REPORT

Habitat Assessment Report for Candidate Phase 1 Areas Hudson River PCBs Superfund Site

General Electric Company
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Exponent®

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Acronyms

BBL	=	Blasland, Bouck & Lee, Inc.
BMI	=	benthic macroinvertebrate
BMP	=	Baseline Monitoring Program
cfs	=	cubic feet per second
cm	=	centimeter
cm^2	=	square centimeter
DO	=	dissolved oxygen
DQO	=	data quality objective
ESUH	=	Especially Sensitive or Unique Habitat
fps	=	feet per second
FCI	=	Functional Capacity Index
GE	=	General Electric Company
g/cm^3	=	grams per cubic centimeter
g/m^2	=	grams per square meter
GI	=	Griffin Island
GIA	=	Griffin Island Area
HD Report	=	*Habitat Delineation Report*
HDA Work Plan	=	*Habitat Delineation and Assessment Work Plan*
HSI	=	Habitat Suitability Index
HGM	=	hydrogeomorphic
Kd	=	light extinction coefficient
LWD	=	Large woody debris
m	=	meter
m^2	=	square meter
mg/kg	=	milligrams per kilogram
mg/L	=	milligrams per liter
ND	=	Northumberland Dam
NDA	=	Northumberland Dam Area
NOAA	=	National Oceanic and Atmospheric Administration
NTIP	=	Northern Thompson Island Pool
NWI	=	National Wetland Inventory

NYSDEC	=	New York State Department of Environmental Conservation
Phase 1 DAD Report	=	*Phase 1 Dredge Area Delineation Report*
Phase 2 DAD Report	=	*Phase 2 Dredge Area Delineation Report*
Phase 1 HA Report	=	*Habitat Assessment Report for Candidate Phase 1 Areas*
Phase 2 HA Report	=	*Habitat Assessment Report for Phase 2 Areas*
PMI	=	phytophilous macroinvertebrate
QEA	=	Quantitative Environmental Analysis, LLC
RD	=	remedial design
RD AOC	=	Remedial Design Administrative Order of Consent
RD Work Plan	=	*Remedial Design Work Plan*
RM	=	River Mile
ROD	=	Record of Decision
RS	=	River Section
RTE	=	rare, threatened, or endangered
SAV	=	submerged aquatic vegetation
SEDC	=	Supplemental Engineering Data Collection
shoots/m^2	=	shoots per square meter
SOPs	=	Standard Operating Procedures
SSAP	=	Sediment Sampling and Analysis Program
SSS	=	side-scan sonar
TOC	=	total organic carbon
USEPA	=	United States Environmental Protection Agency
USFWS	=	U.S. Fish and Wildlife Service

1. Introduction

1.1 Site Background

This *Habitat Assessment Report for Candidate Phase 1 Areas* (Phase 1 HA Report) is submitted by the General Electric Company (GE) as part of the remedial design (RD) program for the remedy selected by the United States Environmental Protection Agency (USEPA) for the Upper Hudson River. The RD program is established in the *Remedial Design Work Plan* (RD Work Plan) (Blasland, Bouck & Lee, Inc. [BBL], 2003a). Unless stated otherwise, the approach to the habitat assessments described in this Phase 1 HA Report follows the scope of work described in the *Habitat Delineation and Assessment Work Plan* (HDA Work Plan) (BBL, 2003b) and Attachments A through D thereto (reprinted for convenience as Appendices A through D of this Phase 1 HA Report). Both the RD Work Plan and the HDA Work Plan are part of the Administrative Order on Consent for Remedial Design (RD AOC) (USEPA/GE, 2003), which was executed in August 2003.

On February 1, 2002, the USEPA issued a Superfund Record of Decision (ROD) that calls for, among other things, the removal of substantial quantities of PCB-containing sediments from the Upper Hudson River (USEPA, 2002). In the ROD, the USEPA divided the Upper Hudson River into three sections (River Section 1, River Section 2, and River Section 3) (hereinafter referred to as the "Upper Hudson River" or the "project area"). These sections, illustrated on Figure 1, are defined as follows:

- *River Section 1*: Former location of Fort Edward Dam to Thompson Island Dam (approximately 6.3 miles);
- *River Section 2*: Thompson Island Dam to Northumberland Dam (ND) (approximately 5.1 miles); and
- *River Section 3*: ND to the Federal Dam at Troy (approximately 29.5 miles).

1.2 Goal of Habitat Assessment

The goal of the habitat assessment, as described in the HDA Work Plan, is to collect information on habitat specific physical and biological variables, listed in Table 2 of that Work Plan, that are related to the ecological functions provided by those habitats in reference areas and areas that are potentially affected by sediment removal activities. This information will be used to develop the basis of design for habitat replacement and reconstruction in Phase 1 areas and to determine when post-remediation habitat conditions fall within the ranges of reference conditions.

To quantify the ecological functions within the Upper Hudson River habitats, the assessment procedures focused on direct measurements of the specified physical and biological parameters in the habitats. These parameters include both structural and functional attributes of the habitats. The concept that these types of parameters can be used to quantify ecological functions is one of the foundations of the hydrogeomorphic (HGM) approach (Shafer and Yozzo, 1998; Ainslie et al., 1999; Smith and Wakeley, 2001; Clairain, 2002) and habitat evaluation procedures (e.g., Habitat Suitability Indices [HSIs]), and is used in aquatic habitat monitoring and restoration programs (Niedowski, 2000; Fonseca et al., 2000). As recommended by those programs, the parameters listed in Table 2 of the HDA Work Plan include measures of both structural and functional parameters (as discussed further in Section 4 below).

1.3 Data Quality Objectives and Scope of this Report

The data quality objectives (DQOs) for the habitat assessment program, as set forth in the HDA Work Plan, are to:

- Determine the range of structural parameters that are relevant to and associated with ecological functions within each habitat type;
- Define the relationships between selected structural parameters and ecological functions within each habitat type; and
- Develop a database of habitat-specific data to facilitate subsequent identification and establishment of design criteria, success criteria, and monitoring requirements for the habitat replacement and reconstruction program.

These DQOs require that data on the specified parameters of habitats be collected following the assessment protocols included in Appendices A through D of this Phase 1 HA Report. Data included in this report were collected from September 8 to October 1, 2003 and September 14 to September 20, 2004. The remainder of the Phase 1 data was collected in September 2005. The 2005 data will be reported in the *Phase 1 Final Design Report*. Data collection from Phase 2 areas was initiated in September 2005 and will be completed in subsequent years to fulfill the HDA Program as described in the HDA Work Plan. Phase 2 habitat assessment data will be reported in a *Habitat Assessment Report for Phase 2 Areas* (Phase 2 HA Report).

As described in the HDA Work Plan, habitats were assessed as:

- Unconsolidated (unvegetated) river bottom;
- Aquatic vegetation beds;
- Shoreline habitats, including maintained and natural shorelines; and
- Wetland habitats, specifically riverine fringing wetlands.

The HDA Work Plan required that, in the field season immediately following the execution of the RD AOC (2003), GE conduct habitat delineation activities for all three river sections and also conduct habitat assessment activities for the "candidate Phase 1 areas," which were identified in the RA Work Plan as: 1) the upper portion of the Thompson Island Pool (Northern TIP or NTIP) in River Section 1; 2) the Griffin Island Area (GIA) in River Section 1; and 3) and the areas of River Section 2 in the vicinity of Hot Spots 33-35, known as the Northumberland Dam Area (NDA). In 2003, GE conducted the habitat delineation activities throughout the project area and, due to time and seasonal constraints, conducted habitat assessment activities at a subset of the candidate Phase 1 areas and certain available reference habitats. At the time that prior versions of this Phase 1 HA Report were submitted to USEPA in April and September 2004, all three candidate Phase 1 areas were still under consideration. Subsequently, GE submitted a revised *Phase 1 Target Area Identification Report* (Phase 1 TAI Report) (Quantitative Environmental Analysis, LLC [QEA], 2004), which proposed that Phase 1 consist of: 1) the most upstream dredge areas in the NTIP; and 2) the portion of the GIA on the east side of Griffin Island (GI). USEPA approved that proposal in a letter of January 20, 2005. Nevertheless, since the habitat assessment activities conducted to date included stations in all three of the candidate Phase 1 areas, this Phase 1 HA Report continues to include the data and results from the assessment activities conducted in those candidate Phase 1 areas. Simultaneously with the submission of this Phase 1 HA Report, GE is submitting as a separate document, the *Habitat Delineation Report* (BBL and Exponent, 2005a) (HD Report), which provides the results of the habitat delineation activities conducted in all river sections, as well as an evaluation of off-site reference areas outside the project area.

In August 2005, GE submitted a *Supplemental Habitat Assessment Work Plan* (SHAWP) to USEPA and finalized that SHAWP in September 2005 (BBL and Exponent, 2005b). The SHAWP presented GE's proposed approach and locations for conducting detailed habitat assessment activities in the Phase 1 areas (as defined in the approved Phase 1 TAI Report) and in the Phase 2 dredging areas, as well as in suitable reference areas. The SHAWP noted that the proposed Phase 2 assessment station locations and associated reference locations are subject to change following completion and USEPA approval of the *Phase 2 Dredge Area Delineation Report* (Phase 2 DAD Report). The SHAWP was approved by USEPA on November 17, 2005. The additional assessment activities in Phase 1 areas were completed in September 2005. Assessment activities at Phase 2 areas were initiated in September 2005. Assessment activities at remaining Phase 2 areas, associated reference areas, and off-site reference areas will be completed following completion and USEPA approval of the *Phase 2 Dredge Area Delineation Report* (Phase 2 DAD Report). As indicated above, the results of subsequent assessments as they pertain to the remaining Phase 1 areas will be presented in the *Phase 1 Final Design Report*, and the results of the assessments for Phase 2 areas will be presented in a Phase 2 HA Report.

Habitat delineation and assessment tasks for the land-based sediment and water processing facilities and associated terrestrial access routes to the river are beyond the scope of this Phase 1 HA Report; these tasks were conducted by the USEPA (Ecology and Environment, 2003).

1.4 Report Objectives

The objectives of this Phase 1 HA Report are to:

- Document the habitat assessment results for candidate Phase 1 areas that were assessed in 2003 and 2004, in accordance with the procedures detailed in the HDA Work Plan;
- Present the Functional Capacity Index (FCI) models based on data collected in 2003 and those based on data collected in 2004 from the Phase 1 areas; and
- Present HSI models from the U.S. Fish and Wildlife Service (USFWS) that will be used to supplement FCI models for the wildlife habitat (habitat suitability) function for representative species.

This Phase 1 HA Report provides the foundation for implementing the habitat replacement and reconstruction program for the Phase 1 areas. As stated in the HDA Work Plan, the overall goal of that program is "to replace the functions of the Upper Hudson River habitats that are affected by dredging to within the range of functions found in similar physical settings in the Upper Hudson River, given the changes in river conditions that will result from remedy implementation or from other factors" (BBL, 2003b). The habitat-specific variables summarized in Section 3 of this Phase 1 HA Report provide the underlying data that will be used for developing the basis of design for habitat replacement and reconstruction in the candidate Phase 1 areas. Details of additional factors important to the habitat replacement and reconstruction will be provided in the *Adaptive Management Plans*, which will be part of the Phase 1 and Phase 2 Final Design Reports.

The associated FCI models and HSI models are the fundamental tools that will be used to assess whether the overall program goals have been met once the habitat replacement and reconstruction designs have been implemented. In addition, secondary success criteria (e.g., based on quantitative observations of fish and wildlife presence and abundance) may be used if the primary criteria based on the above models and the measured parameters used in them are not indicative of success.

1.5 Format of Phase 1 HA Report

The remainder of this Phase 1 HA Report consists of the following six sections:

- Section 2 describes the overall approach, sources of information, and methods used to conduct the assessments for each habitat type;
- Section 3 describes the results of the habitat assessments conducted in 2003 and 2004 in the candidate Phase 1 areas;
- Section 4 describes the overall approach, sources of information, and methods used to develop the FCI models for each habitat;
- Section 5 describes the HSI models that will be used;
- Section 6 describes additional data needs for the Phase 1 areas; and
- Section 7 lists the references used to prepare this Phase 1 HA Report.

In addition, several appendices are included in this report to provide more detailed information on the habitat assessment activities and underlying data.

This Phase 1 HA Report uses English and metric units of measurement consistent with the standard practice for the data being reported and in accordance with the methods described in the Standard Operating Procedures (SOPs) from the HDA Work Plan. Where appropriate, English conversions are applied to metric units reported in the text or shown in the tables.

2. Habitat Assessment Approach

2.1 Sampling Design and Station Selection

The four habitat types (i.e., unconsolidated river bottom, aquatic vegetation beds, shoreline, and fringing wetlands) of the Upper Hudson River potentially impacted by the sediment removal activities were assessed in accordance with procedures outlined in the HDA Work Plan. Ultimately, habitat assessments will be completed in representative areas for each habitat type in both Phase 1 and Phase 2 areas, prior to the commencement of the dredging in each area, respectively. The HDA Work Plan stated that assessments were to be completed at 136 unconsolidated river bottom, 52 aquatic vegetation bed, 68 shoreline, and 10 fringing wetland habitat stations. Based on subsequent field work, the number of riverine fringing wetland stations was increased to 16 to include some areas identified as especially sensitive or unique habitats (ESUH) and to represent a greater variety of wetlands. In addition, riverine fringing wetland stations greater than 0.5 acre (only present in Phase 2 areas) and aquatic vegetation beds greater than 3 acres were/will be sampled at two locations within each station to evaluate variability within wetlands/aquatic vegetation beds (BBL and Exponent, 2005b). Therefore, the number of unconsolidated river bottom stations was reduced to 100 stations to compensate for the greater number of riverine fringing wetland and aquatic vegetation bed stations. Nine samples are to be collected from within each unconsolidated river bottom, aquatic vegetation bed, and riverine fringing wetland station; three transects are to be used at each shoreline station (see Appendices A through E for specifics on the sample design).

The main text of this Phase 1 HA Report describes the results of the habitat assessments that were completed in 2003 for a subset of candidate Phase 1 areas and reference areas (i.e., areas that are not expected to be directly affected by the sediment removal activities) at six unconsolidated river bottom, nine aquatic vegetation bed, 14 shoreline, and four fringing wetland habitat stations. The number of stations assessed in 2003 was limited due to the seasonal restrictions prescribed in the HDA Work Plan and signing of the Administrative Order on Consent for Hudson River Remedial Design and Cost Recovery (RD AOC) on August 13, 2003. Field work was initiated immediately following the signing of the RD AOC. The first effort involved groundtruthing the aerial photographs (which were taken “at risk” by GE prior to the signing of the RD AOC). Identification of target and reference stations for subsequent assessment sampling was not possible until that work was completed. Once the target and reference stations were identified, fieldwork was scheduled to maximize the number of stations that could be sampled within each habitat before the seasonal window closed. In addition, collection of data from target stations was prioritized over collection of data from reference stations. However, at the time of the 2003 sampling, all stations effectively represent "reference" conditions because no dredging had occurred.

In addition to the habitat assessment work conducted in 2003, several stations that were assessed in that year were spot-checked and reassessed in 2004. That reassessment effort is described further in subsection 6.1. The data from that reassessment are presented in Appendix K and area also included, in summary form, in the tables in Section 3 of this report.

Detailed habitat assessment activities were completed in September 2005 in the remaining Phase 1 areas (as defined in the approved Phase 1 TAI Report) that were not sampled in 2003 and 2004. Due to time constraints, the results of those assessments are not included in this Phase 1 HA Report, but will be included in the *Phase 1 Final Design Report*. Habitat assessment activities in additional suitable reference areas, off-site reference areas, and data gap areas (if necessary) will be conducted in 2006. The results of those additional assessment activities will be incorporated into the Phase 2 HA Report.

As described in the HDA Work Plan and its Attachments A through D (Appendices A through D of this Phase 1 HA Report), sampling stations for each habitat type were selected to meet the following criteria:

- Adequately characterize habitat strata identified from the habitat delineation information;
- Include an equal number of target stations (in proposed dredge areas) and reference stations (outside of proposed dredge areas); and
- Be allocated among river sections in rough proportion to the relative areas of the habitat to be dredged (i.e., potentially affected habitat) in each river section.

To select specific target and reference stations for each habitat type, information from the field verification activities conducted to delineate the habitats in the project area, existing habitat information (e.g., New York State Department of Environmental Conservation [NYSDEC] wetland maps), and data from the Sediment Sampling and Analysis Program (SSAP) were integrated into a series of overlay maps. These maps were then compared with the proposed dredge area delineations that were in production as working drafts for the Phase 1 DAD Report to identify sampling locations for the detailed habitat assessment activities. Specific habitat station locations were selected based on sediment type, overlying water depth, adjacent land use, and proximity to other habitat features (e.g., NYSDEC wetlands). In addition, stations were selected to include both target stations (i.e., in proposed dredge locations) and reference stations (i.e., outside of proposed dredge locations). All reference stations described in this Phase 1 HA Report are on-site reference stations. Target or reference stations are selected in equal numbers by river section and not by Phase 1 and Phase 2 areas; however, until remediation begins, all samples are collected under "reference" conditions (i.e., unimpacted by remedial activities). If changes are made to dredge areas prior to the start of remediation activities, the stations may be reallocated; therefore, the designation of these stations as target and reference is subject to change. Off-site reference stations were investigated in 2003 (see subsection 3.2 of the HD Report [BBL and Exponent, 2004] and subsection 6.5 of this report for more information), and will be sampled in the 2006 field season.

