SHEARON HARRIS ADVANCED REACTOR PROJECT

INSTREAM FLOW STUDY PLAN

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Section 1

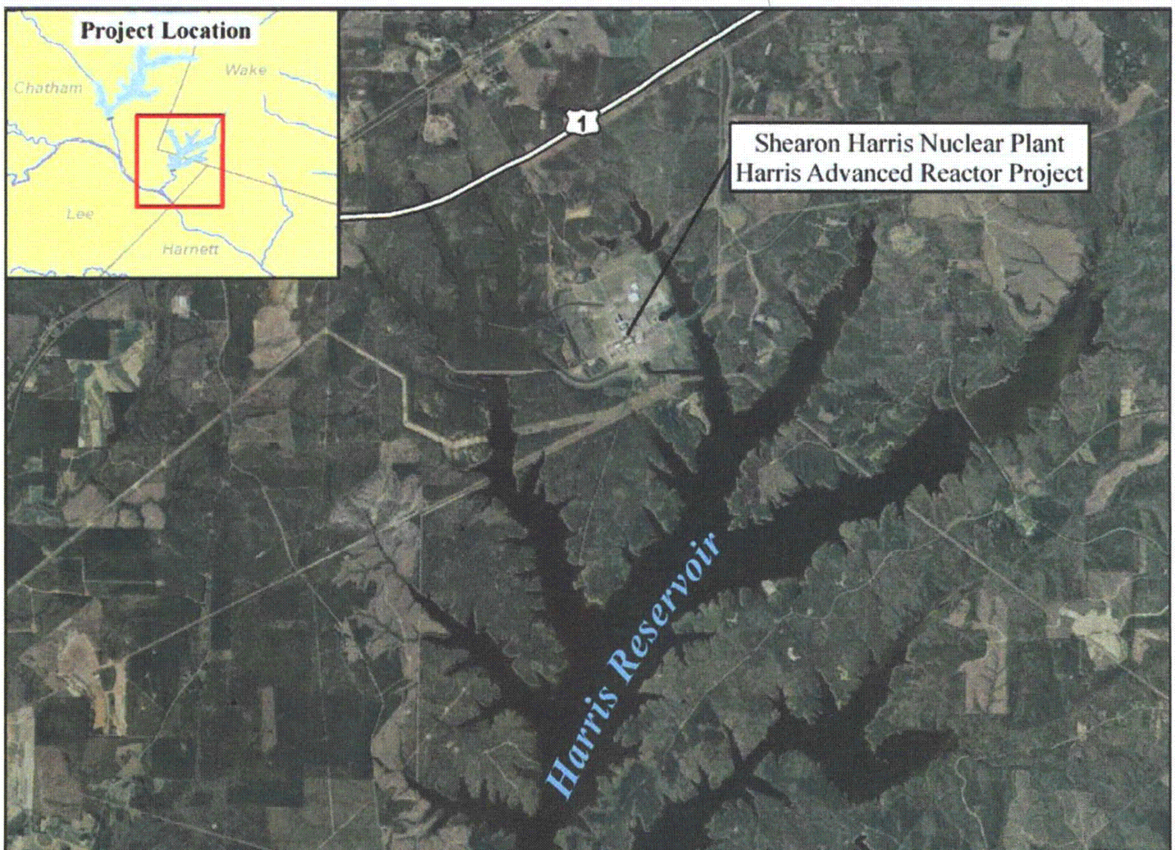
Study Background

The proposed Harris Advanced Reactor (HAR) Units 2 and 3 will be co-located with the existing Shearon Harris Nuclear Plant Unit 1 currently owned by Progress Energy Carolinas, Inc. (PEC). The Project is the subject of a Combined Operating License Application (COLA) submitted to the Nuclear Regulatory Commission (NRC) in February 2008. The HAR Project site will be located northwest of the existing facility and on the same peninsula that extends into Harris Reservoir (Figure 1). The HAR Project site is located in Wake and Chatham counties and within the Cape Fear River Basin.

Harris Reservoir was created by impounding Buckhorn Creek, a tributary to the Cape Fear River (Figure 1). Construction of Harris Dam was completed in December 1980 and the existing Harris Nuclear Plant (HNP) was first operated in 1987. The primary purpose of Harris Reservoir is to provide cooling tower makeup water for the HNP. Harris Reservoir is also used for public recreation, primarily fishing and boating activities. The current full-pool elevation in Harris Reservoir is 220 feet mean sea level (ft msl) and is controlled by a reinforced concrete overflow spillway located adjacent to the main earthen dam. Harris Reservoir has a surface area of approximately 3,561 acres, a reservoir storage volume of approximately 73,000 acre-ft, a maximum depth of 59 ft, and a mean depth of approximately 17.4 ft (Progress Energy 2008).

Operation of the proposed HAR Units 2 and 3 will require additional makeup water from Harris Reservoir. As a result, the existing concrete overflow spillway elevation will be raised 20 ft to create a future full-pool elevation of 240 ft msl. With this increase in full-pool elevation, Harris Reservoir will have a surface area of approximately 7,616 acres and a reservoir volume of approximately 177,563 acre-ft (Progress Energy 2008). To provide makeup water to the reservoir, a new intake structure and pump-house will be located along the north bank of the Cape Fear River immediately upstream from Buckhorn Dam. Water will be withdrawn from the Cape Fear River via the new intake structure and pumped through a proposed 2.6-mile pipeline to a new outfall structure on Harris Reservoir.

FIGURE 1
HAR PROJECT LOCATION MAP



The proposed maximum withdrawal rate from the Cape Fear River above Buckhorn Dam is 137 cubic feet per second (cfs) (Progress Energy 2008). The actual rate at which water is withdrawn will be based on a set of operational rules that will be developed to minimize impacts on downstream flow needs and hydrologic conditions.

The streams and rivers in the Harris Reservoir drainage area have North Carolina water quality designations of Class B and Class C. Class B applies to waters used for primary recreation on an organized basis. Class C waters are defined as those supporting aquatic life propagation and maintenance of biological integrity, wildlife, secondary recreation, and agriculture. The B and C classifications allow any type of National Pollutant Discharge Elimination System (NPDES) facility as long as the discharge will not violate water quality standards. Buckhorn Creek has a water quality designation of Class C between Harris Dam and the Cape Fear River. PEC proposes to maintain a minimum continuous flow of approximately 20 cfs in the Buckhorn Creek reach. During periods of the year where more water is available, PEC proposes to release flows of 20 cfs or higher in Buckhorn Creek.

During the HAR Project NRC consultation process, the North Carolina Department of Environment and Natural Resources (NCDENR) – Division of Water Resources (DWR), North Carolina Wildlife Resources Commission (NCWRC), and U.S. Army Corps of Engineers (COE) requested that an instream flow study be conducted to evaluate the impacts of the withdrawal of makeup water from the Cape Fear River. In addition, these agencies also requested a study to evaluate minimum instream flow requirements for Buckhorn Creek between Harris Dam and the Cape Fear River. This Instream Flow Study Plan addresses the water withdrawals from the Cape Fear River and an evaluation of minimum instream flow requirements in Buckhorn Creek.

In conjunction with this instream flow study, PEC will also be evaluating operating scenarios for the water withdrawals using the Cape Fear River Basin Hydrologic Model (CFRBHM). The CFRBHM will be used to model effects on upstream and downstream users of withdrawals from the Cape Fear River and water releases from Harris Reservoir during various flow conditions. Data resulting from the instream flow study will be used to inform the CFRBHM modeling process.

Section 2
Study Objectives

The objectives of this study are two-fold. The first objective is to determine instream aquatic habitat flow needs for Buckhorn Creek between Harris Dam and the Cape Fear River. The second study objective is to determine effects that Project operations may have on the aquatic resources in the Cape Fear River resulting from the proposed withdrawal of makeup water immediately upstream from Buckhorn Dam. These two study objectives are linked because minimum flow releases into Buckhorn Creek will result in removal of water from Harris Reservoir. This water volume will need to be replaced in part by pumping water from the Cape Fear River to Harris Reservoir. In addition, results of this study will be used to provide hydrologic inputs to the Cape Fear River Basin Hydrologic Model (Progress Energy 2008).

