Lower Passaic River Restoration Project

Draft
Ecological Functional Assessment Technical Memorandum

April 2004

PREPARED BY:
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FOR:
New Jersey Department of Transportation
Office of Maritime Resources

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April 28, 2004

Ms. Lisa A. Baron
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1035 Parkway Avenue, E & O Building
Trenton, NJ 08625-0837

RE: Draft Technical Memo Ecological Functional Assessment
Lower Passaic River Investigation and Feasibility Study
Remediation and Ecosystem Restoration Program
<u>NJDOT Agreement No. 2001-NJMR02</u>

Dear Ms. Baron:

TAMS Consultants, Inc. (TAMS) is pleased to submit the attached Draft Technical Memo for the Ecological Functional Assessment. This represents the interim deliverable for Task 3 – Ecological Functional Assessment that was prepared for the Lower Passaic River Investigation and Feasibility Study. This submittal is a partial fulfillment of the requirements under the above referenced contract for the Lower Passaic River Site. If you have any questions concerning this submittal, please call me at (973) 338-6680.

Very truly yours,

TAMS Consultants, Inc.

Original Signed

Mark D. Moese, Ph.D.
Project Manager

LOWER PASSAIC RIVER
RESTORATION PROJECT

ECOSYSTEM FUNCTIONAL ASSESSMENT
DRAFT TECHNICAL MEORANDUM

BY
TAMS CONSULTANTS, INC.

FOR
STATE OF NEW JERSEY
DEPARTMENT OF TRANSPORTATION
OFFICE OF MARITIME RESOURCES

April 29, 2004

ECOSYSTEM FUNCTIONAL ASSESSMENT
DRAFT TECHNICAL MEORANDUM

TABLE OF CONTENTS

Page

INTRODUCTION

The objectives of the ecological functional assessment (EFA) are outlined in the April 2003 Project Management Plan (PMP) for the Lower Passaic River Investigation and Feasibility Study for Remediation and Ecosystem Restoration. Major Task JDN of the PMP outlines the objectives of the habitat assessment technique developed for the study as the following:

- Establish existing ecological conditions in the project area.
- Assist in the formulation of habitat restoration alternatives.
- Determine success criteria following implementation of preferred alternatives.
- Quantify increases in ecological outputs associated with plans and plan scales.

Thus, the EFA will be used as a planning and design tool, and as a technique for evaluating and monitoring the implemented restoration actions.

This draft technical memorandum presents preliminary recommendations as to how the EFA will be developed, and comprises the following sections:

Section 1 – Potential Habitats for Restoration
Section 2 – Functional Profiles of Potential Habitats for Restoration
Section 3 – Candidate Metrics for EFA Development
Section 4 – References

The draft technical memorandum is intended to be a working document that will serve to solicit comments and guidance from, and coordinate with representatives of the Office of Marine Resources – New Jersey Department of Transportation (OMR-NJDOT), the New Jersey Department of Environmental Protection (NJDEP), the United States Environmental Protection Agency (USEPA), the United States Army Corps of Engineers (USACE), and other resource agencies. To present a large volume of data clearly and succinctly, most of the information contained in the memorandum is organized in a series of tables. Because of the number and size of the tables, all tables are presented together at the end of the document, in the order in which they are referenced in the text.

1. POTENTIAL HABITATS FOR RESTORATION

The Lower Passaic River, as defined for this report, includes the tidal portion of the Lower Passaic River Basin, which extends 17 miles up to the Dundee Dam, and all its influences. The study area may be expanded based on models that will determine if recommended alternatives may be affected by other sources (i.e., upstream of the Dundee Dam, Hackensack River, Newark Bay, etc.).

More than a century of heavy industrial use in the area of the Lower Passaic has resulted in extensive shoreline impacts, including an almost complete loss of tidal and freshwater wetland habitat through bulkheading and other anthropogenic structural changes. Impacts to wildlife have been extensive. Additionally, a number of historical tributaries to the Passaic have been converted to stormsewer drains or filled in, and freshwater flows have been reduced dramatically (Deason, May 2001).

The Corps Reconnaissance Report of April 2003 identifies seven areas as potential restoration alternatives. Four areas of restoration opportunity exist within the Lower Passaic River (miles 1-17). These areas are:

- Area #1 – Six Mile Reach.
- Area #3 – Upstream Reach.
- Area #6 – Passaic River left descending bank East Rutherford to Kearney Point.
- Area #7 – Passaic River left descending bank Garfield to Wallington.

Miles 0-1 of the Lower Passaic River is Kearney Point Reach, which is itself identified as an area of restoration opportunity (Area #2 – Kearny Point Reach). Two additional areas were identified outside of the Lower Passaic River proper. These are, Area #4 – Oak Island Yards in the City of Newark bordering Newark Bay, and Area #5 – Second River Corridor, which extends from the Lower Passaic River at approximately river mile 8 (TAMS/Malcolm Pirnie, 2004). Further detail regarding these sites can be found below in Table 1-1.

In addition, provided in this document is a series of figures (Figures 1 through 9) based on aerial photographs of the site that preliminarily depict potential areas above mean low water to serve as straw-men for discussion of initial locations for restoration. We have not depicted sub-tidal areas on these figures for ease of presentation. We fully anticipate that sub-tidal areas within the Lower Passaic River study area will be evaluated in the feasibility study. Potential restoration areas were selected based on the review of available aerial photography, the two site reconnaissance boat trips in December 2003, and with the view of not requiring major real estate takings.

2. FUNCTIONAL PROFILES OF POTENTIAL HABITATS FOR RESTORATION

The potential restoration sites identified in the Table 1-1 contains habitats that falls into the following three systems (complexes of wetlands and deepwater habitats that share the influence of similar hydrologic, geomorphologic, chemical, or biological factors) defined by Cowardin *et al.* (December 1979), Estuarine, Riverine, or Palustrine. The Cowardin system is commonly used when categorizing wetland and deepwater habitats, and has been adopted by the Federal Geographic Data Committee as the National Vegetation Classification Standard (NVCS) for wetlands. As such, it was used in this report as the primary method for classification of wetlands in the Lower Passaic River study area.

Without a detailed site inspection and data from each of the proposed restoration sites it is difficult to quantify the existing functionality of the site. We know that there has been an approximately 88 percent loss of wetland acreage in the Newark Bay estuary since 1816, with an estimated 1,926 linear feet of aquatic vegetation remaining in the Passaic River study area (TSI, 2002). We also know that the benthic community and fish population in the river is depauperate and wetland areas are limited to degraded mudflats and fringe vegetation. Based on this information, we have concluded that the Lower Passaic River is functionally degraded.

2.1 Estuarine, Riverine, and Palustrine Systems

The Estuarine System consists of deepwater tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed, or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by freshwater runoff from the land. Upstream the Estuarine System extends landward to where ocean-derived salts measure less than 0.5 percent during the period of average annual low flow. Downstream the Estuarine System extends to an imaginary line closing the mouth of a river, bay, or sound; and to the seaward limit of wetland emergents, shrubs, or trees where they are not included in the mouth boundary. The Estuarine System also includes offshore areas of continuously diluted seawater. In subtidal estuarine systems, the substrate is continuously submerged. In intertidal estuarine systems, the substrate is exposed and flooded by tides and includes the associated splash zone.

The Riverine System includes all wetlands and deepwater habitats contained within a channel, with two exceptions; the first being wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and the second being habitats with water containing oceanderived salts in excess of 0.5 percent. The Riverine System is bounded on the landward side by upland, by the channel bank (including natural and man-made levees), or by wetland dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens. The Riverine System terminates at the downstream end where the concentration of ocean-derived salts in the water exceeds 0.5 percent during the period of annual average low flow, or where the channel enters a lake. It terminates at the upstream end where tributary streams originate, or where the channel leaves a lake. In the Tidal Riverine Subsystem, the gradient is low and water velocity fluctuates under tidal influence. The streambed is mainly mud with occasional patches of sand. Oxygen deficits may sometimes occur. The fauna is composed mostly of species that reach their maximum abundance in still water, and true planktonic organisms are common. The floodplain is typically well developed.

The Palustrine System includes all non-tidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 percent. It also includes wetlands lacking such vegetation, but with all of the following four characteristics: (1) area less than 8 hectares (20 acres); (2) active wave-formed or bedrock shoreline features lacking; (3) water depth in the deepest part of basin less than 2 meters at low water; and (4) salinity due to ocean-derived salts less than 0.5 percent. The Palustrine System is bounded by upland or by any of the other four Systems. (Cowardin *et al*., December 1979)

Table 2-1 highlights the geomorphic and hydrologic features characteristic of Estuarine, Riverine Tidal, and Palustrine Systems.

2.2 Subsystems and Classes of Estuarine, Riverine, and Palustrine Systems

Subsystems and Classes of Estuarine, Riverine, and Palustrine Systems that may currently exist or may be restored within the project area are addressed in Table 2-2. The table presents a general description of the sub-classification and typical habitat functions of that habitat type, as well as possible locations to find or restore that habitat. The corresponding hydrogeomorphic (HGM) classifications have been added where applicable for reference purposes (see Sections 2.3 and 3.2).

2.3 Hydrogeomorphic (HGM) Wetland Classification

A complimentary approach to the Cowardin system of wetland classification is to classify wetlands into HGM types. Functions and locations of HGM wetland types in the Lower Passaic River project area are outlined in Table 2-3. Classification of wetlands into HGM wetland types supports the use of the HGM Approach to wetland functional assessment, as outlined in Section 3.2 of this technical memorandum.

3. CANDIDATE METRICS FOR EFA DEVELOPMENT

Numerous habitat assessment procedures, and especially wetland assessment procedures, have been developed, each using differing approaches and assessment metrics. Table 3-1 summarizes the applicability of 40 assessment methodologies to the formulation and evaluation of habitat restoration actions in the Lower Passaic River study area in terms of the geographic coverage, habitat types, and values and functions assessed by the methodologies.

As discussed in Section 1, a variety of habitats in the Lower Passaic River study area have been identified as potentially suitable for restoration. Broadly classified, the potential habitats for restoration comprise benthic habitats in the Passaic River and tributary streams, mudflats, intertidal and freshwater wetlands, riparian areas, and adjacent terrestrial areas. Few habitat assessment methodologies were developed for use in this wide range of habitats. A notable exception is the Habitat Evaluation Procedures (HEP) that have been used throughout the United States to assess habitat suitability for a variety of invertebrate, fish, and wildlife species for which habitat suitability index (HSI) models have been developed.

For this reason, in part, adoption of a single habitat assessment methodology as the core of the Lower Passaic River EFA is not recommended. Rather, as outlined under Major Task JDN of the PMP, specific metrics from applicable habitat assessment methodologies will be integrated into the EFA, depending on conditions within the Lower Passaic River study area and the metrics most likely to be affected by the restoration measures. Further, it is likely that metrics will be modified based on local conditions – in particular the highly urbanized characteristics and the high degree of habitat disturbance that is characteristic of the study area – to fine-tune the EFA to the environment of the Lower Passaic.

Metrics from the following three assessment methodologies are proposed for incorporation, although metrics from additional methodologies also could be used:

- Habitat Evaluation Procedures (HEP).
- Hydrogeomorphic (HGM) Approach.
- Rapid Bioassessment Protocols (RBPs).

In combination, these three assessment methodologies use assessment procedures and metrics that are applicable to the full range of potential restoration habitats, and all three are widely used and recognized methodologies. The methodologies generate results that include acreage size in the measure of function, and use a scale of 0 to 1.0 for the function index. Thus, they will enable formulation of a standardized approach for tracking both function and size of the restoration areas, and therefore will enable comparing alternative restoration plans that potentially will employ several restoration activities on differing assemblages of restoration sites.

3.1 Habitat Evaluation Procedures (HEP)

As stated above, HEP assesses habitat suitability for a variety of species for which HSI models have been developed. However, although the HSI models are specific to the model species, they can be used to assess habitat suitability for groupings of ecologically similar species or guilds. Also, although the HEP user can develop HSI models for specific applications, the use of previously developed and reviewed models is preferable. Table 3-2 lists the HSI models that have been developed for species that have been collected or observed in the Lower Passaic River, between River Miles 1 and 7, or in Newark Bay.