The specific locations selected for detailed assessment activities for the unconsolidated river bottom, aquatic vegetation bed, shoreline, and riverine fringing wetland habitat types were randomly selected from the stations identified in the candidate Phase 1 areas as described above, in accordance with the respective SOPs. The specific locations of the assessment stations are shown on the maps provided as Figures 2 through 4 and described in more detail in Section 3 below. Figures 2 through 4 consist of maps of the three candidate Phase 1 areas and show the habitat delineation features described in the HD Report (BBL and Exponent, 2004). The specific assessment locations for each habitat type have been added to these maps.

2.2 Assessment Methodology

The following subsections describe the methods used to assess:

- Unconsolidated river bottom;
- Aquatic vegetation beds;
- Shorelines;
- Riverine fringing wetlands; and
- Fish and wildlife observations.

2.2.1 Unconsolidated River Bottom

Methods used to assess the unconsolidated river bottom habitats in the candidate Phase 1 areas followed the SOP in Attachment A of the HDA Work Plan (Appendix A of this Phase 1 HA Report). Clarifications or modifications to habitat assessment methods presented in the SOP are described below along with supporting rationale.

Embeddedness is the extent to which rocks (gravel, cobble, and boulders) and snags are covered or sunken into the silt, sand, or mud of a “high gradient” stream bottom (Barbour et al., 1999). This parameter (Appendix A; Step 5) was not evaluated in the assessment of unconsolidated river bottom habitats for candidate Phase 1 areas due to the lack of high gradient areas.

Surface-water quality data (temperature, conductivity, dissolved oxygen [DO], pH, and turbidity) were added to the sampling program and were recorded using a Horiba U-23 multiparameter probe. The probe was calibrated daily and surface-water quality data were collected at each unconsolidated river bottom sampling station in accordance with the manufacturer’s instructions included with the equipment.

Light availability and current velocity data were collected at the approximate center of each sampling station concurrently with the assessment of the unconsolidated river bottom habitats using the same procedures described for the aquatic vegetation bed in Appendix B. Light availability data were collected using an LI-1400 datalogger connected to an LI-190SA Quantum sensor (to record underwater light) and an LI-192SA Quantum sensor (to record surface light levels). Current velocity was recorded using a Marsh McBirney 201 Electromagnetic flow meter.

2.2.2 Aquatic Vegetation Beds

Methods used to assess the aquatic vegetation beds in the candidate Phase 1 areas followed the SOP in Attachment B of the HDA Work Plan (Appendix B of this Phase 1 HA Report). Specific sampling locations were randomly selected within the depth and species composition strata of the aquatic vegetation bed. Clarifications or modifications to habitat assessment methods prescribed in the SOP are described below along with supporting rationale.

Due to the effective date of the RD AOC, the start date for the 2003 habitat assessment work was delayed. On August 21, 2003, GE submitted a letter to the USEPA requesting an extension of the timeframe for assessing habitats. As indicated in the HDA Work Plan, the preferred period to conduct habitat assessments for the aquatic vegetation bed habitat was July 15 through August 30. GE requested that the schedule be modified to allow data collection to continue through mid-October if necessary. In a response dated August 28, 2003, the USEPA agreed to the schedule modification. Assessments of the aquatic vegetation bed habitats in 2003 were completed between September 22 and 29, 2003. In 2004, reassessment of a subset of those stations assessed in 2003 was conducted between September 14 through September 20. The dominant aquatic vegetation species, such as wild celery and pondweeds, are actively growing during this period; however, certain early-season species of aquatic vegetation may not have been present at the time of the assessments and reassessment.

Surface-water quality data (temperature, conductivity, DO, pH, and turbidity) were added to the sampling program and were recorded using a Horiba U-23 multiparameter probe. The probe was calibrated daily and surface-water quality data were collected at each aquatic vegetation bed sampling station in accordance with the manufacturer's instructions included with the equipment.

2.2.3 Shorelines

Methods used to assess the shoreline habitats in the candidate Phase 1 areas followed the SOP in Attachment C of the HDA Work Plan (Appendix C of this Phase 1 HA Report). Transects were located within stations after field verification of the shoreline condition as natural or maintained. Clarifications or modifications to habitat assessment methods prescribed in the SOP are described below along with supporting rationale.

The assessment of organic shoreline substrate components in the Shoreline Substrate Assessment Protocol (Appendix C) requires an estimate of length and width of large woody debris in contact with surface waters within 50 meters (m) on either side of the transect. In the field, this procedure dictated the position of the three transects at each shoreline station. Where possible, transects were placed approximately 100 m apart to avoid transect overlap and prevent artificially inflated estimates of shoreline debris. When transects could not be placed 100 m apart due to habitat constraints, shoreline debris measurements for each transect were taken at half the distance to the neighboring transect.

2.2.4 Riverine Fringing Wetlands

A new HGM subclass of "riverine fringing" wetlands has been used to classify the Hudson River wetlands. Riverine fringing wetlands possess characteristics similar to traditional HGM classes of riverine and tidal fringe, but riverine fringing wetlands have a unique combination of HGM setting and hydrodynamics. Benches or slopes inside the river banks provide the HGM setting for riverine fringing wetlands, and within-channel flow is the dominant water source. Hydrodynamics have both a vertical component and a horizontal component. The vertical component results from seasonal changes in precipitation and evapotranspiration in the watershed and episodic changes due to hydrofacilities on the river. The horizontal component results from non-tidal river flow.

Methods used to assess the riverine fringing wetlands in the candidate Phase 1 areas followed the SOP in Attachment D of the HDA Work Plan (Appendix D of this Phase 1 HA Report). Specific sampling locations were randomly selected within the vegetation community strata of the fringing wetlands. Clarifications or modifications to the fringing wetland habitat assessment methods prescribed in the HDA Work Plan are described below along with supporting rationale.

In accordance with the HDA Work Plan, three transects were established on each assessed wetland. Transects were used to evaluate and characterize topography and orientation of plant community zonation within each study wetland. Sampling quadrats (i.e., a 1-square-meter [m^2] sampling grid) for vegetation and soil analysis were randomly placed within vegetation community strata identified at assessed wetlands.

The soils present in the assessed wetlands are alluvial and do not possess true O (organic) or A (topmost mineral layer) horizons. Therefore, percent cover for O and A soil horizons was not measured as described in Appendix D.

2.2.5 Fish and Wildlife Observations

As described in the HDA Work Plan, fish and wildlife were observed at each sampling location as a distinct task to document the occurrence of fish, birds, reptiles, amphibians, and mammals in each of the four habitat types. Specifically, during the habitat assessment field activities, personnel experienced in identifying wildlife species surveyed the habitat being assessed for the presence of fish or wildlife using that habitat or for signs of such wildlife (e.g., calls, tracks, scat, slides, dens, burrows, daybeds, and huts). Field personnel observed the wildlife from boats or on the shore depending on the type of habitat being surveyed. Field personnel began recording their observations on approach to a station to document any wildlife flushed by the approach of the field team. Field personnel then continued their observations for the entire duration of the sampling event, covering the habitat-specific station and surrounding environs. Data were recorded on the Fish and Wildlife Survey Form (Appendix E), including species name, number observed, sight code, sign code, observer's initials, and habitat type/location. The completed forms are provided in Appendix L.

In addition, the HDA Work Plan specifies that field personnel document the location(s) of any rare, threatened, or endangered (RTE) species of biota or sensitive habitats observed during field activities. The ROD specifies that the Indiana bat, Karner blue butterfly, and bald eagle have been identified by the USFWS, and the shortnose sturgeon has been identified by the National Marine Fisheries Service (National Oceanic and Atmospheric

Administration [NOAA] Fisheries), as those species that could be affected by the Hudson River PCB cleanup. Queries of the Natural Heritage Program did not identify any other species of concern. At each sampling station, the immediate and adjacent areas were observed by a dedicated wildlife biologist for the duration of the habitat sampling (usually more than 1 hour). No investigative surveys were conducted specifically to identify RTE species. As discussed in Section 3, the only RTE species observed was the bald eagle (*Haliaeetus leucocephalus*).

3. Habitat Assessment Results

This section summarizes the results of the habitat assessment activities conducted at the selected assessment locations within the candidate Phase 1 areas. Field data were collected from those locations between September 8 and October 1, 2003. The specific locations are listed, by geographic coordinates, in Appendix F and the data are listed, for each habitat type, in Appendix G. Several stations were also reassessed in 2004 from September 14 through September 20. That reassessment is discussed further in subsection 6.1, and the resulting data are summarized in the tables in this section and are presented in Appendix K. The remainder of this section describes the 2003 assessment data in detail.

As an initial screening to determine how the sampling stations compared to other candidate Phase 1 areas, the range of sediment total organic carbon (TOC) and percent fines data from the top 2 inches of the sediment were compared (Figure 5). Percent fines and TOC data were obtained from the SSAP stations within 100 feet of the nearest aquatic vegetation bed and unconsolidated river bottom sampling quadrat. Sediment samples were also collected from within SAV beds to characterize sediment nutrient availability. This sediment interval was used because percent fines data were available only from surficial sediment samples (0 to 2 inches) used for groundtruthing the side-scan sonar (SSS) data. In addition, the 0-2 inch surface interval is the interval to which recruiting macroinvertebrate and plants species are initially exposed, and the layer that is most likely to be changed by normal river hydrodynamics. The data indicate that sediments in the unconsolidated river bottom that were assessed have similar TOC concentrations to those generally found in the NTIP, but have somewhat lower TOC and percent fines than those generally found in the GIA and the NDA (see Figure 5). The NTIP had the lowest percentage of fines. Subsequent Phase 1 assessment stations will be located in areas with higher TOC and percent fines. In addition, TOC data from deeper sediment intervals, if available from the SSAP, will be reviewed and included in the final evaluation of Phase 1 areas in the *Phase 1 Final Design Report*.

3.1 Unconsolidated River Bottom

Six stations were sampled between September 30 and October 1, 2003 (see Table 1, below). Five stations were located in River Section 1 and one station was located in River Section 2 (as shown on Figures 2 through 4). At the six stations, sand was the most common substrate often mixed with other finer types of sediment (Stations 2, 4, 5, and 6 in Table 1). Boulders were most common at sample points within Station 3 (in the river channel near the northern tip of GI) and, within this station, were occasionally abundant (10% to 50% of total composition).

Clay was most common at sample points within Station 4 (in river channel near southern tip of GI), but only at 10% of the total substrate composition.

Table 1 – Unconsolidated River Bottom Stations for Detailed Functional Assessments

Station	Type[1]	Approximate Location (RS/RM[2])	Substrate Composition
1	Target	West side of Rogers Island; east side of smaller island in the West River Channel (RS1/RM194.1)	Sand/gravel mix with small quantities (10%) cobble; shell fragments; Detritus
6	Target	East side of Roger's Island above POTW outfall (RS1/RM194)	Sand dominant with silt; trace gravel; leafy organics, shell fragments and muck/mud at similar fractions
2	Target	~300 yards south of Lock 7; west side of channel (RS1/RM193.4)	Sand/silt mix; muck/mud dominant; leafy organics; mussels present
3	Target	Just south of north end of GI ~100 yards south, east side of channel (RS1/RM190.3)	Variable boulder/cobble to gravel/silt mix; muck/mud with leafy organics; shell fragments; mussels present
4	Target	South end of GI ~300 yards north of south tip, west side of channel (RS1/RM189.7)	Sand/silt mix with small quantities (10%) clay; muck/mud dominant; leafy organics: mussels present
5	Target	~300 yards north of Northumberland Bridge; east side of channel (RS2/RM184.1)	Sand/silt mix; leafy organics dominant; mussels present

Notes:
1. Stations are shown in the order that they occur from upriver to downriver locations in the river. The designation of the habitats as "target" or "reference" is based on a review of proposed dredge area delineations that were in production as working drafts for the Phase 1 DAD Report and is subject to change. For this Phase 1 HA Report, information collected from all unconsolidated river bottom habitats is considered "reference" data for the development of the FCIs (see Section 4).
2. RS = River Section; RM = River Mile

Organic substrate components varied greatly between stations. As shown in Table 2, detritus (in the form of leafy organic matter) was consistently found at all stations, usually between a trace and 40% of the total substrate composition, with the exception of Station 5 where it was the dominant substrate. Muck/mud dominated Stations 2, 3, and 4, but at other stations was absent or, if present, was at smaller fractions (<30% of total substrate composition). Shell fragments were most common at Station 1, but also noted at other stations. Mussels (*Elliptio* spp.) were at moderate densities (30% to 50% cover), in small clusters or individually, at Stations 2 through 5.

Available cover (Appendix A; Step 4) provides an indication of the abundance of boulders, snags, and cobble. These components of unvegetated river bottom habitats, if present, provide structural complexity to an otherwise featureless river bottom and thus provide habitat for aquatic organisms. The results for available cover varied within, and between, stations (Appendix G). For example, Station 3 had the highest amount of available cover (greater than 50%) at three of the nine sample points. Available cover at Station 1 was generally from 30% to

50%, with one sample point greater than 50% cover. Available cover at the majority of sample points at all other stations was 10% to 30% (see Appendix G). Only two sample points (at Station 6) had areas where available cover was less than 10%. Pool substrate (Appendix A; Step 6) was scored similarly to available cover.

Table 2 – Range of Conditions Observed in Unconsolidated River Bottoms in the Upper Hudson River in 2003. (2004 Reassessment Data Are Shown in Brackets.)

Parameter	Units	Minimum	Maximum	Mean	Standard Deviation
Inorganic Substrate					
Bedrock	Percent	0 [0]	0 [0]	0 [0]	0 [0]
Boulder	Percent	Trace (<10) [0]	50 [60]	20.5 [36.67]	16.24 [21.60]
Cobble	Percent	Trace (<10) [0]	50 [50]	18.46 [24.38]	15.05 [13.99]
Gravel	Percent	Trace (<10) [0]	70 [30]	30.17 [16.88]	24.55 [9.61]
Sand	Percent	Trace (<10) [0]	80 [90]	42.65 [44.44]	22.21 [33.25]
Silt	Percent	Trace (<10) [0]	80 [70]	42.62 [29.33]	19.06 [21.54]
Clay	Percent	Trace (<10) [0]	10 [10]	9.17 [10]	2.04 [0]
Organic Substrate					
Detritus	Percent	Trace (<10) [0]	70 [70]	17.92 [16.88]	12.88 [20.56]
Muck-Mud	Percent	Trace (<10) [0]	100 [80]	40.81 [48.85]	32.59 [27.85]
Marl	Percent	Trace (<10) [0]	100 [80]	40.38 [18.75]	35.13 [22.87]
Mussels	Percent	30 [0]	50 [30]	16.67 [1.17]	0.78 [0.92]
Epifaunal Substrate					
Pool Substrate[1]	Percent	<25 [25]	>80 [55-75]	49.1 [46.9]	16.4 [14.36]
TOC	mg/kg	1,000	320,000	25958	51657
Percent Fines	Percent	21.9	96.6	37.1	31.4

Notes:
1. To calculate the mean, the mid-range value was used for the "suboptimal" and "marginal" categories. The resultant mean value equates to "marginal." Trace was set to 5 to calculate the mean and standard deviation.
2. Sediment total organic carbon and percent fines were obtained from the SSAP dataset and were not resampled in 2004.

3.2 Aquatic Vegetation Beds

Nine aquatic vegetation bed stations were sampled from September 22 to 29, 2003. Each station was located in (and represented) a separate aquatic bed. Seven aquatic vegetation bed stations were located in River Section 1 and two aquatic vegetation bed stations were located in River Section 2 (Figures 2 through 4). Wild celery (*Vallisneria americana*) was the dominant submerged aquatic macrophyte species in all aquatic vegetation beds sampled (see Table 3, below). However, all stations sampled contained at least one other submerged aquatic macrophyte species, with the exception of Station 9 located just above the ND. Combined, these other species contributed from less than 1% to 27% of the total aquatic macrophyte biomass at the stations (see Table 3, below). The species most commonly co-occurring with wild celery were American pondweed *(Potamogeton nodosus)*, common waterweed (*Elodea canadensis),* and redhead grass (*P. perfoliatus*). This is consistent with the Law Environmental report (1991) that documented wild celery, common waterweed, and pondweeds as the most commonly occurring species in the Upper Hudson River. Exponent (1998) also documented wild celery as the dominant species in River Section 1. Law Environmental (1991) documented six species in River Section 1; Exponent (1998) documented eight species; this Phase 1 HA Report documents seven species. In the 2003 habitat delineation, on a spatially weighted basis, approximately one-third (32%) of the delineated aquatic vegetation beds had a percent cover from 75% to 100%. Approximately half of the aquatic vegetation beds had moderate percent cover (23% of the beds at 25% to 50% cover and 28% of the beds at 50% to 75% cover). Sixteen percent of the beds had a percent cover of 0% to 25%. In comparison, Law Environmental (1991) reported 80% to 90% cover for the aquatic vegetation beds in the Phase 1 areas (Table 4). Within the Phase 1 areas, the total number of aquatic vegetation species has remained relatively consistent, with 6 species identified in 1991 (Law Environmental, 1991) and 5 species in 2003 (this study). Aquatic vegetation beds in the Upper Hudson River have been found to range in size from less than one-tenth acre to 37 acres (see HD Report). The aquatic vegetation beds sampled to date as part of the HDA program range from 1.4 acres to 14.8 acres as shown in Table 3.

