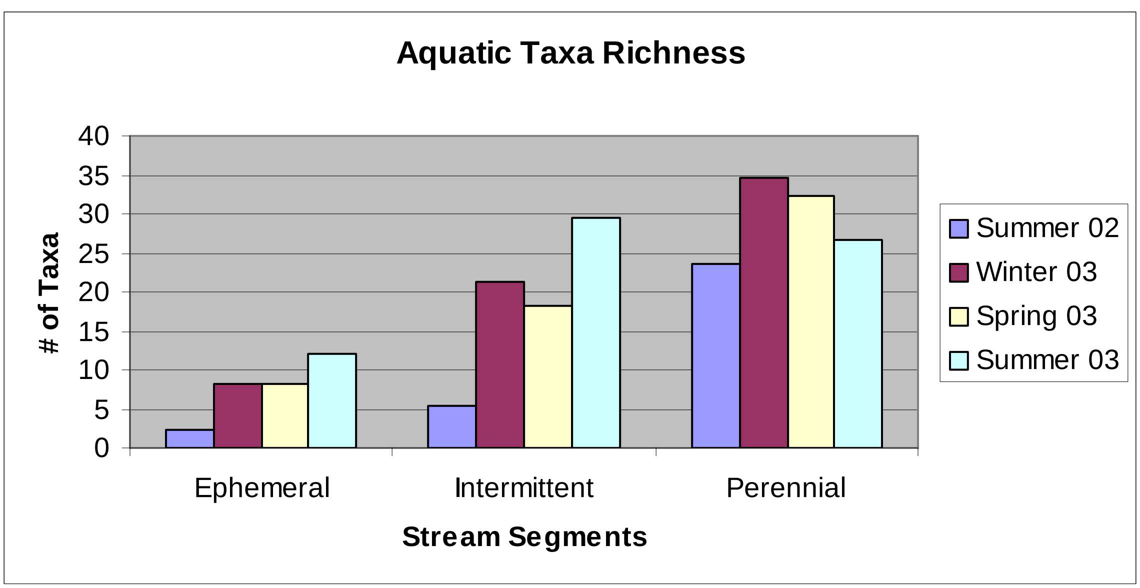


Figure 1. Aquatic Taxa Richness in Ephemeral, Intermittent, and Perennial Stream Segments.

Table 2. Mean Taxa Richness and Abundance in Ephemeral, Intermittent and Perennial reaches in the Mountains and Piedmont.

	Aquatic Taxa		Aquatic Abundance	
Flow Regime	Piedmont	Mountains	Piedmont	Mountains
Ephemeral	4	3	34	6
Intermittent	16	15	162	239
Perennial	20	32	286	402

Streams arising in the Piedmont and Mountains show a similar pattern, but with increased aquatic life in mountain streams, except in ephemeral reaches. The main differences were how quickly the streams turned perennial, and how much aquatic life the streams supported. Piedmont perennial stream segments supported 190-450 aquatic organisms from 22-45 species. The mountain stream segments supported 200-1200 aquatic organisms from 22-70 species. These values are below those found by Wallace who collected 145 genera over the course of a decade of sampling headwater mountain streams at Coweeta Hydrologic Laboratory, Coweeta, NC (Wallace et. al.1991; Lugthart and Wallace 1992; Wallace et. al. 1999), though a part of this difference is certainly due to the extended sampling duration and pristine location of Wallace's sampling.

References

Boulton, A.J. and P.S. Lake. 1992. The ecology of two intermittent streams in Victoria, Australia. II.Comparisons of faunal composition between habitats, river and years. Freshwater Biology 27: 99-121.

Del Rosario, R.B. and V.H. Resh. 2000. Invertebrates in intermittent and perennnial streams: is the hyporheic zone a refuge from drying? J. N. Am Benthol. Soc. 19(4): 680-696.

Feminella, J.W. 1996. Comparison of benthic macroinvertebrate assemblages in small streams along a gradient of flow permanence. J. N. Am. Benthol. Soc. 15(4): 651-669.

Lugthart, J.G. and J. B. Wallace. 1992. Effects of disturbance on benthic functional structure and production in mountain streams. J. N Am. Benthol. Soc. 11:138-164.

Triska, F. J., J. H. Duff, R. W. Sheibley, A. P. Jackman and R. J. Avanzino. 2007. DIN retention-transport through four hydrologically connected zones in a headwater catchment of the upper Mississippi River. . J. Amer. Water Resources Assoc. 43(1): 60-71.

Vannote, RL; Minshall, GW; Cummins, KW; Sedell, JR; Cushing, CE. 1980. The River Continuum Concept. Canadian Journal of Fisheries and Aquatic Sciences 37(1): 130-137.

Wallace, J. B., A. D. Huryn and G. J. Lugthart. 1991. Colonization of a headwater stream during three years of seasonal insecticidal application. Hydrobiologia, 211:65-76

Wallace, J.B., S.L. Eggert, J.L. Meyer and J.R. Webster. 1999. Effects of resource limitation on a detrital-based ecosystem. Ecological Monographs 69:409-442.

Williams, N. B. 2005. Relationship between flow regime and aquatic macroinvertebrate abundance in headwater streams in the Piedmont Region of North Carolina. Masters Thesis. North Carolina State University. 173pp.

Winter, T. C. 2007. The role of ground water in generating streamflow in headwater areas and in maintaining base flow. J. Amer. Water Resources Assoc. 43(1): 15-25.

Wipfli, M.S., J.S. Richardson and R.J. Naiman. 2007. Ecological linkages between headwaters and downstream ecosystems: transport of organic matter, invertebrates and wood down headwater channels. J. Amer. Water Resources Assoc. 43(1): 72-85.

Table 3. List of Taxa collected from Traditionally Navigable Waters (TNW) in North Carolina.

EPHEMEROPTERA

Acerpenna pygmaea
Acentrella ampla
Acentrella alachua
Acentrella turbida
Acentrella spp
Baetis flavistriga
Baetis intercalaris
Baetis pluto
Baetis tricaudatus
Baetis spp
Callibaetis spp
Centroptilum triangulifer
Centroptilum spp
Cloeon spp
Heterocloeon curiosum
Heterocloeon petersi
Heterocloeon spp
Paracloeodes spp
Plauditus dubius gr
Plauditus punctiventris
Procloeon spp
Procloeon appalachia
Procloeon viridoculare
Pseudocentroptiloides usa
Pseudocloeon dardanum
Pseudocloeon ephippiatum
Pseudocloeon frondale
Pseudocloeon propinquum
Pseudocloeon spp
Baetisca carolina
Baetisca gibbera
Baetisca laurentina
Baetisca obesa
Baetisca spp
Amercaenis sp
Brachycercus spp
Caenis spp
Attenella attenuate
Dannella simplex
Drunella allegheniensis
Drunella cornutella
Drunella tuberculata
Drunella walkeri
Ephemerella argo
Ephemerella dorothea
Ephemerella invaria
Eurylophella bicolor
Eurylophella doris
Eurylophella prudentalis
Eurylophella spp
Eurylophella temporalis
Eurylophella verisimilis
Serratella carolina
Serratella deficiens
Serratella serrata
Serratella serratoides
Hexagenia spp
Epeorus dispar
Epeorus pleuralis
Epeorus rubidus
Epeorus spp
Heptagenia marginalis
Heptagenia pulla
Heptagenia spp
Leucrocuta aphrodite
Leucrocuta spp
Macdunnoa brunnea
Rhithrogena spp
Stenacron interpunctatum
Stenacron pallidum
Stenonema carlsoni
Stenonema exiguum
Stenonema integrum
Stenonema ithaca
Stenonema mediopunctatum
Stenonema merririvulanum
Stenonema modestum
Stenonema spp
Stenonema pudicum
Stenonema pulchellum
Stenonema terminatum
Leptophlebia bradleyi

Leptophlebia intermedia
Leptophlebia spp
Paraleptophlebia spp
Siphloplecton spp
Neoephemera spp
Neoephemera youngi
Isonychia spp
Ephoron leukon
Ameletus lineatus
Leptohyphes dolani
Leptohyphes spp
Tricorythodes robacki
Tricorythodes spp

PLECOPTERA

Allocapnia spp
Haploperla brevis
Suwallia spp
Sweltsa spp
Leuctra spp
Amphinemura spp
Prostoia sp
Acroneuria abnormis
Acroneuria arenosa
Acroneuria mela
Agnetina annulipes
Agnetina capitata
Agnetina flavescens
Paragnetina fumosa
Paragnetina ichusa
Paragnetina immarginata
Paragnetina kansensis
Perlesta placida
Perlesta spp
Perlinella drymo
Perlinella spp
Clioperla clio
Helopicus subvarians
Isoperla bilineata
Isoperla holochlora
Isoperla namata (gr)
Isoperla orata
Malirekus hastatus
Pteronarcys dorsata
Pteronarcys spp
Strophopteryx spp
Taeniopteryx spp

TRICHOPTERA

Brachycentrus appalachia
Brachycentrus incanus
Brachycentrus lateralis
Brachycentrus nigrosoma
Brachycentrus numerosus
Brachycentrus spinae
Brachycentrus spp
Micrasema bennetti
Micrasema charonis
Micrasema watauga
Phylocentropus spp
Glossosoma spp
Culoptila spp
Protoptila spp
Goera spp
Helicopsyche borealis
Arctopsyche irrorata
Cheumatopsyche spp
Hydropsyche betteni
Hydropsyche decalda
Hydropsyche demora
Hydropsyche incommode
Hydropsyche phalerata
Hydropsyche mississippiensis
Hydropsyche rossi
Hydropsyche scalaris
Hydropsyche venularis
Macrostemum spp
Symphitopsyche bronta
Symphitopsyche morosa
Symphitopsyche sparna
Hydroptila spp
Leucotrichia pictipes
Neotrichia sp
Orthotrichia spp
Oxyethira spp
Lepidostoma spp
Ceraclea ancylus
Ceraclea cancellata
Ceraclea enodis

Ceraclea maculate
Ceraclea mentiea
Ceraclea nepha?
Ceraclea nr excisa
Ceraclea ophioderus
Ceraclea punctata
Ceraclea resurgens
Ceraclea spp
Ceraclea transversa
Mystacides sepulchralus
Nectopsyche candida
Nectopsyche exquisita
Nectopsyche pavida
Nectopsyche spp
Oecetis avara
Oecetis cinerascens
Oecetis ditissa gr
Oecetis georgia
Oecetis inconspicua
Oecetis morsei
Oecetis nocturna
Oecetis osteni
Oecetis persimilis
Oecetis scala gr
Oecetis sp a (floyd)
Oecetis sp d (floyd)
Oecetis sp f (floyd)
Oecetis sp1
Oecetis sp2
Oecetis spp
Setodes spp
Triaenodes ignitus
Triaenodes injusta
Triaenodes ochraceus
Triaenodes perna
Triaenodes perna/helo
Triaenodes spp
Hydatophylax spp
Ironoquia punctatissima
Pycnopsyche divergens
Pycnopsyche guttifer
Pycnopsyche lepida
Pycnopsyche scabripennis
Pycnopsyche spp
Molanna blenda
Molanna tryphena
Molanna uniophila
Chimarra spp
Dolophilodes spp
Ptilostomis spp
Cernotina spicata
Cyrnellus fraternus
Neureclipsis spp
Paranyctiophylax celta
Paranyctiophylax moestus
Paranyctiophylax nephophilus
Paranyctiophylax spp
Polycentropus spp
Platycentropus sp
Lype diversa
Psychomyia flava
Psychomyia nomada
Psychomyia spp
Rhyacophila acutiloba
Rhyacophila carolina
Rhyacophila fuscula
Rhyacophila nigrita
Rhyacophila vuphipes
Neophylax concinnus
Neophylax consimilis
Neophylax fuscus
Neophylax oligius
Neophylax ornatus
Neophylax spp

COLEOPTERA

Helichus fastigiatus
Helichus lithophilus
Helichus spp
Agabus spp
Anodocheilus exiguus
Celina spp
Copelatus spp
Coptotomus spp
Cybister fimbriolatus
Deronectes griseostriatus
Deronectes sp
Desmopachria grana
Dytiscus sp

Hydaticus bimarginatus
Hydroporus mellitus
Hydroporus spp
Hydrovatus spp
Hygrotus farctus
Ilybius spp
Laccophilus spp
Lioporeus pilatei
Lioporeus spp
Matus ovatus
Neoporus spp
Rhantus spp
Ancyronyx variegatus
Dubiraphia spp
Dubiraphia vittata
Macronychus glabratus
Microcylloepus pusillus
Optioservus spp
Optioservus ovalis
Promoresia elegans
Promoresia tardella
Promoresia sp.
Stenelmis antennalis
Stenelmis fuscata
Stenelmis spp
Stenelmis xylonastis
Dineutus spp
Gyrinus spp
Haliplus spp
Peltodytes spp
Scirtes spp
Berosus spp
Enochrus spp
Helophorus sp
Hydrobius spp
Hydrochus spp
Hydrophilus triangularis
Laccobius sp
Sperchopsis tessellatus
Tropisternus collaris
Tropisternus spp
Hydrocanthus spp
Suphisellus spp
Ectopria nervosa
Psephenus herricki

ODONATA

Basiaeschna janata
Boyeria grafiana
Boyeria vinosa
Epiaeschna heros
Nasiaeschna pentacantha
Calopteryx spp
Hetaerina americana
Hetaerina spp
Hetaerina titia
Argia spp
Enallagma divigens
Enallagma durum
Enallagma signatum
Enallagma spp
Ischnura spp
Cordulegaster spp
Epicordulia princeps
Epicordulia spp
Epitheca spp
Helocordulia uhleri
Helocordulia spp
Neurocordulia molesta
Neurocordulia obsoleta
Neurocordulia spp
Neurocordulia virginiensis
Somatochlora spp
Tetragoneuria cynosura
Tetragoneuria spp
Dromogomphus spp
Dromogomphus spinosus
Erpetogomphus designatus
Gomphus spiniceps
Gomphus spp
Hagenius brevistylus
Lanthus vernalis
Ophiogomphus spp
Progomphus obscurus
Stylogomphus albistylus
Brachymesia gravida
Celithemis eponina
Erythemis simplicicollis
Erythrodiplax connata

Erythrodiplax spp
Libellula spp
Pachydiplax longipennis
Perithemis spp
Plathemis lydia
Sympetrum spp
Didymops transversa
Macromia spp

MEGALOPTERA

Chauliodes pectinicornis
Chauliodes rastricornis
Chauliodes sp
Corydalus cornutus
Nigronia serricornis
Sialis spp

DIPTERA (CHIRONOMIDAE)

Ablabesmyia annulata
Ablabesmyia mallochi
Ablabesmyia monilis
Ablabesmyia parajanta/janta
Ablabesmyia peleensis
Ablabesmyia simpsoni
Ablabesmyia spp
Axarus spp
Brillia spp
Cardiocladius spp
Chaetocladius spp
Chernovskia orbicus
Chironomini genus b (pinder & reiss)
Chironomini sppa (roback)
Chironomus crassicaudatus
Chironomus spp
Cladopelma spp
Cladotanytarsus sp1
Cladotanytarsus sp2
Cladotanytarsus sp2a
Cladotanytarsus sp3
Cladotanytarsus sp4
Cladotanytarsus sp5
Cladotanytarsus sp6
Cladotanytarsus sp7
Cladotanytarsus sp7
Cladotanytarsus sp8
Cladotanytarsus sp9 (Epler Sp F)
Cladotanytarsus spp
Clinotanypus pinguis
Coelotanypus concinnus
Coelotanypus scapularis
Coelotanypus spp
Coelotanypus tricolor
Conchapelopia group
Corynoneura lobata
Corynoneura sp b epler
Corynoneura sp c epler
Corynoneura spp
Cricotopus bicinctus: c/o sp1
Cricotopus infuscatus gr: c/o sp5
Cricotopus nr flavocinctus: c/o sp31
Cricotopus nr trifasciata: c/o sp36
Cricotopus varipes gr: c/o sp6
Cricotopus vieriensis gr: c/o sp46
Cricotopus/orthocladius sp2
Cricotopus/orthocladius sp24
Cricotopus/orthocladius sp34
Cricotopus/orthocladius sp41
Cricotopus/orthocladius sp44
Cricotopus/orthocladius sp45
Cricotopus/orthocladius sp51
Cricotopus/orthocladius sp57
Cricotopus/orthocladius sp7
Cricotopus/orthocladius sp8
Cricotopus/orthocladius sp9
Cryptochironomus blarina gr
Cryptochironomus fulvus
Cryptochironomus spp
Cryptotendipes spp
Demeijerea brachialis
Demicryptochironomus sp3
Demicryptochironomus sp4
Demicryptochironomus spp
Diamesa sp
Dicrotendipes fumidus
Dicrotendipes lobus
Dicrotendipes lucifer
Dicrotendipes modestus
Dicrotendipes neomodestus
Dicrotendipes nervosus
Dicrotendipes simpsoni

Dicrotendipes spp
Einfeldia spp
Endochironomus nigricans
Endochironomus spp
Epoicocladius spp
Eukiefferiella brehmi gr (e sp12)
Eukiefferiella brevicalar gr (e sp6)
Eukiefferiella claripennis gr (e sp11)
Eukiefferiella devonica gr (e sp2)
Eukiefferiella gracei gr (e sp14)
Eukiefferiella pseudmontana
Genus nr nanocladius b
Glyptotendipes spp
Goeldichironomus holoprasinus
Guttipelopia guttipennis (=currani)
Harnischia complex genus a
Harnischia curtilamelata
Harnischia spp
Heleniella spp
Hydrobaenus spp
Kiefferulus dux
Kiefferulus spp
Labrundinia beckae
Labrundinia johanseni
Labrundinia neopilosella
Labrundinia pilosella
Labrundinia spp
Labrundinia virescens
Larsia spp
Limnophyes spp
Lopescladius spp
Microchironomus spp
Micropsectra spp
Microtendipes sp1
Microtendipes sp3
Microtendipes spp
Nanocladius downesi
Nanocladius spp
Natarsia spp
Nilotanypus spp
Nilothauma spp
Odontomesa fulva
O. (euorthocladius) (8 laterals)
Omisus pica
Orthocladius robacki: c/o sp12
Orthocladius (euorthocladius): c/o sp13
Orthocladius (euorthocladius): c/o sp20
Orthocladius (euorthocladius): c/o sp3
Orthocladius annectens
Orthocladius clarkei gr: c/o sp54
Orthocladius lignicola
Orthocladius obumbratus gr: c/0 sp10
Orthocladius oliveri
Pagastia spp
Pagastiella ostansa
Parachironomus abortivus
Parachironomus carinatus
Parachironomus directus
Parachironomus frequens
Parachironomus monochromus
Parachironomus pectinatellae
Parachironomus spp
Parachironomus subletti
Paracladopelma doris
Paracladopelma nereis
Paracladopelma species 1 jackson
Paracladopelma spp
Paracladopelma undine
Parakiefferiella sp4
Parakiefferiella spp
Parakiefferiella triqueta
Paralauterborniella nigrohalteralis
Parametriocnemus lundbecki
Paraphaenocladius sp2
Paratanytarsus spp
Paratendipes connectens (group)
Paratendipes spp
Pentaneura spp
Phaenopsectra flavipes
Phaenopsectra sp1
Phaenopsectra sp2
Phaenopsectra sp3
Phaenopsectra sp4
Phaenopsectra spp
Polypedilum fallax
Polypedilum flavum
Polypedilum halterale gr
Polypedilum illinoense gr

Polypedilum laetum
Polypedilum scalaenum
Polypedilum spa
Polypedilum trigonus
Polypedilum tritum
Potthasita gaedi
Potthastia longimanus
Procladius spp
Psectrotanypus dyari
Psectrotanypus spp
Pseudochironomus fulviventris
Pseudochironomus spp
Pseudosmittia spp
Rheocricotopus robacki
Rheocricotopus tuberculatus
Rheocricotopus sp2a
Rheocricotopus spp
Rheopelopia sp
Rheosmittia spp
Rheotanytarsus spp
Robackia claviger
Robackia demeijerei
Saetheria tylus
Stelechomyia perpulchra
Stenochironomus spp
Stictochironomus spp
Sublettia coffmani
Sympotthastia spp
Synorthocladius spp
Tanypus concavus?
Tanypus neopunctipennis
Tanypus punctipennis
Tanypus spp
Tanypus stellatus
Tanytarsus sp1
Tanytarsus sp10
Tanytarsus sp13
Tanytarsus sp14
Tanytarsus sp15
Tanytarsus sp2
Tanytarsus sp3
Tanytarsus sp4
Tanytarsus sp6
Tanytarsus spp
Thienemaniella lobapodema
Thienemaniella sp b epler
Thienemaniella spp
Thienemaniella xena
Thienemanniella similis
Tribelos fuscicorne
Tribelos jucundum
Tribelos jucundum
Tribelos spp
Tvetenia bavarica gr (e sp1)
Tvetenia discoloripes gr (e sp3)
Tvetenia sp ga epler
Xenochironomus (anceus)
Xenochironomus spp
Xenochironomus xenolabis
Xestochironomus sublettei
Xylotopus par
Zalutschia spp
Zavrelia spp
Zavreliella varipennis
Zavrelimyia spp

DIPTERA (MISCELLANIOUS)

Aedes sp
Alluaudomyia spp
Anopheles spp
Antocha spp
Atherix lantha
Atrichopogon spp
Blephraricera spp
Ceratopogonidae
Chaoborus punctipennis
Chaoborus spp
Chlorotabanus crepuscularis
Chrysops spp
Cnephia spp
Culex spp
Culicoides spp
Culiseta sp
Dasyhelea spp
Dicranota spp
Dixa
Dolichopodidae
Empididae
Ephydridae

Forcipomyia spp
Hexatoma spp
Limonia spp
Muscidae
Palpomyia (complex)
Pericoma spp
Polymeda/ormosia spp
Prosimulium spp
Protoplasa fitchii
Pseudolimnophila spp
Psychoda spp
Simulium (phosterodoros) spp
Simulium congareenarum
Simulium decorum
Simulium podostemi
Simulium spp
Simulium tuberosum
Simulium vittatum
Stegopterna mutata/diplomutata
Stratiomysis spp
Tabanus spp
Tipula spp

HEMIPTERA

Belostoma spp
Gerridae
Gerris spp
Lethocerus spp
Notonecta spp
Palmocorixa spp
Pelocoris spp
Ranatra spp
Sigara spp
Trepobates spp
Trichocorixa spp

OLIGOCHAETA

Cambarinicolidae
Enchytraeidae
Haplotaxis gordioides
Lumbriculidae
Opisthopora
Amphichaeta americana
Arcteonais lomondi
Bratislavia unidentata
Dero (aulophorus) vaga
Dero furcatus
Dero spp
Haemonais waldvogeli
Nais behningi
Nais simplex
Nais spp
Nais variabilis
Ophidonais serpentina
Pristina leidyi
Pristina longiseta
Pristina osborni
Pristina spp
Pristinella
Slavina appendiculata
Specaria josinae
Stephansoniana sp
Stylaria lacustris
Vejdovskyella comata
Aulodrilus limnobius
Aulodrilus pigueti
Aulodrilus pluriseta
Branchiura sowerbyi
Haber speciosus
Ilyodrilus templetoni
Isochaetides curvisetosus
Isochaetides freyi
Limnodrilus cervix
Limnodrilus hoffmeisteri
Limnodrilus udekemianus
Limnodrilus spp
Potamothrix moldaviensis
Quistadrilus multisetosus
Rhyacodrilus cocinneus
Spirosperma carolinensis
Spirosperma ferox
Spirosperma nikolskyi
Spirosperma spp
Tubifex tubifex
Tubificidae

CRUSTACEA

Copepoda
Caecidotea forbesi
Caecidotea obtusus
Caecidotea racovitzai australis

Caecidotea sp1
Caecidotea sp3
Caecidotea spp (streams)
Lirceus spp
Cambarus spp
Cambarus (D.) latimanus
Cambarus (P.) hobbsorum
Orconectes spp
Oronectes cristavarius
Orconectes (C.) virginiensis
Orconectes (P.) carolinensis
Orconectes (P.) Spinosus
Procambarus spp
Procambarus (O.) A. Acutus
Crangonyx spp
Crangonyx serratus
Gammarus spp
Gammarus fasciatus
Palaemonetes spp
Palaemonetes paludosus
Hyalella spp

MOLLUSCA (GASTROPODA)

Lioplax subcarinata
Ferrissia spp
Laevapex fuscus
Cratena pilata
Amnicola spp
Hydrobia
Hydrobia minuta
Somatogyrus spp
Fossaria modicella
Pseudosuccinea columella
Stagnicola spp
Physella spp
Gyraulus deflectus
Gyraulus spp
Helisoma anceps
Helisoma trivolvis
Micromenetus dilatatus
Planorbella spp
Planorbella trivolvis
Planorbula armigera
Elimia sp
Leptoxis spp
Pleurocera spp
Campeloma decisum

MOLLUSCA (PELCYPODA)

Corbicula fluminea
Eupera cubensis
Musculium sp
Pisidium spp
Sphaerium spp
Alasmidonta undulata
Anodonta spp
Elliptio complanata
Elliptio congaraea
Elliptio lanceolata
Elliptio spp
Lampsilis cariosa
Lampsilis radiata radiata
Lasmigonia subviridis
Leptodea ochracea
Utterbackia imbecillis
Villosa sp

OTHER

Alboglossiphonia heteroclita
Carinoma tremaphoros
Climacia areolaris
Cura foremanii
Desserobdella phalera
Desserobdella phalera
Dina spp
Dugesia tigrina
Erpobdella/mooreobdella
Gloiobdella elongata
Gordius
Helobdella fusca
Helobdella papillata
Helobdella spp
Helobdella stagnalis
Helobdella triserialis
Hydracarina
Hydrolimax grisea
Mooreobdella melanostoma
Mooreobdella tetragon
Myzobdella lugubris
Nematoda
Nemertea

Petrophila sp
Placobdella montifera
Placobdella nuchalis
Placobdella ornata
Placobdella papillifera
Placobdella parasitica
Placobdella spp
Prostoma graecens
Pyralidae

Appendix C

Observations and Findings of Headwater Stream Analysis In Selected Areas of North Carolina

North Carolina Division of Water Quality
August 21, 2007

The hydrologic and ecologic importance of headwater streams in watersheds has been thoroughly documented (Coats 1972; Vannote et al., 1980; Kiffney et al., 2000; Peterson et al., 2001; McGlynn and Seibert, 2002; and others). More recently, The Journal of America Water Resources dedicated a portion of the February 2006 issue to headwater stream research. Headwater streams are the primary sources of water in a drainage network (Stanford 1996) and serve as a critical hydrologic link between the surrounding landscape and larger, downstream surface waters. The progressive downstream connection between sub-basins results in a continuous hydrologic network consisting of streams, rivers, ponds, lakes, and wetlands (Colson 2006). Due to their location and prevalence in the landscape, headwater streams are the primary transport mechanism for nonpoint source pollution since they convey stormwater and associated pollutants to downstream surface waters. Research suggests that small first order streams cumulatively drain up to 85% of a watershed area (McGlynn and Seibert 2002; Peterson et al. 2001). Additionally, headwater streams are an important component of the aquatic habitat, as they transport water, sediments, nutrients, organic matter, and woody debris to downstream reaches where they influence productivity (Kiffney et al. 2000; Vannote et al. 1980).

The role of headwater streams is recognized in North Carolina by the existence of state and federal programs intended to protect headwater stream values and functions. A basic necessity of a successful stream management program is an accurate stream map. In response to this need, The North Carolina Division of Water Quality (DWQ), The North Carolina

Department of Transportation (DOT), and North Carolina State University (NCSU) partnered in early 2004 to develop a stream map for the state that more accurately depicts the location of 1st and 2nd order streams, their length and their flow duration. Within the context of the stream mapping project, data have been collected that, while preliminary, begins to shed more light on headwater stream characteristics and the factors that influence their landscape position, extent and flow duration classification. The intent of this document is to relay the observations made thus far that may be relevant in making regulatory decisions with respect to headwater streams.

Methods

Stream mapping data were collected in 23 watersheds in seven Level IV ecoregions (Figure 1). Study sites for field data collection were selected to represent Level IV ecoregions with the number of sites per ecoregion based on the size the ecoregion. Study watersheds were typically 1000 acres in size and averaged 40 stream origins per watershed. Field data were collected by starting at the most downstream point of a study watershed and walking upstream until an incoming tributary was observed. The tributary was subsequently walked upstream until another tributary was encountered, or until an origin (or origins) was reached. Origin locations were geo-referenced at sub-meter accuracy with a GPS unit. Intermittent and/or perennial flow was determined using the North Carolina Stream Identification Methodology (2005). Once the origin was determined and geo-referenced, the field investigator returned to the mainstem to continue the walk upstream. The process was repeated until the entire stream network was observed and all origins and flow duration data were collected. Stream mapping field data was transferred and post-processed with Pathfinder software. ARC Map GIS shapefiles were created for use in the geo-spatial phase of work.

