REPORT

Phase 1 Final Design Report Hudson River PCBs Superfund Site

Attachment H – Phase 1 Adaptive Management Plan

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Albany, New York

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engineers, scientists, economists

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1. Introduction

This *Phase 1 Adaptive Management Plan* (Phase 1 AM Plan) describes the adaptive management process for habitat replacement and reconstruction in areas dredged in Phase 1 of the remedial action for the Upper Hudson River. This Phase 1 AM Plan has been prepared on behalf of the General Electric Company (GE) as part of the remedial design for the remedy selected by the United States Environmental Protection Agency (EPA). This Phase 1 AM Plan has been prepared in accordance with: (1) the *Habitat Delineation and Assessment Work Plan* (HDA Work Plan) (BBL, 2003), which is part of the Administrative Order on Consent for Remedial Design and Cost Recovery (RD AOC), effective August 18, 2003 (Index No. CERCLA-02-2003-2027); (2) GE's *Habitat Assessment Report for Candidate Phase 1 Areas* (Phase 1 HA Report) (BBL and Exponent, 2005b), which was approved by EPA in November 2005; and (3) Section 4 of the *Operation, Maintenance, and Monitoring Scope* (OM&M Scope), which is Attachment E to the Statement of Work (SOW) that is part of the Consent Decree (CD) executed by GE and EPA and lodged in federal district court in October 2005 (EPA/GE, 2005).

1.1 Background

In the 2002 Record of Decision (ROD) for the Site (EPA, 2002), EPA divided the Upper Hudson River into three sections, illustrated on Figure 1-1, as follows:

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

The ROD calls for sediment remediation to be undertaken in two distinct phases. Phase 1 of the remedial action will consist of the first year of dredging and will occur within River Section 1. Phase 2 of the remedial action will consist of the remainder of the dredging project. The Phase 1 dredge areas are shown on Figure 1-2 and discussed in detail in the *Phase 1 Final Design Report* (Phase 1 FDR) (BBL, 2006).

As described in the HDA Work Plan, the habitat types within the Upper Hudson River consist of: unconsolidated river bottom, aquatic vegetation bed, shoreline, and riverine fringing wetland habitats. Beginning in 2003, habitat delineation and assessment were conducted to:

- Document the nature and distribution of habitats potentially affected by remediation;
- Identify reference habitat locations representing the range (i.e., distribution) of existing conditions; and
- Identify physical and biological parameters that are related to ecological function and hence are appropriate for use to determine when post-remediation habitat conditions fall within the ranges of reference conditions.

A summary of the habitat delineation and assessment activities within the Upper Hudson River is provided in Section 2. Further details on the habitat delineation activities can be found in the *Habitat Delineation Report* (HD Report) (BBL and Exponent, 2005a) (which will be revised and resubmitted based on comments received from EPA on February 21, 2006); the habitat assessment to date is described in the Phase 1 HA Report (BBL and Exponent, 2005b).

1.2 Habitat Replacement and Reconstruction and Adaptive Management

Following sediment remediation, habitat replacement and reconstruction will be implemented. Its primary goal 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 EPA-selected remedy and from possible independent environmental changes that may occur from other factors" (BBL, 2003, page 1-2). The ROD specifies, "A habitat replacement program will be implemented in an adaptive management framework to replace SAV communities, wetlands, and river bank habitat" (EPA, 2002, page A-3). This Phase 1 AM Plan describes that adaptive management process for the Phase 1 dredge areas.

Adaptive management is a suite of assessment and management tools most appropriately applied where uncertainty exists and where decisions are best made on the basis of accumulated information – which is precisely the case for the Upper Hudson River habitat replacement and reconstruction. Since ecosystems are not machines that can be engineered to yield precisely determined outcomes, the habitat replacement and reconstruction program is a challenge best met by a "design with nature" approach (Kangas, 2004). In this situation, adaptive management is the process by which ecological processes of natural engineering are applied to assist habitat replacement and reconstruction following the "hard engineering" of the remedial action.

In adaptive management, the goal of returning habitats to the desired range of characteristics is met by applying site-specific habitat information in an iterative framework of measurement and response (Holling, 1978; Thom, 1997). In adaptive management, no single goal determines success or failure. Rather, if certain goals are not being met, additional monitoring is conducted and decisions are made regarding the need for and approach to particular adaptive responses. Flexibility is an important component of adaptive management, so the potential responses cover a broad range of possibilities. These potential responses include additional monitoring, literature research, simple experiments, consultations with discipline experts, re-evaluation and restatement of goals and success criteria, and/or active intervention (such as planting desired species or removing invasive plant species). Potential responses and applications are identified and discussed in greater detail in Section 4.

Success in habitat replacement and reconstruction in the Upper Hudson River will be achieved when the characteristics of the reconstructed habitats fall within the range of attainable characteristics as defined by those characteristics in physically similar areas of the Upper Hudson River and those characteristics are sustainable (these concepts are addressed in detail in Sections 3 and 4). The range of characteristics will be established primarily by measuring specific physical and biological parameters, as provided in the HDA Work Plan and OM&M Scope.

As described in the Phase 1 FDR, Phase 1 of the remedial action is designed to remove a target volume of 265,000 cubic yards of sediments from portions of the Upper Hudson River, followed by backfilling with clean material or capping. Dredging and backfilling/capping activities will necessarily disturb the existing habitats. Adaptive management provides a framework for design and monitoring of the habitat replacement and reconstruction to be implemented after dredging and backfilling/capping. The adaptive management process will be used in a systematic manner to maximize the probability that the areas impacted by Phase 1 of the remedial action will return to within the range of conditions in reference areas, as provided in the HDA Work Plan and the OM&M Scope.

1.3 Overview of the Upper Hudson River Adaptive Management Program for Habitat Replacement and Reconstruction

A schematic diagram of Phase 1 adaptive management is presented on Figure 1-3. The figure shows the iterative process of data gathering (measuring, monitoring), evaluation and comparison to criteria, adaptive response to the findings of the comparisons, and closure when success is achieved. The tiered process described on this figure is discussed in Section 1.3.5. Adaptive management involves ongoing decision-making in the context of multiple information sources and changing site conditions. Thus, adaptive management for habitat replacement and reconstruction is intended to be iterative, open, and transparent. As described in the OM&M Scope and Section 5 of this Phase 1 AM Plan, adaptive management at the Upper Hudson River will include frequent and routine reporting of habitat monitoring data collected under the OM&M program. Specifically, this program will include monthly reporting of monitoring data collected as part of the habitat OM&M program and annual reporting of the habitat monitoring data collected, the results of adaptive management evaluations, and any actions performed during the current year and previous years.

The adaptive management framework for habitat replacement/reconstruction has the following components:

- Establish the range of present habitat conditions in the Upper Hudson River;
- Develop design specifications for post-remediation habitats;
- Develop success criteria for habitat replacement and reconstruction;
- Construct post-backfilling/capping habitats in accordance with the Phase 1 Final Design;
- Monitor;
- Evaluate monitoring results;
- Respond as needed to evaluation; and
- Close the program when success is achieved.

The following subsections provide an overview of each of these components. Details are provided in subsequent sections of this Phase 1 AM Plan and in previously submitted reports (cited as appropriate below).

1.3.1 Establish Present Habitat Conditions

To characterize the current habitat conditions within the Upper Hudson River and at offsite reference areas, a habitat delineation and assessment program was developed and implemented, as described in the HDA Work Plan and the *Supplemental Habitat Assessment Work Plan* (SHAWP) (BBL and Exponent, 2005c), which was approved by EPA. Habitat sampling was conducted in 2003, 2004, and 2005. The sampling provided information for program design as well as characterization data on existing conditions in Phase 1 dredge areas. Onsite reference areas (areas within the Upper Hudson River which will not be dredged) were identified and sampled along with areas within the dredge footprints (target areas).

Data collected prior to dredging are useful for establishing design specifications and for preparing monitoring metrics and success criteria. They also provide insight into the overall range of conditions as general reference for post-backfill/capping habitat replacement and reconstruction. However, since the river is a dynamic system, the pre-dredging data cannot stand alone as reference data. After dredging, sampling will be conducted at reference areas to account for temporal changes in river habitat conditions. As stated in the OM&M Scope, the reference data will include both post-remediation data from specific non-dredge areas selected as reference areas and data collected from onsite target and reference areas prior to remediation.

Results of habitat delineation are reported in the HD Report (BBL and Exponent, 2005a). Results of habitat assessment activities conducted in 2003 and 2004 in the areas that were then candidates for Phase 1 dredging are reported in the Phase 1 HA Report (BBL and Exponent, 2005b). The results of the habitat assessment conducted in 2005 in Phase 1 areas are reported in the Field Data Summary provided in Exhibit A to this Phase 1 AM Plan. All the habitat assessment results from areas relevant to Phase 1 of the remedial action are discussed in the context of adaptive management in Section 2 of this Phase 1 AM Plan.

1.3.2 Develop Habitat Design Specifications

The habitat delineation and assessment have documented the physical and biological conditions in each habitat type. These data and projections of physical conditions after remediation were used to develop post-dredging habitat replacement and reconstruction design specifications presented in the Phase 1 FDR. The habitat design specifications represent the conditions within specific habitat types expected after remediation, based on the range of conditions in each habitat category before dredging.

The habitat design process is separate from future adaptive management. The Phase 1 Final Design includes Functional Capacity Indices (FCIs) developed using data acquired in Phase 1 dredge areas and associated reference stations; these FCIs are provided in Exhibit B to this Phase 1 AM Plan. The habitat assessment data and resulting FCIs are a “snapshot” of conditions in these areas and are the basis for the habitat replacement and reconstruction designs. The adaptive management process will be iterative and include data accumulated and evaluated over the course of the OM&M and Phase 1 adaptive management programs. Thus, it is possible that as part of adaptive management, FCIs may be slightly altered from those presented in this Phase 1 AM Plan. Any changes to the FCIs and the rationale for those changes will be presented in the relevant annual *Adaptive Management Report* submitted to EPA (see Section 5 of this Phase 1 AM Plan).

Section 3 of this Phase 1 AM Plan details the application of the habitat delineation and assessment data in the habitat design. For the purposes of the contracting and design specifications developed to support this program, habitat replacement and reconstruction is referred to as “habitat construction.”

1.3.3 Develop Success Criteria

Success criteria will be developed for each habitat type based on the range of specific parameter values and FCI values represented by reference data, supplemented by HSI values for those indicator species listed in the Phase 1 HA Report, as appropriate. Success criteria will be applied at the river reach scale – that is, success will be evaluated relative to the ecological functioning of habitats present in each river reach relative to reference conditions. The Upper Hudson River is composed of eight river reaches, defined by the locks. River Section 1 constitutes one river reach; River Section 2 comprises two reaches; and River Section 3 comprises five river reaches.

Success criteria also play an important role in evaluating temporal progress in habitat replacement and reconstruction. Since habitat monitoring is conducted over time, it is expected that measured physical and biological parameters and FCIs in the dredged areas will converge with and meet the respective success criteria. If physical and biological conditions and FCI recovery are slow relative to expectations (after accounting for lag times and natural temporal variability) or do not appear to be sustainable (in the dynamic context of the river ecosystem), adaptive management responses will be triggered (described in Section 4 of this Phase 1 AM Plan).

Data collection and findings and development of FCIs and HSIs are described in Section 2 of this Phase 1 AM Plan, while the manner in which findings will be applied through adaptive management is detailed in Section 4.

1.3.4 Monitor Habitats

Specifications for habitat delineation and assessment have been developed (HDA Work Plan and SHAWP) and findings to date were reported in previously submitted reports (HD Report and Phase 1 HA Report) and this Phase 1 AM Plan. These findings provide the basis for developing FCIs for Upper Hudson River habitats. For OM&M, habitat monitoring will be undertaken in dredged (target) areas and undredged reference areas within the Upper Hudson River and in offsite reference areas both prior to and following remediation (OM&M Scope).

1.3.5 Evaluation and Response

As shown on Figure 1-3, there are three tiers to the Phase 1 adaptive management evaluation. Each tier involves comparison of findings to a set of criteria that describe habitat replacement and reconstruction success. The specifications presented in both the OM&M Scope and the Phase 1 HA Report for the monitoring and maintenance of the habitat replacement and reconstruction are implemented through this tiered process. The

OM&M Scope and the Phase 1 HA Report identify three categories of data by which habitat replacement and reconstruction success may be judged:

1. Specific parameters characterizing physical and biological conditions in each habitat category (listed in Section 4.3 of the OM&M Scope).
2. FCIs and habitat suitability indices (HSIs).
3. Direct measures of relevant habitat functions (e.g., presence and abundance of fish and/or wildlife species).

Adaptive management Tiers 1 and 2 (Figure 1-3) correspond to the first two categories – specific habitat parameters and FCIs and HSIs – and are the primary success criteria. Tier 3 (Figure 1-3) corresponds to the third category of data and consists of secondary success criteria that will not be used in the first instance to judge success. However, if the primary criteria do not fall within the range of reference conditions, direct measures of habitat functions can be used to establish success, if data are sufficient to make the necessary comparisons and to indicate that such conditions are likely to be sustainable.

Monitoring will be conducted annually, and findings will be evaluated relative to habitat replacement and reconstruction success criteria in annual *Adaptive Management Reports*. If success criteria have not been met or if recovery is unexpectedly slow, the need for response will be assessed**,** including the need to revise the habitat-specific goal or success criteria (as discussed in Section 4). The need for response will be assessed annually until success is achieved.

1.3.6 Success and Closure

When habitat conditions in target areas achieve success criteria for the relevant river reach and are sustained for the appropriate period, adaptive management will end. Adaptive management monitoring will be conducted annually until success is achieved, as detailed in Section 4.

2. Existing Information

2.1 Habitat Distribution in Upper Hudson

Delineation of four habitat types (unconsolidated river bottom, aquatic vegetation bed, shoreline, and riverine fringing wetlands) was completed in 2003 in accordance with the HDA Work Plan (BBL, 2003). The delineations were completed to document the nature and extent of the four habitat types within the Upper Hudson River and to facilitate the selection of assessments stations. Details regarding the habitat delineation process and results are presented in the HD Report (which is currently under revision based on comments received from EPA on February 21, 2006).

2.2 Habitat Assessments

Habitat assessments were completed in target and reference areas and included collecting habitat-specific data for use in the Phase 1 habitat replacement and reconstruction designs and for the adaptive management program. Data collection was originally identified in the HDA Work Plan, and supplemented by additional data needs identified in the Phase 1 HA Report. The SHAWP identified the locations of the target and reference stations at which the habitat assessment data were to be collected. The SHAWP also presented the standard operating procedures for collecting data and calculating the HSIs for the selected species (see Section 2.3.2 below). EPA approved both the Phase 1 HA Report and the SHAWP on November 17, 2005.

Field data were collected from habitat assessment locations on September 8 through October 1, 2003, September 14 through September 20, 2004, and August 29 through September 30, 2005. The habitat assessment activities conducted in 2003 and 2004 focused on a subset of three areas that were identified at that time as "candidate Phase 1 areas," areas that were candidates for dredging in Phase 1 (the upper portion of the Thompson Island Pool in River Section 1, the Griffin Island Area in River Section 1, and the areas of River Section 2 in the vicinity of Hot Spots 33-35, known as the Northumberland Dam Area). The 2003 and 2004 assessments and results are described in the Phase 1 HA Report. In 2005, habitat assessment activities were conducted in the remaining portions of the Phase 1 areas, areas that were targeted for dredging in Phase 1, as set out in the approved *Phase 1 Dredge Area Delineation Report* (Phase 1 DAD Report) (QEA, 2005), and in some Phase 2 areas. The 2005 assessments and data from the areas to be dredged in Phase 1 (which are specified in the Phase 1 FDR and are more limited than those delineated in the Phase 1 DAD Report) are described in Exhibit A of this

Phase 1 AM Plan. Phase 1 habitat assessment stations are presented on Figures A-1 through A-20 in Exhibit A of this Phase 1 AM.

The overall habitat assessment results for the areas to be dredged in Phase 1 (i.e., those included in the Phase 1 FDR) and associated reference stations are summarized below. The data from all other areas, including areas previously designated as "candidate Phase 1 areas" or delineated as Phase 1 areas but not encompassed in the Phase 1 FDR, are not included in the following summaries, since they no longer constitute areas to be dredged in Phase 1. Those data, together with the habitat assessment results from other Phase 2 areas, will be provided in the Phase 2 HA Report following completion of the remaining habitat assessment activities in Phase 2 areas. As such, the number of stations described below differs from the number of Phase 1 stations described in the SHAWP, as the latter was based on the dredge areas described in the Phase 1 DAD Report. For the stations discussed below, target stations are those stations that are located within areas to be dredged during Phase 1. Associated reference stations are those stations located outside of areas to be dredged (in either Phase 1 or Phase 2) in River Sections 1, 2, or 3.

2.2.1 Unconsolidated River Bottom

In Phase 1 dredge areas and associated reference areas, habitat assessments were completed at 26 unconsolidated river bottom stations (nine target and 17 reference) in 2005 and four such stations in 2003 (all target). In 2004, two of the stations sampled in 2003 were re-sampled to evaluate interannual variability. All target stations are located in River Section 1, and the associated reference stations are located in all three river sections. The data from unconsolidated river bottom stations assessed in these areas in 2003 through 2005 were used to develop the FCI models described in Section 2.3.1.1. All data collected to date from the unconsolidated river bottom stations in Phase 1 dredge areas and associated reference stations are summarized in Table 2-1 below. The 2005 data are further described in Exhibit A.