Water chestnut (*Trapa natans*), a nonnative invasive species, was identified in River Sections 1 and 3 and will be assessed during subsequent sampling. Eurasian Water Milfoil (*Myriophyllum spicatum*), also a nonnative invasive species, was identified between Lock 1 and the Federal Dam by Law Environmental (1991), and above Lock 4 and between Locks 3 and 4 during the 2003 groundtruthing effort (see Appendix A in the HD Report).

Neither these, nor any other invasive species, will be a component of any restoration or reconstruction effort. Instead, habitat replacement efforts will focus on providing suitable conditions for recolonization of the Phase 1 area by appropriate and desirable native species, such as wild celery, in areas where water chestnut and/or milfoil or any other invasive species are removed as part of the remediation, to the extent feasible and consistent with the remediation design. This includes consideration of timing habitat replacement efforts to coincide with native species growth periods and providing a sufficient stock of seeds, tubers, or plants to jump-start the establishment of native species and prevent invasive species from gaining a foothold in the remediated areas. The location and extent of the water chestnut beds identified in the HD Report (BBL and Exponent, 2004) is consistent with that shown in Law Environmental (1991) (for the entire project area) and Exponent (1998) (for River Section 1), indicating that water chestnut has not greatly expanded over the past decade.

Table 3 — Aquatic Vegetation Bed Stations for Detailed Functional Assessments

Station	Type[1]	Area (ac.)	Approximate Location (RS/RM)	Species Composition (% of total station biomass)
1	Target	13.9	West Channel of northern tip of Rogers Island across from Rec. park (RS1/RM194.4)	Wild celery (84%), American pondweed (12%), redhead grass (4%)
3	Target	1.4	~300 yards south of railroad bridge down to Lock 7 (RS1/RM194.1) in East River channel	Wild celery (95%), common waterweed (3%), American pondweed (2%)
2	Target	2.7	Southern end of Rogers Island, West River Channel (RS1/193.8)	Wild celery (96%), American pondweed (4%), common waterweed (<1%)
4	Target	2.0	~500 yards south of Lock 7; western side of channel (RS1/RM193.2)	Wild celery 99%), American pondweed (1%)
5	Target	1.9	~500 yards north of GI; eastern side of channel (RS1/RM190.8)	Wild celery (95%), redhead grass (5%)
6	Target	7.0	~600 yards south of northern end of GI; eastern side of channel across from private airfield (RS1/RM190.1)	Wild celery (97%), common waterweed (3%)
7	Target	3.3	Southern end of GI, along eastern side of GI at mouth of *Trapa* bed (RS1/RM189.5)	Wild celery (95%), grassy pondweed (*P. gramineus;* 4%), common waterweed (1%)
9	Target	14.8	~200 yards north of Northumberland Bridge, eastern side of channel (RS2/RM184)	Wild celery (100%)
8	Target	3.2	South of Northumberland Bridge ~100 yards western and eastern sides of channel (RS2/RM183.6)	Wild celery (73%), American pondweed (20%), common waterweed (7%)

Note:
1. Stations are shown in the order that they occur from upriver to downriver locations in the river. The designation of the habitats as "target" or "reference" is based on a review of proposed dredge area delineations that were in production as working drafts for the Phase 1 DAD Report and is subject to change. For this Phase 1 HA Report, information collected from all aquatic vegetation bed habitats is considered "reference" data for the development of the FCIs (see Section 4).

Aquatic vegetation was sampled in water from less than 0.5 m deep to greater than 2.5 m deep within nine quadrats (1-m^2 sampling grid, subdivided into 25-square-centimeter [cm^2] subquadrats) at each station (see Table 5 for summary of results). River flow during the sampling period ranged from 2,178 cubic feet per second (cfs) to 3,214 cfs. Aquatic vegetation was sampled from a variety of substrate types that ranged from fine sediments (90.3% fines) to coarser sediments (16.4% fines). TOC content ranged from 990 to 250,000 milligrams per kilogram (mg/kg) (Figure 5). Dry bulk density ranged from 0.17 grams per cubic centimeter (g/cm^3) to 1.5 g/cm^3, moisture content ranged from 12% to 82%, and specific gravity ranged from 2.1 to 2.7 (see Appendix G for additional sediment property data). The quantity of nutrients available for plant growth was estimated through measures of exchangeable potassium and ammonia, and extractable phosphorus in the sediment. Extractable phosphorus ranged from 15.8 to 68.2 mg/kg. Exchangeable phosphorus and ammonia ranged from 9.13 to 133 mg/kg and 2.38 to 33.1 mg/kg respectively.

Table 4 - Percent Cover of Aquatic Vegetation in the Thompson Island Pool (River Reach 1; Law Environmental 1991)

River Reach	West Bank	East Bank
1 (≈River Mile 195 – 188.5)	90	80

Average aboveground biomass for each station (i.e., the average of the nine quadrats) ranged from 55.2 grams per square meter (g/m^2) to 133.7 g/m^2, with an overall average of 82.4 g/m^2 for the stations sampled. Average shoot density (all species combined) for each station ranged from 195 (shoots per square meter [$shoots/m^2$]) to 346 ($shoots/m^2$), with an overall average of 237 ($shoots/m^2$) for the stations sampled. Percent cover for each station ranged from 44% to 78% with an overall average of 59%. The crown density scale shown on the habitat delineation maps also indicates percent cover, but of the entire bed, which generally covers a larger area than an assessment station.

Light availability and current velocity data were also collected inside and outside the aquatic vegetation bed at each station (see Appendix G). Light availability (percent of surface light reaching a depth of 50 centimeters [cm]) measured at the center of the aquatic vegetation bed ranged from 32% to 66%. The light measurements at 0.5 m and 1.0 m were used to calculate Kd (the light extinction coefficient) following the Lambert-Beer equation:

$(I_z = I_o e^{-kdz})$,

where Iz = light measured at a water depth of 1.0 m and Io = light measured at a water depth of 0.5 m.

Kd values ranged from 0.88 m^{-1} to 1.84 m^{-1} within the aquatic vegetation beds, and 0.72 m^{-1} to 1.26 m^{-1} at the outside edge of the beds. Light data were not collected at Stations 8 and 9 due to rain just prior to and during sampling. These Kd values represent light availability under low flow and low turbidity conditions that existed during the time of sampling.

Current velocity measurements were collected inside and outside the aquatic vegetation bed at each station (see Appendix G). Within the aquatic vegetation beds, current velocity ranged from 0.00 to 1.12 feet per second (fps). At the outside edge of the aquatic vegetation beds, current velocity ranged from 0.06 to 0.86. The highest current velocity recorded was inside Station 1 located just south of the former Fort Edward Dam. Overall, the current velocities were lower in the aquatic vegetation bed than current velocities taken immediately outside the bed on the channel side. However, current velocities were relatively low and showed little variability between or within stations.

Based on the limited information available from the 2003 sampling (in which only nine of a planned 52 aquatic vegetation beds were assessed), a Spearman rank correlation matrix was constructed using station averages for aboveground biomass, stem density, percent cover, adjusted depth, nutrients (K, NH4, PO4), TOC, percent fines, light attenuation (Kd), and current (Table 5 below). Two significant ($p<0.05$) correlations were identified – between stem density and depth and between stem density and K (exchangeable potassium in the sediment).

Table 5 – Significance Levels for Spearman Rank Correlation of Aquatic Vegetation Bed Parameters

	Biomass	No. Stems	Cover	Depth	K	NH4	PO4	TOC	Fines	Kd	Current
NoStems	0.971										
Cover	0.5233	0.7018									
Depth	0.5365	0.0181	0.3715								
K	0.4896	0.0242	0.841	0.1905							
NH4	0.2301	0.8844	0.3524	0.8844	0.4237						
PO4	0.7711	0.3633	0.4329	0.6364	0.0809	0.7435					
TOC	0.9062	0.7954	0.465	0.7593	0.3832	0.358	0.465				
Fines	0.9436	0.5557	0.6543	0.7954	0.9062	0.4943	0.3108	0.7954			
Kd	0.4059	0.3583	0.1751	0.7595	0.088	0.3144	0.0729	0.2742	0.5118		
Current	0.0832	0.7845	0.1645	0.8268	0.7984	0.1954	0.282	0.887	0.8128	0.627	

The *p*-value indicates whether the correlation is statistically significant, indicating either a positive or negative relationship between the two variables. *P*-values less than 0.05 are considered significant and bolded.

In accordance with the HDA Work Plan, data collected during the assessment of candidate Phase 1 areas was used to assess the variability between sampling locations and to evaluate whether any modification to the sampling design was warranted.

Based on an assessment of the variability observed in aboveground biomass, stem density, and percent cover data for wild celery, the standard error using nine quadrats per station approaches the underlying station-to-station variability for the stations sampled. Using more than nine quadrats per station would not increase precision because estimates become dominated by the station-to-station variability. The standard error of quadrat values at each station was compared to the standard deviation of the station average values (see Appendix M). Based on nine quadrats, all but one station has less variability within a station than the variability between station averages for biomass, stem density, and percent cover. Stem density at station 1 has one anomalous quadrat with a value of 229, whereas the remaining quadrats range from 16 to 85. Variability estimates excluding that quadrat are well below the station variability. Biomass at station 9 has a few quadrats with high values as compared to all other quadrats, which increases the variability among quadrats at this station. However, in order to avoid preferentially weighting small areas higher, an additional sampling station was added for large aquatic vegetation beds (i.e., greater than 3 acres) in the 2005 sampling. These additional stations will also provide the flexibility to evaluate variability in characteristics within an aquatic bed. Based on an evaluation (using standard t-test methods) of the aquatic vegetation data, the current sampling design will allow detection of 4.7%, 6.9%, and 16.8% reduction in biomass, stem density, and percent cover, respectively. These percentages are the smallest detectable reduction that the current sampling design would be able to detect, using a standard t-test. Calculations use a one-sided test for reduction only and an alpha of 0.05, or 95 percent confidence. Site variability was assumed to be equal to reference variability with nine samples from each area. This assumption is based on the fact that all stations are currently "reference" stations since no dredging has occurred. Once the full target and reference dataset is available, this assumption will be tested to ensure that the most appropriate statistical tests are used for future comparisons. Biomass and stem density were log10 and square-root transformed, respectively. Percent cover was not transformed. Transformations of biomass and stem density were done to meet the assumption of normality required by the standard t-test. Evaluations of normality were done using normal probability plots and Lilliefors goodness of fit tests (See Appendix M). This level of precision is expected to increase as additional stations are sampled.

Table 6 – Range of Conditions in Aquatic Vegetation Beds in the Upper Hudson River in 2003 (2004 Reassessment Data Are Shown in Brackets.)

Parameter	Units	Minimum	Maximum	Mean	Standard Deviation
River flow	cfs	2,178	3,214	2,898 [6778]	341.31
Total organic carbon	mg/kg	990	250,000	26,013	39,593
Percent fines	percent	16.4	90.3	68.15	32.42
Dry Bulk Density	g/cm^3	0.17	1.5	0.93	0.32
Moisture Content	percent	12	82	38.0	16.80
Exchangeable phosphorus	mg/l	9.13	133	33.25 [0.94]	12.96
Exchangeable ammonia	mg/l	2.38	33.1	10.77 [0.82]	7.14
Extractable potassium	mg/l	15.8	68.2	35.11 [14.2]	26.12
Aboveground biomass	g/m^2	55.2	133.7	82.34 [70.28]	52.88
Shoot density	$number/m^2$	195	346	296.39 [211.56]	200.46
Percent cover	percent	44	78	58.35 [52.22]	21.32
Light availability - center of bed	light attenuation coefficient	0.88	1.84	1.2	.40
Current – inside bed (outside bed)	feet per second (fps)	0.00 [0.00] (0.06 [0.07])	1.12 [1.93] (0.86 [0.68])	0.12 [0.31] (0.23 [0.39])	0.29 [0.46] (0.29 [0.25])

Notes:

1. Only one aquatic vegetation bed was reassessed in 2004 and those data are shown in the Mean column. All aquatic vegetation beds were reassessed for current velocity which allowed calculation of minimum, maximum, mean and standard deviation for that parameter. No light data were taken in 2004 due to rain.
2. Sediment total organic carbon, percent fines, dry bulk density and moisture content were obtained from the SSAP dataset and were not resampled in 2004.

3.3 Shorelines

Fourteen shoreline stations (three reference and 11 potential target stations) were assessed between September 8 and September 11, 2003 (see Table 7). Twelve stations were located in River Section 1, and two stations were located in River Section 2 (see Figures 2 through 4). The dominant inorganic substrate was sand, mixed mostly with smaller fractions of silt and/or gravel. Only one shoreline station was dominated (100%) by silt (Shoreline Station 7I). Clay was < 40% of the total sediment composition. Boulders were infrequently observed on shoreline substrates.

Table 7 – Shoreline Stations for Detailed Functional Assessments

Station	Type1	Approximate Location (RS/RM)	Dominant Substrate Composition	Dominant Bank Composition
1R	Reference	Upstream from road bridge across from park on Roger's Island; western shore (above RS1/RM194.4)	Sand/gravel; low cobble/silt mix with trace clay; leafy detritus and muck/mud; woody debris	Stable; optimal vegetation cover2
3R	Reference	½ m north of Rt. 4 Bridge; western shore (RS2/RM184)	Sand; low gravel/silt/clay; low leafy detritus; mostly shell hash and trace algae; high woody debris	Stable – unstable; vegetation cover suboptimal or marginal in sections
1	Target	~50 m downstream from railroad trestle bridge at Rogers Island; western shore (RS1/RM194.1)	Sand/silt/clay mix; low leafy detritus with muck/mud; woody debris	Stable; optimal vegetation cover
2	Target	Western shore of Roger's Island Boat House; north of south tip (RS1/RM194)	Sand; low silt mix; low leafy detritus with muck/mud; low woody debris	Stable; optimal vegetation cover
3	Target	East bank, north of Lock 7, east of Rogers Island (RS1/RM193.9)	Sand; low silt/clay mix; low leafy detritus with muck/mud; woody debris	Moderately stable; optimal vegetation cover
4	Target	Eastern shore of Rogers Island, ~300 m north of Lock 7 (RS1RM193.8)	Sand; low gravel/silt mix; low leafy detritus with muck/mud; low woody debris	Moderately stable – Moderately unstable; optimal vegetation cover
2R	Target	North of GI ~150 m; eastern shore (RS1/RM190.6)	Sand; low gravel and silt; leafy detritus and muck/mud; woody debris	Stable; optimal vegetation cover
5	Target	Northeastern shore of GI (RS1/RM190.5)	Gravel; sand/cobble mix; shale; low leafy detritus; woody debris absent	Stable; suboptimal vegetation cover
6	Target	Eastern shore, across channel from GI (RS1/RM190.4)	Sand/gravel; low cobble/silt mix; mix of leafy detritus, muck/mud, shell hash; low woody debris	Stable – moderately stable; optimal vegetation cover
7	Target	Western shore of GI in the back channel (RS1/RM189.9)	Silt; trace sand/clay; low leafy detritus with muck/mud and vegetation on shore; woody debris	Moderately unstable – optimal vegetation cover
8	Target	Eastern shore across from airstrip on GI, just south of riprap bank along road (RS1/RM189.9)	Gravel; cobble/sand and low silt mix; low detritus and muck/mud; mostly shell hash; woody debris	Stable – moderately stable; optimal vegetation cover with suboptimal to marginal area
10	Target	Eastern shore of GI, ~500 m north of inlet (RS1/RM189.7)	Sand/silt; low detritus and trace muck/mud; shell hash and sand; woody debris	Stable – moderately unstable; optimal vegetation cover
9	Target	0.3 mile north of Rt. 4 Bridge working western shore (RS2/RM183.9)	Sand/clay; low gravel and silt; low detritus and muck/mud; algae; woody debris	Stable – moderately stable; optimal vegetation cover
11	Target	Rt. 4 Bridge, south of wetland (RS2/RM183.6)	Silt; low sand/clay mix low detritus and muck/mud; shell hash and clay/silt; woody debris	Stable – moderately stable; optimal – suboptimal vegetation cover

<u>Notes:</u>

1. Stations are shown in the order that they occur from upriver to downriver locations in the river. The designation of the habitats as "target" or "reference" is based on a review of proposed dredge area delineations that were in production as working drafts for the Phase 1 DAD Report and is subject to change. For this Phase 1 HA Report, information collected from all natural shoreline habitats is considered "reference" data for the development of the FCIs (see Section 4).
2. Vegetation cover is determined by percent cover of bank vegetation according to Table C.5 in Attachment C.