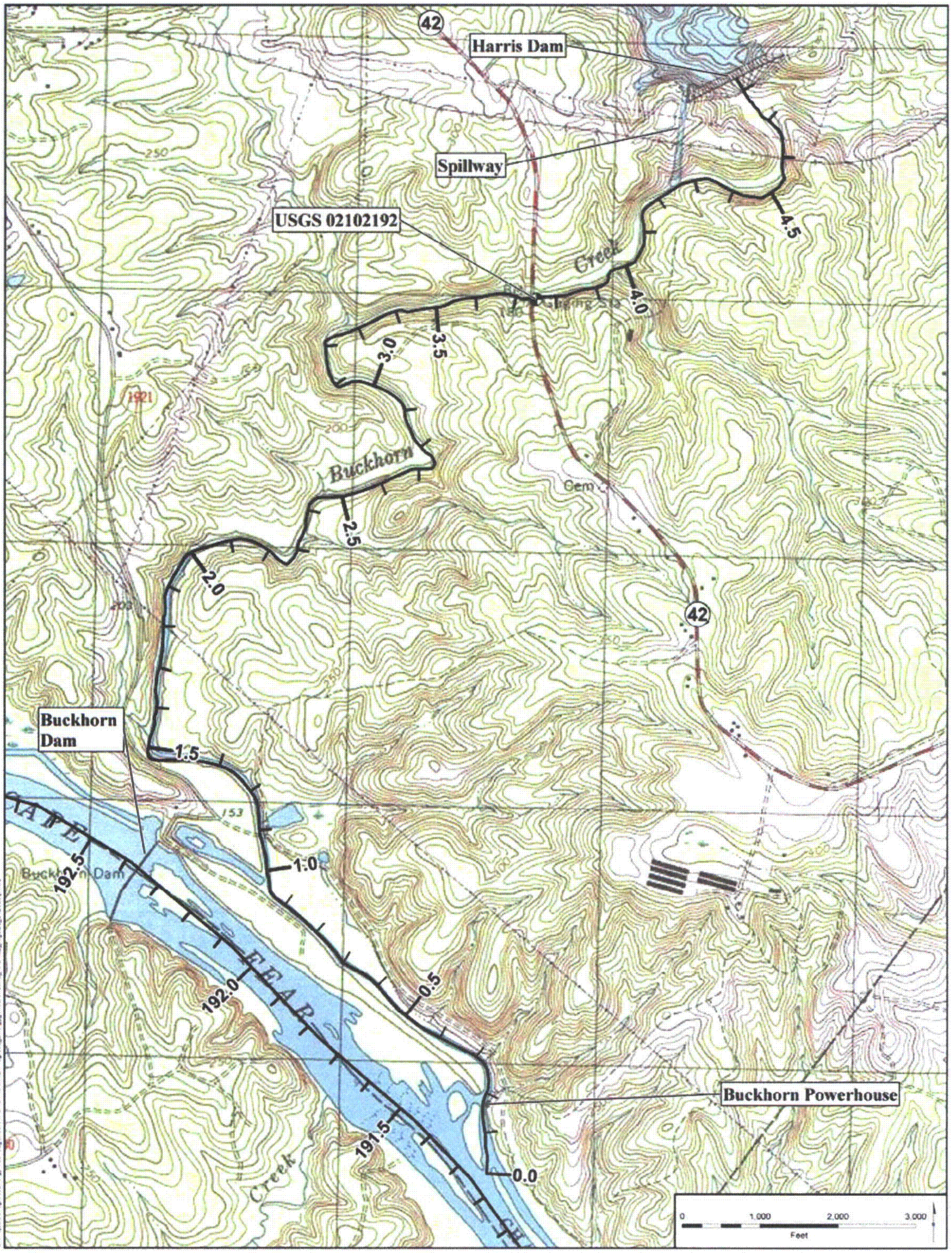
Section 3

Study Area

The proposed study area for Buckhorn Creek extends from the confluence with the Cape Fear River (river mile [RM] 0.0) upstream to Harris Dam (RM 4.8) (Figure 2). The proposed study area for the Cape Fear River extends from the confluence with Buckhorn Creek (RM 191.2) upstream to the proposed location of the new water intake structure above Buckhorn Dam (RM 192.5) (Figure 2). This 1.3-mile section of river is significantly wider than the Cape Fear River immediately upstream and downstream of the proposed study area. Because of this increase in river channel width, river depths are expected to be shallower in this reach and more sensitive to changes in river flow rates.

As noted in Section 1, the proposed maximum withdrawal rate from the Cape Fear River above Buckhorn Dam is 137 cfs and the proposed minimum continuous flow rate in Buckhorn Creek is 20 cfs. It is noted that these two flow rates are not expected to occur at the same time. As a result, the reach between Buckhorn Dam and the confluence with Buckhorn Creek is expected to be the most affected, from an aquatic habitat standpoint, by future water withdrawals. As mentioned in Section 1, PEC will also be evaluating operating scenarios for the water withdrawals using the CFRBHM. The CFRBHM will be used to model the effects on downstream users of withdrawals from the Cape Fear River and water releases from Harris Reservoir during various flow conditions. Since continuous minimum flows in Buckhorn Creek will be coordinated with withdrawals from the Cape Fear River above Buckhorn Dam, the Cape Fear River downstream from the confluence of Buckhorn Creek is expected to be less affected by future Project operations.

FIGURE 2
PROPOSED STUDY AREAS FOR BUCKHORN CREEK AND THE CAPE FEAR RIVER



Section 4

Study Methodology

4.1 Recommended Modeling Approach and Field Study Method

PEC has assembled an instream flow study team to review the process and methodologies for evaluating effects associated with withdrawing supplemental makeup cooling water from the Cape Fear River and determining an appropriate flow regime in Buckhorn Creek. This study team is comprised of individuals representing PEC and its consultant (HDR|DTA), as well as state and federal resource and regulatory agencies including the NCDENR, NCWRC, U.S. Fish and Wildlife Service (USFWS), COE, and NRC. Recommendations and revisions made by the study team will be incorporated into this study plan.

In selecting a process for evaluating aquatic effects resulting from Project operations, PEC's goal is to develop a technical basis for systematically evaluating and balancing the needs and priorities of the various flow-related resources. To address the flow-related variables encompassed within the study objectives, PEC proposes to develop two instream flow models.

For Buckhorn Creek, PEC proposes to use the Physical Habitat Simulation (PHABSIM) Methodology developed by the USFWS. PHABSIM is a one-dimensional modeling tool that simulates the relationship between river flow and aquatic habitat and is commonly used to conduct instream flow studies. Using this modeling tool, aquatic habitat is determined based on the physical parameters of depth, velocity, channel substrate, and cover type. PHABSIM is especially helpful when evaluating the effect of different flow release regimes from dams on downstream aquatic habitat. The PHABSIM study will be conducted under the overall framework of the Instream Flow Incremental Methodology (IFIM) process (Bovee et al. 1998) to determine the incremental relationship between river flow and a standard index of habitat suitability for specific life stages of selected resident and migratory species and/or community guilds, as determined through study scoping and literature review. Data collected for the PHABSIM study will also be used to determine wetted perimeter conditions at the individual Buckhorn Creek study sites in order to evaluate flow related effects on mussel habitat.

For the Cape Fear River instream flow study, PEC is proposing to use a water surface elevation/wetted perimeter study methodology. Withdrawing water from the proposed new intake structure above Buckhorn Dam would remove water from a 1.3-mile section of the Cape Fear River between Buckhorn Dam and the confluence with Buckhorn Creek (Figure 2). This reach is comprised of relatively wide, shallow shoal- and braided channel-type aquatic habitat that would be sensitive to changes in water depth. Using a water surface elevation/wetted perimeter approach would address how changes in river flow affect the aquatic habitat in shallow areas in the mainstem and side channels located in this reach. A wetted perimeter approach would provide useful information on flow-related effects on wetting and drying in both the main channel and side channels of the Cape Fear River in this area. It would also provide information on connectivity within the braided side channel area and between this area and the mainstem reach of the Cape Fear River. This kind of information is directly related to determining flow effects on aquatic habitat for species with low mobility (i.e., mussels) or that would potentially rely on the braided side channel areas for spawning or nursery habitat. As a result, this information would be used to help guide decision making activities concerning water withdrawals above Buckhorn Dam and continuous minimum flows in Buckhorn Creek.

4.2 Study Design and Planning

Before the fieldwork portion of the instream flow study begins, literature review and planning activities will take place including:

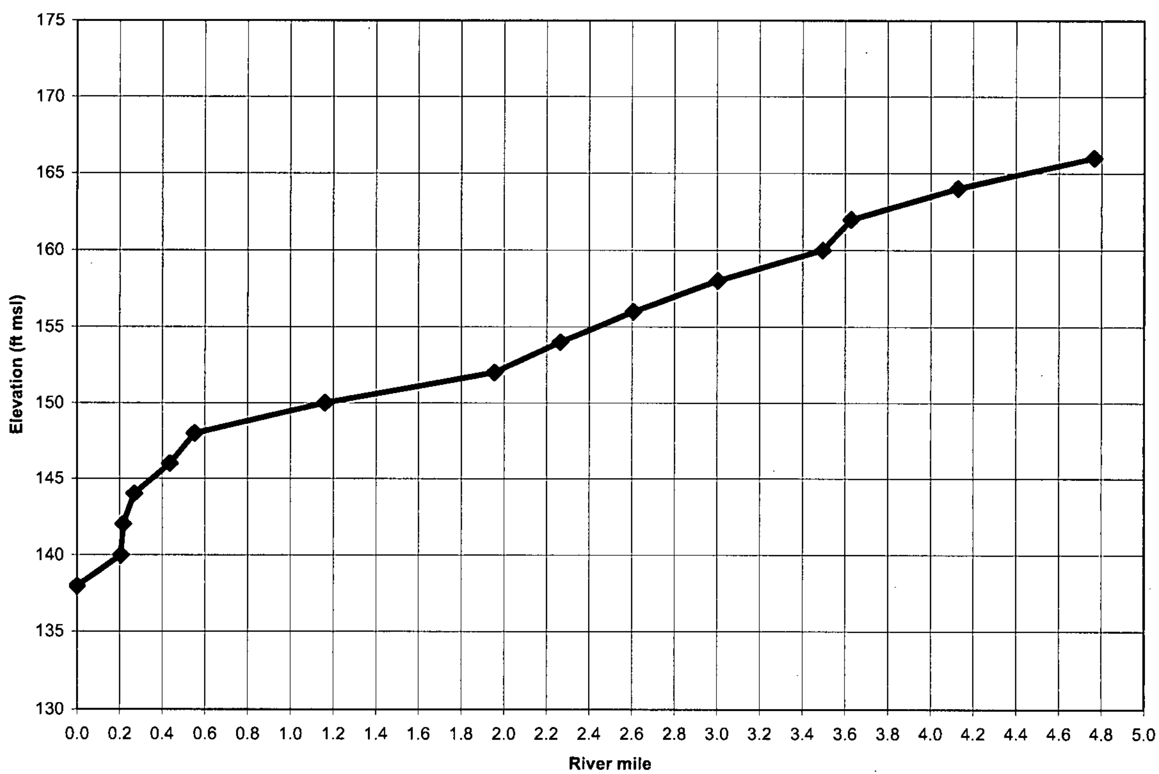
- Habitat mapping and selection of study site(s),
- Selection of species to model and habitat suitability indices,
- Consideration of other instream needs/uses,
- Development of a hydrologic record,
- Selection of target flows for field data collection, and
- Finalization of the study design.

4.2.1 Habitat Mapping and Selection of Study Sites

For Buckhorn Creek, selection of representative study sites will occur after a field reconnaissance trip has been conducted to map channel habitat characteristics (i.e., habitat types) between Harris Dam and the confluence with the Cape Fear River. PEC conducted this reconnaissance trip on May 20 and 21, 2009 by walking/wading the entire 4.8-mile reach from the mouth of Buckhorn Creek upstream to Harris Dam.

Channel habitat characteristics are oftentimes influenced by the longitudinal profile (i.e., slope) of the river reach. The longitudinal profile of Buckhorn Creek between the confluence with the Cape Fear River and Harris Dam is shown in Figure 3.