Table 2-1 – Range of Conditions Observed in Unconsolidated River Bottoms in the Upper Hudson River Based on Data Collected in Areas Relevant to Phase 1[1] from 2003 through 2005

Parameter	Units	Minimum			Maximum			Mean			Standard Deviation		
		2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005
Inorganic Substrate													
Bedrock	percent	0	0	0	0	0	100	0	0	12.30	0	0	27.56
Boulder	percent	Trace (< 10)	0	Trace (< 10)	50	60	70	3.52	12.22	12.55	10.49	21.30	8.78
Cobble	percent	Trace (< 10)	Trace (< 10)	Trace (< 10)	50	50	50	4.26	10.56	13.62	10.75	15.52	10.68
Gravel	percent	Trace (< 10)	Trace (< 10)	Trace (< 10)	70	30	50	15.74	7.22	14.42	24.23	10.74	15.78
Sand	percent	Trace (< 10)	Trace (< 10)	Trace (< 10)	80	90	90	39.81	43.89	14.11	24.46	33.98	24.64
Silt	percent	Trace (< 10)	0	Trace (< 10)	80	70	60	34.63	24.44	9.89	24.08	22.55	16.43
Clay	percent	Trace (< 10)	0	Trace (< 10)	10	10	70	0.93	1.67	8.70	2.93	3.83	10.89
Organic Substrate													
Detritus	percent	Trace (< 10)	Trace (< 10)	Trace (< 10)	70	70	80	15.19	12.78	6.47	14.11	21.37	16.12
Muck-Mud	percent	Trace (< 10)	Trace (< 10)	Trace (< 10)	100	80	50	32.04	35.00	5.47	33.84	32.76	8.74
Marl	percent	Trace (< 10)	Trace (< 10)	Trace (< 10)	100	80	40	19.26	11.67	6.24	31.67	20.93	6.72
Mussels	percent	0	0	Trace (< 10)	4	3	70	1.02	1.17	9.87	1.02	0.92	14.46
Epifaunal Substrate													
Pool Substrate[1]	percent	<25	<25	<25	>80	55-75	>80	54.72	46.81	49.87	22.70	14.70	24.51
TOC	mg/kg	0	0	0	320,000	43,000	330,000	27,308	19,671	27,543	51,757	15,571	57,371
Percent Fines	percent	0	0	0	80	80	80	35.56	26.11	9.51	25.15	25.70	24.24

Notes:
1. Areas relevant to Phase 1 consist of target stations within areas to be dredged during Phase 1 and associated reference stations.
2. TOC = total organic carbon
3. mg/kg = milligram per kilogram

2.2.2 Aquatic Vegetation Beds

In Phase 1 dredge areas and associated reference areas, habitat assessments were completed at 7 aquatic vegetation bed stations (all reference) in 2005 and 5 aquatic bed stations (all target) in 2003. In 2004, one of the stations sampled in 2003 was re-sampled to evaluate interannual variability. All target stations are located in River Section 1 and the associated reference stations are located in both River Sections 1 and 2. The data from aquatic vegetation bed stations assessed in these areas in 2003 through 2005 were used to develop the FCI models described in Section 2.3.1.2. All data collected to date from the aquatic vegetation beds in Phase 1 dredge areas and associated reference stations are summarized in Table 2-2 below. The 2005 data are further described in Exhibit A.

Table 2-2 – Range of Conditions Observed in Aquatic Vegetation Beds in the Upper Hudson River Based on Data Collected in areas relevant to Phase 1[1] from 2003 through 2005

Parameter	Units	Minimum			Maximum			Mean			Standard Deviation		
		2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005
River Flow	Cfs	2,178	2,560	2,140	3,214	7,840	5,600	2,898	5,774	3,032	341.31	1,652	1,025
Total Organic Carbon	mg/kg	0	3100	0	250,000	52,000	58,000	30,290	19,233	13,339	45,779	15,710	13,860
Percent Fines	percent	5.2	5.2	4.1	45.2	54.5	64.8	20.48	19.15	29.98	14.36	16.38	17.65
Dry Bulk Density	g/cm^3	0.12	0.37	0.39	2.70	2.7	1.60	0.97	1.11	1.13	0.55	0.65	0.28
Moisture Content	percent	15	15	12	82	67	92	41.23	37.2	30.70	18.21	14.28	18.98
Exchangeable Phosphorus	mg/l	14.6	14.2	4.95	133	14.2	569.74	38.72	14.2	70.08	36.36	-	136.40
Exchangeable Ammonia	mg/l	4.39	0.82	7.08	26.2	0.82	32.94	10.66	0.82	20.95	6.29	-	8.63
Extractable Potassium	mg/l	18.7	0.94	1.42	48.3	0.94	115.8	31.68	0.94	34.14	8.46	-	31.01
Aboveground Biomass	g/m^2	24.48	38.96	108.72	561.99	127.52	2266.32	101.74	78.09	585.07	90.09	32.19	457.81
Shoot Density	$number/m^2$	32	120	8	1880	368	2,464	364	211.56	694.26	343.32	86.45	406.42
Percent Cover	percent	10	30	10	100	70	100	53.11	52.22	69.22	23.14	15.63	24.55
Light Availability - Center of Bed	light attenuation coefficient	0.38	NA	0.28	2.57	NA	2.53	1.00	NA	0.87	0.90	NA	0.76
Current – Inside Bed (Outside Bed)	ft/s	0.01 (0.02)	0.16 (0.39)	0 (0.04)	1.12 (0.86)	0.4 (0.8)	1.15 (1.25)	0.23 (0.42)	0.28 (0.59)	0.19 (0.46)	0.38 (0.30)	0.17 (0.29)	0.27 (0.41)

Notes:
1. Areas relevant to Phase 1 consist of target stations within areas to be dredged during Phase 1 and associated reference stations.
2. cfs = cubic feet per second
3. ft/s = feet per second
4. g/cm^3 = grams per cubic centimeter
5. mg/l = milligram per liter
6. g/m^2 = grams per square meter

2.2.3 Shoreline

In Phase 1 dredge areas and associated reference areas, habitat assessments were completed at 9 shoreline stations (2 target and 7 reference) in 2005 and 7 shoreline stations (5 target 2 reference) in 2003. In 2004, four of the stations sampled in 2003 were re-sampled to evaluate interannual variability. All target stations are located in River Section 1 and the associated reference stations are located in both River Sections 1 and 2. The data from shoreline stations assessed in these areas in 2003 through 2005 were used to develop the FCI models described in Section 2.3.1.3. All data collected to date from the shoreline stations in Phase 1 dredge areas and associated reference stations are summarized in Table 2-3, below. The 2005 data are further described in Exhibit A.

Table 2-3 – Range of Conditions Observed in Natural Shorelines in the Upper Hudson River Based on Data Collected in Areas Relevant to Phase 1[1] Areas from 2003 through 2005

Parameter	Units	Minimum			Maximum			Mean			Standard Deviation		
		2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005
Inorganic Substrate													
Bedrock	percent	0	0	0	0	0	Trace (< 10)	0	0	0.83	0	0	1.90
Boulder	percent	0	0	0	Trace (< 10)	10	45	0.00	1.11	5	0.00	3.33	10.73
Cobble	percent	0	0	0	20	50	20	1.91	5.56	5.45	5.12	16.67	5.54
Gravel	percent	0	0	0	70	100	60	12.38	22.22	15	20.95	36.67	19.88
Sand	percent	20	0	0	90	70	90	60.00	45.56	38.33	26.46	28.33	30.49
Silt	percent	0	0	Trace (< 10)	50	30	60	15.72	18.89	30.22	16.30	12.69	20.36
Clay	percent	0	0	0	40	10	40	10.00	3.34	8.48	14.49	5.00	15.18
Organic Substrate													
Detritus	percent	0	0	0	40	0	95	13.34	0	33.75	11.10	0	30.65
Muck-Mud	percent	Trace (< 10)	0	0	100	0	Trace (< 10)	63.33	0	0.21	33.81	0	1.02
Marl	percent	0	0	0	100	0	Trace (< 10)	19.05	0	0.42	37.00	0	1.41
Vegetated	percent	0	0	Trace (< 10)	30	0	100	4.29	0	65.63	8.70	0	30.30
Woody Debris	feet	Trace (< 10)	NA	Trace (< 10)	31.67	NA	58.17	19.11	NA	16.50	6.78	NA	13.75
Bank Assessment													
Stable	percent	Trace (< 10)	0	15	100	100	100	34.29	44.44	75.21	41.90	52.70	26.02
Moderately Stable	percent	Trace (< 10)	0	0	90	100	80	50.95	48.89	22.92	37.54	48.85	23.86
Moderately Unstable	percent	Trace (< 10)	0	0	80	50	15	10	6.67	1.88	18.44	16.58	4.38
Unstable	percent	Trace (< 10)	0	0	0	0	0	0	0	0	0	0	0
Bank Vegetation													
Optimal	percent	Trace (< 10)	0	0	100	100	100	92.86	55.56	46.67	23.05	52.70	42.90
Suboptimal	percent	Trace (< 10)	0	0	20	100	50	1.43	44.44	20.42	4.78	52.70	16.54
Marginal	percent	Trace (< 10)	0	0	20	0	90	0.95	0	30.42	4.36	0	35.32
Poor	percent	Trace (< 10)	0	0	0	0	30	0	0	2.5	0	0	8.47
Riparian Edge													
Canopy	percent	Trace (< 10)	20	10	100	90	85	49.05	53.33	44.58	25.08	27.84	24.40
Understory	percent	Trace (< 10)	Trace (< 10)	Trace (< 10)	80	80	95	36.67	36.67	38.33	27.26	23.45	30.13
Herbaceous	percent	10	30	20	100	100	95	67.62	81.11	63.13	24.06	23.69	22.50
Adjacent Landuse	none	Maintained Field	Residential	NA	Forested	Forested	NA	NA	NA	NA	NA	NA	NA

Notes:

1. Areas relevant to Phase 1 consist of target stations within areas to be dredged during Phase 1 and associated reference stations.

2.2.4 Riverine Fringing Wetlands

In Phase 1 dredge areas and associated reference areas, habitat assessments were completed at one riverine fringing wetland station (reference) in 2005 and one station (target) in 2003. Both riverine wetland stations are in River Section 1. The data from these two riverine fringing wetlands stations were used to develop the FCI models described in Section 2.3.1.4. All data collected to date from these riverine fringing wetlands stations are summarized in Table 2-4 below. The 2005 data are further described in Exhibit A.

Table 2-4 – Range of Conditions Observed in Riverine Fringing Wetlands in the Upper Hudson River Based on Data Collected in Areas Relevant to Phase 1[1] from 2003 and 2005

Parameter	Units	Minimum		Maximum		Mean		Standard Deviation	
		2003	2005	2003	2005	2003	2005	2003	2005
Size	acre	0.32	0.12	0.32	0.12	0.32	0.12	NA	NA
Slope	percent	11.4	9.02	11.4	9.02	11.4	9.02	NA	NA
Biomass	g/m^2	169.44	184.58	507.04	349.16	334.24	288.84	133.75	57.27
Stem Density	$number/m^2$	41	1901	91	4656	65.56	3044.17	15.25	1044.35
Percent Contiguous	percent	100	100	100	100	100	100	NA	NA
Wetland Edge	feet	490	233	490	233	490	233	NA	NA

Note:

1. Areas relevant to Phase 1 consist of target stations within areas to be dredged during Phase 1 and associated reference stations.

2.3 Habitat Functions

The habitat assessments include measurement of physical and biological parameters (e.g., stem density, substrate type), some of which are functional parameters (e.g., biomass, species composition). In addition to these direct measures, the HDA program uses functional assessment models, specifically FCI models and HSI models, to quantify other habitat-specific functions based on the directly measured physical and biological parameters. 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., HSIs) and is established in the HDA Work Plan.

Functional assessment 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 (FCI models) or provide suitable habitat for a specific fish or wildlife species (HSI models). The basis for selecting the variables that are included in the FCI models was described in the Phase 1 HA Report. That report also provides the basis for selecting the specific fish and wildlife species for which HSI models were completed. This section describes the results of the final FCI and HSI models that were completed based on data collected from 2003 through 2005 for Phase 1 areas.

2.3.1 FCI Models

The basis for selecting the variables that are included in the FCI models is summarized below and is fully described in the Phase 1 HA Report. The specific parameters (i.e., the variables defined for the Phase 1 FCI models) that were initially selected for measurement in each habitat were identified and selected using four screening criteria (adapted from Shafer and Yozzo, 1998):

1. 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.
2. Basis of importance: Supporting data describe the relationship between the variable and function.
3. Feasibility of measurement: The variable can be easily measured, observed, or recorded at sufficient resolution for the data to be of use.
4. 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).

The data collected have different units and scales. Before the variables can be aggregated in a simple equation to produce an FCI, they must be transformed into a set of comparable unitless measures referred to as a model variable subindex. 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). Text and graphs in Exhibit B show the transformations. 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 defined optimal value (equal to a subindex of 1.0). For the purposes of developing the

FCI models for Phase 1, 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, in some cases, was in between (e.g., for stem density) – and was used to scale the measured variables. The FCI value for the hypothetical optimal habitat thus calculates to 1.0. The FCI for each habitat type is habitat-specific and cannot be used for comparisons among different habitat types to evaluate the success of the habitat replacement and reconstruction effort. However, comparisons of FCIs among different habitat types may be useful to evaluate changes in habitat types or functions that may result from the remedial action. This section describes the results of the Phase 1 FCI models that were completed based on data collected from 2003 through 2005 in Phase 1 areas.

2.3.1.1 Unconsolidated River Bottom

Two FCI models are used for unconsolidated river bottom habitat: one for potential to support macroinvertebrate populations, and the other for potential to support fish populations. Based on the 2003 through 2005 data for the stations relevant to Phase 1 (i.e., those in the Phase 1 dredge areas and associated reference stations), FCI values for the former function ranged from 0.07 to 0.65 and for the latter function from 0.16 to 0.99. FCI values for all Phase 1 unconsolidated river bottom stations are shown in Table 2-5. Further discussion on the derivation of the unconsolidated river bottom FCI models is provided in Exhibit B.

Table 2-5 – Calculated FCI Values for Unconsolidated River Bottoms Based on 2003-2005 Data from Areas Relevant to Phase 1

Unconsolidated River Bottom	Potential to Support Macroinvertebrates	Potential to Support Fish Populations
UCB-01R	0.12	0.25
UCB-01T	0.36	0.92
UCB-02R	0.23	0.99
UCB-02T	0.39	0.57
UCB-03R	0.17	0.60
UCB-03T	0.21	0.81
UCB-04R	0.59	0.35
UCB-05R	0.47	0.75
UCB-06R	0.44	0.33

Unconsolidated River Bottom	Potential to Support Macroinvertebrates	Potential to Support Fish Populations
UCB-06T	0.44	0.64
UCB-07R	0.20	0.65
UCB-07T	0.20	0.47
UCB-08R	0.11	0.29
UCB-08T	0.65	0.43
UCB-09R	0.44	0.41
UCB-09T	0.13	0.40
UCB-10R	0.31	0.47
UCB-10T	0.07	0.16
UCB-11R	0.20	0.25
UCB-11T	0.17	0.26
UCB-12R	0.20	0.53
UCB-12T	0.09	0.53
UCB-13R	0.13	0.43
UCB-14R	0.24	0.61
UCB-15R	0.23	0.91
UCB-16R	0.20	0.51
UCB-16T	0.20	0.46
UCB-17R	0.21	0.44
UCB-18T	0.41	0.56
UCB-19T	0.21	0.58

2.3.1.2 Aquatic Vegetation Beds

Four FCI models are used for aquatic vegetation beds. The first, for potential to support phytophilous and benthic macroinvertebrate (PMI and BMI, respectively) populations, had values ranging from 0.41 to 0.78. The second, for potential to support fish populations, had values ranging from 0.47 to 0.86. The third, for stabilization of substrate, had values ranging from 0.39 to 0.80. The fourth function, nutrient cycling, had values ranging from 0.13 to 0.69. FCI values for all aquatic vegetation beds are shown in Table 2-6. Further discussion on the derivation of the aquatic vegetation bed FCI models is provided in Exhibit B.

Table 2-6 – Calculated FCI Values for Aquatic Vegetation Beds Based on 2003-2005 Data from Areas Relevant to Phase 1

Aquatic Vegetation Bed	Support PMI/BMI Populations	Support Fish Populations	Stabilization of Substrate	Nutrient Cycling
SAV-1T	0.58	0.55	0.41	0.22
SAV-2T	0.44	0.47	0.48	0.17
SAV-3T	0.57	0.59	0.43	0.13
SAV-4T	0.41	0.50	0.44	0.16
SAV-6T	0.59	0.75	0.73	0.22
SAV-10R	0.68	0.70	0.45	NA
SAV-11R	0.65	0.73	0.39	0.24
SAV-12R	0.62	0.70	0.80	0.45
SAV-13R	0.49	0.74	0.65	0.33
SAV-14R	0.52	0.74	0.54	0.36
SAV-15R	0.78	0.86	0.72	0.69
SAV-16R	0.52	0.47	0.59	0.41

2.3.1.3 Natural Shorelines

Three FCI models are used for natural shorelines. The first, for shoreline stability, had values ranging from 0.45 to 0.99. The second, for shade and cover, had values ranging from 0.21 to 0.94. The third, for wildlife habitat, had values ranging from 0.36 to 0.87. The fourth and last function, nutrient cycling, had values ranging from 0.10 to 0.51. FCI values for all aquatic vegetation beds are shown in Table 2-7. Further discussion on the derivation of the natural shoreline FCI models is provided in Exhibit B.

Table 2-7 – Calculated FCI Values for Natural Shorelines Based on 2003-2005 Data from Areas Relevant to Phase 1

Shoreline Station	Shoreline Stability	Shade and Cover	Wildlife Habitat
SHO-01T	0.99	0.52	0.63
SHO-01R	0.83	0.52	0.57
SHO-02T	0.91	0.56	0.64
SHO-03T	0.83	0.59	0.61
SHO-03R	0.79	0.67	0.66
SHO-04T	0.80	0.56	0.57
SHO-04R	0.85	0.65	0.68
SHO-05R	0.96	0.67	0.74
SHO-06T	0.90	0.54	0.63

Shoreline Station	Shoreline Stability	Shade and Cover	Wildlife Habitat
SHO-06R	0.97	0.72	0.79
SHO-07R	0.97	0.65	0.72
SHO-08R	0.69	0.39	0.54
SHO-09R	0.73	0.34	0.50
SHO-10R	0.94	0.85	0.89
SHO-12T	0.81	0.77	0.82
SHO-15T	0.59	0.24	0.38

2.3.1.4 Riverine Fringing Wetlands

Five FCI models are used for riverine fringing wetlands. The first, for surface water exchange, had values ranging from 0.76 to 0.89. The second, for energy dissipation, had values ranging from 0.86 to 0.94. The third, for nutrient and organic cycling, had values ranging from 0.82 to 0.89. The fourth, for maintenance of characteristic plant community, had values ranging from 0.72 to 0.99. The fifth, for provision of wildlife habitat, had values ranging from 0.77 to 0.93. FCI values for all aquatic vegetation beds are shown in Table 2-8. Further discussion on the derivation of the riverine fringing wetland FCI models is provided in Exhibit B.