As shown in Table 8, organic substrate components varied greatly between stations, but at most stations leafy detritus (range: zero to 60%) and muck/mud (range: zero to 100%) were the most common substrate components of the shoreline. Small portions of vegetation (< 40%) in the form of an unclassified freshwater alga were found at some shoreline stations. Another common organic substrate component of the shoreline was large woody debris (LWD). LWD was most extensive at Shoreline Station 3R in River Section 2, and absent at Shoreline Station 5I in River Section 1. At the assessed stations, LWD varied in length from 1 to 60 feet, and was usually less than 1 foot wide.

Table 8 – Range of Conditions Observed in Shorelines in the Upper Hudson River in 2003 (2004 Reassessment Data Are Shown in Brackets.)

Parameter	Units	Minimum	Maximum	Mean	Standard Deviation
Inorganic Substrate					
Bedrock	percent	0 [0]	0 [0]	0 [0]	0 [0]
Boulder	percent	0 [0]	Trace (<10) [10]	5 [10]	0 [0]
Cobble	percent	Trace (<10) [0]	30 [50]	13.3 [30]	8.35 [28.28]
Gravel	percent	Trace (<10) [0]	70 [100]	28.5 [43]	23.18 [38.99]
Sand	percent	Trace (<10) [0]	100 [70]	50.6 [49.54]	29.66 [23.71]
Silt	percent	Trace (<10) [0]	100 [30]	27.7 [22]	27.53 [9.19]
Clay	percent	Trace (<10) [0]	40 [70]	21.05 [16.67]	12.65 [21.51]
Organic Substrate					
Detritus	percent	Trace (<10) [NA]	40 [NA]	16.6	12.59
Muck-Mud	percent	Trace (<10) [NA]	100 [NA]	49.5	33.76
Marl	percent	Trace (<10) [NA]	100 [NA]	81.0	21.32
Vegetated	percent	Trace (<10) [NA]	40 [NA]	13.4	11.38
Woody Debris	Feet	Trace (<10) [NA]	60 [NA]	14.44	10.19
Bank Assessment					
Stable	percent	Trace (<10) [0]	100 [100]	74.3 [100]	27.55 [0]
Moderately Stable	percent	Trace (<10) [0]	90 [100]	43.7 [80]	32.09 [21.38]
Moderately Unstable	percent	Trace (<10) [0]	80 [50]	30.6 [32]	27.68 [17.88]
Unstable	percent	Trace (<10) [0]	0 [0]	0 [0]	0 [0]
Bank Vegetation					

Parameter	Units	Minimum	Maximum	Mean	Standard Deviation
Optimal	percent	Trace (<10) [0]	100 [100]	90.5 [100]	21.64 [0]
Suboptimal	percent	Trace (<10) [0]	100 [100]	31.3 [100]	24.75 [0]
Marginal	percent	Trace (<10) [0]	20 [0]	20.0 [0]	0 [0]
Poor	percent	Trace (<10) [0]	0 [0]	0 [0]	0 [0]
Riparian Edge					
Canopy	percent	Trace (<10) [20]	100 [90]	55.7 [54.2]	26.2 [25.4]
Understory	percent	Trace (<10) [Trace]	90 [80]	41.4 [43.7]	25.86 [23.1]
Herbaceous	percent	10 [30]	100 [100]	65.2 [76.7]	22.33 [27.1]
Adjacent Landuse	None	Maintained field [Residential]	Forested [Forested]	NA	NA

Notes:
1. To calculate the mean, the mid-range value was used for the "suboptimal" and "marginal" categories. The resultant mean value equates to "marginal." Trace was set to "5" to calculate the mean and standard deviation.
2. In 2004, organic substrate measurements could not be recorded due to elevated water levels at the time of sampling.

In the candidate Phase 1 areas, no natural shoreline banks were found to be completely unstable (i.e., 60% to 100% of the bank visibly eroding), although several stations contained small areas of exposed root mats and/or sloughing (Appendix G). The majority of natural shoreline banks had visible erosion in less than 30% of the area assessed. Stability did not appear to be influenced by adjacent land use: forested areas had shorelines that were as stable as shorelines adjacent to maintained lands.

The dominant canopy, understory, and herbaceous species observed along the riparian edge of the river are shown in Appendix G. In each of these vegetated "layers," percent cover ranged from less than 10% to greater than 90% with minimum station averages of 20% (canopy), 15% (understory), and 43% (herbaceous).

3.4 Riverine Fringing Wetlands

Four riverine fringing wetland stations were assessed between September 8 and 11, 2003. Two wetland stations were located in River Section 1, and two in River Section 2 (Figures 2 through 4). The riverine fringing wetlands range in size from less than one-tenth acre to 5.65 acres (see HD Report). The riverine fringing wetlands sampled to date range from 0.12 acres to 0.27 acres, as shown in Table 9. Larger riverine fringing wetlands and wetlands identified as ESUHs, to the extent that such areas are targeted for dredging and not represented by existing stations, were included in 2005 sampling and will be included in subsequent sampling in Phase 2 areas. Slope of the wetlands ranged from 2.2% to 11.4%. The assessed wetlands contained an average biomass of 412.6+194.4 g/m^2 with an average stem density of 243.7+365.4 stems/m^2. The following six emergent wetland communities were identified within the sampled wetlands based on biomass (Table 9):

1) Pickerelweed/arrowhead (*Pontederia cordata/Sagittaria latifolia*);
2) Great burreed (*Sparganium eurycarpum)*;
3) Reed canary grass (*Phalaris arundinacea*);
4) Cattail (*Typha latifolia*);
5) Rice cutgrass/millet (*Leersia oryzoides/Echinochloa walteri*); and
6) Pickerelweed.

In addition, one community, wild rice (*Zizania aquatica*), was included based on stem density. Wild rice was common in the great burreed community at Wetland 1, and had high stem density, but relatively little biomass compared to that of great burreed.

Table 9 – Riverine Fringing Wetland Stations for Detailed Functional Assessments

Station	Type1	Approximate Location (RS/RM)	Area (ac.)	Dominant Vegetation Communities
2	Target	Western bank of Upper Hudson, South of Snook Kill (RS1/RM191.5)	0.12	Pickerelweed/Arrowhead; Reed canary grass; Great burreed
1	Reference	Western side of Unnamed Island at Northern End of Lock 7 (RS1/RM 188.9)	0.15	Great burreed, wild rice
3	Reference	Western bank of Upper Hudson below Lock 6 (RS2/RM185.7)	0.27	Rice cutgrass/Water millet
4	Target	Eastern bank of Upper Hudson above Georgia- Pacific Site (RS2/RM183.9)	0.24	Cattail; Great burreed; Pickerelweed

Note:
1. Stations are shown in the order that they occur from upriver to downriver locations in the river. The designation of the habitats as “target” or “reference” is based on a review of proposed dredge area delineations that were in production as working drafts for the Phase 1 DAD Report and is subject to change. For this Phase 1 HA Report, information collected from all fringing wetland habitats is considered “reference” data for the development of the FCIs (see Section 4).

The assessments of the riverine fringing wetlands in the candidate Phase 1 areas provide useful information for defining and characterizing this specific wetland system. The riverine fringing wetlands assessed in the candidate Phase 1 areas are small (less than 0.5 acre in size), dynamic systems that lie within the river’s highwater mark during average summer flow conditions (Table 10). Hydrology for these wetlands is primarily influenced by flow conditions of the Upper Hudson River and its tributaries; minimal hydrologic input is received from upland sources. Hydrological conditions are dominated by diurnal fluctuations in the river's water level created by periodic releases of water from Sacandaga Reservoir. Hydrologic conditions of the project area are controlled to a lesser extent by other hydroelectric facilities upstream of River Section 1, episodic flooding due to storm events, tributary input, and seasonal ice flow.

No obvious anthropogenic impacts were noted at Wetland Stations 1, 3, and 4. Wetland Station 2 is bordered by an adjacent roadway along the upland edge of the wetland.

Table 10 – Range of Conditions Observed in Riverine Fringing Wetlands in the Upper Hudson River in 2003. (2004 Reassessment Data Are Shown in Brackets.)[1]

Parameter	Units	Minimum	Maximum	Mean	Standard Deviation
Size	Acre	0.12	0.27	0.19 [0.27]	0.071
Slope	Percent	2.2	11.4	6.45 [0.22]	3.80
Biomass	g/m^2	0.07	783.38	113.56 [26.35]	177.78 [50.62]
Stem Density	$number/m^2$	1	1532	80.35 [375.18]	213.5 [609.51]
Percent Contiguous	Percent	50	100	87.5 [100]	25
Wetland Edge	Feet	324	437	366 [324]	52.12

Note:
1. Only one riverine fringing wetland was reassessed in 2004 and those data are shown in brackets in the Mean column. The separate quadrat values were used to calculate the mean and standard deviations for biomass and stem density.

3.5 Fish and Wildlife Observations

The fish and wildlife species observed during the habitat assessments are shown in Table 11, below. The completed wildlife observations forms are included in Appendix L.

Table 11 – Fish and Wildlife Species Observed During Habitat Assessments

Species Scientific	Name	Number Observed	Sight/Sign Code	Observation Location
		Unconsolidated River Bottom		
Birds				
Double-Crested Cormorant	*Phalacrocorax auritus*	63	Flight	UCB-1, UCB-5
Ring Billed Gull	*Larus delawarensis*	16	Flight	UCB-3
Mallard	*Anas platyrhynchos*	31	Feeding	UCB-1, UCB-4, UCB-6
		Fish		
Smallmouth Bass	*Micropterus dolomieui*	8	Foraging	UCB-3, UCB-4
American Eel	*Anguilla rostrata*	1	Foraging	UCB-1
		Aquatic Vegetation Bed		
Birds				
Mallard	*Anas platyrhynchos*	89	Feeding, Resting	SAV-2, SAV-3, SAV-6, SAV-7, SAV-8
Great Blue Heron	*Ardea herodias*	12	Foraging, Flight, Resting	SAV-1, SAV-2, SAV-3, SAV-5, SAV-7, SAV-8
Double-Crested Cormorant	*Phalacrocorax auritus*	10	Foraging, Flight, Resting	SAV-1, SAV-2, SAV-3, SAV-8
		Mammals		
Beaver	*Castor canadensis*	1	Foraging, Fresh cuttings	SAV-2
		Amphibians		
N. Leopard Frog	*Rana pipiens*	10	Resting	SAV-2
		Riverine Fringing Wetlands		
Birds				
Mallard	*Anas platyrhynchos*	6	Feeding	WET-1
Belted Kingfisher	*Ceryle alcyon*	2	Flight, Calling	WET-4
Great Blue Heron	*Ardea herodias*	2	Feeding, Tracks	WET-2, WET-4
Fish				
Minnow spp.	Not Applicable	Numerous	Feeding, Swimming	WET-1, WET-2, WET-3, WET-4
Sunfish spp.	*Lepomis* sp.	21+	Swimming, Foraging	WET-1, WET-2
Smallmouth Bass	*Micropterus dolomieui*	4+	Swimming, Foraging	WET-1, WET-2
Mammals				
Muskrat	*Ondatra zibethica*	6	Tracks	WET-2, WET-3, WET-4
White Tail Deer	*Odocoileus virginianus*	2	Browse, Feeding	WET-1, WET-3
Long Tail Weasel	*Mustela frenata*	1	Tracks	WET-1
Amphibians				
Green Frog	*Rana clamitans melanota*	29	Resting	WET-1, WET-4
N. Leopard Frog	*Rana pipiens*	3	Sight	WET-1
		Shoreline		

Species Scientific	Name	Number Observed	Sight/Sign Code	Observation Location
Birds				
Great Blue Heron	*Ardea herodias*	14	Tracks, Calling, Flight	SHO-1I, SHO-2I, SHO-3R, SHO-10I, SHO-11I
Canada Goose	*Branta Canadensis*	11	Flight, Calling	SHO-8I
Black Capped Chickadee	*Poecile atricapillus*	9	Calling	SHO-3I, SHO-41
Mammals				
Eastern Chipmunk	*Tamias striatus*	5	Foraging, Tracks, Calling, Resting	SHO-2R, SHO-10I, SHO-11I
Woodchuck	*Marmota monax*	4	Den, Tracks	SHO-3I, SHO-6I
Raccoon	*Procyon lotor*	4	Tracks	SHO-3R, SHO-7I
Amphibians				
N. Leopard Frog	*Rana pipiens*	10	Resting	SHO-11I

Note:
1. Browse refers to indications of feeding on herbaceous material and, where observed in combination with other sign/sight codes (e.g., tracks), is attributed to a specific species.

One RTE species, the bald eagle, was observed during field activities. Bald eagles were observed on three occasions during groundtruthing activities and while in transit between assessment stations. Specifically, an immature bald eagle was observed on August 28, 2003 perched in a tree on the west bank of the river below the Lock 6 pool (River Section 2). On August 29, 2003, an immature bald eagle was observed in flight above the Lock 6 pool. On September 29, 2003, a mature bald eagle was observed perched in a tree on the east bank of the river below the Lock 6 pool. The bald eagle is not included in Table 11 above, because it was not observed at a specific habitat assessment station.

4. FCI Models

Functional assessment models, such as FCI models, use a series of measured, recorded, and/or calculated variables that represent the extent to which selected physical, hydrologic, biological, and sometimes geographic characteristics of a given site reflect the ability of that site to perform certain ecological functions (Shafer and Yozzo, 1998). In accordance with the habitat assessment procedures described in the HDA Work Plan, direct measurements of certain specified physical and biological variables, which were listed in Table 2 of the HDA Work Plan, are being used to quantify the selected habitat functions. The concept that these types of variables can be used to quantify habitat functions is one of the foundations of the HGM approach (Shafer and Yozzo, 1998; Ainslie et al., 1999; Smith and Wakeley, 2001; Clairain, 2002) and habitat evaluation procedures (e.g., HSIs), and is established in the HDA Work Plan. While these variables consist largely of structural parameters, some of them can serve as functional parameters as well. For example, the biomass of aquatic vegetation is not only a structural parameter, but also a functional parameter demonstrating aquatic bed productivity. Similarly, plant species composition is not only a structural parameter, but also a functional parameter relating to habitat diversity.

The specific parameters (i.e., the variables defined for the preliminary FCI models) that were initially selected for measurement in each habitat, as listed in Table 2 of the HDA Work Plan were identified and selected using four screening criteria (adapted from Shafer and Yozzo, 1998):

a. Presumed importance: There is a documented or hypothesized relationship between the variable and the function. Potential contribution for describing the function(s) is sufficient to warrant its inclusion in the model.
b. Basis of importance: Supporting data describe the relationship between the variable and function.
c. Feasibility of measurement: The variable can be easily measured, observed, or recorded at sufficient resolution for the data to be of use.
d. d. Integrative measurement: The variable is not subject to extreme inter- or intra-annual variability, and/or is independent of other variables (i.e., does not duplicate another variable).

As noted above, field data were collected from assessment locations within the candidate Phase 1 areas in September and October 2003 and are presented in Appendix G. Data from the reassessment of a subset of stations, conducted in September 2004, are presented in Appendix K. The preliminary functions and variables were then reevaluated to identify variables that warranted inclusion in the current FCI models described below in this section. The FCI values presented in this section are based solely on the 2003 data. (FCI values calculated from the 2004 reassessment data are presented in subsection 6.1). If there were insufficient data for a specific variable, or data were not obtained due to field conditions, the variable(s) was removed from the current FCI model as described below. However, all variables listed in Table 2 of the HDA Work Plan will be retained for re-evaluation once remaining Phase 1 and Phase 2 data are available. The mathematical relationships among variables will also be re-evaluated once the remaining data have been collected.

Collected data have different units and scales. Therefore, all data were transformed into unitless subindices ranging from 0.0 to 1.0 for integration into the FCI models (Smith and Wakeley, 2001). Appendix H provides text and graphs showing how these transformations were completed. These graphs show that, for most variables, the highest measured value is set at 1.0 and that the higher the measured value, the higher the subindex score (to a maximum of 1.0). However, for several variables (e.g., percent cover of aquatic vegetation), the subindex score decreases from 1.0 as the measured value increases past a maximum measured value (equal to a subindex of 1.0). For the purposes of developing the FCI models for the candidate Phase 1 areas, and in accordance with the HDA Work Plan, all stations were considered "reference stations" (since they represent current, pre-dredging conditions), and a hypothetical "optimal habitat" was developed by combining the optimal subindex scores from these stations for each of the habitat types. For each of the parameters measured, a subindex value of 1.0 was assigned to the optimal observed condition – which, in some cases, was the highest measured value (e.g., for aboveground biomass) and, in some cases, was the lowest measured value (e.g., for percent nuisance species) – and was used to scale the measured variables. The FCI value for the hypothetical optimal habitat thus calculates to 1.0. Based on the data collected in 2003, FCI values for the unconsolidated river bottom range from 0.39 to 0.88, for aquatic vegetation beds from 0.31 to 0.87, for shorelines from 0.50 to 1.0, and for riverine fringing shoreline wetlands from 0.60 to 0.84. The FCI for each habitat is habitat-specific and cannot be used for comparisons between habitats to evaluate the success of the habitat replacement/reconstruction effort. However, comparisons of FCIs among habitat types may be useful to evaluate changes in habitat types or functions that may result from the remediation project.