Sixteen HSI models have been developed for three mammal species, seven avifauna species, and seven fish species that are known to occur in the Lower Passaic River study area. (A single HSI model is used to assess habitat suitability for two fish species, alewife and blueback herring.) Table 3-3 lists the metrics, or HSI model variables, for these sixteen models.

3.2 Hydrogeomorphic (HGM) Approach

The HGM Approach was developed by the USACE and other environmental agencies to assess the functional value of wetlands, by identifying and measuring the physical, chemical, and biological processes performed by a given wetland ecosystem. A wetland is classified according to its geomorphic setting, hydrology, and hydrodynamics and compared to reference wetlands that are representative of a particular hydrogeomorphic wetland type. The seven-hydrogeomorphic classes of wetlands are the following:

- Tidal fringe.
- Depression.
- Slope.
- Mineral soil flats.
- Organic soil flats.
- Riverine.
- Lacustrine fringe.

Seven national guidebooks are planned to provide a template for developing regional guidebooks for wetlands belonging to each of the hydrogeomorphic classes. The first two national guidebooks address riverine wetlands (Brinson *et al*., December 1995) and tidal fringe wetlands Shafer and Yozzo, December 1998). Table 3-4 describes the HGM Approach metrics presented in the national guidebook for riverine wetlands, and Table 3-5 describes those presented in the national guidebook for tidal fringe wetlands.

The New Jersey Meadowlands Commission initiated and sponsored the preparation of a regional guidebook for hydrogeomorhpic assessment of tidal fringe wetlands in the Hackensack Meadowlands (The Louis Berger Group, Inc., January 2004). Due to the proximity of the Hackensack Meadowlands to the Lower Passaic River, and due to the fact that both the Hackensack River and the Lower Passaic River are estuarine systems in a highly urbanized region and both rivers empty into Newark Bay, many of the HGM metrics incorporated into the regional guidebook for tidal fringe wetlands in the Hackensack Meadowlands may be suitable for inclusion in the Lower Passaic River EFA. Table 3-7 describes the metrics incorporated in the Hackensack Meadowlands model.

3.3 Rapid Bioassessment Protocols (RBPs)

The RBPs were developed as a synthesis of existing methods for conducting biological assessments of lotic (moving water) systems; in particular, streams and shallow rivers. All of the protocols have been tested in streams in various parts of the United States. Table 3-7 summarizes the RBP metrics for characterizing and assessing periphyton, benthic macroinvertebrate, and fish assemblages, and for assessing low-gradient stream habitats. (RBP metrics for assessing high-gradient stream habitats were not included due to the absence of high-gradient streams in the Lower Passaic River study area.)

Several RBP metrics are the same as those used by the New Jersey Department of Environmental Protection (NJDEP), Bureau of Freshwater and Biological Monitoring in the Bureau's index of biotic integrity (IBI) for fish. These metrics are indicated in Table 3-7. RBP periphyton and benthic macroinvertebrate metrics that are used in the New Jersey IBI also will be identified for inclusion in the final technical memorandum.

4. REFERENCES

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Brinson, Mark M., Richard D. Rheinhardt, F. Richard Hauer, Lyndon C. Lee, Wade L. Nutter, R. Daniel Smith, and Dennis Whigham. December 1995. Operational Draft: *A Guidebook for Application of Hydrogeomorphic Assessments to Riverine Wetlands*. United States Army Engineer Waterways Experiment Station, Wetlands Research Program Technical Report WRP-DE-11.

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United States Geological Survey (USGS), National Wetlands Research Center, Habitat Suitability Index Model Series website accessed during March and April 2004 at http://www.nwrc.usgs.gov/wdb/pub/hsi/hsiintro.htm.

Table 1-1
Potential Sites for Restoration Alternative Consideration

Area	Name	Location	Possible Existing Habitat Types*	Additional Habitat Information
1	Six Mile Reach	Point-No-Point, Harrison, Newark, Kearny, and Arlington Reaches (between miles 1-7 of the Lower Passaic River)	<u>Estuarine Subtidal</u> – rock bottom, unconsolidated bottom, aquatic bed <u>Estuarine Intertidal</u> – aquatic bed, rocky shore, unconsolidated shore, emergent wetland	Opportunity for sediment and water quality improvement, and restoring benthic habitat and submerged aquatic vegetation. Subtidal bottoms comprise 92% of the PRSA. (Terra Solutions, Inc., September 2002 Habitat Characterization) Intertidal flats (unconsolidated shore) comprise 8% of PRSA, and are key habitats, although very degraded. (Terra Solutions, Inc., September 2002 Habitat Characterization) Frank's Creek confluence area (limited *Spartina alterniflora* stand) and Lawyer's Creek confluence area (mixed *Phragmites australis* and *Spartina* stand) are key habitats in the PRSA. (Terra Solutions, Inc., September 2002 Habitat Characterization) Plankton and Fish Community - Sufficient data for PRSA (miles 1-7). (TAMS/Malcolm Pirnie, 2004) Benthic Community - Sufficient data for PRSA (miles 1-7). (TAMS/Malcolm Pirnie, 2004) Submerged aquatic vegetation and Fish Community - No data for PRSA (miles 1-7). (TAMS/Malcolm Pirnie, 2004) <u>Facing downstream in the PRSA, miles 1 through 7:</u> -Emergent wetland vegetation comprises 6% of the right bank, 6% of the left bank, and 6% of total PRSA shoreline (3,843 ft. of 67,770 ft.). -Aquatic vegetation interspersed (laterally and/or longitudinally) with riprap and/or bulkhead, and areas of riprap shoreline with significant over-hanging riparian vegetation comprises 9% of the right bank, 15% of the left bank, and 12% of total PRSA shoreline (8,307 ft. of 67,770 ft.). -Riprap comprises 32% of the right bank, 28% of the left bank, and 30% of the total PRSA shoreline (20,330 ft. of 67,770 ft.) -Bulkhead comprises 53% of the right bank, 51% of the left bank, and 52% of the total PRSA shoreline (35,290 ft. of 67,770 ft.) (Terra Solutions, Inc., September 2002Habitat Characterization)

Table 1-1
Potential Sites for Restoration Alternative Consideration

Area	Name	Location	Possible Existing Habitat Types*	Additional Habitat Information
2	Kearny Point Reach	Kearny Point Reach (between miles 0-1 of the Lower Passaic River)	Estuarine Subtidal – rock bottom, unconsolidated bottom, aquatic bed Estuarine Intertidal– aquatic bed, rocky shore, unconsolidated shore, emergent wetland	Opportunity for sediment and water quality improvement, and restoring benthic habitat and submerged aquatic vegetation.
3	Upstream Reach	Belleville, Nutley, Rutherford, and Wallington Reaches (between miles 7 and 17)	Estuarine Subtidal – rock bottom, unconsolidated bottom, aquatic bed Estuarine Intertidal– aquatic bed, rocky shore, unconsolidated shore, emergent wetland Riverine Tidal – rock bottom, unconsolidated bottom, aquatic bed, rocky shore, unconsolidated shore, emergent wetland	Opportunity for sediment and water quality improvement, and restoring benthic habitat and submerged aquatic vegetation. Plankton and Fish Community - Insufficient data from PRSA to Dundee Dam (miles 7-17). (TAMS/Malcolm Pirnie, 2004) Benthic Community - Insufficient data from PRSA to Dundee Dam (miles 7-17). (TAMS/Malcolm Pirnie, 2004) Submerged aquatic vegetation and Fish Community - No data from PRSA to Dundee Dam (miles 7-17). (TAMS/Malcolm Pirnie, 2004)
4	Oak Island Yards	Newark	Estuarine Subtidal – rock bottom, unconsolidated bottom, aquatic bed Estuarine Intertidal– aquatic bed, streambed rocky shore, unconsolidated shore, emergent wetland Palustrine – emergent wetland, unconsolidated bottom, unconsolidated shore	Opportunity to restore contiguous network of remaining tidal, intertidal and palustrine wetland areas.

Table 1-1
Potential Sites for Restoration Alternative Consideration

Area	Name	Location	Possible Existing Habitat Types*	Additional Habitat Information
5	Second River Corridor	From the Passaic River to Montclair	Estuarine Subtidal – rock bottom, unconsolidated bottom, aquatic bed Estuarine Intertidal– aquatic bed, streambed rocky shore, unconsolidated shore, emergent wetland Riverine Tidal – rock bottom, unconsolidated bottom, aquatic bed, streambed, rocky shore, unconsolidated shore, emergent wetland Palustrine – emergent wetland, unconsolidated bottom, unconsolidated shore	Opportunity to restore natural stream channel substrate, vegetated riverbank, palustrine and tidal wetlands, and reduce local flooding.

Table 1-1 Potential Sites for Restoration Alternative Consideration				
Area	**Name**	**Location**	**Possible Existing Habitat Types***	**Additional Habitat Information**
6	Passaic River Left Descending Bank – *from Kearny Point to East Rutherford*	from Kearny Point to East Rutherford, roughly along miles 1 through 14.	Estuarine Subtidal – rock bottom, unconsolidated bottom, aquatic bed Estuarine Intertidal – aquatic bed, streambed rocky shore, unconsolidated shore, emergent wetland Riverine Tidal – rock bottom, unconsolidated bottom, aquatic bed, streambed, rocky shore, unconsolidated shore, emergent wetland	Opportunity to restore filled in former saltmarshes, to provide shoreline stabilization, and to create riparian vegetative buffer. Frank's Creek confluence area (limited *Spartina alterniflora* stand) and Lawyer's Creek confluence area (mixed *Phragmites australis* and *Spartina* stand) are key habitats in the PRSA. (Terra Solutions, Inc., September 2002 Habitat Characterization) Intertidal flats (unconsolidated shore) comprise 8% of PRSA, and are key habitats, although very degraded. (Terra Solutions, Inc., September 2002 Habitat Characterization) Facing downstream in the PRSA, miles 1 through 7: -Emergent wetland vegetation comprises 6% of the right bank, 6% of the left bank, and 6% of total PRSA shoreline (3,843 ft. of 67,770 ft.). -Aquatic vegetation interspersed (laterally and/or longitudinally) with riprap and/or bulkhead, and areas of riprap shoreline with significant over-hanging riparian vegetation comprises 9% of the right bank, 15% of the left bank, and 12% of total PRSA shoreline (8,307 ft. of 67,770 ft.). -Riprap comprises 32% of the right bank, 28% of the left bank, and 30% of the total PRSA shoreline (20,330 ft. of 67,770 ft.) -Bulkhead comprises 53% of the right bank, 51% of the left bank, and 52% of the total PRSA shoreline (35,290 ft. of 67,770 ft.) (Terra Solutions, Inc., September 2002Habitat Characterization) Available Shoreline Information: Vegetative Community - Insufficient data for PRSA (miles 1-7), No data from PRSA to Dundee Dam (miles 7-17). Bird Community - Sufficient data for PRSA (miles 1-7), Insufficient data from PRSA to Dundee Dam (miles 7-17). Mammal, Herpetile, and T&E Communities - Insufficient data for PRSA (miles 1-7), Insufficient data from PRSA to Dundee Dam (miles 7-17). (TAMS/Malcolm Pirnie, 2004)

Table 1-1 Potential Sites for Restoration Alternative Consideration				
Area	**Name**	**Location**	**Possible Existing Habitat Types***	**Additional Habitat Information**
7	Passaic River Left Descending Bank – *Wallington and Garfield*	Wallington and Garfield, roughly along miles 14 through 17.	Estuarine Subtidal – rock bottom, unconsolidated bottom, aquatic bed Estuarine Intertidal – aquatic bed, streambed rocky shore, unconsolidated shore, emergent wetland Riverine Tidal – rock bottom, unconsolidated bottom, aquatic bed, streambed, rocky shore, unconsolidated shore, emergent wetland Palustrine – emergent wetland, unconsolidated bottom, unconsolidated shore	Opportunity to restore filled in former saltmarshes, to remove derelict structures, and improve underutilized and abandoned shoreline areas. Available Shoreline Information: Vegetative Community - No data from PRSA to Dundee Dam (miles 7-17). Bird Community - Insufficient data from PRSA to Dundee Dam (miles 7-17). Mammal, Herpetile, and T&E Communities - Insufficient data from PRSA to Dundee Dam (miles 7-17). (TAMS/Malcolm Pirnie, 2004)