Table 2-8 – Calculated FCI Values for Riverine Fringing Wetlands Based on 2003 and 2005 Data from Areas Relevant to Phase 1

Wetland	Surface-water Exchange	Energy Dissipation	Nutrient and Organic Cycling	Maintain Character Plant Community	Wildlife Habitat
1	0.89	0.86	0.82	0.99	0.93
5	0.76	0.94	0.89	0.72	0.77

2.3.2 HSI Models

HSI models, developed by the U.S. Fish and Wildlife Service, are another type of functional assessment model. HSI 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 suitability of the site for a specific fish or wildlife species. 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 for this reason. Representative fish species were selected based on functional groups and/or association with habitats that could be impacted by remediation. The resulting refined list of species for which HSI models were reviewed was provided in the Phase 1 HA Report. Based on that review and input from EPA, the 11 key species listed below were selected. 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. This section describes the scores for the HSI models that were calculated based on data collected from 2003 through the 2005 sampling seasons.

In accordance with the Phase 1 HA Report, HSI model scores have been calculated 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*).

In accordance with the SHAWP (BBL and Exponent, 2005c), data collected as part of ongoing monitoring programs were used to complete the HSI models for the selected species. These programs included the Baseline Monitoring Program (BMP) (water quality data), the Sediment Sampling and Analysis Program (SSAP) (substrate data), and the HDA program (water quality, habitat parameters). The data used for the HSIs do not allow for the calculation of HSI values for each individual dredge area. Rather, in accordance with the SHAWP, HSI values were calculated for River Section 1 (see Table 2-9). The HSI values are further divided into those for target areas and reference areas of River Section 1 to illustrate the similarity of those areas under current conditions (although, as noted above, both types of areas are currently part of the reference condition). More detailed information on data collection and use of the data in the HSI models is provided in Exhibit B.

Table 2-9 - Calculated HSI Values for River Section 1

Species	HSI Value for River Section 1	HSI Value for Target Areas	HSI Value for Reference Areas
Belted Kingfisher	0.41	0.40	0.41
Great Blue Heron	0.32	0.39	0.27
Wood Duck	0.19	0.17	0.19
Muskrat	0.59	0.57	0.6
Mink	0.87	0.81	0.91
Snapping Turtle	0.42	0.43	0.41
Yellow Perch[1]	0.0	0.0	0.0
Largemouth Bass	0.82	0.84	0.82
Smallmouth Bass	0.57	0.55	0.57
Bluegill	0.89	0.88	0.89
Common Shiner	0.3	0.1	0.3

Note:
1. The degree days required for one of the variables in this model are likely underestimated due to limited winter sampling. See Exhibit B for further discussion.

2.4 Habitat Models

Models for aquatic vegetation, shoreline, and riverine fringing wetland habitats were developed to aid in the completion of the habitat replacement and reconstruction designs and in developing the monitoring elements for use in the adaptive management program. These habitat models were used to relate selected controlling factors to the occurrence of that habitat type within River Section 1. Controlling factors form the basis of the habitat replacement and reconstruction designs. The assumption is that if the controlling factors are within the range of values required by a specific habitat type (e.g., aquatic vegetation beds), then that habitat type will have suitable conditions within which to develop. For the purposes of this program, unconsolidated river bottom habitat is defined as those areas where aquatic vegetation is absent or scarce, and a model for that habitat was considered unnecessary.

2.4.1 Aquatic Vegetation Beds

A model for aquatic vegetation bed replacement and reconstruction was created in ArcGIS by combining the following data layers:

- Bathymetry (used as a surrogate for light availability) from the SSAP;
- Substrate type from the SSAP;
- Aquatic vegetation bed distribution from the HDA program;

- Current velocity from the hydrodynamic model (described in Attachment F of the Phase 1 FDR);
- Debris areas from the SSAP (i.e. logs and areas with accumulations of other downfall); and
- Shoreline type (natural or maintained) from the HDA program.

The model is currently specific to River Section 1 (including both Phase 1 and Phase 2 areas), where high resolution bathymetry and hydrodynamic model output are available. The information in the data layers listed above was combined with the hydrodynamic model grid for River Section 1. In each cell, scores were assigned for all variables using the categories shown in Table 2-10, with a arbitrary maximum value of 20 in each. The scores were determined based on the frequency distributions of existing aquatic vegetation beds and professional judgment. For example, frequency distribution of aquatic vegetation and water depth showed that the majority of aquatic vegetation beds exist between 2 and 6 feet at 3,661 cfs (long-term average summer flow). As such, areas between 2 and 6 feet deep were scored higher in the model, compared to areas that were shallower or deeper. The final aquatic vegetation habitat score for each cell equals the sum of variable scores with a maximum value of 100.

Table 2-10 – Scoring Criteria for Aquatic Vegetation Model

Variable		Range of Values					
Depth (@ 3661 cfs)		*0-2 feet*	*2-6 feet*	*6-8 feet*	*8-10 feet*	*10-12 feet*	*>12 feet*
	Score	5	20	15	10	5	-100
Substrate Type		*Unknown*	*Fine*	*Transitional*	*Sand*	*Gravel*	*Bedrock*
	Score	0	20	20	5	5	10
Velocity (@ 3661 cfs)		*<15 cm/s*	*15-40cm/s*	*>40cm/s*			
	Score	20	10	0			
Shoreline Type		*None*	*Natural*	*Maintained*			
	Score	20	5	20			
Debris		*Absent*	*DA*	*A*	*B*	*C*	
	Score	5	10	10	15	20	

Notes:
1. Natural shorelines received lower scores than maintained shorelines because the tree canopy common in natural shorelines overhangs the river and can reduce light available to aquatic vegetation.
2. Debris type is defined in the HD Report.

The model was run multiple times to assess the sensitivity of the input parameters:

- One model run using all parameters;
- Five model runs with one parameter removed each time (e.g., the full model without velocity); and
- Five model runs using a single parameter each time (e.g., velocity only).

When the model was run with a subset of parameters, the resulting model score was normalized by the maximum possible score to be comparable to the full model. Therefore, when using a single variable, a final score of 5 would equal a normalized score of 25 (based on the equation [5/20] * 100 = 25).

A series of metrics was then used to assess the accuracy of each set of model predictions. Model scores were compared to the actual aquatic vegetation cover in each cell to determine the number of times the model predicted vegetation correctly. Multiple model score cut-off values were used (0, 40, 60, 70, and 80) to assess model prediction (e.g., for a cut-off value of 40, no cells with a model score of 40 or less should have aquatic vegetation). These tests assessed the following:

- Percent correct;
- Percent of false negatives – model score is less than or equal to the cutoff value and aquatic vegetation cover is greater than 0 %; and
- Percent of false positives – model score is greater than the cutoff value and there is no aquatic vegetation cover.

The objective of this series of tests was to find the simplest model without sacrificing performance, based primarily on the percentage of correct predictions.

Based on the output of these tests (see Figures D-1 through D-11 in Exhibit D), water depth alone emerged as the simplest and most accurate predictor of the presence of aquatic vegetation (i.e., the prediction was not improved by adding other parameters). Cartographic output of the model results using only water depth is shown on Figures 2-1 through 2-5. Based on the analyses and mapping, the model predicts (with 80% accuracy) where aquatic vegetation does not or cannot grow in the Upper Hudson River (i.e., there are few areas with low model scores that are currently vegetated). The model also accurately predicts where "potential" aquatic vegetation bed habitat occurs. However, some of the "potential" habitat is currently unvegetated and the model does not predict which of these "potential" beds will ultimately support aquatic vegetation. The results of the model have been used in the habitat decision criteria to determine whether specific areas that supported aquatic vegetation before dredging will be planted as part of habitat replacement and reconstruction (see Section 3.2).

2.4.2 Shoreline

To the extent that maintained shoreline is impacted by remedial activities, it will be replaced and/or reconstructed to pre-dredging conditions to the extent feasible, given the constraints of meeting remedial performance standards. As such, a model for maintained shoreline was not developed. A model was developed for natural shoreline replacement and reconstruction based on river velocity. River velocities will be used to determine the backfill material type that will be placed in a specific area. For areas where the river flow velocity is less than 1.5 feet per second (ft/s), backfill will consist of Type 1 material (medium sand). In such areas, topsoil material may also be used as part of the planting specifications. For areas where the river flow velocity is greater than 1.5 ft/s, backfill will consist of Type 2 material (fine gravel).

2.4.3 Riverine Fringing Wetlands

A model for riverine fringing wetland replacement and reconstruction was developed based on three controlling factors: elevation, inundation period, and river velocity. Daily water elevation data collected at the locks along the Upper Hudson River by the New York State Canal Corporation (NYSCC) were used to calculate the average inundation period during the growing season (May 30 through September 30 for Washington, Warren and Saratoga Counties) for the riverine fringing wetlands in the project area. Data were available from 2001 through 2003 from the NYSCC. The elevation at field-collected data points for the wetland/open water interface, water/land interface, and wetland/upland interface were compared to the NYSCC water elevation data to determine the number of days each wetland location was inundated. The average number of days that all wetland points within that pool were inundated was used to determine the average inundation period (Table 2-11). Table 2-11 also shows the average maximum and average minimum daily water elevations during the 2001 through 2003 period.

Table 2-11 – Water Levels and Inundation Period for Riverine Fringing Wetlands in the Upper Hudson River

River Reach (River Section)	Average Inundation Period (days)	Average Minimum Water Level (feet)[1]	Average Maximum Water Level (feet)
Thompson Island Pool (RS1)	51.33	117.78	121.93
Fort Miller Dam Pool (RS2)	41.87	114.78	118.93
Northumberland Pool (RS3)	58.12	102.85	104.85

Note:

1. River water surface elevation, relative to North American Vertical Datum (NAVD) 1988.

In addition to the hydrological information (inundation period and water level), current velocity was also included in the model. Under present conditions, riverine fringing wetlands occur in areas where current velocity exceeds 1.5 ft/s. These riverine fringing wetlands will be replaced at their existing locations if feasible given the constraints of the remedy. However, for habitat replacement and reconstruction, the model specifies that current velocity must be less than 1.5 ft/s so that finer-grained material used as backfill will be stable under the 2-year event. Thus, if replacement or reconstruction of riverine fringing wetlands is needed in areas other than where they currently exist, those areas must have current velocities less than 1.5 ft/s (during a 2-year flood event) and water elevation between 117.78 and 121.93 feet for an average of 51 days during the growing season.

3. Design

3.1 Design Criteria for Habitat Replacement and Reconstruction Program

One objective of the HDA program was to collect data at both target and reference areas to establish a range of habitat-specific parameters in Upper Hudson River habitats prior to dredging. As discussed above, data collected from any area of the Upper Hudson River prior to dredging are considered part of reference conditions. From the full suite of parameters, several key parameters were used as the primary design criteria to identify areas for habitat-specific replacement and reconstruction. The key design criteria consist of:

- Presence of riverine fringing wetlands;
- River velocity;
- Water depth; and
- Current aquatic vegetation beds.

Additionally, the aquatic vegetation model described in Section 2.4.1 was used to further aid in identifying areas for replacement or reconstruction of aquatic vegetation beds. The key design criteria and aquatic vegetation model have been used in a decision matrix for arriving at a specific approach in the reconstruction or replacement of habitat types.

3.2 Habitat Decision Matrix

A habitat decision matrix has been developed as part of Final Design to provide criteria for determining the type of backfill and habitat for the various types of dredged areas. This decision matrix, presented in Figure 3-1, uses each of the key design criteria to determine spatially where habitat-specific designs will be applied. The decision matrix is designed for use once dredging and capping have been completed. Design criteria and the habitat models (described in Section 2.4 of this Phase 1 AM Plan) were used in the decision matrix as follows:

- <u>Presence of Riverine Fringing Wetlands</u>. Riverine fringing wetlands affected by the remediation will be replaced at their current locations, to the extent practicable and appropriate consistent with the remedy. For locations where it is not practicable to replace the wetland in its original location, and where it is determined appropriate by EPA to do so, additional mitigation will be conducted in other dredged areas with post-dredging conditions favorable for construction of riverine fringing wetlands.

- River Velocity. The shear-stress analysis for the 2-year flood event (Attachment H of the Phase 1 Intermediate Design Report) was used to determine the specifications for material that would be stable under the 2-year flood. For a flow velocity of 1.5 ft/s or less, backfill material of Type 1 (medium sand), Type 2 (fine gravel), or Type 3 (Type 1 material amended with organics) can be used. When flow velocities exceed 1.5 ft/s, only Type 2 material can be used. When flow velocities are less than 1.5 ft/s, the selection of backfill material is based on water depth (specifically whether the area is above or below the photic zone) and other parameters related to habitat type. In areas identified for active planting or natural recolonization, Type 3 material will be used. All reconstructed riverine fringing wetlands will use Type 1 backfill (with topsoil material added as needed for planting).

- Water Depth. In areas less than 9 feet deep (post-dredging, using average summer flow) that are designated to be aquatic vegetation beds, Type 3 material will be used in areas where river velocity is less than 1.5 ft/s, and Type 2 material will be used in areas where river velocity is greater than 1.5 ft/s. In areas less than 2 feet deep, riverine fringing wetlands will be targeted if those areas supported riverine fringing wetlands prior to dredging (if feasible given the constraints of the remedy), as discussed above. Type 1 material amended with topsoil (if needed) will be used for riverine fringing wetland construction. For shoreline areas, Type 2 material will be used in areas where river velocities exceed 1.5 ft/s, and Type 1 material will be used when river velocities are less than 1.5 ft/s.

- Currently Vegetated Areas. Areas where aquatic vegetation beds exist prior to dredging may be more likely to support aquatic vegetation in the post-dredging environment if controlling factors such as depth, substrate, and velocity are appropriate. Post-dredging areas between 2 and 9 feet deep that supported aquatic vegetation prior to dredging are designated for planting or recolonization of aquatic vegetation beds. (This criterion applies to areas other than riverine fringing wetlands, which are discussed above.)

- Aquatic Vegetation Model. The aquatic vegetation model incorporates parameters related to the pre-remediation distribution of aquatic vegetation to identify those areas with conditions that are suitable for supporting aquatic vegetation. The output scores of the model based on pre-dredging conditions have been used in two ways to identify areas that will be designated for aquatic vegetation or for raising into the photic zone. First, for areas that have river velocity less than 1.5 ft/s and are between 2 and 9 feet deep (after dredging or capping) but were not previously vegetated, the model will be used to identify those areas that are nonetheless suitable for aquatic vegetation. Second, for areas that have river velocity less than 1.5 ft/s and water depth greater than 9 feet (after dredging or capping) and that were previously vegetated, the model results will be used to identify areas suitable for raising into the photic zone. If such areas have a model score that indicates that the areas had suitable conditions for aquatic vegetation prior to dredging, they will be raised into the photic zone and designated for aquatic vegetation. For areas that require more than one foot of backfill to be returned to the photic zone (see description below), Type 3 material will be used for the top layer (12 inches) and the remainder of the backfill may be composed of Type 1, Type 2, or Type 3 material.

These design criteria and the decision matrix shown on Figure 3-1 were used to produce a series of maps that illustrate the spatial distribution of reconstructed or replaced habitats. Figures 3-2 and 3-3 show the habitat replacement and reconstruction design in the Rogers Island area and Griffin Island area, respectively. Areas designated as unconsolidated river bottom habitat are shown based on backfill material type (Type 1 or Type 2). Areas designated as aquatic vegetation beds are shown based on material type (Type 2 or Type 3) and vegetation source (active planting or natural recolonization [passive technique]). Areas designated for riverine fringing wetlands are shown at the locations where they currently exist. All riverine fringing wetlands will be planted and seeded. The figures also show those locations where aquatic vegetation beds exist in areas that are currently less than 8 feet deep (based on long-term average summer flow conditions) but will be greater than 8 feet deep following dredging (hatched areas). At these locations, additional backfill material will be used to return the area to within the photic zone (defined as 8 feet deep for the design) to facilitate the recolonization or planting of aquatic vegetation. This approach implements the provision in the *Critical Phase 1 Design Elements* (Attachment A to the Statement of Work for the CD [EPA/GE 2005]) that additional backfill up to 15% of the total 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 in dredged areas where such additional backfill is necessary to support aquatic vegetation.

Figures 3-2 and 3-3 were used to develop the habitat construction drawings as described in Section 3.4 below.

3.3 Aggregation Criteria

Following development of the base maps indicating the locations of the habitat-specific designs (Figures 3-2 and 3-3), those maps were modified based on condition-specific "aggregation" criteria to reduce the number of small, isolated areas that would be difficult to construct and/or manage. The aggregation criteria were as follows:

1. Where areas designated for aquatic vegetation via natural recolonization were less than 0.025 acre and not located adjacent to riverine fringing wetlands or areas of aquatic vegetation planting, these areas were included in the largest surrounding habitat type.
2. Where areas designated for aquatic vegetation via natural recolonization were less than 0.025 acre and located upstream of and adjacent to aquatic vegetation planting areas, these areas were changed to aquatic vegetation planting areas.
3. Where unconsolidated river bottom areas were less than 0.025 acre and located within areas identified for natural recolonization or planting of aquatic vegetation, these areas were included with the largest surrounding habitat type.
4. Where natural recolonization areas less than 0.025 acre did not have an apparent upriver colonization source (as either a reconstructed or reference aquatic vegetation bed), the areas were included in the largest surrounding habitat type.
5. Where unconsolidated river bottom with Type 1 backfill material was less than 0.025 acre, between 2 and 9 feet deep, and bordered by areas planned for planting aquatic vegetation, those areas were included in the aquatic vegetation planting areas.