FIGURE 3
LONGITUDINAL PROFILE OF BUCKHORN CREEK BETWEEN THE CAPE FEAR RIVER (RM 0.0) AND HARRIS DAM (RM 4.8)



In order to clearly see the creek bottom, and for safety considerations, the habitat mapping effort was conducted during low flow conditions (1 – 2 cfs) where most of the channel bottom was visible. During the reconnaissance trip, aquatic habitat types were continuously recorded using a handheld Global Positioning System (GPS) unit. The habitat types were separated into pools (shallow and deep); runs (shallow and deep); glides (shallow and deep); and riffles. Habitat segments that were braided (i.e., multiple channels or small island complexes) were also noted. In addition to habitat types, segment lengths, widths, maximum depths, and dominant substrate types were also recorded. Substrate was measured either visually and/or by tactile inspection as most all depths were wadeable. Classification was in accordance with the NCDENR methods and was coded using the descriptions shown below in Table 1.

TABLE 1
SUBSTRATE SIZE CLASSIFICATION AND CODES

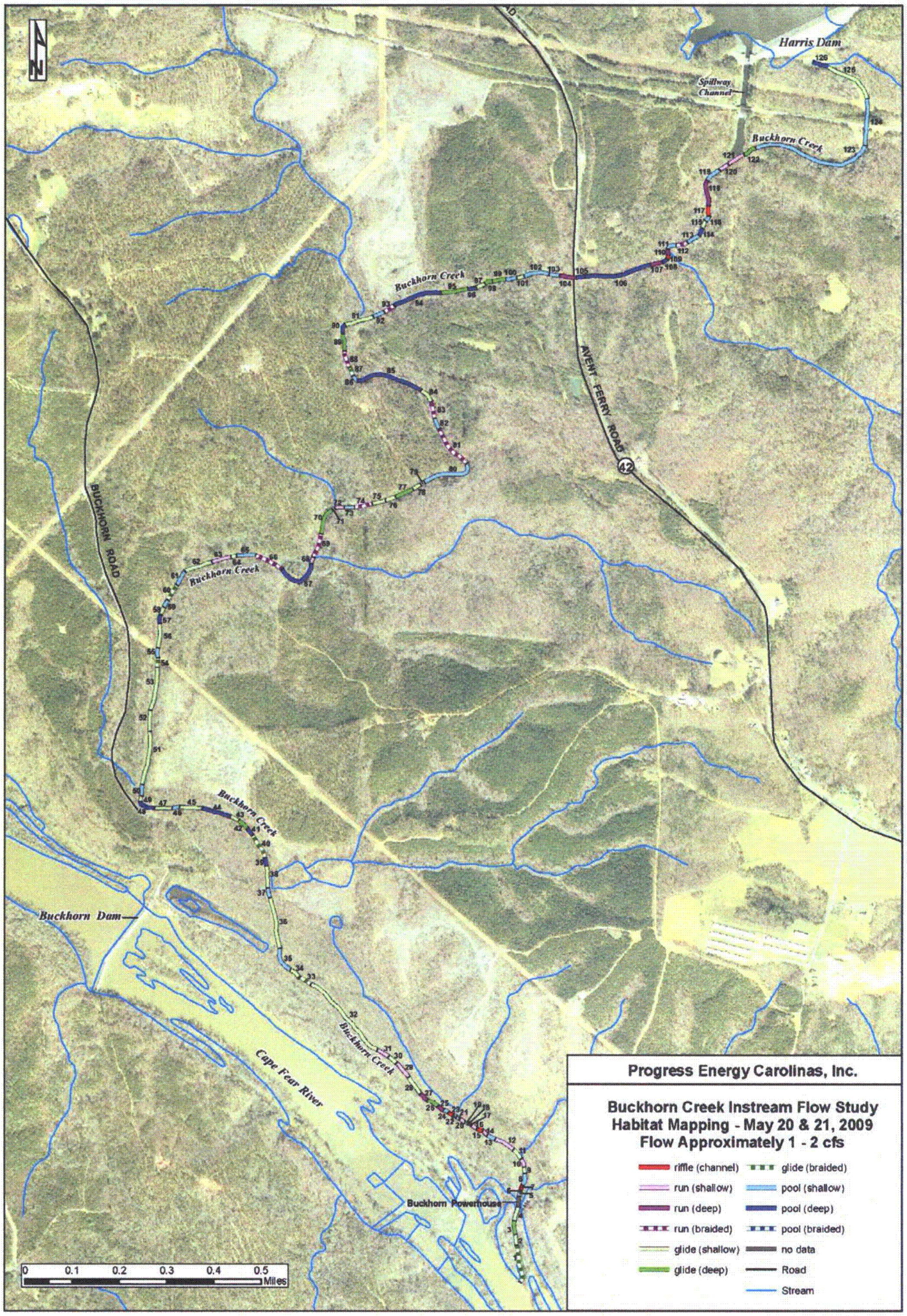
Code	Abbreviation	Description	Inches
0	ORG	Organic Detritus	N/A
1	SI	Silt, Clay	<0.1
2	SA	Sand	<0.1
3	SGR	Small Gravel	0.1–0.5
4	MGR	Medium Gravel	0.5–1.5
5	LGR	Large Gravel	1.5–3.0
6	SCOB	Small Cobble	3.0–6.0
7	LCOB	Large Cobble	6.0–12.0
8	SBOL	Small Boulder	12.0–36.0
9	LBOL	Large Boulder	>36.0
10	SBR	Smooth Bedrock	N/A
11	IBR	Irregular Bedrock	N/A

A summary of all data collected during the habitat mapping field trip is provided in Table 2. This data was also uploaded to Geographic Information System (GIS) software to create a map showing the location of the different habitat types along Buckhorn Creek as shown in Figure 4.