*As defined by Cowardin *et al.* (December 1979). Classifications based upon information gathered from the Corps Reconnaissance Report (ACOE 2003), various aerial photographs, NWI maps, and NJ Bureau of Freshwater and Biological Monitoring data

Table 2-1
Cowardin *et al.* (December 1979) Wetland Classification Systems in the Lower Passaic Project Area

System	Geomorphic Setting	Water Source and Hydrology
Estuarine (Subtidal and Intertidal)	Usually semi-enclosed by land but will have open, partly obstructed, or sporadic access to the open ocean. Includes areas that extend (1) upstream and landward to where ocean-derived salts measure less than 0.5% during the period of average annual low flow; (2) to an imaginary line closing the mouth of a river, bay, or sound; and (3) to the seaward limit of wetland emergents, shrubs, or trees where they are not included in (2)	The primary water source is ocean water. The ocean water in estuarine systems is at least occasionally diluted by freshwater runoff from the land Estuarine water regimes and water chemistry are affected by one or more of the following forces: oceanic tides, precipitation, freshwater runoff from land areas, evaporation, and wind. In subtidal estuarine systems, the substrate is continuously submerged. In intertidal estuarine systems, the substrate is exposed and flooded by tides; includes the associated splash zone.
Riverine (Tidal)	The Riverine System is bounded on the landward side by upland, by the channel bank (including natural and man-made levees), or by wetland dominated by vegetative cover. The Riverine System terminates at the downstream end where the concentration of ocean-derived salts in the water exceeds 0.5% during the period of annual average low flow, or where the channel enters a lake. It terminates at the upstream end where tributary streams originate, or where the channel leaves a lake.	The primary water source is freshwater runoff from upland and other adjacent wetland areas. In the Tidal Riverine Subsystem, the gradient is low and water velocity fluctuates under tidal influence. Oxygen deficits may sometimes occur, the fauna is composed mostly of species that reach their maximum abundance in still water, and true planktonic organisms are common.
Palustrine	The Palustrine System is bounded by upland or by any of the other four wetland systems. The Palustrine System includes all nontidal wetlands dominated by vegetative cover, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5%. It also includes wetlands lacking such vegetation, but with the following additional characteristics: (1) area less than 8 ha (20 acres); (2) lacks active wave-formed or bedrock shoreline; and (3) deepest water depth is less than 2 m at low water.	The primary water source is freshwater runoff from upland and other adjacent wetland areas. The hydrology of palustrine wetlands varies and is associated with what type of wetland or upland is bordering it.

Table 2-2
Cowardin *et al.* (December 1979) Wetland Classification Subsystems and Classes in the Lower Passaic Project Area

Cowardin Classification	Description	Typical Habitat Functions and Influencing Factors	HGM Classification	Possible Locations
Estuarine Subtidal Rock Bottom	Substrate is permanently flooded by tidal water. Includes substrates having an areal cover of stones, boulders, or bedrock 75% or greater and vegetative cover of less than 30%.	The stability of the bottom can allow a rich assemblage of plants and animals to develop. Temperature, salinity, current, and light penetration are also important factors in determining the composition of the benthic community. Animals that live on the rocky surface are generally firmly attached by hooking or sucking devices, although they may occasionally move about over the substrate. Some may be permanently attached by cement. A few animals hide in rocky crevices and under rocks, some move rapidly enough to avoid being swept away, and others burrow into the finer substrates between boulders. Plants are also firmly attached (e.g., by hold fasts)	N/A	Areas 1, 2, 3, 4, and 5
Estuarine Subtidal Unconsolidated Bottom	Substrate is permanently flooded by tidal water. Includes habitats with at least 25% cover of particles smaller than stones, and a vegetative cover less than 30%.	In the Marine and Estuarine Systems, Unconsolidated Bottom communities are relatively stable. Exposure to wave and current action, temperature, salinity, and light penetration determines the composition and distribution of organisms. Unconsolidated Bottoms are characterized by the lack of large stable surfaces for plant and animal attachment. Most macroalgae attach to the substrate by means of basal holdfast cells or discs; in sand and mud, however, algae penetrate the substrate and higher plants can successfully root if wave action and currents are not too strong. Most animals in unconsolidated sediments live within the substrate.	N/A	Areas 1, 2, 3, 4, and 5

Table 2-2
Cowardin *et al.* (December 1979) Wetland Classification Subsystems and Classes in the Lower Passaic Project Area

Cowardin Classification	Description	Typical Habitat Functions and Influencing Factors	HGM Classification	Possible Locations
Estuarine Subtidal Aquatic Bed	Permanently flooded by tidal water. Includes habitats dominated by plants that grow principally on or below the surface of the water for most of the growing season in most years.	Aquatic Beds represent a diverse group of plant communities that requires surface water for optimum growth and reproduction. They are best developed in relatively permanent water or under conditions of repeated flooding. The plants are either attached to the substrate or float freely in the water above the bottom or on the surface.	N/A	Areas 1, 2, 3, 4, and 5
Estuarine Intertidal Aquatic Bed	The substrate is exposed and flooded by tides. Includes wetlands and deepwater habitats dominated by plants that grow principally on or below the surface of the water for most of the growing season in most years. Water regimes include irregularly exposed, regularly flooded, permanently flooded, intermittently exposed, semipermanently flooded, and seasonally flooded.	Aquatic Beds represent a diverse group of plant communities that requires surface water for optimum growth and reproduction. They are best developed in relatively permanent water or under conditions of repeated flooding. The plants are either attached to the substrate or float freely in the water above the bottom or on the surface.	Tidal Fringe Wetland	Areas 1, 2, 3, 4, 5, and 6
Estuarine Intertidal Streambed	The substrate is exposed and flooded by tides. Includes all channels of the Estuarine System that are completely dewatered at low tide. Water regimes are restricted to irregularly exposed, regularly flooded, irregularly flooded, seasonally flooded, temporarily flooded, and intermittently flooded.	Streambeds vary greatly in substrate and form depending on the gradient of the channel, the velocity of the water, and the sediment load. In most cases streambeds are not vegetated because of the scouring effect of moving water, but, like Unconsolidated Shores, they may be colonized by "pioneering" annuals or perennials during periods of low flow or they may have perennial emergents and shrubs that are too scattered to qualify the area for classification as Emergent Wetland or Scrub-Shrub Wetland.	Tidal Fringe Wetland	Areas 4, 5, and 6

Table 2-2 Cowardin *et al.* (December 1979) Wetland Classification Subsystems and Classes in the Lower Passaic Project Area				
Cowardin Classification	**Description**	**Typical Habitat Functions and Influencing Factors**	**HGM Classification**	**Possible Locations**
Estuarine Intertidal Rocky Shore	The substrate is exposed and flooded by tides; includes the associated splash zone. Includes wetland environments characterized by bedrock, stones, or boulders which singly or in combination have an areal cover of 75% or more and an areal coverage by vegetation of less than 30%. Water regimes are restricted to irregularly exposed, regularly flooded, irregularly flooded, seasonally flooded, temporarily flooded, and intermittently flooded.	In Estuarine Systems, Rocky Shores are generally high-energy habitats, which lie exposed as a result of continuous erosion by wind-driven waves or strong currents. The substrate is stable enough to permit the attachment and growth of sessile or sedentary invertebrates and attached algae or lichens. Rocky Shores usually display a vertical zonation that is a function of tidal range, wave action, and degree of exposure to the sun.	Tidal Fringe Wetland	Areas 1, 2, 3, 4, 5, and 6

Table 2-2
Cowardin *et al.* (December 1979) Wetland Classification Subsystems and Classes in the Lower Passaic Project Area

Cowardin Classification	Description	Typical Habitat Functions and Influencing Factors	HGM Classification	Possible Locations
Estuarine Intertidal Unconsolidated Shore	The substrate is exposed and flooded by tides; includes the associated splash zone. Includes all wetland habitats having three characteristics: (1) unconsolidated substrates with less than 75% areal cover of stones, boulders, or bedrock; (2) less than 30% areal cover of vegetation other than pioneering plants; and (3) any of the following water regimes: irregularly exposed, regularly flooded, irregularly flooded, seasonally flooded, temporarily flooded, intermittently flooded, saturated, or artificially flooded. Intertidal channels of the Estuarine System are classified as Streambed.	Unconsolidated Shores are characterized by substrates lacking vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable. Erosion and deposition by waves and currents produce a number of landforms such as beaches, bars, and flats, all of which are included in this Class. Found adjacent to Unconsolidated Bottoms. The particle size of the substrate and the water regime are the important factors determining the types of plant and animal communities present. Different substrates usually support characteristic invertebrate fauna. Faunal distribution is controlled by waves, currents, interstitial moisture, salinity, and grain size In Mud Shores (Flats), anaerobic conditions often exist below the surface. Mud Shores have a higher organic content than Cobble-Gravel or Sand Shores. They are typically found in areas of minor wave action. They tend to have little slope and support diverse populations of tube-dwelling and burrowing invertebrates that include worms, clams, and crustaceans	Tidal Fringe Wetland	Areas 1, 2, 3, 4, 5, and 6
Estuarine Intertidal Emergent Wetland	The substrate is exposed and flooded by tides. Characterized by erect, rooted, herbaceous hydrophytes, excluding mosses and lichens. This vegetation is present for most of the growing season in most years. These wetlands are usually dominated by perennial plants. All water regimes are included except subtidal and irregularly exposed.	Habitat Functions include maintenance of characteristic plant community composition, resident nekton utilization, nekton prey pool, wildlife habitat utilization (Shafer and Yozzo, 1998) Plant community composition is influenced by level of tidal flow in and out of the wetland, and corresponding salinity levels.	Tidal Fringe Wetland	Areas 1, 2, 3, 4, 5, and 6

Table 2-2
Cowardin *et al.* (December 1979) Wetland Classification Subsystems and Classes in the Lower Passaic Project Area

Cowardin Classification	Description	Typical Habitat Functions and Influencing Factors	HGM Classification	Possible Locations
Riverine Tidal Rock Bottom	Includes all wetlands and deepwater habitats with substrates having an areal cover of stones, boulders, or bedrock 75% or greater and vegetative cover of less than 30%. Water regimes are restricted to permanently flooded, intermittently exposed, and semipermanently flooded.	The stability of the bottom can allow a rich assemblage of plants and animals to develop. Temperature, salinity, current, and light penetration are also important factors in determining the composition of the benthic community. Animals that live on the rocky surface are generally firmly attached by hooking or sucking devices, although they may occasionally move about over the substrate. Some may be permanently attached by cement. A few animals hide in rocky crevices and under rocks, some move rapidly enough to avoid being swept away, and others burrow into the finer substrates between boulders. Plants are also firmly attached (e.g., by hold fasts)	Riverine Wetland	Areas 3, 5, 6 and 7
Riverine Tidal Unconsolidated Bottom	Includes all wetland and deepwater habitats with at least 25% cover of particles smaller than stones, and a vegetative cover less than 30%. Water regimes are restricted to permanently flooded, intermittently exposed, and semipermanently flooded.	Unconsolidated Bottoms are characterized by the lack of large stable surfaces for plant and animal attachment. They are usually found in areas with lower energy than Rock Bottoms, and may be very unstable. Exposure to wave and current action, temperature, salinity, and light penetration determines the composition and distribution of organisms. In the Riverine System, the substrate type is largely determined by current velocity, and plants and animals exhibit a high degree of morphologic and behavioral adaptation to flowing water. Most macroalgae attach to the substrate by means of basal holdfast cells or discs; in sand and mud, however, algae penetrate the substrate and higher plants can successfully root if wave action and currents are not too strong. Most animals in unconsolidated sediments live within the substrate.	Riverine Wetland	Areas 3, 5, 6 and 7