3.4 Habitat Construction Drawings and Specification

Figures 3-2 and 3-3 were modified based on the condition-specific "aggregation" criteria described in Subsection 3.3 to produce the Phase 1 Final Design Habitat Construction Areas (Figures 3-4 through 3-6). Table 3-1 shows the resulting acreages associated with each of the habitat areas based on Figures 3-4 through 3-6. These areas were transferred into CADD and used to produce the Habitat Construction Contract Drawings, which are appended to the Phase 1 FDR. These habitat drawings depict only those areas where active planting of aquatic vegetation beds, riverine fringing wetlands, and shoreline habitats will occur. Placement of backfill and other habitat-related work, such as shoreline stabilization, will be completed as part of the dredging and backfilling/capping operations and are not shown on the Habitat Construction Contract Drawings.

Table 3-1 – Habitat Design Specifications and Estimated Acreages or Linear Feet

Design Specification	Area or Length	Units
Type 1 - RFW Planting	1.9	acre
Type 3 - SAV Natural Recolonization	0.5	acre
Type 3 - SAV Planting	7.1	acre
Type 1 – UCB	4.1	acre
Type 2 - SAV Natural Recolonization	14.2	acre
Type 2 - SAV Planting	1.6	acre
Type 2 – UCB	63.8	acre
Total	**93.3**	**acre**
Moderate Energy Shoreline	3,775	lf
Low Energy Shoreline	7,093	lf
Lowest Energy Shoreline	2,068	lf
Total	**12,396**	**lf**

Notes:
1. The areas and lengths shown in this table are approximate. Final acreages and lengths cannot be determined until dredging has been completed and final elevations have been determined after placement of backfill or caps. Capping will only occur if necessary in order to meet the Engineering Performance Standards (EPA, 2004).
2. Moderate energy shorelines are where river velocity is greater than 1.5 ft/s at the shoreline. Low energy shorelines are where the river velocity is less than 1.5 ft/s at the shoreline. Lowest energy shorelines are where the river velocity is less than 1.5 ft/s at the shoreline and a riverine fringing wetland is shown on the drawings.

The Habitat Construction Contract Drawings also provide detailed drawings related to planting (including species selected and planting interval) and shoreline treatments, as described below.

The aquatic vegetation bed details show planting on 2-foot centers over approximately one-third of the area designated as aquatic vegetation beds, consistent with the acreage and spacing interval described in Exhibit F of the Feasibility Study (FS) (EPA, 2000). The species selected for planting are wild celery (*Vallisneria americana*), American pondweed (*Potamogeton nodosus*), and white water lily (*Nymphaea odorata*). These species commonly occur (with wild celery dominating the aquatic vegetation beds sampled to date) and were selected to create specific components of aquatic vegetation bed structure: meadow (wild celery), canopy (American pondweed), and floating leaved (water lily). All species will be planted in those areas where Type 3 backfill material will be used. Targeted test-plantings will also occur in areas that receive Type 2 backfill material (Table 3-1).

All other areas that currently support aquatic vegetation beds and will be less than 9 feet deep post-dredging are shown as natural recolonization areas on the plans. These areas are expected to silt in over time to allow for natural recolonization of the area by desirable species. Natural recolonization of freshwater systems by aquatic vegetation is well documented (e.g., Lauridsen et al., 1994; Rybicki et al., 2001; Harwell and Havens, 2003). The ability of plants to colonize is a function of the mechanisms for spread, sediment conditions, current velocity, light and temperature. Suitable substrate conditions (within the range of those currently found in aquatic vegetation beds) will be provided by the Type 2 and Type 3 backfill material. Mechanisms of spread include rhizome growth, plant fragmentation, seed dispersal, and seed bank emergence (Spencer et al., 2000; Crossle and Brock, 2002; Liu et al., 2005). The most often cited mechanisms for colonization has been vegetative (e.g., rhizome) growth, and to a lesser extent fragment transport and establishment. Seed banks are also a source of recruitment, especially in areas where lowered water levels has caused exposure and drying of the sediments (e.g., Harwell and Havens, 2003). Light is critical to the spread of aquatic vegetation, and has been shown to explain wide variation in its distribution through time (e.g., Coops and Doef, 1996; Kraemer et al., 1999; Rybicki et al., 2001; Findlay et al., 2006). Current velocities can affect colonization (e.g., Gantes and Caro, 2001; Madsen et al., 2001), though aquatic macrophytes can exist in areas with current velocities up to 3.29 ft/s (Chambers et al., 1991). Temperature is often warmer in shallow low velocity zones during the growing season in temperate systems, which can facilitate seed germination and initial plant growth. Natural colonization of aquatic vegetation in the project areas will depend on the above factors, in particular the presence of vegetation upstream of the colonization areas, as well as adequate light. Mechanisms of spread will predictably be initially by belowground (i.e., vegetative) reproduction and fragmentation, followed by seed dispersal and germination. Habitat assessment data and the aquatic vegetation model have shown that current velocities and light will be within acceptable ranges over the areas planned for natural recolonization.

The majority of natural recolonization areas (summarized in Table 3.1) are located where river velocities exceed 1.5 ft/s and are therefore unlikely to be colonized by water chestnut (*Trapa natans*) and Eurasian watermilfoil (*Myriophyllum spicatum*) which prefer still or slow moving water.

The riverine fringing wetland details show the species for each wetland planting zone. The species were selected based on their occurrence in the riverine fringing wetlands assessed to date. Riverine fringing wetland plants will be installed on 2-foot centers. Wetland seed mix will also be applied to areas with elevations between 118 and 119 feet.

Shoreline details are provided for moderate, low, and lowest energy areas (based on river velocities). Moderate energy shorelines are those where current velocities exceed 1.5 ft/s adjacent to the shoreline. Low energy shorelines are those where current velocity is less than 1.5 ft/s adjacent to the shoreline. Lowest energy shorelines are those where current velocity is less than 1.5 ft/s adjacent to the shoreline and where riverine fringing wetlands are planned. The shoreline details illustrate potential replacement and reconstruction treatments that could be used for areas above the 119-foot elevation. However, it is unlikely that areas above the 119-foot elevation will be affected by remedial activities. The majority of shoreline replacement and reconstruction will occur at elevations at or below 119 feet (i.e., areas below the water level during most of the year). Stabilization of these areas to minimize erosion is the primary consideration on which the design details are based. The stabilization measures for the lowest energy and low energy areas include both structural and vegetative methods.

3.5 Design Uncertainties

The decision matrix includes assumptions that introduce some degree of uncertainty in the design process. Specific points of uncertainty in the decision matrix include:

- River Velocity and Erosion Potential. As noted above, the shear stress analysis for the 2-year flood event predicts that flow velocities of 1.5 ft/s or less would permit the use of Type 1, Type 2, or Type 3 material, and that flow velocities exceeding 1.5 ft/s would require used of Type 2 material. The uncertainties associated with this analysis relate to the accuracy and precision of the predicted velocities for a particular location in the river. In the event that the post-dredging environment results in small areas where resulting velocities are different from those predicted, and an erosional effect influences habitat recovery, this effect will be identified as part of adaptive management, and corrected if feasible.

- Water Depth. Minimum (< 2-foot-depth) and maximum (> 9-foot-depth) water depths have been selected to define a range for the reconstruction of aquatic vegetation beds. The majority of aquatic vegetation beds (70%, based on data collected in the HDA program) are found within this depth range. Conditions of the recovering river following dredging may require the selection of a broader or narrower depth range.

- Previously Vegetated Areas. An assumption is made in the design matrix that where vegetation exists prior to dredging, the same area will likely be more suitable for vegetation to become reestablished following dredging, assuming additional post-dredging conditions such as depth, substrate, and river velocity are appropriate. Uncertainty exists because other factors, such as herbivory, propagule transport and germination rates, currently not taken into consideration in the decision matrix, may influence the ability of an area to support vegetation in the post-remediation environment.

- Aquatic Vegetation Model. The aquatic vegetation model is primarily based on the fact that the distribution of existing aquatic vegetation beds is largely related to depth. It does not include factors specifically related to seed and tuber dispersal, germination percentages (for seeds and tubers), or herbivory.

4. Post-Backfill/Capping Activities

Data obtained to date provide the foundation for habitat replacement and reconstruction and adaptive management. As described in Section 2, various biological and physical measurements have been made, and FCIs have been developed from these data. This section describes the activities that will be conducted following completion of the dredging and backfilling or capping in Phase 1 – namely, the reviews to be undertaken within the first year after backfilling/capping, the longer-term adaptive management evaluations and application of success criteria, future data collection, and potential adaptive responses. Capping will only occur if necessary to meet the Engineering Performance Standards (EPA, 2004).

4.1 Short-Term Assessment of Post- Backfilling/Capping "As Built" Habitat Conditions

One must first determine that the "as built" habitats after backfilling/capping reflect those anticipated in the habitat designs prepared prior to dredging. This is a short-term (within the first year following dredging) and small-scale (at the level of the dredge areas) evaluation of field conditions against design specifications. This step is crucial to the success of habitat replacement and reconstruction, as post-backfilling/capping conditions at each location determine the potential for the occurrence of that habitat type and thus the potential for achieving habitat success.

The Phase 1 Project Specifications and Contract Drawings appended to the Phase 1 FDR show the habitats proposed for replacement and reconstruction by dredge area. Plans and specifications were prepared on the basis of anticipated post-backfilling/capping conditions according to the logic flow presented in Section 3.

After dredging, as part of the certification process, the actual (or as built) physical habitat features of each certification unit will be compared with design drawings. If actual conditions vary from pre-dredge projections, action appropriate to each habitat category will be taken and reflected on CU Certification Form 3 (included in Attachment F to the Statement of Work for the CD). For each habitat, rectification of actual and projected conditions when there is a variance will comprise the following:

- Shorelines – For shoreline habitats, water depth and erosion potential will be recorded. If either of these parameters varies from pre-dredging assumptions to a degree that would impede establishing the planned shoreline condition, shoreline specifications for that location will be revised to the appropriate shoreline Contract Drawing (Drawings H-0021 through H-0023 in Appendix 5 to the Phase 1 FDR).

- Riverine Fringing Wetlands – The goal of the habitat program for riverine fringing wetlands is to replace the functions provided by those wetlands (i.e., no net loss of functions). This 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 a wetland in its original location, and EPA agrees with that determination, additional mitigation activities will be undertaken in other dredge areas to replace the lost functions of that wetland. Post-dredging or capping slope, substrate, and elevation will be recorded at the location of each wetland. If it is determined that a particular wetland must be relocated, this conclusion will be recorded on CU Certification Form 3. The Riverine Fringing Wetland Planting Specification Sheet (Drawing H-0021 in Appendix 5 to the Phase 1 FDR) will be applied where it is deemed appropriate to do so by GE and EPA.

- Aquatic Vegetation Beds – Water depth and substrate condition will be recorded. If these parameters vary from pre-dredging assumptions to a degree that would preclude establishment of aquatic vegetation, habitat specifications for that location will be revised to unconsolidated river bottom.

4.2 Adaptive Management Evaluations

After verifying that the as-built conditions meet the habitat-specific design specifications, the longer-term (multi-year) and larger-scale (at the level of the river reach) adaptive management evaluation will go forward.

4.2.1 Tiered Approach

Figure 1-3 shows adaptive management in the form of a tiered decision tree reflecting a hierarchical process. Tier 1 consists of the specific parameters for characterizing physical and biological conditions in each habitat category (listed below). Tier 2 consists of the FCIs supplemented as necessary with HSIs. Tier 3 consists of direct measures of relevant habitat functions (e.g., presence and abundance of fish and/or wildlife species). In accordance with the OM&M Scope, the "primary" success criteria for Phase 1 will be based on both Tier 1 and Tier 2 – i.e., both Tier 1 and Tier 2 must meet the success criteria. Each of these tiers is described further below.

Tier 1 consists of specific parameters for characterizing physical and biological conditions in the pertinent habitat category. Numerous such parameters are listed in Section 4.2.2 of the OM&M Scope as the parameters to be sampled in the OM&M program and used in the development of the FCI and HSI models. However, the selected habitat-specific parameters specified on page 4-10 of the OM&M Scope for use as primary success criteria are the ones that will be used in Tier 1 of the evaluation. They are:

- Unconsolidated river bottom:
  - substrate type (i.e., inorganic substrate from Table A.2 of the HDA Work Plan).

- Aquatic vegetation beds:
  - shoot density;
  - percent cover; and
  - plant species composition.

- Shoreline:
  - bank vegetation protection;
  - bank stability; and
  - plant species composition and percent cover (by vegetation strata).

- Riverine fringing wetlands:
  - percent cover; and
  - plant species composition.

Tier 2 consists of the FCIs, supplemented by the HSIs if the FCIs for fish and wildlife functions are not met. As discussed below, these are linked to the Tier 1 criteria since both are “primary” success criteria. The FCIs and HSIs that comprise Tier 2 are described in Section 2.

Tier 3 comprises direct measurements of relevant habitat functions (for example, presence of fish and/or wildlife species) and may be used as “secondary” success criteria. Such Tier 3 information will only be used if the primary success criteria (based on both Tier 1 and Tier 2) are not being met. To the degree that such secondary information is required, data obtained under existing programs (such as the BMP) will be used as appropriate. If necessary, detailed specifications for additional secondary data collection will be developed and submitted to

EPA, and additional data that are agreed upon by GE and EPA will be collected under the OM&M program as appropriate.

Each year after the completion of Phase 1 dredging, a monitoring program will be implemented as set out in the OM&M Scope. Data from each habitat type will be compiled and compared with habitat-specific success criteria (presented in a narrative form in the following subsections, and developed quantitatively beginning with data collected in the year following Phase 1 dredging). Success will be evaluated according to the tiered methodology – first against Tier 1 criteria (the specific physical and biological parameters listed above), then against Tier 2 criteria (FCIs), and then (if necessary) against Tier 3 criteria (data on biological communities or other direct measures of habitat functions). Tier 1 and Tier 2 evaluations are linked in that the specific parameters (Tier 1) and the FCIs (Tier 2) must both meet the success criteria for the Phase 1 habitat replacement and reconstruction areas to be considered successful. However, if the specific parameters meet the success criteria but the FCI related to fish or wildlife for that habitat does not, supplemental data provided by the HSIs will be used to assess the success of that function and to determine whether habitat-specific adaptive adjustments may be warranted.

4.2.2 Spatial and Temporal Evaluation

Because the location and extent of all habitats following remediation cannot be fully and accurately predicted, the mix of habitats will be evaluated on a scale (i.e., river reach) that acknowledges this uncertainty but will result in a landscape of habitats that will eventually be sustainable by habitat-forming processes. To document the mix of habitats and functional equivalence within each habitat category, evaluations are appropriately conducted at the spatial scale of the river reach and at a time scale of years.[1] Accordingly, the success criteria described below would be applied at a river reach scale, such that all target areas within a river reach would be evaluated against the reference areas. As noted above, the Phase 1 target areas are all within a single river reach.

The time scale for return of habitat functions in the replacement and reconstruction areas cannot be precisely determined before dredging. In general, it is to be expected that the habitat complex at the scale of the river reach could take years to return to functional equivalence with reference areas.

[1] The OM&M Scope states (page 4-12) that "[i]t is anticipated that habitats will be well established within a period of 20 years or less, and considerably shorter periods for some habitat types or areas."

It is expected that, within 5 years of Phase 1 dredging, habitats in all categories will show positive signs of recovery. Specifically, the majority of measurements of physical and biological parameters and the majority of calculated FCI and/or HSI values are expected to be trending toward the range of those in reference areas. Data and indices will be plotted against time starting in the second year after Phase 1 dredging. Changes over time will be a consideration for decision-making regarding the need for and type of adaptive responses. Recovery trajectories will be presented in each annual *Adaptive Management Report* beginning in the first year after backfilling/capping.

4.3 Narrative Success Criteria

4.3.1 General Criterion

Adaptive management for the Phase 1 habitat replacement and reconstruction includes a broad array of indicators based on diverse data. One suite of indicators, the FCIs and HSIs, are scaled for comparative purposes, and both FCIs and HSIs are derived from arithmetic combinations of measurement and categorical data and of data with differing underlying distributions and variances. Under such circumstances, an effective approach to developing and applying comparative success criteria is to rely on simple and robust descriptive statistics. Such an approach has been the foundation of successful applications of adaptive management for other large-scale habitat programs (e.g., Weinstein et al., 1997; Thom et al., 2002). Criteria based on descriptive statistics allow consideration of the overall distribution of habitat functions and the range of habitat conditions in reference and target areas, as specified in the OM&M Scope. Such an approach also allows a single narrative criterion (if applicable) to apply to multiple parameters, which would otherwise each require a distinct criterion devised to accommodate specific aspects of scale, input variable types, measurement units, and index derivation. Criteria based on descriptive statistics correspondingly have the virtue of being easily understood and interpreted by all parties, maximizing likelihood of agreement on decisions regarding the need for and type of response or corrective measures, an important aspect of adaptive management itself.

The evaluation for success is to be made for each habitat type, and it is expected that success criteria will not be biased to the high or low ends of the bounds of expectation; rather, they will reflect overlapping distributions of habitat functions in target and reference areas. An appropriate, generally applicable narrative success criterion that is consistent with these principles is as follows: *For data aggregated at the river reach for each habitat type, success is achieved when 50% of the target station values exceed the 25th percentile of the reference data.* This criterion – referred to as the "25/50" criterion – is generally applicable. It can be used for comparing FCIs and specific habitat physical and biological variables. This criterion provides the threshold for triggering adaptive management responses (see Section 4.5 of this Phase 1 AM Plan). It establishes distributional overlap, and sets a "floor" reflecting the OM&M Scope requirement to avoid "low end" bias, and allows the distributions to range freely to the upper ends of their distributions. See Exhibit C for additional details on the derivation of this criterion.