Under the habitat replacement and reconstruction program, it is not the goal that the specific pre-dredging FCI value at each station be attained after dredging. Nor is it the goal of the program to improve overall habitat conditions of the Upper Hudson River so as to achieve an optimal subindex and/or FCI score of 1.0 at each station or to reach a higher overall level than recorded at baseline conditions. The goal of the habitat replacement and reconstruction program is to replace the functions of the habitats of the Upper Hudson River to within the range of functions found in similar physical settings in the Upper Hudson River, given the changes in river conditions that will result from remedy implementation or other factors. . This goal will be achieved if the post-dredging habitat-specific FCI values within impacted areas at an appropriate spatial scale fall within the range of FCI values in non-impacted areas, accounting for habitat size. The appropriate spatial scale for these comparisons will be determined by the data and may consist of comparisons on a reach basis or on an overall river section basis. At some stations, the post-dredging FCI values may be higher than current values (e.g., when the amount of nuisance species is reduced), while at other stations the post-dredging FCI values may be lower than current values. However, the goal will be attained so long as the overall range of values is within the range at reference areas, with a similar overall habitat value. The specific spatial scale at which post-dredging habitat-specific FCI values will be compared, and the specific statistical methods to be used in the comparisons, will be specified in the *Adaptive Management Plans*. The specific variables and FCI models for the candidate Phase 1 areas are described in the following subsections.

4.1 Unconsolidated River Bottom

As described in the HDA Work Plan, assessing the unconsolidated river bottom habitats consisted of measuring habitat-specific structural data to represent selected unconsolidated river bottom habitat functions. The preliminary list of structural data (variables) and associated functions for unconsolidated river bottom habitats is included in Table 2 of the HDA Work Plan.

An introduction to unconsolidated river bottom and a description of the FCI models based on candidate Phase 1 area data for this habitat are presented below.

4.1.1 Introduction

Substrate is one of the most important environmental factors that influence the abundance, composition, and distribution of infaunal and epifaunal benthic macroinvertebrate (BMI) communities that may reside in unconsolidated river bottom habitats. Typically, coarse sediments (e.g., cobble, rock, and coarse sand) are characteristic of substrates in systems of more rapid surface-water flow. Substratum represented by larger particles or stones is higher in structural complexity and supports a diverse macroinvertebrate community (Hynes, 1966). BMI species that prefer these habitats include mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) (Merritt and Cummins, 1984). In addition, substrates with larger particles (e.g., rock/cobble) are used by many species of fish as spawning substrate. For example, smallmouth bass (*Micropterus dolomieu*) spawn primarily on rock or gravel beds in rivers and lakes (Sowa and Rabeni, 1995).

Fine sediments (e.g., fine sands and silt) are typically colonized by BMI communities that are tolerant of reduced-flow conditions. BMI species that prefer fine sediments include opportunistic aquatic earthworms (Oligochaeta) and midges (Chironomidae) (Merritt and Cummins, 1984). These groups often dominate (or codominate) invertebrate assemblages in sediments from depositional habitat systems where finer sediments are often associated with higher TOC. In addition, lower species diversity is typically reported for fish collected over featureless substrates when compared to habitats containing cobble and/or rubble (Danehy et al., 1991; Snyder et al., 1996).

4.1.2 FCI Models Based on Candidate Phase 1 Area Data

Subsection 3.1 of this Phase 1 HA Report generally describes the data results for unconsolidated river bottom in the candidate Phase 1 areas. Those descriptions are based on data collected in accordance with the protocols for assessing unconsolidated river bottom habitats (Appendix A). However, it should be noted that some data were not collected due to habitat constraints within candidate Phase 1 areas of the river bottom. For example, there are no "high gradient" areas of the river where embeddedness of substrate features can accurately be assessed. Therefore, in accordance with the protocols for assessing the unconsolidated river bottom habitats (Appendix A); substrates were assessed as "pooled" areas. This information was included, as appropriate, into the development of the FCI models.

After review of the studies listed above, other FCI models (Shafer and Yozzo, 1998; Ainslie et al., 1999; Findlay et al., 2002), and data from the candidate Phase 1 areas, the following FCI models were developed for the unconsolidated river bottom habitats in the Upper Hudson River (Table 12, below). The mathematical relationships between model variables are based on national and regional guidebooks (Shafer and Yozzo, 1998; Ainslie et al., 1999), local FCI models (Findlay et al., 2002), and professional judgment. These relationships will be re-evaluated, and revised if necessary, based on the additional data collected and any validation of assumptions performed in accordance with subsection 6.3.3. (Note that downfall will be added as a variable to this model, and that the FCI model will be revised once downfall data have been collected.)

Table 12 – Unconsolidated River Bottom Measured Variables and FCI Models

Function (FCI Code)	Measured Variable (Units)	Variable Code
Potential to Support Benthic Macroinvertebrates (**$FCI_{UNVEGBMI}$**)	TOC (percent)	V_{TOC}
	Substrate and cover (percent)	$V_{SUBCOVER}$
	Percent fines (percent)	V_{FINES}
Potential to Support Fish Populations (**$FCI_{UNVEGFISH}$**)	Substrate and cover (percent)	$V_{SUBCOVER}$
	Percent fines (percent)	V_{FINES}
Unconsolidated River Bottom Habitat FCI Models for Candidate Phase 1 Areas		
$FCI_{UNVEGBMI}$	$\left[V_{TOC} \times \frac{(V_{SUBCOVER} + V_{FINES})}{2}\right]^{1/2}$	
$FCI_{UNVEGFISH}$	$\frac{(V_{SUBCOVER} + V_{FINES})}{2}$	

The first FCI function ($FCI_{UNVEGBMI}$) for unconsolidated river bottom is the provision of habitat and food resources for macroinvertebrates. This function is represented by three measurement variables that are representative of the availability of substrate for attachment or burrowing (substrate and cover) and food resources (TOC and percent fines) (Angradi, 1999; Weatherhead and James, 2001). For supporting BMI community function, percent epifaunal substrate and cover ($V_{SUBCOVER}$), and percent fines (V_{FINES}) contribute equally (i.e., the parenthetical inclusion of these variables) to the suitability of the bottom for BMI colonization. The measurement variable $V_{SUBCOVER}$ is specific to the quality and stability of aboveground substrate and cover provided by submerged snags and logs, or larger substrate such as cobble. Values that approach 1.0 for this variable indicate stable and optimal habitat, whereas values approaching 0.0 are less favorable. Because it is possible to have these types of epifaunal substrate and cover over a range of substrate types, the variable V_{FINES} is included in the model to incorporate conditions of the substrate. TOC is an important food source for the BMI, and is included using a geometric mean to indicate that both the food source and suitable substrate must be present for the supporting BMI function to occur. Thus, if either TOC or substrate/cover is absent (scored as zero), the product and therefore the FCI are zero.

The second FCI function ($FCI_{UNVEGFISH}$) is the provision of habitat and resources for fish populations. This function is represented by food availability (epifaunal substrate), shelter (cover), and spawning habitat (percent fines) (Diehl, 1993). To support fish populations, the amount of cover serving as fish habitat (also the potential location of prey) contributes equally with the availability of suitable spawning substrate to the function.

4.2 Aquatic Vegetation Beds

As described in the HDA Work Plan, assessing the aquatic vegetation bed habitats consisted of measuring habitat-specific structural data to represent selected aquatic vegetation bed habitat functions. The preliminary list of structural data (variables) and associated functions for aquatic vegetation bed habitat is included in Table 2 of the HDA Work Plan.

An introduction to aquatic vegetation beds and a description of the FCI models based on candidate Phase 1 area data for this habitat are presented below.

4.2.1 Introduction

Numerous studies have shown that aquatic vegetation is excellent habitat for fish. Aquatic vegetation commonly contains large densities of macroinvertebrate prey (Rozas and Odum, 1987; Scott, 1987; Gotceitas and Colgan, 1987; Bain and Boltz, 1992; Hayse and Wissing, 1996; Randall et al., 1996; Cyr and Downing, 1998) that appear to be present due to the structural "complexity" of the plants (Gerrish and Bristow, 1979). In addition to food sources, fish find refuge and cover from predation in aquatic vegetation beds (Gotceitas and Colgan, 1987; Rozas and Odum, 1987; Mittelbach and Osenberg, 1993; Hayse and Wissing, 1996; Randall et al., 1996). Aquatic vegetation beds may also serve as nursery habitat in rivers for juvenile game fish (Casselman and Lewis, 1996).

Aquatic vegetation beds increase the structural complexity of shallow water habitats, which has been suggested by several authors as the reason for increased species richness in these areas (Bain and Boltz, 1992; Randall et al., 1996). For example, a common species in the Upper Hudson River, largemouth bass (*Micropterus salmoides*), is most abundant in areas with vegetation (Jenkins et al., 1952; Miller, 1975) and other forms of cover (e.g., logs, brush, and debris). Other researchers have suggested that aquatic vegetation beds support behavioral mechanisms related to foraging strategy or functional biology of a species. The physical presence of the plant also baffles wave energy, creating a depositional environment and provides sediment stabilization (Madsen et al., 2001; Koch, 2001). In addition, aquatic vegetation beds mediate nutrient exchange between the sediments and the overlying water column and have the ability to take-up and retain nutrients from both media (Carpenter and Lodge, 1986). Many species of aquatic vegetation are able to export DO to the water column, and there is evidence that the dynamics of the DO may vary among species. In studies conducted in the tidal portion of the Hudson River, DO measurements varied diurnally and tidally for aquatic vegetation beds dominated by water chestnut and wild celery, respectively (Caraco and Cole, 2002; Findlay et al., In Review). Water chestnut DO concentrations measured on the edge of the beds were generally similar to those found in the river channel (7.0-8.0 milligrams per liter [mg/L]); however, DO concentrations measured within water chestnut beds with values below 2.5 mg/L up to 40% of the time. DO concentrations measured in wild celery were often at or above concentrations found in the river channel but did not drop below 5.0 mg/L even during warmer surface water temperatures.

4.2.2 FCI Models Based on Candidate Phase 1 Area Data

Subsection 3.2 of this Phase 1 HA Report generally describes the results from the aquatic vegetation bed habitat assessment in the candidate Phase 1 areas. Those descriptions are based on data collected in accordance with the protocols for assessing the aquatic vegetation bed habitats (Appendix B). Some of the data are limited and are not included in the FCI models presented here. Specifically, the light availability and current velocity data from the candidate Phase 1 areas were collected late in the growing season for a short time (late September) and provide limited information on the role that these variables play in determining the functions of aquatic vegetation bed habitats. The light availability and current velocity variables will be re-considered for inclusion in the models once remaining Phase 1 and 2 data are collected. However, information on these variables derived from bathymetric data (related to light availability) and the hydrodynamic model (current velocity) are being used in the SAV model to be provided in the *Adaptive Management Plan*. Additionally, plant species composition (% non-native) is not included in the current calculations because non-native species have not been sampled to date. The variable will be retained and used, as necessary, following review of the remaining assessment data.

Similarly, aboveground biomass is an important variable for several functions being assessed, including supporting fish populations, phytophilous and benthic macroinvertebrate (PMI and BMI, respectively) populations and nutrient cycling. Initially a separate function, macrophyte primary productivity was identified. That function is largely represented by biomass (Downing and Anderson, 1985; Mellors, 1991). Therefore, the macrophyte primary productivity function was removed and aboveground biomass is included, where appropriate, in the other functional indices for the aquatic vegetation beds. Finally, the variables listed for the water quality enhancement function in Table 2 of the HDA Work Plan are a subset of those listed for the stabilization of substrate function. The water quality enhancement function is provided largely by the structure of the vegetation that baffles wave/current energy to allow particles to settle out of suspension. This function is also captured in the stabilization of substrate function; thus a separate water quality enhancement function is not included for the candidate Phase 1 areas. However, it will be retained for re-evaluation following collection of data from the Phase 2 areas.

After reviewing the studies described above, other FCI models (e.g., Shafer and Yozzo, 1998; Ainslie et al., 1999; Findlay et al., 2002), the preliminary variable and functions described in the HDA Work Plan, and data from the candidate Phase 1 areas, the following FCI models were developed for the aquatic vegetation bed habitats in the Upper Hudson River (Table 13, below). The mathematical relationships between model variables are based on national and regional guidebooks (Shafer and Yozzo, 1998; Ainslie et al., 1999), local FCI models (Findlay et al., 2002), and professional judgment. These relationships will be re-evaluated, and revised if necessary, based on the additional data collected and any validation of assumptions performed in accordance with subsection 6.3.3. (Note that downfall will be added as a variable to this model, and that the FCI model will be revised once downfall data have been collected.)

Table 13 – Aquatic Vegetation Bed Habitat Measured Variables and FCI Models

Function (FCI Code)	Measured Variable (Units)	Variable Code
Support PMI/BMI Populations **($FCI_{SAVMACROS}$)**	Shoot biomass (g/m2)	V_{SAVBIO}
	Shoot density (number/m2)	$V_{SAVDENSE}$
	Plant species composition (% native)	V_{SAVSPP}
	TOC (percent)	V_{SAVTOC}
	Water depth (cm)	$V_{SAVDEPTH}$
Provide Habitat for Fish Populations **($FCI_{SAVFISH}$)**	Shoot biomass (g/m2)	V_{SAVBIO}
	Shoot density (number/m2)	$V_{SAVDENSE}$
	Plant species composition (% native)	V_{SAVSPP}
	TOC (percent)	V_{SAVTOC}
	Water depth (cm)	$V_{SAVDEPTH}$
	Percent cover (percent)	$V_{SAVCOVER}$
Stabilization of Substrate **($FCI_{SAVSTAB}$)**	Shoot density (g/m2)	$V_{SAVDENSE}$
	Percent fines (percent)	V_{FINES}
	Percent cover (percent)	$V_{SAVCOVER}$
Nutrient Cycling **($FCI_{SAVNUTS}$)**	Shoot biomass (g/m2)	V_{SAVBIO}
	TOC (mg/kg)	V_{SAVTOC}
	Sediment nutrient availability (mg/kg)	V_{SNN}
Aquatic Vegetation Bed Habitat FCI Models for Phase 1 Areas		
$FCI_{SAVMACROS}$	$\frac{(V_{SAVBIO} + V_{SAVTOC} + V_{SAVDENSE} + V_{SAVSPP} + V_{SAVDEPTH})}{5}$	
$FCI_{SAVFISH}$	$\frac{(FCI_{SAVMACROS} + V_{SAVCOVER})}{2}$	
$FCI_{SAVSTAB}$	$\left[\frac{(V_{SAVDENSE} + V_{SAVCOVER})}{2} \times V_{FINES}\right]^{1/2}$	

Aquatic Vegetation Bed Habitat FCI Models for Phase 1 Areas (cont'd)	
$FCI_{SAVNUTS}$	$\left[V_{SAVBIO} \times \frac{(V_{SAVTOC} + V_{SNN})}{2}\right]^{1/2}$

The first function, habitat support for BMI and PMI communities ($FCI_{SAVMACROS}$), is represented by food availability for macroinvertebrates (shoot biomass and TOC) and factors related to recruitment/settlement (shoot density, plant species composition, and water depth) (Diehl and Kornijow, 1998; McCreary Waters and San Giovanni, 2002). The five variables are assumed to contribute equally and independently to the function.

The second function, habitat support for fish populations ($FCI_{SAVFISH}$), is represented by food availability (the PMI/BMI support function, which includes shoot biomass) and provision of nursery areas and protection from predation (percent cover) (Randall et al., 1996; Diehl and Kornijow, 1998). Both factors are assumed to contribute equally and independently to the function, although it should be noted that the PMI/BMI support function is composed of five separate variables.

The third function, substrate stabilization ($FCI_{SAVSTAB}$), is represented by the susceptibility of the sediment to resuspension (determined by percent fines in the sediment) in relation to the dampening effect of the plants (shoot density and percent cover) (Schutten and Davy, 2000; Madsen et al., 2001). Shoot density and percent cover are averaged as they contribute equally and independently to the dampening effect provided by the plants. The two sides of the equation are combined using a geometric mean to indicate that both must be present for the function to occur.

The fourth function, nutrient cycling ($FCI_{SAVNUTS}$), is represented by the amount of living (shoot biomass) and dead organic material (TOC) available for recycling, and the availability of recycled nutrients for uptake by plants (sediment nutrient pools) (Zalewski et al., 1998; Koetsier and McArthur, 2000). The TOC and sediment nutrients are averaged as they contribute equally and independently to sediment-based nutrient sources. They are combined with shoot biomass using the geometric mean to indicate that both the nutrient sources (i.e., the TOC and sediment nutrient pools) and nutrient sinks (i.e., represented by aboveground biomass) must be present for this function to occur.