Table 2-2 Cowardin *et al.* (December 1979) Wetland Classification Subsystems and Classes in the Lower Passaic Project Area				
Cowardin Classification	**Description**	**Typical Habitat Functions and Influencing Factors**	**HGM Classification**	**Possible Locations**
Riverine Tidal Aquatic Bed	Includes wetlands and deepwater habitats dominated by plants that grow principally on or below the surface of the water for most of the growing season in most years. Water regimes include irregularly exposed, regularly flooded, permanently flooded, intermittently exposed, semipermanently flooded, and seasonally flooded.	Aquatic Beds represent a diverse group of plant communities that requires surface water for optimum growth and reproduction. They are best developed in relatively permanent water or under conditions of repeated flooding. The plants are either attached to the substrate or float freely in the water above the bottom or on the surface.	Tidal Fringe or Riverine Wetland	Areas 3, 5, 6 and 7
Riverine Tidal Streambed	Includes all channels of the Tidal Subsystem of the Riverine System that are completely dewatered at low tide. Water regimes are restricted to irregularly exposed, regularly flooded, irregularly flooded, seasonally flooded, temporarily flooded, and intermittently flooded.	Streambeds vary greatly in substrate and form depending on the gradient of the channel, the velocity of the water, and the sediment load. In most cases streambeds are not vegetated because of the scouring effect of moving water, but, like Unconsolidated Shores, they may be colonized by "pioneering" annuals or perennials during periods of low flow or they may have perennial emergents and shrubs that are too scattered to qualify the area for classification as Emergent Wetland or Scrub-Shrub Wetland.	Riverine Wetland	Areas 5, 6 and 7
Riverine Tidal Rocky Shore	Includes wetland environments characterized by bedrock, stones, or boulders which singly or in combination have an areal cover of 75% or more and an areal coverage by vegetation of less than 30%. Water regimes are restricted to irregularly exposed, regularly flooded, irregularly flooded, seasonally flooded, temporarily flooded, and intermittently flooded.	In Riverine Systems, Rocky Shores support sparse plant and animal communities. In the Riverine systems various species of lichens, as well as blue-green algae, frequently form characteristic zones on Rocky Shores. The distribution of these species depends on the duration of flooding or wetting by spray and is similar to the zonation of species in the Marine and Estuarine Systems	Tidal Fringe or Riverine Wetland	Areas 3, 5, 6 and 7

Table 2-2
Cowardin *et al.* (December 1979) Wetland Classification Subsystems and Classes in the Lower Passaic Project Area

Cowardin Classification	Description	Typical Habitat Functions and Influencing Factors	HGM Classification	Possible Locations
Riverine Tidal Unconsolidated Shore	Includes all wetland habitats having three characteristics: (1) unconsolidated substrates with less than 75% areal cover of stones, boulders, or bedrock; (2) less than 30% areal cover of vegetation other than pioneering plants; and (3) any of the following water regimes: irregularly exposed, regularly flooded, irregularly flooded, seasonally flooded, temporarily flooded, intermittently flooded, saturated, or artificially flooded. Intermittent or intertidal channels of the Riverine System are classified as Streambed.	Unconsolidated Shores are characterized by substrates lacking vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable. Erosion and deposition by waves and currents produce a number of landforms such as beaches, bars, and flats, all of which are included in this Class. Found adjacent to Unconsolidated Bottoms and may occupy the entire basin. The particle size of the substrate and the water regime are the important factors determining the types of plant and animal communities present. Different substrates usually support characteristic invertebrate fauna. Faunal distribution is controlled by waves, currents, interstitial moisture, salinity, and grain size	Tidal Fringe or Riverine Wetland	Areas 3, 5, 6 and 7
Riverine Tidal Emergent Wetland	Characterized by erect, rooted, herbaceous hydrophytes, excluding mosses and lichens. This vegetation is present for most of the growing season in most years. These wetlands are usually dominated by perennial plants. All water regimes are included except subtidal and irregularly exposed.	Habitat Functions include maintenance of characteristic plant community composition, resident nekton utilization, nekton prey pool, wildlife habitat utilization. (Shafer and Yozzo, 1998)	Tidal Fringe or Riverine Wetland	Areas 3, 5, 6 and 7

Table 2-2
Cowardin *et al.* (December 1979) Wetland Classification Subsystems and Classes in the Lower Passaic Project Area

Cowardin Classification	Description	Typical Habitat Functions and Influencing Factors	HGM Classification	Possible Locations
Palustrine Unconsolidated Bottom	Includes all wetland and deepwater habitats with at least 25% cover of particles smaller than stones, and a vegetative cover less than 30%. Water regimes are restricted to permanently flooded, intermittently exposed, and semipermanently flooded.	Unconsolidated Bottoms are characterized by the lack of large stable surfaces for plant and animal attachment. Exposure to wave and current action, temperature, salinity, and light penetration determines the composition and distribution of organisms. Most macroalgae attach to the substrate by means of basal holdfast cells or discs; in sand and mud, however, algae penetrate the substrate and higher plants can successfully root if conditions are favorable. Most animals in unconsolidated sediments live within the substrate. There is usually a high correlation between the nature of the substrate and the number of species and individuals. The erosive forces of wind and water are of minor importance except during severe floods.	Depressional Wetland	Areas 4, 5 and 7
Palustrine Unconsolidated Shore	Includes all wetland habitats having three characteristics: (1) unconsolidated substrates with less than 75% areal cover of stones, boulders, or bedrock; (2) less than 30% areal cover of vegetation other than pioneering plants; and (3) any of the following water regimes: irregularly exposed, regularly flooded, irregularly flooded, seasonally flooded, temporarily flooded, intermittently flooded, saturated, or artificially flooded.	Unconsolidated Shores are characterized by substrates lacking vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable. The particle size of the substrate and the water regime are the important factors determining the types of plant and animal communities present. Different substrates usually support characteristic invertebrate fauna. Faunal distribution is controlled by waves, currents, interstitial moisture, salinity, and grain size The erosive forces of wind and water are of minor importance except during severe floods.	Depressional Wetland	Areas 4, 5 and 7

Table 2-2 Cowardin *et al.* (December 1979) Wetland Classification Subsystems and Classes in the Lower Passaic Project Area				
Cowardin Classification	**Description**	**Typical Habitat Functions and Influencing Factors**	**HGM Classification**	**Possible Locations**
Palustrine Emergent Wetland	Characterized by erect, rooted, herbaceous hydrophytes, excluding mosses and lichens. This vegetation is present for most of the growing season in most years. These wetlands are usually dominated by perennial plants. All water regimes are included except subtidal and irregularly exposed.	The erosive forces of wind and water are of minor importance except during severe floods. As palustrine characteristics vary depending on surrounding habitat and area hydrology, habitat functions and influencing factors also are varied and dependent upon the physical aspects of the wetland, but are similar to riverine and estuarine emergent wetlands.	Depressional Wetland	Areas 4, 5 and 7

Table 2-3 Hydrogeomorphic (HGM) Wetland Classifications in the Lower Passaic River Project Area			
HGM Classification	**Description**	**Cowardin Subsystems**	**Locations**
Tidal Fringe Wetland	Tidal fringe wetlands occur along coasts and estuaries and are under the influence of sea level. (Shafer and Yozzo, 1998) Hydrogeomorphic Functions: tidal surge attenuation, sediment deposition, tidal nutrient and organic carbon exchange Habitat Functions: maintenance of characteristic plant community composition, resident nekton utilization, nekton prey pool, wildlife habitat utilization	Estuarine Intertidal, Riverine Tidal	Areas 1, 2, 3, 4, 5, 6, and 7
Depressional	Depressional wetlands occur in topographic depressions. Dominant water sources are precipitation, groundwater discharge, and interflow from adjacent uplands. Elevation contours are closed, thus allowing the accumulation of surface water. Dominant hydrodynamics are vertical fluctuations and primarily seasonal. Depressional wetlands may lose water through intermittent or perennial drainage from an outlet and by evapotreanspiration and, if they are not receiving groundwater discharge, may slowly contribute to groundwater. (Shafer and Yozzo, 1998) Habitat Functions: maintenance of characteristic plant community composition, resident nekton utilization, nekton prey pool, wildlife habitat utilization	Palustrine	Areas 4, 5, and 7
Riverine	Riverine wetlands occur in floodplains and riparian corridors in association with stream channels. (Shafer and Yozzo, 1998) Hydrolic Functions: dynamic surface water storage, long-term surface water storage, energy dissipation, subsurface water storage, moderation of groundwater flow or discharge Biogeochemical Functions: nutrient cycling, removal of imported elements and compounds, retention of particulates, organic carbon export Habitat Functions: maintains characteristic plant community, characteristic detrital biomass, spatial structure of habitat, interspersion and connectivity, distribution and abundance of invertebrates, and distribution and abundance of vertebrates	Riverine Lower Perennial	Does not occur within any of the current seven potential restoration areas.

Table 3-1
Alternative Assessment Methodologies

Methodology		Applicability		
Acronym or Short Title	**Full Title**	**Region**	**Habitat Type**	**Functions and Values Assessed**
AREM	Avian Richness Evaluation Method	Colorado Plateau	Lowland wetlands and riparian areas	Avian richness.
–	Coastal Method	New Hampshire	Tidal marshes	Ecological integrity; shoreline anchoring; storm surge protection; wildlife, finfish, and shellfish habitat; water quality maintenance; recreation potential; aesthetic quality; education potential; and noteworthiness.
CT Method	Connecticut Method	Connecticut	Non-tidal wetlands	Flood control; ecological integrity; wildlife habitat; finfish habitat; nutrient retention and sediment trapping; educational potential; visual/aesthetic quality; agricultural potential; water-based recreation; groundwater use potential; shoreline anchoring and dissipation of erosive forces; and noteworthiness.
Descriptive Approach	Wetland Functions and Values: A Descriptive Approach	USACE New England District	All wetland types	Groundwater recharge/discharge; floodflow alteration; fish and shellfish habitat; sediment/toxicant/pathogen retention; nutrient removal/retention/transformation; production export; sediment/shoreline stabilization; wildlife habitat; recreation; educational/scientific value; uniqueness/heritage; visual quality/aesthetics; and threatened or endangered species habitat.
EPW	Evaluation for Planned Wetlands	United States	All wetland types	Shoreline bank erosion control; sediment stabilization; water quality; wildlife; fish; and uniqueness/heritage.
HAT	Habitat Assessment Technique	–	Wetland, aquatic and terrestrial habitats	Breeding bird habitat quality, although in theory any taxa could be assessed.
HEP	Habitat Evaluation Procedures	United States	Most terrestrial, wetland, and aquatic habitats	Habitat suitability for selected fish, wildlife, or invertebrates.
HGM Approach	Hydrogeomorphic Approach	United States	All wetland types; however, not all assessment models are developed	Variety of wetland functions related to hydrologic processes, biogeochemical processes, and habitat; the actual list of functions depending upon the wetland regional subclass.
Hollands-Magee Method	Method for Assessing the Functions of Wetlands	Glaciated Northeast and Midwest	Non-tidal wetlands	Biological; hydrologic support; groundwater; storm and flood water storage; shoreline protection; water quality maintenance; cultural and economic; recreational; aesthetic; and educational.
IBI	Index of Biological Integrity	–	Variety of habitats including streams, lakes, and wetlands.	Biological condition.
–	Interim HGM	United States	All wetland types; however, not all assessment models are developed	Variety of wetland functions related to hydrologic processes, biogeochemical processes, and habitat; the actual list of functions depending upon the wetland regional subclass.
IVA	Indicator Value Assessment	United States	All wetland types; however, not all assessment models are developed	Variety of wetland functions likely including hydrologic processes, biogeochemical processes, habitat, and social issues; the actual list of functions depending upon the wetland study area (watershed or planning area).
Larson Method	Models for Assessment of Freshwater Wetlands	Massachusetts	Freshwater non-tidal wetlands	Wildlife value (Golet submodel); groundwater potential (Heeley-Motts submodel); and visual-cultural value (Smardon-Fabos submodel).
MDE Method	Method for the Assessment of Wetland Function	Maryland	Non-tidal palustrine vegetated wetlands	Groundwater discharge; floodflow alteration; modification of water quality; sediment stabgilization; aquatic diversity/abundance; and wildlife diversity/abundance.