The 25/50 criterion will be applied separately to evaluate success for each habitat category (except riverine fringing wetlands, discussed below). All values of each variable listed for each such habitat in Section 4.2.1 of this Phase 1 AM Plan will be weighted equally and included in the evaluation. The habitat-specific data from target sample locations will be compared with the habitat-specific reference area data. Similar comparisons will also be made for the FCIs, supplemented, if necessary, with the HSIs to assess the fish and wildlife function (as discussed above) to the extent that such HSIs are amenable to the 25/50 criterion. Data will be collected and comparisons made annually. Following collection of post-dredging reference and target station data,[2] the 25th percentile for each parameter and FCI (and HSI if used) will be enumerated from the reference data set and compared to data from the target stations to determine if 50% of the target stations exceed the 25th percentile of the reference data.

When the 25/50 success criterion listed above is achieved for two consecutive years or three out of five years for the habitat-specific parameters listed in Section 4.2.1 and the FCIs (supplemented, if necessary, with the HSIs), monitoring will cease and the habitat replacement and reconstruction will be considered successful for that habitat type in that river reach.

If success is not achieved based on the specific parameters listed in Section 4.2.1 and the FCIs (supplemented by HSIs), secondary information regarding the abundance of fish and wildlife species from available data sets may be examined. If available, abundance data amenable to application of the 25/50 criterion will be compared; such data would necessarily include multiple monitoring points with comparable density estimates of the same species within reference and dredge areas. If adequate data are available and these data indicate that reference and dredge areas are comparable and that this condition is likely to be sustainable, the habitat replacement and reconstruction will be considered successful for that habitat type in that river reach. (For purposes of this evaluation, sustainability will be evaluated in the same way as described above – i.e., achieving the success

[2] As described in the HD Report (BBL and Exponent, 2005a), the accuracy of aquatic vegetation bed delineations is about 72% based on ground-truthing. If mapping accuracy is equivalent at stations in reference and target areas (a reasonable assumption, as identical methods were used), mapping accuracy should not bias the adaptive management comparisons.

criterion for 2 consecutive years or 3 out of 5 years). If adequate data are not available, EPA and GE will discuss what additional data collection might be appropriate under the OM&M program.

When neither primary nor secondary data indicate habitat replacement and reconstruction success, adaptive response measures will be evaluated.

4.3.2 Specific Criteria for Riverine Fringing Wetlands

In River Section 1, the total area of riverine fringing wetland habitat available for sampling is too small to support the number of samples required for confident application of the 25/50 criterion (see analysis in Exhibit C). To account for this, narrative success criteria for this habitat consist of simple parameter-specific thresholds for:

- Emergent macrophyte stem density;
- Emergent macrophyte percent cover; and
- Emergent macrophyte diversity (proportion of invasive species).

The success criteria will still be based on the 25/50 comparison, but the comparison will be made at the quadrat level rather than station level.

When the success criteria listed above are met for 2 consecutive years or 3 out of 5 years, the replacement of the riverine fringing wetlands will be considered successful.

4.4 Data Collection in Reference and Target Areas

Data collection for Phase 1 adaptive management will begin in the first field season after Phase 1 has been implemented. These data will be collected at both target (dredged) and reference stations using the same methodologies. The locations of these stations, as well as sample numbers and distribution, and methodologies, will be the same as those used for the pre-dredging data collected in Phase 1 dredge areas and associated reference areas, as defined in the SHAWP (see Figure A-1 through A-20), unless GE proposes changes to those items to EPA prior to data collection.

A basic tenet of adaptive management is that collecting information and learning about the system while the program is underway are continuous activities, and that revisions and modifications should be made as suggested by project needs and findings. When monitoring data indicate that success criteria are not being met, the first response is to evaluate existing data and determine if additional data collection can help address the issue. To accommodate this aspect of adaptive management, ongoing review and documentation are built into the program. Habitat replacement and reconstruction monitoring in the Phase 1 areas will be conducted annually. In each year after the completion of Phase 1 dredging, an *Adaptive Management Report* will be prepared, assessing data collection, monitoring methods, and changes over time in success comparisons for each habitat category. Habitat recovery trajectories will be evaluated as changes in physical and biological parameters and FCIs (as well as HSIs if relevant) in target areas relative to reference areas over time. Each year's *Adaptive Management Report* will include recommendations for revisions to the data collection program for the next year (as appropriate). Each year's report will also document areas that meet success criteria, and make recommendations for ceasing monitoring in successful habitats, if appropriate.

4.5 Adaptive Response

Under the adaptive management approach, there are three basic alternatives if the system is not meeting its performance or success criteria:

1. No action – do nothing and wait to see if the system will eventually meet its criteria;

2. Do something – implement an action (described below) that will help the recovery process, and is based on information from the site studies; or

3. Change the goal and/or success criteria – when monitoring has shown that the condition(s) is unlikely to meet the performance or success criteria due to unexpected circumstances or inaccuracies in the initial information. Any change to success criteria must be agreed to by EPA and GE.

Adaptive management responses will be recommended as an outcome of the data evaluation and decision process based on each year's data and the accumulated findings over time, as reasonable and necessary. For example, it is reasonable to assume that success will not be achieved in the first year after habitat construction. In that instance, adaptive responses will likely be unnecessary. Similarly, if monitoring results demonstrate that reconstructed habitats are on a trajectory towards success, continued monitoring and assessment, rather than adaptive responses, would be recommended.

One possible response is additional information gathering, which includes continued monitoring without program revisions, continued monitoring under revised monitoring protocols, review of relevant literature, contact with scientists conducting applicable research on similar habitat programs, and consultation with relevant experts. Additional information-gathering responses may include, as appropriate, experiments to evaluate specific aspects of habitat recovery that are not currently addressed by monitoring data.

Natural engineering, by which the ecosystem itself optimizes its recovery, is fundamental to adaptive management. In some situations, natural engineering may not lead to success within the expected time frame. In such situations, active adaptive responses may be needed to enhance or accelerate the recovery process.

In the short term, if monitoring indicates that specific measures are necessary to prevent or halt specific problems such as bank slope failure where structural integrity is needed to support infrastructure or habitat, GE will implement such measures. In the longer term, adaptive adjustments may be necessary to support natural engineering. If monitoring data indicate that success criteria are not being met, the following steps, intended to maximize habitat recovery while minimizing human interference with natural engineering, will be used to evaluate whether an adaptive response(s) is required:

1. Examine available data, acknowledge and account for lag times following implementation, and determine if additional information is required.
2. Establish a plan for obtaining additional information if needed.
3. Implement additional data collection, if needed.
4. Examine the cumulative data set, including newly acquired information, and determine if a problem exists and a management response is needed. If a response is needed, go to Step 5. If no response is needed, go to Step 7.
5. Identify appropriate management response.
6. Implement management response.
7. Continue monitoring, and determine if habitat functional trajectory is improved.

The selection of appropriate actions will be based on the nature and extent of the identified problem(s) (e.g., shoot density in replaced or reconstructed aquatic vegetation beds is below that in reference beds), and may require additional information, continuation of monitoring, adjustment of site-specific goals (e.g., a portion of the site may no longer be suitable for aquatic vegetation and thus the goals for that area would need to be altered), or implementation of a field responses. Decisions regarding the need for adaptive responses, and a description of any response(s) will be documented in the annual *Adaptive Management Reports*. Adaptive response actions will not include placement or removal of backfill material or any alteration of bathymetric conditions.

Consistent with the OM&M Scope, adaptive adjustment measures (other than information analysis and minor field activities) will consist of the following field response actions, plus any additional actions that are agreed upon by GE and EPA, as appropriate for adaptive management, based on field experience:

- Bank stabilization measures, including placement of riprap or vegetated material to stabilize riverbanks. Favored measures will have both physical stabilization and habitat benefit. Examples include placement of natural or manufactured ("bio") logs, cobble, gravel, and protective or plant-growth matting. Regrading banks will only be considered if access agreements exist for the area in question.

- Invasive species management in replaced/reconstructed areas to maintain the extent of invasive species below specific levels (percent of a site). This field response action does not include the complete elimination of invasive species from replaced/reconstructed areas. An Invasive Species Management Plan is included as Exhibit E.

- Targeted plantings in aquatic vegetation beds, wetlands, and shoreline habitats. This field response action does not include complete replanting of a site unless the cause(s) for the initial failure of the plantings has been identified and corrected/controlled. Targeted planting will be undertaken only with non-invasive species and will be subject to EPA approval. Target plantings will occur within the planting windows specified in the designs. The amount of material replanted will not exceed 50% of the material initially installed at any site.

- Maintenance of habitat replacement/recolonization structures. This field response action is limited to the maintenance of boulder clusters or reefs (placed in unconsolidated river bottom habitat to provide structure for fish habitat**)** to ensure that they do not pose a hazard to navigation**.**

- Actions to respond to the impacts of unforeseen anthropogenic (i.e., non-natural) events. For example, if vessel groundings or unusually low water levels (e.g., due to maintenance activities on locks or hydrofacilities) reduce plant survival, targeted plantings may be needed.

5. Schedule and Reporting

As stated in the OM&M Scope, GE will submit annual *Adaptive Management Reports* to EPA by January 31 of each year following habitat reconstruction. Each report will present the habitat monitoring data collected during the prior calendar year(s), the results of the adaptive management evaluations (including trend analysis), and actions (if any) performed during that year. In addition, during the OM&M program, GE will provide the data from the habitat replacement and reconstruction monitoring program to EPA, inclusive of data files, shape files, and photodocumentation, in the monthly progress reports and database updates under the Consent Decree.

6. References

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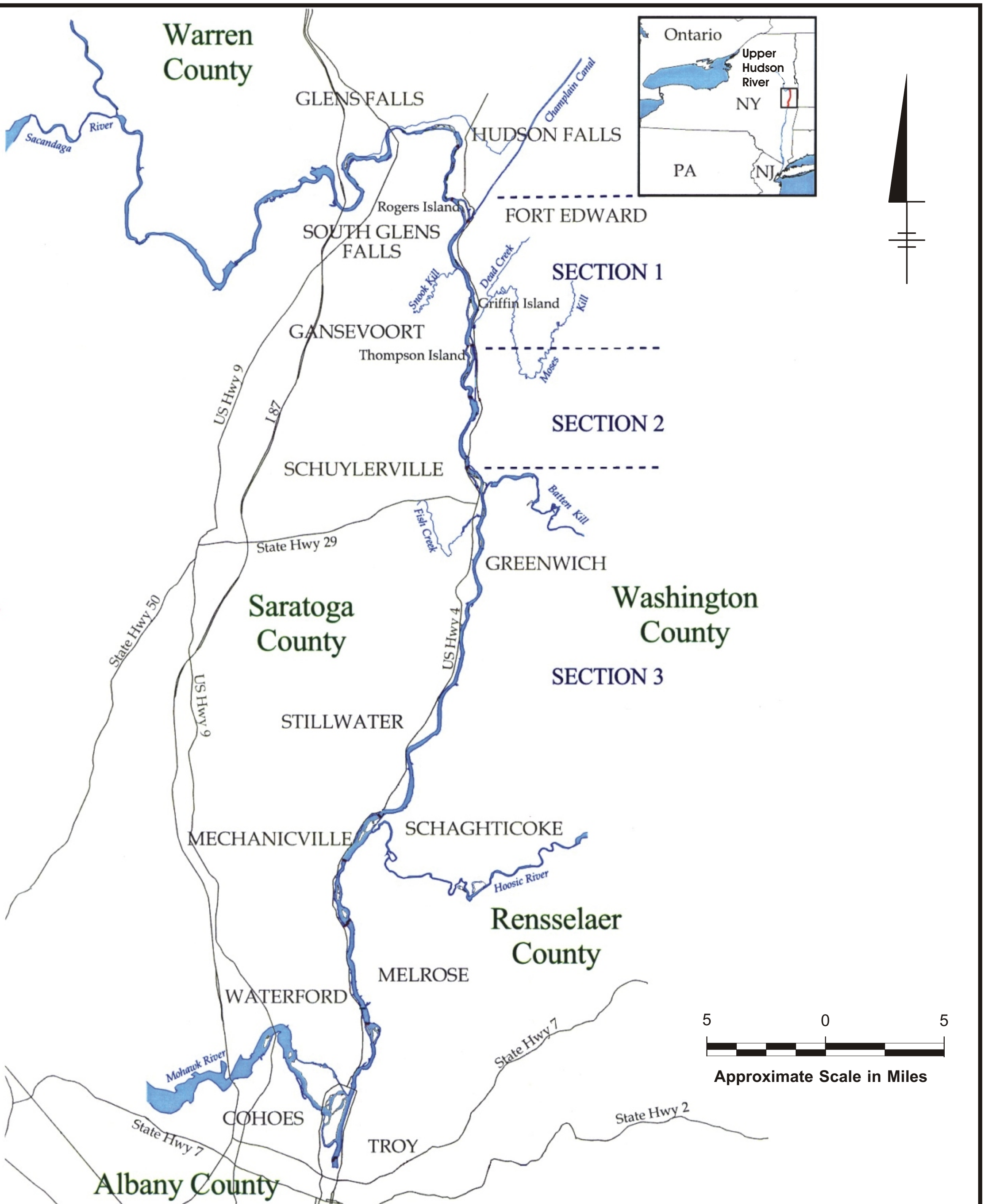
Figures



NOTES:
1. All locations are approximate.
2. Adapted from EPA Feasibility Study (December 2000).

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PHASE 1 ADAPTIVE MANAGEMENT PLAN

UPPER HUDSON RIVER

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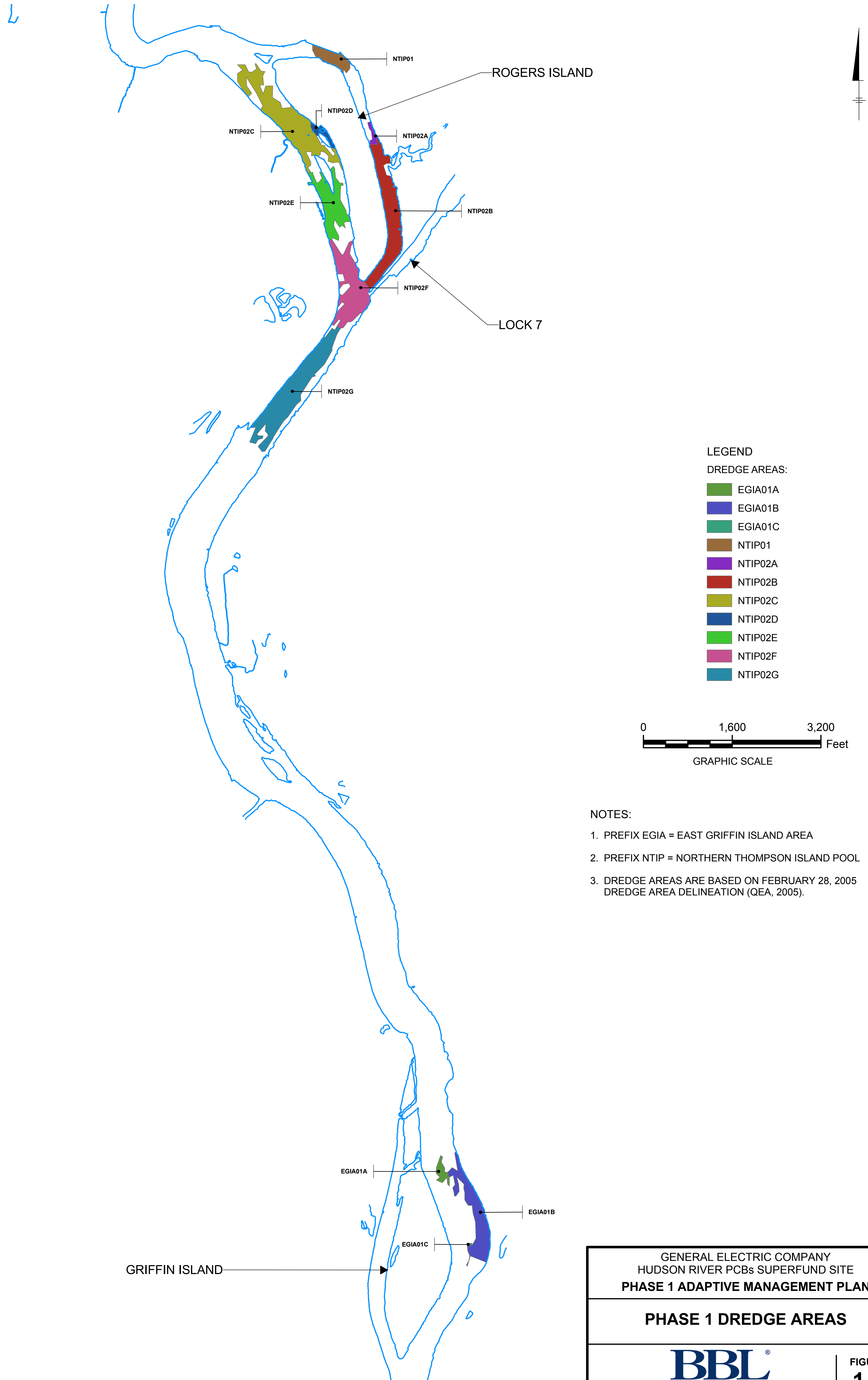
FIGURE 1-1



NOTES:

1. PREFIX EGIA = EAST GRIFFIN ISLAND AREA
2. PREFIX NTIP = NORTHERN THOMPSON ISLAND POOL
3. DREDGE AREAS ARE BASED ON FEBRUARY 28, 2005 DREDGE AREA DELINEATION (QEA, 2005).