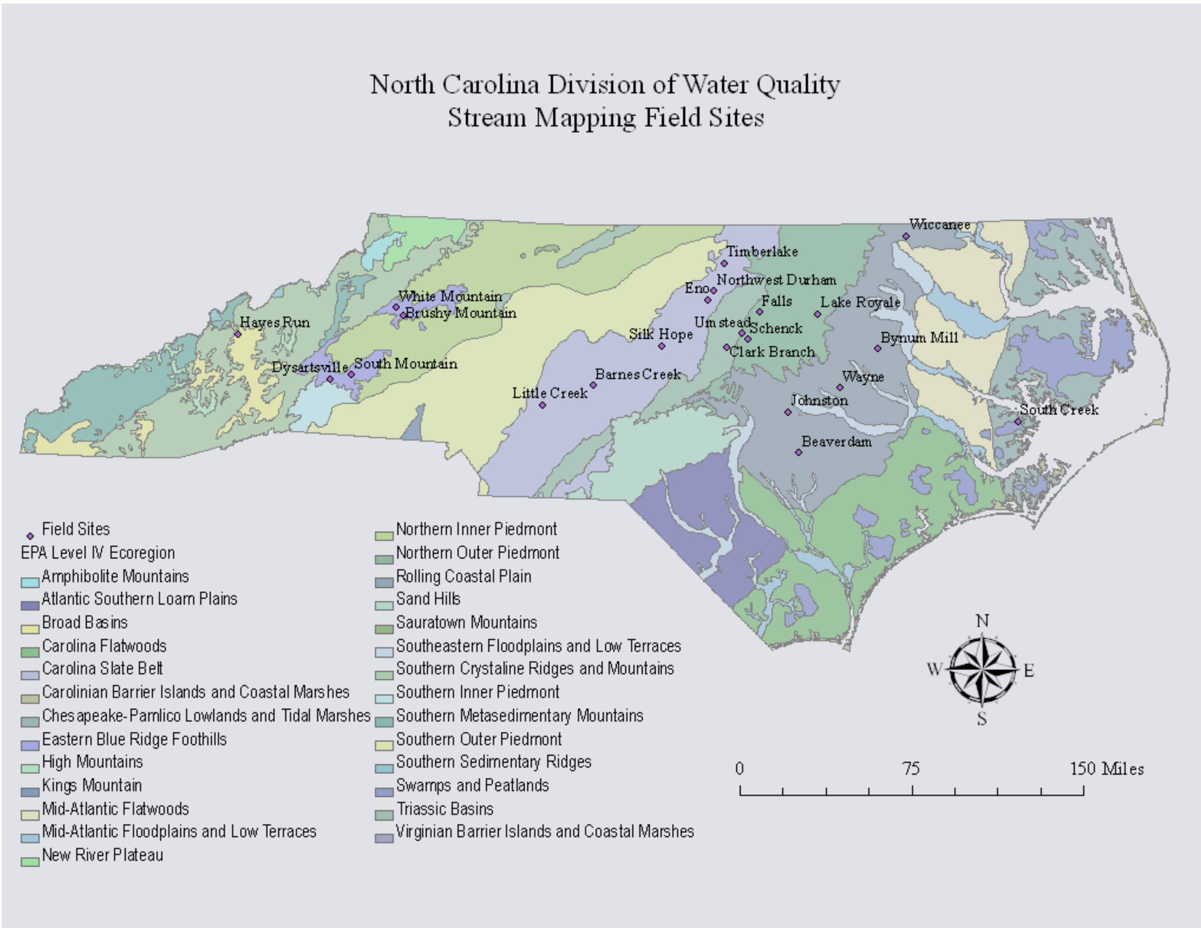


Figure 1: Map of Field Sites

Ecoregion, soils and geology maps were available in digital format and easily acquired. LIDAR bare earth points were downloaded from NC Flood Mapping Program website (2003). Digital elevation models (DEM) were generated from LIDAR bare earth points and terrain variables were derived using ARC MAP geotools. All data was entered into the geodatabase. Part of the pilot phase of the stream mapping project involved rigorous analysis and method development by NCSU for establishing standards for generating the most accurate digital elevation model (DEM) from LIDAR bare-earth points. These methods were used to generate high resolution topography required for various analyses. A more detailed description of the methods can be found in Colson's (2006) NCSU dissertation. Some preliminary observations were made using 30-meter resolution DEMs downloaded from the USGS National Hydrography Dataset (NHD) website.

Headwater Streams

Origins and Flow Duration Descriptions

Streams were mapped in twenty-three watersheds resulting in over 600 mapped origins. To date, data from 21 watershed sites have been processed for analysis. Complete coverage of Lidar bare earth points for two of the mountain sites has not been available to generate DEMs so has delayed processing. The following assessment includes stream identification data and landscape attribute data from 542 intermittent and perennial origins. Additionally, transition types of intermittent and perennial origins within the sampled level IV ecoregions are included (Table 1).

The most common origin transitions are transitions from ephemeral flow to intermittent flow (46%) and intermittent flow to perennial flow (36%). These transitions are examples of the current perception of headwater stream behavior where discharge and flow duration increase as drainage area increases. Variation in first order landscape influences is revealed in the distribution of transition types between geologic province and selected ecoregions. In the low-relief, sedimentary deposits of the Triassic Basin, ephemeral to intermittent transitions account for over 71% of all types within that ecoregion. In contrast, the majority of origins in the high relief, metamorphic rocks of the mountain sites are ephemeral to perennial and are typically springs. Very few mountain stream origins transition from ephemeral to intermittent.

Rolling Coastal Plain stream flow transitions are also predominately ephemeral to intermittent, but more transition types are present, including the 5% of wetland to intermittent transitions.

Table 1: Headwater Stream Origin Transitions as Percentage of Totals

Type of Origin	Carolina Slate Belt n=162	Northern Outer Piedmont n=82	Triassic Basin n=85	Rolling Coastal Plain n=109	Eastern Blue Ridge Foothills n=106	% Total Origin Type
	% Origin Type and Ecoregion					
Ephemeral to Intermittent	52%	45%	71%	55%	10%	46%
Intermittent to Perennial	30%	51%	17%	36%	43%	36%
Ephemeral to Perennial	11%	0%	10%	1%	47%	14%
Intermittent Modified	1%	1%	0%	1%	0%	1%
Perennial Modified	0%	0%	0%	1%	0%	0%
Intermittent Ditch	1%	1%	0%	2%	0%	1%
Perennial Ditch	0%	1%	0%	0%	0%	0%
Wetland to Intermittent Transition	1%	0%	1%	5%	0%	1%
Wetland to Perennial Transition	1%	0%	0%	0%	0%	0%
Intermittent to Pond	1%	0%	1%	0%	0%	1%
Pond to Intermittent	1%	0%	0%	0%	0%	0%
Perennial to Pond	1%	0%	0%	0%	0%	0%
Intermittent to Ephemeral	1%	0%	0%	0%	0%	0%
% Total by Ecoregion	30%	15%	15%	20%	20%	100.00

The length of first order intermittent streams in the mountains, the coast and in the Triassic Basin is greater relative to first order perennial stream length, and is roughly equal in the Carolina Slate Belt. Although most streams begin as perennial springs (ephemeral to perennial transition, Table 1) in the Eastern Blue Ridge Foothills, the length of the first order intermittent streams is greater. First order perennial streams originating from springs may occur at lower elevations in the landscape, and subsequently have a shorter distance to travel to reach the next ordered stream. The intermittent streams likely originate higher in the landscape, and thus, a longer distance is required to reach a 2^{nd} order stream, or to accumulate sufficient watershed area for perennial flow. As the overall relief decreases east of the mountains, the Piedmont first order intermittent lengths also decrease about 10%. But, first order intermittent stream lengths tend to increase in response to declining slopes on the coast. Though only hypothetical at this research phase, the data suggests a strong landscape influence related to geologic structure, local relief, topography and soil properties.

Table 2: Percent Length of Headwater Streams by Level IV Ecoregion

		Length of Intermittent and Perennial Streams by Stream Order (%miles)							
Geologic Province	EcoRegion	1		2		3		Total	
		int	per	int	per	int	per	int	per
Mountains	Eastern Blue Ridge	33%	22%	8%	20%	0%	16%	42%	58%
		55%		28%		16%		100%	
Piedmont	Carolina Slate Belt	22%	24%	3%	33%	0%	18%	25%	75%
		46%		36%		18%		100%	
	Triassic Basin	26%	18%	2%	38%	0%	16%	28%	72%
		44%		40%		16%		100%	
	Northern Outer Piedmont	20%	43%	1%	30%	0%	6%	21%	79%
		63%		31%		6%		100%	
	Total	22%	29%	2%	33%	0%	14%	24%	76%
		51%		35%		14%		100%	
Coast	Rolling Coast Plain	32%	18%	5%	29%	0%	16%	37%	63%
		50%		34%		16%		100%	
	Chesapeake-Pamlico Lowlands and Tidal Marshes*	56%	44%	0%	0%	0%	0%	56%	44%
		100%		0%	0%	0%	0%	100%	
	Total	34%	21%	4%	26%	0%	14%	39%	61%
		55%		31%		14%		100%	
All Total		28%	25%	4%	29%	0%	14%	31%	69%
		53%		33%		14%		100%	

*Appendix C-1, South creek Analysis

The character of streams in the Chesapeake-Pamlico Lowlands is more indicative of outer coast plain streams that flow directly into estuaries and sounds. The South Creek area where the data were collected has a parallel drainage pattern with few incoming tributaries. Additional data is needed to determine if the drainage pattern and stream flow duration is typical for similar areas.

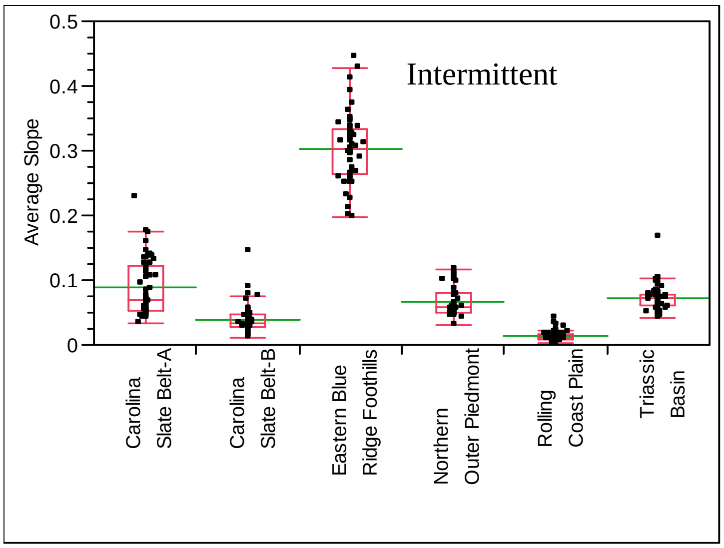
Generally, the ratio of intermittent to perennial streams in the Piedmont is 1:3, that is, total intermittent length is approximately 1/3 of perennial length, whereas the approximate ratio in the mountains and coast is closer to 1:2. Although intermittent and perennial stream lengths vary with landscape, according to the stream mapping data, about half of all first order streams across the state are intermittent streams.

Terrain Characteristics

Terrain characteristics were derived from 5-meter resolution DEMs for testing their influence on headwater streams and flow duration. Terrain derivatives include local and averaged topographic slope shape, gradient, and drainage areas for each origin. Other landscape characteristics such geology, soil, or land use have not yet been added to the spatial database. Descriptive statistics, distributions, significant difference (t-test), and correlations were evaluated for each terrain derivative. Average slope (flow weighted) and contributing drainage area proved to have the greatest influence on intermittent and perennial stream origins.

Comparisons Between Ecoregions

Distributions of average slope and contributing drainage area illustrate the range of values between ecoregions (Figure 2 and 3). In the piedmont ecoregions, average slope distributions are very similar. Closer examination of the Carolina Slate Belt data indicated higher than expected variability between sites, and so the data was determined to be insufficient for representing the entire ecoregion. Additional analysis revealed similarities and differences in rock strength between sites and so the Slate Belt was divided into 2 groups, A-strong rocks and B-weak rocks. Geology is one of many explanatory variables to be analyzed in the near future with respect to origins, and its use to sub-divide Slate Belt ecoregion sites is preliminary.



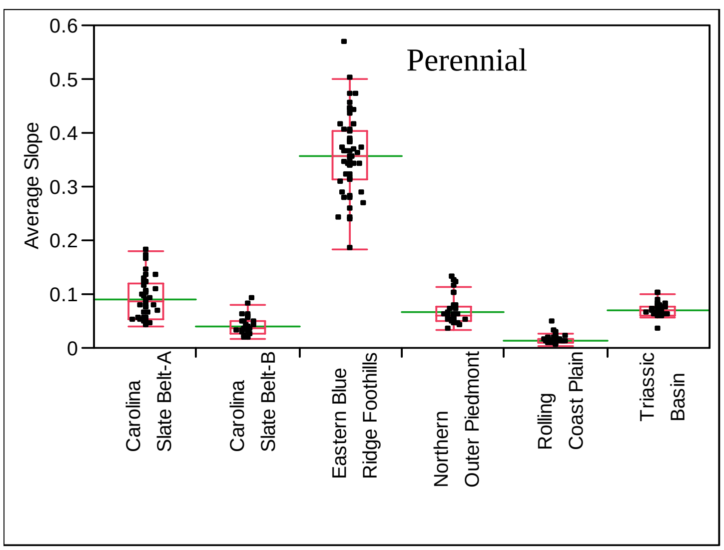
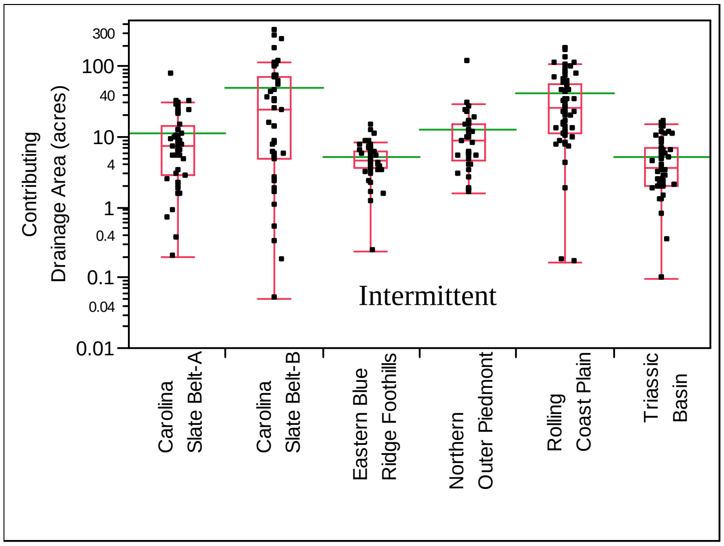


Figure 2: Distribution of Average Slope Above Intermittent and Perennial Stream Origins



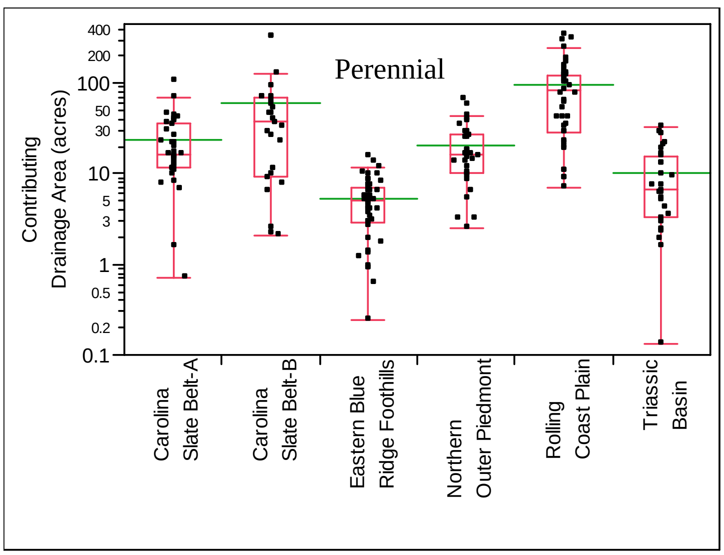


Figure 3: Distribution of Contributing Drainage Area Above Intermittent and Perennial Stream Origins

As expected, the Eastern Blue Ridge Foothills and Rolling Coast Plain ecoregion slope and drainage area distributions represent the upper and lower extremes of the data collected thus far. The range in average slope tends to correspond with topographic relief. Low relief areas, such as the Coast Plain and Triassic Basin, have narrow slope ranges, but in high relief terrains, the range broadens to reflect the overall availability of varying slopes. Generally, the opposite is true for contributing drainage area, that is, lower relief corresponds to higher drainage area and vice verse (Figure 4).

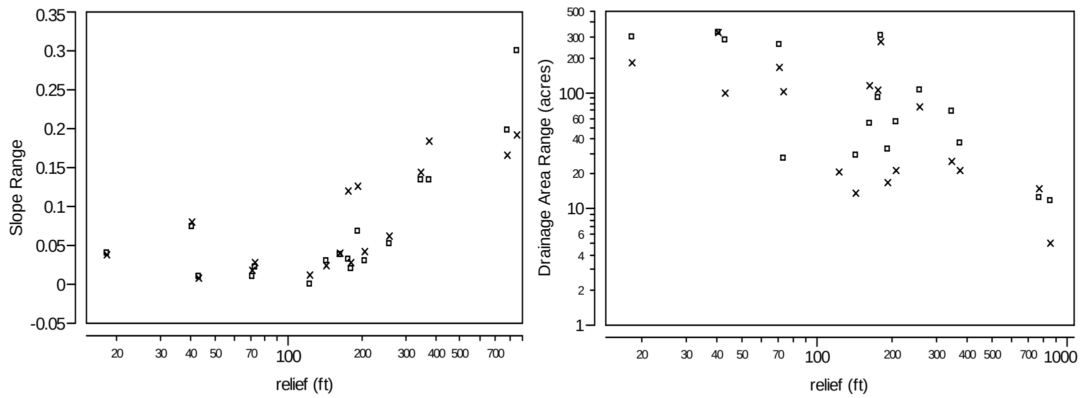


Figure 4: Trend Plots of Average Slope and Contributing Drainage Area (acres) Range (max-min) and Topographic Relief (ft) by Site.

<u>Comparisons Within Ecoregions</u>

With the exception of the Eastern Blue Ridge Foothill ecoregion, the average slope above an intermittent origin is not statistically different than the average slope above a perennial origin. Contributing drainage area distribution between intermittent and perennial origins indicated all were significantly different (Northern Outer Piedmont Lower Limit Only) except the Eastern Blue Ridge Foothills and the group B-weak rocks in the Carolina Slate Belt. Drainage area distributions are shown in Table 4.

The average slope may not vary enough between intermittent and perennial stream origins to be effective in predicting location, except for the mountain sites. Conversely, contributing drainage area may help in determining origin locations in all ecoregions except for mountain sites, and geologically weak areas in the Carolina Slate Belt. This finding provides additional insight into landscape processes that influence intermittent and perennial stream origins.

Table 4: Distribution of
Intermittent and Perennial Origin Contributing Drainage Area (acres)

	Carolina Slate Belt-A		Carolina Slate Belt-B		Eastern Blue Ridge Foothills		Northern Outer Piedmont		Rolling Coast Plain		Triassic Basin	
	int	per	int	per	int	per	int	per	int	per	int	per
Min	0.20	0.72	0.05	2.04	0.23	0.24	1.55	2.54	0.16	7.16	0.10	0.13
10%	1.47	7.53	0.77	2.39	2.17	1.02	1.80	4.07	7.52	10.76	1.24	1.89
25%	2.85	11.58	4.89	9.52	3.72	2.91	4.48	10.05	11.15	28.82	1.95	3.27
50%	7.36	15.99	23.80	37.50	4.60	4.98	8.82	16.18	25.67	84.00	3.70	6.85
Mean	11.20	23.74	50.86	60.85	5.16	5.27	12.72	20.52	40.66	95.59	5.11	10.40
75%	14.47	35.40	69.96	68.16	6.34	7.04	15.06	27.11	55.15	122.00	7.16	15.79
90%	27.39	43.33	142.41	187.26	8.16	9.81	22.99	41.31	101.33	217.34	11.87	27.80
Max	74.63	107.00	322.27	328.28	14.60	15.85	115.95	64.81	173.65	343.66	16.51	32.49

The product of average slope and contributing drainage area is an index that serves as a surrogate for erosion or energy potential of overland flow or stream flow. Its use in the context of stream origins is to represent the interaction of drainage area and slope and the potential to sufficiently incise through the soil profile to intersect with the water table. The index was examined for its predictive strength in delineating intermittent and perennial origins.

Statistically, the slope-area product is significantly different between intermittent and perennial origins in all ecoregions except Slate Belt – B and Blueridge Foothills. The t-test result is similar to the t-test result for drainage suggesting that drainage area is the strongest individual predictive variable. However, the slope-area product yielded higher statistical confidence and lower p-values for significant differences as well as boosting the confidence for Northern Outer Piedmont intermittent and perennial origins.

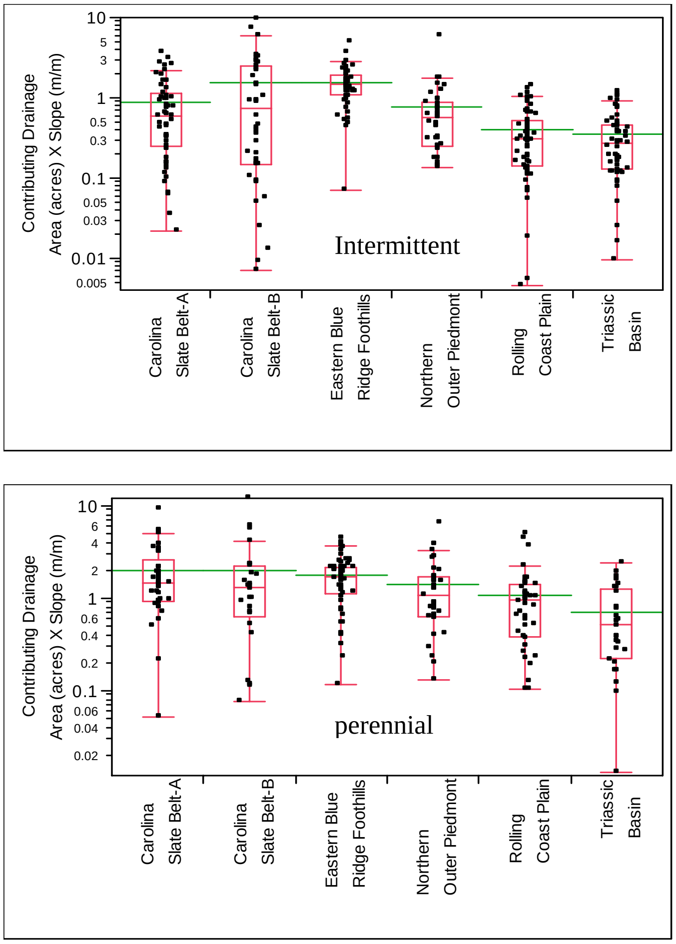


Figure 5: Distribution of Slope-Area Index

Table 5: Distribution of
Intermittent and Perennial Origin Avg Slope X Contributing Drainage Area (acres)

	Carolina Slate Belt-A		Carolina Slate Belt-B		Eastern Blue Ridge Foothills		Northern Outer Piedmont		Rolling Coast Plain		Triassic Basin	
	int	per	int	per	int	per	int	per	int	per	int	per
Min	0.02	0.05	0.01	0.08	0.07	0.11	0.14	0.13	0.00	0.10	0.01	0.01
10%	0.09	0.56	0.04	0.11	0.56	0.45	0.14	0.26	0.07	0.21	0.09	0.12
25%	0.25	0.92	0.15	0.63	1.08	1.12	0.25	0.64	0.14	0.37	0.13	0.23
50%	0.60	1.46	0.73	1.29	1.46	1.68	0.57	1.06	0.31	0.97	0.27	0.52
Mean	0.87	1.99	1.56	1.96	1.55	1.75	0.76	1.41	0.40	1.08	0.35	0.71
75%	1.12	2.62	2.45	2.20	1.91	2.17	0.89	1.68	0.52	1.40	0.45	1.24
90%	2.32	4.05	4.59	5.66	2.44	3.17	1.52	3.03	0.97	1.97	0.91	1.70
Max	3.74	9.27	9.60	11.80	4.92	4.38	5.83	6.54	1.44	4.89	1.19	2.37

The descriptions and analyses of stream origin data provide supplementary information regarding influences on stream origin and flow duration within selected regions of North Carolina. But, additional data collection is planned and analysis of the stream origin data is far from complete. Although more work in needed, information derived to date illustrates the influence of landscape on the complex processes that govern the flow duration of streams and their origins. While drainage area and slope are surrogates for landscape process, they represent only a fraction of determinants that require investigation. The effort to understand headwater streams, their role and function in watersheds and the links to the stream network will continue and made available as work in completed.

References

Coats, D. R., 1972. Quantitative geomorphology of small drainage basins in Southern Indiana. Tech. Rep. 10, Office of Naval Research, Department of Geography, Columbia University.

Colson, T. P. 2006. Stream Network Delineation from High Resolution Digital Elevation Models. Ph.D. Dissertation, Dept. of Forestry and Environmental Resources, NC State University, Raleigh, NC.

Kiffney, P. M., Richardson, J. S., Feller, M. C., 2000. Fluvial and epilithic organic matter dynamicsin headwater streams of Southwestern British Columbia, Canada. Archiv Fur Hydrobiologie 149 (1), 109–129.

McGlynn, B. L., Seibert, J., 2002. Distributed assessment of contributing area and riparian buffering along stream networks. Water Resources Research 39 (4), 2(1)–2(7).

North Carolina Division of Water Quality(NCDWQ), 2005. Identification methods for the origins of intermittent and perennial streams, version 3.1[Online]. Available at http://h2o.enr.state.nc.us/ncwetlands/documents/NC Stream ID Manual.pdf. Raleigh, NC.

North Carolina Floodplain Mapping (NCFMP), 2003. LiDAR and digital elevation data[Online], N.C. Division of Emergency Management, Available at http://www.ncfloodmaps.com/pubdocs/lidar final jan03.pdf. Raleigh, NC.

Peterson, B. J., Wollheim, W. M., Mulholland, P. J., Webster, J. R., Meyer, J. L., Tank, J. L., Marti, E., Bowden, W. B., Valett, H. M., Hershey, A. E., McDowell, W. H., Dodds, W. K., Hamilton, S. K., Gregory, S.,Morrall, D. D., 2001. Control of nitrogen export from watersheds by headwater streams. Science 292 (5514), 86–90.

Stanford, J., 1996. Landscapes and catchment basins. In: Hauer, F.R. and Lamberti., G.A. (Eds.) Methods in Stream Ecology. Academic Press, San Diego, pp. 3–22.

Vannote, R. L., Minshall, G.W., Cummins, K.W., Sedell, J. R., Cushing, C. E., 1980. River continuum concept. Canadian Journal Of Fisheries And Aquatic Sciences 37 (1), 130–137.

Appendix D

Stream Origin Assessment
South Creek, NC (PCS Phosphate Company)
NC Division of Water Quality
December 7, 2006

The Division of Water Quality (DWQ) and North Carolina State University (NCSU), in association with a North Carolina Department of Transportation (NCDOT) initiated a project in early 2004 to map intermittent and perennial streams and origins (IPSO) across the state. The project consists of gathering detailed field sample data with respect to stream origins and generating predictive models to estimate landscape controls on origin locations. As part of an effort to gain additional knowledge about stream origins, effort beyond the official stream project is continually conducted as stream origin data becomes available from various sources in North Carolina. In 2005, CZR Incorporated, by request from PCS Phosphate Company, field mapped intermittent and perennial streams in the South Creek region of PCS Phosphate Company land on the outer coast plain as part of the 404 permitting process. These data were used to assess stream origin characteristics in the South Creek area.

Stream origins in North Carolina are affected by multiple natural and anthropogenic characteristics. The complete analysis of these characteristics is being researched and documented within the stream mapping project framework. The goal of this assessment is to review a subset of stream origin related factors for potential use in management applications. Soil, slope, current contributing drainage area and historic contributing drainage area were evaluated with respect to stream origins in the PCS Phosphate study area.

Study Area

The mapping area includes streams draining to South Creek, a tributary to the Pamlico River near Aurora, NC (Figure 1) in Beaufort County. This area is located in Level III EPA Ecoregion Middle Atlantic Coastal Plain (63) and Level IV Chesapeake-Pamlico lowlands and tidal marsh (63b)(Griffith et al. 2002) South Creek and its tributaries are underlain by Quaternary marine fluvial, aeolian and lacustrine deposits consisting of sand, clay, gravel and peat. Relief is extremely low relative to the rest of North Carolina and stream gradients are typically less than 0.5 %. As in most coastal areas of North Carolina, ditching to redirect drainage is common around South Creek and has existed in the 200 years since European settlement. In response to ditching, it is likely that stream origins and flow regimes have adapted to changing drainage patterns.

Methods

Stream Identification

CZR, Inc. conducted stream identification and flow duration delineation using the DWQ methodology described in the Stream Identification Manual version 3.1 (2005). This methodology was originally developed by DWQ, NCSU along with other agency and private industry personnel, and was implemented as state policy in 1998. The upper and lower limits of streams were verified on site by regulatory representatives from the US Army Corps of Engineers and the NC Division of Water Quality. Once identified, all streams were professionally surveyed by licensed surveyors (Figure 2). Data were processed in CAD and ARCMAP.

Additional Data

Digital soil maps (Figure 3) were obtained from the North Carolina State University (NCSU) GIS library (Soil Survey of Beaufort County 1995) and the 20ft Digital Elevation Model (DEM) was downloaded from the North Carolina Flood Mapping Program (NCFM) Server. Hancock and Evans (2006) determined that a minimum grid size of 10X10 meters is needed to accurately assess channel origins. The 20-ft grid used in these analyses is equivalent to a 6.5 meter grid and so is within the range of acceptable grid size. Additionally, CZR, Inc. personnel estimated historic (pre-ditching) watershed boundaries using soil and topography maps (Figure 4). Historic watersheds were digitized and delivered to DWQ as an ARC shape file. Initially, ARC Hydro was used to delineate the current contributing watershed area upstream of origins. These areas were estimated based on flow accumulation generated using the NCFM 20ft DEM. However, the results of the ARC application proved unreliable due to the extensive ditching network. Contours were then generated from the DEM and current contributing area was estimated by 'heads up' digitizing directly on the computer screen using an ARC script to calculate area. Slopes were estimated in ARC MAP based on the DEM and the local slope upstream of the origin was estimated for analysis. Data are shown in Appendix 1.