4.3 Shorelines

As described in the HDA Work Plan, assessing the shoreline habitats consisted of measuring habitat-specific structural data to represent selected shoreline habitat functions. The preliminary list of structural data (variables) and associated functions for shoreline habitat is included in Table 2 of the HDA Work Plan. A brief introduction to shorelines and a description of the FCI models based on candidate Phase 1 area data for this habitat are presented below.

4.3.1 Introduction

Natural shorelines with an extensive riparian canopy serve many functions. An established canopy provides shade and cover, which can minimize daily and seasonal temperature fluctuations and keeps temperatures relatively cool (Hunter, 1991; Sowa and Rabeni, 1995). Deadfall (e.g., fallen and submerged trees) and vegetation may provide spawning habitat and cover for many types of aquatic organisms (Herman et al., 1964; Ward and Robinson, 1974; Kitchell et al., 1977; Helfman, 1979; Hunter, 1991). For shorelines in candidate Phase 1 areas, the composition of the organic substrate, bank stability, and range of vegetation cover in the canopy, understory, and herbaceous layers are described in more detail in subsection 3.3 (see also Appendix G for station-specific values).

4.3.2 FCI Models Based on Candidate Phase 1 Area Data

Subsection 3.3 of this Phase 1 HA Report generally describes the data results for shoreline habitats in the candidate Phase 1 areas. These descriptions are based on data that were collected using methods described in the protocols for assessing shoreline habitats (Appendix C).

During the conceptual development of selecting measured variables for shoreline stability function, downfall was thought to provide an “armoring” effect against high flows. Downfall, such as layered tree revetments or root wads, is often used in this manner to aid in shoreline replacement and reconstruction, but along natural shorelines where it is patchily distributed, downfall can also be associated with unstable bank conditions. Because downfall may be interpreted as both an indicator of bank stability or instability along natural shorelines, it was removed as a variable from the shoreline stability FCI model.

Clearly, many of the functions provided by natural shorelines are based, at a minimum, on the existence of sufficient bank stability and vegetation to provide cover, shade, and habitat for fish and wildlife. Thus, the functions to be assessed in natural shorelines consist of shoreline stability, shade and cover, and the provision of wildlife habitat. The following FCI models have been developed for these functions (Table 14, below). The mathematical relationships between model variables are based on national and regional guidebooks (Shafer and Yozzo, 1998; Ainslie et al., 1999), local FCI models (Findlay et al., 2002) and professional judgment. These relationships will be re-evaluated, and revised if necessary, based on the additional data collected and any validation of assumptions performed in accordance with subsection 6.3.3.

Table 14 – Shoreline Habitat Measured Variables and FCI Models

Function (FCI Code)	Measured Variable (Units)	Variable Code
Shoreline Stability **($FCI_{SHORESTAB}$)**	Bank stability (percent)	$V_{BANKSTAB}$
	Bank vegetation protection	$V_{BANKVEG}$
Shade and Cover **($FCI_{SHORECOV}$)**	Downfall (trees/m2)	V_{DOWN}
	Bank vegetation protection (percent)	$V_{BANKVEG}$
	Riparian edge cover (percent)	$V_{RIPARIAN}$
Wildlife Habitat (Habitat Suitability) **($FCI_{SHOREHAB}$)**	Downfall (trees/m2)	V_{DOWN}
	Bank stability (percent)	$V_{BANKSTAB}$
	Bank vegetation protection (percent)	$V_{BANKVEG}$
	Riparian edge cover (percent)	$V_{RIPARIAN}$
Aquatic Vegetation Bed Habitat FCI Models for Phase 1 Areas		
$FCI_{SHORESTAB}$	$\frac{(V_{BANKSTAB} + V_{BANKVEG})}{2}$	
$FCI_{SHORECOV}$	$\frac{(V_{DOWN} + V_{BANKVEG} + V_{RIPARIAN})}{3}$	
$FCI_{SHOREHAB}$	$\frac{(V_{DOWN} + V_{BANKSTAB} + V_{BANKVEG} + V_{RIPARIAN})}{4}$	

The first FCI function, shoreline stability ($FCI_{SHORESTAB}$), is represented by two measurement variables ($V_{BANKSTAB}$ and $V_{BANKVEG}$) that correspond to stable banks (low percentage of eroded area), and protective vegetation (percentage of all vegetative layers present), respectively (Rosgen, 1996). Both variables contribute equally and independently to the function and are averaged.

The second FCI function, shade and cover ($FCI_{SHORECOV}$), is represented by three measurement variables ($V_{BANKVEG}$, $V_{RIPARIAN}$, and V_{DOWN}). Bank vegetation protection ($V_{BANKVEG}$) provides shade and cover as habitat for terrestrial wildlife. Riparian edge cover ($V_{RIPARIAN}$) provides in-water cover and cooling to shallow water areas of the river. Also, deciduous species along the riparian edge that drop leaves into the river during the fall provide an organic food source to aquatic organisms. Downfall (V_{DOWN}) provides cover for wildlife that forage along the shoreline, and cover for fish that use submerged portions of the tree (Barbour et al., 1999). All three variables contribute equally and independently to the function and are therefore averaged. The third FCI function, wildlife habitat suitability ($FCI_{SHOREHAB}$), depends on the nature and type of vegetation present (downfall, riparian vegetation, bank vegetation) and stability of the habitat (bank stability) (Barbour et al., 1999). All four variables contribute equally and independently to the function and are therefore averaged.

4.4 Riverine Fringing Wetlands

As described in the HDA Work Plan, assessments for the riverine fringing wetland habitats consisted of measuring habitat-specific structural data to represent selected fringing wetland habitat functions. The preliminary list of structural data (variables) and associated functions for fringing wetland habitats is included in Table 2 of the HDA Work Plan. A brief introduction to riverine fringing wetlands and a description of the FCI models based on candidate Phase 1 area data for this habitat are presented below.

4.4.1 Introduction

Wetlands in the Upper Hudson River that could potentially be impacted by remediation activities are relatively small, fringing, emergent wetlands. A new HGM subclass of "riverine fringing" wetlands has been used to classify the Hudson River wetlands. Riverine fringing wetlands possess characteristics similar to traditional HGM classes of riverine and tidal fringe, but riverine fringing wetlands have a unique combination of HGM setting and hydrodynamics. Benches or slopes inside the river banks provide the HGM setting for riverine fringing wetlands, and within-channel flow is the dominant water source. Hydrodynamics have both vertical and horizontal components. The vertical component results from seasonal changes in precipitation and evapotranspiration in the watershed and episodic changes due to hydrofacilities on the river. The horizontal component results from non-tidal river flow.

Brazner and Magnuson (1994) found higher fish species diversity and abundance in wetlands adjacent to undeveloped land, as opposed to wetlands near sandy beaches and developed lands. Based on their HGM setting and vegetation community, these fringing wetlands are expected to provide a variety of hydrologic, biogeochemical, and habitat functions. Because riverine fringing wetlands of the Upper Hudson River possess characteristics common to both riverine wetlands, as described by Ainslie et al. (1999) and Brinson et al. (1995), and tidal fringing wetlands, as described by Shaffer and Yozzo (1998), the riverine fringing wetlands will provide some of the functions found in each.

4.4.2 FCI Models Based on Candidate Phase 1 Area Data

Subsection 3.4 of this Phase 1 HA Report generally describes the data results for riverine fringing wetland habitats in the candidate Phase 1 areas. These descriptions are based on data that were collected using methods described in the protocols for assessing riverine fringing wetland habitats (Appendix D).

The riverine fringing wetlands found within the Upper Hudson River range in size from one-tenth acre to 5.65 acres, but are predominantly small (less than 0.5 acre in size), dynamic systems that lie within the river's highwater level under normal flow conditions. Changes in water levels and scouring by ice flows likely impede the development of shrub-land and forested vegetative communities within the fringing wetland area. Scouring of the sediment and vegetation by annual ice flow is likely a major factor in developing the dynamic characteristics of these wetlands and has been documented as a major factor in limiting the diversity of habitats and preventing the development of shrub and tree communities (Stromberg et al., 1997). Permanently flooded conditions in the wetlands may also contribute to the limited development of shrub and tree communities, as few woody species are able to adapt to such conditions in this region. As a result, the fringing wetlands of the Upper Hudson River are dominated by emergent wetland species. Due to the position of these fringing wetlands in relation to, and the hydrologic influence of, the Upper Hudson River, soils present in these wetlands are alluvial and do not possess true O or A horizons (see Appendix J), redoximorphic features, or indicators of a fluctuating water table. As such, data for these variables could not be collected from the candidate Phase 1 areas. Data could also not be collected for the interior core area variable due to the small width of most Phase 1 wetlands. In accordance with the HDA Work Plan, the wetlands must be at least 100 meters wide and of similar length to allow for this information to be collected.

The three preliminary functions (listed in Table 2 of the HDA Work Plan) that depended on the soil property variables (export organic carbon, nutrient cycling, and remove and hold elements and compounds) were reevaluated and combined to provide a function (nutrient and organic cycling) related to the ability of the wetland to import and/or export nutrients and organic carbon. Additionally, due to the small size and dynamic nature of the fringing wetlands, primary production may not be a significant function of these wetlands *per se*. However, primary production, represented by aboveground biomass, is an important component of several functions such as energy dissipation and nutrient and organic cycling (Shafer and Yozzo, 1998). Therefore, aboveground biomass has been included as a variable in those functions where appropriate and a separate function for primary production is not included for the candidate Phase 1 areas. However, each of the preliminary functions listed in Table 2 of the HDA Work Plan will be retained for re-evaluation following collection of data from the remaining Phase 1 and Phase 2 areas.

After review of the studies described above, other FCI models (e.g., Shafer and Yozzo, 1998; Ainslie et al., 1999; Findlay et al., 2002), the preliminary variable and functions described in the HDA Work Plan, and data from the candidate Phase 1 areas, the following FCI models were developed for the fringing wetland habitats in the Upper Hudson River (Table 15, below). The mathematical relationships between model variables are based on national and regional guidebooks (Shafer and Yozzo, 1998; Ainslie et al., 1999), local FCI models (Findlay et al., 2002), and professional judgment. These relationships will be re-evaluated, and revised if necessary, based on the additional data collected and any validation of assumptions performed in accordance with subsection 6.3.3. (Note that downfall will be added as a variable to this model, and that the FCI model will be revised once downfall data have been collected.)

Table 15 – Wetland Habitat Measured Variables and FCI Models

Function (FCI Code)	Measured Variable (Units)	Variable Code
Surface-Water Exchange **($FCI_{WATEREX}$)**	Wetland Edge (m)	$V_{WETEDGE}$
	Stem density (number/m^2)	$V_{WETDENSE}$
	Slope (percent)	$V_{WETSLOPE}$
Energy Dissipation **(FCI_{ED})**	Wetland Edge (m)	$V_{WETEDGE}$
	Slope (percent)	$V_{WETSLOPE}$
	Stem density (number/m^2)	$V_{WETDENSE}$
	Stem thickness (mm)	$V_{WETTHICK}$
	Stem length (cm)	$V_{WETLENGTH}$
Nutrient and Organic Cycling **($FCI_{WETCYCLING}$)**	Aboveground biomass (g/m^2)	V_{WETBIO}
	Stem length (cm)	$V_{WETLENGTH}$
	Stem thickness (mm)	$V_{WETTHICK}$
	Stem density (number/m^2)	$V_{WETDENSE}$
	Wetland Edge (m)	$V_{WETEDGE}$
	Slope (percent)	$V_{WETSLOPE}$
Maintain Character Plant Community **($FCI_{MAINTAINSPP}$)**	Plant species composition (percent)	V_{WETSPP}
	Nuisance species (percent)	$V_{WETNUISANCE}$
Wildlife Habitat (habitat suitability) **(FCI_{WETHAB})**	Wetland Edge (m)	$V_{WETEDGE}$
	Contiguous with other habitats (percent)	V_{CONTIG}
	Plant species composition (percent)	V_{WETSPP}
	Stem density (number/m^2)	$V_{WETDENSE}$
Wetland Habitat FCI Models for Candidate Phase 1 Areas		
$FCI_{WATEREX}$	$\frac{(V_{WETEDGE} + V_{WETSLOPE} + V_{WETDENSE})}{3}$	
FCI_{ED}	$\left[FCI_{WATEREX} \times \frac{(V_{WETLENGTH} + V_{WETTHICK})}{2}\right]^{1/2}$	

Function (FCI Code)	Measured Variable (Units)	Variable Code
$FCI_{WETCYCLING}$	$\left[FCI_{WATEREX} \times \frac{(V_{WETLENGTH} + V_{WETTHICK} + V_{WETBIO})}{3}\right]^{1/2}$	
$FCI_{MAINTAINSPP}$	$\frac{(V_{WETSPP} + V_{WETNUISANCE})}{2}$	
FCI_{WETHAB}	$\left[\frac{(V_{WETEDGE} + V_{CONTIG})}{2} \times \frac{(V_{WETSPP} + V_{WETDENSE})}{2}\right]^{1/2}$	

The first function, surface-water exchange ($FCI_{WATEREX}$), can be represented by the extent of the surface-water interface (wetland edge), the inundation period (represented by slope) (Findlay et al., 2002), and impedance to flow (stem density). The variables are averaged in the equation based on the assumption that they contribute equally and independently to the function.

The second function, energy dissipation (FCI_{ED}), is the conversion of water's energy into other forms as it flows through a wetland. The energy dissipation function limits erosion along the banks of the river and induces deposition of suspended sediment. Sediment accretion increases the area available for future development of riverine fringing wetlands. A riverine fringing wetland provides this function as a result of vegetation structure provided by stem density, stem thickness, and stem length. The function of energy dissipation also depends on the amount of flowing water in contact with the wetland (represented by the surface-water exchange function described above). In the first part of the equation, the components of vegetation structure contribute equally and independently and are averaged. The two parts of the equation are combined using the geometric mean to indicate that both vegetation structure and water exchange must be present for the function to occur.

The third function, nutrient and organic carbon cycling ($FCI_{WETCYCLING}$), involves the import, export, and transformation of various macronutrients (such as nitrogen, phosphorus), micronutrients, and organic carbon. A wetland's function to cycle these materials depends on both abiotic and biotic processes. Abiotic processes include adsorption to soil/sediment, precipitation, and sediment retention. Biotic processes include plant uptake, microbial immobilization, and biogeochemical transformation. Through these processes, wetlands can also serve to intercept or filter certain forms of pollution, such as excess nutrients, pesticides, and metals (Brinson et al., 1995).

Due to the dynamic nature of riverine fringing wetland habitats, the substrate tends to be more variable in organic and inorganic content than the substrate of depositional wetlands. Thus, the substrate is relatively devoid of adsorption sites associated with clays and organic matter. For this reason, the nutrient and organic carbon cycling function primarily depends on biological and hydrological wetland characteristics. Surface-water exchange ($FCI_{WATEREX}$) drives nutrient and organic carbon cycling by allowing interaction between the wetland edge and river flow. Nutrient and organic carbon cycling is proportional to the size of the vegetation community (aboveground biomass, stem length, stem thickness) because vegetation provides surface area for microbial populations, which play a large role in cycling, and influences the quantity of detritus produced (Shafer and Yozzo, 1998). For the second part of the equation, the components of the vegetation community contribute equally and independently and are averaged. The two parts of the equation are combined using the geometric mean to indicate that both vegetation community and water exchange must be present for the function to occur.

The fourth function, maintenance of characteristic plant community ($FCI_{MAINTAINSPP}$), is related to the ability of the wetland to provide characteristic species composition (plant species composition). This function generally decreases when exotic or invasive species comprise a higher proportion of plants present (nuisance species). Both variables contribute equally and independently to the function and are averaged. The wetland plant community is critical to the provision of many wetland functions and values, such as maintaining biodiversity, improving water quality, stabilizing beds/banks, cycling nutrients, and providing habitat (Brinson et al., 1995; Shafer and Yozzo, 1998).

The fifth function, wildlife habitat (FCI_{WETHAB}), is the potential use by resident and migratory invertebrates, avifauna, herptofauna, nekton, and mammals. Wetland habitat can also be important to terrestrial wildlife due to trophic links or cohabitation between upland and wetland areas (Shafer and Yozzo, 1998). Thus, the wildlife habitat function depends on the structure and composition of the vegetation community (plant species composition, stem density), the size of the wetland interface with the river (wetland edge), and connectivity between upland and wetland areas (contiguous with other habitats). The two parts of the equation are combined using the geometric mean to indicate that both contiguous habitats and the vegetation community must be present for the function to occur.