TABLE 2
BUCKHORN CREEK HABITAT MAPPING FIELD DATA

Segment ID	Habitat Type	Width (ft)	Max Depth (ft)	Length (ft)	Substrate	Notes	Begin (mi)	End (mi)
1	glide	37.0	1.50	430	SA	braided; BR/SCOB subdom	0.000	0.082
2	glide	37.0	2.00	120	SBR		0.082	0.104
3	glide	36.0	3.00	157	SA		0.104	0.134
4	glide	32.0	1.50	166	LGR		0.134	0.165
–	N/A	N/A	N/A	116	N/A	Buckhorn Powerhouse	0.165	0.187
5	pool	21.0	1.50	56	SA		0.187	0.198
6	run	21.0	1.00	18	SA		0.198	0.201
7	riffle	20.0	1.00	59	LCOB		0.201	0.212
8	pool	24.0	2.50	140	SBOL	LBOL subdominant	0.212	0.239
9	glide	26.0	2.00	73	SA		0.239	0.253
10	run	23.0	1.50	100	LBOL		0.253	0.272
11	glide	17.0	2.00	134	SA		0.272	0.297
12	run	19.0	1.50	241	SBOL		0.297	0.343
13	riffle	30.0	1.00	97	LBOL	BR subdominant	0.360	0.378
14	run	30.0	1.00	75	SBOL		0.378	0.393
15	riffle	32.0	1.00	70	SBR		0.393	0.406
16	run	43.0	1.00	69	SBOL		0.406	0.419
17	riffle	41.0	2.00	26	SBR		0.419	0.424
18	pool	30.0	1.50	21	SBR		0.424	0.428
19	glide	28.0	2.00	42	LBOL		0.428	0.436
20	run	31.0	1.00	61	SBR		0.436	0.447
21	pool	32.0	2.00	47	SBR		0.447	0.456
22	pool	32.0	2.50	43	SBOL		0.456	0.464
23	riffle	35.0	1.00	63	LBOL		0.464	0.476
24	pool	36.0	2.50	64	SA		0.476	0.488
25	run	35.0	2.00	77	IBR		0.488	0.503
26	glide	29.0	2.50	137	IBR		0.503	0.529
27	run	30.0	2.00	103	IBR		0.529	0.549
28	glide	30.0	2.00	232	IBR	SA overlaying	0.549	0.593
29	run	29.0	1.50	214	SBOL	SA subdominant	0.593	0.633
30	glide	39.0	1.50	111	SA	chub redd	0.633	0.654
31	run	39.0	1.50	148	IBR	SA overlying; woody debris	0.654	0.682
32	glide	29.0	1.50	1,065	SA		0.682	0.884
33	glide	51.0	2.50	158	SA	braided	0.884	0.914
34	glide	35.0	2.00	131	SA		0.914	0.939
35	pool	29.0	3.50	291	SA		0.939	0.994
36	glide	37.0	1.50	592	SA		0.994	1.106
37	pool	40.0	3.50	111	SA	bridge ruins	1.106	1.127
38	glide	47.0	1.50	247	SA	tributary	1.127	1.174
39	pool	32.0	4.50	96	SA		1.174	1.192
40	glide	47.0	1.00	288	SA	braided	1.192	1.246
41	pool	42.0	4.00	101	SA		1.246	1.266
42	glide	49.0	2.50	132	SA	SGR subdominant	1.266	1.291
43	glide	42.0	1.50	106	SA		1.291	1.311
44	pool	42.0	6.00	331	SA		1.311	1.373
45	glide	28.0	2.00	249	SA		1.373	1.421
46	pool	29.0	3.50	87	SA	BR subdominant	1.421	1.437
47	glide	32.0	2.00	195	SA		1.437	1.474
48	pool	24.0	4.00	188	SBR	SA overlaying; large darters	1.474	1.510
49	glide	24.0	1.00	64	SA		1.510	1.522
50	pool	40.0	3.00	125	SA	tributary	1.522	1.545
51	glide	34.0	2.00	607	SA	SGR subdominant; juvenial mussels	1.545	1.660
52	glide	30.0	1.50	239	SA		1.660	1.706
53	glide	39.0	1.00	488	SA		1.706	1.798
54	glide	35.0	1.00	109	SA	braided	1.798	1.819
55	pool	35.0	3.00	113	SA		1.819	1.840
56	glide	28.0	1.50	272	SA		1.840	1.892
57	pool	32.0	4.50	103	IBR	SA overlaying	1.892	1.911
58	glide	37.0	2.00	88	SA		1.911	1.928
59	pool	28.0	2.50	94	SA		1.928	1.946
60	glide	50.0	2.00	198	SA	braided	3.892	3.929
61	pool	28.0	3.00	179	SA	SGR/BOL subdominant	1.946	1.980
62	glide	35.0	1.50	318	SA	tributary	1.980	2.040
63	run	43.0	0.50	222	SA	SGR subdominant	2.040	2.082
64	glide	35.0	1.00	64	SA		2.082	2.094
65	pool	37.0	3.00	211	SA		2.094	2.134
66	run	37.0	1.50	337	SA	braided	2.134	2.198
67	pool	31.0	4.00	513	SA	large woody debris	2.198	2.295
68	run	28.0	1.00	71	SA		2.295	2.308
69	run	41.0	1.00	280	SA	braided; SGR sub; lg woody debris	2.308	2.361
70	glide	32.0	2.50	315	SA	LBOL subdominant	2.361	2.421
71	pool	40.0	4.00	40	SA	braided; trib; lg woody debris	2.421	2.429
72	run	32.0	0.50	106	SA	SGR subdominant	2.429	2.449
73	pool	34.0	3.00	116	SA		2.449	2.471
74	run	35.0	1.50	205	SA	braided; short runs, pools, glides mixed in	2.471	2.509
75	glide	28.0	2.00	150	SA		2.509	2.538
76	glide	29.0	1.00	121	SA		2.538	2.561
77	glide	24.0	2.50	212	SA	lg woody debris; clay banks/mussels	2.561	2.601
78	glide	18.0	1.00	101	SA		2.601	2.620
79	run	35.0	0.80	50	SA	braided; SGR subdom	2.620	2.629
80	pool	30.0	3.50	605	SA	LBOL subdominant	2.629	2.744
81	run	30.0	1.00	509	SA	braided	2.744	2.840
82	pool	30.0	3.00	132	SA		2.840	2.865
83	run	30.0	1.00	191	SA	braided; SGR subdom	2.865	2.901
84	glide	30.0	1.50	170	SA		2.901	2.934
85	pool	30.0	6.00	766	SA	LBOL subdominant	2.934	3.079
86	pool	24.0	3.00	77	SA		3.079	3.093
87	glide	19.0	1.00	101	SA	braided	3.093	3.112
88	run	32.0	1.50	199	SA	braided	3.112	3.150
89	glide	47.0	3.00	199	SA		3.150	3.188
90	pool	34.0	5.00	110	SA	SA layer on top of bedrock	3.188	3.209
91	glide	37.0	2.00	331	SGR	SA subdominant	3.209	3.271
92	pool	34.0	3.00	135	SA		3.271	3.297
93	run	50.0	1.50	131	SA	braided; SGR subdom	3.297	3.322
94	pool	34.0	4.00	555	SA	beaver dam influence	3.322	3.427
95	glide	50.0	3.00	304	SA		3.427	3.484
96	pool	36.0	4.50	95	SI		3.484	3.502
97	glide	50.0	1.50	108	SA		3.502	3.523
98	glide	54.0	2.50	90	SA		0.343	0.360
99	glide	47.0	2.50	155	SA		3.523	3.552
100	pool	47.0	3.00	121	SA	large woody debris; downed trees	3.552	3.575
101	glide	53.0	1.50	86	SA		3.575	3.591
102	pool	47.0	4.00	288	SA		3.591	3.646
103	pool	36.0	2.00	119	SA		3.646	3.668
104	run	28.0	3.00	191	SA		3.668	3.705
105	pool	45.0	4.00	95	SA	large woody debris	3.705	3.723
106	pool	45.0	4.00	764	SA	beaver dam influence	3.723	3.867
107	run	28.0	2.00	129	MGR	mussels	3.867	3.892
108	pool	20.0	4.00	68	SGR	ledge pool	3.929	3.942
109	riffle	20.0	0.50	54	LGR	mussels	3.942	3.952
110	run	20.0	2.00	67	LGR	chub redd; mussel habitat	3.952	3.965
111	pool	30.0	2.00	116	MGR		3.965	3.987
112	run	30.0	1.00	134	LGR	braided; trib; mussels	3.987	4.012
113	pool	35.0	2.50	151	SBOL	LBOL / SA subdominant	4.012	4.041
114	pool	40.0	4.00	90	SGR		4.041	4.058
115	glide	35.0	2.00	96	LGR	sunfish nest	4.058	4.076
116	pool	35.0	3.00	62	LGR		4.076	4.088
117	riffle	30.0	1.00	117	LGR	mussels	4.088	4.110
118	run	30.0	2.00	300	SBOL	mussels	4.110	4.167
119	pool	35.0	2.00	185	SBOL		4.167	4.202
120	run	25.0	1.00	114	SCOB	BR subdominant	4.202	4.223
121	run	20.0	1.00	209	LGR	mussels; emergent vegetation	4.223	4.263
122	glide	30.0	2.50	149	SBOL		4.263	4.291
123	pool	25.0	2.00	1,373	SA		4.291	4.551
124	pool	20.0	1.50	531	SA	culvert under railroad	4.551	4.652
125	glide	45.0	1.00	589	SI	mussels	4.652	4.763
126	pool	50.0	5.00	179	SI	backwater to dam	4.763	4.797
				25,330	**Total feet**			

FIGURE 4
BUCKHORN CREEK HABITAT MAP



The habitat data that was collected has been analyzed to determine the habitat weighting factors that will be used in the PHABSIM model. This analysis was based on the habitat type and length of each segment. The different habitat percentages are provided below in Table 3.

TABLE 3
SUMMARY OF HABITAT TYPES AND PERCENTAGE BASED ON LENGTH

Habitat Type / Description			Number of Occurrences	Total Length (ft)	Percent (%)
Riffle	All	All	7	486	2
Run	Shallow	< 2 ft	13	1,648	7
	Deep	>= 2 ft	6	867	3
	Braided	All	9	2,035	8
Glide	Shallow	< 2.5 ft	31	7,537	30
	Deep	>= 2.5 ft	10	1,849	7
	Braided	All	6	1,285	5
Pool	Shallow	< 4 ft	28	5,303	21
	Deep	>= 4 ft	15	4,164	16
	Braided	All	1	40	0
Total			126	25,214	100

The results of the habitat mapping effort will be used to determine the number of study sites and types of transects that will be required to represent the different habitat types that are present in each study site. Unique or very low percentage habitats may be omitted from transect representation if they are ecologically insignificant. Likewise, certain habitat types may be excluded from the analysis because they cannot be modeled with PHABSIM. Examples of these habitat types include channel types where the flow dynamics are too complex for one-dimensional analysis.

Each study site will contain a representative and proportional number of individual transects based on the results of the habitat mapping effort. It is essential for each habitat type to be modeled in a study site to be represented by at least one transect. Ideally, the individual transects can be located near a good river access point, as this facilitates efficient field data collection. Potential transects identified will be visited by the study team for final approval before the field data collection process begins.

For the Cape Fear River reach, selection of study sites or transects will be based primarily on channel shape and hydraulic characteristics. Individual transects will be selected that are representative of habitats that could be significantly affected by changes in water surface elevation and wetted perimeter. These transects will cover both mainstem and side channel areas of this reach. As with the Buckhorn Creek transects, the Cape Fear River transects will involve study team input and approval before the fieldwork portion of the study begins.

4.2.2 Selection of Species to Model and Habitat Suitability Indices

Resource management goals determined through consultation with the study team will aid in identifying aquatic species of interest, namely fish, freshwater mussels, and aquatic insects (Ephemeroptera, Plecoptera, and Trichoptera [EPT]). Game and non-game fish species, as well as those considered rare, threatened, and endangered (RTE), are usually evaluated as a part of instream flow studies. Much of the fishing pressure in the Cape Fear River is exerted on catfish largemouth bass, crappie, sunfish (*Lepomis* spp.), and, to a lesser extent, Hybrid Striped Bass (*Morone saxatilis* x *M. chrysops*) originating from a previous stocked population in Jordan Lake (no Hybrid Striped Bass have been stocked in Jordan Lake in recent years) (Progress Energy 2008). The Cape Fear Shiner (*Notropis mekistocholas*), a federally endangered fish, is endemic to the Cape Fear River basin in the Piedmont physiographic province. The species has primarily been found upstream of Buckhorn Dam in the Rocky River, Haw River, and Deep River; however, in 2007, one individual was collected in the Cape Fear River downstream from Buckhorn Dam and the proposed instream flow study areas (NCWRC 2008). Two federal fish species of concern are also known to occur in the Cape Fear River drainage in Chatham County: Carolina darter (*Etheostoma collis lepidinion*) and Carolina redhorse (*Moxostoma* sp.). Table 4 provides a species list of fish occurring or potentially occurring in the upper Cape Fear River basin. Many of the larger, riverine fish species are not expected to utilize habitats in Buckhorn

Creek; however, there may be potential for the Cape Fear shiner and other smaller stream fish (e.g., minnows and darters) to occur in the creek.

Little to no current data exists on the fish community in Buckhorn Creek downstream from Harris Dam. As a result, fisheries surveys will be conducted to provide additional information that will aid in the analysis of modeling results. A backpack and/or pram electrofisher will be used to sample wadeable habitats in Buckhorn Creek and in the side channels associated with the mainstem Cape Fear River immediately downstream of Buckhorn Dam. It is expected that the fishery will be similar to that found in Buckhorn Creek above Harris Reservoir and other tributaries to the Cape Fear River. Results from previous sampling efforts in tributaries upstream of Harris Reservoir were dominated by sunfish (*Micropterus* and *Lepomis* spp.), shiners, and catfish (Progress Energy 2008).

Habitat Suitability Criteria (HSC) curves describe the relationship between depth, velocity, and substrate/cover and the degree to which these physical parameters provide suitable habitat for each aquatic species/life stage of concern. For each species/life stage that is modeled, HSC curves will be obtained, modified, or a surrogate will be used for each aquatic species/life stage using available regional information and site-specific information.

Table 4 provides a list of fish species known to occur, or likely to occur, in the upper Cape Fear Basin. It is anticipated that the list of species to be modeled will be a subset of the species listed in Table 4. Table 5 provides a list of individual HSC curves that are available for species listed in Table 4 that are likely to be modeled. The species and guilds that may be used in the Buckhorn Creek study include sunfish (*Micropterus* and *Lepomis* spp.), channel catfish (*Ictalurus punctatus*), composite chub, native stream fish guilds, native mussels, and aquatic insects. Often, a particular species life stage will be chosen to represent a habitat guild that other species utilize, and surrogates may be used for species lacking specific HSC curves.