South Creek Study Area
Beaufort County, NC

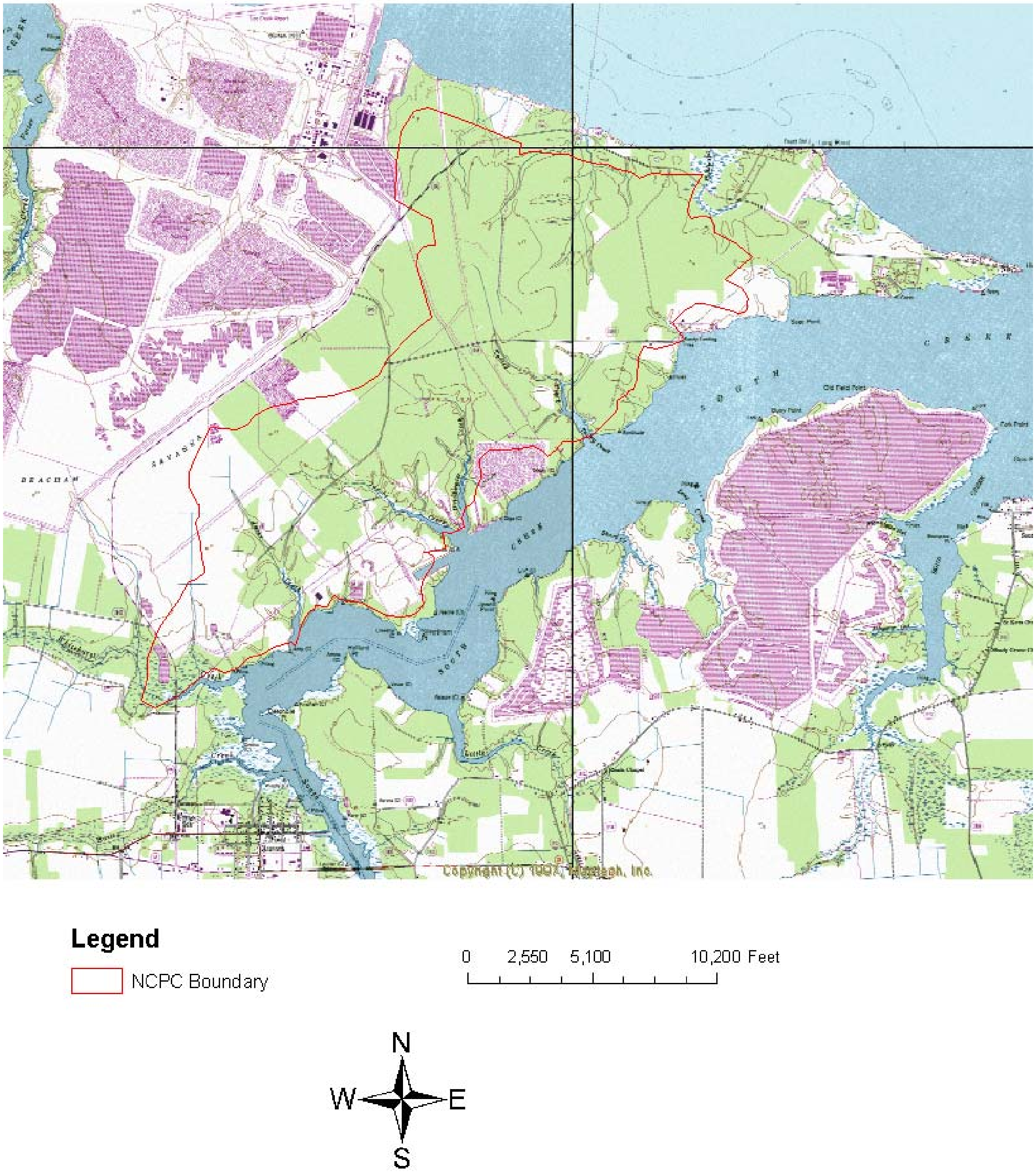


Figure 1: South Creek Study Area

Figure 2: Intermittent and Perennial Streams
PCS Phosphate Company Study Area
Beaufort County, NC

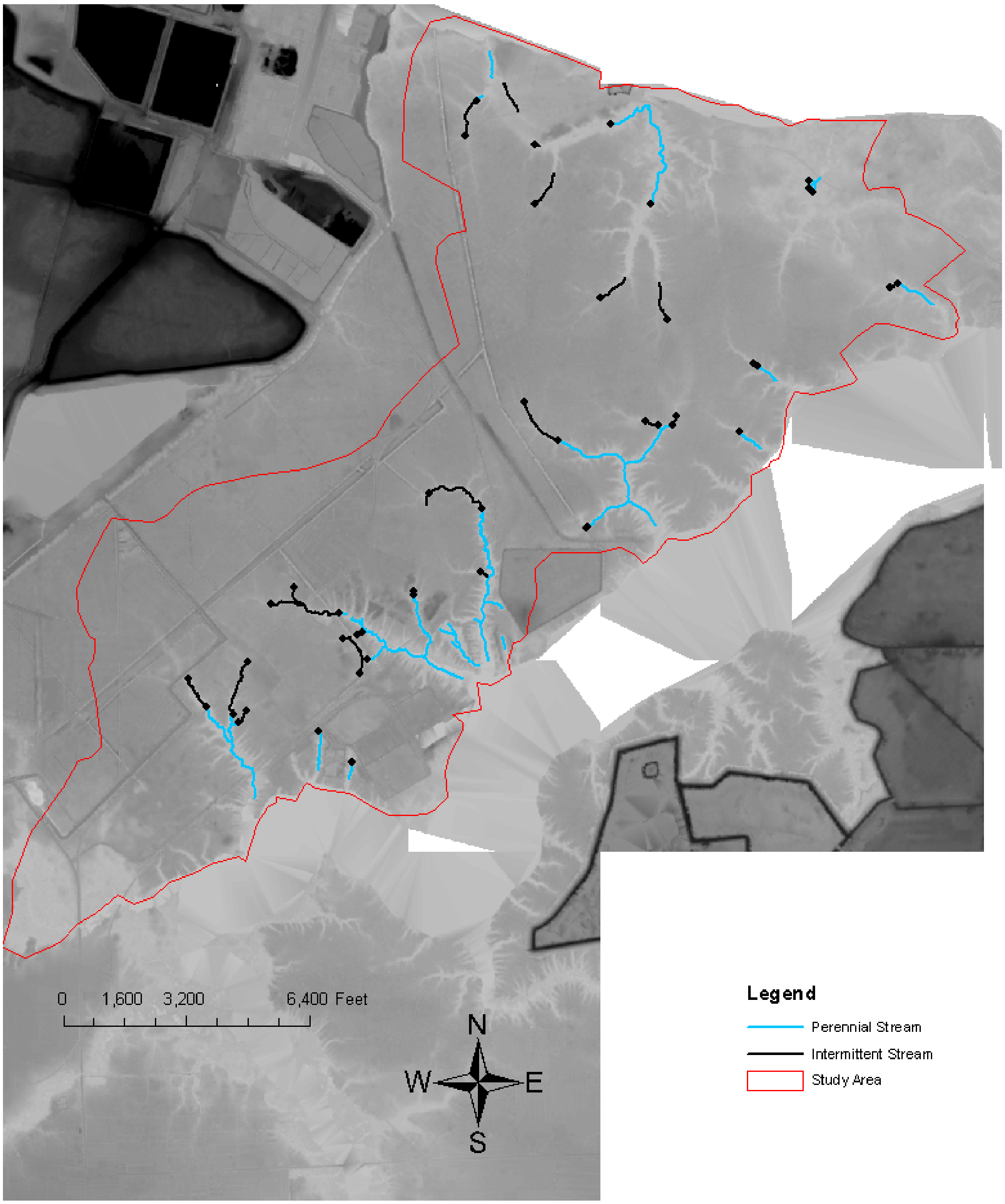


Figure 3: Area Soils
PCS Phosphate Company Study Area
Beaufort County, NC

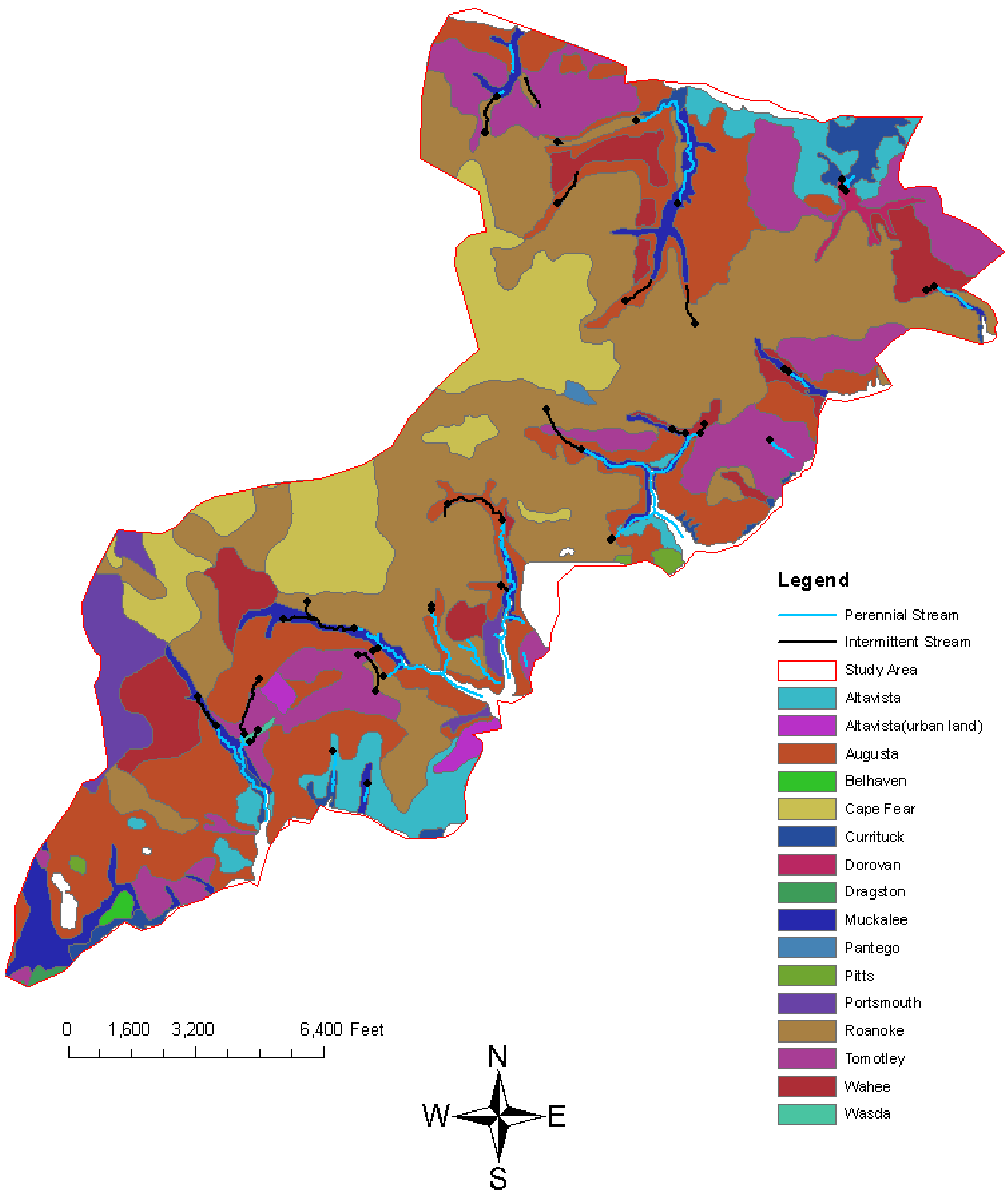
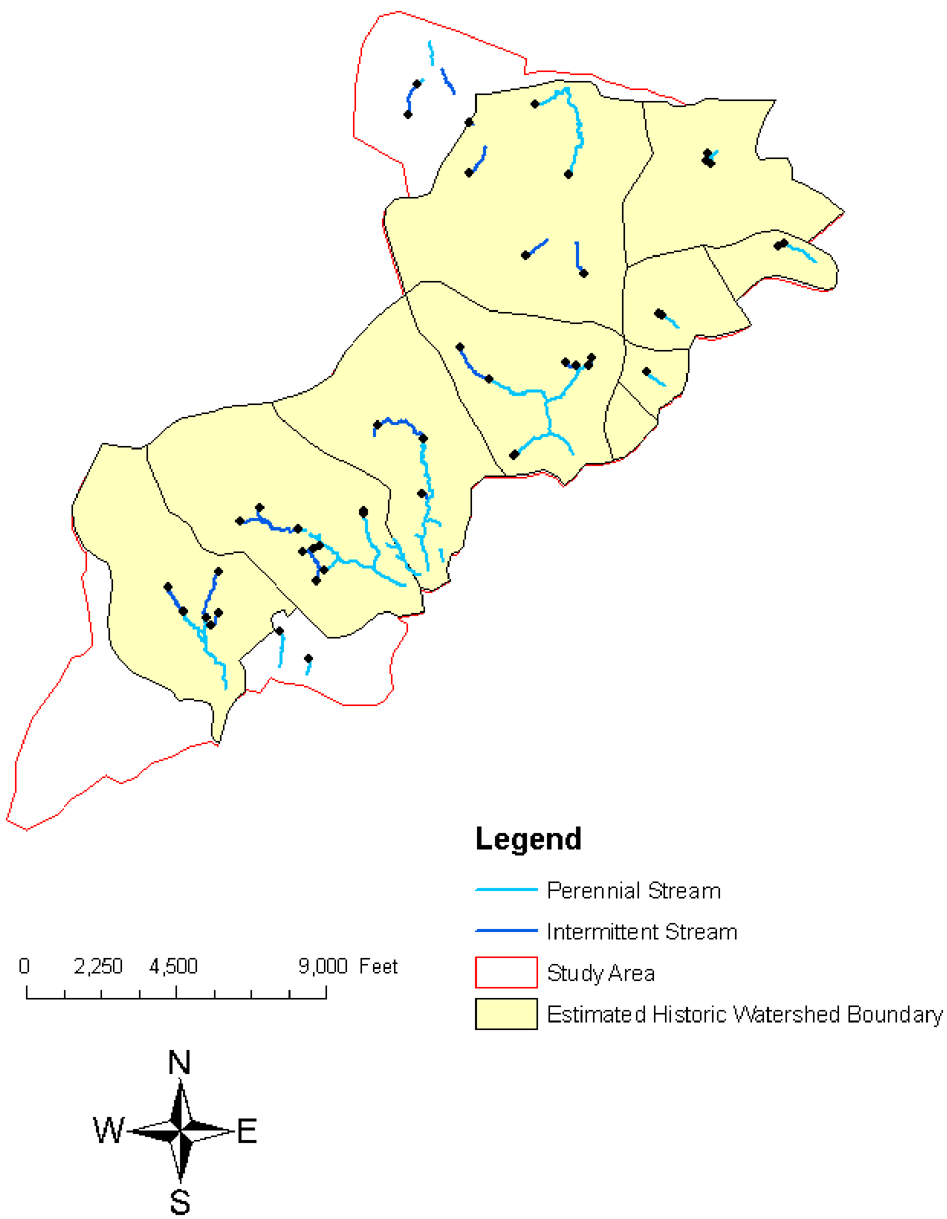


Figure 3: Estimated Historic Watersheds
PCS Phosphate Company Study Area
Beaufort County, NC



Results

Historical and Current Conditions

Forty five stream origins were mapped and evaluated, of which 23 are intermittent and 22 are perennial. The distribution of contributing watershed area for current and historic conditions spans 0.44 acres to 411 acres for all origin flow durations (Figure 5). The range of historical contributing drainage area is generally broader than current drainage area reflecting the changes in drainage patterns due to ditching. However, it is also possible that historic stream origin locations differed from current locations and that increases or decreases in contributing area resulted in the migration of the origin upstream or downstream respectively. Essentially, current contributing drainage area may be described as the area required to maintain the current flow duration for a particular stream.

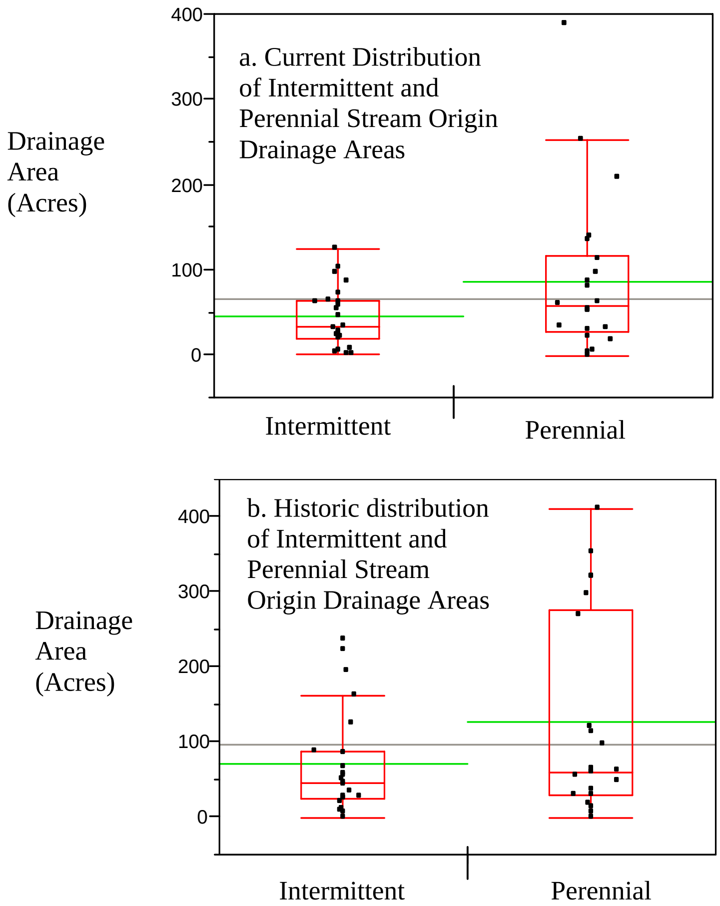


Figure 5a,5b: Current and Historic Drainage Area Distributions. Box plots indicate quantiles, green line represents mean, gray line is grand mean.

Distribution of current drainage area (Table 1) for intermittent streams ranges from approximately 1 to 125 acres with a median of 35 acres and a mean of 46 acres. Perennial stream areas have a broader range from 0.42 to 389 acres with an approximate median of 58 acres and mean 87 acres. While drainage area independently may not account for the variability in flow duration, it is reasonable to expect greater drainage area contributions for perennial flows. Historic contributing areas tend to be greater than current areas suggesting the influence of altered drainage in ditching efforts. It is also possible the location of the origin as well as the flow duration for streams has changed due to altered drainage patterns, but data are not available to investigate potential changes. Adequately addressing location and flow duration changes from past to present would require a detailed study that would include the influence of ground water.

Table 1: Distribution of Stream Origin Current and Historic Drainage Areas

Quantiles	**Current Contributing Area (Acres)**		**Historic Contributing Area (Acres)**	
	Intermittent	Perennial	Intermittent	Perennial
Minimum	1.23	0.42	0.44	0.84
10%	3.68	3.84	7.73	8.62
25%	22.14	20.88	25.24	30.61
Median	35.09	57.78	46.19	61.33
Mean	46.48	86.52	71.01	127.20
75%	65.28	118.12	88.18	277.01
90%	100.54	240.40	211.98	344.11
Maximum	125.36	388.65	237.51	411.51

Assuming flow duration and origin location remained relatively constant over time, intermittent streams netted a 50% change in contributing area from historic to current conditions. Approximately 68% of perennial streams lost contributing drainage area with an average change of – 39.50 acres. The range of change in intermittent drainage area is – 236 to 54 acres where the range for perennial area is –265 to 52 acres (Appendix 2).

Soils

Intermittent and perennial stream origins were also evaluated by soil type. Table 2 illustrates the frequency of origins by soil and the density of origins by soil. Density serves to normalize the number of origins by the soil area to more accurately describe the influence of soil type. These data were obtained by intersecting the origin layer with the soil layer in ARC MAP and so reflect any error (unknown) associated with soil mapping. Overall, Roanoke and Muckalee soils have the greatest number of streams of both flow durations, though the Muckalee had a greater density. The one origin in Wasda was mapped closely to a contact zone between soil types, as were 5 others in Tomotley and Roanoke. The data indicate more intermittent origins in Roanoke and Augusta and more perennial origins in Muckalee. Although Currituck, Wahee and Dorovan have a greater density of origins, the low number of origins along with the potential error in soil mapping limits a confident conclusion. Belhaven, Cape Fear, Dragston, Pantego, Pitts and Portsmouth soils are not associated with stream origins in this area.

Table 2: Current Contributing Area by Soil Type

Soil	Area (acres)	Intermittent Frequency	Perennial Frequency	Total Frequency	Density (Freq/Area)
Tomotley	128.64	2	4	6	0.05
Roanoke	177.62	8	4	12	0.07
Altavista	10.56	0	1	1	0.09
Augusta	37.75	6	1	7	0.19
Currituck	4.55	0	1	1	0.22
Wahee	7.88	2	2	3	0.38
Dorovan	2.16	0	2	2	0.93
Muckalee	12.00	5	7	12	1.00
Wasda	0.36	1	0	1	2.75

Erosion Threshold Index

Past researchers have mathematically described the stream origin or channel head as the exceedance of an erosional threshold that is influenced by geology, soils, climate regime and land use (Montgomery and Dietrich 1988,1989). The threshold is specific to the controlling water delivery mechanism, i.e., overland flow or seepage erosion, and is a function of contributing drainage area and the local ground slope (Dietrich et al. 1992, 1993; Montgomery and Dietrich 1994; Hancock and Evans 2006). Drainage area is commonly used in channel initiation models since drainage area is positively correlated with discharge and may serve as a surrogate. The slope-area plot for current conditions (Figure 6) indicates the relationship between slope and contributing area for each flow duration.

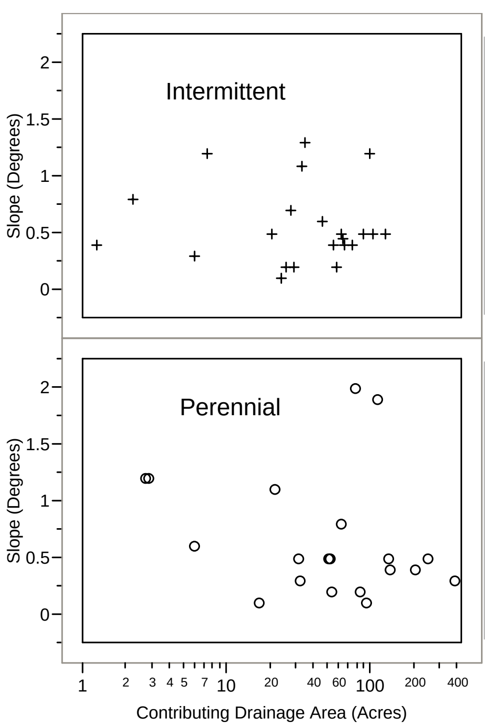


Figure 6: Local Slope vs Contributing Drainage Area

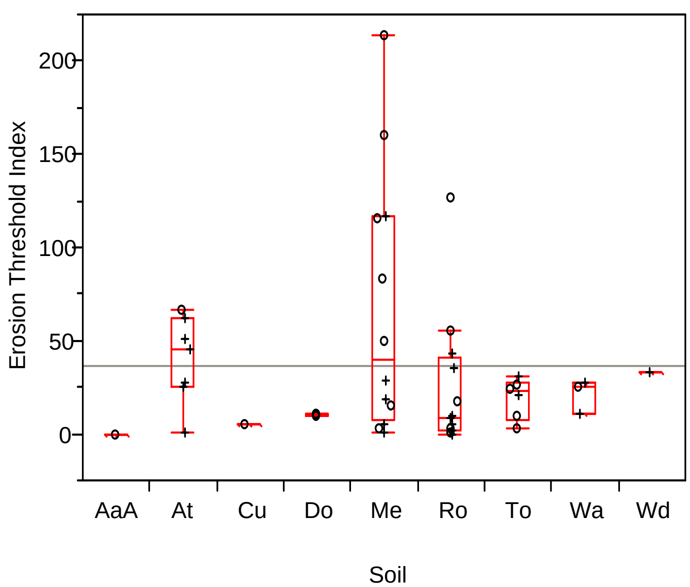
Generally, an inverse relationship exists for perennial origins. This result is consistent with other studies investigating slope and area dependence and channel origins (Montgomery 1994, 1999; Montgomery and Dietrich 1994; Dalla Fontana and Marchi 2003; Hancock and Evans 2006). However, an inverse is not evident for intermittent origins. In most studies, 100 or more origin points were obtained for analysis to adequately represent the variability of the data. The low number of data points and map-derived slope estimates are both limiting factors for analysis. Specifically, since the true slope range in the outer coast plain is narrow (0-2% average), slope estimates contain greater error than they would if derived in a steep, mountainous area. Additionally, slope, area and soils are not the only contributing factors to intermittent and perennial origin locations. In the South Creek area where ditching has altered the natural flow regime, the method of capturing contributing drainage area from digital maps masks the local characteristics of flow patterns. Major and minor ditching is likely to have large effects on flow paths that can not be discerned at the 20-ft DEM resolution. Field measurement of local slope and additional origin points would provide for more accurate analysis and would provide the information for better interpretation.

The raw data used for the slope-area relationship was also used to calculate an erosion threshold index with the equation

$$\text{ET index} = DA*S$$

where DA is the contributing drainage area and S is the generalized local slope at the origin.

In Figure 7 below, ET serves as an overall index of stream origin formation. ET represents the relative difference between stream origins. Figure 7 illustrates the relative ET ranges of intermittent and perennial origins based on soil types.



Soil	Abbreviation
Altavista	AaA
Augusta	At
Currituck	Cu
Dorovan	Do
Muckalee	Me
Roanoke	Ro
Tomotley	To
Wahee	Wa
Wasda	Wd

Figure 7: Distribution of Erosion Threshold Index by Soil Type.
Intermittent (+); Perennial (o)

The distribution of the erosion threshold index across soil types indicates the largest range of ET lies within Muckalee soils. The same number of origins (12) was mapped in Roanoke soils but the range of ET is smaller even though the total area of Roanoke soils in the study area is much greater than Muckalee. Muckalee soils cover an area of 12 acres compared to the Roanoke soil area of 177 acres. These data strengthen the general hypothesis that stream origin and formation processes differ between soil types. Muckalee loams tend to be poorly drained, floodplain soils with moderate permeability and water capacity and experience frequent flooding due to high seasonal water table elevations. Roanoke fine sandy loams are also poorly drained, but tend to be located along stream terraces and therefore a bit higher in elevation so are not subject to frequent flooding. The difference between water table elevations within each soil type is indicative of the range of slope and drainage area required to maintain flow regimes. The higher elevation of the water table in Muckalee soils may allow for higher variation in the slope-area product due to the availability of water regardless of the slope. The Augusta soils (also fine sandy loam) tend to maintain intermittent streams at an ET range of 25 to 58 and perennial streams slightly above at 67.

Conclusions

The data used in this investigation are insufficient for statistical analysis since other factors beyond slope, soil type and drainage area contribute to the variability in flow regimes and their origins. Outer coastal plain streams are also strongly influenced by water table elevations that are, in turn, are affected by land use and ditching. The magnitude of these additional influencing factors is unknown. However, the slope-area plots may be useful as a supplementary guide to land managers in making management decisions. Erosion threshold ranges within soil types may also allow for slope-area adjustments for site specific conditions or site limitations. These indices provide qualitative information regarding the slope and drainage area required to maintain current flow regimes of streams. Since the slope and drainage area were derived from digital maps, additional origins and field measured slopes would enhance the reliability of the analysis. Field measured local slope would at least provide the data for error analysis between map and field derived slopes. More rigorous analysis should include the effects of ditching on flow paths to capture more accurate drainage areas contributing to stream origins and their flow regimes.

References

Dalla Fontana G, Marchi L. 2003. Slope-Area relationships and sediment dynamics in two alpine streams. Hydrological Processes 17:73-87.

Griffith et al. 2002. Ecoregions of North and South Carolina (color poster with map, descriptive text, summary tables and photographs): Reston, Virginia US Geological Survey (map scale 1:1,500,000).

Hancock GR and Evans KG 2006. Channel head location and characteristics using digital elevation models. Earth Surface Processes and Landforms 31: 809-824.

Montgomery DR**,** 1994. Road surface drainage, channel initiation and slope stability. Water Resources Research 30(6):1925-1932.

Montgomery DR**,** 1999. Erosional processes at an abrupt channel head: implications for channel entrenchment and discontinuous gully formation. In *Incised River Channels: Processes, Forms, Engineering and Management*, Darby SE, Simon A (eds). John Wiley: New York;247-276.

Montgomery DR, Dietrich WE, 1988.Where do channels begin? Nature 336:232-234.

Montgomery DR and Dietrich WE 1992. Source Area, Drainage Density and Channel Initiation. Water Resources Research 29(12):3925-34.

Montgomery DR and Dietrich WE 1989. Channel Initiation and the problems of landscape scale. Science 255:826-830.

NC Division of Water Quality. 2005. Identification Methods for the Origins of Intermittent and Perennial streams, Version 3.1. North Carolina Department of Environment and Natural Resources, Division of Water Quality. Raleigh, NC.