4.5 Current Status and Future Use of FCI Models

The transformation of the field data to the unitless subindices for each of the variables included in the habitat-specific FCI models described in the preceding sections is detailed in Appendix H. That appendix also contains figures depicting the output of the transformation process for each of these variables. As noted above and discussed in Appendix H, a value of 1.0 has been assigned to the optimal measured value for each parameter among all stations, and was then used to scale the values for that parameter at all other stations. As a result, the optimal FCI score for a given station is a hypothetical value of 1.0, but most stations have lower FCI values. The current, preliminary FCI value for each function and habitat is shown in Table 16, below. It is important to note that the FCI models and the mathematical relationships for each model are preliminary. Once data have been collected from all Phase 1 and Phase 2 areas, the subindices and FCIs will be revised using the entire site-specific data set (Clairain, 2002). At that time, the subindices for the all stations will be revised using the "optimal" conditions from reference stations as the "1.0" value for each habitat. It should be noted that FCI values are habitat-specific. For example, although unconsolidated bottom may have a higher mean FCI for the potential to support fish populations than aquatic vegetation beds have for providing habitat for fish populations, the value of unconsolidated bottom to fish populations cannot be said to greater than or equal to that of aquatic vegetation beds. While direct comparison of different habitat types cannot be done to evaluate the success of the habitat replacement/reconstruction effort, such comparisons may be useful to evaluate changes in habitat types and functions that may result from the remediation project.

Additional site-specific data may be necessary to support the full development of the FCI model equations for the Upper Hudson River. Additional data needs for the FCI models are discussed in subsection 6.3.3 below.

Table 16 – Calculated FCI Values for Phase 1 Areas

Unconsolidated River Bottom	Potential to Support Macroinvertebrates	Potential to Support Fish Populations
Station	$FCI_{UNVEGBMI}$	$FCI_{UNVEGFISH}$
UCB-1	0.39	0.88
UCB-2	0.88	0.77
UCB-3	0.49	0.82
UCB-4	0.41	0.74
UCB-5	0.48	0.55
UCB-6	0.81	0.70

Aquatic Vegetation Bed	Support PMI/BMI Populations	Fish and Wildlife Habitat	Stabilization of Substrate	Nutrient Cycling
Station	$FCI_{SAVMACROS}$	$FCI_{SAVFISH}$	$FCI_{SAVSTAB}$	$FCI_{SAVNUTS}$
SAV-1	0.75	0.67	0.34	0.67
SAV-2	0.51	0.53	0.59	0.40
SAV-3	0.54	0.59	0.35	0.40
SAV-4	0.62	0.62	0.32	0.50
SAV-5	0.51	0.68	0.47	0.33
SAV-6	0.74	0.87	0.47	0.63
SAV-7	0.52	0.73	0.57	0.42
SAV-8	0.62	0.73	0.31	0.51
SAV-9	0.68	0.68	0.55	0.68

Shoreline	Shoreline Stability	Shade and Cover	Wildlife Habitat
Station	$FCI_{SHORESTAB}$	$FCI_{SHORECOV}$	$FCI_{SHOREHAB}$
1R	0.96	0.56	0.65
1I	1	0.53	0.65
2I	0.83	0.46	0.59
2R	0.99	0.55	0.66
3I	0.96	0.61	0.69
3R	0.93	0.85	0.86
4I	0.95	0.57	0.65
5I	0.95	0.56	0.67
6I	1	0.57	0.68
7I	0.88	0.61	0.65
8I	0.97	0.5	0.62
9I	0.99	0.57	0.67
10I	0.97	0.57	0.66
11I	0.97	0.58	0.68

Wetland	Surface-water Exchange	Energy Dissipation	Nutrient and Organic Cycling	Maintain Character Plant Community	Wildlife Habitat
Station	$FCI_{WATEREX}$	FCI_{ED}	$FCI_{WETCYCLING}$	$FCI_{MAINTAINSPP}$	FCI_{WETHAB}
1	0.74	0.65	0.62	0.82	0.78
2	0.83	0.84	0.83	0.60	0.66
3	0.76	0.61	0.64	0.65	0.60
4	0.74	0.75	0.74	0.76	0.71

4.6 Success Criteria for Habitat Replacement and Reconstruction

As stated in the HDA Work Plan, "[t]he primary goal of the habitat program is to replace the functions of the habitats of the Upper Hudson River to within the range of functions found in similar physical settings in the Upper Hudson River, in light of the changes in river hydrology, bathymetry, and geomorphology that will result from the implementation of the USEPA-selected remedy and from possible independent environmental changes that may occur from other factors" (page 1-2). In accordance with the HDA Work Plan, the range of functions found in the Upper Hudson River is being assessed through measurement of certain specified variables (listed in Table 2 of the HDA Work Plan) in the four habitat types during remedial design. As noted above, these variables consist largely of structural parameters, but also include some functional parameters. That program will establish the range of these habitat-specific parameters in the Upper Hudson River habitats prior to dredging, by measuring those parameters both in areas that will be directly impacted by dredging and those that will not. Based on those data, the specific parameters to be used as design criteria for the habitat replacement and reconstruction program will be selected to achieve the above objective. Further, these data will be used to develop "bounds of expectation" for the replaced and reconstructed habitats for use in design, and a suite of adaptive management techniques will be identified for use in the long-term monitoring and adaptive management program. The design criteria will be included in the *Adaptive Management Plan*, which will be part of the *Final Design Report* for each phase of dredging.

Success criteria for each habitat type will be developed based on the range of conditions found in reference areas. This range of conditions defines the "bounds of expectation" for habitat replacement and reconstruction. Bounds of expectation and success criteria will be developed for:

- Conditions within specific habitats (e.g., an area anticipated to be replaced as unconsolidated river bottom will be expected to have sediment with grain size falling within the range of grain sizes defined by reference sites); and
- The overall distribution of habitat types and functions, taking habitat size into consideration, over each River Section or reach (i.e., for each River Section or reach, the mosaic of post remediation habitats will be expected to fall within the range of habitats supported by areas of similar physical conditions, such as water depth, flow, substrate, bank conformation, etc., as in reference areas).

For riverine fringing wetlands unavoidably lost or adversely affected by the dredging project, the goal is to replace the functions provided by those wetlands, i.e., no net loss of functions. Functional replacement of riverine fringing wetlands will be accomplished by the replacement of the riverine fringing wetlands in their original locations, to the extent practicable and appropriate, consistent with the remedy. For locations where it is not practicable or appropriate to replace the wetland in its original location, and where it is determined appropriate by USEPA to do so, additional mitigation activities will be undertaken in other dredge areas to replace the lost function of that wetland.

For submerged aquatic vegetation (SAV) beds, the replacement of SAV beds will be dictated by the post-dredging river bathymetry (depth) and other factors that control the occurrence of SAV beds (e.g., current velocity, light availability) within the project area. Where water depths and controlling factors support the replacement of SAV beds, the goal is to replace those beds. Consistent with agreements between GE and USEPA, areas in the project area that supported SAV beds prior to dredging and backfilling will be evaluated to determine if the resulting water depth has increased to a point where these beds would no longer be supported. These areas will be evaluated to determine if placement of additional backfill would reduce the water depth so that SAV beds would be supported. Additional backfill, up to 15% of the total volume estimated during design to be placed as part of the entire project (1 foot over all dredge areas), will be allocated for creation of aquatic vegetation beds.

As stated in the HDA Work Plan, monitoring of the reference areas after the completion of the remediation will allow for modifications of the "bounds of expectation" for the measured parameters. Post-dredging comparisons of those parameters in the dredged areas to those in the reference area data set (i.e., parameters measurements taken in non-target areas before and after dredging, and in target areas before dredging) will provide the primary basis for judging the success of the habitat replacement and reconstruction program. The specific parameter measurements taken for each habitat type will be used to develop FCIs for the relevant functions for that habitat (as listed in Table 2 of the HDA Work Plan). The habitat replacement and reconstruction program will be designed to return the overall distribution of the relevant FCI parameters within the dredged areas to be similar to the overall distribution of such parameters in the habitat-specific reference areas, accounting for habitat size. It is anticipated that comparisons of the range of conditions in reference and remediated areas will be made by statistical tests appropriate for the collected data. A "spatially-weighted average" and use of negative null hypotheses are possible techniques that will be considered. The appropriate spatial scale for these comparisons will be determined by the data, and may consist of comparisons on a reach basis or on an overall river section basis. The spatial scale for these comparisons and the specific statistical techniques to be used in the comparisons will be included in the *Adaptive Management Plan*, which will be part of the *Final Design Report*, for each phase of dredging.

In addition to the site-specific FCI models, HSI models will be used to quantify the fish and wildlife habitat functions for the species listed in Section 5 below. The HSI models will be used for this purpose in conjunction with the FCI models, as many of the input parameters are not independent of the FCI variables.

When parameter(s) from target areas within an appropriate spatial scale (e.g., river section or reach) are within the range of parameter(s) from reference areas (considering overall distribution of values within habitats and within the relevant river section or reach) for a specific habitat type, the habitat replacement/reconstruction within those target areas will be considered successful. Given the changes in river conditions that will result from the dredging, the objective for a specific dredged area cannot be established a priori as either the "low end" or the "high end" of the range, since physical conditions in each area will determine where the post-dredging habitat falls within these bounds. A mix of habitats will be established, taking account of physical conditions in the post-remediation environment, and that habitat mix will be evaluated against the mix of habitats in reference sites with similar physical conditions. The evaluation of success will be made for each habitat type and will be based on comparing the overall distribution of the relevant parameters from the dredged areas within a given spatial extent of the river to the overall distribution of such parameters in the pertinent reference areas, using appropriate statistical tests. The specific spatial extent (scale) at which post-dredging FCI values will be compared, and the specific statistical methods to be used in the comparisons, will be specified in the *Adaptive Management Plans* that will accompany the *Final Design Reports*.

FCIs and HSIs will be calculated directly from parameters in both target and reference stations to evaluate the functional equivalency of targeted and reference habitats. The approach employed to determine success will be presented in the *Adaptive Management Plans*.

If the primary success criteria based on the above-mentioned parameters and FCI/HSI models are not met within the appropriate spatial extent, other data that directly measure the relevant functions (e.g., presence and abundance of fish and/or wildlife species), to the extent available, may be used as secondary success criteria provided that data allows scientific comparisons of the data. As stated in the HDA Work Plan (page 1-5), such secondary criteria will not be used in the first instance to judge success – i.e., if the above-mentioned parameters in the dredged areas fall within the range of conditions in the reference areas, the habitat replacement/reconstruction will be considered successful, without further consideration of the secondary criteria. However, if those parameters in the dredged areas do not fall within the range of conditions in the reference areas, the available data directly measuring function (e.g., fish and/or wildlife presence) will be reviewed as a secondary measure for evaluating success; if those data in dredged areas fall within the range of those in the reference areas, and if the data are sufficient to indicate that such conditions are likely to be sustainable, then the habitat replacement/reconstruction will be considered successful. The information on the presence of biota including fish and wildlife will be obtained from observations conducted under this HDA program (if any) and/or biological data collected under other remediation programs (e.g., fish information from the Baseline Monitoring Program [BMP]).

5. Supporting Data for HSI Models

The key species for which HSI models will be calculated for habitat assessment purposes are identified in the HD Report and reprinted in Table 12, below.

Site-specific FCI models measuring the functional capacity of the four types of habitats assessed in the Upper Hudson River are being developed to evaluate the success of the habitat replacement and reconstruction program. Section 4 of this Phase 1 HA Report describes the FCI models that have been developed for the candidate Phase 1 areas and the rationale and underlying measurement variables that were used to develop those models.

HSI models will also be used, as a supplement to site-specific FCI models, to quantify the fish and wildlife habitat functions for representative indicator species. HSI models will be used for this purpose in conjunction with the FCI models, as many of the input parameters are not independent of the FCI variables. HSI models exist for 157 species, many of which are not found or are uncommon in the Upper Hudson River (Edinger et al., 2002). Of these fish and wildlife species, some are predominantly terrestrial or are observed infrequently on the river. White-tailed deer, wild turkey, gray squirrel, and fisher are examples of terrestrial species that were removed from further consideration. Representative fish species were selected based on functional groups and/or association with habitats that could be potentially impacted by remediation. The resulting refined list of species for which HSI models were reviewed is shown in Table 17, below. The results of the review, indicating whether the species was retained for further consideration, are shown in that table.

Table 17 – List of Species for HSI Models

Species (Scientific Name)	Associated Habitat	Retained (Yes/No)	Rationale
Birds			
Belted Kingfisher (*Ceryle alcyon*)	SHO, UCB	Yes	• Habitat potentially impacted by dredging • Forested habitat along edge of the river provides foraging and nesting • River likely provides suitable prey population
Great Blue Heron (*Ardea herodius*)	SHO, UCB, WET, SAV	Yes	• Habitat within range of nesting sites • River likely provides suitable prey population • HSI model for Upper Hudson River will only use the foraging index within the overall HSI
American Black Duck (*Anas rubripes*)	SHO, UCB, WET	No	• NY is not in wintering range on which model is dependent
Bald Eagle (*Haliaeetus leucocephalus*)	SHO, UCB, SAV, WET	No	• Species being addressed through a separate assessment of threatened and endangered species

Species (Scientific Name)	Associated Habitat	Retained (Yes/No)	Rationale
Lesser Scaup (*Athya affinis*)	SHO, UCB, WET	No	• HSI model for wintering range applicable only to Gulf of Mexico and southern Atlantic coast • HSI model for the breeding range applicable to the Rocky Mountain area
Great Egret (*Ardea alba*)	SHO, UCB, WET, SAV	No	• HSI applicable only to Atlantic coast, inland Southeastern United States, Texas, and Louisiana coastal wetlands
Pileated Woodpecker (*Dryocopus pileatus*)	SHO	No	• HSI is only applicable to terrestrial and forested wetland habitats that are unlikely to be impacted remedial activities
Wood Duck (*Aix sponsa*)	SHO, UCB, WET, SAV	Yes	• Forested wetlands along river provide potential nesting sites • Overhang and downfall along natural shorelines provide potential cover
Mammals			
Beaver (*Castor Canadensis*)	SHO, WET, SAV	No	• Close proximity of roadways inconsistent with HSI requirements
Mink (*Mustela vison*)	SHO, WET	Yes	• Portions of potential mink habitat in near-shore areas could be impacted by remedial activities; therefore mink has been retained as requested by the USEPA
Muskrat (*Ondatra zibethicus*)	SHO, WET, SAV	Yes	• Abundant herbaceous vegetation on shoreline and in wetlands • Low flow conditions of Upper Hudson River still provide surface water • Tracks frequently observed during assessment of fringing wetlands
Fish			
Yellow Perch (*Perca flavescens*)	UCB, SAV	Yes	• Habitat potentially impacted by dredging • Recreational species • Predator/invertivore
Largemouth Bass (*Micropterus salmoides)*	UCB, WET, SAV	Yes	• Habitat potentially impacted by dredging • Recreational species • Top predator
Smallmouth Bass (*Micropterus dolomieui*)	UCB. SAV	Yes	• Habitat potentially impacted by dredging • Predator/invertivore
Common Shiner (*Notropis cornutus*)	UCB, WET, SAV	Yes	• Habitat potentially impacted by dredging • Representative HSI species for Cyprinidae • Forage base for predatory fish and fish-eating birds
Carp (*Cyprinus carpio*)	UCB, WET, SAV	No	• Non-native and nuisance species • Species resistant to habitat modification
Bluegill (*Lepomis macrochirus*)	UCB, WET, SAV	Yes	• Large woody debris and SAV provide cover
Channel Catfish (*Ictalurus punctatus*)	UCB, SAV	No	• Non-native species
Reptiles/Amphibians			
Bullfrog (*Rana catesbeiana*)	SHO, WET, SAV	No	• HSI applicable only to Midwestern United States
Slider Turtle (*Pseudemys scripta*)	SHO, WET, SAV	No	• HSI applicable only to Southeastern United States
Snapping Turtle (*Chelydra serpentina*)	SHO, UCB, WET, SAV	Yes	• Small tributaries and backwaters present along river edge • Depths in river exceed ice depth; provides overwintering

Notes:
UCB = Unconsolidated river bottom
SAV = Submerged aquatic vegetation
SHO = Shoreline
WET = Wetland

Key species for which HSI models will be calculated are the belted kingfisher, great blue heron, wood duck, muskrat, mink, yellow perch, largemouth bass, smallmouth bass, common shiner, bluegill, and snapping turtle (Allen, 1986; Allen and Hoffman, 1984; Edwards et al., 1983; Graves and Anderson, 1987; Krieger et al., 1983; Prose, 1985; Short and Cooper, 1985; Sousa and Farmer, 1983; Stuber et al., 1982a, b; Trial et al., 1983). Each of these key species is dependent on river habitat that may potentially be directly impacted by sediment removal activities. These species have also been directly or indirectly (e.g., through signs) observed in areas where dredging is likely to occur. The HSI models and data variables for these species are shown in Appendix I. Where models exist for both lacustrine and riverine environments, the riverine models were used. In some cases, such as with the great blue heron, only one index of the overall HSI will be used (the foraging index) as the remaining variables are specific to habitats unlikely to be impacted by remedial activities (i.e., forested wetlands off the river). A rationale for the exclusion of certain variables from the HSI models is provided in Appendix I. Some of the data needed for the HSI models listed in Appendix I have been, or will be, collected under separate programs, including the HDA Program, SSAP, and BMP. The necessary additional data for the HSI models (beyond that which is, or will be, collected under established sampling programs) are described in subsection 6.4 of this Phase 1 HA Report; these data were collected in 2005.