TABLE 4
FISH SPECIES OCCURRING OR POTENTIALLY OCCURRING IN THE UPPER CAPE FEAR RIVER BASIN

Scientific Name	Common Name
Amidae	**Bowfin**
Amia calva	Bowfin
Anguillidae	**Freshwater eels**
Anguilla rostrata	American Eel
Clupeidae	**Herrings**
Dorosoma cepedianum	Gizzard Shad
Dorosoma petenense	Threadfin Shad
Alosa sapidissima	American Shad
Cyprinidae	**Carps and Minnows**
Clinostomus funduloides	Rosyside Dace
Cyprinus carpio	Common Carp
Luxilus albeolus	White Shiner
Notemigonus crysoleucas	Golden Shiner
Hybognathus regius	Eastern Silvery Minnow
Nocomis leptocephalus	Bluehead Chub
Cyprinella analostana	Satinfin Shiner
Cyprinella nivea	Whitefin Shiner
Notropis altipinnis	Highfin Shiner
Notropis amoenus	Comely Shiner
Notropis hudsonius	Spottail Shiner
Notropis mekistocholas	Cape Fear Shiner
Notropis petersoni	Coastal Shiner
Notropis scepticus	Sandbar Shiner
Semotilus atromaculatus	Creek Chub
Catostomidae	**Suckers**
Minytrema melanops	Spotted Sucker
Moxostoma collapsum	Notchlip Redhorse
Moxostoma macrolepidotum	Shorthead Redhorse
Moxostoma sp.	Carolina Redhorse
Erimyzon oblongus	Creek Chubsucker
Ictaluridae	**Bullhead catfishes**
Ictalurus punctatus	Channel Catfish
Ameiurus catus	White Catfish
Ameiurus brunneus	Snail Bullhead
Ameiurus natalis	Yellow Bullhead
Ameiurus nebulosus	Brown Bullhead
Ameiurus platycephalus	Flat Bullhead
Pylodictis olivaris	Flathead Catfish
Noturus insignis	Margined Madtom
Esocidae	**Pikes**
Esox americanus	Redfin Pickerel
Esox niger	Chain Pickerel

TABLE 4
(CONTINUED)

Umbridae	**Mudminnows**
Umbra pygmaea	Eastern Mudminnow
Poeciliidae	**Livebearers**
Gambusia holbrooki	Eastern Mosquitofish
Aphredoderidae	**Pirate perches**
Aphredoderus sayanus	Pirate Perch
Moronidae	**Temperate basses**
Morone americana	White Perch
Morone saxatilis	Striped Bass
Morone saxatilis x *M. chrysops*	Hybrid Striped Bass
Centrarchidae	**Sunfishes**
Enneacanthus gloriosus	Bluespotted Sunfish
Lepomis auritus	Redbreast Sunfish
Lepomis cyanellus	Green Sunfish
Lepomis gibbosus	Pumpkinseed
Lepomis gulosus	Warmouth
Lepomis macrochirus	Bluegill
Lepomis microlophus	Redear Sunfish
Lepomis sp.	Sunfish hybrid
Micropterus salmoides	Largemouth Bass
Pomoxis annularis	White Crappie
Pomoxis nigromaculatus	Black Crappie
Percidae	**Perches**
Etheostoma fusiforme	Swamp Darter
Etheostoma flabellare	Fantail Darter
Etheostoma olmstedi	Tessellated Darter
Etheostoma serrifer	Sawcheek Darter
Percina crassa	Piedmont Darter
Perca flavescens	Yellow Perch

TABLE 5
POTENTIAL TARGET FISH SPECIES, LIFE STAGES, HSC PARAMETERS, AND REFERENCES

Species	Target Life Stage[1]	Available HSC/ Life Stage[1]	HSC Parameter[2]	Reference
Carolina Redhorse	A	Golden Redhorse (use as surrogate)	V, D	Minnesota Department of Natural Resources (2004)
			C	Developed by Pee Dee Instream Flow Relicensing Subgroup, June 2004
	J	Golden Redhorse (use as surrogate)	V, D, C	Minnesota Department of Natural Resources (2004)
American Shad	S	L, J, O, S, I	V, D, S, C	Modification of Stier and Crance (1985)
Striped Bass	TBD	S	V, D, S	EA (1994)
		I, L	V, D	EA (1994)
			S	Pee Dee Instream Flow Relicensing Subgroup, July 2004
Largemouth Bass	TBD	L, F, J, A	V, S, C	Stuber et al. (1982)
Redbreast Sunfish	TBD	F, J, A, S	V, D, S, C	Thomas R. Payne and Associates (2007)
Channel Catfish	TBD	J, A, S	V, D, S, C	Herricks et al. 1980; Thomas R. Payne and Associates (2007)
Composite Chub	TBD	A, S	V, D, S, C	Thomas R. Payne and Louis Berger Group (2007)
Native Stream Fish	Guild Reps.	Guild Reps.	N/A	N/A
Native Mussels	A, J	N/A	N/A	Will use wetted perimeter as a measure of habitat availability
Aquatic Insects	L	L (EPT)	V, D, S	Developed by Jim Gore, provided by Jim Mead, NCDWR, to the Pee Dee Instream Flow Relicensing Subgroup

[1] A = Adult; J = Juvenile; Y = Young of year; F = Fry; L = Larval; D = Drift; I = Incubation; S = Spawning; O = Outmigration

[2] V = Velocity HSC; D = Depth HSC; S = Substrate HSC; C = Cover HSC

It is unlikely that the Carolina redhorse and other large riverine species like striped bass will utilize habitats in Buckhorn Creek. These species were added due to their conservation or recreational importance, respectively. American Shad (*Alosa sapidissima*) are included due to future, diadromous fish restoration initiatives and their potential to use tributaries for staging and spawning in the spring. Native stream fish could include guild representatives/surrogates for native shiners and minnows, suckers, darters, and/or sunfish. For the Pee Dee River instream flow study (Progress Energy 2006), the Golden redhorse (*Moxostoma erythrurum*) was used as a surrogate for creation of HSC curves for the Carolina redhorse. Redbreast sunfish (*Lepomis auritus*) spawning was used as the target species and life stage for a shallow slow guild that uses fine substrate, without cover. The Fantail darter (*Etheostoma flabellare*) was used as a surrogate for the Piedmont darter (*Percina crassa*) to represent a high-velocity, shallow fast guild. These are just a few examples of the guild types and surrogate species that could be developed for the Buckhorn Creek instream flow study.

According to recent reports (NCWRC 2008; Progress Energy 2008), nine rare, threatened, or endangered (RTE) mussel species occur in the upper Cape Fear River basin. Three of these, the Atlantic pigtoe (*Fusconaia masoni*), yellow lampmussel (*Lampsilis cariosa*), and Carolina creekshell (*Villosa vaughaniana*), are federal species of concern and state listed as endangered in North Carolina. State threatened species include the creeper (*Strophitus undulatus*), eastern lampmussel (*Lampsilis radiata*), Roanoke slabshell (*Elliptio roanokensis*), and triangle floater (*Alasmidonta undulata*). Rare species include the notched rainbow (*Villosa constricta*) and eastern creekshell (*Villosa delumbis*). Occurrences of these mussels in Buckhorn Creek and the mainstem Cape Fear River immediately downstream of Buckhorn Dam are presently unknown. Resource agencies will be consulted on available collections data and appropriate transect placement to represent mussel habitat in both Buckhorn Creek and the mainstem Cape Fear River. Species-specific HSC curves for the mussels found in the upper Cape Fear River are not available; therefore, a wetted perimeter analysis will be conducted in both Buckhorn Creek and the mainstem Cape Fear River to determine changes in mussel habitat with flow.

Presence of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa or mayfly, stonefly, and caddisfly larvae in a stream are usually indicators of good water quality (Allan 1995). Development of EPT HSCs was conducted for the Pee Dee River instream flow study (Progress Energy 2006) and can be used as a basis for Buckhorn Creek.

4.2.3 Consideration of Other Instream Needs/Uses

In developing instream flow study objectives and criteria, other instream needs and uses may be taken into consideration if applicable. These may include recreation uses; boating, paddling, and fishing; aesthetics; upstream fish passage; water quality; and other water withdrawals upstream and downstream from the proposed study area.

4.2.4 Development of a Hydrologic Record

Daily average hydrology will be developed for the period of record at a designated flow node for each study reach based on available U.S. Geological Survey (USGS) flow gauge data. For Buckhorn Creek, the proposed flow node location is at the Highway 42 Bridge crossing (RM 3.75 shown on Figure 5). USGS gauge number 02102192 is located on Buckhorn Creek at the Highway 42 Bridge crossing, and data from this gauge will be used to represent flows in the Buckhorn Creek study reach. The drainage area map (Figure 5) for Buckhorn Creek indicates that the total drainage area for this creek – from its headwaters to the confluence with the Cape Fear River – is 79.3 square miles. Of this total drainage area, 70.1 square miles (88%) are located above Harris Dam, 5.5 square miles (7%) are located between Harris Dam and the Highway 42 Bridge, and 3.7 square miles (5%) are located downstream from the Highway 42 Bridge.

For Buckhorn Creek, two different flow records will be developed: one that reflects the current flow regime below Harris Dam and one that approximates an unregulated period of record, as if Harris Reservoir did not exist. Regulated and unregulated flow regimes are often used to evaluate differences in aquatic habitat between these two flow regimes. USGS gauge number 02102192 provides a hydrology record from 1972 to present. According to USGS calibration records for this flow gauging station, the dam impounding Harris Reservoir did not appreciably alter flows on Buckhorn Creek until December 1980.

Therefore, the period from 1972 through December 1980 is considered representative of unregulated flow conditions and the period from 1981 through 2008 is considered representative of regulated flow conditions. For reference, monthly average flow data from USGS gauge number 02102192 is provided in Table 6. In addition, hydrology data being developed by Hydrologics, Inc. for the Cape Fear River Basin Hydrologic Model may also be used to extend the unregulated data set from 1981 through 2008.