Soil Survey of Beaufort County, North Carolina, 1995. NRCS, USDA

APPENDIX 1

originnum	Slope (Degrees)	Area (acres)	originid	Flow Duration	Soil	Contributing Drainage Area (Acres)	Erosion Threshold Index
0	0.6	6.0609802	0	pe	Ro	6.06098021	3.636588126
1	1.2	7.1729304	1	in	Ro	7.172930413	8.607516495
2	0.5	134.68223	2	pe	At	134.6822311	67.34111553
3	0.5	20.372777	3	in	Ro	20.37277692	10.18638846
4	0.1	17.053958	4	pe	Ro	17.05395837	1.705395837
5	0.5	87.418265	5	in	Ro	87.41826454	43.70913227
6	0.4	209.0734	6	pe	Me	209.0734028	83.62936114
7	0.5	62.531992	7	in	To	62.53199173	31.26599586
8	0.8	2.1874031	8	in	At	2.187403135	1.749922508
9	1.2	2.795691	9	pe	Me	2.795690992	3.35482919
10	0.4	140.45123	10	pe	Ro	140.4512331	56.18049324
11	0.4	54.553688	11	in	To	54.55368819	21.82147528
12	0.3	5.9222906	12	in	Me	5.922290578	1.776687173
13	0.4	65.286319	13	in	At	65.28631914	26.11452766
14	1.2	2.9343806	13	pe	To	2.934380623	3.521256748
15	1.5	22.141678	14	in	Wd	22.141678	33.21251701
16	1.1	22.148977	15	pe	To	22.14897746	24.3638752
17	0.2	29.173486	16	in	Me	29.17348563	5.834697127
18	0.4	1.2263083	17	in	Ro	1.22630832	0.490523328
19	0.5	253.83122	19	pe	Ro	253.8312234	126.9156117
20	1.09	32.652892	20	in	Ro	32.65289218	35.59165247
21	0.5	102.5476	20	in	At	102.5476001	51.27380006
22	0.1	23.689162	22	in	Ro	23.68916231	2.368916231
23	0.5	52.247061	23	pe	Wa	52.24706064	26.12353032
24	0.45	63.463889	24	in	Wa	63.46388872	28.55874993
25	0.4	73.060238	25	in	Me	73.06023796	29.22409518
26	2	80.48135	26	pe	Me	80.48134982	160.9626996
27	0.3	33.270913	27	pe	To	33.27091264	9.981273792
28	0.2	58.14502	28	in	Wa	58.1450197	11.62900394
29	0.5	52.804252	29	pe	To	52.80425231	26.40212616
30	1.9	112.59895	30	pe	Me	112.5989487	213.9380025
31	1.2	97.535308	31	in	Me	97.53530818	117.0423698
32	0.2	25.77194	32	in	Ro	25.77193994	5.154387987
33	0.8	63.205975	33	pe	Me	63.20597467	50.56477974
34	0.5	31.884016	34	pe	Me	31.88401633	15.94200816
35	0.6	46.023059	35	in	At	46.02305928	27.61383557
36	0.2	87.072757	36	pe	Ro	87.07275704	17.41455141
37	0.5	125.36902	37	in	At	125.3690184	62.6845092
38	0.1	96.299267	38	pe	Do	96.29926726	9.629926726
39	0.1	60.266728	39	pe	Cu	60.26672775	6.026672775
40	0.7	27.752525	40	in	Me	27.7525252	19.42676764
41	0.3	388.65458	41	pe	Me	388.6545772	116.5963732
42	0.2	0.4209352	42	pe	AaA	0.420935197	0.084187039
43	1.3	35.098209	43	in	At	35.09820936	45.62767217
44	0.2	55.303099	44	pe	Do	55.30309883	11.06061977

APPENDIX 2
Change in Historic and Current Contributing Area For Intermittent Streams

Historic Area (acres)	Current Area (acres)	Flow Duration	Current - Historic (acres)
11.348	65.286	Int	53.94
46.197	97.535	Int	51.34
28.626	62.532	Int	33.91
25.241	58.145	Int	32.90
44.241	73.060	Int	28.82
26.560	54.554	Int	27.99
10.103	32.653	Int	22.55
86.565	102.548	Int	15.98
27.835	35.098	Int	7.26
56.775	63.464	Int	6.69
0.443	2.187	Int	1.74
6.155	7.173	Int	1.02
21.027	5.922	Int	-15.10
35.585	20.373	Int	-15.21
50.556	23.689	Int	-26.87
57.863	22.149	Int	-35.71
67.743	25.772	Int	-41.97
88.182	46.023	Int	-42.16
194.457	125.369	Int	-69.09
162.470	87.418	Int	-75.05
124.517	27.753	Int	-96.76
223.672	2.934	Int	-220.74
237.510	1.226	Int	-236.28

APPENDIX 2 (cont)

Change in Historic and Current Contributing Area For Perennial Streams

Historic Area (acres)	Current Area (acres)	Flow Duration	Current - Historic (acres)
60.693	112.599	Per	51.91
97.857	140.451	Per	42.59
48.508	80.481	Per	31.97
30.673	52.804	Per	22.13
17.895	33.271	Per	15.38
56.267	60.267	Per	4.00
0.838	2.796	Per	1.96
60.528	55.303	Per	-5.22
6.019	0.421	Per	-5.60
14.677	6.061	Per	-8.62
61.966	52.247	Per	-9.72
30.405	17.054	Per	-13.35
37.286	22.142	Per	-15.14
411.512	388.655	Per	-22.86
121.094	96.299	Per	-24.79
64.393	29.173	Per	-35.22
113.962	63.206	Per	-50.76
321.264	253.831	Per	-67.43
353.765	209.073	Per	-144.69
270.427	87.073	Per	-183.35
321.607	134.682	Per	-186.93
296.774	31.884	Per	-264.89

Appendix E
The Water Quality in Headwater Wetlands and Associated Streams in the Coastal Plain and Piedmont of North Carolina
NC Division of Water Quality
August 17, 2007

Headwater wetlands play a critical role both in terms of water quality, hydrology and habitat in North Carolina watersheds. Water quality in North Carolina has been affected by watershed development. Urbanization, agriculture, and silviculture have decreased the quality of storm water runoff that flows into wetlands and streams. This can result in the increase of pollutants such as nutrients, pesticides, metals, oil, grease, bacteria and sediments that enter wetlands and streams. Headwater wetlands and streams (1^{st} and 2^{nd} order) drain 55-85% of watersheds in North Carolina (Gregory, in USFWS 2000). Since headwater systems are small and numerous in the landscape, historically their importance has been underestimated and therefore managed poorly in comparison with rivers and lakes (Peterson et al. 2001). The US has seen a 53% loss of wetlands in the lower forty-eight states since the year 1700 (Mitsch and Gosselink, 2000). In 1780 in North Carolina, there were an estimated 11,090,000 acres of wetlands that were reduced to 5,690,000 acres by the mid 1980s, resulting in a 44% reduction in wetlands over 200 years (Mitsch and Gosselink, 2000). Wetlands and small streams act as a natural filtering system for water quality by removing, reducing or transforming these pollutants (Azous and Horner, 2001, and Ohio EPA, 2006).

Wetland loss has probably had a negative effect on water quality in the US and North Carolina. In North Carolina, ten percent of the stream and river miles are considered to be impaired waters for aquatic life (NCDWQ Water Quality Assessment and Impaired Waters List [2006 Integrated 305[b] and 303[d] Report). According to the EPA, non-point source pollutants from storm water runoff are the leading cause of the decline of water quality in the US (EPA, 1994). Like many parts of the southeast, North Carolina has seen rapid development in recent years with a population growth of 18.1% in the last 10 years compared to the 11.1% US growth rate (demog.state.nc.us). Urbanization, agriculture, and silviculture have all contributed to the decrease the quality of storm water runoff that flows into wetlands and streams within watersheds throughout the state. A better understanding of the role these headwater systems have on improving water quality and how the surrounding landscape affects that water quality is necessary to better protect and manage these highly important aquatic systems.

The NC Division of Water Quality (NC DWQ) has conducted a water quality monitoring effort for headwater wetlands for an EPA funded grant. One of the goals of this research was to determine whether headwater wetlands reduce pollutants and thereby improve downstream waters. NC DWQ monitored 19 chemical and physical water quality parameters at 12 Piedmont and 11 Coastal Plain headwater wetlands study sites over 18 months in 2005 and 2006. For this report, the analysis for this original study has been revised to include only those sites that had water samples collected from the headwater wetland and the associated 1^{st} order headwater stream in order to examine the effect that headwater wetlands have on water quality.

Site Selection and Methods

Twelve sites in the Piedmont and eleven sites in the Coastal Plain were chosen for the original DWQ headwater wetland study (see Figure 1) in 2004 and 2005. The sites chosen were forested wetlands located at the origin of a steam that had various levels of disturbance from fairly pristine to highly disturbed. Most sites in the Piedmont were typically bowl-shaped wetlands that graded into headwater streams. Some sites were similar in the Coastal Plain while others were flatter, wider and covered more area before a stream formed which was often downstream of the study site boundary. Water samples were taken at up to three sample station locations: “upstream”, “downstream”, and “further downstream” (see Figure 2). All sites had an “upstream” location that was located near the head or center of the wetland and a “downstream” location that was typically located 200’ downstream often within the first order stream. Some of the larger and flatter headwater wetland sites within the Coastal Plain resulted in the “downstream” station locations being located in the headwater wetland rather than a stream. The “further downstream” station location was established at five of the Coastal Plain sites after preliminary data analyses suggested Piedmont upstream to downstream water quality station comparisons showed better rates of improvement then Coastal Plain upstream to downstream water quality station comparisons. A “further downstream” sample station was also taken at five of the Coastal Plain sites approximately 150’ to 200’ downstream of the downstream station location.

For this report, seven of the Coastal Plain sites have not been included in the analysis since the downstream station location was sampled within a wetland rather than a stream. Some sites were also excluded because the downstream station location was located considerably less than 200’ from the upstream station location. Table 1 shows the DWQ headwater wetland sites, the physiographic characteristics of each site’s sample stations (i.e. wetland, type of stream, etc), whether the site was included in the ACOE analysis, and why the site was excluded.

Water quality parameters were sampled on a quarterly basis for six times: in April 2005, July 2005, October 2005, January 2006, April 2006 and July 2006. Sampling during these time periods allowed DWQ to obtain information on water quality during the dry season, wet season, and transition periods in between. All water samples were collected, preserved and transported in accordance with Division of Water Quality Laboratory Standard Operating Procedures (SOP - http://h2o.enr.state.nc.us/esb/isu.html) and DWQ Laboratory Sample Submission guidelines (http://h2o.enr.state.nc.us/lab/qa.htm). All samples were analyzed at the Division of Water Quality Laboratory Section in Raleigh, NC. Water samples were analyzed for nutrients (P, NO_2+NO_3 as N, total Kjeldahl-nitrogen [TKN], NH_3-N), heavy metals (Mg, Ca, Cu, Pb, and Zn), dissolved organic carbon (DOC), total organic carbon (TOC), total-suspended solids (TSS), and fecal coliform during all sample periods. Turbidity was only analyzed in the first sample period and was then deemed to be an unnecessary parameter to collect in headwater systems. Additionally, DOC was not analyzed in the second and third (July 2005 and Oct 2005) sample periods due to drought conditions while magnesium and calcium were not analyzed in the first sample period. The physical parameters (pH, DO, specific conductivity, and temperature) were taken in the field at the time the water quality sample was collected. A total of up to 19 sample parameters were collected during each sample period at each sample station.

The hydrological conditions of the water quality station varied according to season and therefore dictated the sampling method chosen on the sampling day; direct grab, bail, or soil pore sample (sample obtained by digging with a plastic/metal shovel). DOC, turbidity, and TSS were not analyzed in soil pore water samples. Digging with a shovel could affect the results since, a metal shovel (in particular), may affect the metal results for copper, lead, or zinc. For the data analyses, as described in the next section, a set of analyses was completed using “all” the data (direct grab, bail, and dig methods) and “No Dug” only data (Data obtained by sampling directly no digging with plastic or metal shovel). A few of the metal results from digging were extreme outliers that were not used in the “all” data analysis.

Data Analysis Methods

Water quality results were organized and entered into an Excel spreadsheet. JMP (Version 6, SAS Institute Inc., 2006) statistical software was used for all statistical analyses on the data. Two sets of results were calculated for each statistical analysis. One set of results was calculated with “all” water quality data (which includes surface water and soil pore water or dug samples) and the other set was calculated with just the “no dug” data. The “no dug” data (or “no dig”) is from samples obtained by bail and direct grab methods, rather than digging with a plastic or metal shovel. This two set analysis was completed to account for the affects that digging to obtain a sample might have on the water quality results.

The mean and median for the water quality results at each station location (upstream, downstream, and further downstream) was calculated for each parameter within each site using all the data results and using just the No Dug results. The upstream (UP), downstream (DN), and further downstream (FD) mean and median station results were compared to determine if the water quality improved downstream. Station comparisons; upstream to downstream (UP-DN), upstream to further downstream (UP-FD), and downstream to further downstream (DN-FD) were deemed to have had either “improvement” or “no improvement” for each of the 19 parameters at each site. A reduced result value for all parameters at the down stream station (DN or FD), except for dissolved oxygen (percent and mg/L) and pH in which and increased result value indicated improvement.

Station comparisons (UP-DN, UP-FD, and DN-FD) were also made for each site for sample periods in which a sample was obtained from at least two sample stations; upstream and downstream, upstream and further downstream, or downstream and further downstream. A tally of the number of “site-paired” station comparison improvements verses no improvements per parameter and overall was made. The percent “improvement” or “no improvement” was also calculated for site paired station comparisons in which water quality samples were obtained from two or more sample stations during the same sample period. An example equation for the UP-DN percent-improvement is shown below. The mean and median values of the percent-improvement of the site-paired station comparisons per parameter were also calculated.

$$\% \text{ improvement} = [(UP\text{-}DN)/UP] * 100$$

ANOVAs were run to determine if there was a significant difference between the upstream, downstream and further downstream station results. The entire data set and the no dug data set were used to perform the ANOVAs. For the Coastal Plain, when a significant ($P \leq 0.15$) ANOVA result was found, a further analysis using Tukeys Multiple comparison test, was completed to differentiate which station comparisons (UP-DN, UP-FD, and DN-FD) were significantly different. The non-parametric Rank Sums tests (Wilcoxon and Kruskall Wallis) were also used to determine if there was a significant difference between the upstream, downstream, and further downstream station results. The Wilcoxon test was used for sites that had two stations and the Kruskall Wallis test was used for sites that had three stations in the Coastal Plain. The parametric statistic ANOVA was run on the data as well as the nonparametric Rank Sums test (Wilcoxon or Kruskal Wallis) because the data are sometimes not as normally distributed as would be desired. Finally, when a significant result occurred where variable had three levels (therefore, three sample location, UP, DN, and FD), a Tukeys multiple comparison test was used to isolate which pairs were significantly different.

The data for surface water and pore water were further analyzed separately for the four Coastal Plain sites and the 12 Piedmont sites. This level of Eco-region was felt to be an important variable and as previously explained, the topography of the headwater wetlands differ in that the Piedmont headwater wetlands tend to be more bowl shaped and emerging to a first order stream whereas the Coastal Plain head water wetlands were larger, flatter, and typically required longer distances before stream channels appeared.

The ANOVA and Ranks Sums statistical tests were also run on “site paired” station comparisons (two or more stations samples obtained on the same day) for all sites combined and the Piedmont and Coastal Plain separately (all data and no dig data analyses). Additionally, those same statistical tests were run on site paired station comparisons for each individual site (all data and no dig data analyses) in order to determine if certain sites significantly improved or significantly worsened water quality flowing downstream.

Statistical Concerns

Multiple statistical tests were run on the data because of the exploratory nature of this stage of the research. The resulting risk of creating a Type I statistical error was considered acceptable to the researchers because it is very important that all results, which are ‘practically significant’, are discovered as this will help guide further research and analysis. In addition a liberal p-value was used again to ensure that all practically significant results were discovered. The researchers also considered this an acceptable risk of increasing the probability for a Type I error. This liberal p-value is also necessary in that field research is not a tightly controlled as laboratory research. A p-value of $0.1 \leq 0.15$ was considered to be of “practical significance” and a p-value of < 0.1 was considered to be a “strong significant” result in the analyses for this report.

Results and Discussion

The mean and median for the water quality results at each station location within each site and whether there was an improvement from upstream to downstream to further downstream stations is shown in Tables A.1 (all data) and A.2 (No Dug Data) for results respectively in the Appendix. Tables 2.a (all data) and 2.b (no dug data) summarize the information shown in Appendix Tables A.1 and A.2 respectively. Tables 2.a and 2.b show the number of sites (16 sites) that had “improvement” and “no improvement” for the mean and median station comparison (UP-DN, UP-FD, and DN-FD) for each parameter. Table 2.a and 2.b also show the total number of sample station mean and median comparisons that improved or did not improve. Dissolved oxygen (% and mg/L), calcium, magnesium, phosphorus, specific conductivity, TKN, turbidity, and Zinc generally had more improvements while lead and NO2+NO3 generally had more no improvements for mean and median station comparisons within sites for all the data analysis (see Table 2.a). Overall for the UP-DN, UP-FD, and DN-FD there were 176:122, 62:10, and 55:17 improvements to no improvements for mean station comparisons respectively and 163:135, 51:21, and 48:24 improvements to no improvements for median station comparisons respectively for the analysis of all the data (see Table 2.a). There were fewer improvements for the analysis of the no dig data mean and median station comparisons (see table 2.b). Calcium, dissolved oxygen (mg and %), specific conductivity, turbidity, and pH generally had more improvements while copper, fecal coliform, lead, and NO2+NO3 generally had more no improvements for mean and median station comparisons within sites (see Table). Overall for the UP-DN, UP-FD, and DN-FD there were 134:135, 50:22, and 58:14 improvements to no improvements for mean station comparisons respectively and 134:135, 42:25 and 52:20 improvements to no improvements for median station comparisons respectively for the analysis of the no dig data only (see Table 2.b).

Table 3.a (all data) and 3.b (no dug data) shows the tally of the number of site-paired station comparison improvements versus no improvements at all sites per parameter (i.e. paired stations comparisons are UP-DN, UP-FD, and DN-FD station comparisons that were made at the same site during the same sample period). Table 3.a and 3.b also shows the overall total number of site-paired station comparisons that had improvement or no improvement. For the analysis of all the data (Table 3.a), dissolved oxygen (mg/L and %), phosphorus, TKN, TOC, TSS, and turbidity had greater than 1.5 times as many improvements as no improvements while ammonia, lead, and NO2+NO3

had greater than 1.5 times no improvements as improvements. Dissolved oxygen (mg/L and %) had the highest number of improvements to no improvements at 57:15 (%) and 58:14 (mg) and NO2 +NO3 had the highest number of no improvements to improvements at 59:11. As indicated in Table 3.a, there were 541:496, 62:21, and 65:53 overall improvements to no improvements for UP-DN, UP-FD, and DN-FD site-paired station comparisons for the analysis of all the data. The site-paired station comparisons had fewer improvements for the analysis of the No Dug Data in comparison to the analysis of all the data as shown in Table 3.b. Dissolved oxygen (mg/L and %), phosphorous, and turbidity had greater than 1.5 times as many improvements as no improvements while calcium, copper, lead, NO2+NO3, specific conductivity, and turbidity had greater than 1.5 times as many no improvements as improvements. Table 3.b also shows there were 291:324, 22:13, and 30:40 overall improvements to no improvements for UP-DN, UP-FD, and DN-FD site-paired station comparisons analysis of the No Dug the data only.

Table 4.a (all data) and 4.b (no dug data) shows the mean and median of the percent "improvement" or "no improvement" for site-paired station comparisons by parameter (see methods for a definition of percent-improvement). Table 4.a (all data analysis) shows that the mean and median values for percent-improvement showed more improvement for the UP-FD and DN-FD then the UP-DN site-paired station comparisons as indicated by the number of UP-FD and DN-FD results in bold blue type. For the UP-DN site-paired station comparisons, the average of the percent-improvements did not show downstream improvement for most parameters while the median of the percent-improvements showed the downstream station improved or stayed the same (as indicated by a red 0.0). This suggests there were higher level of pollutants in some of the downstream stations that acted as outliers in the percent-improvement mean analysis for the UP-DN site-paired station comparison. Fecal coliform had the only negative no improvement value for the UP-DN site paired station comparison in the median analysis. This suggests that more times then not there was a higher level of fecal coliform at the downstream station then the upstream, while all other parameters were more likely to stay the same or improve at the downstream station. Table 4.b (No Dug data analysis) shows the mean and median value for percent-improvement showed more improvement for the UP-FD then the UP-DN and DN-FD site-paired station comparisons, again, as indicated by the number of UP-FD results bold blue type. This may be due to the upstream and further downstream stations are located the farthest apart, therefore the wetland and stream have more time to filter out pollutants. Similarly to the analysis of all water quality, fecal coliform had poor results for the analysis of the No Dig data only (see Table 4.b). There were negative no improvement values for the UP-DN and UP-FD site-paired station comparisons for the both mean and median percent-improvement analysis. This indicates that the downstream compared to the upstream and further downstream compared to the upstream stations were on average and more likely to have higher levels of fecal coliform.

Table 5.a summarizes the significant results of the ANOVA's and the Rank Sums tests, as well as the Multiple Comparison test (Tukeys) when it was warranted (when

there were three station results to be compared). The first set of results uses all of the data in terms of surface water and pore water (dug). The results for all of the chosen sites show that dissolved oxygen (both percent and mg/L) significantly improved downstream from the headwater wetland (UP-DN comparison). TKN and TOC also significantly improved downstream, meaning that potentially harmful levels for TKN were filtered out in the headwater wetland. All of these results were significantly strong results ($p<.067$). Significant result (practical) also occurred for zinc, showing improvement from the headwater wetland to downstream (less zinc downstream), and for pH (less acidic downstream).

The data for surface water and pore water were further analyzed separately (due to eco-region differences) for the four Coastal Plain sites and the 12 Piedmont sites. For the Coastal Plain (see Table 5.a), percent dissolved oxygen significantly improved from upstream (UP) to further down (FD). TSS was practically significant showing definite improvement from the wetland center (UP) to further downstream (FD) while TKN showed a strong improvement ($p<.068$) from the wetland center (UP) to further downstream (FD). Fecal coliform was also significant, however the results show that the levels of fecal coliform increase downstream, an indication that the wetland was not adequately filtering fecal coliform.

For surface water and pore water in the Piedmont, Table 5.a shows strong results for several parameters, all at $p < 0.087$. Dissolved oxygen (percent and mg/L) showed significantly strong improvement from the wetland center to downstream. For the nutrients, phosphorus and TKN, and for TOC, the results all significantly improved downstream (DN) from the wetland center (UP), showing that headwater wetlands are filtering out pollutants properly. Metals on the other hand were mixed, with zinc and copper showing significant improvement from the wetland center (UP) to downstream (DN). Lead however significantly increased from the wetland center (UP) to the downstream sample location (DN).

The next set of results analyzed the surface water only (therefore sampled directly, and no digging of pore water). Table 5.b shows that for all of the sites (Coastal Plain and Piedmont), dissolved oxygen (percent and mg/L) showed improvement from the wetland center (UP) to downstream (DN). Phosphorus also showed improvement downstream resulting in the headwater water filtering out a potential harmful nutrient. Turbidity showed improvement, becoming less turbid downstream from the wetland center. All of these results showed practical significance ($0.09<p<0.147$). Lead had practical significance, as well, resulting in higher levels of lead downstream from (DN) the wetland center (UP).

The surface water data was then split out based on eco-region between the four Coastal Plain sites and the 12 Piedmont sites. For the Coastal Plain, TSS significantly improved down stream from the wetland center (UP) at both downstream and further downstream stations. In terms of nutrients, phosphorus and TKN both significantly improved from the downstream location (DN) to further down (FD). However, phosphorus and lead levels initially significantly increased from the wetland center (UP) to the downstream station location (DN) and then significantly decreased to the further downstream station (FD). This initial lack of improvement of phosphorous and lead from upstream to downstream stations and the improvement from downstream to further downstream stations seems inconsistent. This may be a factor of changes in site topography, soils, vegetation, or sample size. The upstream to downstream comparisons had 6 sample periods and the downstream to further downstream had 2 sample periods. Another explanation could be that additional phosphorous and lead pollutants have entered the headwater stream complex below the upland water quality station, therefore causing the initial increase in of these pollutants.

For the Piedmont sites with surface water only, dissolved oxygen (mg/L) significantly improved downstream (DN) from the wetland center (UP). TKN also improved downstream and was a fairly strong result ($p<.087$). Finally, turbidity decreased downstream which is an improvement from the wetland center.

The fecal coliform result for the Coastal Plain showed increased levels downstream when using both surface water and pore water (dug) data. When only surface water data was used, the fecal coliform result was not significant. This implies that it was the pore water that was causing this result and in fact when the pore water data is analyzed only for the Coastal Plain, the fecal coliform result is significant, therefore increased levels occurred further downstream. Because the water samples that were dug further down had high levels of fecal coliform but the surface water at the same location did not, implies that the fecal coliform was sinking into the soil and was in fact being filtered out of the water. This also indicates that fecal coliform, like some of the metals, may need larger (wetland) areas to be adequately filtered out. Lead for the Piedmont also show the same trend for surface water and pore water, however with surface water only was analyzed, lead was not longer significant. When looking at the pore water (dug) alone, lead came our significant downstream from the wetland center, therefore having higher levels. This probably indicates that the lead in sinking into the soil and as with the fecal coliform, is in fact being filtered out and therefore not being a significant factor in the surface water. Another possibility is that the soil already had higher levels of fecal coliform and lead, independent of the filtering process.

For the site paired station comparisons, an ANOVA and Rank Sums tests were also performed. The analysis of the site paired station comparisons, (i.e. sample periods in which a sample was obtained from at least two sample stations, UP-DN, UP-FD, or DN-FD, on the same day) was done as another way of looking at the massive amount of water quality data. It was hoped that this analysis would provide clearer and stronger results. The surface water and pore water (dig and no dig) results are shown in Table 6.a. For the Coastal Plain and Piedmont, the results for dissolved oxygen (percent and mg/L) were significant with dissolved oxygen improving downstream. The Rank Sums test also was significant for the nutrients phosphorus and TKN, with both improving downstream, indicating better water quality.

The analyses of the Coastal Plain sites only, indicate dissolved oxygen (percent) was significant with both the ANOVA and Rank Sums test, showing improvement downstream. The nutrients phosphorus and TKN were also significant with the Ranks Sums test, both improving downstream. Fecal coliform was significant with the ANOVA, but the results indicate that fecal coliform significantly increased downstream.

The results for the Piedmont sites only also showed significant results for dissolved oxygen (percent and mg/L) with both statistical tests, showing improvement downstream. The nutrients phosphorus and TKN were significant with both the ANOVA and Rank Sums test, and showed lower levels downstream, therefore improving water quality. The metals copper, lead, and zinc were also significant with both tests, shows improvement downstream. TOC was significant with the ANOVA and Rank Sums showing lower levels downstream. TSS showed the same kind of result (significant with the Rank Sums test), with less suspended solids downstream. Finally, fecal coliform was significant with the ANOVA, showing improvement downstream, which is opposite of what the results were for the Coastal Plain sites.

The analysis of the surface water only results (no dig, see Table 6.b.), site paired station comparisons showed only dissolved oxygen came out significant for Coastal Plain and Piedmont sites together, both percent (Ranks Sums test) and mg/L (AVOVA and Rank Sums tests). When the Coastal Plain sites were analyzed alone, again it was only dissolved oxygen showing significant improvement further downstream from upstream (percent (ANOVA and Rank Sums) and mg/L (Rank Sums test)). No Significant results occurred for the Piedmont sites. These results had few statistically significant parameters, but still pointed to improved water quality from headwater wetlands. The fewer significant parameters is likely due to fewer sample points reducing the variability from same day samples. There is also less seasonal variability since sample times in which only one water quality sample was obtained, like during dry summer months were not included in this analysis.

The results of the site paired station comparisons ANOVA and Ranks Sums analysis test also prompted the researchers to do one more set of analyses which looked at each site individually. The goal of this individual site analysis was to discern which sites became significantly better ("significant improvement"), significantly worse ("significant no improvement") or showed little variability ("no significance") in water quality between the upstream, downstream and further downstream stations. This analysis would also allow the researchers to see which parameters had "significant improvement", "significant no improvement", and "no significance" of change in water quality results between stations. The ANOVA and Rank Sums test were run on the water quality data for each site individually. The number of samples are smaller still and the Rank Sums test is less sensitive to the small sample size that the ANOVA.

The significant results (significant improvement and significant no improvement) for the individual site analyses of the site paired station comparisons for the surface water and pore water (all data) are shown in Table 7.a. Most of the sites result in more parameters showing significant improvement, with Fire Tower, PCS, Troxler, Hog Farm Upper, and Umstead having at least nine parameters improving and two or fewer parameters showing significant worsening downstream. Only one site, Pete Harris, is clearly showing more parameters getting significantly worse downstream. There were a total of 75 parameters showing significant improvement downstream and only nine parameters showing significant worsening downstream. A chi-square test shows this result to be highly significant statistically, $p<0.0001$. For the actual parameters, none showed any tendency to consistently become degraded downstream. Fecal coliform is the only parameter that had two instances of worsening downstream. Copper, dissolved oxygen (percent and mg/L), lead, phosphorus, TKN, TOC, and zinc all had at least five instances of showing significant improvement downstream.

The results for surface water only (no dig) are shown in Table 8.a. Looking at the number of parameters that significantly improved versus the number of parameters that significantly worsened downstream, the Fire Tower site in the Piedmont showed eight parameters significantly improved whereas two parameters had significant no improvement (got worse). The Hog Farm Upper site in the Coastal Plain showed ten parameters significantly improved and no parameters got significantly worse. The Piedmont sites Black Ankle Powerline and Umstead had at least two more parameters significantly improving. For the Coastal Plain, East Fayetteville South showed at least two more parameters improving significantly. There was one site that was clearly not filtering water effectively, the Pete Harris site in the Piedmont had two parameters significantly getting worse and no parameters showing improvement downstream.

So based on this analysis of the surface water results (no dig), three Piedmont sites and two Coastal Plain sites showed clear results of significant water quality improvements from the headwater wetland to downstream, whereas one Piedmont site showed significant results of water quality being degraded downstream (significant no improvement). Additionally, seven sites had no significant results. Table 8.b. shows the sum of the parameters with significant improvement versus significant no improvement (28 improved and 8 got worse). A Chi-Square test showed that result significant at $P = 0.0009$. These results again support that headwater wetlands improve the water quality on most parameters.

Finally, in Table 8b, the water quality parameters are listed along with the number of times they showed significant improvement downstream as opposed to the number of times they significantly got worse. Dissolved oxygen clearly showed improvement downstream with increased levels (percent four times improved and mg/L had three times showing improvement whereas they both showed not times getting worse). Other parameters that had at least two more significant improvements than significantly getting worse downstream were copper, phosphorus, TKN, TOC, TSS, and water temperature. In this analysis, these parameters would be an initial indication of being sensitive to water quality improvements.

The analyses with all the data (surface water and pore water) show more positive results for each individual site than surface water alone. This is likely due to the larger variation of the data and therefore allowing larger differences to become significant. The pore water is likely picking up soil characteristics, which still could be an indicator of the wetland filtering potential pollutants. When other data are analyzed, such as the soil data, the effect of the pore water may become clearer.