Table 3-1
Alternative Assessment Methodologies

Methodology		Applicability		
Acronym or Short Title	**Full Title**	**Region**	**Habitat Type**	**Functions and Values Assessed**
ME Tidal Method	Maine Citizens Tidal Marsh Guide	Maine	Vegetated tidal marshes	Ecological integrity; wildlife, finfish, and shellfish habitat; recreational and commercial potential; aesthetic quality; educational potential; and noteworthiness.
MNRAM	Minnesota Routine Assessment Method	Minnesota	Wetlands	Vegetation diversity/integrity; maintenance of hydrologic regime; flood/stormwater attenuation; water quality protection; shoreline protection; wildlife habitat; fishery habitat; aesthetics/recreation/education/cultural; and commercial uses.
MT Form	Montana Wetland Field Evaluation Form	Montana	Wetlands	Plant, fish, and wildlife habitat; flood attenuation and storage; dynamic surface water storage; sediment/nutrient/toxicant retention and removal; sediment/shoreline stabilization; production export/food chain support; groundwater discharge/recharge; uniqueness; and recreation/education potential.
NBM	Narragansett Bay Method	Narragansett Bay, Rhode Island	Tidal salt marshes and brackish/freshwater wetlands that were formerly tidal	Ecological health; and tidal restrictions.
NC-CREWS	North Carolina Coastal Region Evaluation of Wetland Significance	North Carolina coastal area	Tidal and non-tidal wetlands	Surface runoff storage; floodwater storage; shoreline stabilization; terrestrial wildlife; aquatic life; nonpoint source; floodwater cleansing; landscape character; water characteristics; replacement difficulty; and restoration potential.
NC Guidance	Guidance for Rating the Values of Wetlands in North Carolina	North Carolina	Freshwater wetlands (not applicable to stream channels)	Water storage; bank/shoreline stabilization; pollutant removal; wildlife habitat; aquatic life value; and recreation and education.
NEFWIBP	New England Freshwater Wetland Invertebrate Biomonitoring Protocol	New England	Permanently flooded, non-tidal freshwater wetlands	Ecological integrity.
NH Method	New Hampshire Method	New Hampshire	Non-tidal wetlands	Ecological integrity; wetland wildlife habitat; finfish habitat; educational potential; visual/aesthetic quality; water-based recreation; flood control potential; groundwater use potential; sediment trapping; nutrient attenuation; shoreline anchoring and dissipation of erosive forces; urban quality of life; historical site potential; and noteworthiness.
NJ Watershed Method	Watershed-Based Wetland Assessment Method for the New Jersey Pinelands	New Jersey Pinelands	Non-tidal freshwater wetlands	Watershed integrity and potential impacts.
OFWAM	Oregon Freshwater Wetland Assessment Methodology	Oregon	Freshwater wetlands	Wildlife habitat; fish habitat; water quality; hydrologic control; sensitivity to impact; enhancement potential; education; recreation; and aesthetic quality.
PAM HEP	Pennsylvania Modified 1980 Habitat Evaluation Procedure	Pennsylvania	Most terrestrial, wetland, and aquatic habitats	Habitat suitability of selected fish, wildlife, or invertebrates.

Table 3-1
Alternative Assessment Methodologies

Methodology		Applicability		
Acronym or Short Title	**Full Title**	**Region**	**Habitat Type**	**Functions and Values Assessed**
PFC	Process for Assessing Proper Functioning Condition	United States	Riparian-wetlands	Proper functioning condition.
Rapid Assessment Procedure	A Rapid Procedure for Assessing Wetland Functional Capacity	United States; however, assessment models have been developed only for Glaciated Northeast and Midwest	Depressional, slope, lacustrine fringe, extensive peatland, flat and riverine HGM class wetlands	Glaciated Northeast/Midwest models include: Groundwater discharge; Groundwater recharge; storm and flood water storage; stream flow; water quality; export of detritus; abundance and diversity of wetland vegetation; and abundance and diversity of wetland fauna.
RBPs	Rapid Bioassessment Protocols	United States	Lotic systems; specifically streams and shallow rivers	Periphyton, benthic macroinvertebrates, fish, and habitat.
Synoptic Approach	Synoptic Approach for Wetlands Cumulative Effects Analysis	United States	All wetland types	Habitat, water quality, and hydrologic function; value; functional loss; and replacement potential.
VIMS Method	Technique for the Functional Assessment of Virginia Coastal Plain Nontidal Wetlands	Virginia's coastal plain	Non-tidal wetlands	Flood storage and storm flow modification; nutrient retention and transformation; sediment and toxicant trapping; sediment stabilization; wildlife habitat; aquatic habitat; public use; and other factors.
WAFAM	Washington State Wetland Functional Assessment Method	Western Washington and the Columbia Basin	Vegetated riverine (flow-through and impounding) and depressional (outflow and closed) wetlands	Potential for removing sediment; potential for removing nutrients; potential for removing metals and toxic organics; potential for reducing peak flows; potential for decreasing downstream erosion; potential for recharging groundwater; general habitat suitability; habitat suitability for invertebrates; habitat suitability for amphibians; habitat suitability for anandromous fish; habitat suitability for resident fish; habitat suitability for birds; habitat suitability for aquatic mammals; habitat for native plant associations; and potential for primary production and organic export.
WCHE	Wildlife Community Habitat Evaluation	Maryland	Deciduous palustrine forested wetlands	Tract suitability, plot suitability, and native richness for forest interior birds, reptiles, and amphibians.
WET	Wetland Evaluation Technique	Contiguous United States	All wetland types	Groundwater recharge; groundwater discharge; flood flow alteration; sediment stabilization; sediment/toxicant retention; nutrient removal/transformation; production export; wildlife diversity/abundance; aquatic diversity/abundance; recreation; and uniqueness/heritage. Also: habitat suitability for 14 waterfowl species groups, 4 freshwater fish species groups, 120 species of wetland-dependent birds, and 133 species of saltwater fish and invertebrates.

Table 3-1
Alternative Assessment Methodologies

Methodology		Applicability		
Acronym or Short Title	**Full Title**	**Region**	**Habitat Type**	**Functions and Values Assessed**
–	WEThings	New England, and possibly applicable to other states in the range of each species	All wetland types	Habitat potential for wetland-dependent amphibians, reptiles, and mammals.
WHAMS	Wildlife Habitat Assessment and Management System	Pennsylvania	Most terrestrial, wetland, and aquatic habitats	Habitat suitability of selected fish, wildlife, or invertebrates.
WHAP	Wildlife Habitat Appraisal Procedure	Texas	Upland, bottomland, and wetland habitats	Biological habitat components, protected and endangered species, and acquisition and administration.
WIRAM	Wisconsin Rapid Assessment Methodology	Wisconsin	Wetlands	Floral diversity; wildlife habitat; fishery habitat; flood/stormwater attenuation; water quality protection; shoreline protection; groundwater; and aesthetics/recreation/education.
WQI	Wetland Quality Index	Florida Everglades	Freshwater wetlands	Wetland quality, as determined by: aquatic prey base abundance; aquatic prey base diversity; category I exotic pest plant species; diversity of macrophytes; habitat diversity within 1,000 feet; hydroperiod; hydropattern; intactness of wetland resource; peat/muck soil layer; protected animal species use; protected plant species; proximity to aquatic refugia; sheet flow; surrounding landscape condition; water quality; wetland vegetation cover; and wildlife use.
WRAP	Wetland Rapid Assessment Procedure	Florida	Freshwater wetlands	Wildlife utilization; overstory/shrub canopy of desirable species; wetland vegetative ground cover of desirable species; adjacent upland/wetland buffer; field indicators of wetland hydrology; and water quality input and treatment.
WVA	Wetland Value Assessment Methodology	Coastal Louisiana	Fresh/intermediate marsh, brackish marsh, saline marsh, bottomland hardwoods, and fresh swamp	Habitat suitability.

Source:
1. USACE, April 27, 2004. Table A - Assessment procedures, acronyms, and key references.
2. Barbour *et al.*, 1999.

Table 3-2
HSI Models Available for Species Collected or Observed in Lower Passaic River (River Miles 1 – 7) or Newark Bay

Available HSI Models[1]		Species Collected or Observed	
Species	**Scientific Name**	**Lower Passaic River Miles 1 – 7 [2,3]**	**Newark Bay[4]**
Mammals			
Muskrat	*Ondatra zibethicus*	Not Surveyed	
Eastern gray squirrel	*Sciurus carolinensis*		
Eastern cottontail	*Sylvilagus floridanus*		
Avifauna			
Red-winged blackbird	*Agelaius phoeniceus*	**Yes**	Not Surveyed
Wood duck	*Aix sponsa*	**Yes**	
Mallard [a]	*Anas platyrhynchos*	**Yes**	
American black duck	*Anas rubripes*	**Yes**	
Great egret	*Ardea alba*	**Yes**	
Great blue heron	*Ardea herodias*	**Yes**	
Belted kingfisher	*Ceryle alcyon*	**Yes**	
Laughing gull [b]	*Larus atricilla*	**Yes**	
Osprey	*Pandion haliaetus*	**Yes**	
Fish			
Blueback herring	*Alosa aestivalis*	**Yes**	**Yes**
Alewife	*Alosa pseudoharengus*	No	**Yes**
American shad	*Alosa sapidissima*	No	**Yes**
White sucker	*Catostomus commersoni*	**Yes**	No
Carp	*Cyprinus carpio*	**Yes**	No
Gizzard shad [c]	*Dorosoma cepedianum*	**Yes**	**Yes**
Channel catfish	*Ictalurus punctatus*	**Yes**	No
Atlantic croaker [d]	*Micropogonias undulatus*	No	**Yes**
Striped bass	*Morone saxatillis*	**Yes**	**Yes**
Megainvertebrates			
American oyster [e]	*Crassostrea virginica*	No	**Yes**

Notes:

a. Mallard HSI model is specific to the Lower Mississippi Valley.
b. Laughing Gull HSI model is specific to the Gulf of Mexico coast.
c. Gizzard shad HSI model is specific to lakes and reservoirs.
d. Juvenile Atlantic croaker HSI model is specific to the southeast Atlantic coast and the Gulf of Mexico coast.
e. American oyster HSI model is specific to the northern Gulf of Mexico.

Sources:

1. US Geological Survey (USGS), March and April 2004.
2. Tierra Solutions, Inc. September 2002. Passaic River Study Area, Avian Survey. Table 1: Species observed during the Lower Passaic River avian survey (1999 – 2000).
3. Tierra Solutions, Inc. September 2002. Passaic River Study Area, Fish Pathology Data. Table 1: Species and numbers of fish collected from the Passaic and Mullica Rivers for pathological analysis.
4. National Marine Fisheries Service (NMFS), June 1997. Table 1.

Table 3-3
Habitat Suitability Index (HSI) Model Variables for Species Collected or Observed in Lower Passaic River or Newark Bay

Model Variable	Description
Mammals	
M – Muskrat	
Herbaceous Wetlands	
V_1	Percent canopy cover of emergent herbaceous vegetation.
V_2	Percent of year with surface water present.
V_8	Percent of emergent herbaceous vegetation consisting of Olney bulrush, common three-square bulrush, or cattail.
Riverine	
V_2	Percent of year with surface water present.
V_3	Percent stream gradient.
V_4	Percent of riverine channel with surface water present during typical minimum flow.
V_5	Percent riverine channel dominated by emergent herbaceous vegetation.
V_6	Percent herbaceous canopy cover within 10 m (32.8') of water's edge.
Estuarine	
V_1	Percent canopy cover of emergent herbaceous vegetation.
V_7	Percent of emergent herbaceous vegetation consisting of persistent life form species.
V_8	Percent of emergent herbaceous vegetation consisting of Olney bulrush, common three-square bulrush, or cattail.
V_9	Percent of open water supporting submerged or floating aquatic vegetation.
GS – Gray Squirrel	
Deciduous Forest and Deciduous Forested Wetland	
V_1	Percent canopy closure of trees that produce hard mast which are > or = 25.4 cm (10") dbh.
V_2	Diversity of tree species that produce hard mast.
V_3	Percent tree canopy closure.
V_4	Average dbh of overstory trees.
V_5	Percent shrub crown cover.
EC – Eastern Cottontail	
Winter Habitat	
V_1	Percent shrub crown closure.
V_2	Percent tree canopy closure.
V_3	Percent canopy closure of persistent herbaceous vegetation.
V_4	Diversity index (a measure of the amount of cover type edge).
Avifauna	
RWB – Red-Winged Blackbird	
Herbaceous Wetlands	
V_1	Type of emergent herbaceous vegetation available in wetland.
V_2	Water regime.
V_3	Abundance of carp within the wetland.
V_4	Abundance of larval stages of emergent aquatic insects (Order Odonata) within the wetland.
V_5	Percent emergent herbaceous canopy.
V_6	Types of foraging sites available outside the wetland.
Upland – Forbland, Grassland, Pasture/Hayland	
V_7	Presence of dense, sturdy herbaceous vegetation on upland site.
V_8	Occurrence of disturbances like grazing, mowing, burning, and tilling on potential upland nest sites.
WD – Wood Duck	
Breeding	
V_1	Number of potentially suitable tree cavities per 0.4 ha (1.0 ac).