For the Cape Fear River, flow data recorded at the Lillington, North Carolina USGS gauge (number 02102500) will be used to develop the hydrologic record for this study reach (between Buckhorn Dam and the confluence with Buckhorn Creek). The Lillington gauge is downstream from the Cape Fear River study site and has a total drainage area of 3,464 square miles. The drainage area at Buckhorn Dam is 3,230 square miles. Due to the similar size of these two drainage areas, flow data from the Lillington gauge will be pro-rated upstream to Buckhorn Dam based on a linear ratio of 3,230 / 3,464 = 0.93. Therefore, a hydrologic period of record from 1924 to present will be available for modeling the Cape Fear River reach. Hydrology from the Buckhorn Creek gauge will also be used (as appropriate) to adjust the pro-rated flows from the Lillington gauge in the Cape Fear River reach near Buckhorn Dam.

FIGURE 5
BUCKHORN CREEK DRAINAGE AREA MAP

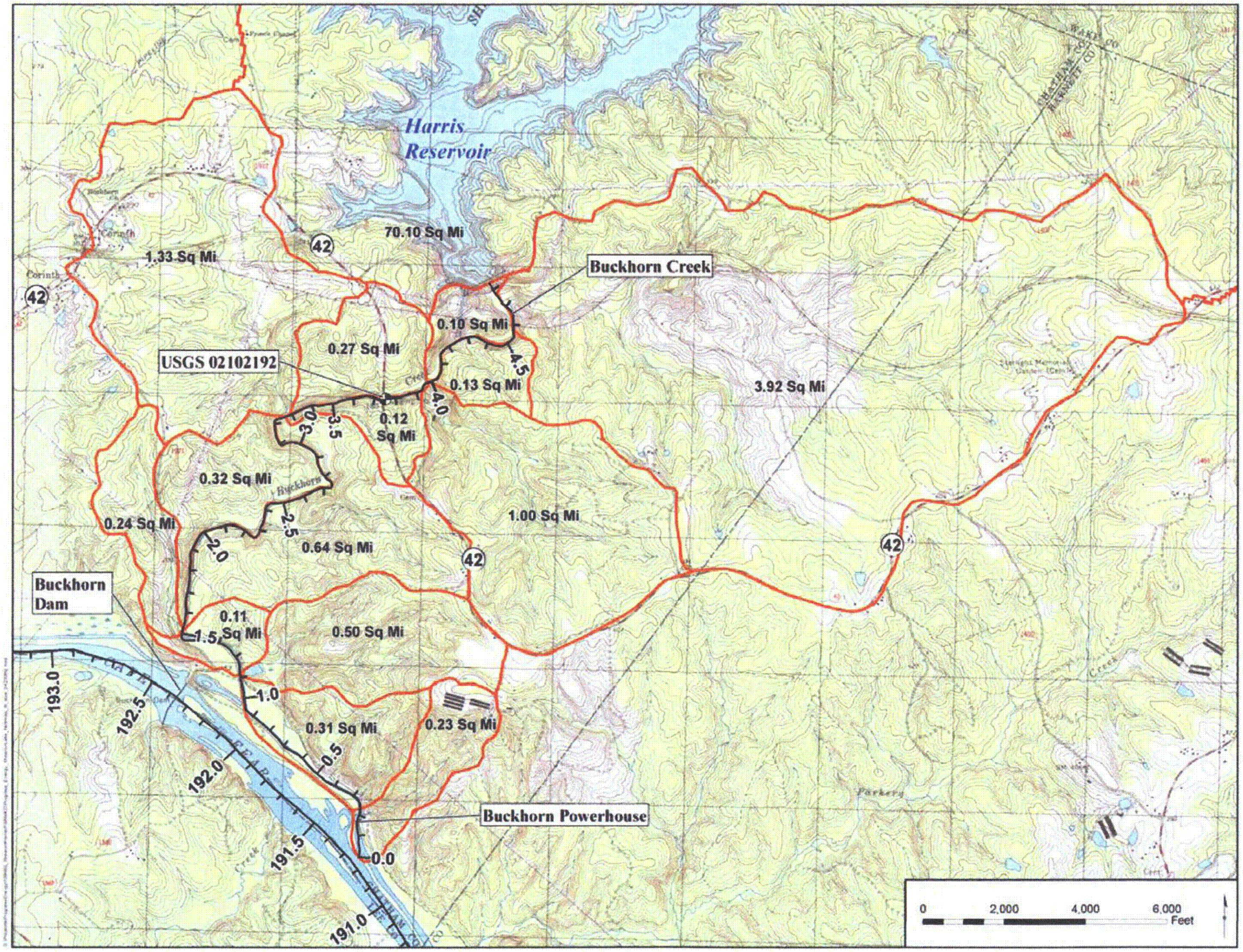


TABLE 6
BUCKHORN CREEK NEAR CORINTH, NC (USGS 02102192)
MONTHLY AVERAGE FLOWS (CFS)

Pre-Harris Dam (1972 - 1980)													
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Avg**
1972										15.8	146.6	220.7	128
1973	134.9	343.5	158.1	177.8	35.1	152.6	32.5	15.4	4.8	2.8	4.9	25.9	91
1974	110.2	176.0	110.4	62.7	181.2	37.4	8.3	95.5	64.6	10.3	12.0	68.8	78
1975	298.6	187.8	208.7	52.1	24.4	12.7	290.5	8.5	34.4	24.7	48.5	95.3	107
1976	153.0	82.5	68.4	24.4	20.5	28.6	5.1	3.2	4.3	14.1	13.9	89.8	42
1977	150.4	40.2	279.1	66.1	8.5	4.8	1.7	3.5	12.4	22.8	46.7	57.5	58
1978	386.8	64.7	213.0	229.1	143.4	50.7	18.1	12.7	2.4	7.1	12.7	35.5	98
1979	178.1	270.4	105.0	136.9	165.5	44.1	38.7	10.8	159.6	28.7	224.2	41.1	117
1980	156.2	74.2	250.1	82.3	20.7	20.3	8.6	2.1	2.0	3.8	2.8	2.7	52
Avg	**196**	**155**	**174**	**104**	**75**	**44**	**50**	**19**	**36**	**14**	**57**	**71**	**83**

Post-Harris Dam (1981 - 2008)													
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Avg**
1981	2.5	8.9	2.7	1.8	2.0	0.7	0.3	1.1	0.9	0.7	1.9	3.0	2
1982	9.5	9.2	11.0	5.2	2.3	7.4	7.4	3.1	1.1	1.1	3.2	4.4	5
1983	9.8	214.7	248.8	239.6	73.7	35.0	9.6	1.3	1.4	3.4	7.2	143.5	82
1984	241.2	222.9	250.0	261.5	107.2	138.1	80.3	58.7	1.9	16.8	15.2	14.0	117
1985	46.7	186.8	46.3	12.1	4.5	1.9	11.0	24.9	3.9	1.3	37.3	38.5	35
1986	15.6	31.3	74.8	21.0	14.2	8.0	0.5	198.9	40.2	0.9	2.4	18.8	36
1987	219.1	159.2	247.9	148.6	44.6	3.2	1.7	1.1	1.8	0.9	2.0	3.8	70
1988	5.7	24.3	14.9	6.9	2.8	2.8	1.3	0.7	1.1	2.2	7.0	2.2	6
1989	2.6	46.5	334.5	168.1	184.4	48.3	101.8	28.0	10.6	60.5	48.7	121.1	96
1990	89.7	120.1	104.3	129.8	34.8	14.6	1.0	1.2	1.2	7.3	6.3	7.4	43
1991	64.8	30.4	78.3	57.7	55.5	21.6	6.6	3.4	1.2	1.0	0.8	1.4	27
1992	2.5	1.4	1.7	1.1	1.6	42.9	56.3	1.7	1.8	2.1	100.0	105.3	27
1993	202.6	64.3	268.7	311.8	23.1	1.7	1.1	1.0	1.1	3.1	1.9	8.5	74
1994	6.3	28.8	150.5	57.8	15.1	1.6	4.6	1.3	1.2	9.6	18.8	20.8	26
1995	26.0	122.8	165.5	9.6	8.3	93.0	74.2	2.5	3.8	128.0	146.0	31.9	68
1996	83.0	155.9	101.1	57.0	51.7	18.3	8.9	4.3	335.3	66.5	49.7	85.6	85
1997	85.3	143.4	76.5	63.5	105.9	26.8	16.4	3.0	1.0	1.0	4.0	12.6	45
1998	153.3	347.5	420.7	137.5	103.8	12.0	1.2	0.7	1.5	2.6	3.0	2.4	99
1999	10.4	12.2	21.8	13.7	3.8	1.1	1.1	1.0	188.6	136.5	25.5	45.5	38
2000	125.4	215.0	55.7	31.3	10.4	8.7	2.9	8.4	6.6	2.8	1.9	2.3	39
2001	2.1	2.9	42.4	113.9	3.2	98.1	181.9	191.4	9.3	3.9	8.7	8.2	55
2002	83.3	63.6	7.9	44.4	1.5	0.9	0.6	0.3	0.7	5.4	58.3	154.1	35
2003	82.5	179.6	375.8	309.4	62.5	62.0	69.3	241.9	50.2	10.4	5.1	50.7	125
2004	21.3	94.3	73.4	18.7	65.0	26.1	15.7	72.4	98.6	14.7	9.4	8.0	43
2005	26.5	40.0	152.2	75.2	8.9	0.7	0.3	0.3	0.2	0.3	0.4	4.4	26
2006	4.4	3.7	1.7	5.7	51.0	327.6	33.8	0.3	0.5	3.1	92.0	97.8	52
2007	122.0	45.0	100.8	96.7	16.0	3.3	1.6	0.1	0.7	2.7	0.9	2.0	33
2008	1.5	4.1	22.6	67.9	11.1	0.4	0.1	0.2	6.5	1.2	11.4	29.0	13
Avg	**62**	**92**	**123**	**88**	**38**	**36**	**25**	**30**	**28**	**18**	**24**	**37**	**50**