Significant Nexus Test Using Biological Criteria

The results of macroinvertebrate sampling completed in March and April of 2006 were also used to determine if there is a significant nexus between the headwater wetland and headwater first order streams at 14 of the 16 the study sites (macroinvertebrate samples were not obtained at the other two sites). 58 macroinvertebrate sample stations were sampled using either a sweep net, stove pipe, or funnel trap. A total of 207 macroinvertebrate taxon were identified at the 58 stations, of which 103 of those taxon are considered to be found in traditionally navigable waters according to Table 3 of Appendix B (Biological justification for significant nexus in streams in NC) (Walker. 2007). This Table 3 (Appendix B) taxon were identified at all macroinvertebrate sample stations which indicated there was a significant nexus using biological criteria at any site that had a sample station in the wetland and in the downstream stream which was the case for 10 of the sites (see Table 1 of Appendix E). The use of biological criteria, Macroinvertebrates, shows there is a definite hydrological connection or significant nexus between headwater wetlands and downstream first order streams.

Conclusion

The data clearly show that headwater wetlands are improving water quality as it flows into the headwater streams. This is shown by the significant results consistently showing that levels of nutrients and metals are being reduced, as well as dissolved oxygen increasing, all downstream from the wetland center. The various analyses of the all the data (surface and pore) had better results than the analyses of just the no dig data (surface water only). This is potentially due to the fact that the surface and pore water (all the data) is a larger data set then the just the surface water alone (no dug data) therefore increasing variability that caused more significant results. In addition, the surface water data has less seasonal variability due to the fact that surface water was not present at a number of the sites during the dry season. Another reason may simply be that soil pore water (included in the analysis of all the water data) has a longer residency time then surface water therefore more pollutants are filtered out. The comparison of the different analyses of the Coastal Plain to the Piedmont results also showed a common trend. The Piedmont results showed a number of significant improvements from the UP-DN (upstream to downstream) station comparisons while the Coastal Plain did not, however the Coastal Plain did show a number of significant improvements for the UP-DN or UP-FD (upstream to further downstream) station comparisons. This again, could potentially be due to the smaller data set of the Coastal Plain in comparison to the Piedmont (four Coastal Plain sites compared to 12 Piedmont sites). Another possibility may simply be the physiographic differences of the regions, the Coastal Plain sites tended to be larger and flatter while the Piedmont sites were more bowl shaped and less flat. The results overall do demonstrate that headwater wetlands need to be protected in order to protect downstream water resources. This significant improvement of water quality from the headwater wetland into the headwater stream is applicable for the identification of a significant nexus for the Corps of Engineers. The significant nexus test is used to define a significant hydrological connection between wetlands and traditionally navigable waters. This test can be done by looking at biological criteria (fish or Macroinvertebrates) or water quality in the wetland and comparing it to the downstream waters.

REFERENCES

Azous, A.L. and R.R. Horner, eds. (2001). Wetlands and Urbanization. Boca Raton, FL: Lewis Publishers.

Mitsch, W.J. and J.G. Gosselink. (2000). Wetlands. New York, NY: John Wiley & Sons, Inc.

North Carolina Division of Water Quality (2006) Water Quality Assement and Impaired Waters List (2006 Integrated 305(b) and 303(d) Report) Public Review Draft February 2006. Raleigh NC

North Carolina Division of Water Quality (2003). Intensive Survey Unit Standard Operating Procedures. North Carolina Division of Water Quality, Raleigh, NC. Available: http://h2o.enr.state.nc.us/esb/isu.html.

North Carolina Division of Water Quality (2005). *Laboratory Section: Sample Submission Guidance Document*. North Carolina Division of Water Quality, Raleigh, NC. June 1. Available: http://h2o.enr.state.nc.us/lab/qa.htm.

Ohio Environmental Protection Agency. *Wetlands and Water Quality*. Edited January 1997. 31 March 2006. Available http://www.epa.state.oh.us/pic/facts/wetqual.html.

Peterson et al. Control of Nitrogen Export from Watersheds by Headwater Streams. *Science Magazine* 292 (2001): 86-89.

U.S. Census Bureau. 2006. *Annual Population Growth – NC/US*. 10 January 2007. Available: http://demog.state.nc.us/demog/ncsuagr6.html.

U.S. Fish and Wildlife Service (USFWS). 2000. The value of headwater streams: results of a workshop, State College Pennsylvania, April 13, 1999. State College PA.

Walker, Tom. Personal Communication. Wilmington ACOE, NC. 2007

Figure 1 Wetland Monitoring Sites in North Carolina Ecoregions

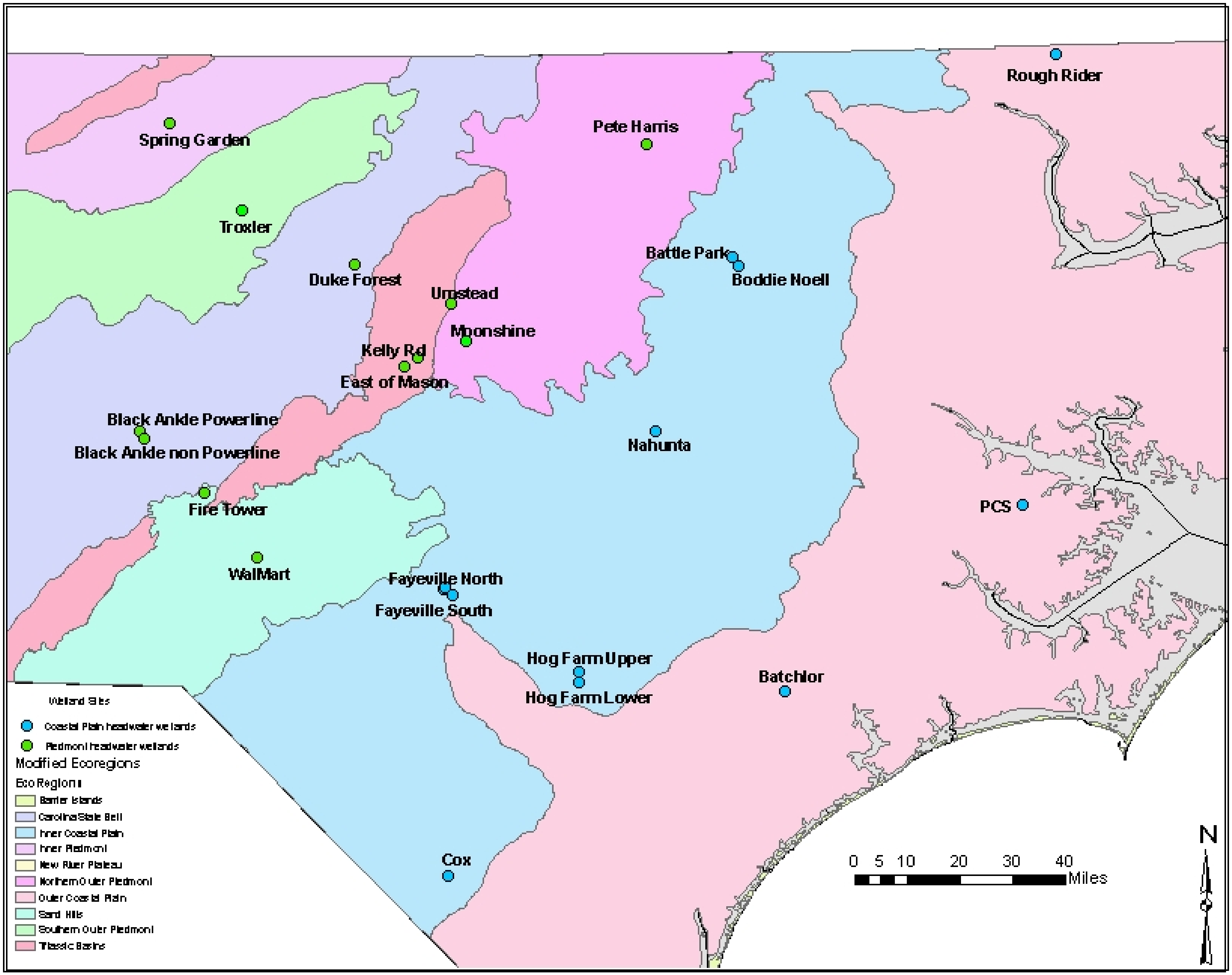


Figure 2 Hog Farm Upper Site Water Quality Station Locations

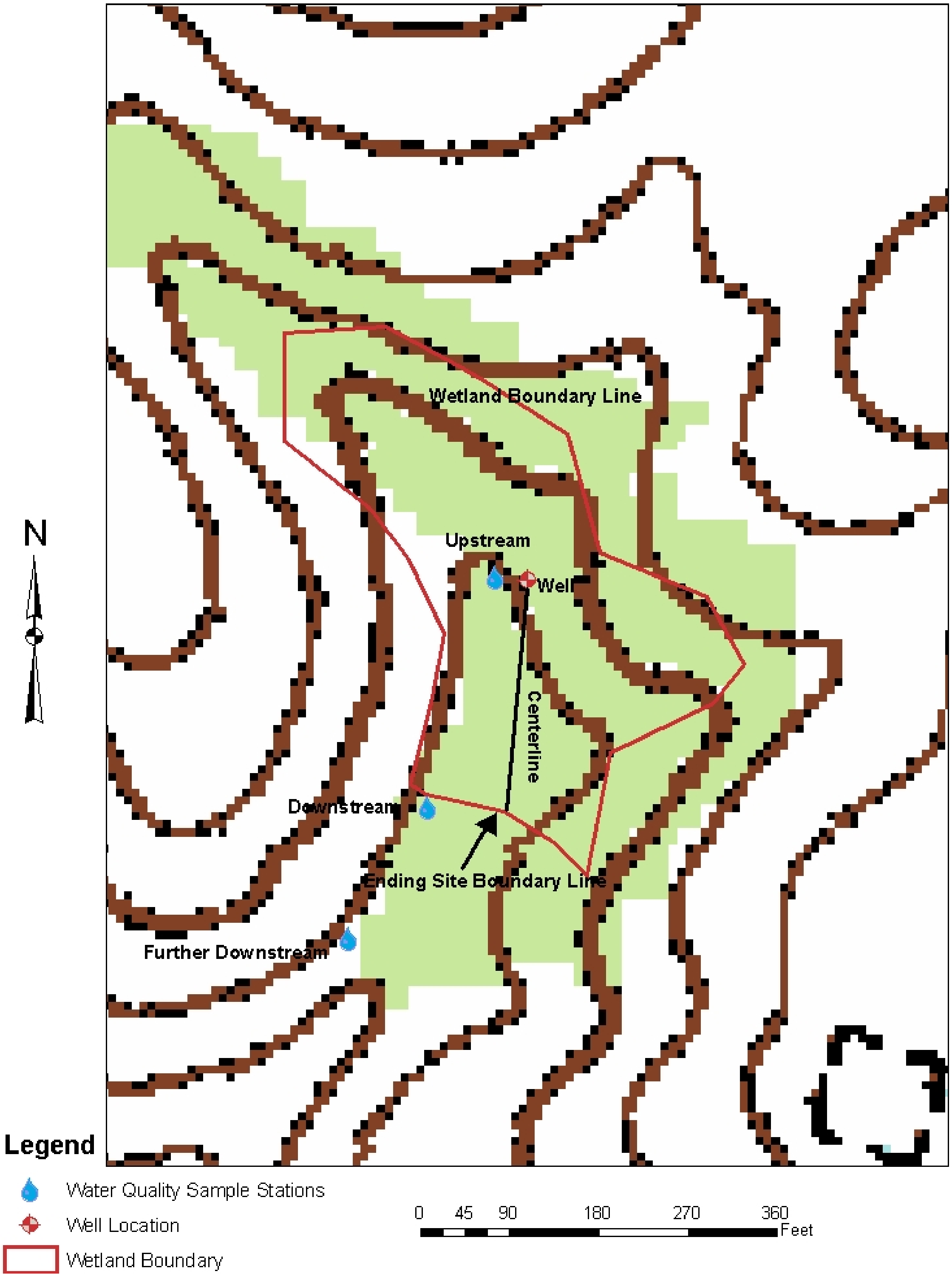


Table 1. NC Division of Water Quality Headwater Wetland Site Descriptions

Region	Site	Upstream	Downstream	Further Down	Usable for Report analysis	Sig Nexus*	Reason
Piedmont	Black Ankle Non-Powerline	Wetland	Perennial	N/A	Y	Y	
Piedmont	Black Ankle Powerline	Wetland	Ephemeral	N/A	Y	Y	
Piedmont	Duke Forest	Wetland	Intermittent	N/A	Y		
Piedmont	East of Mason	Wetland	Intermittent	N/A	Y	Y	
Piedmont	Fire Tower	Wetland	Perennial	N/A	Y	Y	
Piedmont	Kelly Road	Wetland	Intermittent	N/A	Y	Y	
Piedmont	Moonshine	Wetland	Ephemeral	N/A	Y		
Piedmont	Pete Harris	Wetland	Perennial	N/A	Y		
Piedmont	Spring Garden	Wetland	Perennial	N/A	Y	Y	
Piedmont	Troxler	Wetland	Intermittent	N/A	Y		
Piedmont	Umstead	Wetland	Intermittent	N/A	Y	Y	
Piedmont	Walmart	Wetland	Perennial	N/A	Y	Y	
Coastal Plain	Batchelor	Wetland	Wetland	N/A	N		No Stream @ Downstream station
Coastal Plain	Battle Park	Wetland	Culvert	N/A	N		No Stream @ Downstream Station, Wetland has basin characteristics
Coastal Plain	Boddie Noell	Wetland	Culvert	N/A	N		60 feet to Downstream only
Coastal Plain	Cox	Wetland / Stream	Perennial	Perennial	Y	Y	
Coastal Plain	East Fayetteville North	Wetland	Wetland	Wetland	N		No Stream Downstream
Coastal Plain	East Fayetteville South	Wetland	Intermittent	Perennial	Y		
Coastal Plain	Hog Farm Lower	Stream	Perennial	N/A	N		Upstream is a Stream
Coastal Plain	Hog Farm Upper	Wetland	Perennial	Perennial	Y	Y	
Coastal Plain	Nahunta	Wetland	Wetland	N/A	N		No Stream @ Downstream Station
Coastal Plain	PCS	Wetland	Wetland	Perennial Ditch	Y		Usable from Downstream to Further downstream only
Coastal Plain	Rough Rider	Wetland	Wetland	N/A	N		No stream @ Downstream Station

* Significant Nexus between the wetland and stream with use of macroinvertebrate taxons found in traditionally navagable waters.

Table 2.a. Water Quality Station Comparisons of Site Mean and Median by Parameter (All Data)

Parameter	Improvement / No Improvement	UP-DN Mean Improvement	UP-FD Mean Improvement	DN-FD Mean Improvement	UP-DN Median Improvement	UP-FD Median Improvement	DN-FD Median Improvement
Ammonia	improvement	11	4	3	5	3	2
Ammonia	no improvement	5		1	11	1	2
Calcium	improvement	8	4	4	8	4	4
Calcium	no improvement	7			7		
Copper	improvement	9	3	3	7	1	2
Copper	no improvement	7	1	1	9	3	2
DOC	improvement	8	3	1	8	3	1
DOC	no improvement	7	1	3	7	1	3
Dissolved Oxygen (%)	improvement	13	4	4	13	4	4
Dissolved Oxygen (%)	no improvement	3			3		
Dissolved Oxygen (mg/L)	improvement	14	4	4	14	4	4
Dissolved Oxygen (mg/L)	no improvement	2			2		
Fecal Coliform	improvement	7	2	2	9	3	1
Fecal Coliform	no improvement	9	2	2	7	1	3
Lead	improvement	7	3	3	5		1
Lead	no improvement	9	1	1	11	4	3
Magnesium	improvement	9	4	4	9	4	4
Magnesium	no improvement	6			6		
NO2+NO3	improvement	6	4	2	1	1	1
NO2+NO3	no improvement	10		2	15	3	3
Phosphorus	improvement	9	4	4	9	3	3
Phosphorus	no improvement	7			7	1	1
Specific Conductivity	improvement	8	4	4	8	4	4
Specific Conductivity	no improvement	8			8		
TKN	improvement	11	3	3	11	3	3
TKN	no improvement	5	1	1	5	1	1
TOC	improvement	9	4	3	8	3	4
TOC	no improvement	7		1	8	1	
Total Suspended Residue	improvement	10	4	4	9	4	4
Total Suspended Residue	no improvement	6	16		7		
Turbidity	improvement	10			10		
Turbidity	no improvement	3			3		
Water, Temperature	improvement	8	1	1	8	1	1
Water, Temperature	no improvement	8	3	3	8	3	3
Zinc	improvement	9	4	4	11	3	2
Zinc	no improvement	7			5	1	2
pH	improvement	10	3	2	10	3	3
pH	no improvement	6	1	2	6	1	1

Sample Station Comparisons	Improvement / No Improvement	Mean Totals	Median Totals
UP-DN	improvement	**176**	**163**
UP-DN	no improvement	122	135
UP-FD	improvement	**62**	**51**
UP-FD	no improvement	10	21
DN-FD	improvement	**55**	**48**
DN-FD	no improvement	17	24

Blue Bold - Improvement

Red - No Improvement

Table 2.b Water Quality Station Comparisons of Site Mean and Median by Parameter (No Dug Data only)

Parameter	Improvement / No Improvement	UP-DN Mean Improvement	UP-FD Mean Improvement	DN-FD Mean Improvement	UP-DN Median Improvement	UP-FD Median Improvement	DN-FD Median Improvement
Ammonia	improvement	7	4	4	3	3	3
Ammonia	no improvement	7			11	1	1
Calcium	improvement	7	4	4	6	3	4
Calcium	no improvement	5			6	1	
Copper	improvement	5	1	3	6	1	2
Copper	no improvement	9	3	1	8	3	2
DOC	improvement	7	3	1	7	3	1
DOC	no improvement	7	1	3	7	1	3
Dissolved Oxygen (%)	improvement	11	4	4	11	4	4
Dissolved Oxygen (%)	no improvement	5			5		
Dissolved Oxygen (mg/L)	improvement	11	3	3	11	3	4
Dissolved Oxygen (mg/L)	no improvement	5	1	1	5	1	
Fecal Coliform	improvement	5	2	3	7	2	1
Fecal Coliform	no improvement	9	2	1	7	2	3
Lead	improvement	3		3	2		2
Lead	no improvement	11	4	1	12	4	2
Magnesium	improvement	3	3	4	6	3	4
Magnesium	no improvement	9	1		6	1	
NO2+NO3	improvement	3	4	2	2	3	2
NO2+NO3	no improvement	11		2	12	1	2
Phosphorus	improvement	7	2	4	8	2	4
Phosphorus	no improvement	7	2		6	2	
Specific Conductivity	improvement	8	4	4	9	4	4
Specific Conductivity	no improvement	8			7		
TKN	improvement	8	3	3	8	2	3
TKN	no improvement	6	1	1	6	2	1
TOC	improvement	8	2	4	7	3	4
TOC	no improvement	6	2		7	1	
Total Suspended Residue	improvement	7	4	4	6	4	4
Total Suspended Residue	no improvement	7			8		
Turbidity	improvement	8			8		
Turbidity	no improvement	3			3		
Water, Temperature	improvement	8	1	2	7	1	2
Water, Temperature	no improvement	8	3	2	9	3	2
Zinc	improvement	6	3	4	9	3	2
Zinc	no improvement	8	1		5	1	2
pH	improvement	12	3	2	11	3	2
pH	no improvement	4	1	2	5	1	2

Sample Station Comparisons	Improvement / No Improvement	Mean Totals	Median Totals
UP-DN	improvement	**134**	**134**
UP-DN	no improvement	135	135
UP-FD	improvement	**50**	**42**
UP-FD	no improvement	22	25
DN-FD	improvement	**58**	**52**
DN-FD	no improvement	14	20

Blue Bold - Improvement

Red - No Improvement

Table 3.a. Same Sample Time Water Quality Sample Station Comparisons (Site Paired) by Parameter (All Data)

Parameter	.	UP-DN Improvement	UP-FD Improvement	DN-FD Improvement	Totals
Ammonia	improvement	21	3	3	**27**
Ammonia	no improvement	37	2	4	43
Calcium	improvement	28	4	2	**34**
Calcium	no improvement	17	1	5	23
Copper	improvement	27	2	2	**31**
Copper	no improvement	34	3	5	42
DOC	improvement	16	2	2	**20**
DOC	no improvement	21	0	1	22
Dissolved Oxygen (%)	improvement	45	5	7	**57**
Dissolved Oxygen (%)	no improvement	15	0	0	15
Dissolved Oxygen (mg/L)	improvement	47	5	6	**58**
Dissolved Oxygen (mg/L)	no improvement	13	0	1	14
Fecal Coliform	improvement	30	2	4	**36**
Fecal Coliform	no improvement	27	1	2	30
Lead	improvement	23	2	2	**27**
Lead	no improvement	38	3	5	46
Magnesium	improvement	26	4	4	**34**
Magnesium	no improvement	19	1	3	23
NO2+NO3	improvement	8	2	1	**11**
NO2+NO3	no improvement	50	3	6	59
Phosphorus	improvement	37	5	4	**46**
Phosphorus	no improvement	21	0	3	24
Specific Conductivity	improvement	29	4	5	**38**
Specific Conductivity	no improvement	31	1	2	34
TKN	improvement	36	5	5	**46**
TKN	no improvement	22	0	2	24
TOC	improvement	36	5	3	**44**
TOC	no improvement	23	0	3	26
Total Suspended Residue	improvement	20	3	5	**28**
Total Suspended Residue	no improvement	17	0	0	17
Turbidity	improvement	10	0	0	**10**
Turbidity	no improvement	3	0	0	3
Water, Temperature	improvement	33	3	2	**38**
Water, Temperature	no improvement	29	2	5	36
Zinc	improvement	35	4	3	**42**
Zinc	no improvement	26	1	4	31
pH	improvement	34	2	5	**41**
pH	no improvement	26	3	2	31

Sample Station Comparisons	Improvement / No Improvement	Totals
UP-DN	improvement	**541**
UP-DN	no improvement	469
UP-FD	improvement	**62**
UP-FD	no improvement	21
DN-FD	improvement	**65**
DN-FD	no improvement	53

Blue Bold - Improvement

Red - No Improvement

Table 3.b. Same Sample Time Water Quality Sample Station Comparisons (Site Paired) by Parameter (No Dig Data only)

Parameter	Improvement / No Improvement	UP-DN Improvement	UP-FD Improvement	DN-FD Improvement	Totals
Ammonia	improvement	8	1	1	**10**
Ammonia	no improvement	25	1	3	29
Calcium	improvement	12	1	0	**13**
Calcium	no improvement	11	1	4	16
Copper	improvement	10	0	0	**10**
Copper	no improvement	25	2	4	31
DOC	improvement	13	1	2	**16**
DOC	no improvement	17	0	1	18
Dissolved Oxygen (%)	improvement	30	2	4	**36**
Dissolved Oxygen (%)	no improvement	9	0	0	9
Dissolved Oxygen (mg/L)	improvement	30	2	3	**35**
Dissolved Oxygen (mg/L)	no improvement	9	0	1	10
Fecal Coliform	improvement	13	1	3	**17**
Fecal Coliform	no improvement	20	1	1	22
Lead	improvement	7	0	0	**7**
Lead	no improvement	28	2	4	34
Magnesium	improvement	11	1	1	**13**
Magnesium	no improvement	12	1	3	16
NO2+NO3	improvement	3	1	1	**5**
NO2+NO3	no improvement	30	1	3	34
Phosphorus	improvement	20	2	2	**24**
Phosphorus	no improvement	13	0	2	15
Specific Conductivity	improvement	14	1	2	**17**
Specific Conductivity	no improvement	24	1	2	27
TKN	improvement	18	2	2	**22**
TKN	no improvement	15	0	2	17
TOC	improvement	19	2	1	**22**
TOC	no improvement	14	0	2	16
Total Suspended Residue	improvement	15	2	4	**21**
Total Suspended Residue	no improvement	15	0	0	15
Turbidity	improvement	8	0	0	**8**
Turbidity	no improvement	3	0	0	3
Water, Temperature	improvement	22	2	1	**25**
Water, Temperature	no improvement	18	0	3	21
Zinc	improvement	17	1	1	**19**
Zinc	no improvement	18	1	3	22
pH	improvement	21	0	2	**23**
pH	no improvement	18	2	2	22

Sample Station Comparisons	Improvement / No Improvement	Totals
UP-DN	improvement	**291**
UP-DN	no improvement	324
UP-FD	improvement	**22**
UP-FD	no improvement	13
DN-FD	improvement	**30**
DN-FD	no improvement	40

Blue Bold - Improvement

Red - No Improvement

Table 4.a. Percent Improvement for Same Sample Time Water Quality Station Comparisons by Parameter (All Data)

Parameter	UP-DN % Improvement		UP-FD % Improvement		DN-FD % Improvement	
	Mean	**Median**	**Mean**	**Median**	**Mean**	**Median**
Ammonia	-129.6	0.0	**38.0**	**20.0**	**13.1**	0.0
Calcium	-19.8	**12.5**	**43.6**	**39.4**	**2.3**	0.0
Copper	-217.6	0.0	**39.5**	0.0	**22.1**	0.0
DOC	-9.1	0.0	**22.4**	**22.4**	0.0	**1.6**
Dissolved Oxygen (%)	**-100.4**	**-22.0**	**-78.4**	**-70.2**	**-111.4**	**-82.2**
Dissolved Oxygen (mg/L)	**-93.1**	**-33.2**	**-80.5**	**-72.7**	**-97.2**	**-17.5**
Fecal Coliform	-1429.1	**21.4**	**26.1**	**25.6**	-81.2	**31.3**
Lead	-207.5	0.0	**38.0**	0.0	**17.3**	0.0
Magnesium	-27.8	**7.7**	**41.1**	**38.6**	**13.3**	**4.7**
NO2+NO3	-42.5	0.0	**10.8**	0.0	**2.4**	0.0
Phosphorus	-286.4	**43.3**	**81.0**	**88.5**	**21.5**	**14.3**
Specific Conductivity	-12.7	-0.4	**26.4**	**30.0**	**11.1**	**9.2**
TKN	-104.1	**29.7**	**60.6**	**70.5**	**36.8**	**59.1**
TOC	-78.5	**22.2**	**68.5**	**73.9**	**29.0**	**11.3**
Total Suspended Residue	-44.0	**8.2**	**70.8**	**61.0**	**67.9**	**72.3**
Turbidity	**24.9**	**26.7**	.	.	.	.
Water, Temperature	**0.8**	**0.7**	**2.2**	**4.3**	-1.2	0.0
Zinc	-54.5	**11.8**	**31.0**	**47.6**	**12.8**	0.0
pH	**-3.9**	**-0.8**	**-0.8**	2.7	**-3.6**	**-2.7**

Blue Bold - Improvement

Red - No Improvement

Negitive values for Dissolved Oxygen and pH indicate improvement, for all other parameters a possitive value indicates improvement.

Table 4.b. Percent Improvement for Same Sample Time Water Quality Station Comparisons by Parameter (No Dig Data Only)

Parameter	UP-DN % Improvement		UP-FD % Improvement		DN-FD % Improvement	
	Mean	**Median**	**Mean**	**Median**	**Mean**	**Median**
Ammonia	-209.3	0.0	**10.0**	**10.0**	-7.5	0.0
Calcium	-8.9	**4.4**	**16.7**	**16.7**	-5.9	-2.2
Copper	-65.9	0.0	0.0	0.0	0.0	0.0
DOC	-9.1	0.0	**22.7**	**22.7**	0.0	**1.6**
Dissolved Oxygen (%)	**-52.0**	**-18.9**	**-39.4**	**-39.4**	**-30.1**	**-14.4**
Dissolved Oxygen (mg/L)	**-54.5**	**-22.0**	**-49.4**	**-49.4**	0.2	**-10.5**
Fecal Coliform	-1537.8	-140.0	-2.2	-2.2	**24.6**	**31.3**
Lead	-45.9	0.0	0.0	0.0	0.0	0.0
Magnesium	-30.9	0.0	**18.5**	**18.5**	-2.1	-2.4
NO2+NO3	-63.3	0.0	**18.8**	**18.8**	**4.2**	0.0
Phosphorus	-340.4	**30.0**	**64.2**	**64.2**	-4.7	0.0
Specific Conductivity	-12.9	-6.6	**15.5**	**15.5**	**8.1**	**2.3**
TKN	-136.0	**9.1**	**19.3**	**19.3**	-4.0	-3.0
TOC	-78.2	**12.7**	**35.5**	**35.5**	**5.8**	-2.9
Total Suspended Residue	-58.7	**1.8**	**75.7**	**75.7**	**66.7**	**70.1**
Turbidity	**20.1**	**26.7**	.	.	.	.
Water, Temperature	**1.2**	**1.0**	**5.0**	**5.0**	**0.4**	0.0
Zinc	-24.5	0.0	-35.5	-35.5	-11.2	0.0
pH	**-4.5**	**-0.7**	4.1	4.1	**-0.7**	**-1.2**

Blue Bold - Improvement

Red - No Improvement

Negitive values for Dissolved Oxygen and pH indicate improvement, for all other parameters a possitive value indicates improvement.

Table 5.a. Statistal Comparison of Upstream, Downstream, and Further Downstream Station Water Quality Results for All Data.