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PHASE 1 ADAPTIVE MANAGEMENT PLAN

PHASE 1 DREDGE AREAS

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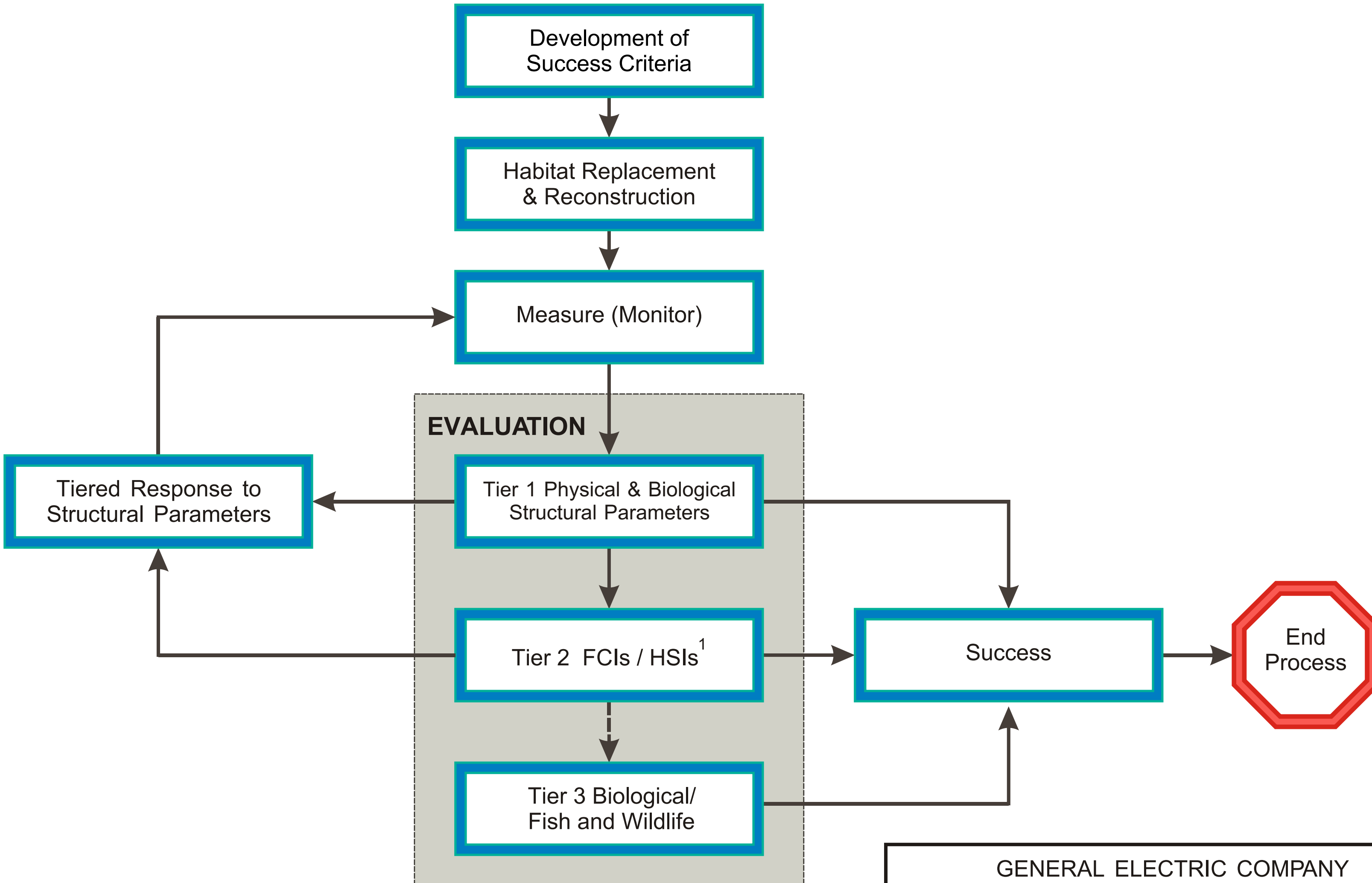
FIGURE
1-2

Adaptive Management Framework



NOTE:

1. HSIs will be used only if habitat-specific fish and wildlife FCIs are not met.

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PHASE 1 ADAPTIVE MANAGEMENT PLAN

SCHEMATIC OF TIERED ADAPTIVE MANAGEMENT PROCESS

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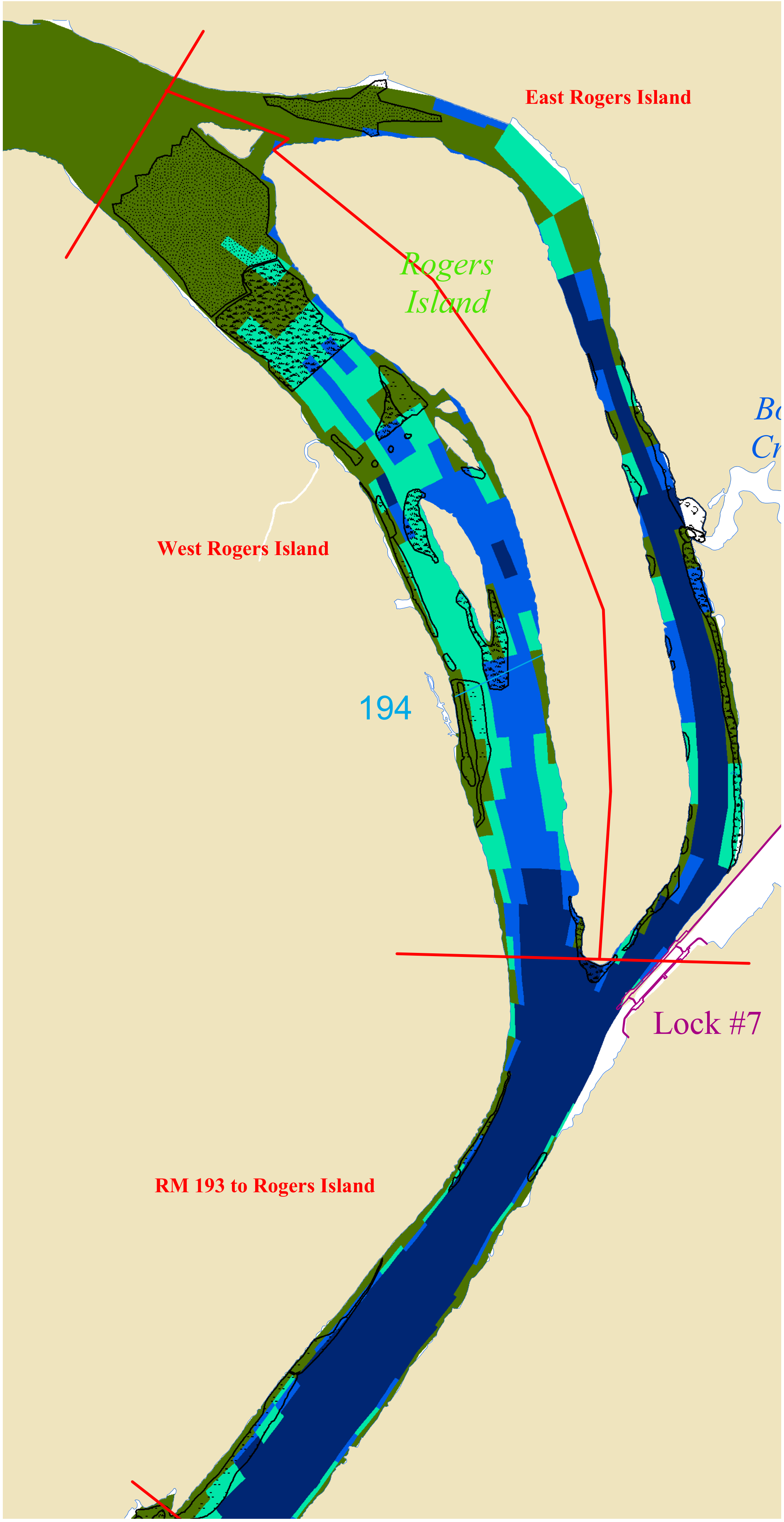
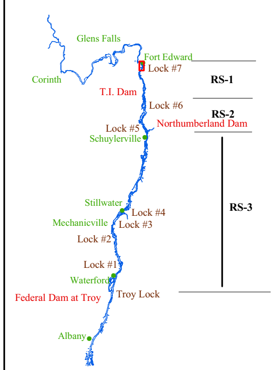
FIGURE
1-3



LOCATOR MAP OF THE UPPER HUDSON RIVER



GRAPHIC SCALE

0 300 600 Feet

LEGEND

- Shore Line
- River Miles
- Dams and Locks
- Land

2003 Habitat Survey

- SAV (0 - 25%)
- SAV (25 - 50%)
- SAV (50 - 75%)
- SAV (75 - 100%)
- SAV (unclassified)
- Trapa

SAV Model Score

- 0 - 40
- 41 - 60
- 61 - 70
- 71 - 80
- 81 - 90
- 91 - 100
- SAV Model Boundaries

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Figure 2.1
River Mile 193 to 194

March 2006.

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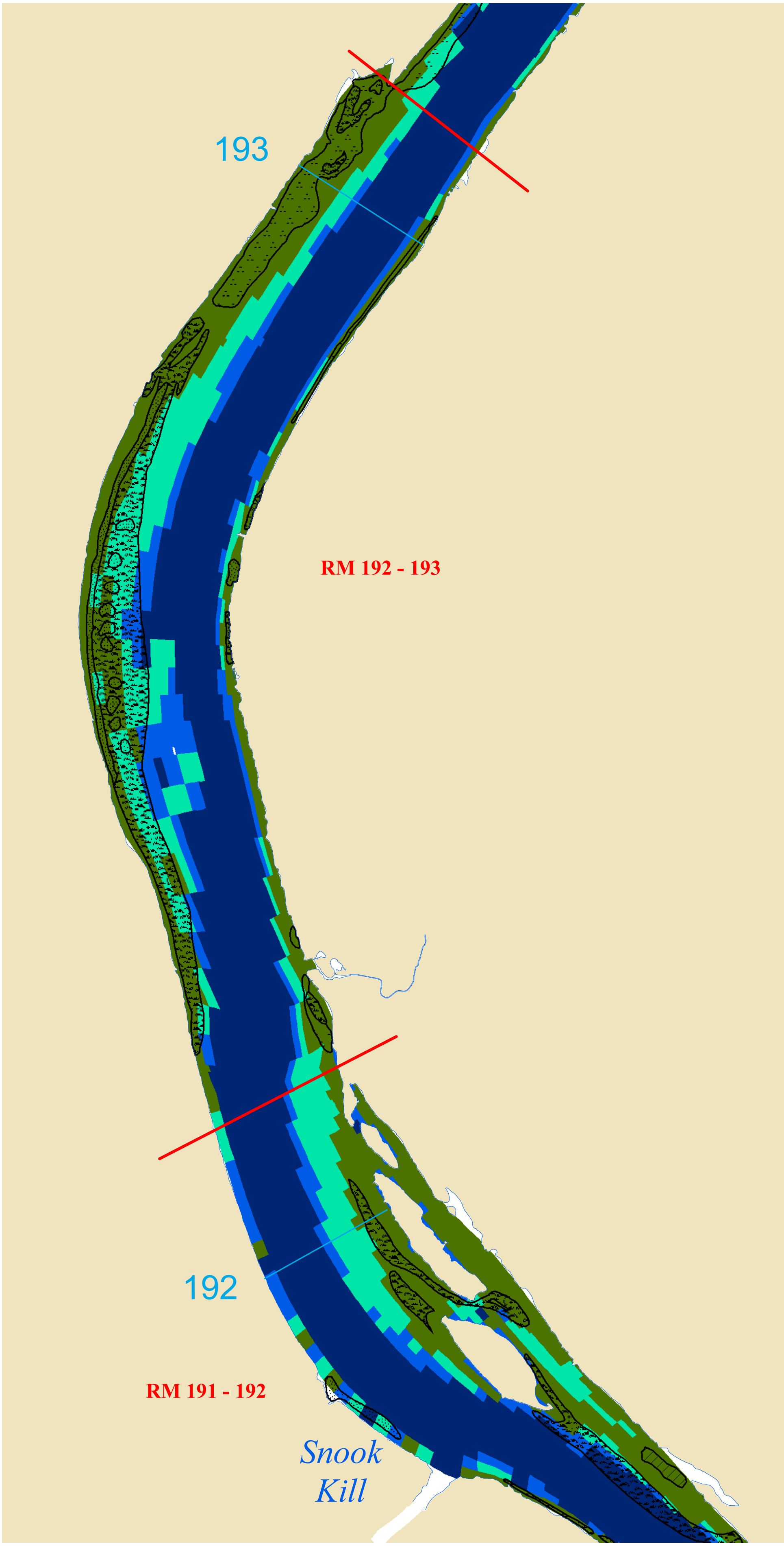

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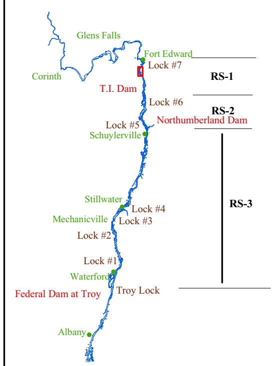

GRAPHIC SCALE

0 300 600 Feet

LEGEND

- Shore Line
- River Miles
- Dams and Locks
- Land

2003 Habitat Survey

- SAV (0 - 25%)
- SAV (25 - 50%)
- SAV (50 - 75%)
- SAV (75 - 100%)
- SAV (unclassified)
- Trapa

SAV Model Score

- 0 - 40
- 41 - 60
- 61 - 70
- 71 - 80
- 81 - 90
- 91 - 100
- SAV Model Boundaries

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Figure 2.2
River Mile 191 to 193

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March 2006.

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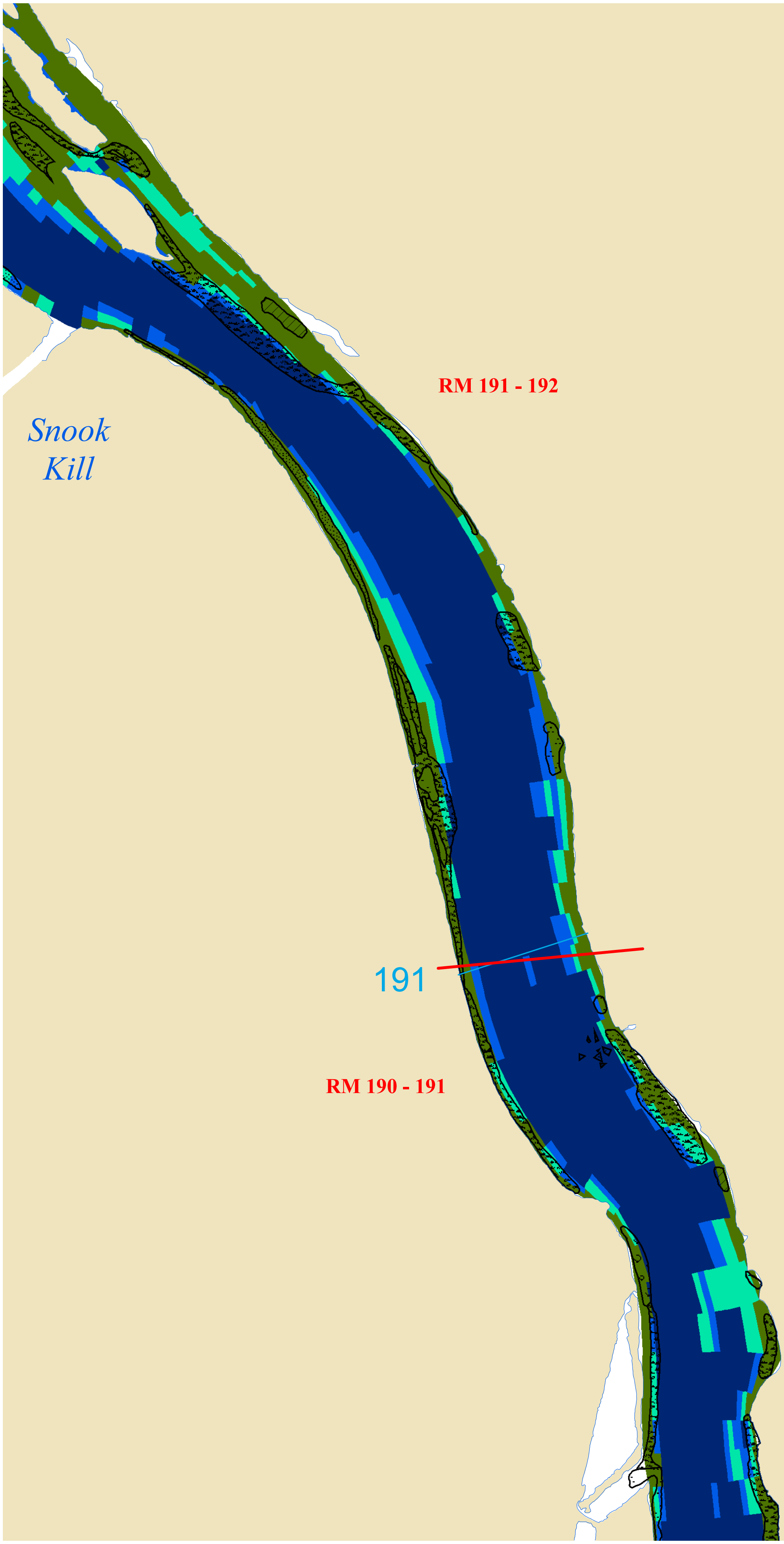
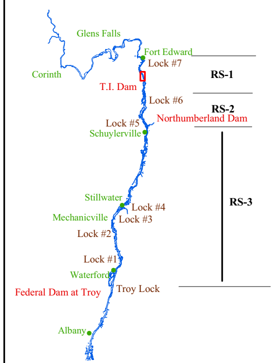


LOCATOR MAP OF THE UPPER HUDSON RIVER



GRAPHIC SCALE

0 300 600 Feet

LEGEND

Shore Line
River Miles
Dams and Locks
Land

2003 Habitat Survey

SAV (0 - 25%)
SAV (25 - 50%)
SAV (50 - 75%)
SAV (75 - 100%)
SAV (unclassified)
Trapa

SAV Model Score

0 - 40
41 - 60
61 - 70
71 - 80
81 - 90
91 - 100
SAV Model Boundaries

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Figure 2.3
River Mile 190 to 191