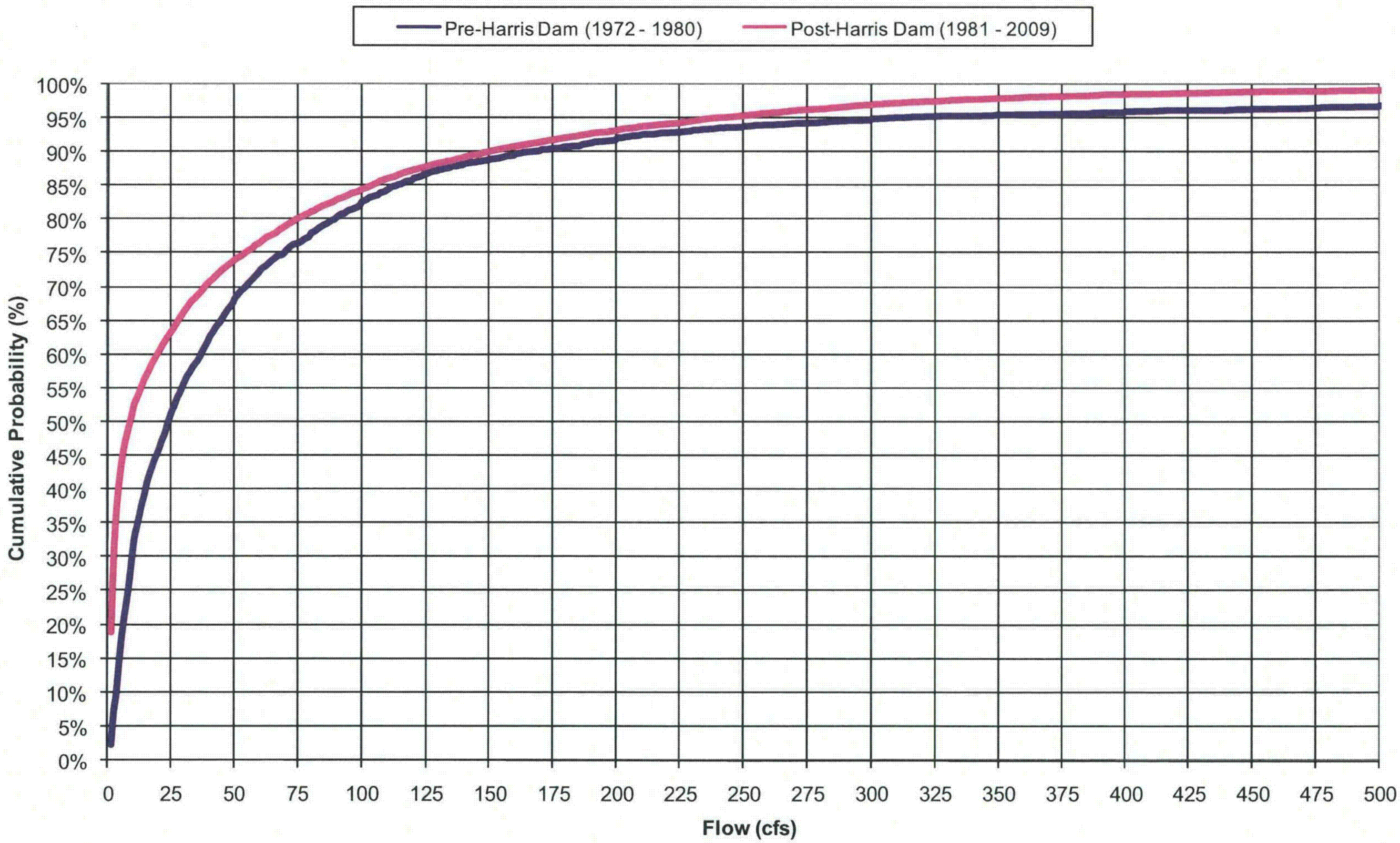
4.2.5 Selection of Target Flows for Field Data Collection

Target flows are necessary in order to collect field data under several different flows used to calibrate the PHABSIM model. Generally, it is required that field data be collected under at least three different flow regimes based on the hydrologic period of record. Figure 6 provides cumulative flow frequency curves for Buckhorn Creek USGS gauge number 02102192 for both the unregulated and regulated periods of record as described above in Section 4.2.4. For the Buckhorn Creek study reach, it is proposed that the PHABSIM model be able to simulate flows representing approximately 90% of the historic flow range (for both unregulated and regulated periods). Based on Figure 6, 90% of the historic flow range is captured by flows ranging from 0.1 to approximately 150 cfs.

To simulate between 0.1 and 150 cfs, three target flows must be selected in order to calibrate the PHABSIM model. Generally, target flows are selected such that each target flow, when multiplied or divided by a factor of 2.5, will extend up to or down to the next target flow simulation range. Following these generally accepted guidelines, proposed target flows for the Buckhorn Creek study reach are 5 cfs, 30 cfs, and 60 cfs. A target flow of 5 cfs will allow a simulation range between 2 cfs to 12.5 cfs. A target flow of 30 cfs will allow a simulation range between 12 cfs and 75 cfs. Finally, a target flow of 60 cfs will allow a simulation range between 24 cfs and 150 cfs.

Since there is no way to deliver controlled releases at Harris Dam or the adjacent spillway, it will be necessary to perform field data collection activities under flows that are naturally available. For this reason, the proposed target flows of 5 cfs, 30 cfs, and 60 cfs may need to be adjusted slightly to accommodate this situation. In addition, because the target flows may be unsteady, appropriate quality control measures will be in place to ensure that the field data collected will be suitable for model calibration purposes. For example, flow data will not be collected during rapidly rising or falling flow conditions and water surface elevations will be monitored continuously while flow/velocity data is being collected at a given study site and transect.

FIGURE 6
CUMULATIVE FLOW FEQUENCY
BUCKHORN CREEK NEAR CORINTH, NC (USGS 02102192)



4.2.6 Finalization of the Study Design

The final study design will be decided upon in collaboration with the study team. Aspects include, but are not limited to number and location of study sites and transects, selection of target species, HSC selection for the species and life stages of interest, hydrology data and flow node location, and number and magnitude of flows to measure in the field.

4.3 Field Data Collection

4.3.1 Buckhorn Creek Field Data Collection

4.3.1.1 General Methods

Physical habitat and hydraulic parameters will be measured using a combination of standard techniques of the USFWS IFIM process (Trihey and Wegner 1981; Bovee 1982; Bovee et al. 1998), the USGS (Rantz 1982), and techniques established in consultation with the study team. PHABSIM data collection and modeling procedures may vary somewhat between study sites, depending on study objectives and hydraulic and channel variations. A detailed description of steps involved in PHABSIM data collection and modeling is provided below.

4.3.1.2 Transect Setup

After the individual study sites and transect locations in Buckhorn Creek have been selected (as described in Section 4.2.1), these transects will be set up to establish a semi-permanent location using established headpins and tailpins on the creek bank. The channel cross sections will be surveyed to top-of-bank, and substrate and cover type will be recorded along the entire length of each transect using approved NCDENR methods. Substrate classification and codes are provided above in Section 4.2.1 (Table 1) and cover types and codes are provided below in Table 7. A GPS point will also be taken to locate each transect on a USGS quadrangle map. The final number and location of individual transects will be determined after the river reconnaissance phase has been completed and in collaboration with the study team.

TABLE 7
COVER TYPE CLASSIFICATION AND CODES

Overhead Cover		Description	Proximal Cover	
Code	Abbreviation		Abbreviation	Code
0.0	NC	No Cover	N/A	N/A
0.1	UCB	Undercut Bank	PUCB	0.14
0.2	OHV	Overhanging Vegetation Touching Water	POHV	0.24
0.3	ROOT	Root Wad (greatest width 1.5 ft)	PROOT	0.34
0.5	SNAG	Snags and Stream Wood	PSNAG	0.54
0.6	WEED	Submerged Aquatic Vegetation	PWEED	0.64
0.7	DEB	Fine Organic Substrate	PDEB	0.74
0.8	TV	Terrestrial Grass and Bushes	N/A	N/A
0.9	ISC	Instream Cover	PISC	0.94

Note: Proximal cover is a cover object not at a vertical, but within 4.0 ft in any direction.

4.3.1.3 Surveying and Controls

All elevations will be surveyed by standard differential survey techniques using an auto level or total station instrument. Headpin and tailpin elevations, water surface elevations (WSEs), hydraulic controls, and above-water bed and bank elevations will be referenced to a temporary benchmark serving a single transect or multiple transects depending on their proximity to one another. Where reasonable (line of sight), benchmarks will be tied together. Transect locations will be fixed, to the accuracy level possible, using a handheld GPS instrument.

4.3.1.4 Flow Measurements

Hydraulic data will be collected at all transects in a manner suitable for one-dimensional PHABSIM modeling (Bovee 1997). Stream depths and velocities will be measured on a cell-by-cell basis at each transect and water surface elevations across each transect will be measured. At a minimum, velocities will be collected at the high target calibration flow. Depending on habitat types and channel characteristics, velocities may also be collected at the middle and/or low calibration flows. Depths and water surface elevations will be collected at the three target calibration flows. If necessary, additional stage/discharge measurements may be collected at higher flows (and possibly at lower flows) to model habitat over a greater range of the flow frequency curve. When only a stage/discharge measurement is taken, the Buckhorn Creek USGS 02102192 flow gauging station will be used to determine discharge through the study site.

Velocities will be collected for at least one calibration flow (typically at the high target calibration flow) in the Buckhorn Creek study reach. Depending on habitat types and channel characteristics, velocities may also need to be collected at the middle and/or low calibration flows. The number of calibration velocity sets needed will be determined after the field reconnaissance has been completed and will include consultation with the study team during the final study design phase.

In Buckhorn Creek, velocities will be collected at each transect primarily using handheld velocity meters. At cross sections and flows where predominant depths are greater than 2.0 feet, velocity distributions may be measured using an acoustic Doppler current profiler (ADCP) mounted on a portable flotation device deployed from either a large or a small watercraft, depending on field conditions. The ADCP uses acoustic pulses to measure water velocities at multiple points in the water column while simultaneously measuring depths across the channel. Depending on the depth and swiftness of the channel, the watercraft can be moved across the channel by motor, paddling, wading, or by a pulley system. The ADCP is connected by cable to a direct current power source and can record data on an on-board computer. According to an extensive evaluation conducted by the USGS (Morlock 1996), an ADCP can be used successfully for data collection under a variety of field conditions.