Parameter	Test*	Coastal Plain		Piedmont		Coastal Plain and Piedmont UP and DN only	
		P-Value**	Significance	P-Value	Significance	P-Value	Significance
Ammonia mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Calcium mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Copper ug/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	**0.008**	**UP>DN Sig**	P>0.15	No Sig
DOC mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Dissolved Oxygen (%)	ANOVA	**0.109**	**UP<FD Sig**	**0.087**	**UP<DN Sig**	**0.042**	**UP<DN Sig**
	Ranks	**0.071**	**UP<FD Sig**	**0.051**	**UP<DN Sig**	**0.035**	**UP<DN Sig**
Dissolved Oxygen (mg/L)	ANOVA	P>0.15	No Sig	**0.036**	**UP<DN Sig**	**0.014**	**UP<DN Sig**
	Ranks	P>0.15	No Sig	**0.038**	**UP<DN Sig**	**0.021**	**UP<DN Sig**
Fecal Coliform cfu/100ml	ANOVA	**0.039**	UP&DN<FD Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Lead ug/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	**0.068**	UP<DN Sig	P>0.15	No Sig
Magnesium mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
NO2+NO3 mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Phosphorus mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	**0.009**	**UP>DN Sig**	P>0.15	No Sig
Specific Conductivity	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Total Kjeldahl (TKN) mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	**0.068**	**UP>FD Sig**	**0.003**	**UP>DN Sig**	**0.065**	**UP>DN Sig**
TOC mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	**0.042**	**UP>DN Sig**	**0.067**	**UP>DN Sig**
Total Suspended Residue (TSS) mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	**0.13**	**UP>FD Sig**	P>0.15	No Sig	P>0.15	No Sig
Turbidity NTU	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Water, Temperature C^o	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Zinc mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	**0.036**	**UP>DN Sig**	**0.144**	**UP>DN Sig**
pH S.U.	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	**0.145**	**UP<DN Sig**

Test* - For the Coastal Plain, A Tukeys test was performed in combination with the ANOVA and Ranks Test

P-Value** P-Values are considered significant if P< 0.15

Blue Bold - There was a significant improvement for UP-DN, UP-FD, or DN-FD station comparisons.

Red- There was significantly no improvement for UP-DN, UP-FD, or DN-FD stations comparisons.

Table 5.b. Statistal Comparison of Upstream, Downstream, and Further Downstream Station Water Quality Results for No Dig Data Only.

Parameter	Test*	Coastal Plain		Piedmont		Coastal Plain and Piedmont UP and DN only	
		P-Value**	Significance	P-Value	Significance	P-Value	Significance
Ammonia mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Calcium mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Copper ug/L	ANOVA	**0.069**	**DN>FD Sig**	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
DOC mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Dissolved Oxygen (%)	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	**0.13**	**UP<DN Sig**
Dissolved Oxygen (mg/L)	ANOVA	P>0.15	No Sig	**0.118**	**UP<DN Sig**	**0.093**	**UP<DN Sig**
	Ranks	P>0.15	No Sig	**0.143**	**UP<DN Sig**	**0.104**	**UP<DN Sig**
Fecal Coliform cfu/100ml	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Lead ug/L	ANOVA	**0.083**	**DN>FD Sig** UP<DN Sig	P>0.15	No Sig	**0.106**	UP<DN Sig
	Ranks	**0.01**	**DN>FD Sig** UP<DN Sig	P>0.15	No Sig	**0.136**	UP<DN Sig
Magnesium mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
NO2+NO3 mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Phosphorus mg/L	ANOVA	**0.075**	**DN>FD Sig** UP<DN Sig	P>0.15	No Sig	**0.147**	**UP>DN Sig**
	Ranks	**0.133**	**DN>FD Sig** UP<DN Sig	P>0.15	No Sig	P>0.15	No Sig
Specific Conductivity	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Total Kjeldahl (TKN) mg/L	ANOVA	**0.114**	**DN>FD Sig**	P>0.15	No Sig	P>0.15	No Sig
	Ranks	**0.079**	**DN>FD Sig**	**0.087**	**UP>DN Sig**	P>0.15	No Sig
TOC mg/L	ANOVA	**0.068**	**DN>FD Sig**	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Total Suspended Residue (TSS) mg/L	ANOVA	**0.057**	**UP&DN > FD Sig**	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Turbidity NTU	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	**0.134**	**UP>DN Sig**	**0.142**	**UP>DN Sig**
Water, Temperature C^o	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Zinc mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
pH S.U.	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig

Test* - For the Coastal Plain, A Tukeys test was performed in combination with the ANOVA and Ranks Test

P-Value** P-Values are considered significant if P< 0.15

Blue Bold - There was a significant improvement for UP-DN, UP-FD, or DN-FD station comparisons.

Red- There was significantly no improvement for UP-DN, UP-FD, or DN-FD stations comparisons.

Table 6.a. Statistal Comparison of Site Paired Station Comparisons Upstream, Downstream, and Further Downstream Station Water Quality Results for All Water Quality Data.

Parameter	Test*	Coastal Plain		Piedmont		Coastal Plain and Piedmont UP and DN only	
		P-Value**	**Significance**	**P-Value**	**Significance**	**P-Value**	**Significance**
Ammonia mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Calcium mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Copper ug/L	ANOVA	P>0.15	No Sig	**0.044**	**UP>DN**	P>0.15	No Sig
	Ranks	P>0.15	No Sig	**0.008**	**UP>DN**	P>0.15	No Sig
DOC mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Dissolved Oxygen (%)	ANOVA	**0.148**	**UP<FD**	**0.062**	**UP<DN**	**0.066**	**UP<DN**
	Ranks	**0.075**	**UP<FD**	**0.033**	**UP<DN**	**0.041**	**UP<DN**
Dissolved Oxygen (mg/L)	ANOVA	P>0.15	No Sig	**0.022**	**UP<DN**	**0.032**	**UP<DN**
	Ranks	P>0.15	No Sig	**0.024**	**UP<DN**	**0.033**	**UP<DN**
Fecal Coliform cfu/100ml	Ranks	**0.049**	**UP&DN<FD**	**0.105**	**UP>DN**	P>0.15	No Sig
		P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Lead ug/L	ANOVA	P>0.15	No Sig	**0.073**	**UP>DN**	P>0.15	No Sig
		P>0.15	No Sig	**0.039**	**UP>DN**	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
		P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Magnesium mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
NO2+NO3 mg/L	ANOVA	P>0.15	No Sig	**0.123**	**UP>DN**	P>0.15	No Sig
	Ranks	0.145	**UP&DN>FD**	**0.017**	**UP>DN**	**0.106**	**UP>DN**
Phosphorus mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Specific Conductivity	ANOVA	P>0.15	No Sig	**0.035**	**UP>DN**	P>0.15	No Sig
	Ranks	**0.077**	**UP>FD**	**0.007**	**UP>DN**	**0.077**	**UP>DN**
Total Kjeldahl (TKN) mg/L	ANOVA	P>0.15	No Sig	**0.069**	**UP>DN**	P>0.15	No Sig
	Ranks	P>0.15	No Sig	**0.043**	**UP>DN**	P>0.15	No Sig
TOC mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	**0.12**	**UP>FD**	P>0.15	No Sig
Total Suspended Residue (TSS) mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Turbidity NTU	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Water, Temperature C^{o}	ANOVA	P>0.15	No Sig	**0.117**	**UP>FD**	P>0.15	No Sig
	Ranks	P>0.15	No Sig	**0.098**	**UP>FD**	P>0.15	No Sig
Zinc mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
pH S.U.	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig

Test* - For the Coastal Plain, A Tukeys test was performed in combination with the ANOVA and Ranks Test

P-Value** P-Values are considered significant if P< 0.15

Blue Bold - There was a significant improvement for UP-DN, UP-FD, or DN-FD station comparisons.

Red- There was significantly no improvement for UP-DN, UP-FD, or DN-FD stations comparisons.

Table 6.b. Statistal Comparison of Site Paired Station Comparisons Upstream, Downstream, and Further Downstream Station Water Quality Results for No Dig Data Water Quality Only.

Parameter	Test*	Coastal Plain		Piedmont		Coastal Plain and Piedmont UP and DN only	
		P-Value**	Significance	P-Value	Significance	P-Value	Significance
Ammonia mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Calcium mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Copper ug/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
DOC mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Dissolved Oxygen (%)	ANOVA	**0.041**	**UP<FD**	P>0.15	No Sig	P>0.15	No Sig
	Ranks	**0.0023**	**UP<FD**	P>0.15	No Sig	**0.111**	**UP<DN**
Dissolved Oxygen (mg/L)	ANOVA	P>0.15	No Sig	P>0.15	No Sig	**0.094**	**UP<DN**
	Ranks	0.095	**UP<FD**	P>0.15	No Sig	**0.097**	**UP<DN**
Fecal Coliform cfu/100ml	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Lead ug/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Magnesium mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
NO2+NO3 mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Phosphorus mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Specific Conductivity	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Total Kjeldahl (TKN) mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
TOC mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Total Suspended Residue (TSS) mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Turbidity NTU	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Water, Temperature C^{o}	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
Zinc mg/L	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
pH S.U.	ANOVA	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig
	Ranks	P>0.15	No Sig	P>0.15	No Sig	P>0.15	No Sig

Test* - For the Coastal Plain, A Tukeys test was performed in combination with the ANOVA and Ranks Test

P-Value** P-Values are considered significant if P< 0.15

Blue Bold - There was a significant improvement for UP-DN, UP-FD, or DN-FD station comparisons.

Red- There was significantly no improvement for UP-DN, UP-FD, or DN-FD stations comparisons.

Table 7.a. Statistical Comparison of Site Paired Station Comparisons by Individual Site for Upstream, Downstream, and Further Downstream Water Quality Results for All Data.

Parameter	Site	ANOVA P-Value*	Ranks Sums P-Value**	Significance
Ammonia	PCS		0.029	DN>FD
	Troxler		0.103	UP>DN
	Walmart		0.02	UP>DN
Calcium	Black Ankle PowerLine	0.14	0.121	UP>DN
	Fire Tower		0.073	UP>DN
	Pete Harris		0.121	UP<DN
	Walmart	0.015	0.021	UP>DN
Copper	Fire Tower	0.034	0.002	UP>DN
	PCS		0.087	UP&DN>FD
	Troxler	0.067	0.121	UP>DN
	Umsted	0.063	0.049	UP>DN
	Walmart	0.007	0.005	UP>DN
DOC	Hog Farm Upper	0.052	0.108	UP>DN
	Spring Garden	0.056	..083	UP<DN
	Troxler		0.121	UP>DN
DO%	Black Ankle PowerLine	0.0002	0.049	UP<DN
	E.Fayetteville South	0.088	0.134	UP&DN<FD
	Fire Tower	0.0001	0.004	UP<DN
	Hog Farm Upper	0.0001	0.004	UP<FD
	PCS	0.06	0.134	UP<FD
	Walmart	0.007	0.021	UP<DN
DO mg/L	Black Ankle PowerLine	0.001	0.049	UP<DN
	Duke Forest	0.139	0.121	UP<DN
	Fire Tower	0.0001	0.004	UP<DN
	Hog Farm Upper	0.004	0.01	UP<FD
	PCS	0.102	0.134	UP<DN
	PCS	0.102	0.134	DN>FD
	Walmart	0.021	0.043	UP<DN
Fecal Coliform	Duke Forest		0.121	UP>DN
	E. Fayetteville South	0.147		UP&DN<FD
	East of Mason	0.076	0.049	UP<DN
	Fire Tower		0.076	UP>DN
	Troxler		0.121	UP>DN
Lead	Black Ankle PowerLine		0.127	UP>DN
	Fire Tower	0.045	0.007	UP>DN
	PCS		0.048	DN>FD
	Troxler	0.083	0.102	UP>DN
	Walmart	0.006	0.005	UP>DN
Magnesium	Black Ankle PowerLine		0.121	UP>DN
	E. Fayettville South	0.03	0.105	UP>DN&FD
	Fire Tower		0.076	UP>DN
	Hog Farm Upper	0.028	0.08	UP>FD
	PCS		0.114	DN>FD
	Pete Harris		0.121	UP<DN
	Walmart	0.01	0.021	UP>DN
NO2+NO3	Hog Farm Upper		0.127	UP&DN>DN

Table 7.a. Statistical Comparison of Site Paired Station Comparisons by Individual Site for Upstream, Downstream, and Further Downstream Water Quality Results for All Data.

Parameter	Site	ANOVA P-Value*	Ranks Sums P-Value**	Significance
Phosphorus	Duke Forest		0.121	UP>DN
	Fire Tower	0.023	0.004	UP>DN
Phosphorous	Hog Farm Upper	0.032	0.023	UP>DN&FD
	PCS		0.117	DN>FD
	Troxler	0.003	0.121	UP>DN
	Walmart	0.0003	0.018	UP>DN
	Duke Forest		0.121	UP<DN
Special Conductivity	PCS	0.082	0.109	UP>FD
	Troxler		0.121	UP>DN
	Walmart	0.003	0.009	UP>DN
TKN	Cox		0.101	DN>FD
	Cox		0.101	UP<DN
	Duke Forest		0.121	UP>DN
	E. Fayetteville South		0.121	UP>DN&FD
	Fire Tower	0.069	0.006	UP>DN
	Hog Farm Upper		0.087	UP>DN&FD
	PCS		0.041	UP<DN
	Troxler		0.121	UP>DN
	Walmart	0.036	0.02	UP>DN
TOC	Duke Forest		0.121	UP>DN
	Fire Tower	0.083	0.004	UP>DN
	Hog Farm Upper	0.004	0.007	UP>DN&FD
	PCS		0.049	UP&DN>FD
	Troxler	0.019	0.121	UP>DN
	Walmart	0.013	0.009	UP>DN
TSS	Fire Tower	0.029	0.102	UP>DN
	Hog Farm Upper		0.108	UP>FD
	Kelly Rd		0.149	UP<DN
	Troxler		0.121	UP>DN
	Umsted	0.15	0.127	UP>DN
Turbidity				
Water Temp	Umsted	0.036	0.049	UP>DN
Zinc	Duke Forest		0.102	UP<DN
	Fire Tower	0.098	0.04	UP>DN
	PCS		0.029	DN>FD
	Troxler	0.15	0.121	UP>DN
	Walmart	0.008	0.007	UP>DN
pH	E. Fayetteville South	0.064	0.094	UP<DN
	Fire Tower	0.0001	0.004	UP<DN

* For the Coastal Plain, A Tukeys test was performed in combination with the ANOVA Ranks Test P-Value** P-Values are considered significant if P<0.15

Blue Bold - There was a significant improvement for UP-DN, UP-FD, or DN-FD station comparisons.

Red- There was significantly no improvement for UP-DN, UP-FD, or DN-FD stations comparisons.

Table 7.b. Statistical Comparison of Site Paired Station Comparisons by Individual Site Summary Table for All Data

	Site	Significant Improvement	Significant No Improvement
Piedmont	Black Ankle Non-Powerline	0	0
	Black Ankle Powerline	5	0
	Duke Forest	6	1
	East of Mason	0	1
	Fire Tower	13	0
	Kelly Road	0	1
	Moonshine	0	0
	Pete Harris	0	2
	Spring Garden	0	1
	Troxler	11	0
	Umstead	3	0
	Walmart	12	0
Coastal Plain	Cox	1	1
	East Fayetteville South	4	1
	Hog Farm Upper	9	0
	PCS (DN-FD only)*	11	1
	Total	75	9

Chi Square Test < 0.0001

Table 8.a. Statistical Comparison of Site Paired Station Comparisons by Individual Site for Upstream, Downstream, and Further Downstream Water Quality Results for No Dig Data Only.

Parameter	**Site**	**ANOVA P-Value***	**Ranks Sums P-Value****	**Significance**
Ammonia	Fire Tower	0.095	0.103	UP<DN
Calcium	Pete Harris		0.121	UP<DN
Copper	Fire Tower	0.0006	0.103	UP>DN
	Umstead	0.063	0.049	UP>DN
DOC	Hog Farm Upper	0.126		UP>DN
	Spring Garden		0.121	UP<DN
DO%	Black Ankle Powerline	0.007	0.121	UP<DN
	E.Fayetteville South	0.129		UP<DN
	Fire Tower	0.082	0.121	UP<DN
	Hog Farm Upper	0.0001	0.006	UP<FD
DO mg/L	Black Ankle Powerline	0.005	0.121	UP<DN
	Fire Tower	0.064	0.102	UP<DN
	Hog Farm Upper	0.009	0.016	UP<FD
Fecal Coliform	East of Mason	0.076	0.049	UP<DN
Lead				
Magnesium	Hog Farm Upper	0.06	0.119	UP>FD
	Pete Harris		0.121	UP<DN
NO2+NO3	Hog Farm Upper		0.138	UP>DN
Phosphorus	E.Fayetteville South	0.107		UP>DN
	Fire Tower	0.012	0.102	UP>DN
	Hog Farm Upper	0.071	0.047	UP>FD
Special Conductivity	Fire Tower		0.121	UP<DN
TKN	East Fayetteville South	0.06		UP>DN&FD
	Fire Tower		0.121	UP>DN
	Hog Farm Upper		0.15	UP>DN
TOC	Fire Tower	0.044	0.121	UP>DN
	Hog Farm Upper	0.011	0.011	UP>DN&FD
TSS	Fire Tower	0.029	0.102	UP>DN
	Hog Farm Upper	0.131	0.125	UP>FD
	Kelly Rd	0.0015	0.049	UP<DN
	Umstead		0.127	UP>DN
Turbidity				
Water Temp	Black Ankle Powerline		0.121	UP>DN
	Umstead	0.036	0.049	UP>DN
Zinc				
pH	Black Ankle Powerline		0.121	UP>DN
	Fire Tower	0.073	0.102	UP<DN

* For the Coastal Plain, A Tukeys test was performed in combination with the ANOVA Ranks Test

P-Value** P-Values are considered significant if P<0.15

Blue Bold - There was a significant improvement for UP-DN, UP-FD, or DN-FD station comparisons.

Red- There was significantly no improvement for UP-DN, UP-FD, or DN-FD stations comparisons.

Table 8.b. Statistical Comparison of Site Paired Station Comparisons by Individual Site Summary Table for No Dig Data Only

	Site	Significant Improvement	Significant No Improvement
Piedmont	Black Ankle Non-Powerline	0	0
	Black Ankle Powerline	3	1
	Duke Forest	0	0
	East of Mason	0	1
	Fire Tower	8	2
	Kelly Road	0	1
	Moonshine	0	0
	Pete Harris	0	2
	Spring Garden	0	1
	Troxler	0	0
	Umstead	3	0
	Walmart	0	0
Coastal Plain	Cox	0	0
	East Fayetteville South	4	0
	Hog Farm Upper	10	0
	PCS (DN-FD only)*	0	0
Total		28	8

Chi Square Test P=0.0009

Appendix Table A.1 Site Mean Station Comparisons of Water Quality Data (All Data)										
		Mean Results			**Mean Station Comparisons**			**Improvement / Not Improvement of Mean Station Comparisons**		
Parameter	**Site Name**	**UP**	**DN**	**FD**	**UP-DN**	**UP-FD**	**DN-FD**	**UP-DN Mean Improvement**	**UP-FD Mean Improvement**	**DN-FD Mean Improvement**
Ammonia mg/L	Black Ankle Non-Powerline	0.02	0.37	.	-0.34	.	.	no improvement		
Ammonia mg/L	Black Ankle Powerline	0.06	0.03	.	0.03	.	.	improvement		
Ammonia mg/L	Cox	0.07	0.05	0.04	0.01	0.03	0.01	improvement	improvement	improvement
Ammonia mg/L	Duke Forest	0.05	0.09	.	-0.04	.	.	no improvement		
Ammonia mg/L	East Fayetteville South	0.26	0.04	0.06	0.22	0.21	-0.02	improvement	improvement	no improvement
Ammonia mg/L	East of Mason	0.05	0.05	.	0	.	.	improvement		
Ammonia mg/L	Fire Tower	0.05	0.05	.	0	.	.	improvement		
Ammonia mg/L	Hog Farm Upper	0.04	0.03	0.03	0	0.01	0.01	improvement	improvement	improvement
Ammonia mg/L	Kelly Rd	0.05	0.04	.	0.01	.	.	improvement		
Ammonia mg/L	Moonshine	0.02	0.09	.	-0.07	.	.	no improvement		
Ammonia mg/L	PCS	0.1	0.18	0.02	-0.08	0.08	0.16	no improvement	improvement	improvement
Ammonia mg/L	Pete Harris	0.09	0.08	.	0.01	.	.	improvement		
Ammonia mg/L	Spring Garden	0.03	0.06	.	-0.03	.	.	no improvement		
Ammonia mg/L	Troxler	0.05	0.02	.	0.03	.	.	improvement		
Ammonia mg/L	Umstead	0.16	0.04	.	0.11	.	.	improvement		
Ammonia mg/L	Walmart	0.41	0.03	.	0.38	.	.	improvement		
Calcium mg/L	Black Ankle Non-Powerline	1.44	13.83	.	-12.38	.	.	no improvement		
Calcium mg/L	Black Ankle Powerline	2.75	1.31	.	1.45	.	.	improvement		
Calcium mg/L	Cox	2.8	6.37	2.5	-3.57	0.3	3.87	no improvement	improvement	improvement
Calcium mg/L	Duke Forest	30	19.6	.	10.4	.	.	improvement		
Calcium mg/L	East Fayetteville South	17.87	5.36	4.2	12.51	13.67	1.16	improvement	improvement	improvement
Calcium mg/L	East of Mason	7.05	6.7	.	0.35	.	.	improvement		
Calcium mg/L	Fire Tower	2.64	1.58	.	1.06	.	.	improvement		
Calcium mg/L	Hog Farm Upper	17	15.66	9.85	1.34	7.15	5.81	improvement	improvement	improvement
Calcium mg/L	Kelly Rd	2.35	5.45	.	-3.1	.	.	no improvement		
Calcium mg/L	Moonshine	.	3.1	.	.	.	.			
Calcium mg/L	PCS	4.61	4.99	1.75	-0.38	2.86	3.24	no improvement	improvement	improvement
Calcium mg/L	Pete Harris	2.25	4.67	.	-2.42	.	.	no improvement		
Calcium mg/L	Spring Garden	6.3	5.48	.	0.82	.	.	improvement		
Calcium mg/L	Troxler	4.7	4.9	.	-0.2	.	.	no improvement		
Calcium mg/L	Umstead	4.05	8.33	.	-4.28	.	.	no improvement		
Calcium mg/L	Walmart	8.9	2.48	.	6.42	.	.	improvement		
Copper ug/L	Black Ankle Non-Powerline	2.84	145.8	.	-142.96	.	.	no improvement		

Appendix Table A.1 Site Mean Station Comparisons of Water Quality Data (All Data)										
		Mean Results			**Mean Station Comparisons**			**Improvement / Not Improvement of Mean Station Comparisons**		
Parameter	**Site Name**	**UP**	**DN**	**FD**	**UP-DN**	**UP-FD**	**DN-FD**	**UP-DN Mean Improvement**	**UP-FD Mean Improvement**	**DN-FD Mean Improvement**
Copper ug/L	Black Ankle Powerline	10.73	5.33	.	5.4	.	.	improvement		
Copper ug/L	Cox	13.14	4.25	2	8.89	11.14	2.25	improvement	improvement	improvement
Copper ug/L	Duke Forest	81.3	7.7	.	73.6	.	.	improvement		
Copper ug/L	East Fayetteville South	18.13	11.7	7.5	6.43	10.63	4.2	improvement	improvement	improvement
Copper ug/L	East of Mason	7.43	10.6	.	-3.17	.	.	no improvement		
Copper ug/L	Fire Tower	25.23	2	.	23.23	.	.	improvement		
Copper ug/L	Hog Farm Upper	2	2	2	0	0	0	no improvement	no improvement	no improvement
Copper ug/L	Kelly Rd	2.4	7.81	.	-5.41	.	.	no improvement		
Copper ug/L	Moonshine	3.8	2.65	.	1.15	.	.	improvement		
Copper ug/L	PCS	75.62	87.45	2	-11.83	73.62	85.45	no improvement	improvement	improvement
Copper ug/L	Pete Harris	4.5	7.83	.	-3.33	.	.	no improvement		
Copper ug/L	Spring Garden	3.25	3.28	.	-0.03	.	.	no improvement		
Copper ug/L	Troxler	30.5	2.8	.	27.7	.	.	improvement		
Copper ug/L	Umstead	6.6	5.03	.	1.58	.	.	improvement		
Copper ug/L	Walmart	88.2	2	.	86.2	.	.	improvement		
DOC mg/L	Black Ankle Non-Powerline	3.2	2.57	.	0.63	.	.	improvement		
DOC mg/L	Black Ankle Powerline	11	8.5	.	2.5	.	.	improvement		
DOC mg/L	Cox	20.5	23.5	25	-3	-4.5	-1.5	no improvement	no improvement	no improvement
DOC mg/L	Duke Forest	12	8.3	.	3.7	.	.	improvement		
DOC mg/L	East Fayetteville South	13.5	10.6	12	2.9	1.5	-1.4	improvement	improvement	no improvement
DOC mg/L	East of Mason	8.37	8.45	.	-0.08	.	.	no improvement		
DOC mg/L	Fire Tower	2.95	3.63	.	-0.68	.	.	no improvement		
DOC mg/L	Hog Farm Upper	7	5.13	5.9	1.88	1.1	-0.78	improvement	improvement	no improvement
DOC mg/L	Kelly Rd	4.09	4.6	.	-0.51	.	.	no improvement		
DOC mg/L	Moonshine	8.2	20.5	.	-12.3	.	.	no improvement		
DOC mg/L	PCS	24	28	10	-4	14	18	no improvement	improvement	improvement
DOC mg/L	Pete Harris	10.5	8.87	.	1.63	.	.	improvement		
DOC mg/L	Spring Garden	3.73	5.03	.	-1.3	.	.	no improvement		
DOC mg/L	Troxler	13.95	6.7	.	7.25	.	.	improvement		
DOC mg/L	Umstead	18.33	15.75	.	2.58	.	.	improvement		
DOC mg/L	Walmart	.	2.78	.	.	.	.			
Dissolved Oxygen (%)	Black Ankle Non-Powerline	44.6	25.78	.	18.82	.	.	no improvement		
Dissolved Oxygen (%)	Black Ankle Powerline	24.07	54.03	.	-29.97	.	.	improvement		
Dissolved Oxygen (%)	Cox	25.28	28.75	53.3	-3.47	-28.02	-24.55	improvement	improvement	improvement

Appendix Table A.1 Site Mean Station Comparisons of Water Quality Data (All Data)										
		Mean Results			**Mean Station Comparisons**			**Improvement / Not Improvement of Mean Station Comparisons**		
Parameter	**Site Name**	**UP**	**DN**	**FD**	**UP-DN**	**UP-FD**	**DN-FD**	**UP-DN Mean Improvement**	**UP-FD Mean Improvement**	**DN-FD Mean Improvement**
Dissolved Oxygen (%)	Duke Forest	34.65	35	.	-0.35	.	.	improvement		
Dissolved Oxygen (%)	East Fayetteville South	9.2	15.3	30.2	-6.1	-21	-14.9	improvement	improvement	improvement
Dissolved Oxygen (%)	East of Mason	42.47	46.43	.	-3.96	.	.	improvement		
Dissolved Oxygen (%)	Fire Tower	12.01	43.15	.	-31.14	.	.	improvement		
Dissolved Oxygen (%)	Hog Farm Upper	42.52	62.18	75.05	-19.67	-32.53	-12.87	improvement	improvement	improvement
Dissolved Oxygen (%)	Kelly Rd	28.4	44.68	.	-16.28	.	.	improvement		
Dissolved Oxygen (%)	Moonshine	44.5	30.25	.	14.25	.	.	no improvement		
Dissolved Oxygen (%)	PCS	7.77	10.72	18.8	-2.95	-11.03	-8.08	improvement	improvement	improvement
Dissolved Oxygen (%)	Pete Harris	20.27	19.98	.	0.29	.	.	no improvement		
Dissolved Oxygen (%)	Spring Garden	49.05	54.15	.	-5.1	.	.	improvement		
Dissolved Oxygen (%)	Troxler	62.1	66.85	.	-4.75	.	.	improvement		
Dissolved Oxygen (%)	Umstead	46.65	48.5	.	-1.85	.	.	improvement		
Dissolved Oxygen (%)	Walmart	17.25	36.06	.	-18.81	.	.	improvement		
Dissolved Oxygen (mg/L)	Black Ankle Non-Powerline	4.32	2.55	.	1.77	.	.	no improvement		
Dissolved Oxygen (mg/L)	Black Ankle Powerline	2.5	5.45	.	-2.94	.	.	improvement		
Dissolved Oxygen (mg/L)	Cox	2.42	3	5.2	-0.58	-2.78	-2.2	improvement	improvement	improvement
Dissolved Oxygen (mg/L)	Duke Forest	3.53	3.6	.	-0.07	.	.	improvement		
Dissolved Oxygen (mg/L)	East Fayetteville South	0.88	1.46	1.52	-0.59	-0.64	-0.06	improvement	improvement	improvement
Dissolved Oxygen (mg/L)	East of Mason	4.05	4.71	.	-0.66	.	.	improvement		
Dissolved Oxygen (mg/L)	Fire Tower	1.24	3.95	.	-2.71	.	.	improvement		
Dissolved Oxygen (mg/L)	Hog Farm Upper	4.09	6.04	7.09	-1.95	-3	-1.05	improvement	improvement	improvement
Dissolved Oxygen (mg/L)	Kelly Rd	2.78	4.42	.	-1.64	.	.	improvement		
Dissolved Oxygen (mg/L)	Moonshine	3.9	2.68	.	1.22	.	.	no improvement		
Dissolved Oxygen (mg/L)	PCS	0.73	1.08	1.77	-0.34	-1.04	-0.7	improvement	improvement	improvement
Dissolved Oxygen (mg/L)	Pete Harris	1.98	2.04	.	-0.06	.	.	improvement		
Dissolved Oxygen (mg/L)	Spring Garden	4.77	5.59	.	-0.83	.	.	improvement		
Dissolved Oxygen (mg/L)	Troxler	5.42	6.94	.	-1.52	.	.	improvement		
Dissolved Oxygen (mg/L)	Umstead	3.99	4.62	.	-0.63	.	.	improvement		
Dissolved Oxygen (mg/L)	Walmart	1.65	3.39	.	-1.74	.	.	improvement		
Fecal Coliform cfu/100 ml	Black Ankle Non-Powerline	134	11026.8	.	-10892.8	.	.	no improvement		
Fecal Coliform cfu/100 ml	Black Ankle Powerline	39	13.67	.	25.33	.	.	improvement		
Fecal Coliform cfu/100 ml	Cox	2686.6	1379.5	3200	1307.1	-513.4	-1820.5	improvement	no improvement	no improvement
Fecal Coliform cfu/100 ml	Duke Forest	65	260.67	.	-195.67	.	.	no improvement		
Fecal Coliform cfu/100 ml	East Fayetteville South	1285	2974.33	55500	-1689.33	-54215	-52525.67	no improvement	no improvement	no improvement