6. Data Needs for Phase 1 Areas

The HDA Work Plan specifies that the Phase 1 HA Report will identify any additional habitat assessment data needs. When this Phase 1 HA Report was initially prepared in April 2004, there were numerous additional habitat assessment data needs in Phase 1 areas, and this Section 6 was included in the report to identify those data needs and to propose additional investigations to satisfy those data needs. Since that time, most of these investigations have been completed. As noted above, spot checking and reassessment at a limited number of stations assessed in 2003 were conducted in 2004. Section 6.1 of this section describes that effort. The remainder of this section identifies additional data needs to complete the habitat assessment of the Phase 1 areas. As also noted above, most of those data collection efforts were completed in 2005 in accordance with the SHAWP, and the results will be presented in the *Phase 1 Final Design Report*. While they are still included as data needs in this report, this section identifies the data collection activities that were conducted in 2005.

6.1 Spot-Checking and Reassessment in 2004

The HDA Work Plan states that a subset of assessed areas will be spot-checked in subsequent years to assess fluctuations in size and location of habitat types, particularly SAV beds. If substantial changes occurred in habitat characteristics (e.g., percent cover, species composition, or size of the habitat) at a given station, the station is to be re-sampled in accordance with the SOPs provided as Appendices A through D of this Phase 1 HA Report. Such spot checking and reassessment activities were conducted in 2004, as described below.

Due to the limited number of stations assessed in 2003, each station was visually examined to determine if substantial changes had occurred in the size, location, percent cover, or species composition of the habitat. The percent cover at some of the wetland stations was estimated to be less than that observed in 2003. As such, a "substantial change" was determined to have occurred, and one riverine wetland station was randomly selected and reassessed. In addition, water levels within River Sections 1 and 2 were elevated compared to the time at which the 2003 assessments were completed (average flow of 2898 cfs in 2003 versus average flow of 6778 cfs in 2004 during the same period). As such, many of the shoreline characteristics (e.g., slope) were difficult to visually compare with the 2003 results. Although no "substantial changes" were identified, four shoreline stations were reassessed due to the change in field conditions. Finally, as a conservative measure, stations from each of the other habitat types were also randomly selected and reassessed. A total of 2 unconsolidated river bottom, 1 aquatic vegetation bed, 4 shoreline, and 1 wetland station were reassessed in 2004. Data from the reassessment are provided in Appendix K. Those data were used to calculate new FCI values for comparison with 2003 FCI values (see Table 18). FCI values at the stations assessed in 2003 and reassessed in 2004 varied +/- 21%, which may indicate the level of variability that can be expected within the Upper Hudson River under normal conditions.

Table 18 – Calculated FCI Values for Phase 1 Areas Assessed in 2003 and Reassessed in 2004

Unconsolidated River Bottom	Potential to Support Macroinvertebrates	Potential to Support Fish Populations
Station	$FCI_{UNVEGBMI}$	$FCI_{UNVEGFISH}$
UCB-2 (2003)	0.88	0.77
UCB-2 (2004)	0.83	0.69
UCB-3 (2003)	0.49	0.82
UCB-3 (2004)	0.44	0.65

Aquatic Vegetation Bed	Support PMI/BMI Populations	Fish and Wildlife Habitat	Stabilization of Substrate	Nutrient Cycling
Station	$FCI_{SAVMACROS}$	$FCI_{SAVFISH}$	$FCI_{SAVSTAB}$	$FCI_{SAVNUTS}$
SAV-4 (2003)	0.62	0.62	0.32	0.50
SAV-4 (2004)	0.58	0.62	0.32	0.47

Shoreline	Shoreline Stability	Shade and Cover	Wildlife Habitat
Station	$FCI_{SHORESTAB}$	$FCI_{SHORECOV}$	$FCI_{SHOREHAB}$
1R (2003)	0.96	0.56	0.65
1R (2004)	0.96	0.53	0.64
2I (2003)	0.83	0.46	0.59
2I (2004)	0.97	0.58	0.68
6I (2003)	1.00	0.57	0.68
6I (2004)	0.94	0.57	0.66
9I (2004)	0.99	0.57	0.67
9I (2004)	0.90	0.57	0.64

Wetland	Surface-water Exchange	Energy Dissipation	Nutrient and Organic Cycling	Maintain Character Plant Community	Wildlife Habitat
Station	$FCI_{WATEREX}$	FCI_{ED}	$FCI_{WETCYCLING}$	$FCI_{MAINTAINSPP}$	FCI_{WETHAB}
3 (2003)	0.76	0.61	0.64	0.65	0.60
3 (2004)	0.87	0.69	0.63	0.75	0.76

6.2 Assessments in Remaining Phase 1 Areas

The HDA Work Plan specified that, in total, assessments would be completed at 136 unconsolidated river bottom, 52 aquatic vegetation bed, 68 shoreline, and 10 riverine fringing wetland habitat stations. The number of stations was modified to provide flexibility to evaluate variability in characteristics within aquatic vegetation beds and fringing wetlands. Additional data on these habitats may assist in habitat reconstruction and achievement of attaining success criteria, as described in Section 2 of the SHAWP (BBL and Exponent, 2005b). The assessments for each habitat type follow a balanced design – i.e., 50% of the total stations are to be areas that may potentially be impacted by dredging (target stations), and the remaining 50% of the stations are to be in reference locations outside of dredge areas (reference stations).

At the time the RD AOC was executed in August 2003, neither the habitat delineations nor the dredge area delineations for the Phase 1 areas had been completed. As a result, specific habitat station locations for the candidate Phase 1 areas were selected based on sediment type, overlying water depth, adjacent land use, proximity to other habitat features (e.g., NYSDEC-designated wetlands), and draft working copies of the preliminary dredge areas. This process resulted in the selection of 29 unconsolidated river bottom, 11 aquatic vegetation bed, 16 shoreline, and three riverine fringing wetland stations in candidate Phase 1 areas. The locations for an equal number of reference stations could not be finalized due to the status of the dredge area and habitat delineations.

Moreover, at that time, there was not sufficient time left in the 2003 field season to complete detailed habitat assessments at all the identified stations. As a result, only a subset of the assessment stations in candidate Phase 1 areas could be assessed in detail within the remaining sampling windows in 2003. Specifically, as described in Section 3, habitat assessments in 2003 were completed at six unconsolidated river bottom stations, nine aquatic vegetation bed stations, 14 shoreline stations, and four riverine fringing wetland stations. Therefore, habitat assessments remained to be completed at the remaining stations in the Phase 1 areas (as well as in the Phase 2 areas).

As discussed above, the SHAWP finalized in September 2005 proposed the locations of habitat assessment stations in the remaining Phase 1 areas and in additional suitable reference areas. These additional stations included 41 unconsolidated river bottom stations (19 target and 22 reference), seven aquatic vegetation bed stations (all reference), six shoreline stations (all reference), and two riverine fringing wetland stations (both target). Habitat assessments were conducted at these stations in 2005, with the results to be incorporated into the *Phase 1 Final Design Report*. Subsequent habitat field work may need to be completed to evaluate inter-annual variability and/or fill data gaps. The results of the post-2005 assessments will be incorporated in the Phase 2 HA Report.

6.3 Data Needs for FCI Models

Additional data needs were identified to complete the FCI models. These are described below. These data have been collected in 2005 from the candidate Phase 1 areas previously sampled in 2003, the Phase 1 areas sampled in 2005, and some Phase 2 areas, and will continue to be collected from Phase 2 areas to be assessed in the future.

6.3.1 Current Velocity

Current velocities were recorded in 2003 at 10 cm and 1 m above the substrate within unconsolidated river bottom and aquatic vegetation bed habitats. Because velocity typically increases exponentially from the bottom to just near the surface, recordings taken from set depths above the substrate may not be comparable among stations. Therefore, current velocity data collected in 2005 included not only the measurements at 10 cm and 1 m above the substrate, but also measurements at 80% and 20% of the water depth so that these data can be normalized to water depth to allow between station comparisons. In addition, current velocity was measured at 60% of the water depth for use in the HSI models. These measurements will continue to be made in the future.

Current velocity measurements are being collected as part of the BMP and Supplemental Engineering Data Collection (SEDC) Program at multiple transect locations under low (less than 3,000 cfs), moderate (3,000 to 7,000 cfs), and high (greater than 7,000 cfs) flows. These data will be used to update the QEA 2-D hydrodynamic model (QEA 1999a, b), which may be used to predict areas of higher or lower current. Current velocity measurements collected in the candidate Phase 1 areas sampled in 2003 and during the habitat assessments of the remaining Phase 1 areas and the Phase 2 areas will be compared with the BMP and SEDC measurements to determine maximum flow conditions in the unconsolidated river bottom and aquatic vegetation beds (based on measurements collected inside the beds). In addition, current velocity measurements taken at unconsolidated river bottom and aquatic vegetation beds (inside and outside of bed) will be used in the HSI models for several fish species.

6.3.2 Inundation Period

During the assessments for riverine fringing wetlands, it was determined that these habitats lack true O and A horizons. The three preliminary functions (listed in Table 2 of the HDA Work Plan) that depend on these soil property variables ("export organic carbon," "nutrient cycling," and "remove and hold elements and compounds") were combined to provide one function ("nutrient and organic cycling") related to the ability of the wetland to import and/or export nutrients and organic carbon. Fundamental to the nutrient and organic cycling function is contact of the river water with the wetland – currently being quantified by the surface-water exchange function. The function will be revised to include inundation period to more accurately reflect the surface-water exchange (Shafer and Yozzo, 1998). Data on inundation period during the growing season have been collected in 2005 in the Phase 1 areas sampled in 2003, the remaining Phase 1 areas, and some Phase 2 areas, and will continue to be collected from Phase 2 areas to be sampled in the future. In the Upper Hudson River, fluctuations due to the hydrofacilities typically occur on a daily cycle with resulting changes in water depth and flow of up to 18 inches (6 to 12 inches typically) and 5,000 cfs respectively for a duration of 6 to 12 hours. Due to the water level fluctuations, the mean daily water elevations during the growing season will be used for water depth. In addition, minimum and maximum daily water elevations during the growing season will be reported in the *Phase 1 Final Design Report*. The inundation period will be evaluated as number of days inundated during the growing season. The start and end of the growing season will be obtained from Natural Resource Conservation Service soil surveys. Elevations used in habitat reconstruction design will be derived from ecological benchmarks present in reference riverine fringing wetlands/aquatic vegetation beds. To supplement ecological benchmark information, water level measurements obtained during riverine fringing wetland assessments will be correlated with available river gauge measurements.

6.3.3 Validation of FCI Models

Additional site-specific data may be necessary to support the full development of the FCI model equations. The FCI models presented in this Phase 1 HA Report are primarily based on the literature and professional judgment. Site-specific data may be used to calibrate, verify, and/or validate the FCI models for the Upper Hudson River. Some such site-specific data are currently being collected, or are planned to be collected, under the HDA program or other programs. These data sources include the following:

- *Existing Data*. Relevant existing data from former studies (e.g., Law Environmental, 1991, and Exponent, 1998) will be used with the additional field data to revise the FCI models. In addition, GE's catch-per-unit-effort data from its fish sampling activities, as well as other existing resource agency data (to the extent they are made available to GE), will be used to further develop the FCI models.

- *Functional Data Assessment*. To the extent available, direct functional data relating to the secondary success criteria, such as fish and wildlife observations being collected under other programs (e.g., the Baseline Monitoring Program) and the current habitat assessment program, will be used to calibrate the fish and wildlife support functions. To enhance the ability to use such data, habitat assessment activities at the remaining stations (all of which currently represent reference conditions) will include more quantitative fish and wildlife observations that include a temporal component at dawn and dusk. The life stage of organisms observed, to the degree that life stage can be determined during observational activities, will be recorded. These observations and recordings were made during the habitat assessment activities conducted in 2005. In addition, if, after dredging, functional data such as invertebrate, fish and wildlife observations beyond those being collected under the other programs mentioned above (e.g., benthic invertebrate community analysis) would be useful to judge success under the secondary success criteria, appropriate studies and data collection may be implemented at that time in both dredged areas and non-impacted reference areas. If such data are adequate to support reliable evaluations, they will provide an additional line of evidence for calibrating the precision and accuracy of the FCI models insofar as they relate to fish and wildlife support functions.

- *Ongoing Data Collection*. Data from other on-going sampling programs can also be used to verify or validate FCI models. For example, data obtained from the SEDC program, under which information on physical features of the Upper Hudson River is being collected to aid in the final design process, can be used to verify values of certain FCI variables. Similarly, fish and/or macroinvertebrate data currently collected by the resource agencies (to the extent such data are made available to GE) or others may be used to aid in validating FCI models if data quality objectives of the HDA program are satisfied.

6.4 Data Needs for HSI Models

Post-dredging comparisons of habitat parameters in the target areas to those in the reference area data set will provide the primary basis for determining the success of the habitat replacement and reconstruction program (Section 4.6 and BBL, 2003b). As stated in the HDA Work Plan, the FCI models are being used to relate habitat-specific parameters to the functions provided by those habitats. Similarly, as noted above, HSI models will also be used in conjunction with site-specific FCI models for fish and wildlife habitat function for representative indicator species.

As discussed in the HD Report and in Section 5 of this Phase 1 HA Report, HSI models will be developed for the following species:

- Belted Kingfisher (*Ceryle alcyon*);
- Great Blue Heron (*Ardea herodius*);
- Wood Duck (*Aix sponsa*);
- Muskrat (*Ondatra zibethicus*);
- Mink *(Mustela vison);*

- Snapping Turtle (*Chelydra serpentina*);
- Yellow Perch (*Perca flavescens*);
- Largemouth Bass (*Micropterus salmoides);*
- Smallmouth Bass (*Micropterus dolomieui*);
- Bluegill (*Lepomis macrochirus*); and
- Common Shiner (*Notropis cornutus*).

For these HSI models, there are several model variables where additional data are needed. As one example, for the largemouth bass HSI model, data on average water temperature within pools, backwaters, or littoral areas during the growing season, minimum DO levels during midsummer within pools or littoral areas, and pH range during the growing season may be needed. These data are not currently collected under existing sampling and analyses programs (e.g., HDA, SSAP, or BMP).

Appendix I provides the complete list of variables proposed for collection for each of the above-listed species. The SHAWP submitted in September 2005 specified the number of stations and locations for the collection of additional data to support these HSI models, as well as the specific data proposed for collection. These data were collected in 2005.

6.5 Assessments in Off-Site Reference Areas

As discussed in the HD Report, reference stations for each of the four habitats (i.e., unconsolidated river bottom, aquatic vegetation bed, shoreline, and fringing wetland) will be selected for detailed assessment in appropriate locations of the Upstream Upper Hudson and/or Lower Mohawk River. The specific locations for conducting detailed habitat assessments in these off-site reference areas are tentatively identified in the SHAWP, subject to change based on field conditions. Further data collection in off-site reference areas is currently scheduled for 2006. Habitat assessment procedures will follow methods described in the SOPs provided as Appendices A through D of this Phase 1 HA Report.

6.6 Spot-Checking and Reassessment in Subsequent Seasons

As noted in subsection 6.1 above, the HDA Work Plan states that a subset of assessed areas will be spot-checked in subsequent years to assess fluctuations in size and location of habitat types, particularly aquatic vegetation beds, and that if substantial changes occurred in habitat characteristics at a given station, the station is to be resampled in accordance with the SOPs provided as Appendices A through D of this Phase 1 HA Report and the HDA Work Plan. The spot-checking and reassessment approach described in the HDA Work Plan and implemented for the stations that were spot-checked in 2004 (see subsection 6.1) relies on a "visual examination" for deciding which stations would need to be reassessed. For subsequent field seasons before dredging begins, GE proposes to follow a revised spot-checking/reassessment approach that will remove the potential source of uncertainty (i.e., the visual examination step) from the process. Specifically, in those field seasons, a minimum of one station and maximum of two stations for unconsolidated river bottom, aquatic vegetation bed and shoreline habitats will be reassessed within each river reach (as defined in the BMP QAPP [QEA 2003]), for a total number of reassessment stations not to exceed 24 stations. For the riverine fringing wetlands, one station will be reassessed within each river reach, for a total number of wetland reassessment stations not to exceed four stations. The specific station(s) to be reassessed will be randomly selected from the stations assessed in the previous season, including those stations identified as visibly different from previous years. If the preliminary results from the initial reassassements indicate that any habitat-specific parameters have changed considerably, additional stations may be reassessed. The reassessment results will be provided in the *Final Design Report for Phase 2* or other appropriate report to USEPA relating to the HDA or adaptive management program.

In addition, in each subsequent field season, all stations to be assessed or reassessed will first be groundtruthed to verify the originally delineated boundaries of that habitat. For the aquatic vegetation bed and unconsolidated river bottom habitats, stratified (depth-based) random groundtruthing will be used to determine whether the delineated area has changed.

6.7 Schedule

As discussed above, most of the investigations described above in this section to satisfy the identified data needs in Phase 1 areas were conducted in 2004 or 2005. The investigations described in subsection 6.5 will be conducted in the 2006 field season, and those described in subsection 6.6 will be conducted in that and subsequent field seasons.

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