Table 3-3 Habitat Suitability Index (HSI) Model Variables for Species Collected or Observed in Lower Passaic River or Newark Bay	
Model Variable	**Description**
V_2	Number of nest boxes per 0.4 ha (1.0 ac).
V_3	Density of potential nest sites per 0.4 ha (1.0 ac); i.e., $(0.09 * V_1) + (0.95 * V_2)$.
V_4	Percent of water surface covered by potential brood cover.
Winter	
V_5	Percent of water surface covered by potential winter cover.
ABD – American Black Duck (Wintering)	
Marine and Estuarine Subtidal Open Water South of Cape Cod, Massachusetts	
V_1	Percentage of subtidal open water < or = 1 m deep at low tide.
V_2	Percentage of total open-water area that becomes exposed streambaeds, banks, bars, and tidal flats at low tide.
V_3	Percentage of subtidal open water (< or = 1 m deep at low tide) that supports rooted vascular aquatic plants.
V_4	Percentage of area of tidal flats, streambeds, banks, and bars that have > or = 300 clams per m^2.
Estuarine Vegetated Wetlands	
V_5	Percentage of estuarine emergent and forested wetlands occupied by creeks, ponds, and impoundments.
V_6	Percentage of substrate samples, from ponds or impoundments that is occupied by *Ruppia* or *Potamogeton*.
V_7	Percentage of emergent marsh that supports > or = 750 snails per m^2.
GE – Great Egret	
Feeding	
V_1	Percentage of study area with water 10-23 cm deep.
V_2	Percentage of substrate in zone 10-23 cm deep covered by submerged or emergent vegetation.
Nesting	
V_3	Percentage of island covered by woody vegetation > or = 1 m in height.
V_4	Mean water depth in wooded wetlands.
V_5	Mean height of woody vegetation.
V_6	Distance to road or dwelling.
V_7	Distance to human disturbance other than road or dwelling.
GBH – Great Blue Heron	
Reproduction and Feeding	
V_1	Distance between potential nest sites and foraging areas.
V_2	Presence of a water body with suitable prey population and foraging substrate.
V_3	A disturbance-free zone up to 100 m around potential foraging area.
V_4	Presence of treeland cover types within 250 m of wetland.
V_5	Presence of 250 m (land) or 150 m (water) disturbance-free zone around potential nest sites.
V_6	Proximity of potential nest site to an active nest site.
BK – Belted Kingfisher	
Breeding and Feeding	
V_1	Percent of shoreline subject to severe wave action.
V_2	Average water transparency.
V_3	Percent water surface obstruction.
V_4	Percent of water area that is < or = 60 cm (24") in depth.
V_5	Percent riffles.
V_6	Average number of lentic shoreline or stream subsections that contain one or more perches.
V_7	Distance to nearest suitable soil bank from 1-km sections of lentic shoreline or stream.
O – Osprey	
Riverine – Reproduction and Feeding	
V_2	Water surface obstruction class.

Table 3-3 Habitat Suitability Index (HSI) Model Variables for Species Collected or Observed in Lower Passaic River or Newark Bay	
Model Variable	**Description**
V_3	Mean secchi disk water transparency (cm).
V_4	Human activity class.
Fish	
ABH – Alewife and Blueback Herring	
Riverine – Spawning Adult, Egg and Larva	
V_1	Dominant substrate type for river herring spawning.
V_{2a}	Mean daily water temperature during spawning season (alewife).
V_{2b}	Mean daily water temperature during spawning season (blueback herring).
Riverine and Estuarine – Juvenile	
V_3	Mean number of zooplankton per liter.
V_4	Mean salinity during spring or summer.
V_{5a}	Mean surface water temperature (alewife).
V_{5b}	Mean surface water temperature (blueback herring).
AS – American Shad	
Riverine – Adult (spawning) and Egg-Larval	
V_1	Mean surface water temperature during spawning season.
V_2	Mean water velocity during spawning season.
V_3	Mean surface water temperature during egg and larval development.
Estuarine – Juevenile	
V_4	Mean near-bottom water temperature during winter and spring.
V_5	Percentage of area supporting emergent and/or submerged vegetation.
WS – White Sucker	
Riverine	
V_1	Maximum monthly average turbidity during the year.
V_2	Weekly average pH during year under stable conditions.
V_3	Minimum dissolved oxygen levels near sunrise during May through August in areas of most suitable water temperature.
V_4	Average of mean weekly water temperatures at mid-afternoon during July and August (adult and jevenile).
V_5	Average of mean weekly water temperatures during July and August (fry).
V_6	Average of mean weekly water temperatures during spawning and incubation (April through July – embryo).
V_7	Average riffle velocity during spawning and incubation (April through July – embryo).
V_8	Mean riffle depth during spawning and incubation (April through July – embryo).
V_9	Percent instream and overhanging shoreline cover.
V_{10}	Percent pools during average summer flows (July through August – adult, juvenile, and fry).
CoC – Common Carp	
Riverine	
V_1	Percent vegetative cover in shallow areas during spring and summer.
V_2	Percent cover in pools.
V_3	Percent pools, backwaters, and marsh areas during average summer flow.
V_6	Maximum monthly average turbidity during average summer flow or summer stratification.
V_7	Maximum midsummer water temperature (adult).
V_8	Average water temperatures during spawning within specified areas (embryo).
V_9	Maximum midsummer water temperature within pools, backwaters, or littoral areas (juvenile and fry).
V_{10}	Maximum depth of pools, marshes, and backwaters during spawning.
V_{11}	Maximum salinity.
V_{12}	Minimum dissolved oxygen levels during midsummer (fry, juvenile, and adult).

Table 3-3 Habitat Suitability Index (HSI) Model Variables for Species Collected or Observed in Lower Passaic River or Newark Bay	
Model Variable	**Description**
V_{13}	Minimum dissolved oxygen levels within specified areas during spawning (March through June – embryo).
V_{14}	pH levels during the year.
ChC – Channel Catfish	
Riverine	
V_1	Percent pools during average summer flow.
V_2	Percent cover (logs, boulders, cavities, brush, debris, or standing timber) during summer within pools, backwater areas, and littoral areas.
V_4	Food production potential in river by substrate type present during average summer flow.
V_5	Average midsummer water temperature within pools, backwaters, or littoral areas (adult).
V_6	Length of agricultural growing season (frost-free days).
V_7	Maximum monthly average turbidity during summer.
V_8	Average minimum dissolved oxygen levels within pools, backwaters, or littoral areas during midsummer.
V_9	Maximum salinity during summer (adult).
V_{10}	Average water temperatures within pools, backwaters, and littoral areas during spawning and embryo development (embryo).
V_{11}	Maximum salinity during spawning and embryo development (embryo).
V_{12}	Average midsummer water temperature within pools, backwaters, or littoral areas (fry).
V_{13}	Maximum salinity during summer (fry, juvenile).
V_{14}	Average midsummer water temperature within pools, backwaters, or littoral areas (juvenile).
V_{18}	Average current velocity in cover areas during average summer flow.
SB – Coastal Stocks of Striped Bass	
Riverine and Estuarine	
V_1	Percent natural river discharge during the spawning season.
V_2	Maximum total dissolved solids (TDS) concentration during the spawning season.
V_3	Average water temperature during the spawning season and period of egg development.
V_4	Minimum dissolved oxygen level during egg and larval development.
V_5	Average current velocity in water column during period of egg development.
V_6	Percent original salt marsh in estuary.
V_7	Percent of original freshwater input (average volume) to estuary during the late winter and spring high flow period.
V_8	Average water temperature during period of larval development.
V_9	Average salinity during period of larval development.
V_{10}	Average dissolved oxygen during the growing season.
V_{11}	Average water temperature during growing season.
Source: United States Geological Survey (USGS) National Wetlands Research Center (NWRC). Habitat Suitability Index Model Series website accessed during March and April 2004 at http://www.nwrc.usgs.gov/wdb/pub/hsi/hsiintro.htm.	

Table 3-4
Hydrogeomorphic (HGM) Variablesfor Riverine Wetlands

HGM Variable	Variable Code	Description
Hydrologic Functions		
Dynamic Surface Water Storage		
V_{BTREE}	Tree basal area	Basal area or biomass of trees.
V_{CWD}	Coarse woody debris	Volume of dead and down trees and limbs larger than an appropriately defined diameter.
V_{DTREE}	Tree density	Density of large-diameter canopy trees.
V_{FREQ}	Frequency of overbank flow	Frequency or recurrence interval at which bank-full discharge is exceeded.
V_{INUND}	Depth of inundation	Average flooding depth during overbank flooding event.
V_{MICRO}	Microtopographic complexity	Small-scale topographic relief in the form of pit-and-mound or hummock-and-hollow patterns.
V_{SHRUB}	Shrub density, biomass, or cover	Density, biomass, or cover of woody understory plants (shrubs and saplings).
Long-term Surface Water Storage		
V_{MACRO}	Macrotopographic relief	Large-scale relief in the form of oxbows, meander scrolls, abandoned channels, and backswamps.
V_{SURWAT}	Indications of surface water presence	Presence or indication that surface is inundated for at least 1 week.
Energy Dissipation		
V_{CWD}	Coarse woody debris	Volume of dead and down trees and limbs larger than an appropriately defined diameter.
V_{DTREE}	Tree density	Density of large-diameter canopy trees.
V_{FREQ}	Frequency of overbank flow	Frequency or recurrence interval at which bank-full discharge is exceeded.
V_{MACRO}	Macrotopographic relief	Large-scale relief in the form of oxbows, meander scrolls, abandoned channels, and backswamps.
V_{MICRO}	Microtopographic complexity	Small-scale topographic relief in the form of pit-and-mound or hummock-and-hollow patterns.
V_{REDVEL}	Reduction in flow velocity	Reduction in flow through a wetland during an overbank flooding event.
Subsurface Water Storage		
V_{PORE}	Soil pore space	Pore space available for storing water.
V_{WTF}	Fluctuation of water table	Change in water table elevation with rises usually caused by precipitation or flooding events and falls due to evapotranspiration and drainage.
Moderation of Groundwater Flow or Discharge		
V_{SUBIN}	Subsurface flow into wetland	Subsurface flow into a wetland via interflow and return flow.
V_{SUBOUT}	Subsurface flow out of wetland	Subsurface flow from a wetland to aquifer or to base flow.
Biogeochemical Functions		
Nutrient Cycling		
V_{PROD}	Aerial net primary production	Aerial net primary production, measured as leaf area index, aboveground biomass, etc.
V_{TURNOV}	Annual turnover of detritus	Standing stocks of detritus (snags, coarse woody debris, and humus).