Appendix Table A.1 Site Mean Station Comparisons of Water Quality Data (All Data)

Parameter	Site Name	Mean Results			Mean Station Comparisons			Improvement / Not Improvement of Mean Station Comparisons		
		UP	DN	FD	UP-DN	UP-FD	DN-FD	UP-DN Mean Improvement	UP-FD Mean Improvement	DN-FD Mean Improvement
Fecal Coliform cfu/100 ml	East of Mason	78.67	540	.	-461.33	.	.	no improvement		
Fecal Coliform cfu/100 ml	Fire Tower	5553.33	323.67	.	5229.67	.	.	improvement		
Fecal Coliform cfu/100 ml	Hog Farm Upper	816.83	830	725	-13.17	91.83	105	no improvement	improvement	improvement
Fecal Coliform cfu/100 ml	Kelly Rd	46.08	104.92	.	-58.83	.	.	no improvement		
Fecal Coliform cfu/100 ml	Moonshine	33	369	.	-336	.	.	no improvement		
Fecal Coliform cfu/100 ml	PCS	49.5	1470.6	22	-1421.1	27.5	1448.6	no improvement	improvement	improvement
Fecal Coliform cfu/100 ml	Pete Harris	7441	118.25	.	7322.75	.	.	improvement		
Fecal Coliform cfu/100 ml	Spring Garden	1402	524.17	.	877.83	.	.	improvement		
Fecal Coliform cfu/100 ml	Troxler	2015	40	.	1975	.	.	improvement		
Fecal Coliform cfu/100 ml	Umstead	67	394	.	-327	.	.	no improvement		
Fecal Coliform cfu/100 ml	Walmart	734.6	83.5	.	651.1	.	.	improvement		
Lead ug/L	Black Ankle Non-Powerline	12.2	422.8	.	-410.6	.	.	no improvement		
Lead ug/L	Black Ankle Powerline	74	25.67	.	48.33	.	.	improvement		
Lead ug/L	Cox	47.2	23.25	10	23.95	37.2	13.25	improvement	improvement	improvement
Lead ug/L	Duke Forest	87.5	12.67	.	74.83	.	.	improvement		
Lead ug/L	East Fayetteville South	75.5	46.33	36	29.17	39.5	10.33	improvement	improvement	improvement
Lead ug/L	East of Mason	30.33	43	.	-12.67	.	.	no improvement		
Lead ug/L	Fire Tower	41.67	10	.	31.67	.	.	improvement		
Lead ug/L	Hog Farm Upper	10	10	10	0	0	0	no improvement	no improvement	no improvement
Lead ug/L	Kelly Rd	10.5	35.25	.	-24.75	.	.	no improvement		
Lead ug/L	Moonshine	10	10	.	0	.	.	no improvement		
Lead ug/L	PCS	96.67	283.17	10	-186.5	86.67	273.17	no improvement	improvement	improvement
Lead ug/L	Pete Harris	25.33	37.5	.	-12.17	.	.	no improvement		
Lead ug/L	Spring Garden	13.83	13.92	.	-0.08	.	.	no improvement		
Lead ug/L	Troxler	36	10	.	26	.	.	improvement		
Lead ug/L	Umstead	10	12.75	.	-2.75	.	.	no improvement		
Lead ug/L	Walmart	75.8	10	.	65.8	.	.	improvement		
Magnesium mg/L	Black Ankle Non-Powerline	0.55	6.63	.	-6.08	.	.	no improvement		
Magnesium mg/L	Black Ankle Powerline	1.1	0.59	.	0.51	.	.	improvement		
Magnesium mg/L	Cox	2.45	2.23	1.2	0.22	1.25	1.03	improvement	improvement	improvement
Magnesium mg/L	Duke Forest	31	10.6	.	20.4	.	.	improvement		
Magnesium mg/L	East Fayetteville South	4.4	1.61	1.07	2.79	3.34	0.55	improvement	improvement	improvement
Magnesium mg/L	East of Mason	2.6	2.93	.	-0.33	.	.	no improvement		
Magnesium mg/L	Fire Tower	1.18	0.88	.	0.3	.	.	improvement		

Appendix Table A.1 Site Mean Station Comparisons of Water Quality Data (All Data)

Parameter	Site Name	Mean Results			Mean Station Comparisons			Improvement / Not Improvement of Mean Station Comparisons		
		UP	**DN**	**FD**	**UP-DN**	**UP-FD**	**DN-FD**	**UP-DN Mean Improvement**	**UP-FD Mean Improvement**	**DN-FD Mean Improvement**
Magnesium mg/L	Hog Farm Upper	13.4	10.64	8.4	2.76	5	2.24	improvement	improvement	improvement
Magnesium mg/L	Kelly Rd	1.35	2.55	.	-1.2	.	.	no improvement		
Magnesium mg/L	Moonshine	.	1.1	.	.	.	.			
Magnesium mg/L	PCS	0.93	1.74	0.49	-0.81	0.44	1.25	no improvement	improvement	improvement
Magnesium mg/L	Pete Harris	1.2	2.43	.	-1.23	.	.	no improvement		
Magnesium mg/L	Spring Garden	2.01	1.78	.	0.23	.	.	improvement		
Magnesium mg/L	Troxler	2.7	2.1	.	0.6	.	.	improvement		
Magnesium mg/L	Umstead	1.55	3.17	.	-1.62	.	.	no improvement		
Magnesium mg/L	Walmart	3.43	0.92	.	2.51	.	.	improvement		
NO2+NO3 mg/L	Black Ankle Non-Powerline	0.02	0.02	.	0	.	.	no improvement		
NO2+NO3 mg/L	Black Ankle Powerline	0.05	0.02	.	0.03	.	.	improvement		
NO2+NO3 mg/L	Cox	0.04	0.02	0.02	0.02	0.02	0	improvement	improvement	no improvement
NO2+NO3 mg/L	Duke Forest	0.02	0.02	.	0	.	.	no improvement		
NO2+NO3 mg/L	East Fayetteville South	0.04	0.02	0.02	0.02	0.02	0	improvement	improvement	no improvement
NO2+NO3 mg/L	East of Mason	0.02	0.12	.	-0.1	.	.	no improvement		
NO2+NO3 mg/L	Fire Tower	0.12	0.1	.	0.02	.	.	improvement		
NO2+NO3 mg/L	Hog Farm Upper	19.5	22	10	-2.5	9.5	12	no improvement	improvement	improvement
NO2+NO3 mg/L	Kelly Rd	0.02	0.02	.	0	.	.	no improvement		
NO2+NO3 mg/L	Moonshine	0.02	0.02	.	0	.	.	no improvement		
NO2+NO3 mg/L	PCS	0.05	0.05	0.02	0	0.03	0.03	no improvement	improvement	improvement
NO2+NO3 mg/L	Pete Harris	0.02	0.02	.	0	.	.	no improvement		
NO2+NO3 mg/L	Spring Garden	0.04	0.04	.	0	.	.	no improvement		
NO2+NO3 mg/L	Troxler	0.03	0.02	.	0.01	.	.	improvement		
NO2+NO3 mg/L	Umstead	0.02	0.02	.	0	.	.	no improvement		
NO2+NO3 mg/L	Walmart	0.04	0.02	.	0.01	.	.	improvement		
Phosphorus mg/L	Black Ankle Non-Powerline	0.05	1.36	.	-1.31	.	.	no improvement		
Phosphorus mg/L	Black Ankle Powerline	0.27	0.1	.	0.17	.	.	improvement		
Phosphorus mg/L	Cox	0.22	0.78	0.06	-0.56	0.16	0.72	no improvement	improvement	improvement
Phosphorus mg/L	Duke Forest	0.66	0.12	.	0.54	.	.	improvement		
Phosphorus mg/L	East Fayetteville South	1.35	0.59	0.53	0.76	0.82	0.06	improvement	improvement	improvement
Phosphorus mg/L	East of Mason	0.16	0.19	.	-0.03	.	.	no improvement		
Phosphorus mg/L	Fire Tower	0.62	0.06	.	0.56	.	.	improvement		
Phosphorus mg/L	Hog Farm Upper	0.29	0.1	0.06	0.19	0.23	0.04	improvement	improvement	improvement
Phosphorus mg/L	Kelly Rd	0.14	0.15	.	-0.01	.	.	no improvement		

Appendix Table A.1 Site Mean Station Comparisons of Water Quality Data (All Data)										
		Mean Results			**Mean Station Comparisons**			**Improvement / Not Improvement of Mean Station Comparisons**		
Parameter	**Site Name**	**UP**	**DN**	**FD**	**UP-DN**	**UP-FD**	**DN-FD**	**UP-DN Mean Improvement**	**UP-FD Mean Improvement**	**DN-FD Mean Improvement**
Phosphorus mg/L	Moonshine	0.1	0.1	.	0.01	.	.	improvement		
Phosphorus mg/L	PCS	1.08	2.17	0.1	-1.09	0.98	2.07	no improvement	improvement	improvement
Phosphorus mg/L	Pete Harris	0.33	0.73	.	-0.4	.	.	no improvement		
Phosphorus mg/L	Spring Garden	0.23	0.16	.	0.07	.	.	improvement		
Phosphorus mg/L	Troxler	1.05	0.08	.	0.98	.	.	improvement		
Phosphorus mg/L	Umstead	0.08	0.12	.	-0.04	.	.	no improvement		
Phosphorus mg/L	Walmart	1.08	0.03	.	1.05	.	.	improvement		
Specific Conductivity	Black Ankle Non-Powerline	24.86	38.26	.	-13.4	.	.	no improvement		
Specific Conductivity	Black Ankle Powerline	45.8	40	.	5.8	.	.	improvement		
Specific Conductivity	Cox	60.8	82.28	55.6	-21.48	5.2	26.68	no improvement	improvement	improvement
Specific Conductivity	Duke Forest	52.35	100.2	.	-47.85	.	.	no improvement		
Specific Conductivity	East Fayetteville South	66.83	47.45	37.2	19.37	29.63	10.25	improvement	improvement	improvement
Specific Conductivity	East of Mason	85.97	90.95	.	-4.98	.	.	no improvement		
Specific Conductivity	Fire Tower	30.41	35.67	.	-5.25	.	.	no improvement		
Specific Conductivity	Hog Farm Upper	421.63	375.18	247.95	46.45	173.68	127.23	improvement	improvement	improvement
Specific Conductivity	Kelly Rd	55.48	51.7	.	3.77	.	.	improvement		
Specific Conductivity	Moonshine	42.8	55.85	.	-13.05	.	.	no improvement		
Specific Conductivity	PCS	89.07	77.23	69.85	11.83	19.22	7.38	improvement	improvement	improvement
Specific Conductivity	Pete Harris	80.27	78.2	.	2.07	.	.	improvement		
Specific Conductivity	Spring Garden	36.4	47.53	.	-11.13	.	.	no improvement		
Specific Conductivity	Troxler	51.15	34.5	.	16.65	.	.	improvement		
Specific Conductivity	Umstead	76.83	90.35	.	-13.52	.	.	no improvement		
Specific Conductivity	Walmart	60.22	46.2	.	14.02	.	.	improvement		
Total Kjeldahl (TKN) mg/L	Black Ankle Non-Powerline	0.48	12.59	.	-12.1	.	.	no improvement		
Total Kjeldahl (TKN) mg/L	Black Ankle Powerline	2.43	1.38	.	1.06	.	.	improvement		
Total Kjeldahl (TKN) mg/L	Cox	1	4.87	1.2	-3.86	-0.2	3.67	no improvement	no improvement	improvement
Total Kjeldahl (TKN) mg/L	Duke Forest	6.65	0.75	.	5.9	.	.	improvement		
Total Kjeldahl (TKN) mg/L	East Fayetteville South	24.35	7.32	1.25	17.03	23.1	6.07	improvement	improvement	improvement
Total Kjeldahl (TKN) mg/L	East of Mason	1.3	1.03	.	0.28	.	.	improvement		
Total Kjeldahl (TKN) mg/L	Fire Tower	8.94	0.42	.	8.52	.	.	improvement		
Total Kjeldahl (TKN) mg/L	Hog Farm Upper	1.68	0.71	0.98	0.97	0.7	-0.27	improvement	improvement	no improvement
Total Kjeldahl (TKN) mg/L	Kelly Rd	0.78	0.78	.	-0.01	.	.	no improvement		
Total Kjeldahl (TKN) mg/L	Moonshine	0.96	1.1	.	-0.14	.	.	no improvement		
Total Kjeldahl (TKN) mg/L	PCS	43.21	17.98	0.48	25.22	42.73	17.51	improvement	improvement	improvement

Appendix Table A.1 Site Mean Station Comparisons of Water Quality Data (All Data)										
		Mean Results			**Mean Station Comparisons**			**Improvement / Not Improvement of Mean Station Comparisons**		
Parameter	**Site Name**	**UP**	**DN**	**FD**	**UP-DN**	**UP-FD**	**DN-FD**	**UP-DN Mean Improvement**	**UP-FD Mean Improvement**	**DN-FD Mean Improvement**
Total Kjeldahl (TKN) mg/L	Pete Harris	1	1.45	.	-0.45	.	.	no improvement		
Total Kjeldahl (TKN) mg/L	Spring Garden	0.54	0.5	.	0.04	.	.	improvement		
Total Kjeldahl (TKN) mg/L	Troxler	2.04	0.35	.	1.7	.	.	improvement		
Total Kjeldahl (TKN) mg/L	Umstead	1.15	0.87	.	0.28	.	.	improvement		
Total Kjeldahl (TKN) mg/L	Walmart	6.47	0.38	.	6.09	.	.	improvement		
TOC mg/L	Black Ankle Non-Powerline	6.28	250.08	.	-243.8	.	.	no improvement		
TOC mg/L	Black Ankle Powerline	71.33	45.63	.	25.7	.	.	improvement		
TOC mg/L	Cox	48.4	118.33	30	-69.93	18.4	88.33	no improvement	improvement	improvement
TOC mg/L	Duke Forest	57.5	14.77	.	42.73	.	.	improvement		
TOC mg/L	East Fayetteville South	96	64.17	66	31.83	30	-1.83	improvement	improvement	no improvement
TOC mg/L	East of Mason	22.43	18	.	4.43	.	.	improvement		
TOC mg/L	Fire Tower	99.83	6.18	.	93.65	.	.	improvement		
TOC mg/L	Hog Farm Upper	16.13	6.23	5.4	9.9	10.73	0.83	improvement	improvement	improvement
TOC mg/L	Kelly Rd	6.35	8.26	.	-1.91	.	.	no improvement		
TOC mg/L	Moonshine	15	24.5	.	-9.5	.	.	no improvement		
TOC mg/L	PCS	462.75	576.67	12	-113.92	450.75	564.67	no improvement	improvement	improvement
TOC mg/L	Pete Harris	24.53	44.48	.	-19.94	.	.	no improvement		
TOC mg/L	Spring Garden	13.73	16.28	.	-2.55	.	.	no improvement		
TOC mg/L	Troxler	16.5	9.1	.	7.4	.	.	improvement		
TOC mg/L	Umstead	26.67	23	.	3.67	.	.	improvement		
TOC mg/L	Walmart	83.4	4.2	.	79.2	.	.	improvement		
Total Suspended Residue (TSS) mg/L	Black Ankle Non-Powerline	39	37.67	.	1.33	.	.	improvement		
Total Suspended Residue (TSS) mg/L	Black Ankle Powerline	289	879	.	-590	.	.	no improvement		
Total Suspended Residue (TSS) mg/L	Cox	219.25	33.33	17	185.92	202.25	16.33	improvement	improvement	improvement
Total Suspended Residue (TSS) mg/L	Duke Forest	3009.5	98.67	.	2910.83	.	.	improvement		
Total Suspended Residue (TSS) mg/L	East Fayetteville South	123	226.5	82	-103.5	41	144.5	no improvement	improvement	improvement
Total Suspended Residue (TSS) mg/L	East of Mason	170.67	340.75	.	-170.08	.	.	no improvement		
Total Suspended Residue (TSS) mg/L	Fire Tower	157	14.25	.	142.75	.	.	improvement		
Total Suspended Residue (TSS) mg/L	Hog Farm Upper	169	74.25	17.1	94.75	151.9	57.15	improvement	improvement	improvement
Total Suspended Residue (TSS) mg/L	Kelly Rd	61.58	152.25	.	-90.67	.	.	no improvement		
Total Suspended Residue (TSS) mg/L	Moonshine	59	29.5	.	29.5	.	.	improvement		
Total Suspended Residue (TSS) mg/L	PCS	24.5	130	3.2	-105.5	21.3	126.8	no improvement	improvement	improvement
Total Suspended Residue (TSS) mg/L	Pete Harris	318.67	163.33	.	155.33	.	.	improvement		
Total Suspended Residue (TSS) mg/L	Spring Garden	182.5	83.45	.	99.05	.	.	improvement		

Appendix Table A.1 Site Mean Station Comparisons of Water Quality Data (All Data)										
		Mean Results			**Mean Station Comparisons**			**Improvement / Not Improvement of Mean Station Comparisons**		
Parameter	**Site Name**	**UP**	**DN**	**FD**	**UP-DN**	**UP-FD**	**DN-FD**	**UP-DN Mean Improvement**	**UP-FD Mean Improvement**	**DN-FD Mean Improvement**
Total Suspended Residue (TSS) mg/L	Troxler	1155.5	58.5	.	1097	.	.	improvement		
Total Suspended Residue (TSS) mg/L	Umstead	128.33	107.75	.	20.58	.	.	improvement		
Total Suspended Residue (TSS) mg/L	Walmart	19	23	.	-4	.	.	no improvement		
Turbidity NTU	Black Ankle Non-Powerline	12	8.8	.	3.2	.	.	improvement		
Turbidity NTU	Black Ankle Powerline	110	32	.	78	.	.	improvement		
Turbidity NTU	Cox	30	25	.	5	.	.	improvement		
Turbidity NTU	Duke Forest	18	40	.	-22	.	.	no improvement		
Turbidity NTU	East Fayetteville South	110	.	.	.	.	.			
Turbidity NTU	East of Mason	85	50	.	35	.	.	improvement		
Turbidity NTU	Fire Tower	33	7	.	26	.	.	improvement		
Turbidity NTU	Hog Farm Upper	10	13	.	-3	.	.	no improvement		
Turbidity NTU	Kelly Rd	85	27	.	58	.	.	improvement		
Turbidity NTU	Moonshine	15	13	.	2	.	.	improvement		
Turbidity NTU	PCS	14	.	.	.	.	.			
Turbidity NTU	Pete Harris	600	600	.	0	.	.	no improvement		
Turbidity NTU	Spring Garden	5	4.6	.	0.4	.	.	improvement		
Turbidity NTU	Troxler	260	13	.	247	.	.	improvement		
Turbidity NTU	Umstead	40	17	.	23	.	.	improvement		
Turbidity NTU	Walmart	.	1.8	.	.	.	.			
Water, Temperature C^o	Black Ankle Non-Powerline	16.34	18.66	.	-2.32	.	.	no improvement		
Water, Temperature C^o	Black Ankle Powerline	16.1	15.13	.	0.97	.	.	improvement		
Water, Temperature C^o	Cox	17.6	16.75	16.7	0.85	0.9	0.05	improvement	improvement	improvement
Water, Temperature C^o	Duke Forest	14.83	16.53	.	-1.69	.	.	no improvement		
Water, Temperature C^o	East Fayetteville South	17.23	17.75	20	-0.52	-2.77	-2.25	no improvement	no improvement	no improvement
Water, Temperature C^o	East of Mason	17.2	15.25	.	1.95	.	.	improvement		
Water, Temperature C^o	Fire Tower	17.67	18.43	.	-0.76	.	.	no improvement		
Water, Temperature C^o	Hog Farm Upper	17.75	17.32	18.3	0.43	-0.55	-0.98	improvement	no improvement	no improvement
Water, Temperature C^o	Kelly Rd	13.85	14.28	.	-0.43	.	.	no improvement		
Water, Temperature C^o	Moonshine	20.4	20.45	.	-0.05	.	.	no improvement		
Water, Temperature C^o	PCS	16.83	17.27	19.15	-0.43	-2.32	-1.88	no improvement	no improvement	no improvement
Water, Temperature C^o	Pete Harris	16	15.4	.	0.6	.	.	improvement		
Water, Temperature C^o	Spring Garden	18.17	16.75	.	1.42	.	.	improvement		
Water, Temperature C^o	Troxler	18.45	14.7	.	3.75	.	.	improvement		

Appendix Table A.1 Site Mean Station Comparisons of Water Quality Data (All Data)										
		Mean Results			**Mean Station Comparisons**			**Improvement / Not Improvement of Mean Station Comparisons**		
Parameter	**Site Name**	**UP**	**DN**	**FD**	**UP-DN**	**UP-FD**	**DN-FD**	**UP-DN Mean Improvement**	**UP-FD Mean Improvement**	**DN-FD Mean Improvement**
Water, Temperature C^o	Umstead	23.35	18.05	.	5.3	.	.	improvement		
Water, Temperature C^o	Walmart	19.16	19.35	.	-0.19	.	.	no improvement		
Zinc mg/L	Black Ankle Non-Powerline	15.4	381.4	.	-366	.	.	no improvement		
Zinc mg/L	Black Ankle Powerline	38.67	22.67	.	16	.	.	improvement		
Zinc mg/L	Cox	28.6	21	18	7.6	10.6	3	improvement	improvement	improvement
Zinc mg/L	Duke Forest	150.5	17	.	133.5	.	.	improvement		
Zinc mg/L	East Fayetteville South	69	31	22	38	47	9	improvement	improvement	improvement
Zinc mg/L	East of Mason	43.67	54.75	.	-11.08	.	.	no improvement		
Zinc mg/L	Fire Tower	30.67	11.5	.	19.17	.	.	improvement		
Zinc mg/L	Hog Farm Upper	14.17	11.33	10.5	2.83	3.67	0.83	improvement	improvement	improvement
Zinc mg/L	Kelly Rd	22.92	53.63	.	-30.71	.	.	no improvement		
Zinc mg/L	Moonshine	17	13.5	.	3.5	.	.	improvement		
Zinc mg/L	PCS	86.92	235.5	15	-148.58	71.92	220.5	no improvement	improvement	improvement
Zinc mg/L	Pete Harris	19	24.75	.	-5.75	.	.	no improvement		
Zinc mg/L	Spring Garden	19.83	21.17	.	-1.33	.	.	no improvement		
Zinc mg/L	Troxler	515	48	.	467	.	.	improvement		
Zinc mg/L	Umstead	12	17.25	.	-5.25	.	.	no improvement		
Zinc mg/L	Walmart	354	10.67	.	343.33	.	.	improvement		
pH S.U.	Black Ankle Non-Powerline	5.07	5.4	.	-0.33	.	.	improvement		
pH S.U.	Black Ankle Powerline	5.61	5.35	.	0.26	.	.	no improvement		
pH S.U.	Cox	4.63	4.85	4.59	-0.22	0.04	0.26	improvement	no improvement	no improvement
pH S.U.	Duke Forest	6.74	6.43	.	0.31	.	.	no improvement		
pH S.U.	East Fayetteville South	4.27	4.49	5.27	-0.22	-1	-0.78	improvement	improvement	improvement
pH S.U.	East of Mason	5.16	4.97	.	0.19	.	.	no improvement		
pH S.U.	Fire Tower	4.72	5.21	.	-0.49	.	.	improvement		
pH S.U.	Hog Farm Upper	6.02	5.85	6.09	0.17	-0.07	-0.23	no improvement	improvement	improvement
pH S.U.	Kelly Rd	4.89	5.07	.	-0.18	.	.	improvement		
pH S.U.	Moonshine	4.61	5.73	.	-1.12	.	.	improvement		
pH S.U.	PCS	3.55	4.2	3.69	-0.65	-0.14	0.51	improvement	improvement	no improvement
pH S.U.	Pete Harris	5.31	5.34	.	-0.03	.	.	improvement		
pH S.U.	Spring Garden	6.01	5.99	.	0.02	.	.	no improvement		
pH S.U.	Troxler	5.94	5.67	.	0.27	.	.	no improvement		
pH S.U.	Umstead	5.94	6.03	.	-0.09	.	.	improvement		
pH S.U.	Walmart	5.21	5.24	.	-0.03	.	.	improvement		

Appendix Table A.2 Site Mean Station Comparisons of Water Quality Data (No Dig Data Only)

Parameter	Site Name	Mean Results			Mean Station Comparisons			Improvement / Not Improvement of Mean Station Comparisons		
		UP	DN	FD	UP-DN	UP-FD	DN-FD	UP-DN Mean Improvement	UP-FD Mean Improvement	DN-FD Mean Improvement
Ammonia mg/L	Black Ankle Non-Powerline	0.02	0.32	.	-0.29	.	.	no improvement		
Ammonia mg/L	Black Ankle Powerline	0.08	0.03	.	0.05	.	.	improvement		
Ammonia mg/L	Cox	0.06	0.05	0.04	0	0.02	0.01	improvement	improvement	improvement
Ammonia mg/L	Duke Forest	0.02	0.06	.	-0.04	.	.	no improvement		
Ammonia mg/L	East Fayetteville South	0.04	0.04	0.02	0	0.02	0.02	no improvement	improvement	improvement
Ammonia mg/L	East of Mason	0.05	0.05	.	0	.	.	improvement		
Ammonia mg/L	Fire Tower	0.02	0.04	.	-0.02	.	.	no improvement		
Ammonia mg/L	Hog Farm Upper	0.04	0.03	0.03	0	0.01	0.01	improvement	improvement	improvement
Ammonia mg/L	Kelly Rd	0.05	0.05	.	0	.	.	improvement		
Ammonia mg/L	Moonshine	0.02	0.09	.	-0.07	.	.	no improvement		
Ammonia mg/L	PCS	0.03	0.14	0.02	-0.1	0.01	0.12	no improvement	improvement	improvement
Ammonia mg/L	Pete Harris	0.09	0.04	.	0.05	.	.	improvement		
Ammonia mg/L	Spring Garden	0.02	0.02	.	0	.	.	no improvement		
Ammonia mg/L	Troxler	.	0.02	.	.	.	.			
Ammonia mg/L	Umstead	0.16	0.04	.	0.11	.	.	improvement		
Ammonia mg/L	Walmart	.	0.03	.	.	.	.			
Calcium mg/L	Black Ankle Non-Powerline	1.44	1.1	.	0.34	.	.	improvement		
Calcium mg/L	Black Ankle Powerline	2.4	1.31	.	1.09	.	.	improvement		
Calcium mg/L	Cox	2.6	6.37	2.5	-3.77	0.1	3.87	no improvement	improvement	improvement
Calcium mg/L	Duke Forest	.	7.2	.	.	.	.			
Calcium mg/L	East Fayetteville South	6.3	5.36	3.1	0.94	3.2	2.26	improvement	improvement	improvement
Calcium mg/L	East of Mason	7.05	6.7	.	0.35	.	.	improvement		
Calcium mg/L	Fire Tower	1.9	1.68	.	0.23	.	.	improvement		
Calcium mg/L	Hog Farm Upper	17.25	15.66	9.85	1.59	7.4	5.81	improvement	improvement	improvement
Calcium mg/L	Kelly Rd	2.35	3.35	.	-1	.	.	no improvement		
Calcium mg/L	Moonshine	.	3.1	.	.	.	.			
Calcium mg/L	PCS	2.65	2.4	1.75	0.25	0.9	0.65	improvement	improvement	improvement
Calcium mg/L	Pete Harris	2.25	3.35	.	-1.1	.	.	no improvement		
Calcium mg/L	Spring Garden	4.65	4.8	.	-0.15	.	.	no improvement		
Calcium mg/L	Troxler	.	4.9	.	.	.	.			
Calcium mg/L	Umstead	4.05	8.33	.	-4.28	.	.	no improvement		
Calcium mg/L	Walmart	.	2.48	.	.	.	.			
Copper ug/L	Black Ankle Non-Powerline	2.84	7.25	.	-4.41	.	.	no improvement		

Appendix Table A.2 Site Mean Station Comparisons of Water Quality Data (No Dig Data Only)											
		Mean Results			**Mean Station Comparisons**			**Improvement / Not Improvement of Mean Station Comparisons**		
Parameter	**Site Name**	**UP**	**DN**	**FD**	**UP-DN**	**UP-FD**	**DN-FD**	**UP-DN Mean Improvement**	**UP-FD Mean Improvement**	**DN-FD Mean Improvement**
Copper ug/L	Black Ankle Powerline	6.1	5.33	.	0.77	.	.	improvement		
Copper ug/L	Cox	2	4.25	2	-2.25	0	2.25	no improvement	no improvement	improvement
Copper ug/L	Duke Forest	2.6	4.05	.	-1.45	.	.	no improvement		
Copper ug/L	East Fayetteville South	2	11.7	2	-9.7	0	9.7	no improvement	no improvement	improvement
Copper ug/L	East of Mason	7.43	10.6	.	-3.17	.	.	no improvement		
Copper ug/L	Fire Tower	6	2	.	4	.	.	improvement		
Copper ug/L	Hog Farm Upper	2	2	2	0	0	0	no improvement	no improvement	no improvement
Copper ug/L	Kelly Rd	2.4	3.6	.	-1.2	.	.	no improvement		
Copper ug/L	Moonshine	3.8	2.65	.	1.15	.	.	improvement		
Copper ug/L	PCS	7.18	19.35	2	-12.18	5.18	17.35	no improvement	improvement	improvement
Copper ug/L	Pete Harris	4.5	2.77	.	1.73	.	.	improvement		
Copper ug/L	Spring Garden	2.6	2.83	.	-0.23	.	.	no improvement		
Copper ug/L	Troxler	.	3.6	.	.	.	.			
Copper ug/L	Umstead	6.6	5.03	.	1.58	.	.	improvement		
Copper ug/L	Walmart	.	2	.	.	.	.			
DOC mg/L	Black Ankle Non-Powerline	3.2	2.57	.	0.63	.	.	improvement		
DOC mg/L	Black Ankle Powerline	11	8.5	.	2.5	.	.	improvement		
DOC mg/L	Cox	20.5	23.5	25	-3	-4.5	-1.5	no improvement	no improvement	no improvement
DOC mg/L	Duke Forest	12	8.5	.	3.5	.	.	improvement		
DOC mg/L	East Fayetteville South	13.5	10.6	12	2.9	1.5	-1.4	improvement	improvement	no improvement
DOC mg/L	East of Mason	8.37	8.45	.	-0.08	.	.	no improvement		
DOC mg/L	Fire Tower	2.95	3.63	.	-0.68	.	.	no improvement		
DOC mg/L	Hog Farm Upper	6.77	5.13	5.9	1.64	0.87	-0.78	improvement	improvement	no improvement
DOC mg/L	Kelly Rd	4.09	4.4	.	-0.31	.	.	no improvement		
DOC mg/L	Moonshine	8.2	20.5	.	-12.3	.	.	no improvement		
DOC mg/L	PCS	24	31	10	-7	14	21	no improvement	improvement	improvement
DOC mg/L	Pete Harris	10.5	8.87	.	1.63	.	.	improvement		
DOC mg/L	Spring Garden	3.65	4.67	.	-1.02	.	.	no improvement		
DOC mg/L	Troxler	.	5.9	.	.	.	.			
DOC mg/L	Umstead	18.33	15.75	.	2.58	.	.	improvement		
DOC mg/L	Walmart	.	2.78	.	.	.	.			
Dissolved Oxygen (%)	Black Ankle Non-Powerline	44.6	31.1	.	13.5	.	.	no improvement		
Dissolved Oxygen (%)	Black Ankle Powerline	23.4	54.03	.	-30.63	.	.	improvement		
Dissolved Oxygen (%)	Cox	35.57	28.75	53.3	6.82	-17.73	-24.55	no improvement	improvement	improvement