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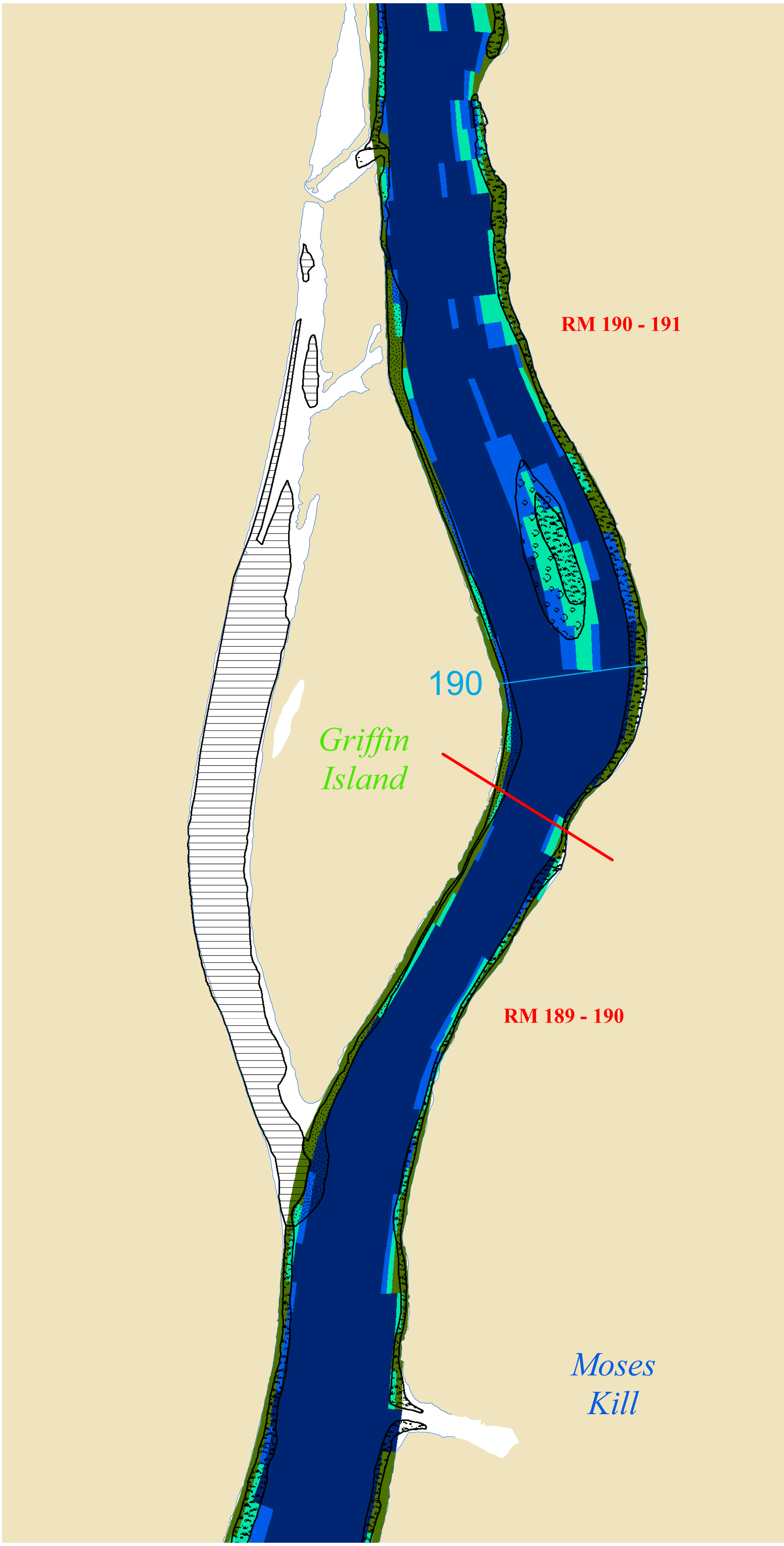
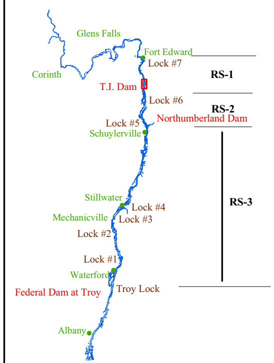


LOCATOR MAP OF THE UPPER HUDSON RIVER



GRAPHIC SCALE

0 300 600 Feet

LEGEND

Shore Line

River Miles

Dams and Locks

Land

2003 Habitat Survey

SAV (0 - 25%)

SAV (25 - 50%)

SAV (50 - 75%)

SAV (75 - 100%)

SAV (unclassified)

Trapa

SAV Model Score

0 - 40

41 - 60

61 - 70

71 - 80

81 - 90

91 - 100

SAV Model Boundaries

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Figure 2.4
River Mile 189 to 190

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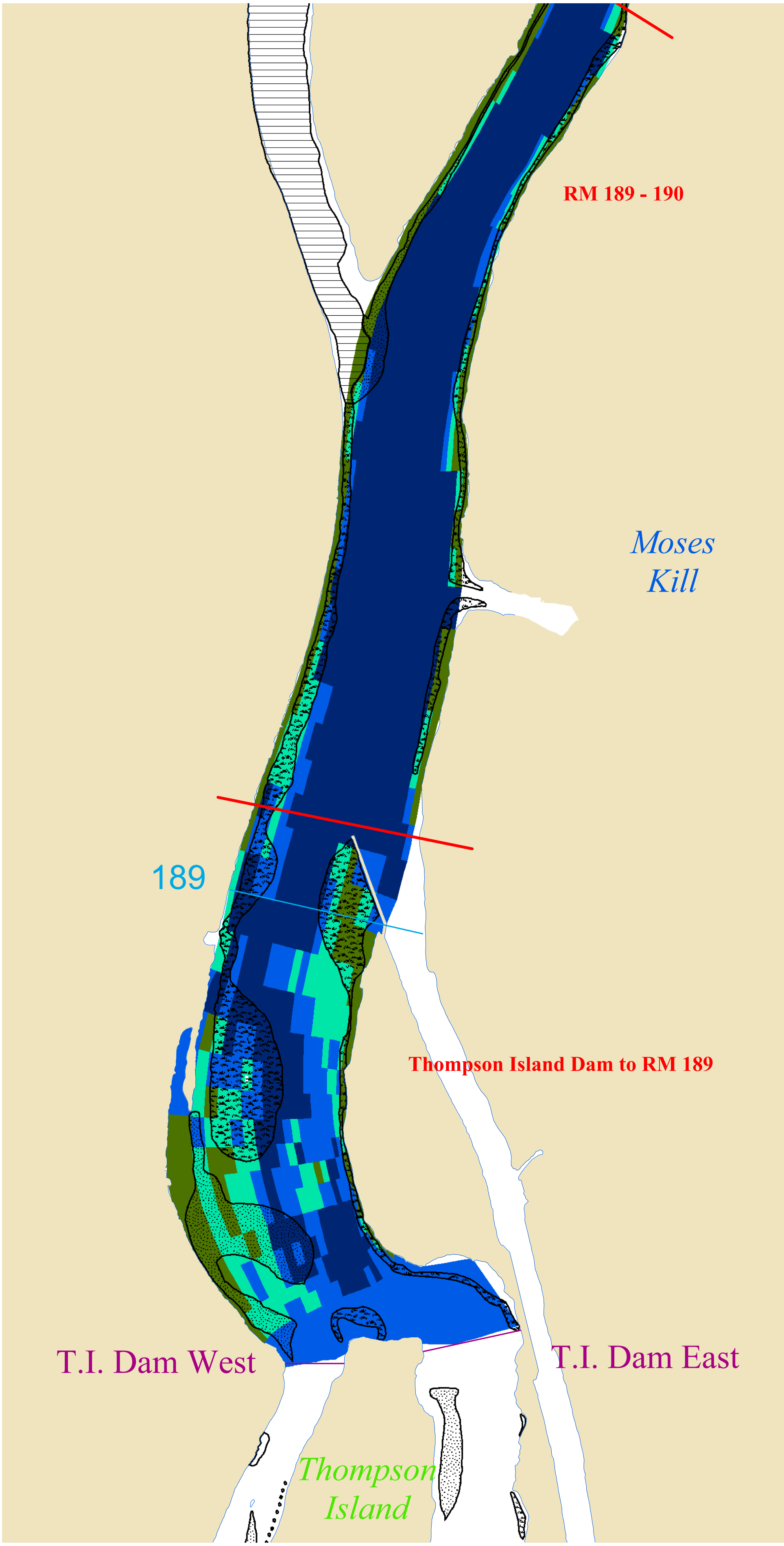
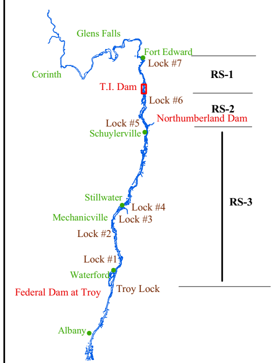


LOCATOR MAP OF THE UPPER HUDSON RIVER



GRAPHIC SCALE

0 300 600 Feet

LEGEND

Shore Line

River Miles

Dams and Locks

Land

2003 Habitat Survey

SAV (0 - 25%)

SAV (25 - 50%)

SAV (50 - 75%)

SAV (75 - 100%)

SAV (unclassified)

Trapa

SAV Model Score

0 - 40

41 - 60

61 - 70

71 - 80

81 - 90

91 - 100

SAV Model Boundaries

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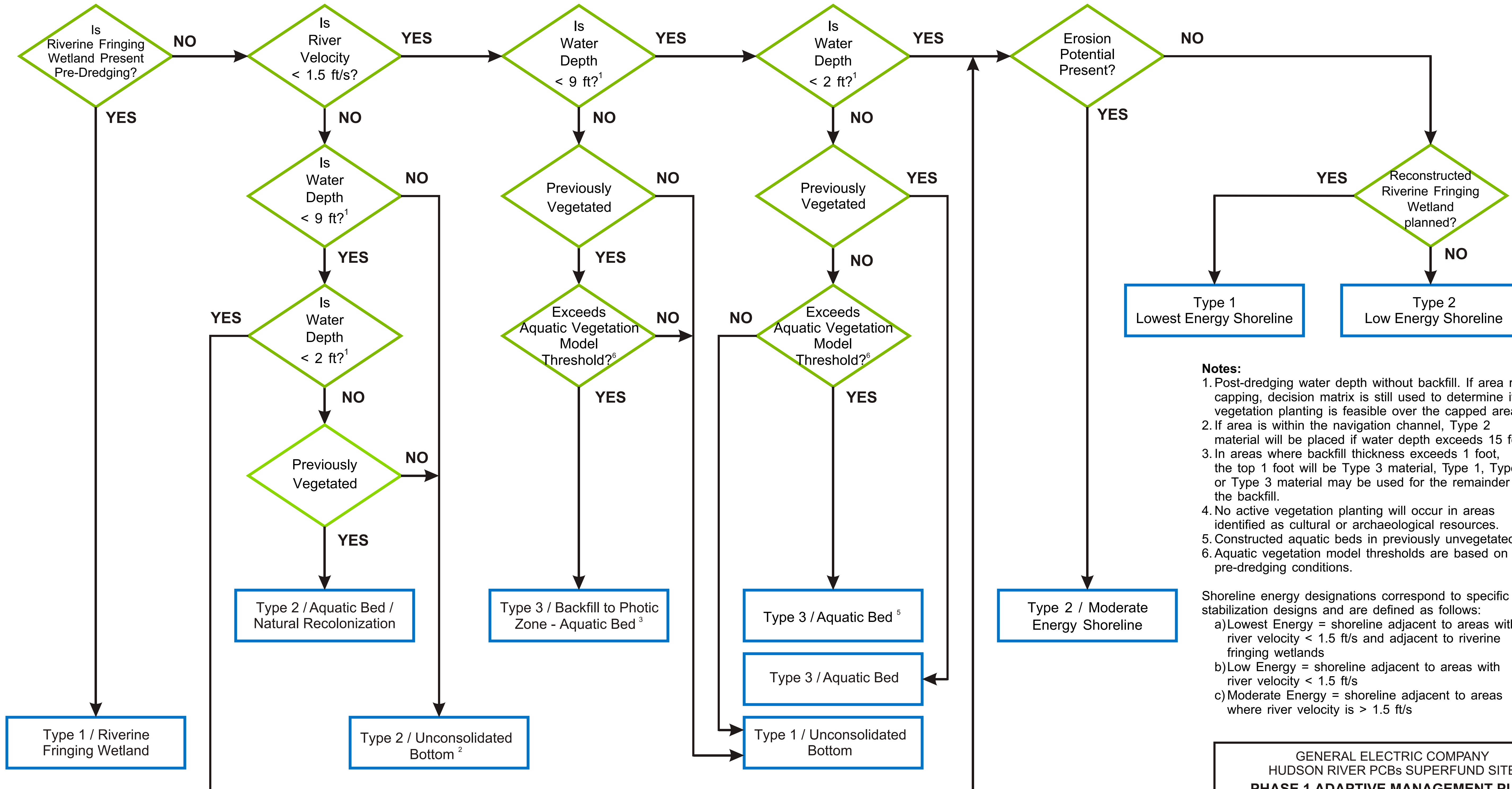
Figure 2.5
River Mile 188 to 189

March 2006.



Notes:

1. Post-dredging water depth without backfill. If area requires capping, decision matrix is still used to determine if vegetation planting is feasible over the capped area.
2. If area is within the navigation channel, Type 2 material will be placed if water depth exceeds 15 feet.
3. In areas where backfill thickness exceeds 1 foot, the top 1 foot will be Type 3 material, Type 1, Type 2, or Type 3 material may be used for the remainder of the backfill.
4. No active vegetation planting will occur in areas identified as cultural or archaeological resources.
5. Constructed aquatic beds in previously unvegetated areas.
6. Aquatic vegetation model thresholds are based on pre-dredging conditions.

Shoreline energy designations correspond to specific stabilization designs and are defined as follows:

a) Lowest Energy = shoreline adjacent to areas with river velocity < 1.5 ft/s and adjacent to riverine fringing wetlands
b) Low Energy = shoreline adjacent to areas with river velocity < 1.5 ft/s
c) Moderate Energy = shoreline adjacent to areas where river velocity is > 1.5 ft/s

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PHASE 1 ADAPTIVE MANAGEMENT PLAN

HABITAT DECISION MATRIX

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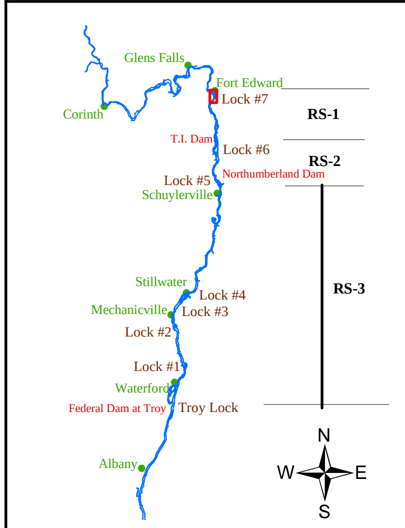
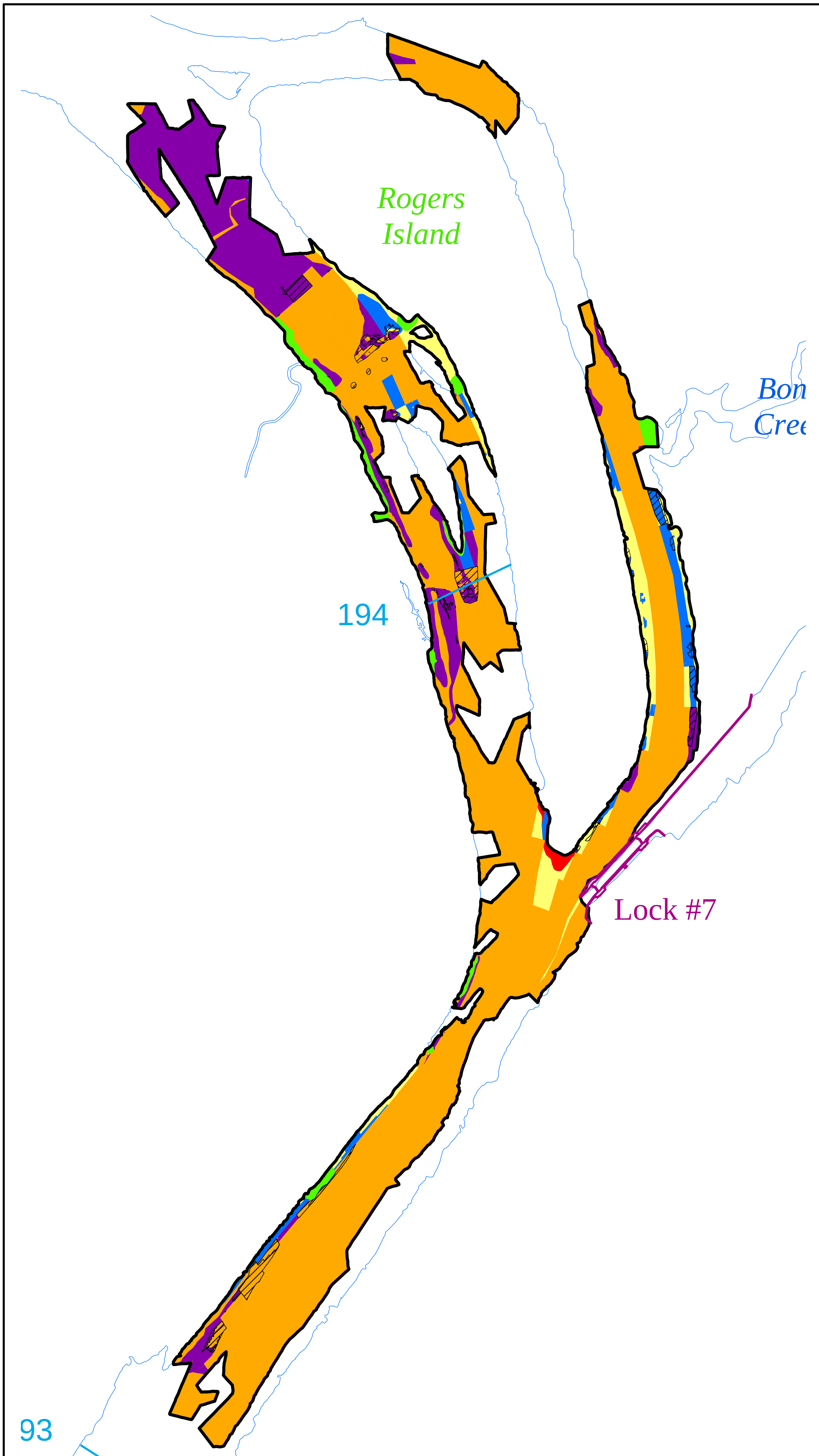
FIGURE **3-1**

LOCATOR MAP OF THE UPPER HUDSON RIVER





GRAPHIC SCALE

0 250 500 Feet

LEGEND

- Type 1 - RFW Planting Area
- Type 1 - UCB
- Type 2 - SAV Recolonization Area
- Type 2 - UCB
- Type 3 - SAV Planting Area
- Type 3 - SAV Recolonization Area
- Backfill to Photic Zone
- Phase 1 Dredge Boundary
- River Miles
- Dams and Locks
- Shore Line

Notes: 1.) Based on 08/05/05 bathymetry and married grid
2.) Assumed flow of 3661 cfs.