Because the ADCP will not measure well in depths less than approximately 2.0 feet, shallower measurements will be taken manually using a calibrated, digital, Swoffer® brand, propeller-type velocity meter mounted on a standard USGS top-set wading rod. The placement of verticals will define substrate, bed elevation, and hydraulic boundaries. The number of verticals across a transect will be expanded as necessary to define these boundaries and to limit discharge in one cell to no more than 10% of the total discharge. Since velocity data collection will be conducted under naturally occurring flows (versus controlled flow releases, as described in Section 4.2.5), it is critically important to record any changes in stage during data collection activities (this will be accomplished by installing temporary staff gauges during field measurements). Continuously recording leveloggers may also be deployed at each study reach to monitor changes in stage during the calibration flow measurements.

During low flow and clear water conditions, substrate and cover will be visually classified according to a methodology that is compatible with the HSC curves for substrate and cover. The final classification scheme will be reviewed by the joint study team.

4.3.2 Cape Fear River Depth and Wetted Perimeter Data Collection

4.3.2.1 Transect Setup

After the individual transect locations in the Cape Fear River study reach have been selected (as described in Section 4.2.1), these transects will be set up to establish a semi-permanent location. The channel cross sections will be surveyed to top-of-bank, and substrate and cover type will be recorded along the entire length of each transect. A GPS point will also be taken to locate each transect on a USGS quadrangle map.

The final number and location of individual transects will be determined after the river reconnaissance phase has been completed and in collaboration with the joint study team.

4.3.2.2 Surveying and Controls

All elevations will be surveyed by standard differential survey techniques using an auto level or total station instrument. Headpin and tailpin elevations, WSEs, hydraulic controls, and above-water bed and bank elevations will be referenced to a temporary benchmark serving a single or multiple transects, depending on their proximity to one another. Where reasonable (line of sight), benchmarks will be tied together. Transect locations will be fixed, to the accuracy level possible, using a handheld GPS instrument.

4.3.2.3 Water Surface Elevation/Discharge

Water surface elevations will be collected by continuously recording leveloggers deployed at each chosen stream cross section. The leveloggers will be set to collect data every 15 minutes over a period of several months in order to capture a range of flow conditions suitable for wetted perimeter analysis. This is a highly cost-effective method to collect an abundance of WSE data as the leveloggers can be deployed for long durations with minimal need for checking and data downloads. By matching WSEs with pro-rated flow measurements from the USGS gauging station at Lillington, North Carolina (as described in Section 4.2.4), a stage versus discharge relationship will be developed for each cross section in the study reach. The stage/discharge relationship can then be plotted (or overlaid) on the individual cross sections to determine how stream depth and wetted perimeter are affected by changing river flows.

4.4 Buckhorn Creek PHABSIM Modeling

HDR|DTA will use PHABSIM to model Weighted Usable Area (WUA) for the Buckhorn Creek instream flow study. While the USFWS provides public domain programs and associated models, DTA uses a commercial version of PHABSIM known as RHABSIM. RHABSIM is the most widely used PHABSIM program in the U.S. and is implemented extensively in southeastern states (North Carolina, South Carolina, and Georgia).

As field data is collected, it will be entered into an electronic database, where it will undergo a rigorous quality assurance/quality control (QA/QC) process. When this process is complete, input data decks will be created and the PHABSIM model will be calibrated to the field flow measurements. HSC curves will then be entered into the model to calculate WUA. WUA curves describe the amount of habitat a given flow provides for each species/life stage modeled.

Next, the WUA information will be merged with the regulated and unregulated hydrology databases (as described in Section 4.2.4) in a time-series program. This time-series analysis tool provides habitat information specific to the stream reach being modeled over a long period of record and various flow release scenarios. The time-series product is a more realistic measure of available habitat in a regulated stream over time than WUA curve analysis alone.

4.4.1 Description of Habitat Duration (Time Series) Model

The WUA function is a static relationship between discharge and habitat that does not represent how often a specific flow/habitat relationship occurs. For this reason, WUA is usually not considered the final result of an instream flow study. A more complete analysis is the habitat duration analysis (HDA), also referred to as a time-series analysis. An HDA integrates WUA with hydrology and project operations to provide a dynamic analysis of flow versus habitat. A habitat duration curve is constructed in exactly the same way as a flow duration curve, but uses habitat values instead of stream discharges as the ordered data.

The HDA is a useful tool for assessing effects of operation alternatives relative to baselines and benchmarks established by the user(s). In this case, both regulated and unregulated databases can be used as baselines or benchmarks to which other flow regimes can be compared.

Results of the HDA are most useful when the broadest possible range of project hydrology and operations is entered into the model. Typically, the PHABSIM flow rating curve is extended to 2.5 times the highest calibration flow and 0.4 times the lowest calibration flow. The precise method and extent of extrapolation will depend on study team consultation and approval.

4.4.2 Habitat Duration Analysis Program

Habitat duration modules of the three PHABSIM programs available are extremely limited in their functionality, are cumbersome, and are prone to "crashing." For these reasons, HDR|DTA developed its proprietary software program, Flow Time Series (written in Power Basic®). Flow Time Series is a flexible, user-friendly, fast program that allows the user to input all necessary data and then select which sets or sub-sets of data to use based on project operation specifics and analysis needs. The program creates individual files of all model runs, which provides an efficient means of data analysis with a large number of species/guilds and life stages and flow scenarios.

Input parameters for the Buckhorn Creek HDA include:

- Daily average hydrologic records at the Highway 42 Bridge crossing flow node,
- WUA by study site for all species/life stages, and
- Periodicity for each species/life stages.

Modeling options could include:

- Multiple baseline and alternative flow scenarios;
- Various methods for extrapolating beyond the highest modeled flow;
- Set or subset of the hydrologic record;
- Portion of the flow exceedance curve to use (any portion, full or trimmed data set); and
- Output metric-index such as "Index C" or area under the habitat duration curve (AUC).
- These modeling options will be discussed with the joint study team and the appropriate options will be chosen for the analysis.

4.4.3 Hydrologic Data Sources

As described in Section 4.2.4, both an unregulated and regulated data set covering the 1972 through 2008 period of record will be developed and used for HDA modeling purposes.

4.4.4 Model Runs

The HDA is generally run as follows:

- All guilds, species, and life stages as agreed upon during study plan development and consultation are used;
- Daily analysis time step with results usually presented in time steps of months;
- All years in period of record are used; and
- Output is by study site and species/guild/life stage, but can be totaled for all study sites combined.

4.4.5 HDA Interactive Analytical Tool

While habitat duration curves are one of the best means of comparing habitat availability over time between one flow scenario and another, the number of graphs required can become overwhelming (oftentimes in the thousands) as study variables become more numerous. To overcome the problems of data overload, HDR|DTA has developed an analytical, interactive habitat duration tool that relies on the computer to store, calculate, and visually organize habitat duration results. With this tool, analyses can be effectively focused on specific instream flow objectives and alternatives.

The program operates in a Microsoft Excel spreadsheet format. It uses a metric of the HDA such as Index C or AUC to compare habitat availability over time between one flow scenario and another. Index C is defined as the mean of the total WUA values between 50% and 100% exceedance on the habitat duration curve (described above in Section 4.4.1). There is an individual Index C value associated with each flow for each month for each species and life stage. The portion of the habitat duration curve between 50% and 100% exceedance represents the lower half of the WUA values. The lower half of the WUA values can be the result of flows that are either too high or too low depending on the species and life stage being evaluated. Using Index C as a metric is relevant because it is associated with the lower, or more critical, end of the habitat scale and as such is a conservative means of evaluating aquatic habitat gains. The AUC metric is very similar to Index C with the exception that it is the total area under the habitat duration curve between 50% and 100% exceedance instead of the mean value between 50% and 100% exceedance.

The spreadsheet program calculates each metric by species, month, and flow scenario. Reviewing modeling results on a monthly basis is important because flow recommendations often have a goal of mimicking monthly or seasonally based flow regimes typical of unregulated streams. Alternative flow regimes can be evaluated and compared to a baseline flow condition. This tool can be used during study team meetings to view results of alternative flow scenarios on a real-time basis, thus shortening the length of time required to determine recommended flows.

4.5 Cape Fear River Depth and Wetted Perimeter Modeling

Wetted perimeter modeling will be accomplished by matching continuously recorded WSEs at each cross section on the Cape Fear River reach with pro-rated flow measurements from the USGS gauging station at Lillington, North Carolina (as described in Section 4.2.4). A spreadsheet model will be developed to analyze changes in channel depth and wetted perimeter based on changes in river flow. This tool can then be used to determine how water withdrawals above Buckhorn Dam will affect hydrology and flow characteristics below Buckhorn Dam. The model results can also be used to infer changes in aquatic habitat based on changes in depth and wetted width at each cross section.

4.6 Analysis and Reporting of Results

A draft summary report will be prepared containing the details of all the methodologies used, why they were selected, field measurements, model calibration and simulation, a discussion of alternative flow regimes analyzed, and the rationale for the final flow recommendation(s).

Specifically, this report will include:

- Study design, methods, and results (including field data sheets and notes and model output);
- Evaluation of Project scenarios on aquatic habitat;
- Recommended flows based on aquatic habitat; and
- Recommended flows based on other water needs, uses, and/or lake levels.

After the final flow recommendations have been determined, PEC will finalize the instream flow studies report and issue it to the study team.

Section 5
Schedule

Planning for the Instream Flow Study began in March 2009 and the first study team meeting was held at the Harris Nuclear Plant Visitor's Center on April 30, 2009. Once the study plan is finalized, it is expected that fieldwork will begin in July 2009 with transect selection and set-up in both Buckhorn Creek and the Cape Fear River. Since a controlled flow release mechanism is not available for Buckhorn Creek, target flow data collection will occur when natural flows are within range. At this time, it is unknown how long it may take to obtain a dataset that can be used for model calibration purposes. In the Cape Fear River study reach, leveloggers will be deployed at the time of transect selection to begin recording the stage versus flow relationship at the various transects. It is anticipated that the leveloggers will need to be deployed for a period of several months to collect a range of flow conditions suitable for wetted perimeter analysis. Model results for both Buckhorn Creek and the Cape Fear study reaches are expected to be available by November 2009. This assumes that model calibration flows will be collected in time to support this schedule. If model results are available by November 2009, the draft report will be provided to the study team in January 2010 with the final plan to be submitted in March 2010.

Section 6

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