Appendix Table A.2 Site Mean Station Comparisons of Water Quality Data (No Dig Data Only)										
		Mean Results			Mean Station Comparisons			Improvement / Not Improvement of Mean Station Comparisons		
Parameter	Site Name	UP	DN	FD	UP-DN	UP-FD	DN-FD	UP-DN Mean Improvement	UP-FD Mean Improvement	DN-FD Mean Improvement
Dissolved Oxygen (%)	Duke Forest	43	45.45	.	-2.45	.	.	improvement		
Dissolved Oxygen (%)	East Fayetteville South	17.2	15.3	41	1.9	-23.8	-25.7	no improvement	improvement	improvement
Dissolved Oxygen (%)	East of Mason	42.47	46.43	.	-3.96	.	.	improvement		
Dissolved Oxygen (%)	Fire Tower	18.63	41.24	.	-22.61	.	.	improvement		
Dissolved Oxygen (%)	Hog Farm Upper	42.04	62.18	75.05	-20.14	-33.01	-12.87	improvement	improvement	improvement
Dissolved Oxygen (%)	Kelly Rd	28.4	55.93	.	-27.53	.	.	improvement		
Dissolved Oxygen (%)	Moonshine	44.5	30.25	.	14.25	.	.	no improvement		
Dissolved Oxygen (%)	PCS	7.4	15.93	18.8	-8.53	-11.4	-2.87	improvement	improvement	improvement
Dissolved Oxygen (%)	Pete Harris	20.27	24.43	.	-4.17	.	.	improvement		
Dissolved Oxygen (%)	Spring Garden	54.1	58.8	.	-4.7	.	.	improvement		
Dissolved Oxygen (%)	Troxler	93	66.85	.	26.15	.	.	no improvement		
Dissolved Oxygen (%)	Umstead	46.65	48.5	.	-1.85	.	.	improvement		
Dissolved Oxygen (%)	Walmart	8.5	36.06	.	-27.56	.	.	improvement		
Dissolved Oxygen (mg/L)	Black Ankle Non-Powerline	4.32	3.1	.	1.22	.	.	no improvement		
Dissolved Oxygen (mg/L)	Black Ankle Powerline	2.21	5.45	.	-3.24	.	.	improvement		
Dissolved Oxygen (mg/L)	Cox	3.46	3	5.2	0.46	-1.74	-2.2	no improvement	improvement	improvement
Dissolved Oxygen (mg/L)	Duke Forest	4	4.78	.	-0.78	.	.	improvement		
Dissolved Oxygen (mg/L)	East Fayetteville South	1.65	1.46	1.4	0.19	0.25	0.06	no improvement	no improvement	no improvement
Dissolved Oxygen (mg/L)	East of Mason	4.05	4.71	.	-0.66	.	.	improvement		
Dissolved Oxygen (mg/L)	Fire Tower	1.97	3.85	.	-1.88	.	.	improvement		
Dissolved Oxygen (mg/L)	Hog Farm Upper	4.12	6.04	7.09	-1.92	-2.97	-1.05	improvement	improvement	improvement
Dissolved Oxygen (mg/L)	Kelly Rd	2.78	5.38	.	-2.6	.	.	improvement		
Dissolved Oxygen (mg/L)	Moonshine	3.9	2.68	.	1.22	.	.	no improvement		
Dissolved Oxygen (mg/L)	PCS	0.69	1.64	1.77	-0.95	-1.08	-0.13	improvement	improvement	improvement
Dissolved Oxygen (mg/L)	Pete Harris	1.98	2.49	.	-0.51	.	.	improvement		
Dissolved Oxygen (mg/L)	Spring Garden	5.37	6.06	.	-0.69	.	.	improvement		
Dissolved Oxygen (mg/L)	Troxler	7.18	6.94	.	0.24	.	.	no improvement		
Dissolved Oxygen (mg/L)	Umstead	3.99	4.62	.	-0.63	.	.	improvement		
Dissolved Oxygen (mg/L)	Walmart	0.8	3.39	.	-2.59	.	.	improvement		
Fecal Coliform cfu/100ml	Black Ankle Non-Powerline	134	1033.5	.	-899.5	.	.	no improvement		
Fecal Coliform cfu/100ml	Black Ankle Powerline	9.5	13.67	.	-4.17	.	.	no improvement		
Fecal Coliform cfu/100ml	Cox	1444.3	1379.5	3200	64.83	-1756	-1821	improvement	no improvement	no improvement
Fecal Coliform cfu/100ml	Duke Forest	80	26	.	54	.	.	improvement		
Fecal Coliform cfu/100ml	East Fayetteville South	417.5	2974.3	1000	-2557	-582.5	1974.3	no improvement	no improvement	improvement

Appendix Table A.2 Site Mean Station Comparisons of Water Quality Data (No Dig Data Only)

Parameter	Site Name	Mean Results			Mean Station Comparisons			Improvement / Not Improvement of Mean Station Comparisons		
		UP	DN	FD	UP-DN	UP-FD	DN-FD	UP-DN Mean Improvement	UP-FD Mean Improvement	DN-FD Mean Improvement
Fecal Coliform cfu/100ml	East of Mason	78.67	540	.	-461.3	.	.	no improvement		
Fecal Coliform cfu/100ml	Fire Tower	1395	168.4	.	1226.6	.	.	improvement		
Fecal Coliform cfu/100ml	Hog Farm Upper	806.2	830	725	-23.8	81.2	105	no improvement	improvement	improvement
Fecal Coliform cfu/100ml	Kelly Rd	46.08	131.22	.	-85.14	.	.	no improvement		
Fecal Coliform cfu/100ml	Moonshine	33	369	.	-336	.	.	no improvement		
Fecal Coliform cfu/100ml	PCS	49.5	3130	22	-3081	27.5	3108	no improvement	improvement	improvement
Fecal Coliform cfu/100ml	Pete Harris	7441	125.33	.	7315.7	.	.	improvement		
Fecal Coliform cfu/100ml	Spring Garden	105.5	71.67	.	33.83	.	.	improvement		
Fecal Coliform cfu/100ml	Troxler	.	54	.	.	.	.			
Fecal Coliform cfu/100ml	Umstead	67	394	.	-327	.	.	no improvement		
Fecal Coliform cfu/100ml	Walmart	.	83.5	.	.	.	.			
Lead ug/L	Black Ankle Non-Powerline	12.2	28.5	.	-16.3	.	.	no improvement		
Lead ug/L	Black Ankle Powerline	41	25.67	.	15.33	.	.	improvement		
Lead ug/L	Cox	10	23.25	10	-13.25	0	13.25	no improvement	no improvement	improvement
Lead ug/L	Duke Forest	10	10	.	0	.	.	no improvement		
Lead ug/L	East Fayetteville South	10	46.33	10	-36.33	0	36.33	no improvement	no improvement	improvement
Lead ug/L	East of Mason	30.33	43	.	-12.67	.	.	no improvement		
Lead ug/L	Fire Tower	10.5	10	.	0.5	.	.	improvement		
Lead ug/L	Hog Farm Upper	10	10	10	0	0	0	no improvement	no improvement	no improvement
Lead ug/L	Kelly Rd	10.5	12	.	-1.5	.	.	no improvement		
Lead ug/L	Moonshine	10	10	.	0	.	.	no improvement		
Lead ug/L	PCS	10	56	10	-46	0	46	no improvement	no improvement	improvement
Lead ug/L	Pete Harris	25.33	13.33	.	12	.	.	improvement		
Lead ug/L	Spring Garden	10	13.33	.	-3.33	.	.	no improvement		
Lead ug/L	Troxler	.	10	.	.	.	.			
Lead ug/L	Umstead	10	12.75	.	-2.75	.	.	no improvement		
Lead ug/L	Walmart	.	10	.	.	.	.			
Magnesium mg/L	Black Ankle Non-Powerline	0.55	0.83	.	-0.29	.	.	no improvement		
Magnesium mg/L	Black Ankle Powerline	1	0.59	.	0.41	.	.	improvement		
Magnesium mg/L	Cox	1.35	2.23	1.2	-0.88	0.15	1.03	no improvement	improvement	improvement
Magnesium mg/L	Duke Forest	.	3.2	.	.	.	.			
Magnesium mg/L	East Fayetteville South	2.3	1.61	0.93	0.69	1.37	0.68	improvement	improvement	improvement
Magnesium mg/L	East of Mason	2.6	2.93	.	-0.33	.	.	no improvement		
Magnesium mg/L	Fire Tower	0.82	0.9	.	-0.08	.	.	no improvement		

Appendix Table A.2 Site Mean Station Comparisons of Water Quality Data (No Dig Data Only)										
		Mean Results			**Mean Station Comparisons**			**Improvement / Not Improvement of Mean Station Comparisons**		
Parameter	**Site Name**	**UP**	**DN**	**FD**	**UP-DN**	**UP-FD**	**DN-FD**	**UP-DN Mean Improvement**	**UP-FD Mean Improvement**	**DN-FD Mean Improvement**
Magnesium mg/L	Hog Farm Upper	13.25	10.64	8.4	2.61	4.85	2.24	improvement	improvement	improvement
Magnesium mg/L	Kelly Rd	1.35	1.4	.	-0.05	.	.	no improvement		
Magnesium mg/L	Moonshine	.	1.1	.	.	.	.			
Magnesium mg/L	PCS	0.46	0.77	0.49	-0.3	-0.03	0.28	no improvement	no improvement	improvement
Magnesium mg/L	Pete Harris	1.2	1.75	.	-0.55	.	.	no improvement		
Magnesium mg/L	Spring Garden	1.6	1.65	.	-0.05	.	.	no improvement		
Magnesium mg/L	Troxler	.	2.1	.	.	.	.			
Magnesium mg/L	Umstead	1.55	3.17	.	-1.62	.	.	no improvement		
Magnesium mg/L	Walmart	.	0.92	.	.	.	.			
NO2+NO3 mg/L	Black Ankle Non-Powerline	0.02	0.02	.	0	.	.	no improvement		
NO2+NO3 mg/L	Black Ankle Powerline	0.02	0.02	.	0	.	.	no improvement		
NO2+NO3 mg/L	Cox	0.05	0.02	0.02	0.03	0.03	0	improvement	improvement	no improvement
NO2+NO3 mg/L	Duke Forest	0.02	0.02	.	0	.	.	no improvement		
NO2+NO3 mg/L	East Fayetteville South	0.06	0.02	0.02	0.04	0.04	0	improvement	improvement	no improvement
NO2+NO3 mg/L	East of Mason	0.02	0.12	.	-0.1	.	.	no improvement		
NO2+NO3 mg/L	Fire Tower	0.3	0.12	.	0.18	.	.	improvement		
NO2+NO3 mg/L	Hog Farm Upper	21	22	10	-1	11	12	no improvement	improvement	improvement
NO2+NO3 mg/L	Kelly Rd	0.02	0.02	.	0	.	.	no improvement		
NO2+NO3 mg/L	Moonshine	0.02	0.02	.	0	.	.	no improvement		
NO2+NO3 mg/L	PCS	0.06	0.1	0.02	-0.04	0.04	0.08	no improvement	improvement	improvement
NO2+NO3 mg/L	Pete Harris	0.02	0.02	.	0	.	.	no improvement		
NO2+NO3 mg/L	Spring Garden	0.02	0.02	.	0	.	.	no improvement		
NO2+NO3 mg/L	Troxler	.	0.02	.	.	.	.			
NO2+NO3 mg/L	Umstead	0.02	0.02	.	0	.	.	no improvement		
NO2+NO3 mg/L	Walmart	.	0.02	.	.	.	.			
Phosphorus mg/L	Black Ankle Non-Powerline	0.05	0.48	.	-0.43	.	.	no improvement		
Phosphorus mg/L	Black Ankle Powerline	0.32	0.1	.	0.21	.	.	improvement		
Phosphorus mg/L	Cox	0.08	0.78	0.06	-0.7	0.02	0.72	no improvement	improvement	improvement
Phosphorus mg/L	Duke Forest	0.12	0.08	.	0.05	.	.	improvement		
Phosphorus mg/L	East Fayetteville South	0.21	0.59	0.23	-0.38	-0.02	0.36	no improvement	no improvement	improvement
Phosphorus mg/L	East of Mason	0.16	0.19	.	-0.03	.	.	no improvement		
Phosphorus mg/L	Fire Tower	0.2	0.03	.	0.17	.	.	improvement		
Phosphorus mg/L	Hog Farm Upper	0.25	0.1	0.06	0.16	0.2	0.04	improvement	improvement	improvement
Phosphorus mg/L	Kelly Rd	0.14	0.09	.	0.05	.	.	improvement		

Appendix Table A.2 Site Mean Station Comparisons of Water Quality Data (No Dig Data Only)

Parameter	Site Name	Mean Results			Mean Station Comparisons			Improvement / Not Improvement of Mean Station Comparisons		
		UP	DN	FD	UP-DN	UP-FD	DN-FD	UP-DN Mean Improvement	UP-FD Mean Improvement	DN-FD Mean Improvement
Phosphorus mg/L	Moonshine	0.1	0.1	.	0.01	.	.	improvement		
Phosphorus mg/L	PCS	0.1	1.1	0.1	-1	0	1	no improvement	no improvement	improvement
Phosphorus mg/L	Pete Harris	0.33	0.6	.	-0.27	.	.	no improvement		
Phosphorus mg/L	Spring Garden	0.08	0.07	.	0.02	.	.	improvement		
Phosphorus mg/L	Troxler	.	0.09	.	.	.	.			
Phosphorus mg/L	Umstead	0.08	0.12	.	-0.04	.	.	no improvement		
Phosphorus mg/L	Walmart	.	0.03	.	.	.	.			
Specific Conductivity	Black Ankle Non-Powerline	24.86	36.15	.	-11.29	.	.	no improvement		
Specific Conductivity	Black Ankle Powerline	61.5	40	.	21.5	.	.	improvement		
Specific Conductivity	Cox	60.33	82.28	55.6	-21.94	4.73	26.68	no improvement	improvement	improvement
Specific Conductivity	Duke Forest	61.1	100.2	.	-39.1	.	.	no improvement		
Specific Conductivity	East Fayetteville South	57.6	47.45	27.4	10.15	30.2	20.05	improvement	improvement	improvement
Specific Conductivity	East of Mason	85.97	90.95	.	-4.98	.	.	no improvement		
Specific Conductivity	Fire Tower	24.2	35.9	.	-11.7	.	.	no improvement		
Specific Conductivity	Hog Farm Upper	411.42	375.18	247.95	36.24	163.47	127.23	improvement	improvement	improvement
Specific Conductivity	Kelly Rd	55.48	44.73	.	10.74	.	.	improvement		
Specific Conductivity	Moonshine	42.8	55.85	.	-13.05	.	.	no improvement		
Specific Conductivity	PCS	85.2	77.47	69.85	7.73	15.35	7.62	improvement	improvement	improvement
Specific Conductivity	Pete Harris	80.27	79.1	.	1.17	.	.	improvement		
Specific Conductivity	Spring Garden	32.87	47.63	.	-14.77	.	.	no improvement		
Specific Conductivity	Troxler	61.1	34.5	.	26.6	.	.	improvement		
Specific Conductivity	Umstead	76.83	90.35	.	-13.52	.	.	no improvement		
Specific Conductivity	Walmart	53.4	46.2	.	7.2	.	.	improvement		
Total Kjeldahl (TKN) mg/L	Black Ankle Non-Powerline	0.48	0.99	.	-0.5	.	.	no improvement		
Total Kjeldahl (TKN) mg/L	Black Ankle Powerline	2.85	1.38	.	1.47	.	.	improvement		
Total Kjeldahl (TKN) mg/L	Cox	0.98	4.87	1.2	-3.89	-0.22	3.67	no improvement	no improvement	improvement
Total Kjeldahl (TKN) mg/L	Duke Forest	1.3	0.62	.	0.68	.	.	improvement		
Total Kjeldahl (TKN) mg/L	East Fayetteville South	8.1	7.32	0.9	0.78	7.2	6.42	improvement	improvement	improvement
Total Kjeldahl (TKN) mg/L	East of Mason	1.3	1.03	.	0.28	.	.	improvement		
Total Kjeldahl (TKN) mg/L	Fire Tower	2.01	0.32	.	1.69	.	.	improvement		
Total Kjeldahl (TKN) mg/L	Hog Farm Upper	1.13	0.71	0.98	0.42	0.16	-0.27	improvement	improvement	no improvement
Total Kjeldahl (TKN) mg/L	Kelly Rd	0.78	0.43	.	0.35	.	.	improvement		
Total Kjeldahl (TKN) mg/L	Moonshine	0.96	1.1	.	-0.14	.	.	no improvement		
Total Kjeldahl (TKN) mg/L	PCS	0.96	12.7	0.48	-11.74	0.49	12.23	no improvement	improvement	improvement

Appendix Table A.2 Site Mean Station Comparisons of Water Quality Data (No Dig Data Only)											
		Mean Results			**Mean Station Comparisons**			**Improvement / Not Improvement of Mean Station Comparisons**		
Parameter	**Site Name**	**UP**	**DN**	**FD**	**UP-DN**	**UP-FD**	**DN-FD**	**UP-DN Mean Improvement**	**UP-FD Mean Improvement**	**DN-FD Mean Improvement**
Total Kjeldahl (TKN) mg/L	Pete Harris	1	1.16	.	-0.16	.	.	no improvement		
Total Kjeldahl (TKN) mg/L	Spring Garden	0.2	0.33	.	-0.13	.	.	no improvement		
Total Kjeldahl (TKN) mg/L	Troxler	.	0.35	.	.	.	.			
Total Kjeldahl (TKN) mg/L	Umstead	1.15	0.87	.	0.28	.	.	improvement		
Total Kjeldahl (TKN) mg/L	Walmart	.	0.38	.	.	.	.			
TOC mg/L	Black Ankle Non-Powerline	6.28	16.77	.	-10.49	.	.	no improvement		
TOC mg/L	Black Ankle Powerline	27	45.63	.	-18.63	.	.	no improvement		
TOC mg/L	Cox	29	118.33	30	-89.33	-1	88.33	no improvement	no improvement	improvement
TOC mg/L	Duke Forest	15	11.15	.	3.85	.	.	improvement		
TOC mg/L	East Fayetteville South	12.5	64.17	36	-51.67	-23.5	28.17	no improvement	no improvement	improvement
TOC mg/L	East of Mason	22.43	18	.	4.43	.	.	improvement		
TOC mg/L	Fire Tower	35	5.02	.	29.98	.	.	improvement		
TOC mg/L	Hog Farm Upper	15.76	6.23	5.4	9.53	10.36	0.83	improvement	improvement	improvement
TOC mg/L	Kelly Rd	6.35	5.84	.	0.5	.	.	improvement		
TOC mg/L	Moonshine	15	24.5	.	-9.5	.	.	no improvement		
TOC mg/L	PCS	34.13	170	12	-135.9	22.13	158	no improvement	improvement	improvement
TOC mg/L	Pete Harris	24.53	22.63	.	1.9	.	.	improvement		
TOC mg/L	Spring Garden	22.9	21.8	.	1.1	.	.	improvement		
TOC mg/L	Troxler	.	8.2	.	.	.	.			
TOC mg/L	Umstead	26.67	23	.	3.67	.	.	improvement		
TOC mg/L	Walmart	.	4.2	.	.	.	.			
Total Suspended Residue (TSS) mg/L	Black Ankle Non-Powerline	39	37.67	.	1.33	.	.	improvement		
Total Suspended Residue (TSS) mg/L	Black Ankle Powerline	289	879	.	-590	.	.	no improvement		
Total Suspended Residue (TSS) mg/L	Cox	25.67	33.33	17	-7.67	8.67	16.33	no improvement	improvement	improvement
Total Suspended Residue (TSS) mg/L	Duke Forest	19	53	.	-34	.	.	no improvement		
Total Suspended Residue (TSS) mg/L	East Fayetteville South	123	226.5	66	-103.5	57	160.5	no improvement	improvement	improvement
Total Suspended Residue (TSS) mg/L	East of Mason	170.67	340.75	.	-170.1	.	.	no improvement		
Total Suspended Residue (TSS) mg/L	Fire Tower	157	14.25	.	142.75	.	.	improvement		
Total Suspended Residue	Hog Farm Upper	199.67	74.25	17.1	125.42	182.57	57.15	improvement	improvement	improvement

Appendix Table A.2 Site Mean Station Comparisons of Water Quality Data (No Dig Data Only)										
		Mean Results			**Mean Station Comparisons**			**Improvement / Not Improvement of Mean Station Comparisons**		
Parameter	**Site Name**	**UP**	**DN**	**FD**	**UP-DN**	**UP-FD**	**DN-FD**	**UP-DN Mean Improvement**	**UP-FD Mean Improvement**	**DN-FD Mean Improvement**
(TSS) mg/L										
Total Suspended Residue (TSS) mg/L	Kelly Rd	61.58	98.33	.	-36.75	.	.	no improvement		
Total Suspended Residue (TSS) mg/L	Moonshine	59	29.5	.	29.5	.	.	improvement		
Total Suspended Residue (TSS) mg/L	PCS	24.5	130	3.2	-105.5	21.3	126.8	no improvement	improvement	improvement
Total Suspended Residue (TSS) mg/L	Pete Harris	318.67	163.33	.	155.33	.	.	improvement		
Total Suspended Residue (TSS) mg/L	Spring Garden	328	81.27	.	246.73	.	.	improvement		
Total Suspended Residue (TSS) mg/L	Troxler	.	97	.	.	.	.			
Total Suspended Residue (TSS) mg/L	Umstead	128.33	107.75	.	20.58	.	.	improvement		
Total Suspended Residue (TSS) mg/L	Walmart	.	23	.	.	.	.			
Turbidity NTU	Black Ankle Non-Powerline	12	8.8	.	3.2	.	.	improvement		
Turbidity NTU	Black Ankle Powerline	110	32	.	78	.	.	improvement		
Turbidity NTU	Cox	30	25	.	5	.	.	improvement		
Turbidity NTU	Duke Forest	18	40	.	-22	.	.	no improvement		
Turbidity NTU	East Fayetteville South	110	.	.	.	.	.			
Turbidity NTU	East of Mason	85	50	.	35	.	.	improvement		
Turbidity NTU	Fire Tower	33	7	.	26	.	.	improvement		
Turbidity NTU	Hog Farm Upper	10	13	.	-3	.	.	no improvement		
Turbidity NTU	Kelly Rd	85	27	.	58	.	.	improvement		
Turbidity NTU	Moonshine	15	13	.	2	.	.	improvement		
Turbidity NTU	PCS	14	.	.	.	.	.			
Turbidity NTU	Pete Harris	600	600	.	0	.	.	no improvement		
Turbidity NTU	Spring Garden	.	4.6	.	.	.	.			
Turbidity NTU	Umstead	40	17	.	23	.	.	improvement		
Turbidity NTU	Walmart	.	1.8	.	.	.	.			
Water, Temperature C^o	Black Ankle Non-Powerline	16.34	17.28	.	-0.93	.	.	no improvement		
Water, Temperature C^o	Black Ankle Powerline	18.75	15.13	.	3.62	.	.	improvement		
Water, Temperature C^o	Cox	15.63	16.75	16.7	-1.12	-1.07	0.05	no improvement	no improvement	improvement
Water, Temperature C^o	Duke Forest	18	14.53	.	3.47	.	.	improvement		

Appendix Table A.2 Site Mean Station Comparisons of Water Quality Data (No Dig Data Only)										
		Mean Results			Mean Station Comparisons			Improvement / Not Improvement of Mean Station Comparisons		
Parameter	**Site Name**	**UP**	**DN**	**FD**	**UP-DN**	**UP-FD**	**DN-FD**	**UP-DN Mean Improvement**	**UP-FD Mean Improvement**	**DN-FD Mean Improvement**
Water, Temperature C°	East Fayetteville South	16.15	17.75	16	-1.6	0.15	1.75	no improvement	improvement	improvement
Water, Temperature C°	East of Mason	17.2	15.25	.	1.95	.	.	improvement		
Water, Temperature C°	Fire Tower	15	17.52	.	-2.52	.	.	no improvement		
Water, Temperature C°	Hog Farm Upper	16.7	17.32	18.3	-0.62	-1.6	-0.98	no improvement	no improvement	no improvement
Water, Temperature C°	Kelly Rd	13.85	16.4	.	-2.55	.	.	no improvement		
Water, Temperature C°	Moonshine	20.4	20.45	.	-0.05	.	.	no improvement		
Water, Temperature C°	PCS	15.95	14.63	19.15	1.32	-3.2	-4.52	improvement	no improvement	no improvement
Water, Temperature C°	Pete Harris	16	15.67	.	0.33	.	.	improvement		
Water, Temperature C°	Spring Garden	17.2	14.7	.	2.5	.	.	improvement		
Water, Temperature C°	Troxler	27.3	14.7	.	12.6	.	.	improvement		
Water, Temperature C°	Umstead	23.35	18.05	.	5.3	.	.	improvement		
Water, Temperature C°	Walmart	16.7	19.35	.	-2.65	.	.	no improvement		
Zinc mg/L	Black Ankle Non-Powerline	15.4	26.75	.	-11.35	.	.	no improvement		
Zinc mg/L	Black Ankle Powerline	28.5	22.67	.	5.83	.	.	improvement		
Zinc mg/L	Cox	15	21	18	-6	-3	3	no improvement	no improvement	improvement
Zinc mg/L	Duke Forest	11	10	.	1	.	.	improvement		
Zinc mg/L	East Fayetteville South	14.5	31	10	-16.5	4.5	21	no improvement	improvement	improvement
Zinc mg/L	East of Mason	43.67	54.75	.	-11.08	.	.	no improvement		
Zinc mg/L	Fire Tower	15.5	11.6	.	3.9	.	.	improvement		
Zinc mg/L	Hog Farm Upper	12.8	11.33	10.5	1.47	2.3	0.83	improvement	improvement	improvement
Zinc mg/L	Kelly Rd	22.92	28.67	.	-5.75	.	.	no improvement		
Zinc mg/L	Moonshine	17	13.5	.	3.5	.	.	improvement		
Zinc mg/L	PCS	30.38	61.5	15	-31.13	15.38	46.5	no improvement	improvement	improvement
Zinc mg/L	Pete Harris	19	16.67	.	2.33	.	.	improvement		
Zinc mg/L	Spring Garden	15	20.67	.	-5.67	.	.	no improvement		
Zinc mg/L	Troxler	.	56	.	.	.	.			
Zinc mg/L	Umstead	12	17.25	.	-5.25	.	.	no improvement		
Zinc mg/L	Walmart	.	10.67	.	.	.	.			
pH S.U.	Black Ankle Non-Powerline	5.07	5.49	.	-0.43	.	.	improvement		
pH S.U.	Black Ankle Powerline	5.34	5.35	.	-0.01	.	.	improvement		
pH S.U.	Cox	4.69	4.85	4.59	-0.16	0.1	0.26	improvement	no improvement	no improvement
pH S.U.	Duke Forest	6.26	6.45	.	-0.19	.	.	improvement		
pH S.U.	East Fayetteville South	4.18	4.49	5.25	-0.31	-1.07	-0.76	improvement	improvement	improvement

Appendix Table A.2 Site Mean Station Comparisons of Water Quality Data (No Dig Data Only)										
		Mean Results			**Mean Station Comparisons**			**Improvement / Not Improvement of Mean Station Comparisons**		
Parameter	**Site Name**	**UP**	**DN**	**FD**	**UP-DN**	**UP-FD**	**DN-FD**	**UP-DN Mean Improvement**	**UP-FD Mean Improvement**	**DN-FD Mean Improvement**
pH S.U.	East of Mason	5.16	4.97	.	0.19	.	.	no improvement		
pH S.U.	Fire Tower	4.79	5.19	.	-0.4	.	.	improvement		
pH S.U.	Hog Farm Upper	5.9	5.85	6.09	0.05	-0.19	-0.23	no improvement	improvement	improvement
pH S.U.	Kelly Rd	4.89	5.06	.	-0.17	.	.	improvement		
pH S.U.	Moonshine	4.61	5.73	.	-1.12	.	.	improvement		
pH S.U.	PCS	3.6	4.84	3.69	-1.24	-0.09	1.15	improvement	improvement	no improvement
pH S.U.	Pete Harris	5.31	5.26	.	0.05	.	.	no improvement		
pH S.U.	Spring Garden	5.94	5.96	.	-0.02	.	.	improvement		
pH S.U.	Troxler	6.41	5.67	.	0.75	.	.	no improvement		
pH S.U.	Umstead	5.94	6.03	.	-0.09	.	.	improvement		
pH S.U.	Walmart	5.2	5.24	.	-0.04	.	.	improvement		