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Figure 3.2

Decision Criteria
Spacial Output:
Rogers Island

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GENhab March 2006

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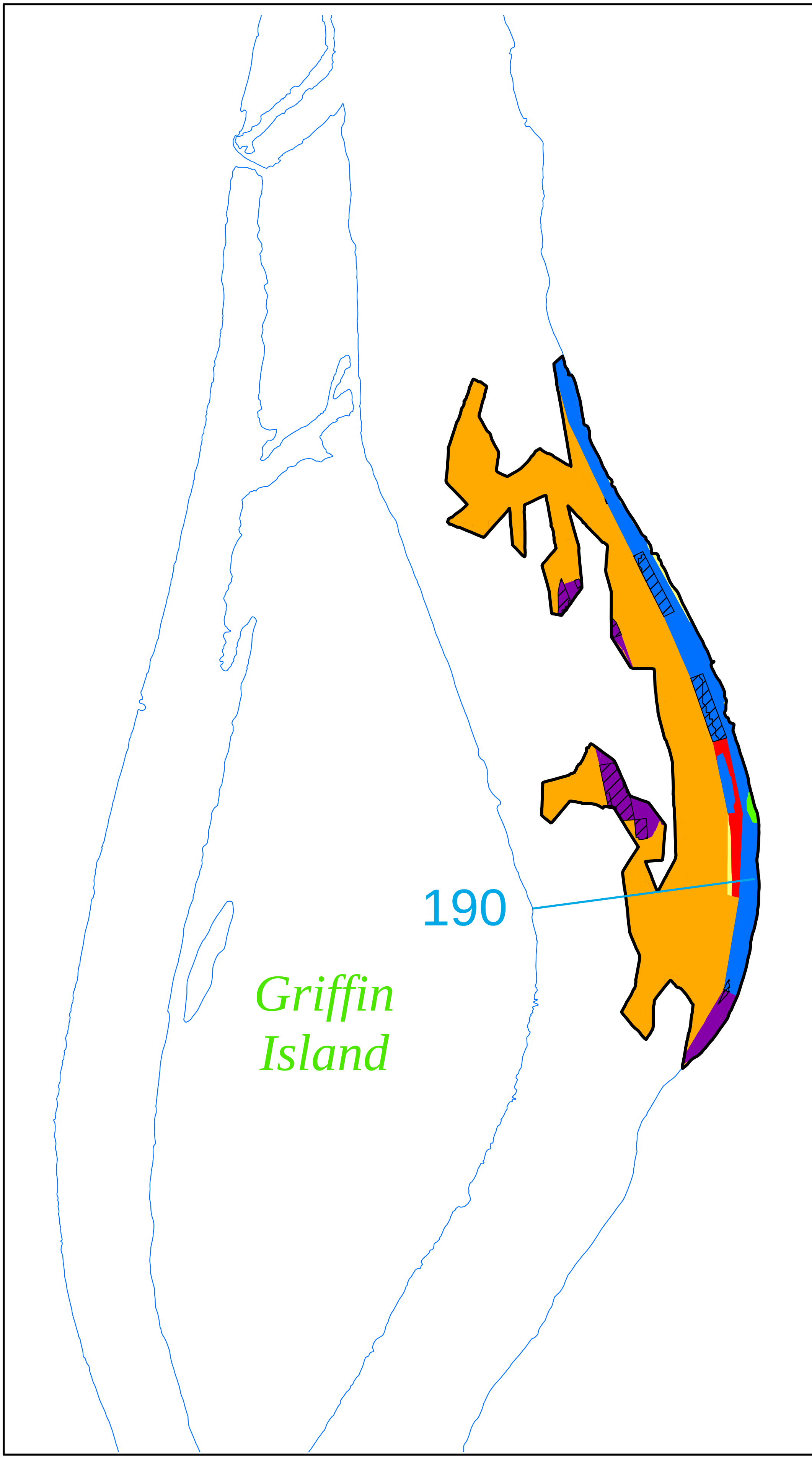
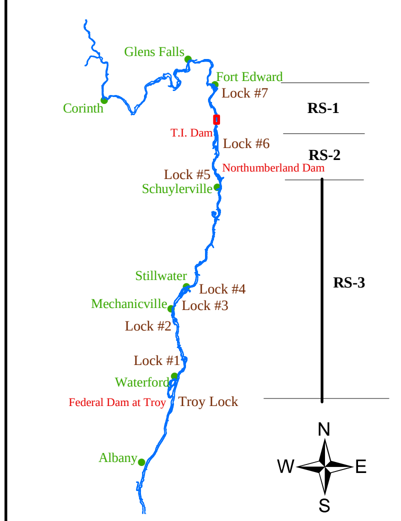


LOCATOR MAP OF THE UPPER HUDSON RIVER



GRAPHIC SCALE

0 250 500 Feet

LEGEND

- Type 1 - RFW Planting Area
- Type 1 - UCB
- Type 2 - SAV Recolonization Area
- Type 2 - UCB
- Type 3 - SAV Planting Area
- Type 3 - SAV Recolonization Area
- Backfill to Photic Zone
- Phase 1 Dredge Boundary
- River Miles
- Dams and Locks
- Shore Line

Notes: 1.) Based on 08/05/05 bathymetry and married grid
2.) Assumed flow of 3661 cfs.

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Figure 3.3

Decision Criteria
Spacial Output:
Griffin Island

GENhab

March 2006

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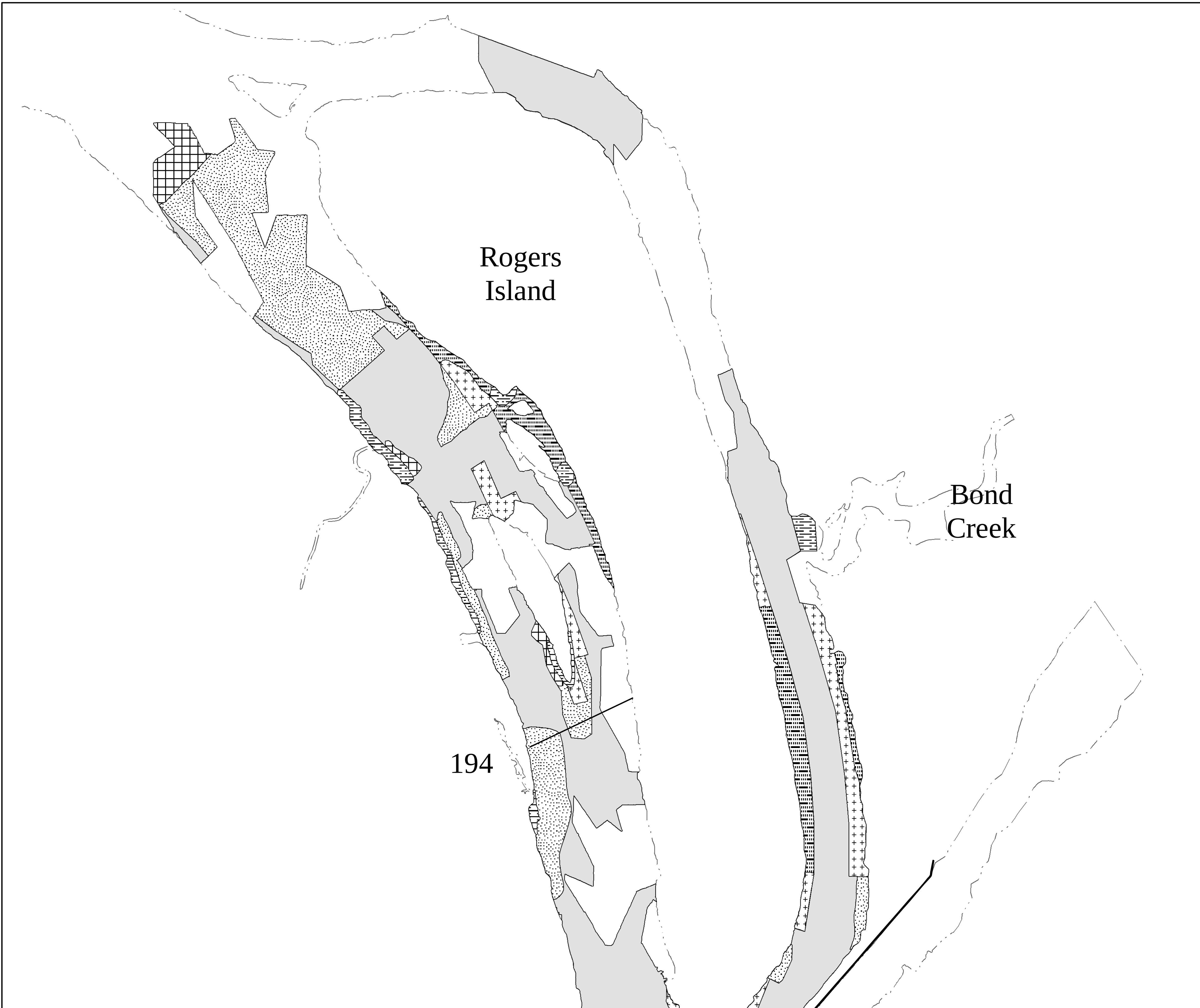
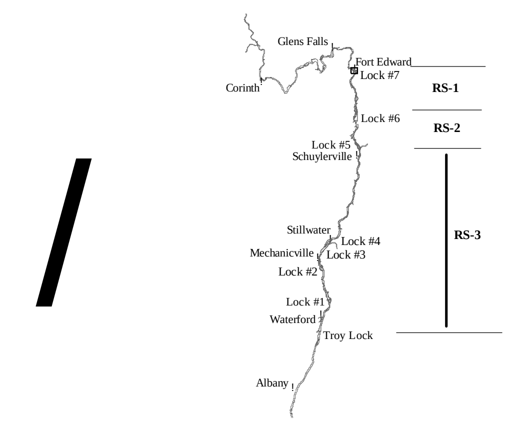


LOCATOR MAP OF THE HUDSON RIVER



GRAPHIC SCALE

0 150,000 300,000 Feet

LEGEND

- Type 1 - RFW Planting Area
- Type 1 - UCB
- Type 2 - UCB
- Type 2 - SAV Planting Area
- Type 2 - SAV Recolonization Area
- Type 3 - SAV Planting Area
- Type 3 - SAV Recolonization Area
- River Miles
- Dams and Locks
- Shoreline

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Figure 3.4

Habitat Construction Areas

GENhab

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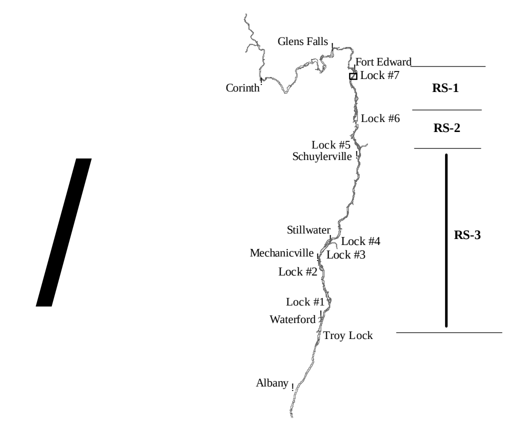
LOCATOR MAP OF THE HUDSON RIVER



GRAPHIC SCALE

0 150,000 300,000 Feet

LEGEND

- Type 1 - RFW Planting Area
- Type 1 - UCB
- Type 2 - UCB
- Type 2 - SAV Planting Area
- Type 2 - SAV Recolonization Area
- Type 3 - SAV Planting Area
- Type 3 - SAV Recolonization Area
- River Miles
- Dams and Locks
- Shoreline

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Figure 3.5

Habitat Construction Areas

GENhab

March 2006

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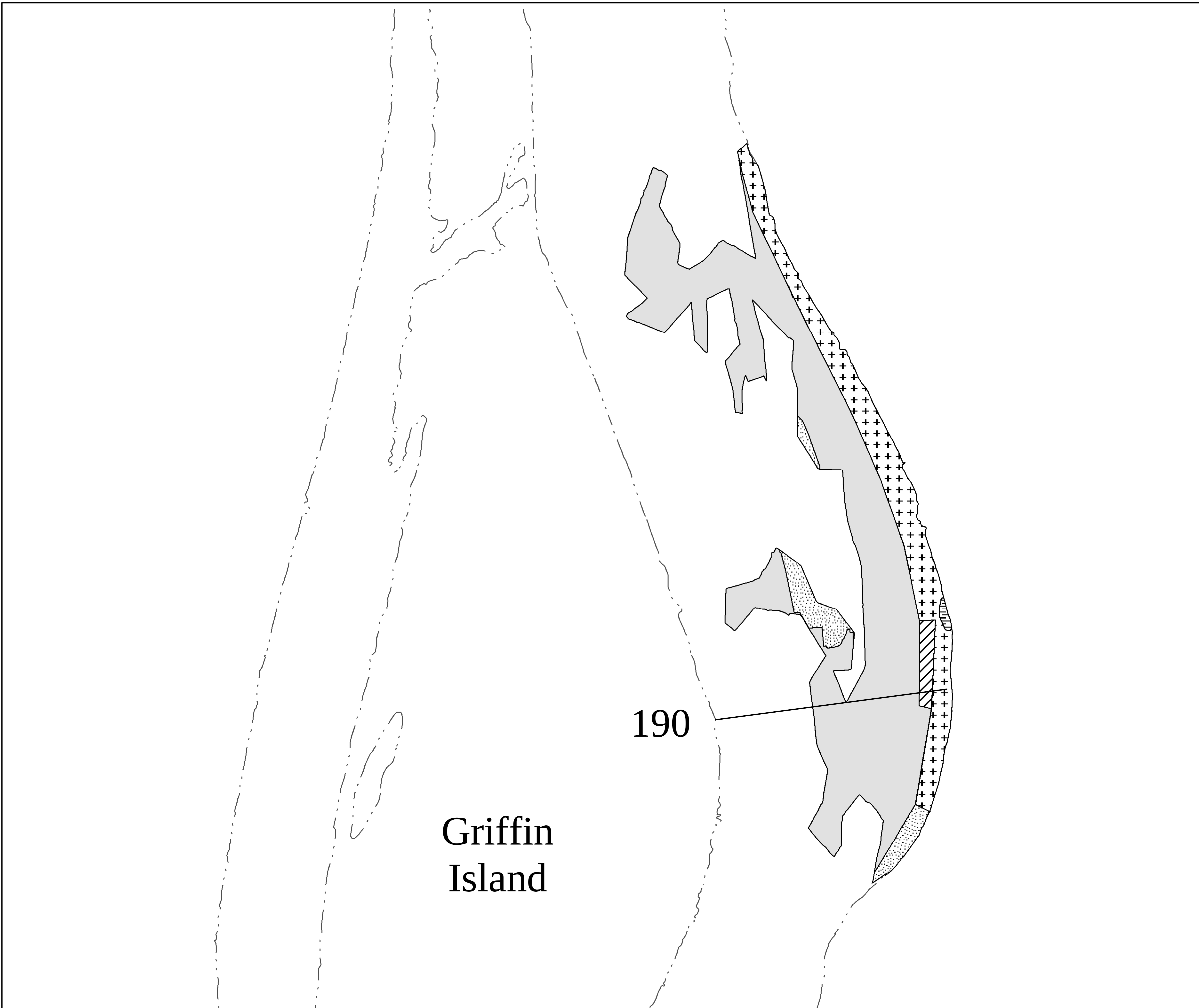
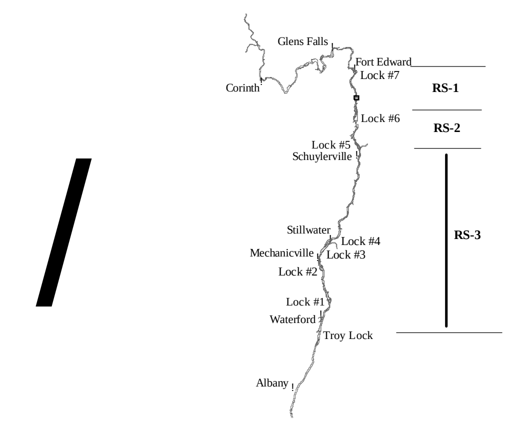


LOCATOR MAP OF THE HUDSON RIVER



GRAPHIC SCALE

0 150,000 300,000 Feet

LEGEND

- Type 1 - RFW Planting Area
- Type 1 - UCB
- Type 2 - UCB
- Type 2 - SAV Planting Area
- Type 2 - SAV Recolonization Area
- Type 3 - SAV Planting Area
- Type 3 - SAV Recolonization Area
- River Miles
- Dams and Locks
- Shoreline

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Figure 3.6

Habitat Construction Areas

GENhab

QEA Quantitative Environmental Analysis, LLC

March 2006

Exhibits

Exhibit A

Habitat Assessment Data

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