Table 3-4 Hydrogeomorphic (HGM) Variablesfor Riverine Wetlands		
HGM Variable	**Variable Code**	**Description**
Removal of Imported Elements and Compounds		
V_{BTREE}	Tree basal area	Basal area or biomass of trees.
V_{FREQ}	Frequency of overbank flow	Frequency or recurrence interval at which bank-full discharge is exceeded.
V_{MICRO}	Microtopographic complexity	Small-scale topographic relief in the form of pit-and-mound or hummock-and-hollow patterns.
V_{MICROB}	Surfaces available for microbial activity	Measure of organic surfaces (litter, plant material, other organic matter) available as platforms for microbial growth.
V_{SORPT}	Sorptive properties of soils	Similarity of soils to reference standard with respect to texture, organic carbon content, and other properties.
V_{SUBIN}	Subsurface flow into wetland	Subsurface flow into a wetland via interflow and return flow.
V_{SURFIN}	Surface inflow to the wetland	Overland flow from upland to wqetland as indicated by rills and rearranged litter on upland slopes leading to wetland.
Retention of Particulates		
V_{BTREE}	Tree basal area	Basal area or biomass of trees.
V_{CWD}	Coarse woody debris	Volume of dead and down trees and limbs larger than an appropriately defined diameter.
V_{DTREE}	Tree density	Density of large-diameter canopy trees.
V_{FREQ}	Frequency of overbank flow	Frequency or recurrence interval at which bank-full discharge is exceeded.
V_{HERB}	Herbaceous density, biomass, or cover	The density, biomass, or percentage cover of herbaceous plants.
V_{MICRO}	Microtopographic complexity	Small-scale topographic relief in the form of pit-and-mound or hummock-and-hollow patterns.
V_{SEDIM}	Retained sediments	Presence of natural levees of coarse sediments near stream and fine sediments in floodplain.
V_{SHRUB}	Shrub density, biomass, or cover	Density, biomass, or cover of woody understory plants (shrubs and saplings).
V_{SURFIN}	Surface inflow to the wetland	Overland flow from upland to wqetland as indicated by rills and rearranged litter on upland slopes leading to wetland.
Organic Carbon Export		
V_{FREQ}	Frequency of overbank flow	Frequency or recurrence interval at which bank-full discharge is exceeded.
V_{ORGAN}	Organic matter in wetland	Dissolved and particulate organic matter (live and dead).
V_{SUBIN}	Subsurface flow into wetland	Subsurface flow into a wetland via interflow and return flow.
$V_{SURFCON}$	Surface hydraulic connections	Hydraulic connections between stream channel and floodplain (usually large-scale features on high-energy rivers).
V_{SURFIN}	Surface inflow to the wetland	Overland flow from upland to wqetland as indicated by rills and rearranged litter on upland slopes leading to wetland.
Habitat Functions		
Maintain Characteristic Plant Community		
V_{BTREE}	Tree basal area	Basal area or biomass of trees.
V_{CANOPY}	Canopy cover	Measure of the percent closure of the canopy.
V_{COMP}	Species	Dominant species for tree, shrub, and herb strata.

Table 3-4
Hydrogeomorphic (HGM) Variablesfor Riverine Wetlands

HGM Variable	Variable Code	Description
	composition	
V_{DTREE}	Tree density	Density of large-diameter canopy trees.
V_{REGEN}	Regeneration from seedlings, saplings, clonal shoots	Comparison of dominant species list between reproductive stages of assessment site and mature stages of reference standard.
Maintain Characteristic Detrital Biomass		
V_{CWD}	Coarse woody debris	Volume of dead and down trees and limbs larger than an appropriately defined diameter.
V_{FWD}	Fine woody debris	Small limbs, twigs, and leaves.
V_{LOGS}	Logs in several stages of decomposition	Biomass of logs in each of several decay classes.
V_{SNAGS}	Snags	Density or biomass of standing dead trees.
Maintain Spatial Structure of Habitat		
V_{GAPS}	Canopy gaps	Density or percent cover of openings (gaps) in forest canopy resulting from tree fall.
V_{MATUR}	Abundance of very mature trees	Density of very mature and dying trees.
V_{PATCH}	Vegetation patchiness	Spatial heterogeneity of vegetation types.
V_{SNAGS}	Snags	Density or biomass of standing dead trees.
V_{STRATA}	Number and attributes of vertical strata	Direct count of the number of vegetation strata.
Maintain Interspersion and Connectivity		
V_{CONTIG}	Contiguous vegetation cover	Contiguous cover and corridors between wetland and upland, between channels, and between upstream-downstream areas.
V_{DURAT}	Duration of overbank flow	Duration of connection between channel and floodplain.
V_{FREQ}	Frequency of overbank flow	Frequency or recurrence interval at which bank-full discharge is exceeded.
V_{MICRO}	Microtopographic complexity	Small-scale topographic relief in the form of pit-and-mound or hummock-and-hollow patterns.
V_{SUBCON}	Subsurface hydraulic connections	Subsurface pathways that connect portions of the wetland with the stream channel.
$V_{SURFCON}$	Surface hydraulic connections	Hydraulic connections between stream channel and floodplain (usually large-scale features on high-energy rivers).
Maintain Distribution and Abundance of Invertebrates		
V_{AQINVT}	Aquatic invertebrates	Composition and abundance of invertebrates that live in aquatic habitats.
V_{LINVT}	Litter invertebrates	Composition and abundance of invertebrates that live in litter.
V_{SINVT}	Soil invertebrates	Composition and abundance of invertebrates that live in soil.
Maintain Distribution and Abundance of Vertebrates		
V_{BEAV}	Beaver	Abundance of beaver.
V_{BIRD}	Birds	Distribution and abundance of resident and migratory birds.
V_{FISH}	Fish	Distribution and abundance of resident and migratory fishes.
V_{HERP}	Herptiles	Distribution and abundance of herptiles.
V_{MAMM}	Mammals	Distribution and abundance of permanent and dseasonally resident mammals.

Table 3-4
Hydrogeomorphic (HGM) Variablesfor Riverine Wetlands

HGM Variable	Variable Code	Description
Source: Brinson *et al.*, December 1995.		

Table 3-5
Hydrogeomorphic (HGM) Variables for Tidal Fringe Wetlands

Variable Code	HGM Variable	Description
Hydrogeomorphic Functions		
Tidal Surge Attenuation		
V_{DIST}	Distance	The width of vegetated marsh surface across which storm surges must travel.
V_{ROUGH}	Surface roughness	Describes the potential effects of emergent vegetation, obstructions, and microtopographic features on the hydrodynamics of tidal floodwaters.
Sediment Deposition		
V_{FD}	Flooding duration	The proportion of time that the marsh surface is flooded due to tidal inundation, compared with reference standard sites in the region.
V_{PSC}	Proximity to source channel	Distance between the center of the wetland assessment area and the nearest large distributary channel, river, bay, or ocean.
V_{ROUGH}	Surface roughness	Describes the potential effects of emergent vegetation, obstructions, and microtopographic features on the hydrodynamics of tidal floodwaters.
Tidal Nutrient and Organic Carbon Exchange		
V_{COV}	Total percent vegetative cover	The proportion of a site covered with macrophytic vegetation compared with reference standard sites in the region.
V_{DEN}	Mean plant density	Mean density of the dominant macrophytic vegetation at a site relative to regional subclass reference standard sites.
V_{FD}	Flooding duration	The proportion of time that the marsh surface is flooded due to tidal inundation, compared with reference standard sites in the region.
V_{HGT}	Mean plant height	Mean height of the dominant macrophytic vegetation at a site divided by mean height of the dominant macrophytic vegetation at reference standard sites.
Habitat Functions		
Maintenance of Characteristic Plant Community Composition		
V_{COV}	Total percent vegetative cover	The proportion of a site covered with macrophytic vegetation compared with reference standard sites in the region.
V_{COMP}	Community composition	Similarity index comparing the emergent macrophyte species composition of a particular site with the species composition of reference standard sites within the regional subclass.
V_{EXOTIC}	Percent vegetative cover by exotic or nuisance species	The proportion of a site covered with exotic or other undesirable plant species.
Resident Nekton Utilization		
V_{AE}	Aquatic edge	The amount of edge between the intertidal vegetated, intertidal unvegetated, and subtidal areas.
V_{FD}	Flooding duration	The proportion of time that the marsh surface is flooded due to tidal inundation, compared with reference standard sites in the region.
V_{NHC}	Nekton habitat complexity	A measure of the habitat heterogeneity of a site, based on the comparison of the number of subhabitat types present at a site relative to the number of possible subhabitats known to occur in the appropriate regional reference standard site.
Nonresident Nekton Utilization		
V_{AE}	Aquatic edge	The amount of edge between the intertidal vegetated, intertidal unvegetated, and subtidal areas.
V_{FD}	Flooding duration	The proportion of time that the marsh surface is flooded due to tidal inundation, compared with reference standard sites in the region.
V_{NHC}	Nekton habitat complexity	A measure of the habitat heterogeneity of a site, based on the comparison of the number of subhabitat types present at a site relative to the number of possible subhabitats known to occur in the appropriate regional reference standard site.
V_{OMA}	Opportunity for marsh access	The density of tidally connected waterways (channels, embayments, and ponds).

Table 3-5
Hydrogeomorphic (HGM) Variables for Tidal Fringe Wetlands

Variable Code	HGM Variable	Description
Nekton Prey Pool		
V_{AE}	Aquatic edge	The amount of edge between the intertidal vegetated, intertidal unvegetated, and subtidal areas.
V_{COV}	Total percent vegetative cover	The proportion of a site covered with macrophytic vegetation compared with reference standard sites in the region.
V_{FD}	Flooding duration	The proportion of time that the marsh surface is flooded due to tidal inundation, compared with reference standard sites in the region.
Wildlife Habitat Utilization		
V_{AE}	Aquatic edge	The amount of edge between the intertidal vegetated, intertidal unvegetated, and subtidal areas.
V_{UE}	Upland edge	The amount of upland edge at a site scaled to the amount of upland edge present at reference standard sites in the region.
V_{WHC}	Wildlife habitat complexity	A measure of the habitat heterogeneity of a site, based on the comparison of the number of subhabitat types present at a site relative to the number of possible subhabitats known to occur in the appropriate regional reference standard site.

Source:
Shafer and Yozzo, December 1998.

Table 3-6 Hackensack Meadowlands Hydrogeomorphic (HGM) Variables for Tidal Fringe Wetlands		
Variable Code	**HGM Variable**	**Description**
Shoreline Stabilization		
V_{SLOPE}	Shoreline slope	Distance from shoreline to water depths of at least 6 feet mean low water.
V_{WIDTH}	Average marsh width	Average distance between shoreline and the nearest upland or obstruction.
V_{EXPOSE}	Exposure	Relative exposure based on wind speed, time wind blows from each compass direction, and fetch distance.
V_{SOIL}	Soil texture	Predominant texture of the mineral component of soil, degree of decomposition of organic matter, and percent live roots.
V_{ROUGH}	Surface roughness	Surface roughness based on soil surface, topographic relief, and vegetation.
Maintain Tidal Marsh Elevation		
V_{ROUGH}	Surface roughness	Surface roughness based on soil surface, topographic relief, and vegetation.
V_{HYDRO}	Hydrologic regime	Presence of hydrological restrictions and extent of inundation at high tide.
V_{NATIVE}	Percent cover by native species	Percentage of site that is occupied by native plant species.
Nutrient, Organic Carbon, and Contaminant Flux		
V_{HYDRO}	Hydrologic regime	Presence of hydrological restrictions and extent of inundation at high tide.
V_{VEGSTR}	Vegetative structure	Total percent cover by both live and dead emergent macrophytic plant species and height at which the bulk of the biomass occurs.
Resident Nekton Utilization		
V_{EDGE}	Aquatic edge	Density of aquatic edge; i.e., length of marsh-wat4er interfaces (edges of tidal creeks, ponds, and riverbanks) divided by total marsh area.
V_{HYDRO}	Hydrologic regime	Presence of hydrological restrictions and extent of inundation at high tide.
V_{NHC}	Nekton habitat complexity	Heterogeneity of site based on a comparison of the number of habitats actually present relative to the number of possible habitats known to occur in the Meadowlands.
Nonresident Nekton Utilization		
V_{EDGE}	Aquatic edge	Density of aquatic edge; i.e., length of marsh-water interfaces (edges of tidal creeks, ponds, and riverbanks) divided by total marsh area.
V_{CD}	Channel density	Linear edge of tidally-connected ponds, creeks, and rivulets divided by the wetland size.
V_{HYDRO}	Hydrologic regime	Presence of hydrological restrictions and extent of inundation at high tide.
V_{NHC}	Nekton habitat complexity	Heterogeneity of site based on a comparison of the number of habitats actually present relative to the number of possible habitats known to occur in the Meadowlands.
Maintain Invertebrate Community		
V_{HYDRO}	Hydrologic regime	Presence of hydrological restrictions and extent of inundation at high tide.
V_{EDGE}	Aquatic edge	Density of aquatic edge; i.e., length of marsh-water interfaces (edges of tidal creeks, ponds, and riverbanks) divided by total marsh area.
V_{COV}	Total Percent Vegetative Cover	Relative proportion of the site that is covered with emergent macrophytic vegetation.
Provide Wildlife Habitat		
V_{SIZE}	Wetland size	Size of the wetland assessment area, defined as a contiguous patch of tidal fringe wetland.
$V_{CONNECT}$	Connectedness of wetland to adjacent wildlife habitat	Percent of the wetland perimeter that is directly connected to undeveloped upland, wetland, and open water habitats.

Table 3-6 Hackensack Meadowlands Hydrogeomorphic (HGM) Variables for Tidal Fringe Wetlands		
Variable Code	**HGM Variable**	**Description**
$V_{RESERVE}$	Effective reserve patch size	Effective area of all undeveloped wetland or upland habitat patches within 0.5 miles of the wetland boundary.
V_{WHC}	Wildlife habitat complexity	Heterogeneity of a site, based on comparing the number of habitats actually present at a site to the number of possible habitats known to occur in or adjacent to tidal fringe wetlands in the Meadowlands.
V_{NATIVE}	Percent cover by native species	Percentage of site that is occupied by native plant species.
Maintain Characteristic Plant Community Composition		
V_{NATIVE}	Percent cover by native species	Percentage of site that is occupied by native plant species.
Plant Biomasss Production (Above-Ground)		
V_{VEGSTR}	Vegetative structure	Total percent cover by both live and dead emergent macrophytic plant species and height at which the bulk of the biomass occurs.
Maintain Tidal Wetland Hydrology		
V_{HYDRO}	Hydrologic regime	Presence of hydrological restrictions and extent of inundation at high tide.
V_{CD}	Channel density	Linear edge of tidally-connected ponds, creeks, and rivulets divided by the wetland size.
$V_{SINUOUS}$	Steam sinuosity	Comparison of the total sinuous length of onsite channels to the total length of straight channels on the site.
$V_{CHWIDTH}$	Channel width	Width of the marsh's main feeder channels that provide the tidal water that flows over the marsh surface.
V_{DEPTH}	Channel depth	Depth of the marsh's main feeder channels that provide the tidal water that flows over the marsh surface.
Source: The Louis Berger Group, Inc., January 2004.		

Table 3-7 Rapid Bioassessment Protocols (RBP) Variables[1]		
RBP Metric	**Description**	**NJDEP IBI[a] Metric[2]**
Habitat Assessment		
Low-gradient Streams		
Epifaunal substrate / available cover	Relative quantity and variety of natural structures in the stream, such as cobble (riffles), large rocks, fallen trees, logs and branches, and undercut banks, available as refugia, feeding, or sites for spawning and nursery functions of aquatic macrofauna.	
Pool substrate characterization	Type and condition of bottom substrates found in pools.	
Pool variability	Overall mixture of pool types found in streams, according to size and depth.	
Sediment deposition	Amount of sediment that has accumulated in pools and the changes that have occurred to the stream bottom as a result of deposition.	
Channel flow status	Degree to which the channel is filled with water.	
Channel alteration	Large-scale changes in the shape of the stream channel.	
Channel sinuosity	Meandering or sinuosity of the stream.	
Bank stability (condition of banks)	Whether the steam banks are eroded (or have the potential for erosion).	
Bank vegetative protection	Amount of vegetative protection afforded to the stream bank and the near-stream portion of the riparian zone.	
Riparian vegetative zone width	Width of natural vegetation from the edge of the stream bank out through the riparian zone.	
Periphyton Protocols		
Metrics of Biotic Integrity		
Species richness	Estimate of the number of algal species (diatoms, soft algae, or both) in a sample.	
Total number of genera	Generic richness. Total number of general (diatoms, soft algae, or both).	
Total number of divisions	Total number of divisions represented by all taxa.	
Shannon diversity (for diatoms)	Function of both the number of species in a sample (species richness) and the distribution of individuals among those species (evenness).	
Percent community similarity (PS_c) of diatoms	Shows community similarities based on relative abundances and thereby gives more weight to dominant taxa than rare ones.	
Pollution tolerance index for diatoms	Representative of relative sensitivity to perturbation.	
Percent sensitive diatoms	Sum of the relative abundances of all intolerant species.	
Percent *Achnanthes minutissima*	Abundance of a cosmopolitan diatom that has a very broad ecological amplitude.	
Percent live diatoms	Measure of the health of the diatom assemblage.	
Diagnostic Metrics that Infer Ecological Conditions		
Percent aberrant diatoms	Percent of diatoms in a sample that have anomalies in striae patterns or frustule shape (e.g., long cells that are bent or cells with indentations).	
Percent motile diatoms	A siltation index, expressed as the relative abundance of *Navicula* + *Nitzschia* + *Surirella*.	
Simple diagnostic metrics	Sum of the percent relative abundances (range 0-100%) of species that have environmental optima in extreme environmental conditions.	

Table 3-7 Rapid Bioassessment Protocols (RBP) Variables[1]		
RBP Metric	**Description**	**NJDEP IBI[a] Metric[2]**
Inferred ecological conditions with simple autecological indices (SAI)	Ecological preferences for different diatom species characterized along an environmental (stressor) gradient to infer environmental conditions and effect on the periphyton assemblage.	
Inferred ecological conditions with weighted average indices	Ecological conditions in a habitat inferred using the optimum environmental conditions (specific ecological optima; ß$_i$) for algae and relative abundances (?$_i$) for taxa in the habitat.	
Impairment of ecological conditions	Deviation (?$_{EC}$) between inferred environmental conditions at a test site and at a reference site.	
Benthic Macroinvertebrate Protocols		
Best Candidate Benthic Metrics		
Richness Measures		
Total number of taxa	Measures the overall variety of the macroinvertebrate assemblage.	
Number of EPT taxa	Number of taxa in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).	
Number of Ephemeroptera taxa	Number of mayfly taxa (usually genus or species level).	
Number of Plecoptera taxa	Number of stonefly taxa (usually genus or species level).	
Number of Trichoptera taxa	Number of caddisfly taxa (usually genus or species level).	
Composition Measures		
Percent EPT	Percent of the composite of mayfly, stonefly, and caddisfly larvae.	
Percent Ephemeroptera	Percent of mayfly nymphs.	
Tolerance/Intolerance Measures		
Number of intolerant taxa	Taxa richness of those organisms considered to be sensitive to perturbation.	
Percent tolerant organisms	Percent of macrobenthos considered to be tolerant of various taypes of perturbation.	
Percent dominant taxon	Measures the dominance of the single most abundant taxon. Can be calculated as dominant 2, 3, 4, or 5 taxa.	
Feeding Measures		
Percent filterers	Percent of the macrobenthos that filter fine particulate organic matter from either the water column or sediment.	
Percent grazers and scrapers	Percent of the macrobenthos that scrape or graze upon periphyton.	
Habit Measures		
Number of clinger taxa	Number of taxa of insects.	
Percent clingers	Percent of insects having fixed retreats or adaptations for attachment to surfaces in flowing water.	
Additional Potential Benthic Metrics		
Richness Measures		
Number of *Pteronarcys* species	Presence or absence of a long-lived stonefly genus (2-3 year life cycle).	

Table 3-7 Rapid Bioassessment Protocols (RBP) Variables[1]		
RBP Metric	**Description**	**NJDEP IBI[a] Metric[2]**
Number of Diptera taxa	Number of “true” fly taxa, which includes midges.	
Number of Chironomidae taxa	Number of taxa of chironomid (midge) larvae.	
Composition Measures		
Percent Plecoptera	Percent of stonefly nymphs.	
Percent Trichoptera	Percent of caddisfly larvae.	
Percent Diptera	Percent of all “true” fly larvae.	
Percent Chironomidae	Percent of midge larvae.	
Percent Tribe Tanytarsini	Percent of Tanytarisinid midges to total fauna.	
Percent other Diptera and non-insects	Percent of composite of those organisms generally considered to be tolerant to a wide range of environmental conditions.	
Percent *Corbicula*	Percent of Asiatic clam in the benthic assemblage.	
Percent Oligochaeta	Percent of aquatic worms .	
Tolerance/Intolerance Measures		
Number of intolerant snail and mussel species	Number of species of mollusks generally thought to be pollution intolerant.	
Percent sediment tolerant organisms	Percent of infaunal macrobenthos tolerant of perturbation.	
Hilsenhoff Biotic Index	Uses tolerance values to weight abundance in an estimate of overall pollution. Originally designed to evaluate organic pollution.	
Florida Index	Weighted sum of intolerant taxa, which are classed as 1 (least tolerant) or 2 (intolerant). Florida Index = 2 * Class 1 taxa + Class 2 taxa.	
Percent Hydropsychidae to Trichoptera	Relative abundance of pollution tolerant caddisflies. Note: Metric could also be regarded as a composition measure.	
Feeding Measures		
Percent omnivores and scavengers	Percent of generalists in feeding strategies.	
Percent individual gatherers and filterers	Percent of collector feeders of coarse particulate organic matter and fine particulate organic matter.	
Percent gatherers	Percent of the macrobenthos that “gather.”	
Percent predators	Percent of the predator functional feeding group. Can be made restrictive to exclude omnivores.	
Percent shredders	Percent of the macrobenthos that “shreds” leaf litter.	
Life Cycle Measures		
Percent multivoltine	Percent of organisms having short (several per year) life cycle.	
Percent univoltine	Percent of organisms relatively long-lived (life cycles of 1 or more years).	
Fish Protocols		
Species Richness and Composition Metrics		
Total number of species	Total number of resident native fish species and number of salmonid age classes.	**Yes**

Table 3-7 Rapid Bioassessment Protocols (RBP) Variables[1]		
RBP Metric	**Description**	**NJDEP IBI[a] Metric[2]**
Number of darter species	Number and identity of sculpin species, benthic insectivore species, salmonid juveniles (individuals); number of sculpins (individuals); percent round-bodied suckers, sculpin, and darter species.	**Yes[b]**
Number of sunfish species	Number and identity of cyprinid species, water column species, salmonid species, headwater species, and sunfish and trout species.	**Yes**
Number of sucker species	Number and identity of adult trout species, number of minnow species, and number of suckers and catfish.	No
Number of intolerant species	Number and identity of sensitive species, amphibian species, and presence of brook trout.	**Yes**
Percent green sunfish	Proportion of individuals as common carp, white sucker, tolerant species, creek chub, and dace.	**Yes[c]**
Trophic Composition Metrics		
Percent omnivores	Proportion of individuals as generalist feeders.	**Yes**
Percent cyprinids	Proportion of individuals as insectivores, specialized insectivores, insectivorous species, and number of juvenile trout.	**Yes[d]**
Percent top carnivores	Proportion of individuals as catchable salmonids, catchable wild trout, and pioneering species.	**Yes**
Fish Abundance and Condition Metrics		
Number of individuals	Density of individuals. Number of individuals in sample or catch per effort.	**Yes**
Percent hybrids	Proportion of individuals as introduced species, simple lithophils, and number of simple lithophilic species.	No
Percent diseased individuals	Proportion of individuals with disease, tumors, fin damage, and skeletal anomalies.	**Yes**
Total biomass	Total fish biomass (optional).	No

Notes:

a. IBI – index of biotic integrity.
b. Actual NJDEP IBI metric is: Number of benthic insectivorous species.
c. Actual NJDEP IBI metric is: Proportion of individuals as white suckers.
d. Actual NJDEP IBI metrics is Proportion of individuals as insectivorous cyprinids.

Sources:

1. Barbour *et al*., 1999.
2. NJDEP, April 2004.

Figures